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Independent or Central Ventilation in Apartment Blocks

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in wohngebauden"
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Independent or central ventilation in apartment blocks

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1 Introduction

Apartment blocks are largely understood to mean buildings for a number of families containing rented or owner-occupied apartments. Terraced houses and smaller detached family houses with a maximum living area of 150 m^2 may also be included in the following considerations. Larger detached family houses or penthouse apartments with additional installations, such as sauna, swimming bath or several large-sized baths, should not be included in this comparative study.

According to the regional building regulations of the individual federal states, adequate ventilation facilities are required for living and day rooms, with evidence of transverse ventilation above external windows or external doors.

Additional requirements are only laid down for small kitchens with an area of less than 8 m^2 and for internal sanitation areas such as the bathroom and WC. In some states of the GFR, windowless inner kitchens are permitted if sufficient ventilation is guaranteed. However, the guidelines or decrees provide no information on the volumetric air flow required for this.

The required evidence of ventilation and its possibilities are represented in figure 1, which shows a ground plan with exterior bath and exterior kitchen, i.e. the natural ventilation is guaranteed, but with all the advantages and disadvantages according to the direction of ventilation. No definite statement can be made with regard to the order of magnitude, range of variation or, therefore, of uncontrolled transmission of energy into the atmosphere.

In the case of interior sanitation areas, the additional ventilation requirements are embodied in DIN 18017, pages 1-3. Figure 2 shows a modification of the ground plan in figure 1, with windowless interior bathroom and WC, and with the shaft ventilation in the vertical section also shown. Both representations shown (figures 1 and 2) are subject to the marginal condition of sufficient permeability of the building shell for continuous flow, in the arrangement shown in figure 1, and for extra ventilation in the arrangement shown in figure 2. The possibilities of air passage through a building are demonstrated in figure 3, as follows:

a) untight encased joints
b) untight window joints
c) untight wall construction (wall permeability)

These three possibilities permit continuous flow in older buildings, provided that there is sufficient wind pressure, thereby guaranteeing transverse ventilation. In the case of more recently erected buildings and old renovated buildings, the ENEG rules that such inadequate structural sealing is no longer permitted, and so the ventilation system described above is also questionable. The solutions

d) gap ventilation and
e) joint ventilation

are the remaining possibilities for adequate extra ventilation, with the natural ventilation as transverse ventilation of an apartment or as flushing of external rooms through interior sanitary rooms with shaft ventilation. However, this extra ventilation only functions if the gap or window ventilation is operated personally; thus sufficient overall ventilation is hardly guaranteed.

2 What constitutes adequate ventilation ?

Up until now, the following values determined the volumetric air flow for day and living rooms:

a) carbon dioxide value
b) heat value
c) humidity value
d) noxious substance value.

For living rooms it has hitherto sufficed to estimate value a), i.e. to determine the outside air flow requirement per hour from the ratio of the quantity of CO2 produced by one person to the discrepancy from the permissible value, minus the value inherent in the flow from the outside air. The values of approx. 20 m^3/person/hour where smoking is prohibited, and 30 m^3/person/hour where smoking is permitted, are sufficiently well known, and form the basis for the required proportion of outside air in ventilation systems according to DIN 1946. This value would therefore also have to be considered to be the minimum ventilation for apartments, i.e. 30 m^3/person/hour.

Value b), heat, is irrelevant to apartments because of the heat discharged, along with the volumetric outside air flow. The heat value may require a volumetric air flow of up to 60 m^3/person /hour only for commercial and industrial areas generating production heat and for assembly rooms with a correspondingly small ambient air volume per person, generating additional heat. However, the proportion of outside air is reduced, for energy saving reasons, to 20 m^3/person/hour, according to the season, and the remainder is then stored as added circulating air.

Where there are built-in mechanical ventilation systems according to VDI 2088, it is also necessary for apartments to have window ventilation in the event of overheating, i.e. fixed glazing without opening facilities is not admissible for apartments unless an exception is granted, in which case DIN 1946, with all its requirements, must be complied with.

Value c), humidity, is of no interest as far as the air balance of the apartment as a whole is concerned, and the volumetric air flow produced is probably below value a), carbon dioxide, for each person. On the other hand, the humidity value may be a decisive factor for interior sanitary rooms, particularly those fitted with shower cubicles.

Figure 5 is a diagrammatic representation of a bath and shower unit, with the associated temperature and humidity values applicable to the area or room of installation during use. The quantities of moisture produced relate to permanent operation, as does the volumetric air flow required for drawing off the moisture. If the normal time during which a unit is used is considered to be 15 to 30 minutes, with a suitable pause after use, and with a permissibly higher humidity value during use, the normal value for baths in apartments is estimated as 60 m^3/h, according to DIN 18017, page 3.

However, the permissible value of a fourfold air exchange within the sanitary room is critical, even with permissible application of the limitation according to DIN 18017. In council housing, bathrooms 3 to 4 m^2 in area are common, producing a volume of 7.5 to 10 m^3. The minimum air exchange of 4x required, therefore, results in an hourly volumetric air flow of 30 to 40 m^3, which experience shows to be too small.

The effects of such low air throughputs are discussed in greater detail later in the paper, using examples of damage incurred. Returning to figure 4, however, a fourth value must be discussed.

A hitherto uncommon value d), noxious substance value, has been listed. There are increasing indications that construction engineering, as practised over the last two decades, and the building materials used, might be decisive in establishing a scale of volumetric air flows for adequate apartment ventilation.

