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Ventilation for buildings — Design and dimensioning of residential ventilation systems

ICS 91.140.30

British Standards

National foreword

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English Version

Ventilation for buildings - Design and dimensioning of residential ventilation systems

Ventilation des bâtiments - Conception et dimensionnement des systèmes de ventilation résidentiels

Lüftung von Gebäuden - Ausführung und Bemessung der Lüftungssysteme von Wohnungen

This Technical Report was approved by CEN on 30 January 2006. It has been drawn up by the Technical Committee CEN/TC 156.

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Contents

Foreword

This Technical Report (CEN/TR 14788:2006) has been prepared by Technical Committee CEN/TC 156 “Ventilation of buildings”, the secretariat of which is held by BSI.

1 Scope

This Technical Report specifies recommendations for the performance and design of ventilation systems which serve single family, multi family and apartment type dwellings during both summer and winter. It is of particular interest to architects, designers, builders and those involved with implementing national, regional and local regulations and standards.

Four basic ventilation strategies are covered; natural ventilation, fan assisted supply air ventilation, fan assisted exhaust air ventilation and fan assisted balanced air ventilation. Combinations of these systems are not excluded and a ventilation system may serve only one dwelling *(individual system)* or more than one dwelling *(central system)*. The ventilation aspects of combined systems (ventilation with heating and/or cooling) are covered.

The ventilation of garages, common spaces, roof voids, sub-floor voids, wall cavities and other spaces in the structure, under, over or around the living space are not covered.

Ventilation systems covered by this Technical Report may affect the entry and dilution of radon and other gases from the ground but these effects are not covered in this Technical Report. Ventilation systems designed to reduce the entry of radon and other gases from the ground are not covered by this Technical Report.

2 References

The following referenced documents are indispensable for the application of this Technical Report. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 779, *Particulate air filters for general ventilation — Determination of the filtration performance*

EN 1507, *Ventilation for buildings — Sheet metal air ducts with rectangular section — Requirements for strength and leakage*

ENV 12097, *Ventilation for buildings — Ductwork — Requirements for ductwork components to facilitate maintenance of ductwork systems*

EN 12236, *Ventilation for buildings — Ductwork hangers and supports — Requirements for strength*

EN 12237, *Ventilation for buildings — Ductwork — Strength and leakage of circular sheet metal ducts*

EN 12792:2003, *Ventilation for buildings — Symbols, terminology and graphical symbols*

EN 13141-1, *Ventilation for buildings — Performance testing of components/products for residential ventilation — Part 1: Externally and internally mounted air transfer devices*

EN 13465, *Ventilation for buildings — Calculation methods for the determination of air flow rates in dwellings*

EN 14134, *Ventilation for buildings — Performance testing and installation checks of residential ventilation systems*

EN 13779, *Ventilation for non-residential buildings — Performance requirements for ventilation and room conditioning systems*

EN 20140-10, *Acoustics — Measurement of sound insulation in building and building elements — Part 10: Laboratory measurement of airborne sound insulation of small building elements (ISO 140-10:1991)*

EN ISO 140-3, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurement of airborne sound insulation of building elements (ISO 140-3:1995)*

EN ISO 10211-1, *Thermal bridges in building construction — Heat flow and surface temperatures — Part 1: General calculation method (ISO 10211-1:1995)*

ISO 9972, *Thermal insulation — Determination of building airtightness — Fan pressurization method*

3 Terms and definitions

For the purposes of this Technical Report, the terms and definitions given in EN 12792:2003 and the following apply.

3.1
activity room
room used for activities such as cooking, washing and bathing which is characterised by relatively high pollutant emission (which may be intermittent), e.g. a kitchen, bathroom, laundry/utility room, WC

3.2
background pollutants
group of indoor pollutants mainly represented by water vapour and carbon dioxide from respiration, but also including a large number of other pollutants emitted by materials, furnishings and products used in the dwelling. Their source rates are relatively low but continuous and diffuse

3.3
common space
corridor, stairway or atrium used for access to a dwelling or dwellings

3.4
cross ventilation (in a natural ventilation system)
natural ventilation in which air flow mainly results from wind pressure effects on the building facades and in which stack effect in the building is of less importance

3.5
fan assisted balanced ventilation
ventilation which employs powered air movement components in both the supply and exhaust air sides in order to achieve a design flow rate/pressure ratio

[EN 12792:2003, 149]

3.6
fan assisted exhaust air ventilation
ventilation which employs powered air movement components in the exhaust air side only

[EN 12792:2003, 150]

3.7
fan assisted supply air ventilation
ventilation which employs powered air movement components in the supply air side only

[EN 12792:2003, 154]

3.8
low pollution room
room used for dwelling purposes which is characterised by relatively low pollution emission, e.g. a bedroom, living room, dining room, study, but not a space used only for storage

3.9
outdoor air
controlled air entering the system or opening from outdoors before any air treatment (coded green)

[EN 12792:2003, 280]

3.10
natural ventilation system
ventilation system which relies on pressure differences without the aid of powered air movement components

3.11
specific pollutants
group of indoor pollutants mainly represented by water vapour, carbon dioxide and odours, whose production is related to specific human activities in the dwelling (such as cooking, washing, bathing). Their source rates are relatively high but of short duration, and in specific locations in the dwelling

3.12
stack effect
movement of air or gas in a vertical enclosure (e.g. duct, chimney, building) induced by density difference between the air or gas in the enclosure and the ambient atmosphere

3.13
standard air
atmospheric air having density 1,2 $kg \cdot m^{-3}$ at 20 °C, 101 325 Pa (1 013,25 mbar) and 65 % relative humidity

[EN 12792:2003, 340]

3.14
ventilation
designed supply and removal of air to and from a treated space

[EN 12792:2003, 388]

3.15
ventilation flow rate
volume flow rate at which ventilation air is supplied and removed

[EN 12792:392]

NOTE Normally uses standard air condition.

3.16
ventilation installation
combination of the ventilation or air conditioning installation and the building itself

3.17
ventilation system
combination of all components required to provide ventilation

NOTE The definitions 3.16 and 3.17 are the reverse of those given in EN 12792 and reflect the terms in more common usage in the industry.

4 Symbols and units

For the purpose of this Technical Report, the symbols and units given in EN 12792:2003 apply.

5 Need for ventilation in dwellings (residences)

5.1 General

A supply of outdoor air in buildings is normally regarded as being required for one or more of the following purposes:

a) dilution and/or removal of background pollutants such as substances emitted by furnishings and building materials and cleaning materials used in the building, odours, metabolic CO_2 and water vapour;

b) dilution and/or removal of specific pollutants from identifiable local sources such as toilet odours, cooking odours, water vapour from cooking or bathing, environmental tobacco smoke, combustion products from fuel burning appliances;

c) provision for occupants for respiration;

d) control of internal humidity;

e) provision of air for fuel burning appliances.

These purposes are all with regard to the health of the occupants and the building. Ventilation is primarily concerned with the first four purposes (a) to d)) but it is linked to the last one (e)). In providing ventilation it is important to also consider other aspects of performance including thermal comfort, durability, fire safety, noise and energy use.

5.2 Composition of outside air

The proportions of the three main elements of outside air, oxygen (20,9 %), nitrogen (79,0 %) and carbon dioxide (0,034 %) do not vary significantly in outside air. Carbon dioxide may be found at higher concentrations in built-up areas and may be high enough to affect ventilation provision.

The main variable constituent of outside air is water vapour. Across Europe the typical specific moisture ranges from 1,0 g up to 16 g moisture per kg dry air during yearly weather conditions (see Annex B for further information).

However, in some situations the concentrations of other outdoor pollutants (mainly pollutants from motor vehicles in city areas) may reach unacceptable levels. The designer may wish to consider filtration of outdoor air by adding filters to the ventilation system. At present it is generally only practicable to provide filters for particulate matter.

5.3 Dilution and removal of indoor pollutants

A wide range of airborne pollutants is generated by sources within dwellings, including gases, vapours, tobacco smoke, biologically inert particulates (e.g. dusts and fibres) and viable particulates (e.g. fungal spores, viruses and bacteria). Such pollutants may have the potential to harm the health or comfort of occupants or may lead to damage to the dwelling fabric.

Indoor pollutants may be divided into three groups: specific pollutants which can be substantially removed by local ventilation close to identifiable local sources; background pollutants which have diffuse sources or for other reasons cannot be dealt with by local ventilation; and combustion products from fuel burning appliances (combustion products are discussed in 5.6 and 7.3).

Production rates of pollutants are best known (or predicable) where the source is combustion or where the pollutant results from the presence or activities of occupants. Production rates are less well defined where the source is related to the fabric or furnishings of the dwelling.

At present there is no consistent approach to setting acceptable indoor concentrations for many of the diverse source pollutants in dwellings, however, in the general case they are believed to be adequately removed by ventilation for those few pollutants whose source rates and acceptable levels are known. The known pollutants are discussed in the following subclauses.

5.4 Human respiration

The body requires oxygen for the production of energy at a rate proportional to metabolic rate. However, the main limiting factor is not the supply of oxygen but the build-up of water vapour and carbon dioxide in expired air, whose production rates from human respiration are given in Annex A.

5.5 Control of indoor humidity

The relative humidity of air is equal to the ratio of the partial vapour pressure in the air to the partial pressure of water vapour in saturated air at the same temperature. Low relative humidities (below approximately 30 %) can give rise to respiratory discomfort and nuisance from electrostatic effects. High relative humidities (above approximately 70 %) incur the risk of condensation and mould growth on surfaces that have temperatures close to or below the dew point temperature of the air. In very cold climates it may be desirable to reduce ventilation rates, and tolerate consequent higher CO_2 levels, in order to avoid relative humidity being uncomfortably low (below approximately 30 %). The concentrations of pollutants (including CO_2) in the dwelling may then rise to unacceptable levels in which case increased ventilation air flow rates can become necessary.

The contribution made by ventilation is to lower the moisture content of the internal air by dilution with outside air which normally has a lower absolute moisture content (as described above, relative humidity of the outside air is reduced when it is heated to indoor temperatures). In cold climates (e.g. central and northern Europe) the problem tends to be low indoor humidity. In temperate climates (e.g. European maritime areas) the problem tends to be high indoor humidity.

For any required indoor humidity level the air flow rate required depends upon the moisture content of the outside air, the rate of moisture input (from such sources as respiration, cooking, bathing, clothes drying and flue-less combustion of certain fuels), the indoor air temperature, the temperature of surfaces in the room(s) and the water vapour absorption characteristics of surfaces and furnishings in the room(s). The latter is discussed in Annex B and Annex C.

Typical moisture generation rates for some common household activities are given in Annex A. It should be noted that these are only a guide because they are strongly dependent upon the habits of the dwelling occupants.

Depending on the type of ground floor construction water vapour can also enter dwellings in significant quantities from the ground. The designer should take it into account when appropriate (see Annex A and national or local building regulations).

5.6 Provision of air for non sealed fuel burning appliances (open flued appliances)

An air supply to a non sealed fuel burning appliance is required for one or more of the following purposes:

a) to supply air for correct combustion and flue operation;

b) to limit the concentration of combustion products within the spaces to an acceptable level (normally taken to be a maximum of 0,5 % carbon dioxide and relative humidity low enough to avoid condensation leading to mould growth);

c) to prevent overheating of the appliance and its surroundings. Carbon monoxide (CO) may also be produced by fuel burning appliances but should be dealt with by correct adjustment of burners and by providing adequate air supply to limit CO_2 concentration and avoid its conversion to CO.

NOTE Room-sealed and balanced-flue type appliances do not require air for a) or b) but may require ventilation air for c).

It is strongly recommended that flue-less space heating appliances are not used in dwellings because of their high CO_2 and water vapour output rates and their high air supply requirement. Flue-less cooking appliances are acceptable because of their relatively low fuel use and intermittent use. In some countries national regulations may forbid the use of flue-less space heating appliances.

Air supply to prevent overheating of the appliance is considered to be a heating issue, not a ventilation issue, and should not be discussed further.

When designing a ventilation system there are two distinct problems to consider with respect to fuel burning appliances: (i) avoiding spillage from open flued appliances and, (ii) dilution of pollutants from flue-less appliances. For correctly designed and installed appliances with flues or chimneys all the combustion products should be discharged directly to outside. For this to happen it is important that the ventilation system does not cause spillage of combustion products by significantly depressurizing the room. Ventilation systems can be designed to remove ventilation extract air and combustion products by the same duct system and fan. In such systems it is essential that safety controls are included to ensure that a failure of the exhaust fan does not result in spillage of combustion products into any dwelling.

Ventilation to limit the concentration of combustion products in the indoor environment should only be applicable to flue-less combustion appliances. These appliances may be categorized as (a) continuous (such as kerosene or gas space heaters) or (b) intermittent (such as gas water heaters and cookers).

The criteria most usually applied in assessing the required ventilation rate for flue-less appliances is the need to maintain the concentration of carbon dioxide below the widely accepted occupational (8 h) exposure limit of 0,5% and indoor relative humidity low enough to avoid condensation leading to mould growth. For continuously operating appliances an equilibrium condition is appropriate but for gas appliances which operate intermittently for limited periods of time a lower air supply rate is permissible. CO_2 and water vapour production rates for fuels commonly used in flue-less appliances are given in Annex A.

NOTE In some countries other criteria may dominate that for CO_2, such as particularly low limiting concentrations of formaldehyde or oxides of nitrogen.

6 Design assumptions for residential ventilation

A ventilation system is designed to provide outdoor air for human and building needs under certain defined conditions. The design performance of a ventilation system can only be achieved within the limits of these conditions. It is essential that the designer specifies these conditions as well as the design performance of the ventilation system.

External environmental and climatic conditions may influence the application of different ventilation principles.

EXAMPLE 1 A slight under-pressure in relation to outdoors especially in severe climates can help to avoid damage to structures caused by moisture.

EXAMPLE 2 In areas where under-pressure can cause the potential risk of an increase in the concentration of radon, the under-pressure indoors should be designed to be a minimum.

EXAMPLE 3 Alternatively, the building can be designed for slight overpressure if the building structures, indoor air humidity and climate conditions are suitable. Special attention should be given to the risk of condensation and moisture damage.

The designer should consider making assumptions about the following:

— outdoor meteorological conditions (e.g. wind speed, air temperature, humidity) which might be expressed as extreme values, average values, value exceeded for a percentage of the time, and may be on a monthly or yearly basis;

— pollutant levels in the outdoor air;

— outdoor noise level;

— shielding of the building;

— air-tightness of the building;

— thermal characteristics of the building;

— noise characteristics of the building (walls, windows etc.);

— maximum acceptable pollutant levels in the indoor air;

— thermal comfort;

— acoustic comfort;

— number of occupants the rooms and/or dwelling are designed for;

— indoor pollutant production rates;

— noise from the ventilation system;

— proper installation of the ventilation system/components (e.g. duct leakage);

— proper use of the ventilation system/components (e.g. running times);

— proper cleaning and maintenance of the ventilation system/components.

These resulting design conditions should be listed in the specification for the system and the operating manual for the ventilation system (see Clause 9). Guidance on the proper use and maintenance of the ventilation system is a particularly important part of this manual.

7 Performance requirements for ventilation systems

7.1 Ventilation air volume flow rate

7.1.1 General

The ventilation system should be designed to provide ventilation according to the performance requirements and design rules given in Clauses 7 and 8. Informative Annex D may also be a useful source of general information and guidance on residential ventilation and air-tightness.

For all residential ventilation systems it is necessary to specify ventilation air volume flow rates such that assumed or predicted concentrations of certain known indoor pollutants are not exceeded. The ventilation air volume flow rate is specified in many different ways in the regulations and standards of different countries and it has not been possible to draw up a simple table with classes which cover all, or even most, of the widely varying requirements and options currently used in European countries. Therefore, this Technical Report does not contain mandatory requirements or classes for residential ventilation air flow rates. The required ventilation air flow rates should be obtained from national and local regulations and/or standards prevailing in the country concerned.

However, this Technical Report does describe a method of establishing the required ventilation air volume flow rate by calculation using pollutant production rates and indoor and outdoor air conditions specified by the user. The equations for use in the calculation method are given in Annex E. Examples of the ventilation air flow rates resulting from such calculations are given in Annex F on the basis of a range of assumptions about pollutants and other parameters.

