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Advanced Humidity Control Device for the Prevention of Mould

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Abstract

The knowledge of IEA-Annex 14 'Condensation and Energy' has been applied to develop a new strategy for humidity control in dwellings. The presented control element assures safe prevention from mould growth at a minimum energy consumption.
The advanced humidity control device consists of a surface temperature and an indoor air temperature sensor, from which readings a microcontroller evaluates the appropriate RH setpoint. A humidity sensor then reads the actual RH in the room air and compares it with the momentary setpoint. If the actual RH in the room exceeds the setpoint, a humidity reducing device (a fan, a dehumidifier etc.) can be activated to lower the humidity level in the room. The advanced humidity control device adapts individually to any building's prevailing boundary conditions (insulation quality, thermal bridging, room air temperature, moisture emissions with regard to occupant behaviour) in such a way, that no favourite conditions for the growth of mould occur.

INTRODUCTION

Many buildings in Europe suffer from moisture damages. The reasons are manifold. To develop measures to cure mould growth in buildings, an international project under the leadership of the International Energy Agency (IEA) Annex 14 'Condensation and Energy' was started in 1987. 5 countries (Belgium, Germany, Italy, The Netherlands, and United Kingdom) joined this research project.

Mould problems are a rather widespread reality in these 5 countries, especially in the rented and/or social housing sector. The outdoor climate conditions of these countries are very different. Additionally, there are various other factors, which impact the possibility of mould growth as there is

- the poor quality of the thermal insulation of the building's envelope
- low room air temperature
- high moisture emission rates in the building

In affected buildings often at least 2 of the 3 facts are the reason for having mould growth. In rarer cases only one cause is sufficient to supply favourite conditions for mould growth.

Mould growth usually starts at the thermally weakest spot in a room, in the corner of an outside wall, at the ceiling under a poorly insulated roof, etc, usually there, where severe thermal bridging is.

There is no doubt about, that proper insulation is the best way to prevent mould growth. However, it is not always possible as retrofitting work is often very expensive. Sometimes a building should be pulled down in 2 or 3 years, but till that time the tenants should live in a healthy environment without mould in the house.

Especially in the 5 new German States, the former German Democratic Republic, the building quality is very poor. It is not possible to retrofit all houses at once. Therefore, another technical approach than insulation is needed to reliably prevent mould growth at the lowest consumption of energy possible.

Coping with Mould Growth in the past

Recommendations for occupants with moisture problems in the buildings are manifold:

- they should open windows after showering or cooking
- they should ventilate regularly
- they should keep room temperatures high
- they should reduce vapour emitting activities to a minimum.

Unfortunately, these recommendations are difficult to put into practice. People have - in the interesting range of 40-80% RH - only a very vage perception against relative humidity (RH) in the room air. Therefore, they are not able to correctly react against too high RH-levels in the building. Higher room temperatures result in a higher heating bill; this is often not accepted. To change occupants habits (e.g. drying of clothes inside the apartment, many flower plants, aquarium, etc.) is very difficult and very seldom successful. Reality shows, that any control mechanism, which needs the input of occupants, fails on a long term.

State of the Art Control Strategies

Bathrooms are very often equipped with a simple exhaust fan. There are different devices on the market to activate such a fan to extract moisture.

Manual control: The occupant activates the fan by using an on/off switch

Light-switch control: Mostly applied to bathrooms without windows. If a person enters a bathroom and turns on the light, the fan is also activated by the light switch. If the light is turned off, the fan is also turned off. A more sophisticated way of fan control involves a timer. The fan is activated approx. 2 minutes after the light is switched on and keeps on running for 10-15 minutes after the light is turned-off.

Photo-diode control: For later installation the industry offers a way to save up the wiring between the fan and the light switch. The fan casing is equipped with a photo diode. If the light is turned on, the signal is detected by the photo diode and the fan is controlled in the same manner as with light-switch control.

Interval timer: Another way to keep up with moisture is an interval timer, which activates the fan independently of any activities in the room every hour for 5 minutes. Time intervals can be adjusted.