So-called hygienically essentially volumetric air flows are often referred to, but so far no-one has proposed a strict definition for them, not even hygiene experts and doctors.

Required air exchange figures of 0.3 to 1.0 (1:h) are mentioned and, when related to an apartment with a living area of 80 m^2, volumetric air flows of between 60 and 200 m^3/h are obtained. Making the normal assumption of three persons, the lowest limit would be sufficient to cover value a), carbon dioxide, provided that smoking was prohibited. On the other hand, for the kitchen and bathroom, the value would be too small to meet value c), humidity, in addition. The fact that an air exchange of 0.5 has hitherto been estimated as the minimum limit in DIN 4701 confirms this statement. According to the Swedish building regulations, an air throughput of approximately 200 m^3/h is required for apartments, producing an air exchange of 1.0 (1:h). In apartments with window joints and no additional ventilation, and in apartments with periodic additional ventilation, it has recently been shown that not only has structural damage been observed as a result of insufficient extraction of moisture, but also that complaints of "lack of oxygen" are increasing among apartment dwellers to describe their poor air conditions.

The previously determined values of 20 to 30 m^3/person per hour are certainly found, thereby indicating the presence of a factor hitherto unknown, or insufficiently known.

It is here assumed that noxious substances are released in the apartment and annoy the user, despite the air exchange value, which was previously considered adequate.

It might well be necessary to beat out or dust the new materials from carpeted floors, through the range of furniture, wallpapers and curtains to plastic windows, to get rid of the noxious substances released due to ageing or other material changes.

Engineers and architects are largely responsible for eliminating the problems of floor heating areas of plastic pipes tending towards oxygen transmission and the risk of corrosion in the adjacent metal areas of the heating system. The chemists, now driven into a corner, are saying that "they already knew".

We should not be surprised if similar information is received on the release of noxious substances, in the form of gases, when plastic materials are beaten and dusted.

3 Independent ventilation - central ventilation

According to DIN 18017, Page 3, the following definition is given: independent ventilation systems are designed to de-aerate a residential area (e.g. apartment or residential unit in hotels), and to be operated when required.

Central ventilation systems may be continuously operated to ventilate rooms with several rest (living) areas. The volumetric flow of the central ventilation system can be reduced at night to as much as 50%. Until now, only interior bathrooms and WC's, with flows of 60 and 30 m^3/h respectively, have been included in the volumetric spent air flow in the standard.

However, the DIN states that at least a 4x air exchange must be guaranteed. In view of the higher proportion of ventilation heat Q_L of the total heat requirement Q_{total} (= $Q_T + Q_L$), due to the reduction in the Q_T proportion resulting from improved thermal insulation of the building shell, there is a growing body of opinion in favour of independent ventilation for further energy saving, offering the possibility of providing ventilation facilities on demand.

The systems according to DIN 18017, Page 3, with mechanical de-aeration and extra ventilation by the outside air through window joints are, as already mentioned, being obstructed in their operation by the increasingly tighter sections of the building shell, hence the following developments:

3.1 Ventilation conditions in an owner-occupied apartment with de-aeration according to DIN 18017, Page. 3 (central ventilation)

On the 4th floor of a 10- to 16-floor split-level apartment block, an apartment was surveyed according to figure 6.

Apartment data

Living room with hall approx.	26.0 m^2	
Child's room 1	9.0 m^2	
Child's room 2	9.0 m^2	
Parents' room	16.0 m^2	
Living and bed-rooms	60.0 m^2	(approx. 155 m^3)
WC	3.0 m^2	
Shower	1.8 m^2	
Bathroom	6.6 m^2	
Kitchen	9.0 m^2	
Utility room	5.6 m^2	
Store room	4.0 m^2	
Sanitary and adjacent rooms	30.0 m^2	(approx. 80 m^3)
Total apartment approx.	90.0 m^2	(approx. 235 m^3 of air space)

According to the standards, the following spent air flows would have to be extracted from the interior rooms:

WC	30 m^3/h according to DIN 18017
Shower	included in the bathroom
Bathroom	60 m^3/h according to DIN 18017
Kitchen	120 m^3/h according to VDI 2088
Utility room	20 m^3/h f = 4.0 (1/h)
Store room	20 m^3/h f = 4.0 (1/h)
Total	250 m^3/h

Related to the total volume of the apartment, this gives an air exchange figure of f = approx. 1.05 (1/h). However, when estimating the rooms with incoming outside air, this figure is 250:155, approx. 1.6 (1/h). With 4 persons in the living area, the value would therefore be 250/4 per person, approx. 62 m^3/h, certainly a very high figure. Even with an anticipated night reduction, according to DIN 18017, Page (4.1), to 50% of the volumetric flow, approx. 31 m^3/h of outside air would still be available per person.

The reality was quite different

The table in figure 6 gives a list of the measured values. When the windows were closed in all rooms with an exterior wall and when an incoming air grid above the living room door opening on to the balcony was sealed, a total volumetric flow of 116 m^3/h was measured at the 6 spent air valves. In relation to the waste water gradient indicator in the bathroom, the apartment had a low pressure of approx. 50 Pa (5 mm water column), whilst in cases 2 and 3 there was compensation to + 0. The volumetric flow, at 116 m^3/h, would theoretically be adequate as incoming air for the four persons, and still represents approximately a 0.75 x air exchange for the living room and bedrooms. The volumetric spent air flows for the kitchen, bathroom, shower and WC, on the other hand, are wholly inadequate.