7.1.2 Pollutant groups

The most common pollutants occurring in dwellings may be grouped into three different groups which can lead to different, but complementary, ventilation strategies.

a) Group of background pollutants. Two types:

   — first type includes a large number of pollutants emitted by materials, furnishings and products used in the dwelling. They are generally not perceivable by the occupants and their sources are at a relatively low but continuous rate;

   — second type includes metabolic products from the occupants mainly represented by water vapour and carbon dioxide from respiration, and odours;

b) Group of specific pollutants, mainly represented by water vapour, carbon dioxide and odours. Their production is related to specific human activities in the dwelling such as cooking, washing, bathing etc., whose duration is relatively short, which result in relatively high pollutant production, and which occur in specific locations in the dwelling;

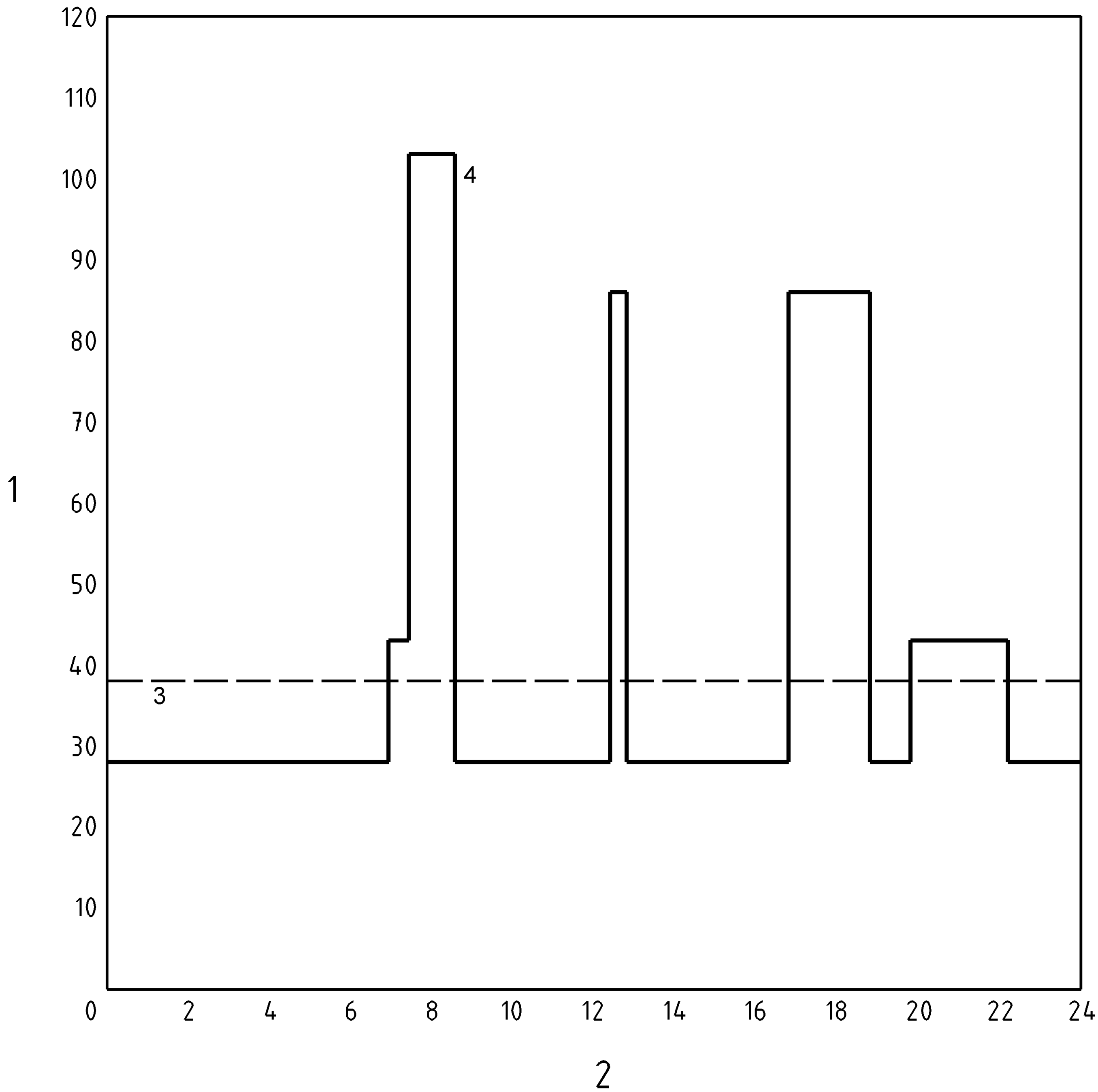
c) Group of combustion products from fuel burning appliances for space and water heating, the most dangerous of which is carbon monoxide. These should be dealt with by proper design of the appliance and a chimney or flue system which carries the pollutants directly to outside the dwelling, if possible.

NOTE it is strongly recommended that flue-less space or water heaters are not used in dwellings because of their high rates of pollutant production.

For residential ventilation purposes it is common to use water vapour as an indicator of ventilation need in activity rooms. In low pollution rooms both water vapour and CO_2 are used as indicators of other metabolic pollutants.

7.1.3 Ventilation strategies

One of the following two ventilation strategies are normally used. First, a continuous and nominally constant ventilation air flow rate may be provided to deal with both specific and background pollutants together. Alternatively, a continuous (relatively low) background ventilation air flow rate may be provided to deal with the background pollutants together with a higher intermittently operated extract air flow rate provided in the activity rooms to deal with most of the specific pollutants. The intermittent operation may be controlled manually by the occupant or automatically by suitable sensors. A typical pattern of intermittent operation over a period of one day, compared with an equivalent extract system operating continuously at a constant rate, is illustrated in Figure 1.



Key

1 total air ventilation air volume flow rate (L/s)

2 time of day (hours)

3 continuous extract ventilation at constant rate

4 intermittent extract and natural background ventilation

Figure 1 — Example of two ventilation strategies

7.1.4 The ventilation air volume flow rate requirement

In all cases the basic intention is to achieve a reasonable level of indoor air quality without wasting energy, i.e.

i) CO_2 concentration to be kept below a reasonable level;

ii) humidity is kept between reasonable levels to avoid an atmosphere which is too dry and to avoid mould growth or condensation;

iii) to remove odours within a reasonable time;

iv) to keep concentrations of other unspecified pollutants below a reasonable level.

Considering the diversity of sources and pollutants in indoor air, and the range of susceptibility in the population, compliance with this Technical Report will not necessarily ensure acceptable indoor air quality for everyone. There may be a conflict between the above criteria; e.g. the ventilation rate to keep below a particular CO_2 level may lead to a level of humidity which is too low to be acceptable. Compromises may then have to be made allowing some pollutant concentrations to rise above intended limits for a limited period.

When determining ventilation air flow rates the total design extract air flow rate and the total design supply air flow rate obtained for the whole dwelling are usually different. The ventilation system should generally be designed to extract air at the greater of those two air flow rates to avoid overpressure and the risk of interstitial condensation in the structure. The ventilation system should be designed to supply air at least to the design total supply air flow rate. The difference between the design total supply and extract air flow rates may be provided by air leakage through the dwelling structure and/or by additional air supply components in the ventilation system. As buildings are getting tighter and tighter, relying only on building leakage could lead to too low ventilation rates.

If air leakage alone is used for the additional air supply then there may be problems with spillage from open-flued combustion appliances in airtight dwellings (see 7.1.9).

Where products intended for high flow intermittent operations, e.g. range hoods, drying machines, consideration should be given to the replacement air requirements.

7.1.5 The calculation method

The starting point for the calculation method is to define the most important, or key, pollutants in each type of room in the dwelling. It is assumed that if the key pollutant is adequately controlled then other pollutants in that room are also adequately controlled. In some rooms it may not be clear which is the key pollutant until some calculations have been made. Key pollutants for various room types are as follows:

Low pollution rooms: CO_2 (metabolic) or water vapour;

— kitchen: water vapour, odours, CO_2 (from combustion of fuels);

— bathroom: water vapour;

— WC: odours;

— laundry/utility room: water vapour.

Other pollutants can be released during specific activities, such as vapours from paints and adhesives used as part of a hobby. If known these may be included in the calculation method.

Pollutant emission rates should be calculated for each room separately based on either known emission rates (where available) or the data given in Annex A. This may require assumptions about the number of occupants in the dwelling, the type and rating of combustion appliances, and occupant habits (clothes washing, cooking, bathing etc.).

7.1.6 Minimum and maximum ventilation air flow rate

Minimum ventilation airflow rate is intended to ensure that a minimum level of air quality is maintained by removing pollutants which are continuously emitted from materials and activities in the dwelling, removing residual pollutants (particularly water vapour) after occupation ceases, and to reduce the risk of a build-up of condensation in ventilation ducts. There may be different minimum air flow rates for when the dwelling is occupied and when it is unoccupied. The minimum ventilation rates (if any) should be as specified in national and local building regulations and standards.

If the ventilation system has automatic demand control of air flow rate, and is kept operating when the dwelling is unoccupied, it should be possible to design the ventilation system with a minimum air flow-rate lower than the specified minimum ventilation air flow rate. There may be a maximum ventilation air flow rate specified for energy efficiency reasons. The maximum ventilation air flow rate (if any) should be as specified in national and local regulations and standards.

7.1.7 Effect of weather on ventilation air flow rates

Natural ventilation is driven by variable forces (wind and stack effect) and therefore the ventilation air volume flow rate is not constant. Fan assisted ventilation systems may also be affected by wind, although the effect should be less than with natural ventilation. The ventilation air volume flow rates specified in this Technical Report are therefore nominal values for appropriate weather conditions.

For natural ventilation systems air flow rates should be calculated on the basis of assumptions about outdoor temperature, internal temperature, wind speed and direction in addition to data on the physical and aerodynamic characteristics of the dwelling and ventilation system. These design values should be according to local climatic conditions during the heating season. It is possible to use local weather statistics to calculate a natural ventilation air volume flow rate which is likely to be exceeded for a chosen percentage of the time using the calculation methods given in EN 13465.

There may be specified a low air flow rate to be exceeded for a large proportion of the time to maintain adequate indoor air quality and a high air flow rate to be exceeded for only a small proportion of the time to limit energy consumption.

7.1.8 Tobacco smoke

It is unusual to make special provision for removal of tobacco smoke in dwellings. However, in rooms where smoking is likely to occur such provision may be made, if required, for example by increasing fan air flow rate, by openable windows or by another device (e.g. an electrostatic filter). Ventilation air flow rates may need to be increased by a factor of 2 to 10 to deal with tobacco smoke.

7.1.9 Combustion appliances

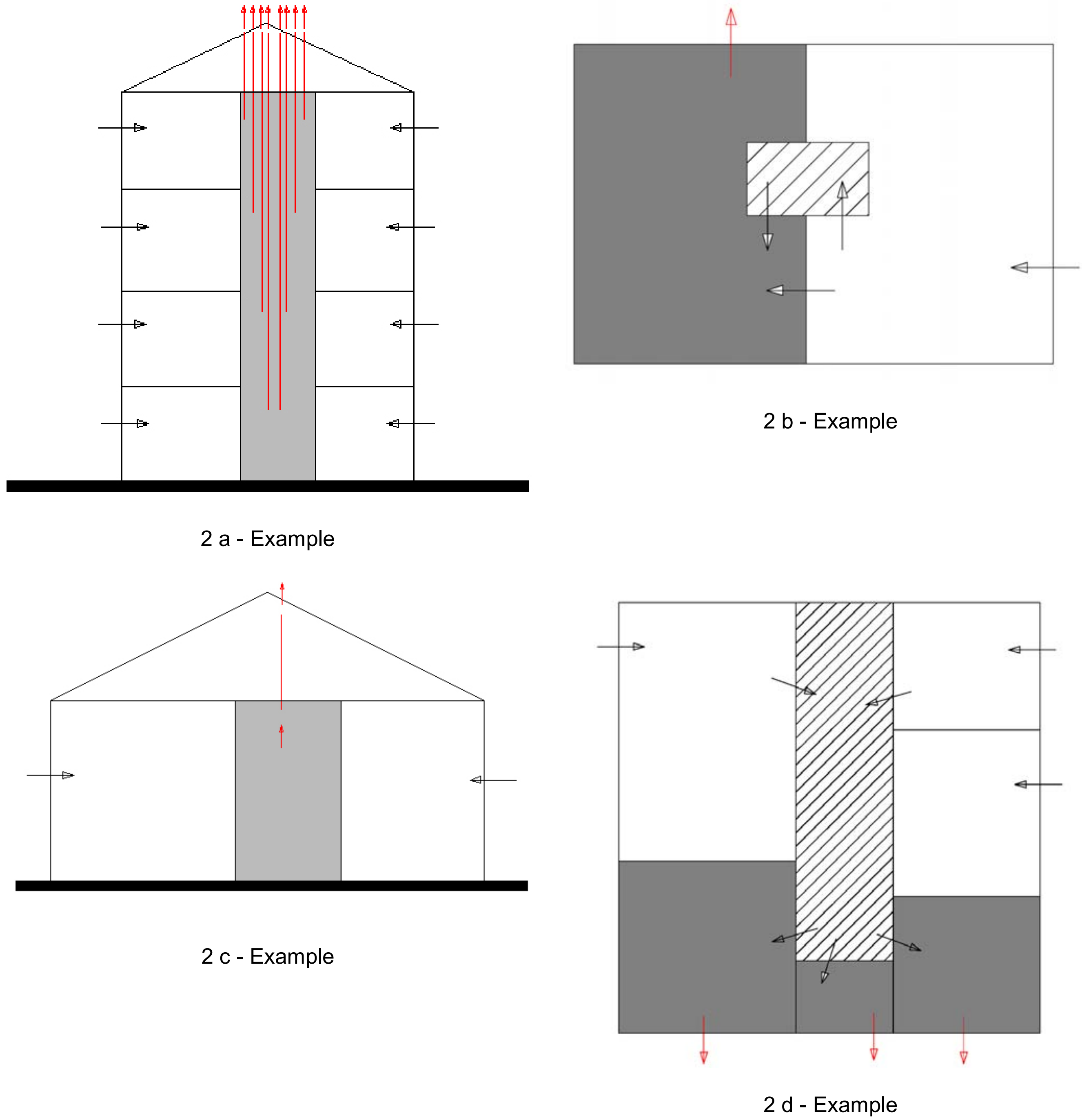
Air supply requirements for open flued combustion appliances are contained in other standards and in national and local regulations. However, such air flows contribute to the removal of pollutants from dwellings and so, for the purposes of this Technical Report, combustion air supplies may be included in the ventilation air flow rates for ventilation of the dwelling.

The air flow rate through the appliance is a function of the design of the appliance, the principle on which it operates and for some types (mainly oil and gas appliances) frequency of burning cycles. This is outside the scope of this Technical Report but a simple method of estimating the contribution made to ventilation air flow rate by combustion appliances may be found in EN 13465. Attention is drawn to the requirements of 7.3 Interaction with combustion appliances in this Technical Report.

Flue-less space heating appliances require very high ventilation air flow rates for removal of their combustion products. Combustion products given off by flue-less appliances for each kW of rated input are equivalent to the CO_2 production from about 8 people, and water vapour production of about 3 people. It is strongly recommended that flue-less space heating appliances are not used in dwellings, but if the ventilation system is designed to deal with them then Equations E.1 and E.2 should be used to calculate the necessary ventilation air flow rates.

7.2 Direction of air flow between rooms

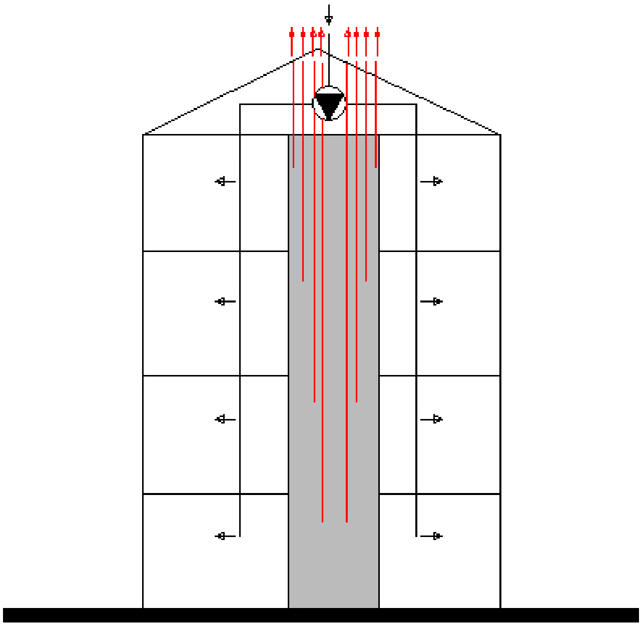
It is a design aim that the direction of air flow inside the dwelling is from low pollution rooms to activity rooms (see Figures 2, 3, 4 and 5). Therefore, air should be supplied and extracted in such a way as to restrict, so far as is practical, the movement of air from rooms containing the main sources of pollutants and excess water vapour (activity rooms) to other rooms (low pollution rooms). Low pollution rooms therefore usually have an outside air supply whilst activity rooms usually have an air extract device. The design condition should be with windows and all doors closed in which case the designer may have to consider making provision for air transfer between rooms to ensure that design air flow rates are achieved in practice.



