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FILTERING AND HUMIDITY MEASUREMENT IN THE EXHAUST AIR OF BATHROOMS AND TOILETS WITHOUT WINDOWS

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Summary
The inadequate dissipation of humidity from living spaces and bathrooms has become a significant problem area in recent years. This can be attributed both to the replacement of old, poorly sealed windows by new windows with better seals, and to the increasing use of tiles and other building materials which hinder an adequate absorption of water vapour.

The residents tend to reject repeated opening of the windows for ventilation purposes on grounds of the ensuing energy costs. The result is the formation of mould both in the living rooms and in the bathrooms.

The installation of humidity controlled ventilation in bathrooms without windows involves the danger, that a drop below the dew point at the humidity sensor may lead to unwanted continuous operation. This, in turn, will result in a very short service life for the filters and excessive energy consumption.

Possible solutions are to be sought both in the construction of the building and in a controlled process of ventilation.

Introduction
The currently applicable Regulations on Thermal Insulation WSVO [5] are aimed at cutting the heat losses in and from buildings, in order to reduce the heating energy input necessary for their compensation (reduction of energy-related CO_2 emissions). Since the Regulations on Thermal Insulation have been in force, it has been possible to reduce the transmission heat losses to 1/4 of their original value, thanks to effective heat insulation of the outer shell of the building and methods of building with sealed joints. The heating consumption for ventilation has not changed significantly over the same period in absolute terms, though this does mean, that the proportion of heating energy consumption attributable to ventilation has increased from 20 % to 50 %.

The release of humidity within the rooms, on the other hand, has remained practically constant. Around 60 to 70 g of water are released per person per hour. Whereas persons and plants represent a practically constant humidity load over the period of the day, showers and cooking facilities are of importance above all as peak loads.

The following table summarises the humidity loads to be expected for the individual rooms of an apartment, together with the resultant minimum outside air flows.

Table 1 illustrates clearly both the heavy humidity loads of the bathrooms in use and a far from negligible humidity emanating from plants. The developments in building construction (water vapour absorption capability tending towards zero) mean that condensation on building elements can only be prevented by way of sufficient ventilation.

Table 1.: Humidity loads in apartments

Room	Typical range or mean value	Air temperature °C	Humidity produced g/h	Outside air flow m^3/h	Room volume m^3	Minimum ventilation h^{-1}
Living rooms	Range Mean value	20	100-300 200	25-70 45	40-80 60	0.3-1.8 0.8
Bedrooms	Range Mean value	16	20-100 60	5-30 20	20-40 30	0.1-1.5 0.8
Children's room	Range Mean value	20	90-200 150	20-45 35	20-60 40	0.3-2.3 0.8
Bathroom - in use - daily average	Range	24	700-2600 50-150	135-500 10-30	20-30	4.5-2.5 0.3-1.5
- in use - daily average	Mean value		1000 100	190 20	25	8 0.8
Kitchen - in use - daily average	Range	20	600-1500 20-180	150-350 5-40	20-40	3.8-1.8 0.1-2.0
- in use - daily average	Mean value		1000 100	230 25	30	8 0.8

Necessity of ventilation

The humidity loads occurring within the apartments can only be removed through ventilation. Two forms must be distinguished in this connection:

- Open-window ventilation
- Controlled ventilation

Open-window ventilation

Fig. 1 shows the distribution of the current ventilation situation in the eastern states of Germany (Saxony, Saxony-Anhalt, Thuringia, Brandenburg, Mecklenburg-West Pomerania). It is revealed clearly, that open-window ventilation dominates. A frequently found variation alongside open-window ventilation is natural air-shaft ventilation.