For on closer examination it is seen that the air from the interior staircase flows subsequently to the storeroom and utility room, in all three cases considered, at an almost constant rate, whilst the living room and bedrooms are supplied with air through:

window joints, case 1, at 74 m^3/h, f = 0.47
window joints + grid, case 2, at 85 m^3/h, f = 0.54
window ventilation, case 3, at 186 m^3/h, f =1.2.

For the 4 persons in the apartment, the values measured are not yet below the theoretical values, but the kitchen de-aeration is wholly inadequate, even with a window ventilation of 53 m^3/h, and the apartment users confirmed that there was a considerable nuisance from odours when using the kitchen for the living and rest areas.

3.2 Ventilation conditions in 2 student apartments with sanitary rooms

3.2.1 Case (FG)

In a 10-storey tower block, with a circular ground plan, 10 living areas are arranged on each floor. For reasons of structural physics, it was necessary to state the air throughput in the vicinity of the sanitary room. A ventilation system was installed in accordance with DIN 18017, Page 3, and the flow rate can be reduced at night.

Figure 7 shows the ground plan of the student apartment described, and the table lists the measured values. They range from approximately 16.0 m^3/h for closed windows, to 25 m^3/h for open (tilted) windows.

There is no disadvantage to the people in the living room, provided that the cooking area is not being used. On the other hand, the sanitary area, when used as a shower room and toilet, must be regarded as under-supplied.

DIN 18017, in 4.1, "Volumetric Flow", and 4.1.1, requires a minimum air exchange of 4x. 60 m^3/h is an adequate volumetric flow even for bathrooms with a toilet.
The sanitary room has a space volume of 3.75 m^3; thus, according to the DIN, 4 x 3.75 = 15.0 m^3/h would be sufficient.

However, it is a well-known fact that such a volumetric flow is unable to exhaust the steam produced when the shower is operated. The consequences are conditions similar to those in a laundry, with saturation humidity and temperatures of around 30°C, and thereby high steam pressures compared with adjacent rooms, with the risk of moisture penetration.

As long as the wall material of the sanitary cubicle seals all areas of the room and is steam-tight, only dripping and precipitation will occur.

On the other hand, if the wall material exposes parts of the building structure, e.g. ceiling and upper wall areas, and is not itself steam-tight or acts as a steam brake, the adjacent rooms are subject to corresponding additional attack, as was the case here.

3.2.2 Case (D)

A 3- to 4-storey apartment block contains student apartments as shown in figure 8. The figure illustrates the arrangement of such a student apartment, with entrance hall and sanitary room. The room sizes are the same as those in case (FG), shown in figure 7, but no cooking area is provided in the living room. A description of the possible results of steam transmission is here confined to the living room, hall and corridor areas. The measured values clearly indicate the effect of the closed windows, with leak-tight joints.

3.2.3 Summary of case (FG) + (D)

This requirement laid down in DIN 18017, Page 3, for air exchanges of at least 4x, is met in both cases, even with the lowest volumetric spent air flow. However, a volumetric flow of 60 m^3/h is required, and the statement in DIN 18017 must therefore be made more specific, with 60 m^3/h representing a minimum value.

4 Cases of damage - sanitary cubicle

The student apartment shown in figure 8 has been built in a German university city, as part of about 250 units, and, after the apartments had been in use for 3 years, the sanitary cubicles were pinpointed as the source of considerable structural damage.

The cubicle is shown in detail in figure 9. The approximate volume of the room is 4.5 m^3. Thus, given the requirement in DIN 18017 for a minimum air exchange of 4x, the volumetric air flow required is 18 m^3/h, a value which must be regarded as critical. On the basis of the estimate of 60 m^3/h in the DIN, there is an exchange of 60:4.5 = approx. 14x and, with the extra air flow through unintended chinks, without air conduction, these sanitary cubicles are generally draughty.

According to figure 8, air throughputs of 20 to 48 m^3/h were measured (see Table), according to whether the windows and doors were open, hence the DIN standard is complied with in both cases. Returning to figure 5, showing the water produced from the shower cubicle and bath, the temperatures and humidity values stated can be represented in an H-X graph as follows (figure 10):

In the sanitary cubicle, a temperature of 26°C and a max. relative humidity of 90% were measured when the shower was used. The latter value is equivalent to approx. 18 g/kg of moisture in dry air. This is commensurate with the steam pressure of 28 mbars. Thus for the adjacent heated areas, such as the hall and living room, there is a gradient of 10 g per kg or 17 mbars. Steam migration and heat flow can be followed by the arrows. Since the wall covering of the cubicle consists of a "breathing" material, it is highly pervious to steam and discoloration was observed in the adjacent hall and living room, together with dust laying and mildew. Not even the demonstrable exchange already mentioned of 20 to 48 m^3/h, according to figure 8, was sufficient to stem the attack by steam.

It is probably necessary, therefore, to provide other possibilities of preventing structural damage for such small sanitary cubicles with shower facilities.

The illustration shows a central extraction ventilation system according to DIN 18017, Page 3, with connected sanitary rooms and apartment kitchens.

This system is designed for continuous operation, but there will be changes in the volumetric air flow when individual kitchens out of the chain of connected kitchens are used.

This variation in volumetric flow is provided by means of a pressure scanning system in the inlet chamber underneath the fan installation, with a suitable control system for varying the fan speed. This will mean that a larger quantity of outgoing air can be extracted from the kitchens when the extractor hood is opened (by tipping), or when the lights are switched on causing a change in the resistance of the air exhaust valve of the kitchen (stove) hood. The fan speed will be varied due to thevariation in pressure in the inlet chamber, and its output will increase until the set pressure is restored.