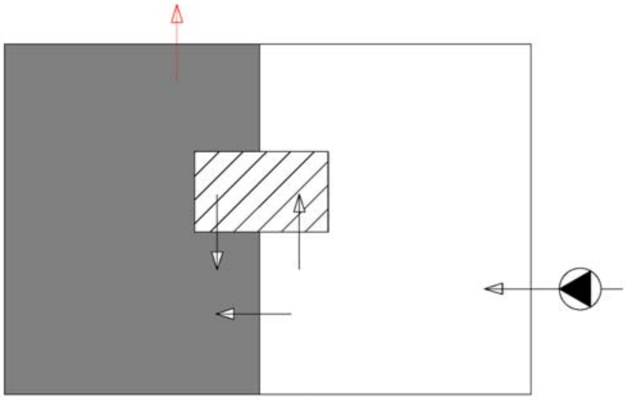
Key

shaded part	extract area
non shaded part	supply area
hashed part	transit area

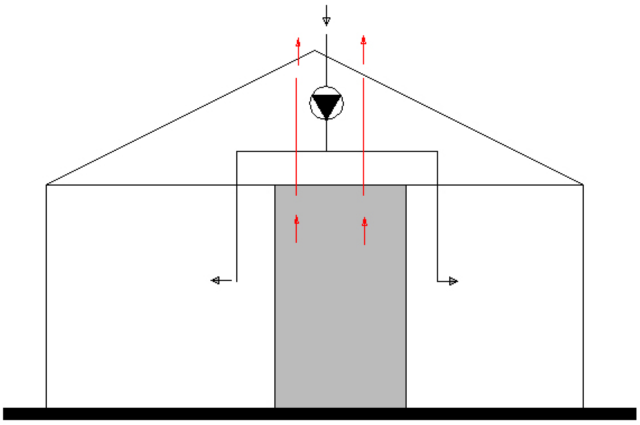
Figure 2 — Examples of natural ventilation



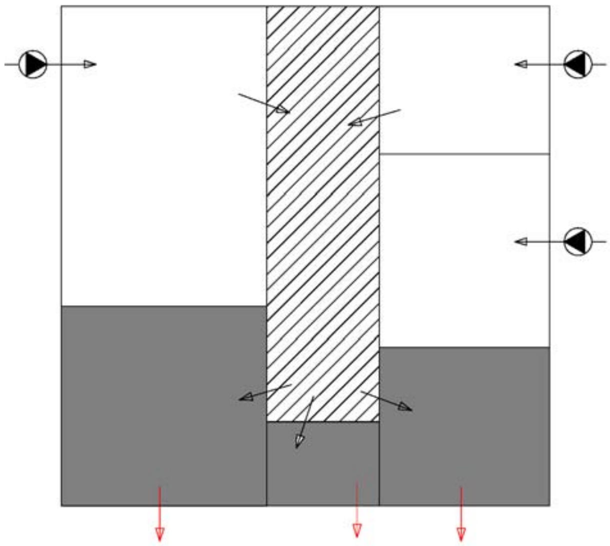
3 a - Example



3 b - Example



3 c - Example

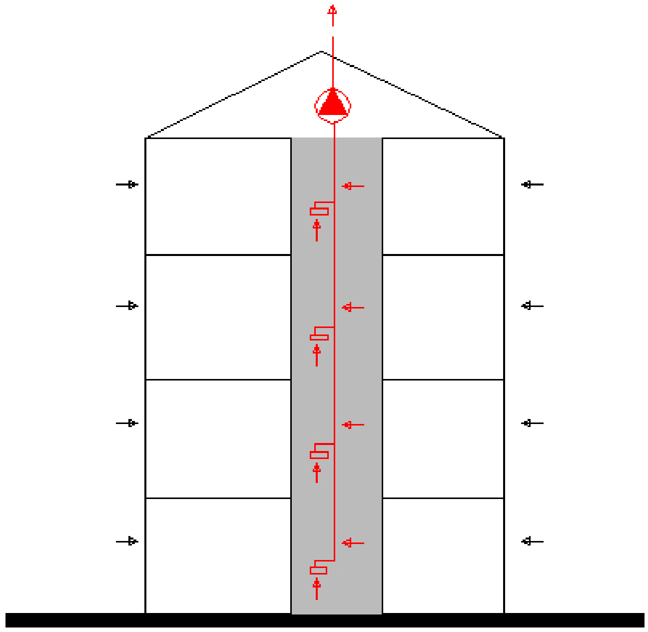


3 d - Example

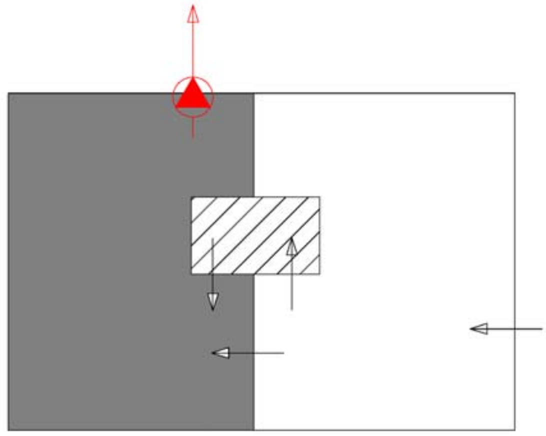
Key

shaded part	extract area
non shaded part	supply area
hashed part	transit area

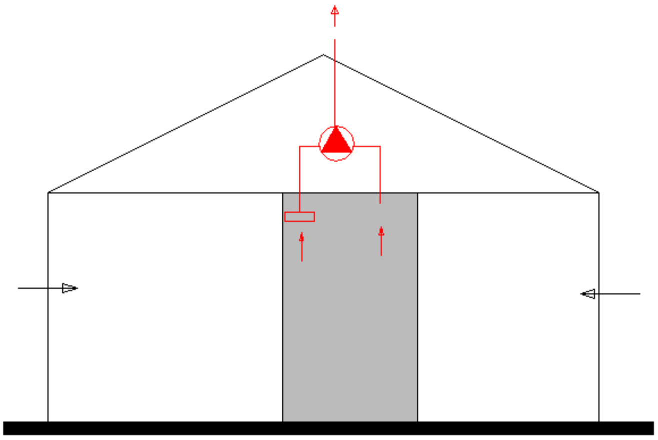
Figure 3 — Examples of fan assisted supply ventilation



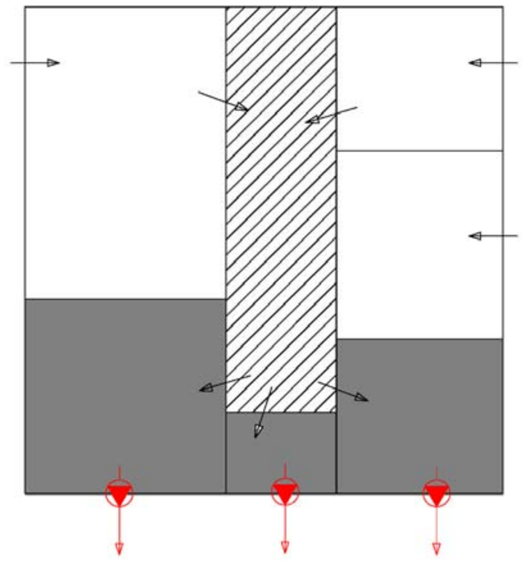
4 a - Example



4 b - Example



4 c - Example

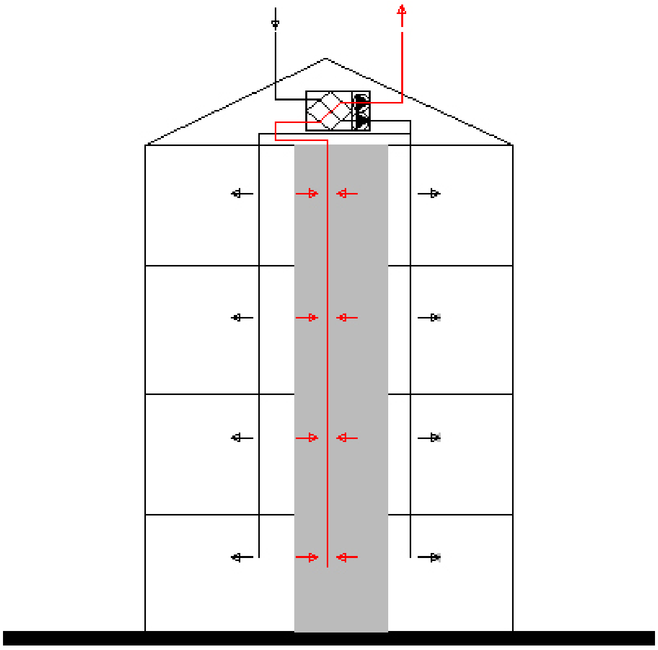


4 d - Example

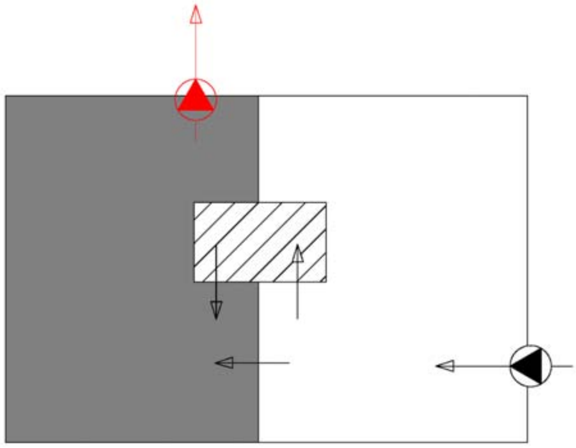
Key

shaded part	extract area
non shaded part	supply area
hashed part	transit area

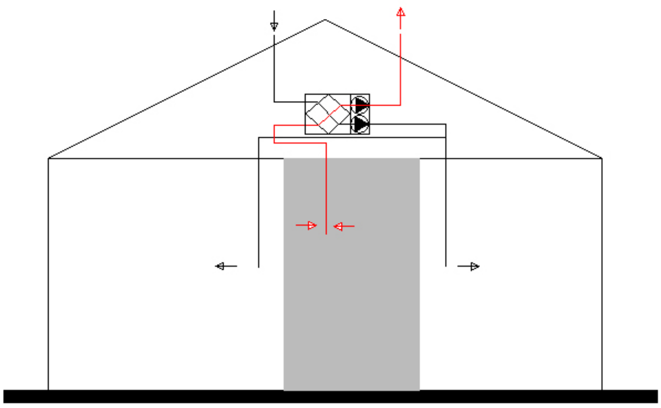
Figure 4 — Example of fan assisted extract air ventilation



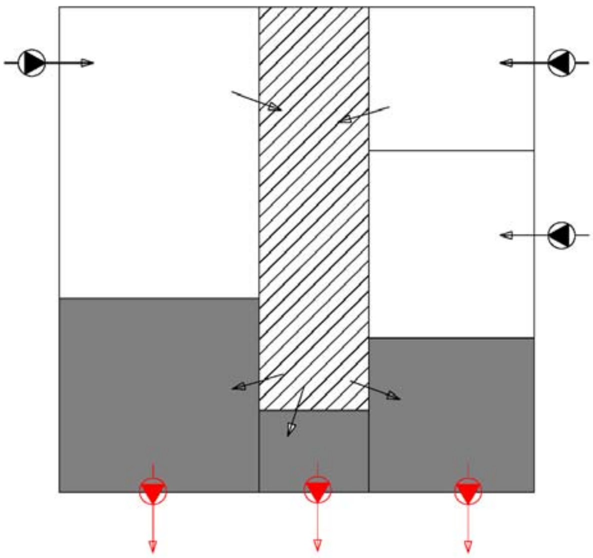
5 a - Example



5 b - Example



5 c - Example



5 d - Example

Key

shaded part	extract area
non shaded part	supply area
hashed part	transit area

Figure 5 — Example of fan assisted balanced air ventilation

7.3 Interaction with combustion appliances

The ventilation system should not adversely affect the safe operation of open-flued combustion appliances (ventilation systems do not normally interact with room sealed appliances). Air extract devices which are not located in the same room as the combustion appliance should be considered because they may also interact with combustion appliances. Particular requirements may be specified in national and local building regulations and standards.

Combustion appliances installed without a specific air supply may be supplied with air through the ventilation system. The compatibility of the ventilation system air extract and supply flow rates with the appliance's air supply rate should then be checked. Combined extracting of air and flue gases is permitted provided this does not lead to improper operation of the combustion appliance.

7.4 Cleaning and maintenance

The ventilation system should be so arranged, designed and installed as to facilitate easy cleaning, maintenance and repair of those components which reduces the performance of the system if they are neglected. Those components which are intended to be replaced during maintenance should also be easily accessible. The basic requirements for ductwork components to facilitate maintenance are given in ENV 12097.

If a component has to be removed for cleaning and/or maintenance its construction should allow remounting and the service instructions should include sufficient guidance for the checking of its function.

Provisions for filter pressure drop measurements or exchange should be provided when applicable as well as clear indications of the limits of range of use of the filter.

NOTE National and local regulations for routine maintenance work may require checking of air flow rates and in such cases permanent air flow measuring points should be installed in the system at convenient places. These measurements are covered in detail in EN 14134.

7.5 Pollutants distributed by the ventilation system

Pollutants should not be allowed to spread between dwellings or between a dwelling and another part of a building through the air ducts of the ventilation system.

Filtration of outdoor air may give a measure of protection to both the occupants of the dwelling and to components of the ventilation system. EN 13779 contains categories of both indoor and outdoor air with recommended filter classes according to EN 779 which may be used for residential purposes.

Filtration of indoor air does not generally protect the occupants but it is desirable to protect, and perhaps extend the life of, components of the ventilation system. Fans and heat exchangers in particular may require less frequent maintenance and cleaning if suitable particulate filters are used upstream of them.

7.6 Strength and durability

A ventilation system should be installed using supports of adequate strength, e.g. as specified in EN 12236.

All components should be made of durable materials which are resistant to the environment in which they are installed over an economically reasonable working life.

7.7 Fire precautions

Ventilation systems and installations should be executed in a manner which ensures that they do not promote the spread of smoke or fire between compartments or into fire escape routes (such as protected stairways and corridors).

Ventilation system components should be made of materials, and mounted in a manner, which ensures that the intended fire resistance is maintained.

NOTE National and local regulations for fire safety may impose other requirements on ventilation system design.

7.8 Noise

7.8.1 Introduction

The ventilation system should be designed in such a way that the acoustic requirements (sound insulation) between dwellings, or between a dwelling and outside are fulfilled. In particular, noise transmission between dwellings via the duct system of a central ventilation system (such as in an apartment type building) is carefully considered.

The ventilation system should not generate excessive noise. Any noise produced should be steady and should not contain any distinguishable tonal or impulsive characteristics. Relatively high noise levels are likely to be tolerated in activity rooms from intermittently operated fans and continuous systems on boost, although even here noise may not be acceptable if it affects activities such as listening to a radio or having a telephone conversation. Noise is least likely to be tolerated in certain rooms and at certain times, particularly bedrooms at night and other low pollution rooms during quiet periods of the day. In addition, a fan assisted ventilation system does not generate unacceptable noise outside the building.

Controlling noise aspects, in particular reducing noise levels, is one of the most important factors that contribute to the satisfaction with a ventilation system. Noise aspects related to ventilation systems can be divided into two main classes: direct noise and indirect noise.

Direct noise is noise generated by the system itself. The system is both the source and the means of transport of the noise. Examples are noise generated by fans and by the mounting materials of air ducts (structure born noise), and noise generated by control valves and air ducts and devices (aerodynamic noise).

Indirect noise includes all noise of which the source is outside the system. In this case the system merely transfers noise which originates outside the system.

Examples are traffic noise, noise from industrial plants, catering establishments and aircraft (outdoor noise), and domestic noise (Internal noise sources).

7.8.2 Problem identification

In general, the following ventilation techniques apply to dwellings:

— natural ventilation;

— fan assisted exhaust ventilation;

— fan assisted balanced ventilation, with or without heat recovery;

— fan assisted supply ventilation.

Noise related to domestic ventilation systems can be divided into three main areas:

— outdoor noise entering the dwelling through ventilation openings (cracks, slots, and air supply- and exhaust openings);

— noise generated by the ventilation system inside the dwelling and outside the building;

— sound transmission within or between dwellings by the ventilation system and/or internal ventilation provisions.

Depending on the type of ventilation system and the strategy, one or more of the three areas indicated in Table 1 below are important.

Table 1 — Noise importance

	Natural ventilation	Fan assisted exhaust ventilation	Fan assisted balanced ventilation	Fan assisted supply ventilation
Outdoor noise	x	x	0	x
System noise	-	x	x	x
Sound transmission	0	x	x	x

- irrelevant/not applicable
o in general of minor importance
x important

7.8.3 Requirements for noise

The acoustic requirements should be such that the requirements defined by national and local regulations and standards for sound insulations are achieved. A discussion of sound insulation requirements and calculation methods is given in informative Annex G.

7.9 Energy

The main purpose of a residential ventilation system is to provide adequate indoor air quality for the occupants and to protect the dwelling fabric from damage due to high indoor humidity. It is desirable to minimize the effect on energy consumption by a ventilation system (impact on heating and cooling need, fan electrical consumption) but it is important that this does not adversely affect indoor air quality. The ventilation system may be controllable (e.g. running time and/or flow rate) to eliminate or reduce the occurrence of high ventilation air flow rates when they are not needed. The control can be automatic (sometimes called demand control) or manual.

It may be possible to use automatic controls which ensure ventilation is provided where and when occupants actually need it. For example, controls could provide a relatively high air flow rate in bedrooms at night when the room is occupied but not during the day when the room is empty, and a relatively high air flow rate in a living room during the day but not at night. However, this type of occupancy control is not recommended for bathrooms or kitchens because of their high moisture production. In this situation, the ventilation demand is better evaluated on basis of the relative humidity than on basis of the presence of occupants.