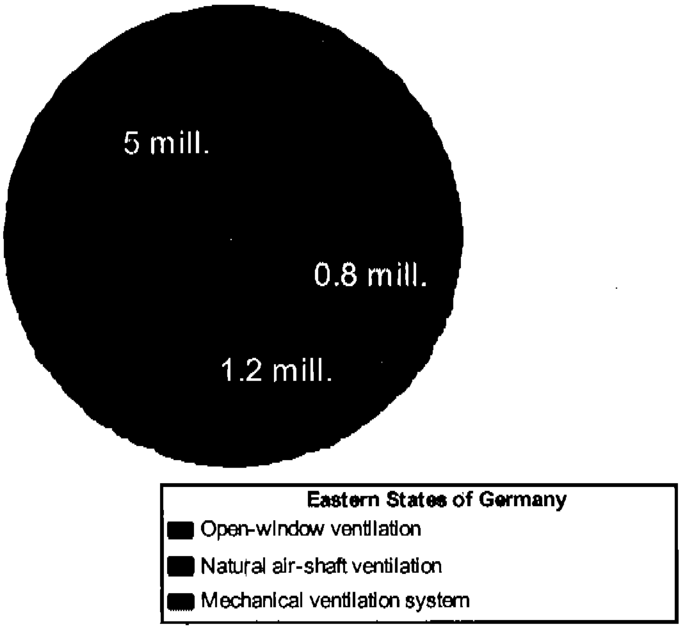

Fig. 1. Distribution of types of ventilation in the eastern states of Germany

In order to guarantee sufficient exchange of air with "non-continuous open-window ventilation", the authors have defined a minimum value, whereby the window should be opened for ventilation for 10 minutes every 2 hours. This value is still considerably below that laid down by Petzold [7] from a building climate point of view.

Open-window ventilation brings the disadvantages, that a scarcely quantifiable volume of outside air flows into the rooms, and that air-borne pollution, noise and possible draughts cannot be excluded. Open-window ventilation is furthermore dependent on the ventilation characteristics of the window.

Open-window ventilation leads to unwanted losses of heating energy, the amounts of which may reach considerable proportions. Fig. 2 shows the ratio of annual heating energy consumption for ventilation, documented in various periods of opening of the windows.

Even when applying the above-mentioned ventilation rule of "10 minutes ventilation every 2 hours", the heating energy consumption for ventilation is already some 30 to 40 kWh/m^2 a.

In other words, as Fig. 3 shows, almost half the annual total heating energy consumption in a modernised pre-fabricated apartment block (the typical housing solution in the eastern states of Germany) is used solely for ventilation.

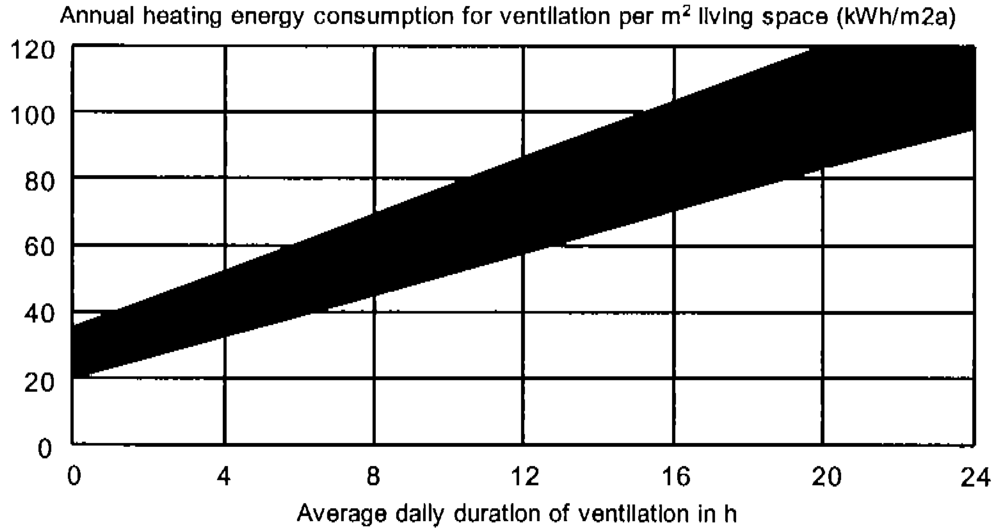

Fig. 2: Heating consumption for ventilation with tilted windows

In the case of permanent ventilation of the rooms, the share of ventilation heat rises significantly above that of transmission heat (compare Fig. 3), which in the final analysis constitutes a waste of energy.