Instead of the arrangement in figure 11, in which the central fan can be controlled, there are two or three systems on the market which are approved by the Berlin Construction Engineering Institute and which control the independent ventilation of rooms connected to a collective shaft. This means that every room to be ventilated has a fan which is switched on from the room itself by means of the lighting or other switching device, and in doing so the extracted spent air is forced into the collective shaft.

To prevent annoyance in other connected rooms, each connected fan must be provided with a non-return valve which, in the stationary condition, prevents outgoing air from flowingback from the collective shaft into the connected room.

There is no doubt that the room can be adequately ventilated with these systems, provided that a suitable switch installation is used, with a sufficient delay, and provided that the non-return valves described above remain leak-tight, even with ageing, thus avoiding nuisance from the shaft itself.

It remains to be seen how far the energy projections of the manufacturers concerning the possibility of economies achieved through partial use of the fan system, when in operation, are confirmed. The projected values are interesting in any case, and these independent ventilation systems with facilities for switching on according to demand should be followed up.

5 Apartment ventilation with heat recovery (HR) and changeover switching in a detached family house

The volumetric air flow of a ventilation system for an apartment is determined from the required outgoing air flow as the minimum value, and the incoming air flow should have at least the same value unless there are special requirements for extra output to cover leakage losses.

Figure 12 shows the ground plan of a detached family house from the Landstuhl 1979 Solar Competition. As adviser to the architect, the author proposed a ventilation system in an apartment with HR in the draft plan for economic utilisation of solar energy. A changeover switching system was planned into the scheme for adaptation to the degree of utilisation so that at night the incoming air can be transferred to the bedrooms, and during the day to the living and dining rooms, according to moderate requirements. Changeover switching in the form of a transfer between the kitchen, bathroom and WC was provided for the outgoing air system.

Figure 13 shows a bar graph of the house in figure 12. In the upper half, a supply of 88 m^3/h (f = 0.8), with changeover switching, is provided for night operation in the bedrooms, and the living room receives the minimum value of 30 m^3/h (f = 0.3).

During the day, 59 m^3/h (f = 0.5) can be allocated to the bedrooms and 46 m^3/h (f = 0.5) to the living room, by using the changeover system for low consumption.

In the peak periods from 6 to 8 a.m., from 11 a.m. to 1 p.m. and from 6 to 10 p.m., the total volumetric flow for incoming and outgoing air is doubled, and for the kitchen there is an increase above the normal value of 60 m^3/h to 120 m^3/h. If it is possible to switch to a different value of outgoing air, a further increase in the kitchen to 190 m^3/h can be achieved, whilst at the same time a minimum amount of outgoing air is extracted in the bathroom and WC. In the example considered, the night value is approximately 130 m^3/h, and the day value 260 m^3/h.

As a result of this reduction, there is a daytime reduction from 8 to 11 a.m. and from 2 to 6 p.m. with reference to the night value. Adaptation to other patterns of use is possible at any time.

For the solar design, the apartment ventilation was also intended to serve as background heating and, furthermore, partial utilisation and transfer, via the heat recovery system, to the north and east rooms of the house should be possible when the living room and dining room are overheated by the solar radiation.

Figure 14 shows a terraced house. It also shows the air distribution and collection system for the dwelling floor in an inconspicuous area of the hall.

The area containing the rooms where the air supply is to be alternately reduced or increased can be seen, served from the two changeover switchboxes.

The room adjacent to the living room, and not included in the supply system, is regarded as a buffer zone for limited use, according to the heat provided externally as a function of the time of the year.

For both designs (figures 12 and 14) the residential ventilation was provided as a background heating system for an ambient temperature of up to + 14°C in the coldest weather conditions for the rooms supplied with incoming air. Extra heating with individual room controls can be provided by radiators and other heating surfaces suitable for individual control.

6 Example of independent ventilation or central ventilation with HR and changeover switching for an apartment in a building for a number of families.

A residential ventilation system was planned as part of a research proposal for a residential development consisting of 4-storey houses containing 2 apartments on each floor. The standard house design was to have a collective shaft ventilation system according to DIN 18017 Page 2 to serve the bathroom and WC. No ventilation was provided for the kitchen, which was situated against the outside wall.

Figure 15 shows an apartment with an area of approx. 70 m^2 for 3 to 4 occupants. The living room and bedroom S2 face south, and the space heating will be provided by a 90 to 70°C water heating system fed by instantaneous gas heaters and installed in the hall. The following air volume figures are obtained:

Kitchen = 120 m^3/h
Bathroom = 60 m^3/h
WC = 30 m^3/h

Total = 210 m^3/h as the daily value.

By switching over, the following figures may be obtained:

Kitchen = 165 m^3/h
Bathroom = 30 m^3/h
WC = 15 m^3/h

Total = 210 m^3/h as the daily value.

When reducing to the permissible 50% value in central heating systems the following pattern is obtained:

Kitchen = 60 m^3/h
Bathroom = 30 m^3/h
WC = 15 m^3/h

Total = 105 m^3/h night value or low load value.

If the incoming air is supplied at the same volumetric flow rate, an adequate volumetric outside air flow of approx. 26 m^3/h per person is ensured at night as far as the outgoing air is concerned, i.e. 210 m^3/h during the day, and 105 m^3/h at night. Moreover, the air exchange values in figure 15 indicate the following changeover switching conditions:

Living room
T = 1.1 - T/U = 1.8
N = 0.7 - N/U + 0.3
Bedrooms S 1 and S 2
T = 1.16 - T/U = 0.6
N = 0.67 - N/U = 0.9
(T = day, N = night, U = changeover switching).

