VENTILATION REQUIREMENTS IN DWELLINGS TO PREVENT SURFACE CONDENSATION

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BACKGROUND

Whilst reducing transmisson losses of a building through insulation measures to very low values is more or less only a question of economy, minimizing ventilation to reduce the respective losses - if brought to far - may bring up a lot of problems regarding air quality and building physics. This experience has been made with a great number of buildings in Germany.

Ventilation in buildings has four tasks:

- to substitute oxygen consumed by people, stoves, and fireplaces
- to remove water vapour produced by washing and cooking activities, by people and plants
- to remove hazardous pollutants originating from building materials, furnishing, protecting agents, tabacco smoke, and countless household chemicals and agents today in use
- to remove odours for comfort reasons.

Only then could ventilation be abolished if it was possible to regenerate the room air in all its components technically and at reasonable cost. But neither are such techniques in sight, nor is it probable that the majority of occupants - which have been found very conservative even towards simple ventilation systems - would accept "artificial" air.

For practice it seems appropriate to consider ventilation requirements under three separate risk aspects:

(1) removal of pollutants harmful to health
(2) avoiding building damage by moisture
(3) safe operation of stoves and fireplaces.

Ventilation is to be provided in such a way and to such an extend, that all threee requirements are met. This paper deals with the second aspect.

VENTILATION EFFICIENCY

Ventilation is an extremely complex phenomenon. With an open window for instance variations in wind and outside temperature have a strong influence on the air change. But even set aside such variations, the opened window will neither provide for a complete mixture of the room's air nor will it effectuate displacement ventilation, thus leaving uncertain the ventilation effieciency (e).

Ventilation efficiency expresses the ability of a system to keep away or to remove pollutants from the sensible areas of a room (e.g.occupational zone or cold surfaces) with a given air change rate. Ventilation efficiency may be defined as (1):

$$e = \frac{CF - CA}{CRi - Ca}$$

with: CF = pollution concentration in the exhaust air
Ca = pollution concentration in the supply air
CRi = pollution concentration in the room air at location i

For CF = CRi (complete mixture, dilution ventilation) e = 1. That case may hardly be found in practice but is most commonly used for calculation and modelling purposes, because of a common lack of ability to account for the complex pattern of air movement in a room.

Relevant for surface condensation is the dew point of the air in the vicinity of cold surfaces, NOT the average water content of the room air, a point of particular relevance for the planning and installation of efficient ventilation systems.

If not otherwise specified, the air change rate in this paper refers to complete mixture too. In many practical cases special provisions (e.g. range hoods) or users behaviour (opening of windows close to the pollution source) will improve vapour removal (e > 1), in some other cases it may reduce it (e.g. in "dead" corners of a room, e < 1). In general however, the air exchange rate referred to complete mixture is assumed to be on the safe side of the estimation of ventilation efficiency.

PRODUCTION RATES OF WATER VAPOUR IN DWELLINGS

Contrasting to the situation with chemical pollutants, with water vapour the potential emission sources are known. Even though users behaviour varies in a broad band, the expected range can be estimated.

The following "model dwelling" shall be investigated:

appartment flat
100 m2 living area
three head family
average factor of presence: .7

A number of publications (2, 3, 4, 5, 6) specify vapour production rates of sources commonly found in dwellings. Table 1 lists the main sources and their emission rates.

With those rates and the data of the model dwelling a vapour load as specified in table 2 results, totaling to about 12 kg per day or to an average of 500 g water per hour.

As already mentioned the amount of water vapour remaining actually in the air can be expected to be considerably lower than the values listet, because part of the vapour generated by particularly critical processes (e.g. cooking, showers) is normally removed by direct ventilation before mixing with the room air. Additional loads would be added if washing would be dried in the rooms. Such drying however cannot be considered usual and is normally interdicted to tenants by contract. Because of the water storage capability of building masses, peak loads of vapour do generally not pose a problem.

CRITICAL BUILDING SURFACES

The cold outer surfaces of a building are the critical ones regarding condensation problems. Gertis (5) has investigated the thermal behaviour of particular critical building geometries. In a three-dimensional corner on the outside walls of a building under a flat roof ceiling (one of the geometries bearing the highest condensation risk) constructed according to the German building standards of 1981, it was found that the surface temperature will fall below the room temperature, by about one third of the difference between room temperature and outside temperature. If e.g. Ta = 2 C and Ti = 20 C, a corner temperature of only 14 C will result. According to the same source the temperature drop in one-dimensional corners of older buildings (flat roofs are seldom encountered with them) is in the same order.

MINIMUM VENTILATION RATES FOR THE MODEL DWELLING

From the point of view of surface condensation the requirement to ventilation is:

> the air change rate must reduce the vapour content in the room air at least so far as to reduce the dew point temperature below the lowest surface temperature.