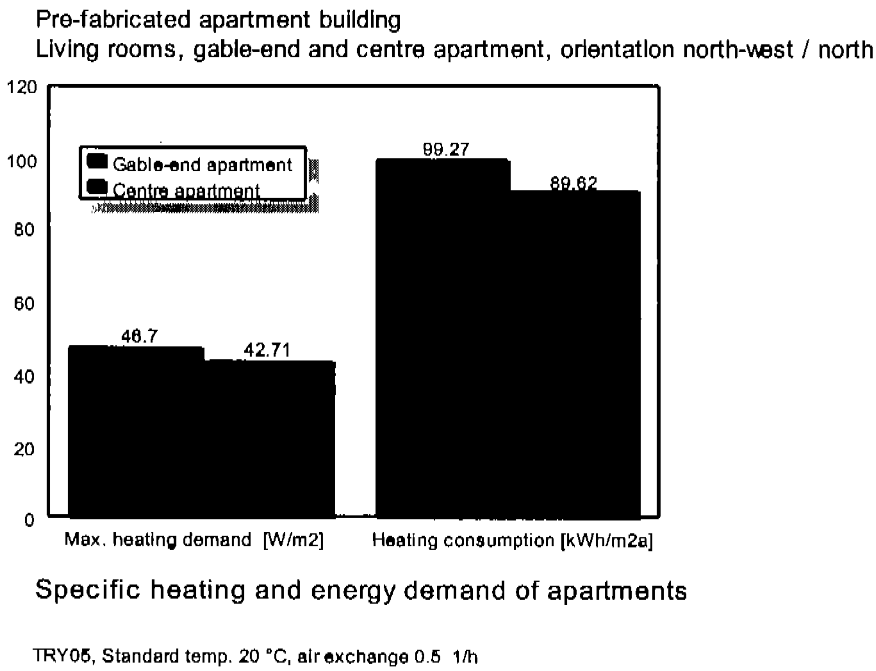

Fig. 3: Specific values of the heating and energy demand of the apartments

The ventilation habits of the residents have not changed in line with the new tighter sealing designs of both the window constructions and the building itself. As a result, negative effects arise, such as a deterioration of the air quality through emissions of pollutants or odours, and the formation of mould on the walls due to the inadequate dissipation of humidity, which are basically attributable to the objective of saving energy costs.