Opening an air supply device in a kitchen during boost operation of a kitchen extract device may be more economic than taking air for boost from low pollution rooms when there is excess of air temperature in the kitchen.

In some climatic regions, or in special circumstances, it is economic to incorporate the facility for recovery of energy from the air extracted from a house. The recovery may be by means of a heat pump or a heat exchanger or both. The energy recovered may be delivered to the supply air part of the ventilation system, to the domestic hot water system or, a wet space heating system. The system performance should be carefully examined to ensure that the heat recovery is justified relative to the energy used to achieve it with respect to cost and environmental impact (e.g. it is common for relatively expensive electrical energy to be used by fans in order to recover cheaper energy from oil or gas). An adequate level of insulation on ventilation ducts is very important for systems incorporating heat recovery to ensure that the energy recovered is not cancelled out by convective and radiant heat loss from the duct system.

It is important that the ductwork associated with ventilation systems is reasonably airtight to avoid unnecessary energy loss due to leakage of warm or cold air. EN 13779 includes several classes of air leakage performance for ductwork, of which it is recommended that class B is suitable for residential systems. Thermal insulation of parts of the ductwork may be required to reduce heat losses and prevent condensation on surfaces (see 7.2).

7.10 Thermal comfort

The main requirement for thermal comfort concerns draughts, which are a function of air temperature and velocity. Guidance on this may be found in EN 13779.

In some climatic regions it may be necessary to preheat supply air in order to achieve required thermal comfort conditions.

7.11 Other requirements

A ventilation installation should be constructed so that reduced ventilation performance and damage to the individual parts of the ventilation installation due to freezing and corrosion is prevented. Provision for defrosting of heat exchangers may be required.

As condensation may occur on or in ducts, attention should be paid to ducts carrying warm air through cold spaces or cold air through warm spaces. Either the ducts should be insulated to avoid condensation or provision should be made to remove water which has condensed.

8 Design rules for residential ventilation systems

8.1 General

The design of residential ventilation systems consists of five basic steps as follows:

i) make the required design assumptions for the items listed in accordance with Clause 6,

ii) determine the design performance requirements in accordance with Clause 7,

iii) select a ventilation strategy (natural of mechanical), and a control and running time strategy (automatic, manual, continuous, intermittent) as discussed in Annex D;

iv) plan the layout of the system including the locations of air supply and extract devices;

v) determine the sizes and performance specifications of air terminals, ducts, air transfer devices, fans etc., required to achieve the design air flow rates.

This clause defines steps (iv) and (v) in the design process which translate the design details to the actual components and their installation in the dwelling.

8.2 System layout and location of components

8.2.1 Air supply and location of air supply devices

Each low pollution room should be equipped with at least one air supply device (e.g. an externally mounted air transfer device and/or a supply air terminal device) to encourage the direction of air flow toward activity rooms. The air supply devices are normally chosen to supply the air flow rates required under Clause 7 above.

Unintentional air leakage (through cracks, gaps, construction joints, etc) should not be taken into account for individual room flows but may be used for total house flows (by calculation) using standard values or measurements. Unintentional leakage can be measured by a fan pressurization or equivalent test (see ISO 9972).

Precautions should be taken to ensure that the source of outside air is not contaminated due to proximity of an exhaust air outlet, flue terminal, or other avoidable source of polluted air. See also 7.3 on interaction with combustion appliances.

The location of air inlets in rooms should be chosen to minimize the risk of draughts. This generally means fitting them at high level (above the top level of the occupied zone) or following calculations based on thermal comfort criteria specified in national or local regulations and standards and the air velocity/temperature difference profiles applicable to the air supply devices used.

Air supply devices may be fitted in activity rooms to provide adequate air supply to the room when a continuous extract system is running on boost setting, but these devices should not adversely affect the pattern of air flows in the other rooms when running on a normal setting to ensure correct operation of the ventilation system through the whole dwelling. Air supply devices may also be fitted in activity rooms which have intermittently operated air extract devices. Air supply and extract devices should be carefully sited to ensure that they do not short circuit the desired air flow.

8.2.2 Location of extract air devices

Each activity room should be fitted with at least one extract air device. Extract air devices are usually placed at high level and as close as is practicable to the main source of pollutants in the room.

8.2.3 Internal air transfer devices

Internal air transfer devices are used to allow air to move between rooms in a dwelling, generally so that individual rooms are not significantly pressurized or depressurized by the ventilation system when internal doors are closed (see also 7.2 and 7.3). They are best located near the floor to avoid transfer of smoke in case of fire and consideration may be given to noise transmission and draught risks. Gaps under doors should also perform the air transfer function but with poor sound insulation performance compared with a sound attenuating internal air transfer device.

8.2.4 Exhaust air outlets

Ventilation systems should not allow significant re-entry of exhaust air into the dwelling or an adjacent building. Arrangements should be made to avoid significant re-entry of exhaust air into the dwelling through externally mounted air transfer devices, outdoor air intakes and windows. This may be achieved by careful design of terminals or by adequate spatial separation.

8.2.5 Ductwork

Where the system uses ducts the duct runs should be kept as short as possible to reduce heat losses, leakage and flow resistance.

8.2.6 Fans

The location for the installation of fan devices should be optimised in accordance of air flow and noise nuisance in occupied spaces; allowing easy access for maintenance; and avoiding long duct runs. In general, fans should be located (in order of preference from best to worst): inside or near hallways, kitchens or bathrooms; near living rooms or dining rooms; near bedrooms. These recommendations still apply when fans are installed in roof spaces.

8.3 Ventilation system design

8.3.1 Design rules which apply to all systems

8.3.1.1 Controls and running time

Controls are used both to maintain the indoor air quality and to optimize energy economy by varying air flow rates and/or running time. Their main function is to match air flow rates provided by the system to the demand for removal and dilution of pollutants. There are many different ways of controlling a residential ventilation system but they all fall into one of two categories: manual or automatic. The designer should select a type of control which is appropriate to the system and which the occupants can easily understand, are likely to use and can afford. No particular control method can therefore be recommended as ideal, although some types may be imposed by national or local regulations.

The types and function of controllers are discussed further in Annex D.

A control may also be required for defrosting of heat exchangers. This can be achieved in various ways which may affect running time.

8.3.1.2 Cleaning and maintenance

The ventilation system should be subjected to a schedule of periodic cleaning and maintenance to ensure it continues to meet the required performance. Therefore it should be possible to gain access to clean and maintain any parts of the ventilation system which would adversely affect the performance, the indoor air quality, or safety of the system if they were not cleaned or maintained. This includes air terminal devices, air transfer devices, ductwork, heat exchangers, fans and filters.

It may be desirable to provide measuring points which enable performance tests to be carried out to confirm that air flow rates and thermal data comply with the design specifications. The positions of these test points should be indicated in the system maintenance manual. See EN 14134 for performance testing.

At the early design stage the duct layout should be as symmetrical as possible, allow for maintenance or servicing (especially of those parts which are not easy to replace), and should avoid long lengths of flexible duct.

8.3.1.3 Energy economy and heat retention

Ventilation is usually regarded as contributing only a small part of the total space heating energy use in dwellings. However, it may reach 50 % of the total space heating energy losses in a well insulated house. The thermal capacity of air is approximately 1,224 W/(dm^3/s)/K and hence the power needed to heat a certain ventilation air flow rate may be written as:

$$P \approx 1{,}224\ Q\ \Delta t \quad \text{(Watts)}$$

where

Q is the air flow rate in dm^3/s;

Δt is the indoor/outdoor temperature difference in K.

If degree hour data are available for the location of a dwelling then the annual energy consumption due to ventilation, using a constant flow rate system, may be estimated from the following table:

Table 2 — Estimated annual ventilation energy consumption in kWh per year for constant flow rates

Degree hours Base 20 °C	**Ventilation air flow rate**						
l/s	0,3	13,9	27,8	41,7	55,6	69,4	83,3
25 000	8,5	425	850	1 275	1 700	2 125	2 550
35 000	11,9	595	1 190	1 785	2 380	2 975	3 570
45 000	15,3	765	1 530	2 295	3 060	3 825	4 590
55 000	18,7	935	1 870	2 805	3 740	4 675	5 610
65 000	22,1	1 105	2 210	3 315	4 420	5 525	6 630
75 000	25,5	1 275	2 550	3 825	5 100	6 375	7 650
85 000	28,9	1 445	2 890	4 335	5 780	7 225	8 670
95 000	32,3	1 615	3 230	4 845	6 460	8 075	9 690
105 000	35,7	1 785	3 570	5 355	7 140	8 925	10 710
115 000	39,1	1 955	3 910	5 865	7 820	9 775	11 730
125 000	42,5	2 125	4 250	6 375	8 500	10 625	12 750
Calculated using: Energy use = 1,224 Q (degree hours) / 1 000 kWh							
NOTE Degree hours = [(20 - t_o) . time in hours for which temperature is t_o during the heating season].							

The above table would apply to a fan assisted extract ventilation system, extracting from activity rooms only. For example, if the extract airflow and supply airflow are almost equal and constant, the order of magnitude energy use for other ventilation strategies may be roughly estimated by multiplying the tabulated values by the following values.

Supply and extract in each room 1,8

Natural ventilation (cross ventilation only) 1,8

Natural ventilation (with vertical ducts) 1,4

Demand controlled ventilation 0,5 to 0,9

Fan assisted balanced system with heat recovery 0,3 to 0,75

It is desirable to minimise the energy consumption of a ventilation system by means of heat recovery, insulation, choice of fans and controls, but it is important that the latter does not adversely affect indoor air quality.

The designer should consider the controls and location of ventilation devices with regard to energy economy. It may be possible to reduce or minimise ventilation energy use by employing demand control of fans, air terminal devices, and/or externally mounted air transfer devices. The quantity of outdoor air required may also be reduced by placing extract devices close to sources of pollutants and/or other consideration of ventilation effectiveness concentration.

Opportunities for heat recovery are mainly limited to fan assisted exhaust systems and fan assisted balanced systems by the use of heat exchangers and heat pumps (see 7.10). The designer should make his own assessment of the need for, the method of, and the cost effectiveness of heat recovery in a residential ventilation system. These matters are outside the scope of this Technical Report.

Those lengths of ductwork which require insulation should be identified and a suitable thickness of an appropriate insulating material determined. For thermal insulation this might depend upon cost effectiveness and for prevention of condensation on duct surfaces it should depend upon air temperatures and humidities in and around the ducts. Consideration should be given to keeping all ducts carrying warm air within the heated and insulated envelope of the dwelling rather than in a roof space where heat losses, even from insulated ducts, may be considerable. In summer, heat gains to ducts in roof spaces may contribute to overheating.

It is also important that the ductwork of the system is airtight so that unwanted loss of warm air and entry of cold air is minimized (see 7.10). Ducts should conform to the requirements of EN 1507 and EN 12237.

8.3.1.4 Noise

Design rules for noise are given in informative Annex G.

8.3.2 Fan assisted ventilation systems

8.3.2.1 Interaction with heating combustion appliances

Except for balanced flue appliances, the designer should specify that an appropriate test (pressure measurement and/or spillage test) be made after installation of the combustion appliance and ventilation system. It should also be prepared to adjust the design (air flow rates and air transfer device sizes) in order to correct any deficiency found during that test.

8.3.2.2 Duct system design and dimensioning

The pressure loss of the duct system should be determined including the resistance of air terminal devices and roof outlets to obtain the required fan performance. The resistance of duct components, air terminal devices and roof outlets should be obtained from manufacturer's specifications. An allowance for duct leakage may be made at the fan selection stage according to the duct leakage class chosen.

The pressure drop of components of the system should be as low as practicable, in order to keep the fan energy consumption as low as possible. In addition, the pressure drop may change due to e.g. dust accumulation, and this may affect the system pressure balance. Particular care should be taken where a ventilation system serves more than one dwellings to avoid movement of air from one dwelling to another via the duct system.

In airtight dwellings the pressure drop of the externally mounted air transfer devices may need to taken into account. The pressure loss of these devices should be taken from manufacturers' specifications for operation in the open position. For a fan assisted extract system the total extract air flow rate should be deemed according to:

— total supply air across the air inlets;

— pressure drop across the air transfer devices;

— pressure drop of the ductwork.

When designing, if the airflow rate is inadequate, changes should be made on the main components: air inlets, transfer devices and ductwork.

8.3.3 Natural ventilation systems

Design and dimensioning of natural ventilation systems requires design tools (e.g. computer models) which are too complex for inclusion in this Technical Report, particularly for tall buildings with common duct systems. Therefore, natural ventilation systems should be designed and dimensioned in accordance with national regulations or standards, or according to a system covered by a European Technical Approval. However, the following guidance and general rules may be useful.

For natural ventilation systems a distinction is made between cross ventilation and ducted ventilation systems. In the case of cross ventilation the air volume flows mainly result from wind effects (wind pressures), the vertical lifting forces (buoyancy) within the building being of less importance.

In the case of ducted ventilation systems the air volume flows result from the vertical lifting forces (buoyancy) within the building, and wind pressure effects on suitably designed cowls at the top of the ventilation ducts. In airtight dwellings the main part of the extract air discharges to the atmosphere by way of the ventilation ducts but as air-tightness reduces more air is exchanged by cross ventilation.

For the above mentioned natural ventilation systems the following building and ventilation system components are important:

— envelope of the building: air-tightness, windows, supply air and extract air devices;

— within the building: internal air transfer devices, ventilation ducts.

The extract air should be taken from the rooms containing the main sources of indoor pollutants and water vapour. These rooms are usually kitchens bathrooms, WCs, laundry rooms.

Ducted ventilation systems are usually designed with a separate duct and roof outlet for each room. However, in some countries ventilation ducts are permitted to be connected to several dwellings provided the connections are made using shunt ducts.

Because the pressure differences are relatively low in a natural ventilation system, the extract ducts should run as near straight and vertical as possible.

9 Specification and documentation

The designer should list all the design assumptions (see Clause 6) and clearly define in drawings and other documentation that he has designed, what components he has selected and any special requirements for the installation of the components.

The designer should ensure documentation is available to the installer stating what the performance of the completed system should be, as well as the required performance of the individual components (e.g. fans, filters, controls), for inclusion in the maintenance and operation manual.

The installer should clearly describe any change between the designed and the installed ventilation system.

System performance should be measured according to the test methods given in EN 14134.

NOTE The maintenance and operation manual is the joint responsibility of both designer and the installer. The required contents of this manual is given in EN 14134.

Annex A
(informative)
Residential pollutant production rates

WARNING — Persons using this Technical Report should be familiar with normal laboratory practice. This Technical Report does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any national regulatory conditions.

A.1 Human respiration

Pollutant production rates from human respiration are dependent on the occupants level of activity. For typical household activities they are as follows (taken from British Standard BS 5925:1991). Water vapour production rate for a sleeping adult is approximately 40 g/h (or 0,014 l/s of vapour), and for an active adult 55 g/h (or 0,019 l/s of vapour). Carbon dioxide production for an adult male sitting quietly is 0,004 l/s, rising to between 0,006 and 0,013 l/s for light work (based on a production rate of 0,000 04 *M* l/s per person where *M* is the metabolic rate in watts). Suggested emission durations are: for a living room 4 h; for a bedroom 10 h.

A.2 Moisture generation rates

Table A.1 — Moisture generation rates

(a) Typical moisture generation rates for household activities	
Household activity	Moisture generation rate
Cooking (electric cooker)	2 000 g/day
Cooking (gas cooker)	3 000 g/day
Dishwashing (by hand)	400 g/day
Bathing/showering/washing	200 g/day per person
Washing clothes (by hand/open top machine)	500 g/day
Drying clothes indoors (natural drying or by un-vented tumble dryer)	1 500 g/day per person

(b) Daily total moisture generation rates for households			
Number of persons in household	Moisture generation rates, kg/day		
	Dry occupancy [a]	Moist occupancy [b]	Wet occupancy [c]
1	3,5	6	9
2	4	8	11
3	4	9	12
4	5	10	14
5	6	11	15
6	7	12	16

[a] Dry occupancy, i.e. where occupant habits limit moisture generation; includes households unoccupied during the day; results in an internal vapour pressure up to 0,3 kPa in excess of the external vapour pressure.

[b] Moist occupancy, i.e. where internal humidities are above normal; possibly a family with children; water vapour excess is between 0,3 kPa and 0,6 kPa.

[c] Wet occupancy, i.e. where there is high moisture generation; probably a family with young children; clothes dried indoors; water vapour pressure excess is greater than 0,6 kPa.

Table A.2 — Moisture generation rates expressed as litres per second of vapour with suggested design emission durations for each activity/source

Room	Emission rate (of vapour)	Duration	Activity
Kitchen	0,6 l/s followed by 1,0 l/s followed by 1,5 l/s	10 min 10 min 10 min	Cooking (including vapour from cooking), three outputs each occurring consecutively during one session
Bathroom	0,5 l/s 0,06 l/s	10 min 12 h	One person taking a shower Clothes drying
NOTE Density of water vapour is approximately 0,8 kg/m^3 at 0 °C and 1 013,25 mbar.			