These values are more than adequate, therefore, assuming the standard outgoing air values for the kitchen, bathroom and WC.

Figure 16 shows the proposed arrangement for an independent ventilation system for each apartment (residential or user unit). It differs from figure 15 in respect of the incoming air supply and the shaft arrangement.

A collective shaft will be required for the outside air and for the extraction of air for four apartments. So far no nationally developed residential ventilation systems suitable for this purpose, with heat recovery of the order of 100 to 250 m^3/h, including extra heating as required, filtration and non-return valves, have come on to the German market.

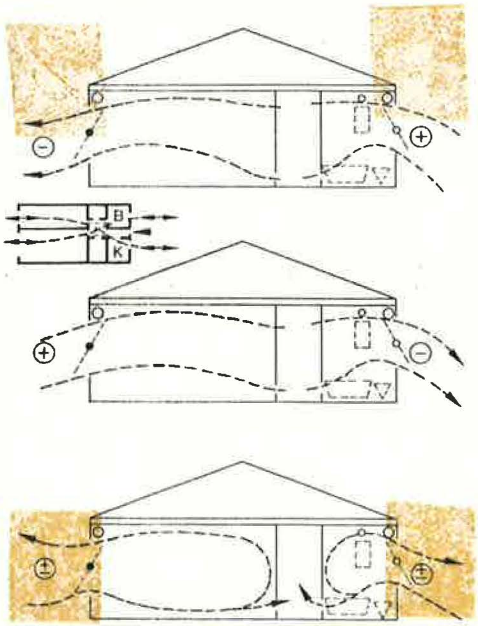
However, two French designs, with heat pumps operating on a compression principle, are now being sold on the German market, and it is hoped that these systems will provide German companies with sufficient encouragement to develop their own.

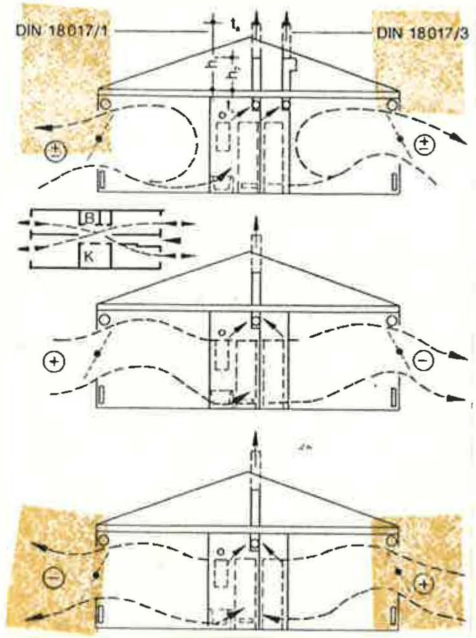
7 Summary

In the arrangement shown in figure 16, the user would be able to measure the energy consumption of his space heating and ventilation and to influence it with a view to saving energy. He would also be able to keep accurate accounts of his consumption. In present instantaneous gas heating systems, the air for combustion must be included in the ventilation figures for the apartment and, similarly, the operation of the independent ventilation system must be closely linked to the instantaneous gas heating system to ensure safe operation of the latter.

The intention of this discussion was to present independent ventilation in an apartment as a better ventilation alternative for saving energy and, in doing so, reference must be made to the need for controlled ventilation, with the possibility of heat recovery and the use of internal and external heat.

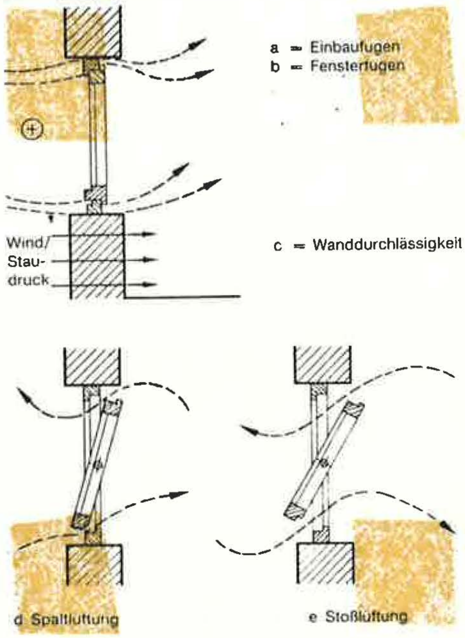
The risk of structural damage due to moisture resulting from inadequate ventilation of the apartment should not be underestimated. Users must be instructed adequately and in good time on the use of the systems, and must be supervised.





1 Natural ventilation of an apartment with exterior bathroom and WC

2 Natural ventilation of an apartment with interior bathroom and shaft ventilation



a = encased joints
b = window joints

Wind/
atmospheric pressure
c = wall permeability

d Gap ventilation e Joint ventilation

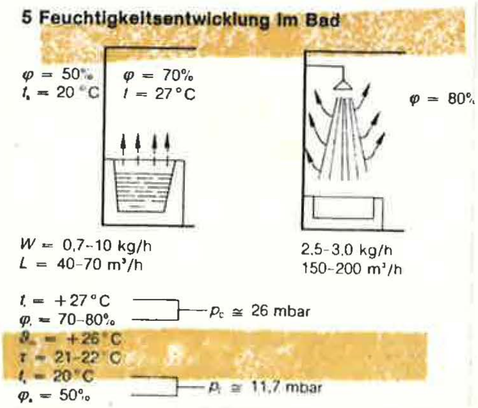
3 Possibilities of air penetration in a building

Kohlensäure-Maßstab	~ 20 bis 30 m³/Pers. h
Wärme-Maßstab	~ 50 bis 60 M³/Pers. h¹)
Feuchte-Maßstab	~ 10 bis 15 m³/Pers. h
Schadstoff-Maßstab	= ?