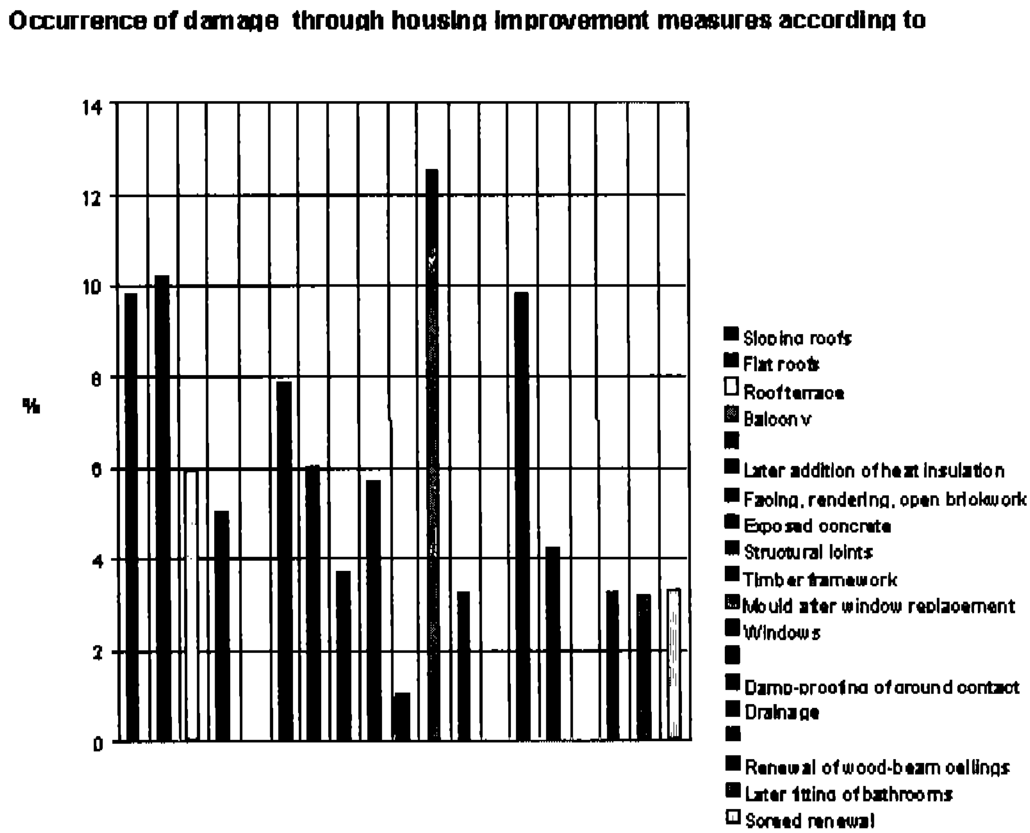

Fig. 4: Occurrence of damage through housing improvement measures from /1/

The share of damage following the replacement of old, poorly sealed windows by new windows with better seals is, according to /1/, over 12 %. This damage is manifested in the form of mould, which can most often be documented by the formation of black spots in inaccessible places. This means, that the necessity of ventilation in the form of open-window ventilation is generally not viewed by the residents under the aspect of humidity. A transition to some form of controlled room ventilation is becoming indispensable.

Controlled ventilation

In order to ensure a minimised, but at the same time adequate exchange of air, taking into consideration the factors hygiene, building physics and energy demand, it is necessary to install a mechanically controlled ventilation system. Such systems permit exact observance of a necessary minimum outside air exchange.

The housing ventilation systems currently available on the market can be divided into four main categories:

- decentralised single-room ventilation units, whereby a distinction is made between systems with and without heat recovery
- central ventilation units, with which a centrally located unit provides ventilation for all the rooms of an apartment or home via a system of air ducts. In this case, a distinction can be made between various technical solutions for heat recovery
- central ventilation units for apartment blocks, which must be viewed separately on account of their special characteristics, such as fire safety, hygiene, and acoustic aspects.
- ventilation units with integrated air heating

While the above systems were developed predominantly for normal living areas, inside bathrooms without windows must be ventilated mechanically, as laid down in DIN 18017 [6]. There is in this respect no direct correlation between DIN 18017 and DIN 1946 part 6. The outside air enters through the incomplete seals of the neighbouring rooms and flows through the bathroom via special ventilation openings. DIN 18017 specifies the following flow rates:

Table 2: Ventilation requirements according to DIN 18017

Room	Planned ventilation flow rate in m^3/h	
	duration of use ≥ 12 h/d	unlimited use
Bathroom also with WC	40	60

Mechanical bathroom ventilation in accordance with DIN 18017 introduces further aspects. Humidity controlled ventilators can and should permit good adjustment to the requirements of the user. The design principle is shown in Fig. 5.