A.3 Production rates of combustion appliances

NOTE For ducted appliances, the major part of pollutants is discharged outside.

Table A.3 — Combustion appliances: typical carbon dioxide and water vapour production rates

Fuel	CO_2 production rate (L/s per kW input)	Water vapour production rate (g/h per kW input)
Natural gas	0,027	150
Manufactured gas	0,027	100
Liquefied petroleum gas	0,033	130
Kerosene	0,034	100

For a single cooking period with natural gas it is suggested that a CO_2 emission rate of 0,05 l/s is used with a duration of 30 min.

A.4 Water vapour from the ground below a dwelling

Depending of the type of ground floor construction, water vapour can also enter the dwelling in significant quantity through the ground floor. This source of water vapour is mainly associated with suspended ground floors of timber or concrete construction (i.e. those with a void or crawl space below the floor). The designer should take this source into account when appropriate.

The entry of water vapour from the crawlspace (or other sub-floor void) into the dwelling is mainly caused by air infiltration. The air-tightness of the ground floor and the pressure difference across it determine the amount of infiltration and so the rate of entry of water vapour.

The supply of water vapour is limited when the air-tightness of the floor is increased or when the concentration of water vapour in the crawlspace is decreased.

Dutch regulations specify the air-tightness of ground floors (to be built) as less then 0,000 02 m^3/s per square meter of ground floor area. This means for a typical dwelling with a 50 m^2 ground floor, the airflow should be less then 1 dm^3/s (driven by a pressure difference of 1 Pa).

Measurements in Dutch dwellings have indicated that:

— floor air-tightness is usually less then the regulated value;

— pressure difference is more then 1 Pa (approximately 1~4 Pa);

— water vapour concentration in the crawlspace is often 6 gr/m^3 more than the concentration in the outside air, especially when the groundwater level is near the surface.

In these cases, every m^3 air-infiltration from the crawlspace brings 6 grams of water vapour into the dwelling. With the assumed airflow of 1~2,5 dm^3/s, this is equivalent to 0,5~1,25 kg per day.

Annex B
(informative)

The relationship between humidity and temperature and use of the psychrometric chart

At a given temperature air is capable of containing a limited amount of water as invisible vapour; the warmer the air the more water vapour it can contain. If moisture laden air comes into contact with a cold surface condensation occurs at the temperature at which air becomes saturated (dew point). Water vapour in the air exerts a pressure, the vapour pressure, and so air containing a large mass of water vapour has a higher vapour pressure than dryer air. The amount of water contained in air can be expressed either as vapour pressure (in kPa) or as the ratio of the mass of the water vapour to the mass of the air (in g/kg or kg/kg) The term usually used to describe whether air is dry or water laden is relative humidity (RH). The relationship between humidity and temperature is illustrated with the aid of a psychrometric chart (see Figure B.1).

The psychrometric chart relates air moisture contents and temperatures and may be used in calculations made to check that condensation does not occur. As an example of the use of the chart consider point A in Figure B.1. This represents an air condition of 0 °C and 90 % RH. From the right-hand scales it can be found that such air contains 3,40 g of water per kilogram and has a vapour pressure of 0,55 kPa. This might well be the condition of outdoor air in winter.

Point B indicates air with the same moisture content and vapour pressure, but as it is now at 20 °C its relative humidity has changed to approximately 24 %. This shows what happens to the outdoor air after it enters a building and is warmed, if no other change occurs.

Point C indicates air still at 20 °C, but with moisture content raised to about 10,2 g/kg. Vapour pressure therefore also rises, to about 1,64 kPa. The increase in moisture content without change in temperature means that relative humidity has risen, and the curved lines show this to be about 70%. This is what might occur when the incoming air has picked up moisture from activities within the building.

Reading horizontally to the left from point C, point D indicates when saturation would occur, i.e. when the air is cooled to a dew point temperature of about 14,3 °C.

NOTE If it is desired to calculate air/moisture characteristics by computer it is necessary to use appropriate equations. A number of equations exist; the following are simplified equations which provide a close approximation to the saturation vapour pressure at a given temperature and have been obtained from the Magnus formula.

Saturation vapour pressure

(for t>0)

$$\text{SVP (kPa)} = 0{,}6105 \exp \{(17{,}269 \times t)/(237{,}3 + t)\}$$

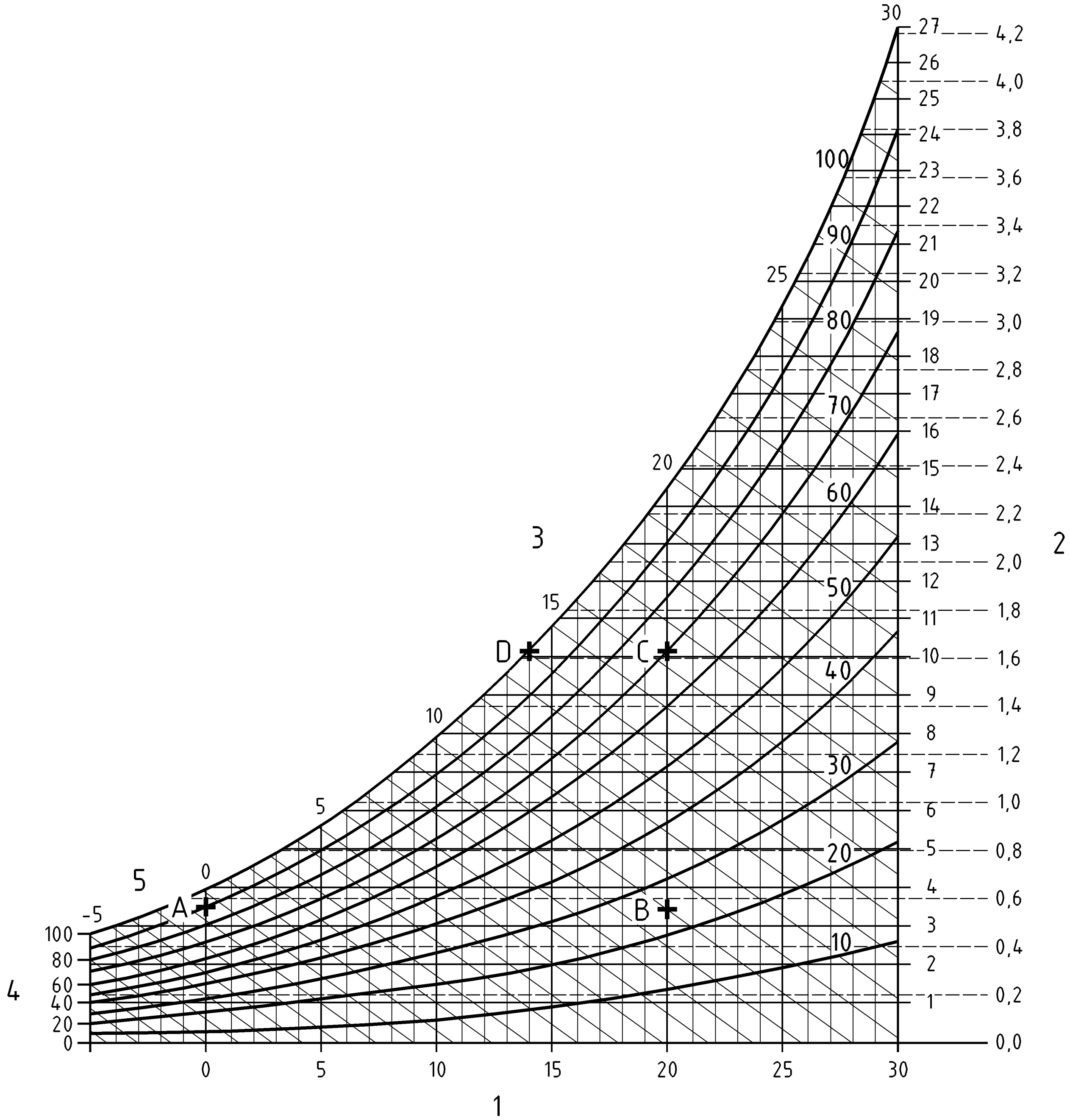
(for t<0)

$$\text{SVP (kPa)} = 0{,}6105 \exp \{(21{,}875 \times t)/(265{,}5 + t)\}$$

where t is the temperature in °C.

In most types of buildings, decorative and furnishing materials have the ability to absorb some moisture, and to release it back into the indoor air when conditions allow. The effect is to enable moisture to be absorbed into the fabric of the building during periods of high moisture generation, such as bathing or cooking, the absorbed moisture being slowly released back into the indoor air over the longer periods between (when indoor air humidity levels have fallen). The peak indoor humidity reached during moisture production is therefore lower than it would be in a non-absorbent building and there is still a need for ventilation between periods of high moisture production when the absorbed moisture is being released.

Annex C includes a method of calculating the effect of absorption on indoor humidity for use in ventilation air flow rate calculations, but it is remembered that the water vapour absorbed still has to be removed by ventilation during a period of time after the activity producing the water vapour ceases. A 24 hour cycle is normally assumed but it may take many cycles to reach dynamic equilibrium.



Key

1 dry bulb temperature, in °C

2 vapour pressure, in kPa

3 wet bulb temperature, in °C

4 relative humidity, in %

5 saturation

Figure B.1 — Psychrometric chart

Annex C
(informative)

Method of calculating water vapour absorption effect

The results from a number of studies of the absorption and de-sorption of moisture by building materials and furnishings have been published. Seven of these were reviewed by R Jones in his paper "Indoor humidity calculation procedures" published by the Chartered Institution of Building Services Engineers of London in their journal "Building Services Research and Engineering Technology", 16(3) pp119-126 (1995). That review concluded that no single method emerges as being markedly better than any other and that they were all at an interim stage of development. Therefore it is not appropriate to recommend a particular method as a normative element of a European Standard at present. However, the effect of absorption and de-sorption of water vapour is so important to ventilation in dwellings that it was felt desirable to offer some guidance in this Technical Report which might be used in an informative annex.

Any of the seven methods described in the paper by Jones could justifiably be used and the reader is referred to that paper for a description of each and the original technical references. The problem generally is in choosing appropriate values for some of the variables used in the calculations. For the purpose of calculating ventilation air flow rates for Annex F of this Technical Report the method developed by the Centre Scientifique et Technique du Bâtiment (CSTB) in France (on the basis of the approach in IEA Annex 14) was arbitrarily chosen and is briefly described below.

$$\frac{dm}{dt} = kA\psi_{svp}\left(RH - \frac{m}{CA\psi_{svp}}\right)$$

The mass transfer equation is expressed as a function of relative humidity:

where

m is the mass of water absorbed in the material, expressed in kg;

t is the time (h);

k is the humidity transfer coefficient (kg $m^{-2}h^{-1}(kg^{-1}kg)$);

A is the surface area, expressed in m^2;

Ψ_{svp} is the vapour content of air at 100 % RH (kg kg^{-1});

RH is the relative humidity of the room air (scale from 0 to 1);

C is the average moisture content of a material (kg kg^{-1});

This may be expressed in the form:

$$\frac{dm}{dt} = \alpha RH - \beta m$$

Values for α and β suggested by CSTB are: α = 0,035*S* and β = 0,018 where *S* is the equivalent absorption surface area in the room (including furniture).

By considering the exponential humidity increase or decrease using humidity equations for the transfer of water from the room air to the material leads to a differential equation offering the solution as follows:

$$\frac{dRH}{dt} + \left(\frac{\alpha}{g_{svp}\upsilon} + n + \beta \right) \frac{dRH}{dt} + \beta n(RH + RH_0) = \frac{\beta P_{(t)}}{g_{svp}V}$$

where

g_{svp} is the air humidity at saturation (kg m^{-3});

υ is the volume of the room (m^3);

n is the ventilation rate (air changes per hour);

RH_0 is the relative humidity of outside air adjusted to the room air temperature (on a scale from 0 to 1);

$P_{(t)}$ is the moisture generation rate at time t (kg m^{-3});

V is the volumetric air change rate (m^3 h^{-1}).

$$RH = A_1 e^{-(C_1 t)} + A_2 e^{-(C_2 t)} + e^{(te)}$$

The general solution to this is:

$$RH = A_1\ e^{-(c_1 t)} + A_2\ e^{-(c_2 t)} + e^{(te)}$$

where

$$C_1 + C_2 = \frac{\alpha}{g_{svp}\upsilon} + n + \beta$$

and

$$C_1C_2 = \beta n$$

In practical situations where there is ventilation, the rate n is considerably greater than the factor β. So in cases where $\beta << n$ an approximation is made so the time constants are defined as:

$$\tau_1 = \frac{1}{C_1} = \frac{g_{svp}V}{\alpha + ng_{svp}V}$$

and

$$\tau = \frac{1}{C_1} = \frac{1}{\beta} + \frac{a}{\beta ng_{svp}V}$$

The modified humidity growth curves from one equilibrium state to another can thus be defined. It has been found that in some cases the time taken to reach equilibrium can be as much as 50 days or more.

Annex D
(informative)

Residential ventilation systems and their interaction with the dwelling

The purpose of this annex is to indicate some common variations in the design of residential ventilation systems and to explain how the actual performance of systems in service may vary according to the characteristics of the buildings in which they are installed.

D.1 Ventilation strategies

In order to provide adequate ventilation either natural or mechanical ventilation systems may be employed, or a combination of both natural and mechanical systems. For the purposes of this Technical Report natural ventilation is taken as one basic ventilation strategy and mechanical ventilation is broken down into three basic strategies according to how air is moved by the system.

The four basic ventilation strategies are illustrated in Figures 2 to 5. Each figure shows an example of a typical system as it might be installed in a single family house and in an apartment type building, together with an example of the resulting air flow directions in a simple room layout. Figures 2 to 5 are examples only and are not intended to be the specific detailed designs which may be used, nor do they represent the way in which the systems should actually work in all residential buildings.

It should be stressed that in apartment buildings there is a choice to be made between a single central ventilation system which serves a number of dwellings in the same building via common ducts (as illustrated in Figures 3, 4 and 5) and an individual ventilation system in each dwelling (such as would be used in a single family house). Central and individual ventilation systems are both acceptable solutions but factors such as fire safety, space requirements for ducts, energy consumption, noise etc., may influence the designer in making his choice.

D.2 Internal air movement in real dwellings

The intended internal air movements from one room to another are indicated in Figures 2 to 5 by arrows pointing in the direction of air flow (e.g. from a room fitted with an air inlet to a kitchen with extract ventilation). In real dwellings this flow could be more complicated than simply one direction as shown and in two storey residences ventilation air flows may be different from those in single storey residences. The buoyancy of warm air in two storey dwellings often causes an upward flow of warm air from the lower floor to the upper floor (mostly by the stairway). At the same time, cool air may also flow down from the upper floor to the lower floor. During cooking, warm moist air moves quickly from the kitchen to the upper floor in a two storey dwelling if internal doors are open.

A further consequence of the buoyancy of indoor air, which may be verified by simple modeling (e.g. the ‘implicit method’ given in EN 13465), is that an extract ventilation system does not induce equal supply air flow rates through externally mounted air transfer devices (EMATDs) at different heights in a dwelling. The inequality of air flow rates is a function of height difference, weather conditions, indoor temperature and air-tightness of the dwelling. The effect becomes important in two and three storey single family dwellings where air may exit rather than enter through EMATDs, even under zero wind conditions, during the heating season. In practice the cross ventilation resulting from wind and stack effects combined tends to compensate for departures from the designed ventilation air flow rates and air flow direction.

D.3 The influence of air-tightness on the performance of ventilation systems

The impact of the air-tightness of the envelope on the global airflow may be huge compared to the airflow due to the system.

In the case of balanced system with heat recovery, the impact on the energy (necessary to heat the air) is even more important than on the flow only as the additional flow does not cross the heat exchanger.

It is therefore very important to lower the air leakage to the lowest level (and to add specific air inlets if necessary, depending on the system itself).

A target could be to have an additional flow (Q_{add}) due to unwanted infiltration lower than 25 % of the system flow (Q_{syst}) or to have the same ratio for energy if a balanced system with heat recovery is used:

Figures D1 and D2 give the maximum values of n_{50} to achieve Q_{add} < 0,25 Q_{syst}.

For 2 systems: single exhaust or supply systems

balanced system

for 3 levels of shielding: A: heavy shielding

B: moderate shielding

C: no shielding

for 4 levels of Q_{syst} : 1 ach - 0,75 ach - 0,5 ach - 0,25 ach.