④ ¹) 30 bis 40 m³ Umluft

Carbon dioxide value	~20 to 30 m³/ person per h
Heat value	~ 50 to 60 m³/ person per h*)
Humidity value	~ 10 to 15 m³/ person per h
Noxious substance value	= ?

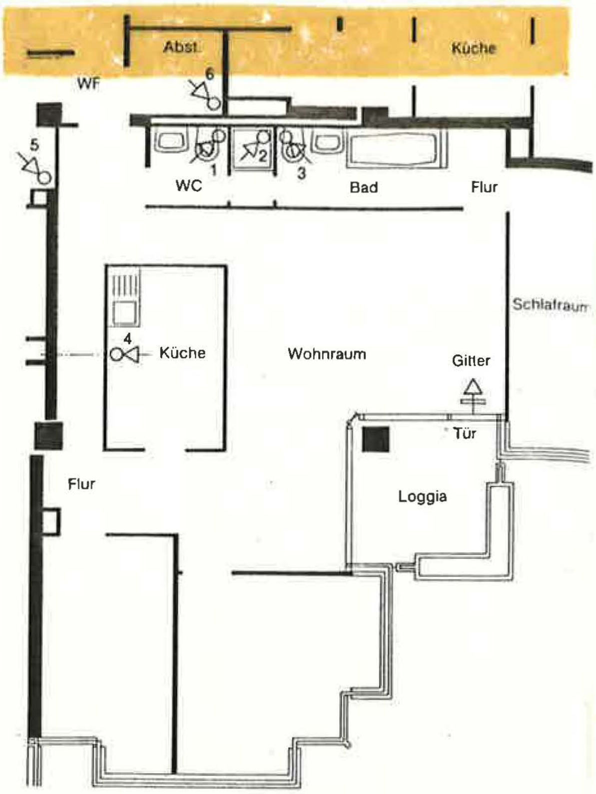
*) 30 to 40 m³ circulating air



W = 0.7-10 kg/h 2.5-3.0 kg/h
L = 40-70 m³/h 150-200 m³/h

t_1 = + 27°C
φ_1 = 70-80% $p_0 \cong$ 26 mbars
ϑ_w = + 26°C
τ_1 = 21-22°C
t_2 = 20°C $p_d \cong$ 11.7 mbars
φ_2 = 50%

5 Moisture build-up in the bathroom



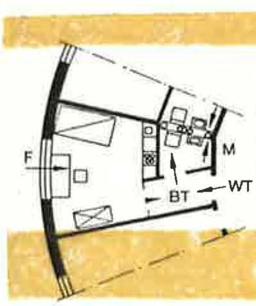
Abluft	Fall 1 alles geschlossen	Fall 2 Gitter geöffnet	Fall 3 Fenster geöffnet
1 WC	13 m³/h	14 m³/h	44 m³/h
2 Dusche	12 m³/h	18 m³/h	50 m³/h
3 Bad	11 m³/h	13 m³/h	39 m³/h
4 Küche	38 m³/h	40 m³/h	53 m³/h
5 Abstr. re	35 m³/h	36 m³/h	43 m³/h
6 Abstr. li	(7 m³/h)	(7 m³/h)	(20 m³/h)
	116 m³/h	128 m³/h	249 m³/h

WF* Store room Kitchen
WC Bathroom Corridor
Bedroom
Kitchen Living room
Grid
Hall Door
Balcony

Spent air	Case 1 everything closed	Case 2 Grid open	Case 3 window open
1 WC	13 m³/h	14 m³/h	44 m³/h
2 Shower	12 m³/h	18 m³/h	50 m³/h
3 Bathroom	11 m³/h	13 m³/h	39 m³/h
4 Kitchen	38 m³/h	40 m³/h	53 m³/h
5 Storeroom on right	35 m³/h	36 m³/h	43 m³/h
6 Storeroom on left	(7m³/h) 116 m³/h	(7 m³/h) 128 m³/h	(20 m³/h) 249 m³/h

*WF = Vestibule

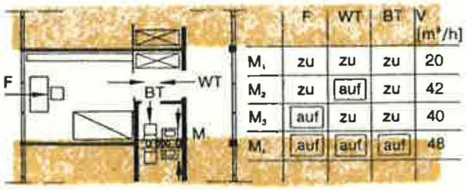
6 Ground plan of a split level owner-occupied apartment with ventilation points



	F	WT	BT	V [m³/h]
M1	zu	auf	zu	27,0
M2	zu	zu	zu	18,3
M3	zu	zu	auf	16,2
M4	auf	zu	zu	23,7
M5	auf	zu	auf	24,8

	Window	WT	BT	V (m³/h)
M1	closed	open	cl.	27.0
M2	closed	cl.	cl.	18.3
M3	closed	cl.	open	16.2
M4	open	cl.	cl.	23.7
M5	open	cl.	open	24.8