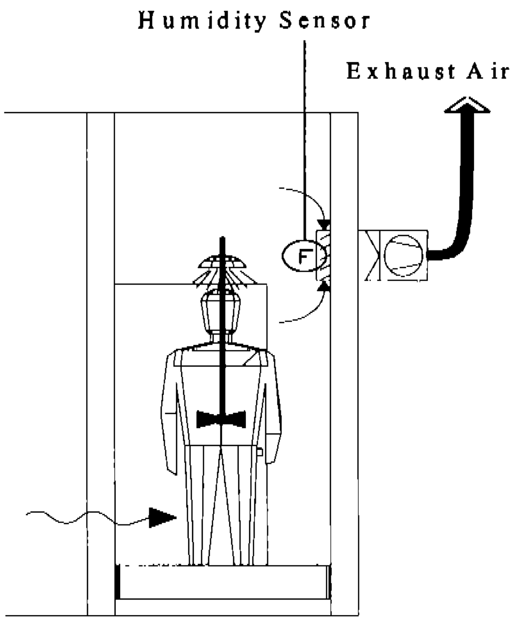

Fig. 5: Design principle of a humidity controlled bathroom ventilation system

The operation of such a system gives rise to the following problems:

- On account of the periodic operation, the piping and installed components (filter, humidity sensor) cool to below the room air temperature
- Water vapour is released suddenly and in large quantities when taking a shower or bath
- The electrical impulse causes the ventilator to start up with a time delay; in many cases there will be a risk of draughts due to inadequate heating
- The exhaust air laden with humidity is passed over the cooler elements of the system and condenses, e.g. on filters and humidity sensors
- The condensation of water at the humidity sensor produces a longer control signal and in turn longer operation of the ventilator

- Moisture saturation in the filter material causes dust contamination in the exhaust air to clog the filter, see Fig. 7
- Longer operation of the system leads to more rapid contamination of the filter
- Mould is formed on the filter material

Fig. 6 shows a new filter, Fig. 7 a contaminated humidity sensor and a contaminated filter.

These individual phenomena lead to an increased power consumption of the ventilators and to acoustic problems on account of the shifting of the working point of the ventilator.