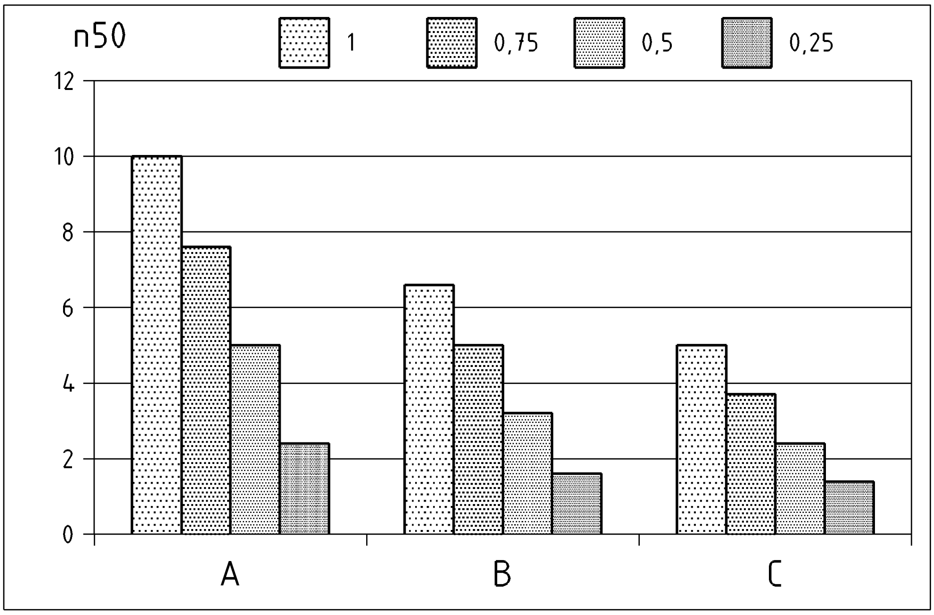


Figure D.1 — Single exhaust or single supply system (flow)

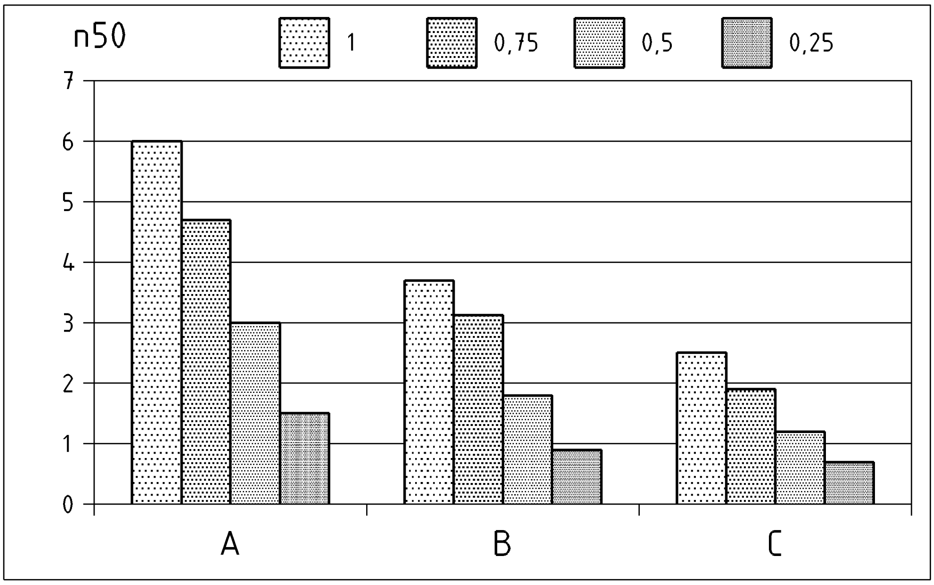


Figure D.2 — Balanced system (flow)

Figure D.3 gives the maximum values of n50 to achieve the target in energy:

Energy (Q_{add}) < 0,25 Energy (Q_{syst}):

For balanced system with heat recovery (65 % efficiency)

for 3 levels of shielding: A: heavy shielding

B: moderate shielding

C: no shielding

for 4 levels of Q_{syst} : 1 ach – 0,75 ach – 0,5 ach – 0,25 ach.

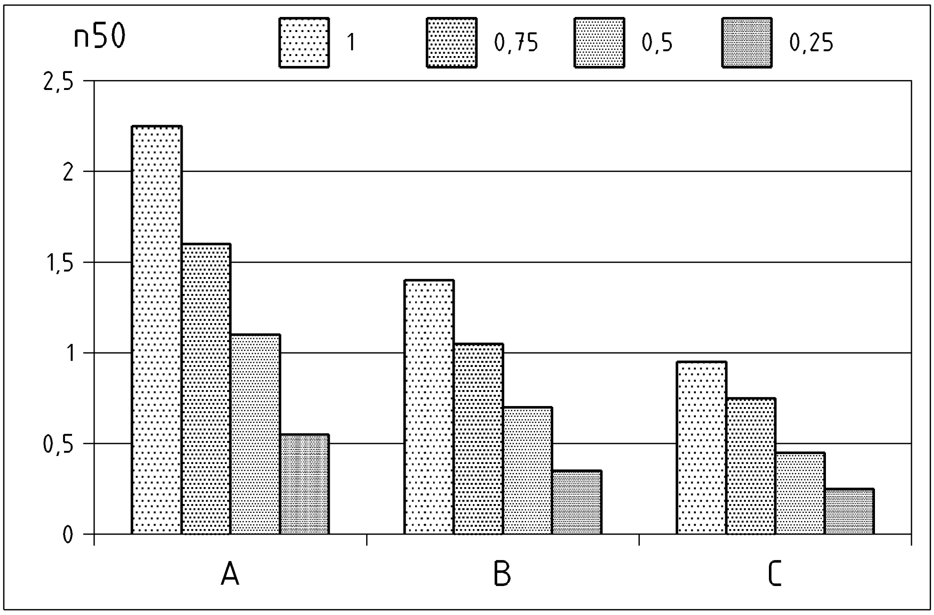


Figure D.3 — Balanced system (energy)

D.4 Location of outdoor air intake and exhaust air outlet terminals

For fan assisted ventilation systems the outdoor air intake and exhaust air outlet terminals can be located on the roof surface, above the roof surface, on the vertical walls, under the edges of a roof, or possibly in other places. However, their location takes into account the proximity of chimney and flue outlets, drain and sewer vents, regions of high wind induced pressures on the building surface, etc. and are discussed in detail elsewhere in this Technical Report.

For natural ventilation systems the outdoor air intake openings are normally in the facade (walls) of the building and the exhaust air outlet terminals cowls are on or above the roof.

The location of air intake openings can be difficult in city areas where pollution in the outdoor air from motor vehicles reaches unacceptable concentrations. In such cases the outdoor air should be taken from the facades away from the street and/or as high as possible above the street. This is somewhat easier where fan assisted ventilation is used than for natural ventilation. Filtration of outdoor air is increasingly being considered in city and urban areas where pollution from motor vehicles is a problem.

D.5 Location of other ventilation system components

The location of some major system components can also vary without detriment to the air flow performance of the system although care should be taken about energy losses. Obvious examples are the fans in exhaust systems (Figure 4) and the fan/heat exchanger unit in balanced supply and exhaust systems (Figure 5).

The simple exhaust system (Figure 4) may have a central fan coupled to kitchen, bathroom, WC and utility room via ducts. The fan may be in the roof space or somewhere within the living space such as in the utility room. The system may also consist of a number of individual room extract fans discharging directly to outside. There are other possibilities.

The fan and heat exchanger unit(s) in a balanced supply and exhaust system (Figure 5) may be fitted in the roof space, in a cupboard, or in the kitchen over the cooker, perhaps with an integral cooker hood. However, it is not essential that the fans and the heat exchanger are in one unit - they may be separated to allow a more versatile set of system components to be used. Whatever the layout of the system, to maintain energy efficiency good thermal insulation of components is important where they are installed in unheated spaces; this applies to both extract air and supply air components.

D.6 Controls and running time

Manual control is likely to be on/off or boost switching of fans and open/shut control of air transfer devices and air terminals. For successful operation the occupants need to understand what the ventilation system does and how to use the manual controls. Automatic control may be more desirable for occupants who cannot do this.

Automatic controls are available in a wide range of types including time switches, run-on timers, humidity sensors, occupant movement detectors, carbon dioxide sensors, pressure difference controllers and even air quality sensors. These may control all or only part of the ventilation system. The following paragraphs illustrate that automatic controls have to be chosen carefully according to how they function relative to the ventilation demand as well as the cost.

Sensors generally use humidity, carbon dioxide or other pollutant concentration as an indicator of general air quality. In mild climates where water vapour is a key pollutant a humidity sensor may be a suitable means of control. However, in very cold climates there may be very low indoor humidity when a humidity sensor may be less useful. Electronic air quality sensors are still under development but have the potential to respond to a wide range of pollutants, not just a single key pollutant such as water vapour or carbon dioxide.

Time switches can be useful where occupant activities are predictable, such as cooking prior to meal times and bathing in the morning or evening but for such activities humidity sensors can give more precise matching of ventilation to demand. If the humidity sensor responds to a rate of change of humidity rather than humidity rising past a set point then it may be more suitable in cold climates.

In internal bathrooms and kitchens the ventilation system may be linked to the light switch on the assumption that someone has entered the room to carry out an activity which requires ventilation. This type of control often includes a run-on timer to ensure ventilation continues for some period after occupancy of the room ceases.

Carbon dioxide and motion sensors are perhaps the least common used types in dwellings but they may still have a role to play. However, a carbon dioxide sensor is probably not appropriate in a bathroom or kitchen where water vapour is likely to be a key pollutant. A motion sensor can be effective in a bedroom even when the occupants are asleep. These sensors need to be sensitive to small movements and each movement detected should run the ventilation system for between 30 min and 60 min.

It is quite common to have a combination of ventilation system strategies in the same dwelling with one of the systems operating under occupant control (e.g. on/off switch) or some form of automatic (e.g. humidistat) control. One example of this continuous fan assisted exhaust air ventilation with a basic level of air flow rate for normal use and one or more boost levels, under occupant or automatic control, for use during periods of high pollutant production in activity rooms.

Another example is separate fan assisted exhaust ventilation units in each activity room which are each operated for perhaps only a few hours per day, with natural ventilation throughout the dwelling for periods when the fan assisted exhaust ventilation is not operating. In such systems it is usual for the extract air volume flow rates to be much greater than are used for continuously running systems.

Annex E
(informative)

Calculation methods for ventilation requirements

E.1 General

This calculation method is in two parts; firstly where a pollutant is released in a space at a constant rate; secondly where a pollutant is released intermittently. Water vapour behaves differently to other pollutants in that is can condense and re-evaporate from surfaces (and may be more readily absorbed and de-sorbed) and is therefore not normally dealt with by use of this method (see Annex C and Annex H).

E.2 Pollutant released at a constant rate

The concentration, c, of a pollutant introduced at a constant rate into a ventilated space of volume, V, is given by:

$$c = \left(\frac{Q.c_e + q.c_i}{Q + q} \right) \left(1 - e^{-\left(\frac{Q+q}{V} \right) t} \right) \tag{E.1}$$

where

q is the inflow rate of the pollutant (in l/s);

V is the volume of the ventilated space (in l);

Q is the volume flow rate of the outside air (in l/s);

c_e is the concentration of the pollutant in the outside air in g/l;

c_i is the concentration of the pollutant in the inside air, in g/l;

t is the time (in s) from the moment the inflow of pollutant starts.

The ratio, Q/V, is usually termed the ventilation rate, R, and is measured in air changes per hour. As t increases, the concentration reaches an equilibrium value, c_E, given by the equation:

$$c_E = \left(\frac{Q.c_e + q.c_i}{Q + q} \right) \tag{E.2}$$

It should be noted that c_E depends upon the volume flow rate of the outside air, Q, and not upon the room volume, V. The room volume affects only the rate at which c approaches the value c_E. The rate of air flow, Q, required to give the equilibrium concentration, c_E, is:

$$Q = q \left(\frac{c_i - c_E}{c_E - c_e} \right) \tag{E.3}$$

If the incoming air is free of pollutant, i.e. c_e = 0, then the expressions simplify. Equation (E.1), with some rearrangement, becomes Equation (E.4) below:

$$c = \left(\frac{c_i}{Q/q+1} \right) \left(1 - e^{-(1+Q/q)\left(\frac{q.t}{V}\right)} \right) \tag{E.4}$$

If q = 0, but there is present an initial concentration, c_0, of pollutant, then the rate of decay of concentration is given by:

$$c = c_0 e^{-Rt} \tag{E.5}$$

E.3 Intermittent pollutant emission

The ventilation rate, Q, given by Equation (E.3) is independent of the magnitude of the volume, V, of the space. This volume does, however, affect the rate at which the equilibrium level is achieved. This may be important in relation to situations where the emission of a pollutant is for a limited period only, say of length t_1. In such a case, if the space were ventilated at a rate, Q, calculated according to Equation (E.3), then the concentration would fall short of the maximum allowable value, set equal to c_E. In principle, this allows a reduction in the magnitude of the minimum ventilation rate to a new value Q^r, given by:

$$Q^r /Q = F(Qt_1 /V) \tag{E.6}$$

The form of the function $F(Qt_1/V)$ is given in Figure E.1. It should be noted that for values of (Qt_1/V) < 1, no ventilation is theoretically required. This is not practical since it is unlikely, however limited the time period, t_1, that the pollutant are not emitted at some later time.

This may be taken into account by considering a regular, intermittent emission for a period of length, t_1, at intervals of length, t_2. The ratio of the modified minimum ventilation rate, Q^r, to Q is then a function of both (Qt_1/V) and the ratio, r, equal to (t_2/t_1). Figure E.2 gives curves for calculating Q^r given these parameters.

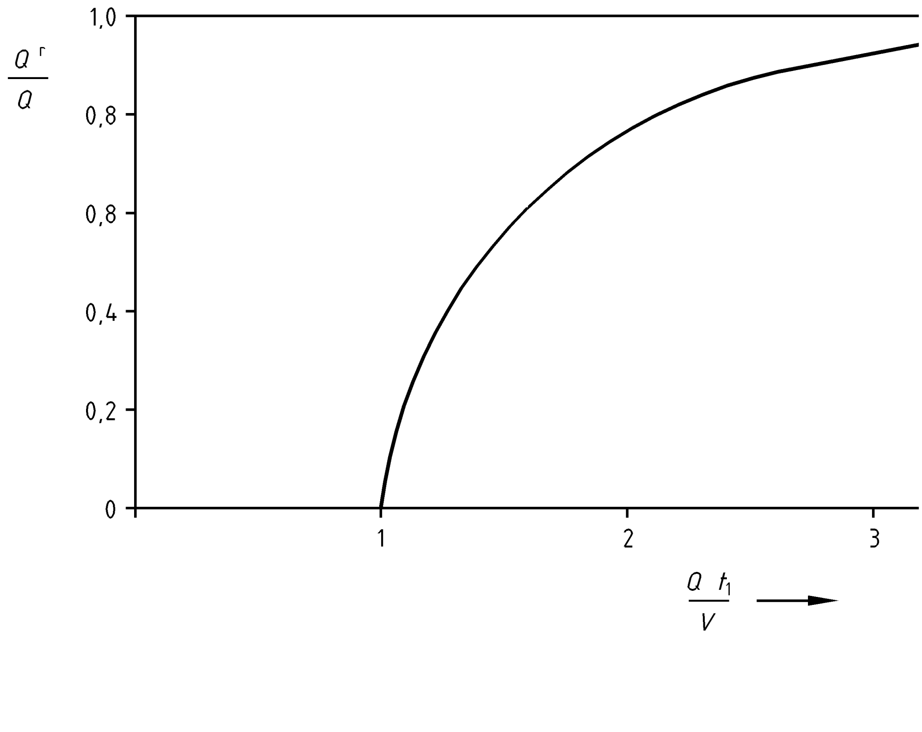


Figure E.1 — Allowable reduction in minimum fresh air supply rate when the pollutant source is present for a limited period, t_1, rather than continuously

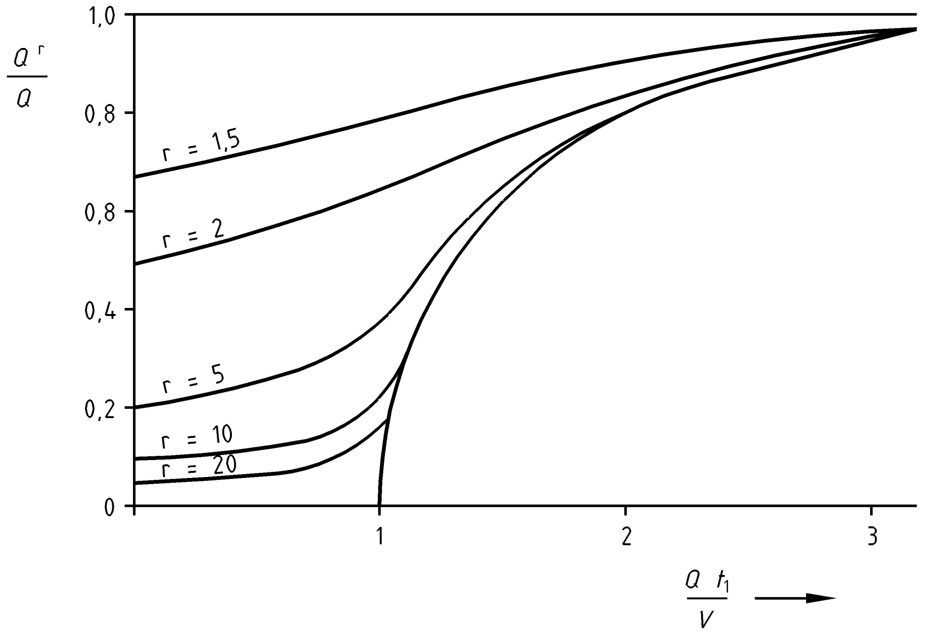


Figure E.2 — Allowable reduction in minimum fresh air supply rate when the pollutant source is intermittent, being present for a length of time t_1, with a return period, t_2 ($r = t_1/t_2$)

Annex F
(informative)

Examples of assumptions and resulting calculated values for ventilation air flow rates

F.1 Introduction

In calculating the air flow rates following the method given in this Technical Report a number of assumptions should be made about such matters as local climate, pollutant production, number of occupants, dwelling characteristics etc. This annex gives examples of those assumptions which might be used (but does not attempt to justify them) and gives the results of calculations which have been done.