Hygrostat control: A hygrostat activates the fan, when the RH in the room air is higher than a chosen setpoint.

All control devices on the market should keep moisture damages away from the room but none of these have the potential to really avoid mould growth because they are not linked to the problem. Also the hygrostat control is a pretty poor solution, because the user doesn't know the appropriate setpoint, he has to choose regarding the thermally weakest spot at his wall at his current indoor air temperature conditions. An often recommended setpoint for dwellings is 60-65% RH. This setpoint range is arbitrarily chosen. It will lead to a continously running fan during summer and a too high setpoint during wintertime. Reflecting the following described influencing factors for mould growth this fixed setpoint is not oriented to the problem and therefore neither able to avoid mould nor to safe energy.

Boundary conditions for mould growth

Mould growth depends of

- the relative humidity against the surface
- the surface temperature
- the nutritive quality of the substrate
- and many other minor factors

One goal of IEA-Annex 14 was, to come up with a simple practical approach to state under what conditions mould growth occurs. Mould growth is a very slowly happening process. Short periods of surface condensation will never lead to problems as long as there are periods in between where the surface can dry out again.

Moisture damages are not a question of momentary peak values but of average values of weeks and months.

Advanced Humidity Control

An advanced humidity control strategy must fulfil the following requirements:

- it must be oriented to the problem, i.e. no global solution for a room, the control strategy must be linked to the problem spot of the wall
- it has to take different occupancy patterns into account e.g. low/high room air temperatures, low/high moisture emissions
- it must be independent of the local meteorological conditions
- it should not need any manual adjustments
- it should activate a humidity reducing device in such a way, that the monthly mean RH against the surface is slightly lower than the critical RH, where mould growth may reappear.
- operating just under the critical RH ensures a minimum of energy consumption (e.g. electric energy for a fan, thermal energy for the heating of the ventilated air).

A problem oriented solution has to be adopted to the conditions, where mould growth becomes impossible. Results of IEA-Annex 14 /1/ show that mould germination occurs when the mean water activity against/on a nutrient surface remains higher during a shorter or longer time than a threshold value '*a*', *a* being a function of the mould species, the temperature, the substrate (nutrient), and other things. Using the fact that in steady state, the water activity is nothing other than the RH, the condition for mould germination becomes possible, when $p_S \geq a \cdot p_S^0$, where p_S is the vapour pressure of the room air against the surface and p_S^0 is the saturation pressure of the room air against the surface, which is only a function of the surface temperature ϑ_S.

Mould growth is a very slowly happening process. Unfavourable conditions may prevail throughout longer periods (days, weeks). A first order approximation has been established which says, that the RH against the surface on a monthly base should not be higher than a defined threshold value *a*, where *a* is a function of the lowest surface temperature in a room, usually a thermally weak spot in the building envelope.

Description of the Advanced Humidity Control Device

As previously discussed, a problem oriented control strategy has to take the thermally weakest spot of a room into account. Via ventilation or other humidity reducing strategies we have to certify that at this location - on a monthly mean - the RH does not exceed the critical value *a*.

This is ensured by a controller, Figure 1, which consists of a first temperature sensor to measure the surface