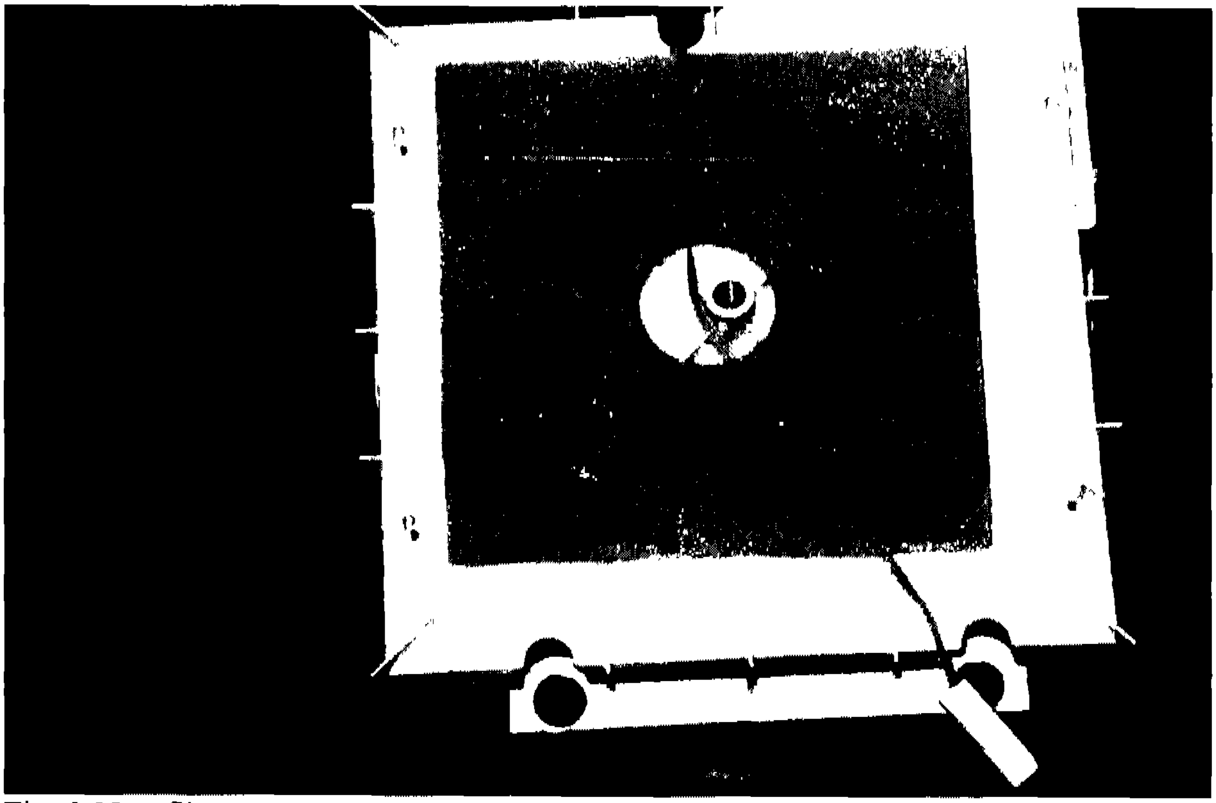

Fig. 6: New filter

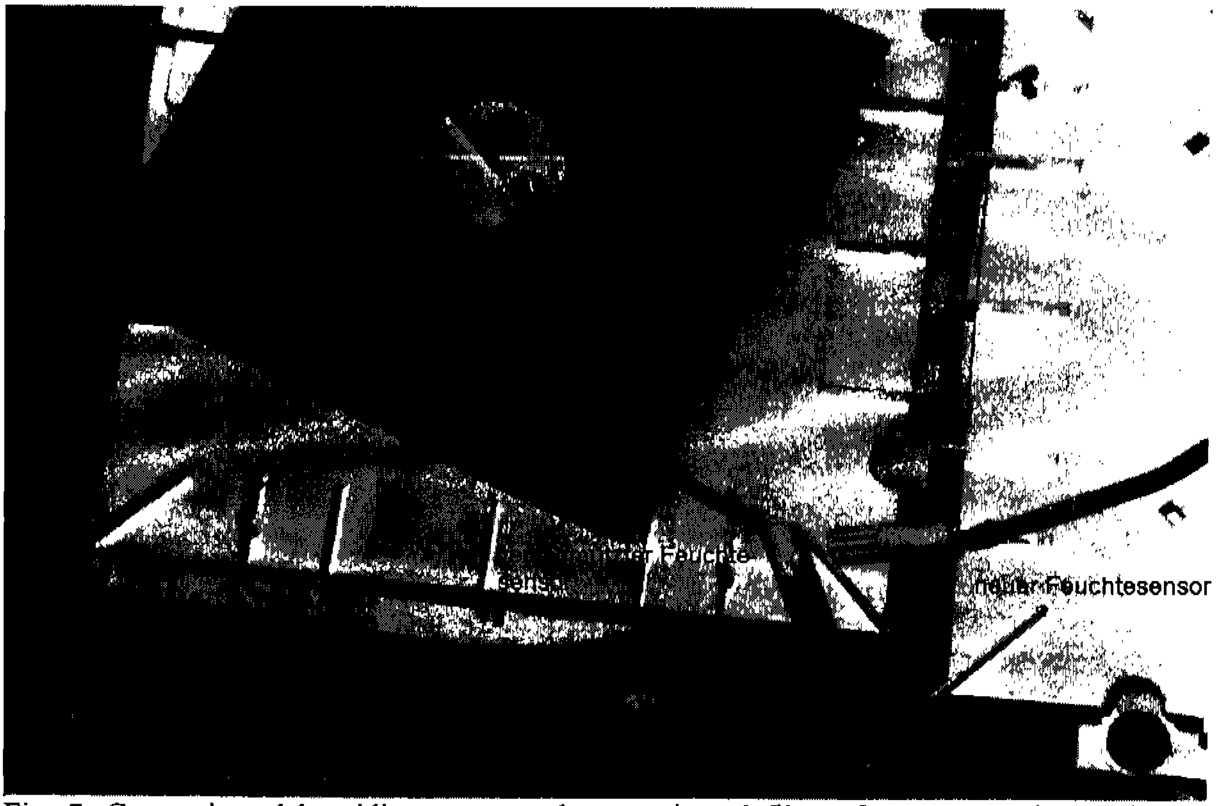

Fig. 7: Contaminated humidity sensor and contaminated filter after an operating period of approx. 1 month

The problem for humidity controlled bathroom ventilation is illustrated in Fig. 8. This diagram shows the development of the measuring signal of a capacitive humidity sensor over time. High-quality humidity sensors are generally characterised by efficient splash-water protection.