The results of the calculations are particularly useful in that they indicate that apparently reasonable assumptions can give rise to ventilation air flow rates which are not acceptable and that apparently small changes in the assumptions can give rise to quite large changes in required ventilation air flow rates.

Note that these are illustrative examples and should not be taken as recommended values.

F.2 General assumptions and criteria for pollutant removal

For the purposes of these calculations it was assumed that there were only three pollutants present: (i) water vapour (from all sources); (ii) carbon dioxide (from human respiration and gas cookers only); and (iii) odours in WCs only.

The criteria for dealing with these pollutants were:

For water vapour it is acceptable to have occasional condensation in rooms (mostly activity rooms) on condition that the relative humidity at surfaces is not high enough, for long enough, to lead to mould growth; however, humidity is not so low that occupants experience discomfort (static electric shocks and irritation of the nasal passages, throat and eyes). For these calculations this was taken to mean that the relative humidity should not exceed 80 % at a surface (other than on glazing) for more than 50 % of the time, nor should the relative humidity in the occupied zone in the room be less than 30 %.

For carbon dioxide it was assumed that there is a concentration which should not be exceeded. A range of values for this maximum concentration were chosen (1 000, 1 500, 2 000, 2 500, 3 500 and 5 000 vppm) but a prohibition on exceeding these limit values at any time is not technically achievable in some situations and in some climates it is often desirable to accept high CO_2 levels to ensure indoor humidity remains within comfortable limits for the occupants.

For odour in WCs it was arbitrarily chosen that the odour strength (analagous to pollutant concentration) is reduced to a certain percentage of its original level within a specified time.

Outdoor climatic conditions applicable to all calculations were: Relative humidity 100 %, Temperature: -5, 0 and +10 °C, Outdoor CO_2 concentration 340 vppm.

For condensation and mould risk assessment it was assumed that absorption of water vapour by surfaces in the room took place according to the calculation method given in Annex C and the inside surface temperature of exposed walls, t_s is given by:

$$t_s = t_o + 0.65(t_i - t_o)$$

where

t_s is the internal surface temperature, °C;

t_o is the outdoor air dry bulb temperature, °C;

t_i is the indoor air dry bulb temperature (centre of room), °C.

The humidity conditions at the surface can be determined using the surface temperature from this equation, the humidity conditions in the occupied zone of the room and the psychrometric chart as shown in Annex B. Note that the absorption by surfaces requires an iterative calculation to be made over many days to establish the equilibrium level of absorption.

An alternative to using this equation might be to calculate surface temperatures using the methods described in EN ISO 10211-1 and the psychrometric chart in Annex B or the condensation risk can be assessed using the nomograph given in Annex H. Note that the most critical areas for condensation and mould growth, other than glazing, are at thermal bridges.

The air flow rates required to achieve the chosen performance for CO_2 and odour removal were calculated using the equations given in Annex E.

F.3 Bedroom

F.3.1 Assumptions for calculations

General assumptions listed in F.2 and the following:

CO_2 production per human adult while sleeping: 12 l/h;

water vapour production per human adult while sleeping : 40 g/h;

room temperatures: 16 °C and 20 °C;

room size: floor area 9 m^2, ceiling height 2,5 m;

occupancy: 2 adults;

ventilation air enters the room from outside.

F.3.2 Calculated ventilation air flow rates for a bedroom

F.3.2.1 Calculated ventilation air flow rates for CO_2 removal from a bedroom

Table F.1 - Calculated ventilation air flow rates for CO_2 removal from a bedroom

Maximum CO2 level at Equilibrium (vppm)	Recommended ventilation air flow rate	
	m^3/h	dm^3/s
1 000	36,4	10,1
1 500	20,7	5,8
2 000	14,4	4,0
2 500	10,8	3,0
3 500	6,9	1,9
5000	3,8	1,1

In all cases the CO_2 level reaches the stated equilibrium level within 8 h. For a larger bedroom of 15 m^2 floor area the equilibrium levels of 2 000 vppm and above were not reached within 8 h.

F.3.2.2 Calculated ventilation air flow rates for water vapour removal from a bedroom

The effect on water vapour removal of the air flow rates calculated in F.3.2.1 above have been calculated as follows:

Table F.2 — Bedroom air temperature 16 °C

Air flow rate	Outdoor temperature -5 °C				Outdoor temperature 0 °C				Outdoor temperature +10 °C			
	Humidity		Risk?		Humidity		Risk?		Humidity		Risk?	
dm^3/s	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould
36,4	3,8	34	N	N	5,0	44	N	N	8,8	78	N	N
20,7	4,5	40	N	N	5,6	50	N	N	9,5	83	N	Y
14,4	5,0	45	N	N	6,2	55	N	N	10,0	88	Y	Y
10,8	5,6	50	N	N	6,8	60	N	N	10,6	93	Y	Y
6,9	6,8	60	N	N	7,9	70	Y	Y	11,6	100	Y	Y
3,8	8,7	77	Y	Y	9,7	86	Y	Y	13,2	100	Y	Y

Table F.3 — Bedroom air temperature 20 °C

Air flow rate	Outdoor temperature -5 °C				Outdoor temperature 0 °C				Outdoor temperature +10 °C			
	Humidity		Risk?		Humidity		Risk?		Humidity		Risk?	
dm^3/s	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould
36,4	3,9	27	N	N	5,1	35	N	N	8,9	61	N	N
20,7	4,6	32	N	N	5,8	40	N	N	9,6	66	N	N
14,4	5,2	36	N	N	6,4	44	N	N	10,2	70	N	N
10,8	5,8	40	N	N	7,0	48	N	N	10,8	74	N	N
6,9	7,1	49	N	N	8,2	57	N	N	12,0	82	Y	Y
3,8	9,4	64	Y	Y	10,5	72	Y	Y	14,1	96	Y	Y

F.4 Living room

F.4.1 Assumptions for a living room

General assumptions listed in F.2 and the following:

CO_2 production per human adult while active: 18 l/s;

water vapour production per human adult while active: 45 g/h;

water vapour production from plants: 30 g/h;

room temperature: 20 ° C;

room size: floor area 20 m^2, ceiling height 2,5 m;

occupancy: room occupied by all persons living in dwelling for 2 h and 6 h;

number of occupants 2, 4 and 6 persons;

ventilation air enters the room from outside.

F.4.2 Calculated ventilation air flow rates for CO_2 removal from a living room

Table F.4 — Living room occupied for 2 h

Maximum CO2 level after 2 hrs	Required ventilation air flow rate					
	2 person occupancy		4 person occupancy		6 person occupancy	
vppm	m^3/h	dm^3/s	m^3/h	dm^3/s	m^3/h	dm^3/s
1 000	45,8	12,7	107,5	29,9	163,5	45,4
1 500	11,2	3,1	55,2	15,3	90,5	25,1
2000	#	#	30,6	8,5	58,8	16,3
2500	#	#	15,1	4,2	39,7	11,0
3 500	#	#	#	#	16,4	4,6
5 000	#	#	#	#	#	#
# Max CO_2 level not reached in 2 h with an air flow rate of 1 m^3/h (0,3 dm^3/s).						

Table F.5 — Living room occupied for 6 h

Maximum CO2 level after 6 hrs	Required ventilation air flow rate					
	2 person occupancy		4 person occupancy		6 person occupancy	
vppm	m^3/h	dm^3/s	m^3/h	dm^3/s	m^3/h	dm^3/s
1 000	54,5	15,1	109	30,3	163,5	45,4
1 500	30,2	8,4	62	17,2	93,0	25,8
2 000	19,6	5,4	43,1	12,0	65,0	18,1
2 500	13,3	3,7	32,6	9,1	49,8	13,8
3 500	5,5	1,5	20,9	5,8	33,5	9,3
5 000	#	#	11,5	3,2	21,3	5,9
# Max CO_2 level not reached in 6 h with an air flow rate of 1 m^3/h (0,3 dm^3/s).						

F.4.3 Calculated ventilation air flow rates for water vapour removal from a living room

Table F.6 — Occupancy for 2 h

Air flow rate	Outdoor temperature -5 °C				Outdoor temperature 0 °C				Outdoor temperature +10 °C			
	Humidity		Risk?		Humidity		Risk?		Humidity		Risk?	
dm^3/s	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould
2 person occupancy for 2 h												
45,8	3,2	22	N	N	4,4	30	N	N	8,2	56	N	N
11,2	5,3	36	N	N	6,4	44	N	N	10,2	70	N	Y
4 person occupancy for 2 h												
107,5	2,6	20	N	N	4,0	28	N	N	7,8	54	N	N
55,2	3,1	22	N	N	4,3	30	N	N	8,1	56	N	N
30,6	3,7	25	N	N	4,8	33	N	N	8,6	59	N	N
15,1	4,9	34	N	N	6,1	42	N	N	9,9	68	N	Y
6 person occupancy for 2 h												
163,5	2.8	19	N	N	3,9	27	N	N	7,7	53	N	N
90,5	2,9	20	N	N	4,1	28	N	N	7,9	54	N	N
58,8	3,2	22	N	N	4,3	30	N	N	8,1	56	N	N
39,7	3,5	24	N	N	4,6	32	N	N	8,5	58	N	N
16,4	5,0	35	N	N	6.2	43	N	N	10,0	69	N	Y

Table F.7 — Occupancy for 6 h

Air flow rate	Outdoor temperature -5 °C				Outdoor temperature 0 °C				Outdoor temperature +10 °C			
	Humidity		Risk?		Humidity		Risk?		Humidity		Risk?	
dm³/s	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould	g/kg	% RH	Cond	Mould
2 person occupancy for 6 h												
54,5	4,0	28	N	N	5,1	36	N	N	9,0	62	N	N
30,2	4,8	33	N	N	6,0	41	N	N	9,8	67	N	N
19,6	5,8	40	N	N	6,9	43	N	N	10,8	74	N	Y
13,3	6,9	48	N	N	8,1	56	N	N	11,9	81	Y	Y
5,5	11,2	76	Y	Y	12,2	84	Y	Y	15,8	100	Y	Y
4 person occupancy for 6 h												
109	3,9	28	N	N	5,1	35	N	N	8,9	61	N	N
62,0	4,7	33	N	N	5,9	40	N	N	9,7	66	N	N
43,1	5,4	37	N	N	6,6	45	N	N	10,4	71	N	N
32,6	6,1	43	N	N	7,2	50	N	N	11,1	76	N	N
20,9	7,5	52	N	N	8,6	59	N	N	12,5	85	Y	Y
11,5	10,3	71	Y	Y	11,3	78	Y	Y	15,2	100	Y	Y
6 person occupancy for 6 h												
163,5	3,9	27	N	N	5,1	35	N	N	8,9	61	N	N
93,0	4,7	33	N	N	5,9	41	N	N	9,7	67	N	N
65,0	5,5	38	N	N	6,6	46	N	N	10,5	72	N	N
49,8	6,1	42	N	N	7,3	50	N	N	11,1	76	N	N
33,5	7,4	51	N	N	8,5	59	N	N	12,4	84	Y	N
21,3	9,2	63	Y	N	10,4	71	Y	N	14,3	97	Y	Y

F.5 Calculated ventilation air flow rates for a bathroom

F.5.1 Assumptions for calculations for a bathroom

General assumptions listed in F.2 and the following:

CO_2 production not relevant;

water vapour production from shower: 10 min at 3 000 g/h = 500 g/shower;

water vapour production from clothes drying: 15 h at 100 g/h per person in dwelling;

room temperature: 22 °C;

room sizes: floor area 6 m^2; ceiling height 2,5 m;

occupancy: All occupants take a shower every day. Number of occupants: 2, 4, or 6;

assume that condensation is unavoidable but that it all evaporates and is totally removed by ventilation each day over a period of 14 h, 20 h or 24 h;

extracted air is at 22 °C and either 70 % RH or 100 % RH.

ventilation air enters the room from outside, or from other rooms (at 19 °C and 50 % RH).

F.5.1.1 Calculated ventilation air flow rates for a bathroom. Extracted air at 100 % RH and 22 °C

Table F.8 — Calculated ventilation air flow rates for a bathroom - Extracted air at 100 % RH and 22 °C

Time for removal of water vapour	Required ventilation air flow rate							
	Outdoor temperature -5 °C		Outdoor temperature 0 °C		Outdoor temperature +10 °C		Air from dwelling at 19 °C and 50 % RH [a]	
h	m^3/h	l/s	m^3/h	l/s	m^3/h	l/s	m^3/h	l/s
2 person occupancy								
14	16,8	4,7	18,3	5,1	26,1	7,2	24,2	6,7
20	11,8	3,3	12,8	3,6	18,2	5,1	16,9	4,7
24	9,8	2,7	10,7	3,0	15,2	4,2	14,1	3,9
4 person occupancy								
14	33,7	9,4	36,5	10,1	52,1	14,5	48,4	13,4
20	23,6	6,6	25,6	7,1	36,5	10,1	33,9	9,4
24	19,7	5,5	21,3	5,9	30,4	8,4	28,2	7,8
6 person occupancy								
14	50,5	14,0	54,8	15,2	78,2	21,7	72,6	20.,2
20	35,4	9,8	38,3	10,7	54,7	15,2	50,8	14,1
24	29,5	8,2	32,0	8,9	45,6	12,7	42,3	11,7
[a] Not possible with outside air at 100 % RH and temperature greater than 8 °C.								

F.5.1.2 Calculated ventilation air flow rates for a bathroom. Extracted air at 70 % RH and 22 °C

Table F.9 — Calculated ventilation air flow rates for a bathroom - Extracted air at 70 % RH and 22 °C

Time for removal of water vapour	Required ventilation air flow rate							
	Outdoor temperature -5 °C		Outdoor temperature 0 °C		Outdoor temperature +10 °C		Air from dwelling at 19 °C and 50 % RH [a]	
h	m³/h	l/s	m³/h	l/s	m³/h	l/s	m³/h	l/s
2 person occupancy								
14	26,5	7,3	30,1	8,4	59,5	16,5	50,7	14,1
20	18,5	5,1	21,1	5,9	41,7	11,6	35,5	9,9
24	15,4	4,3	17,6	4,9	34,7	9,6	29,6	8,2
4 person occupancy								
14	52,9	15,0	60,3	16,8	119,0	33,0	101,3	28,1
20	37,0	10,3	42,2	11,7	83,3	23,3	70,9	19,7
24	30,9	8,6	35,2	9,8	69,4	19,3	59,1	16,4
6 person occupancy								
14	79,4	22,0	90,4	25,1	178,6	49,6	152,0	42,2
20	55,6	15,4	63,3	17,6	125,0	34,7	106,4	29,6
24	46,3	12,9	52,7	14,6	104,2	28,9	88,7	24,6

[a] Not possible with outside air at 100 % RH and temperature greater than 8 °C.

F.6 WC

F.6.1 Assumptions for calculations for a WC

Assume odour produced as a pollutant at a rate of 2 l/s for 1 min.

Odour to be reduced to 10, 20, 30, 40, 50, 60% of its initial concentration within 15 min for each use of the WC.

Room size: floor area 3 m^2; ceiling height 2,5 m.

There is zero odour in air entering the room.

F.6.2 Calculated ventilation air flow rates for a WC

Table F.10 — Calculated ventilation air flow rates for a WC

% of initial concentration after 15 min	10 %	20 %	30 %	40 %	50 %	60 %
Air flow rate, dm^3/s	19,3	13,5	10,1	7,6	5,8	4,3

Annex G
(informative)

Noise

G.1 Outdoor noise

G.1.1 Requirements and methods of calculation and measurement

Road traffic and other activities outside dwellings can be the cause of a noisy environment. The designer should obtain the maximum allowable sound level in a room from the relevant National or Regional regulations. In general, the allowable sound level in rooms is 35 dB(A), however, in some countries only 30 dB(A) is allowed (Sweden, Finland, Denmark).

Dwellings with facades containing windows, unweatherstripped, and with regular glazing (single-pane 4 mm or 6 mm or double pane 4/6/6 mm or 4/12/6 mm) a noise reduction of approximately 20 dB(A) is achieved. With the windows in the ventilation position (ajar - say an opening of approximately 250 cm^2), a noise reduction of approximately 15 dB(A) can be achieved. If outdoor noise levels at the facade exceed 50 to 55 dB(A), natural supply systems require special acoustic measures, particularly with regard to the ventilation system.