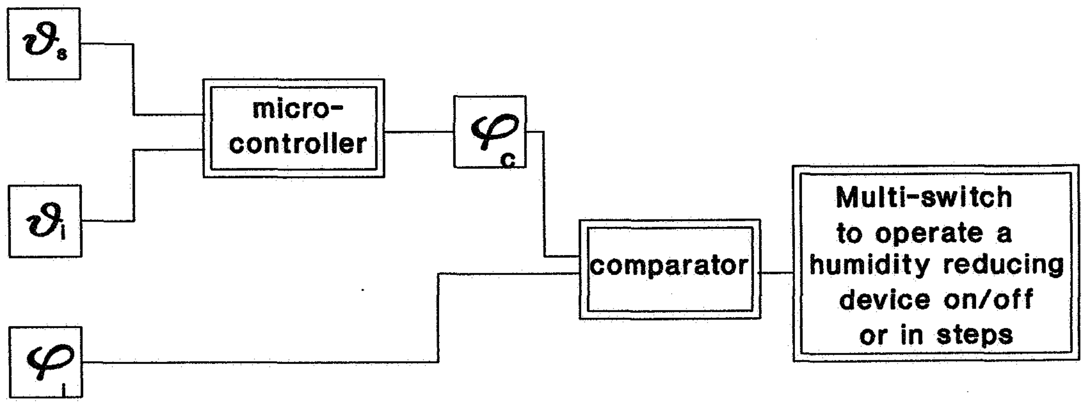

Figure 1: Schematic of control device

temperature ϑ_S at the critical location and a second temperature sensor to measure the room air temperature ϑ_i. From these readings a microcontroller evaluates the appropriate RH setpoint φ_C for the room air. A humidity sensor reads the actual RH φ_i in the room and compares it with the calculated setpoint. If the actual RH exceeds the evaluated setpoint, a first relay is closed. If the room RH still increases, a second relay closes etc. I.e. the control device can operate for example a multi-speed fan.

Field Tests

Field tests have been performed to verify, whether the *a*-value concept holds in practice /2/. As the controller operates due to the momentary values of ϑ_S, ϑ_i, and φ_i, different control algorithms were investigated to operate the fan in such a way, that on a monthly mean the defined threshold value is not exceeded.

In houses with severe moisture problems the system was able to avoid reappearance of mould. During summer the fan run for appox. 10-15 minutes after the end of a shower process. These periods became larger in fall and lasted 6 to 8 hours at minimal fan speed during winter at outdoor temperatures below freezing.

User Behaviour and Acceptance

From the day the humidity controlled system was installed, occupants did never open the bathroom window again. They were highly appreciated by the automatic system which was turned on and off automatically. The mirrors in the bath were free of condensation shortly after showering which increased the quality of living.

In August, when the fan was not installed, the occupants returned to their old habits and ventilated by using the window. It was also appreciated that the extract system prevented the spread of vapour into other rooms of the building.

Limits

The control strategy has no physical limits. If thermal bridging is too severe, i.e. the temperature factor τ which is defined as

$$\tau = \frac{\overline{\vartheta}_s - \overline{\vartheta}_e}{\overline{\vartheta}_1 - \overline{\vartheta}_e}$$

(ϑ_e - exterior temperature; the bars indicate mean values over some days).

is lower than 0.5, it is difficult to avoid mould growth <u>only by ventilation</u>. The air, which is extracted by the fan is supplied to the room partly from outdoors and, usually to a higher proportion, from indoors. As the air of the adjacent rooms has a higher absolute humidity than outdoors, the potential to take up more moisture in the bathroom is reduced. If the setpoint in the bathroom approaches the humidity level of the adjacent rooms the limit is almost reached.

Further Applications

The advanced humidity control device activates one or more switches to operate any device also in more speeds, which has the potential to reduce the humidity level in a room. It can be a fan, which is to be operated in 2 or 3 speeds, it can also be a dehumidifier or a smart window, which is opened and closed automatically or even an electric heating wire attached to the surface to increase the surface temperature.

This advanced humidity control device assures, that the possibility of reappearing mould is at a minimum and the amount of energy used is lowest. It takes the occupant behaviour, which influences the indoor temperature and the vapour emission, directly into account. Furthermore, it is independant of the outdoor climate, as it keeps the humidity reducing device (fan, dehumidifier etc.) running till the threshold criterium is met.

SUMMARY

Based on the knowledge of the biological and physical conditions, under which mould in dwellings germinates and spreads, an *Advanced Humidity Controller* was developed to operate a humidity reducing apparatus (a fan, a dehumidifier etc.) in such a way, that the RH in the room will not exceed a certain threshold value. On one hand mould growth is securely prevented, on the other hand a minimum of energy is used.

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