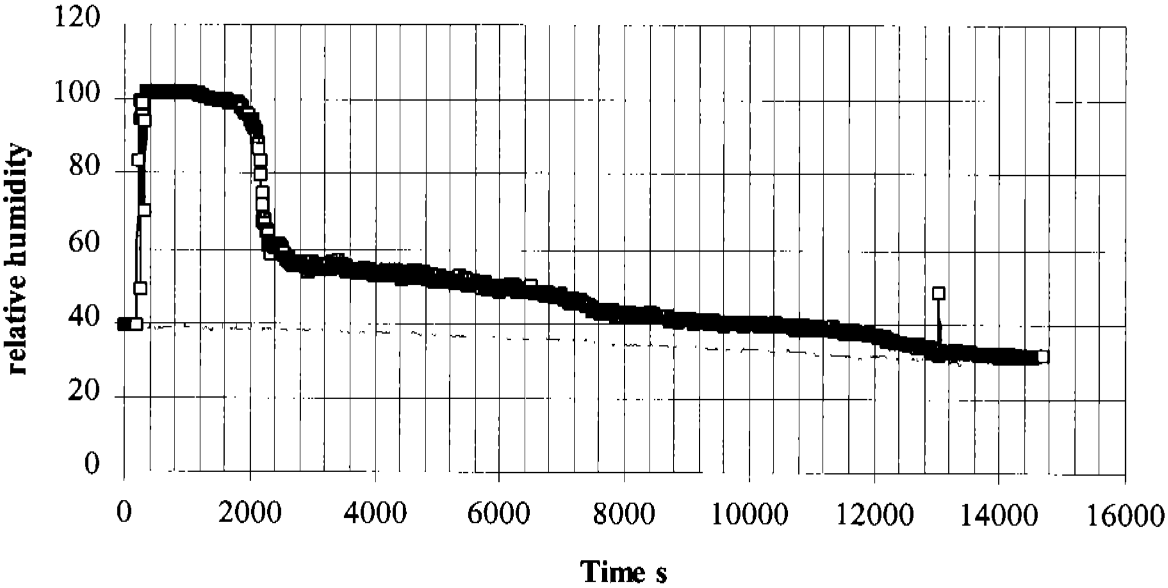

Fig. 8: Humidity measurement with capacitive humidity sensors over time

As Fig. 8 reveals, even direct splashing of the protective cover led only to a temporary signal increase, which was then followed by an immediate drop in the recorded relative humidity. When the protective cover was removed, however, the response was quite different. The water droplets in the sensor led to an exaggerated humidity signal over a period of approx. 30 minutes. Even after this time, the measured value differed noticeably from that of the properly protected humidity sensor for a further period of more than 3 hours. Any significant contamination would prolong this period even further.

Outlook and possible solution

Inadequate ventilation can lead to considerable condensation effects on the surrounding building structures, both in living rooms and in the bathroom. The use of mechanical bathroom ventilation may transfer this problem to the exhaust air filter - which is subject to mould growth due to continual dew-point condensation - or the subsequent duct system.

Solutions to the problem may be found in the following variations:

- suitable storage of humidity in the building structures
- temporary raising of the surface temperature of the surrounding building structures
- active sorption systems (condensation traps), which could be integrated into the bathroom

The humidity sensors should be arranged such that they are not in the permanent condensation area (utilisation of the waste heat of the ventilator). The regulation concept must also be revised, in order to prevent continuous operation.

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