The noise reduction of a facade is the difference between the outdoor noise level (L_o) and the indoor noise level (L_i):

$$L_0 - L_i = R_{facade} + 10\log\left[V / 6 \times T \times S_{tot}\right] - 3 \qquad \text{dB(A)}$$

The resulting noise reduction (L_o - L_i) is determined by the overall sound reduction index (**R_{facade}**), taking into account the noise transfer through ventilation openings, joints and cracks in the construction (K), and the acoustic properties of the room itself ($10\log\left[V / 6 \times T \times S_{tot}\right]$).

where

R_{facade}	is the overall sound reduction index of the facade in dB(A);
V	is the volume of the receiving room;
T	is the reverberation time of the receiving room;
S_{tot}	is the total surface area of the facade in m^2;
-3	is the correction for direct sound field to diffuse sound field.

and

$$R_{facade} = -10 \times \log\left(\sum_{j=1}^{n} \frac{S_j}{S_{tot}} \times 10^{\frac{-R_j}{10}} + \sum_{i=1}^{m} \frac{l \times 10}{S_{tot}} \times 10^{\frac{-D_{n,e,i}}{10}} + K \right) \qquad \text{dB}$$

where

S_j	is the area of element j in m^2;
R_j	is the sound reduction index of element j;

l is the length of the ventilation device in m, (in case the device is tested as one device without a length, l = 1;

$D_{n,e,i}$ is the element normalised level difference according EN 20140-10 in dB;

K is the correction for weather-stripping (K=10^{-3} or no stripping to K=10^{-5} for excellent stripping).

The way in which the contribution of the ventilation openings is taken into account depends on the way in which the sound reduction of each opening is expressed. The sound reduction index of a ventilation opening may concern i.e. the flow capacity, the cross-section of the ventilation surface area, the gross surface area of the devices or a standardised room absorption, such as 10 m^2 sabin.

G.1.2 Noise reduction of facades

The transfer of noise across facades takes the following paths:

— closed facade areas (brickwork, panels);

— windows;

— ventilation openings;

— joints and cracks.

If noise reduction beyond approximately 20 dB(A) is required, any joints and cracks should be properly sealed. Other ventilation provisions are then necessary, such as special - soundproofed - supply openings in windows or facades. Alternatively, the supply air can be achieved in part through noise-free facades.

To illustrate the interdependence of the acoustic properties of the different facade elements (i.e. brickwork, glass, ventilation openings and crack sealing), a mathematical comparison has been made between different facade types. The comparison is based on a room with a volume of 40 m^3. The total facade area is 10 m^2. The facade contains a window with an area of 3 m^2 and the room's reverberation time amounts to 0,5 s. The closed facade consists of brickwork and the supply air takes place by means of a soundproofed or non-soundproofed opening with a cross-section of 150 cm^2. A number of glazing alternatives have been evaluated: standard double glazing (4 mm glass - 12 mm cavity - 6 mm glass), high-quality acoustic glazing (8 mm glass - 20 mm gas-filled cavity - 10 mm layered glass) and optimal soundproofing glass (42 mm layered glass). Table G.1 gives an overview of the maximum attainable noise reduction values pertaining to this type of facade.

Table G.1 — Maximum attainable noise reduction values (GA) for a number of alternative facade types (rounded examples)

Description	Noise reduction dB(A)			
	opening without soundproofing	opening with adequate soundproofing	opening with excellent soundproofing	no ventilation opening
Standard glass, no weather-stripping	21	22	22	22
Standard glass, minor weather-stripping	23	25	26	26
Standard glass, good single weather-stripping	25	28	29	29
HQ ac. glass, double weather-stripping	26	33	36	38
Max. ac. glass, very good weather-stripping	26	34	40	44

Noise reduction can be as much 40 dB(A) if ventilation openings are retained. This can only be achieved by means of proper soundproofing of the closed facade elements. It is important to take into account the noise contribution of the closed facade. Elaborate acoustic provisions to windows and ventilation openings can only be cost-effective if the other facade elements have good soundproofing properties.

Acoustic measures are taken in the correct order:

— first apply adequate weather-stripping;

— then apply soundproofing to the ventilation opening;

— and finally improve the glazing.

G.1.3 Soundproofing of ducts

The noise reduction values of rooms with exhaust ducts for natural ventilation (i.e. ventilation stacks or "shunt" ducts) may be influenced by noise sources at the roof level e.g. from aircraft and elevated roads. If these rooms have facades without soundproofing provisions (GA ~ 20 dB(A) such ducts have a negligible influence on the noise reduction value (0 to 1 dB). If facades have a higher noise reduction value (i.e. 30 dB(A) to 35 dB(A)) the influence of the duct is noticeable. Table G.2 gives an indication of the effect of an exhaust duct with a cross-section of 200 cm^2 on the noise reduction value of a room with a volume of 40 m^3.

Table G.2 — The effect of an exhaust duct on the noise reduction value (ΔR)

GA	ΔR [dB (A)]
20	-1,0
25	-2,5
30	-5,5
35	-9,5

Steel metal ducts in mechanical ventilation systems have similar acoustic properties. If higher noise reduction values than the above are required, then acoustic measures are necessary to undertake such as the application of silencers or soundproofed air-ducts and ducts. In general, however, noise levels resulting from outdoor noise are lower than the sound power level *L*" generated by the fan see also next chapter

G.2 Noise generated by the ventilation system

G.2.1 Requirements and methods of calculation and measurement

The duct system inside dwellings is responsible for the transmission of noise generated by the fan and aerodynamic noise generated by bends, control valves and devices.

The maximum indoor noise level criteria in most of the countries with respect to noise generated by the ventilation system in rooms is 30 dB(A).

The sound power level (L_W) is normally obtained from the manufacturer’s literature. Where the fan type is not known it can be approximated by means of the following simplified formula:

$L_w = L_{ws} + 10 \log q, + 20 \log \Delta p + 10 \log 3,6$ dB

The following applies to all fan types:

$L_{ws} = 1 \pm 4$dB

q, is the flow capacity in dm^3/s;

Δp is the total pressure difference across the fans in Pa;

The octave band spectrum can only be obtained from fan manufacturer's literature.

G.2.2 Sound reducing measures inside ducts

The noise generated by fans is propagated through the duct work system. Sound reducing components in the duct work system may be needed to meet noise level requirements in rooms.

Sound reducing components for domestic ventilation systems are usually silencers which may be of plastic or metal and are often flexible to a certain extent. If plastic silencers are used the maximum allowable air temperature and fire precautions also require attention.

Silencers are relatively cheap and easy to integrate in an air duct system. They demand hardly any extra space (silencer diameter is usually about 100 mm greater than the duct diameter) but the sound attenuation is often poor at low frequencies. Silencers made of thin foil provide better sound reduction at low frequencies, but they radiate more noise into the space surrounding the duct.

Silencers are suitable primarily in duct work systems with diameters not exceeding 150 mm, where silencers up to about 1,0 m long are normally used. Silencers can be used with larger duct diameters but the required silencer length increases considerably.

G.2.3 Acoustic properties of terminal devices

The A-weighted sound power level of terminal devices should be obtained from manufacturer's literature. Terminal devices should be selected on the basis of the nominal sound power levels to meet the required noise levels. Sound power levels of terminal devices are measured in accordance with EN 13141-1 or EN ISO 140-3. In general the maximum allowable sound power levels (L_w) of terminal devices are:

- bedroom: approximately 30 dB(A) to 35 dB(A);
- living room:
  - one terminal device: approximately 35 dB(A);
  - two terminal devices: approximately 32 dB(A);
  - three terminal devices: approximately 30 dB(A).

G.2.4 Aerodynamic noise inside ducts

The following points are observed in order to prevent aerodynamic noise inside the ducts:

- maximum recommended air velocity in main ducts in a single family dwelling is 4 m/s (7 m/s in common ducts) and inside branch ducts to the supply terminal devices the maximum recommended air velocity is 2 m/s;
- use of round ducts is preferred;
- sharp bends should be avoided and changes of cross-sectional areas of the ducts should be smooth;
- system is designed in such a way as to require the minimum number (preferably no) control valves;
- maximum air velocity inside the silencer should be as stated in manufacturer's literature or the maximum velocity in the duct, whichever is the lower.

G.2.5 Fan mounting

Attention should be given to fan mounting to avoid sound transmission to the structure or to the duct system. In general a flexible connection avoids transmission to the duct system. The fan may be mounted in various ways including suspension on wires from the roof or supported by a mineral fibre slab or rubber blocks on a floor.

G.3 Sound transmission between rooms or dwellings

G.3.1 Requirements and methods of calculation and measurement

For acoustic purposes the 'most critical' case should be examined. This may not be with the highest flow rate and a cooker hood running but is more likely to be for normal flow rate at night and with internal doors closed. This applies to sound transmission both between rooms within a dwelling and between separate dwellings.

With respect to the sound isolation requirements between two rooms, a distinction is made between rooms within the same dwelling on one hand and on the other hand between one dwelling and another or between a room in a dwelling and a space outside it. More stringent requirements apply to constructions which separate two adjacent dwellings. To specify the sound insulation between dwellings or between rooms it is not sufficient to use a single figure index as sound insulation is a function of frequency. Hence it should be specified over the frequency range. It is usual to specify the insulation as a curve or as a figure index calculated on basis of this curve. The measured insulation of a wall or floor should not come below this curve by more than a recommended amount.

There are many different ways in which the sound insulation requirements are expressed, but the characteristic of a wall is usually expressed as the sound reduction index R. In general, for most countries, the average sound reduction index *R*, in the range between 125 Hz and 2 000 Hz for constructions between dwellings is 50 dB to 52 dB.

The resulting noise reduction (L_{ps} - L_{pr}) is determined by the overall sound reduction index **(**$R_{dwelling}$**)**, taking into account the noise transfer through ventilation openings, and the acoustic properties of the room itself ($10 \log [V/(6 \times T \times S_{tot})]$).

$$L_{ps} - L_{pr} = R_{dwelling} + 10 \log [V/(6 \times T \times S_{tot})] \qquad \text{dB}$$

where

L_{ps} is the sound pressure in the source room;

L_{pr} is the sound pressure in the receiving room;

$R_{dwelling}$ is the overall sound reduction index between dwellings in dB;

V is the volume of the receiving room;

T is the reverberation time of the receiving room;

S_{tot} is the total surface area of the separating wall or floor in m^2.

$$R_{facade} = -10 \times \log\left(\sum_{j=1}^{n} \frac{S_j}{S_{tot}} \times 10^{\frac{-R_j}{10}} + \sum_{i=1}^{m} \frac{10}{S_{tot}} \times 10^{\frac{-D_{n,e,i}}{10}} \right) \qquad \text{dB}$$

where

S_j is the area of element j in m^2;

R_j is the sound reduction index of element j;

$D_{n,e,i}$ is the element normalized level difference according EN 20140-10 in dB (for example a silencer).

One of the sound channels may be a ventilation system. This phenomenon is also called crosstalk. Crosstalk can be defined as the effect that system components have on the integrity of the sound reduction between two rooms. Crosstalk is of particular concern in balanced ventilation systems and in collective ducts between dwellings. It can be brought about in the following ways:

— through the duct work system;

— between rooms within the same dwelling and between rooms in two different dwellings;

— through the transfer devices or openings underneath doors. To facilitate the transport of air inside the dwelling, that is, from the place where air enters the rooms to the place where the air is exhausted, transfer devices are placed or the doors are shortened at the bottom. Cross-talk may occur in the case where two rooms have such openings near one another;

— through the duct transitions in walls or floors.

G.3.2 Crosstalk through the duct system between dwellings

No decrease of the sound insulation between dwellings as a result of the transfer of noise through shared ducts is normally allowed. Both collective natural and mechanical ventilation systems usually require sound proofing provisions to limit cross talk through the duct system between dwellings. Such provisions may consist of:

— a silencer on each exhaust terminal device or between exhaust terminal devices;

— a soundproofed exhaust terminal device.

The requirement for sound insulation may be found in national regulations and standards (e.g. as a minimum permitted insertion loss for a duct between two dwellings). Sound transmission between dwellings depends not only on the duct but also on the characteristics of the building which are not normally known to the ventilation system designer. Therefore his calculation is limited only to the noise transfer via the duct system.

G.3.3 Cross-talk through the duct work system within dwellings

The principle for designing for cross talk between rooms in a dwelling is the same as for between separate dwellings. Only the design criteria are different and should be found in national regulations and standards.

G.3.4 Cross-talk through internal air transfer devices and provisions

Where an internal air transfer device is used its sound attenuating performance should be obtained from the manufacturers' literature and use a calculation method as above for between dwellings. Where air transfer is via a gap under a door the sound attenuation is relatively poor compared with an air transfer device.

Annex H
(informative)

Nomograph for calculating air flow rate to reduce the risk of surface condensation occurring on the inner wall surface for various wall U-values and ambient air conditions

NOTE Taken from British Standard BS 5925:1991. This nomograph may require permission for use under copyright from the original source (Sugg, P.C. and Milburn, R.J. Heating and controlled winter environment in dwellings of modern construction. Publication No 937, Institution of Gas Engineers, UK).

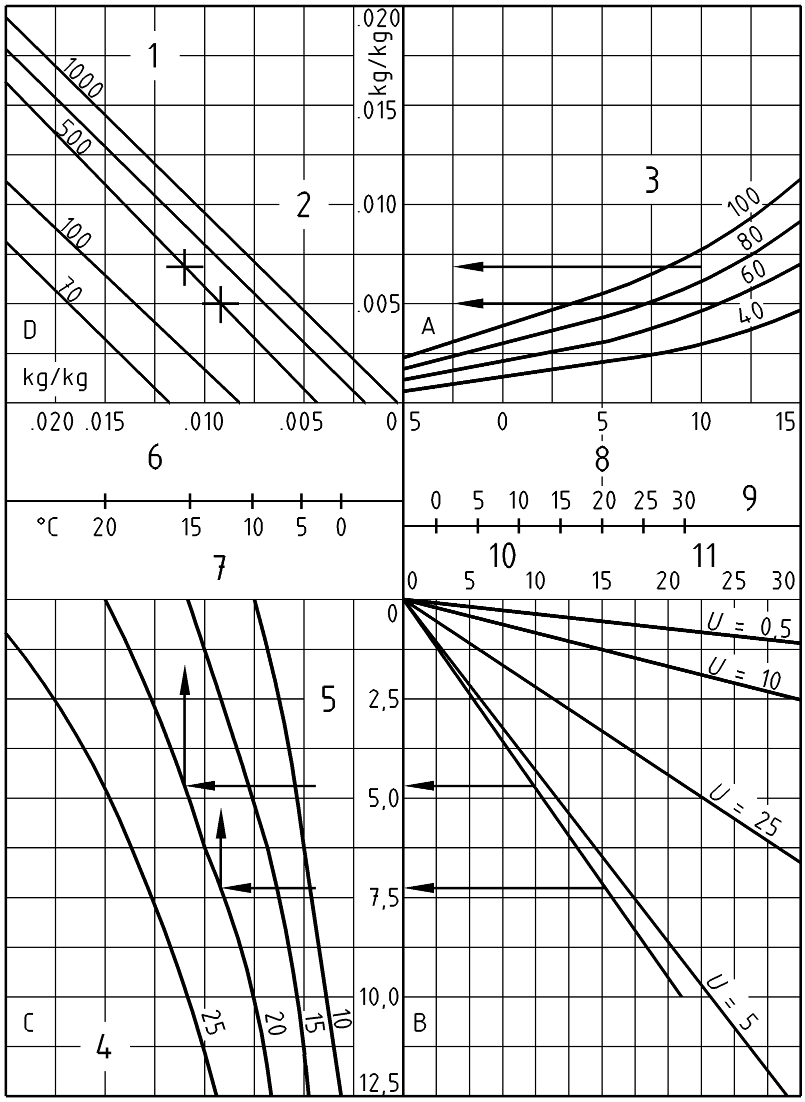
The nomograph (Figure H.1) is used in the following way:

a) Start in quadrant A. Choose outside air temperature and traverse vertically upwards to meet the chosen outside relative humidity. Traverse horizontally to the left into quadrant D, noting the position of this line for later use.

b) Enter quadrant B from the top by drawing a line from the chosen outside air temperature to the chosen inside air temperature (on scale below quadrant A) and extend to meet the top of quadrant B. Traverse vertically down in quadrant B and then horizontally into quadrant C from the line for the chosen U value for outside wall, cold bridge or window.

c) In quadrant C, traverse vertically upwards into quadrant D from the line for the chosen inside air temperature.

d) The intercept in quadrant D of the last line with that found in (a) above will, by reference to the sloping lines, give the minimum volume of outside air required per kilogram of moisture generated in the space to avoid condensation on the surface being considered.



Key

1 volume of air (m^3) required to transport 1 kg moisture
2 moisture content of outside air
3 outside air % RH
4 inside air temperature °C
5 inside air-inner wall surface °C
6 maximum permissible moisture content to avoid condensation
7 maximum permissible internal dew point to avoid condensation on wall surfaces
8 outside air temperature °C
9 inside air temperature °C
10 inside air °C
11 outside air °C

Figure H.1 – Ventilation required to reduce the risk of surface condensation occurring on the inner wall surface for various wall *U*-values and ambient air conditions

Bibliography

[1] BS 5925:1991, *Code of practice for ventilation principles and designing for natural ventilation*

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