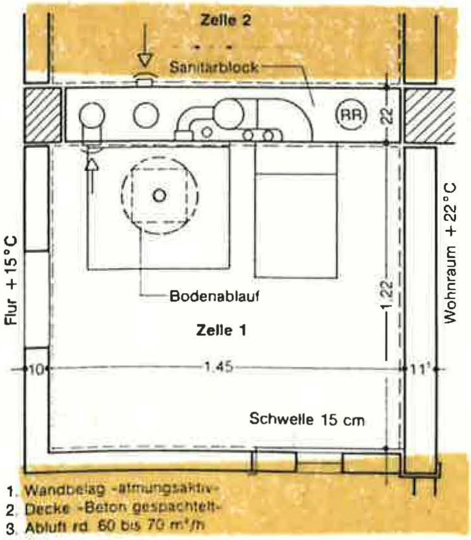
7 Ground plan of a student apartment



	Window	WT	BT	V (m^3/h)
M1	closed	cl.	cl.	20
M2	closed	open	cl.	42
M3	open	cl.	cl.	40
M4	open	open	open	48

8 Student apartment with entrance hall and sanitary room

BT = Door of the bathroom
WT = Door of the appartment to the hall (entrance door)
M = Measuring point for $\dot{V}$



Cubicle 2
Sanitary block

Hall +15°C

Floor drainage

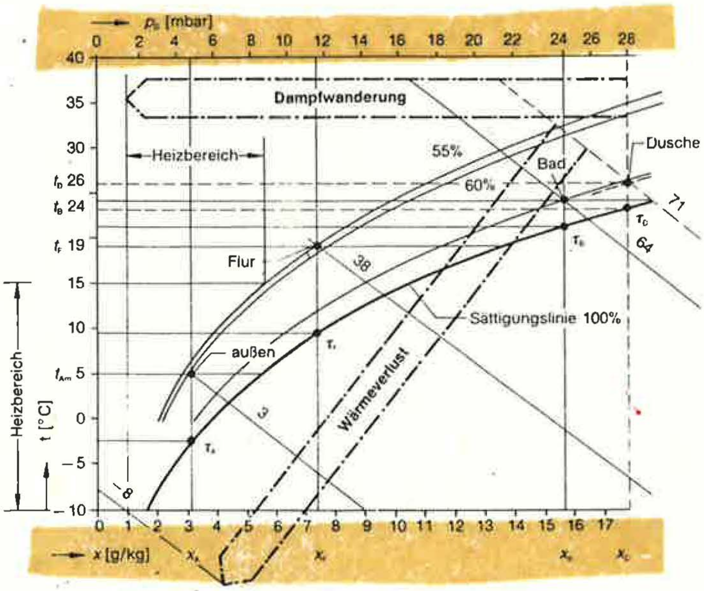
Living room +22°C

Cubicle 1

Threshold 15 cm

1. Wall covering "breathes"
2. "Rendered concrete" ceiling
3. Spent air approx. 60 to 70 m^3/h

9 Sanitary room (cubicl



Steam migration

Shower

← Heating area →

Bathroom

Hall

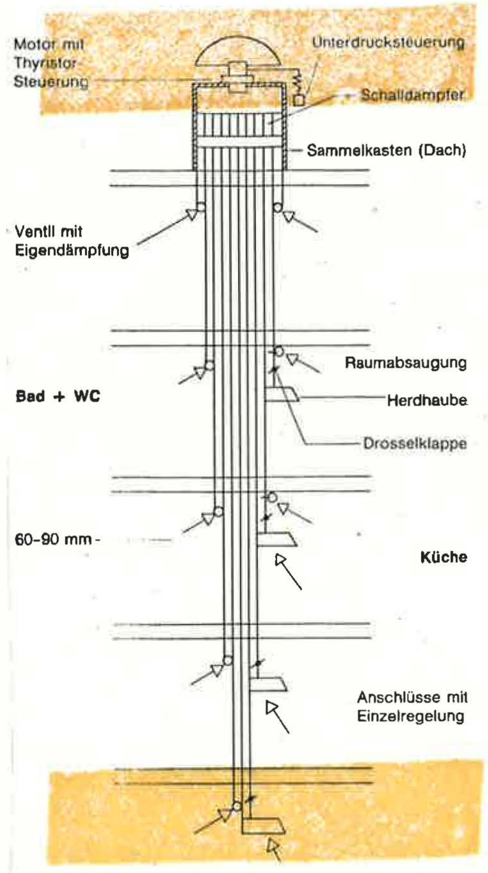
100% Saturation line

outside

Heat loss

← Heating area →

10 H-X graph
Sanitary cubicle



Motor with thyristor control

Low pressure control

Silencer

Collector (roof)