For some typical meteorological situations, the minimum air change required has been calculated, assuming complete mixture of the room air. Table 3 gives the results for a cold and an average winter day, for a typical spring or an autumn day, and for a day just above the outside temperature where heating is no more required. Relative humidity of the outside air is assumed to be 80% in all cases. The surface temperatures according to (5) are used for determination of the maximum allowed water content of the room air. Taking into account the vapour production of the dwelling the necessary air change rate can be determined.

It is seen from the table, that for all temperatures during the heating season, an air change rate of

$\dot{V}_{min} = 85\ m^3/h$

is sufficient in the model dwelling, corresponding to .34 air changes per hour. Even in a considerably smaller dwelling of e.g. 70 m^2 living area and with the same vapour load the generally recommended air change rate of .5/h can be considered sufficient.

With rising outside temperature the minimum required air change too rises. It is therefore important to increase ventilation beyond the specified value outside the heating season. This is less a problem of economy or of comfort, because no energy losses are taking place then and because draught effects play a minor role during the warm season. But it requires deliberate measures to increase ventilation, since just when more ventilation would be required, thermal forces as driving motor of ventilation are week or absent. The experience observed, that condensation problems are encountered particularly in the transitional season proves, that no consciousness exists of this problem in the public.

DISCUSSION OF THE RESULTS

The case presented can be expected to be representative for a great number of dwellings in the existing building stock. New buildings with improved ventilation according to the latest regulations will do with slightly lower air change rates only during the colder season. At higher temperatures in the transitional period differences are neglectible.

Experience that the specified air change is indeed sufficient under normal conditions, is confirmed by the observation, that in many dwellings air change rates under .5 are taking place. Nevertheless condensation problems occur only then, if additional stress factors deteriorate the situation such as:

- additional vapour generation (e.g. drying of washing)
- considerable reduction of the room temperature (e.g. in bedrooms)
- deterioration of the heat transfer coefficient from the room air to critical (cold) building surfaces (e.g. furniture before outside wall).

It should be noticed that this paper considers only surface condensation. With building hulls of unfavourable construction (e.g. vapour barrier wrongly placed) condensation may occur inside a building element, impairing its function and durability.

Person, ruhend	40 g/h
Person, wohnungsübliche Tätigkeit	90 g/h
Topfpflanze (mittelgroß)	10 g/h
Koch- und Feuchtreinigungsprozeß	1000 g/h
Waschmaschine	300 g/Lauf
Duschbad	2600 g/h
Freie Wasseroberflächen	200 g/hm^2

Table 1
Sources of Water Vapour in Dwellings

24 Personenstunden, ruhend	960 g/d
27 Personenstunden, tätig	2430 g/d
15 Topfpflanzen	3600 g/d
3 Stunden Kochen und Feuchtreinigen	3000 g/d
0,5 Waschmaschinenläufe	150 g/d
15 min Duschbad	650 g/d
1000 cm^2 freie Wasseroberflächen	480 g/d
Sonstige Einträge (z.B. regennasse Kleidung)	200 g/d
SUMME	11470 g/d

Table 2
Water Vapour Production in a 3-Head Dwelling

	Symbol	kalter Wintertag	Durchschnittswintertag	Übergangszeit	Tag an der Heizgrenze
Außentemperatur	T_a	-4°C	5°C	11°C	14°C
relative Außenluftfeuchte	φ_a	80 %	80 %	80 %	80 %
Raumtemperatur	T_i	20°C	20°C	20°C	20°C
resultierende Oberflächentemperatur an besonders gefährdeten Gebäudestellen (nach (5))	T_o	12°C	15°C	17°C	18°C
zulässige Raumluftfeuchte, so daß bei T_o noch keine Kondensation erfolgt	φ_{izul}	60 %	73 %	82 %	88 %
durch die Außenluft nach Aufheizen auf T_i und bei Anreichern auf φ_{izul} transportierbare Feuchte	Δx	6,5 g/kg	6,4 g/kg	5,6 g/kg	4,9 g/kg
täglicher Feuchteanfall in der 3-Personen-Modellwohnung (nach Tabelle 4.3-2)	$\dot{m}_{H_2O}$	12000 g/d	12000 g/d	12000 g/d	12000g/d
Erforderliche Luftaustauschrate, zum Abtransport der in der Wohnung anfallenden Feuchte (vollständige Durchmischung der Raumluft)	$\dot{V}_{minF}$	64 m³/h	65 m³/h	75 m³/h	85 m³/h

Table 3
Water Vapour Removal by Ventilation in a 3-Head Dwelling

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(4) Altenhoff K., Botzenhardt K., Holz B., Maier B., Tesche B, Voss K.-F., Werner H.: Erp ung und Vergleich verschiedener Lüftungssysteme im Solarhaus Freiburg
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(5) Gertis K.: Wohnfeuchte und Wärmebrücken
HLH 36, Nr. 3 (1985)

(6) Bley H.: Innenküche. Untersuchung über Feuchte- und Temperaturverhalten von fensterlosten Innenküchen
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