Valve with independent damping

Space extraction

Bathroom + WC

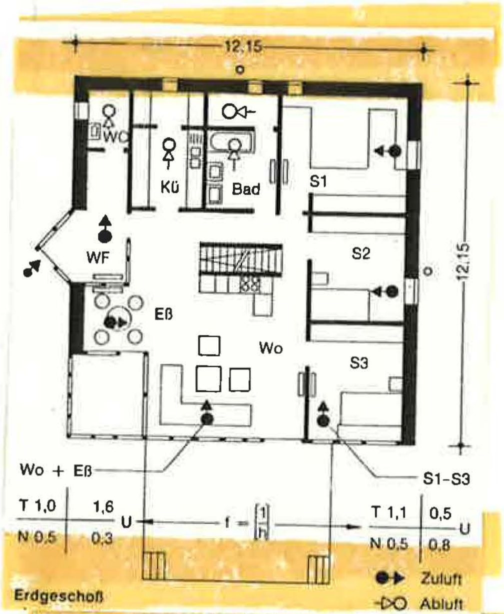
Stove hood

Throttle valve

Kitchen

Connections to independent control system

11 Central ventilation system



WC

Bedroom 1

Vestibule Kitchen Bathroom

Bedroom 2

Dining room Living room

Bedroom 3

T = Day
N = Night
U = Changeover switching

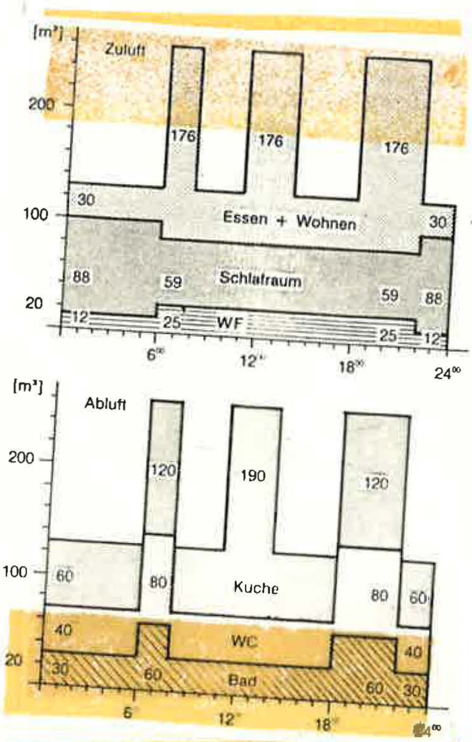
Living and dining rooms

Incoming air

Spent (outgoing) air

Ground floor

2 Ground plan of detached family house from the 1979 Landstuhl Solar Competition



Incoming air

Dining + living rooms

Bedroom

Vestibule

Spent (outgoing) air

Kitchen

WC

Bathroom

13 Bar graph of the house in figure 12

Living + dining areas

Bedroom 1

Living room

Kitchen

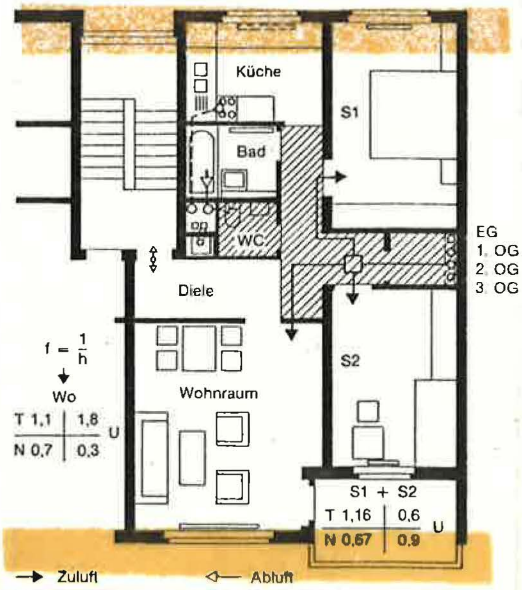
Bedroom 2

Dining room

Bedroom 3

Incoming air
Outgoing air
T = Day
N = Night
U = Changeover

14 Residential ventilation in the Landstuhl 1979 solar house



Kitchen

Bathroom

WC

Hall

Living room

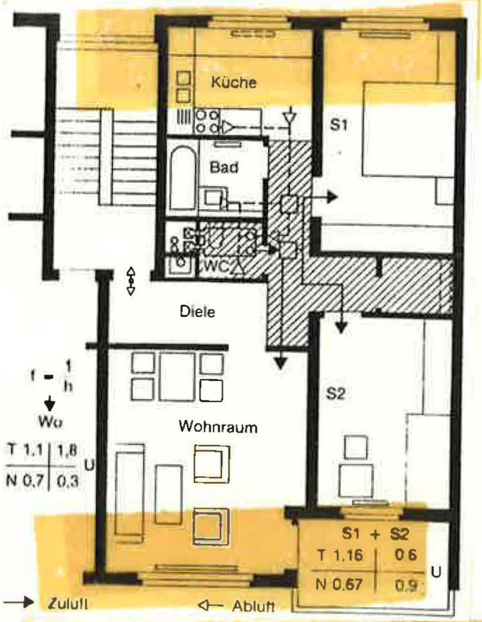
Ground floor
1
2
3

Wo = living room
T = day
N = night
U = changeover switching

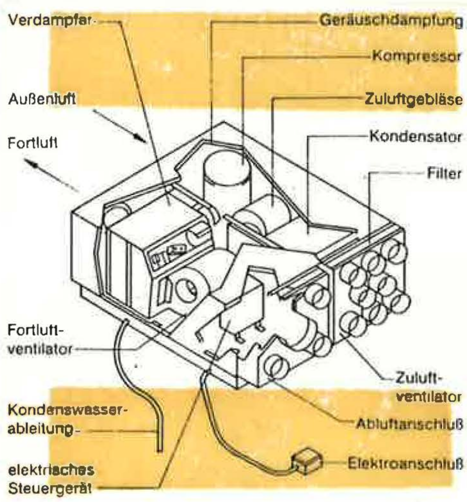
S = Bedroom
T = day
N = night
U = changeover switching

→ Incoming air ← Outgoing air

15 Ground plan of an apartment with an area of approx. 70 m², for 3 to 4 occupants.



16 Apartment as shown in figure 15, but with the installation of an independent ventilation system for the whole apartment.



Evaporator — Silencer

Outside air — Compressor

Exhaust air — Incoming air fan

Exhaust air fan — Condenser

Condensation water discharge — Filter

Incoming air fan

Electrical control unit — Outgoing air connection

Electrical connection

17 Ventilation and extraction system for apartment, with heat recovery and heat pump