RELATIVE HUMIDITY INSIDE ACCOMODATION

Presentation of a Computation Method and its Experimental Validation

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INTRODUCTION

Inside temperature is not the only factor acting on the sensation of comfort or discomfort felt by the person living in the dwelling. Relative humidity, whose perception and consequences are less direct, also plays a major role.

Water vapour due to our presence and activity is produced every day in our accommodation, increased by a certain quantity of water carried by air renewal. Water retention in accommodation also occurs owing to the hygrostatic buffer formed by the furniture and the walls. The different phenomena combined listed above therefore tend to act on inside relative humidity.

The present article gives a computation method for the water vapour balance in a dwelling room, taking account of the absorption-resorption phenomenon together with an initial approach to test validation in a laboratory cell.

1 - THE COMPUTATION METHOD

1.1 - Vapour exchanges with the furniture

After having expressed the known part of the water vapour balance entering a dwelling room, an attempt has been made to describe the term reflecting vapour exchanges between ambient air and the furniture.

Taking it that these exchanges follow a "linear flow" - type law, the flow per unit of mass density of water vapour "$\dot{M}_m$" crossing surface "S" of a material "m" is written :

$$\dot{M}_m = h' \cdot S \cdot (C_a - C_m) \qquad (kg.s^{-1})$$

with $C_{a,m}$: vapour concentration in ambient air and in the material (kg per m^3),

h' : exchange per unit of mass coefficient ($m.s^{-1}$).

Taking water vapour to be a perfect gas at room temperature, this vapour flow can be expressed as a function of the volume of water involved, namely :

$$\dot{M}_m = \lambda_m \cdot M_a - \delta_m \cdot M_m \qquad (kg.s^{-1}) \qquad (1)$$

with $M_{a,m}$: volume of water vapour in ambient air and material "m",

and $\lambda_m = \dfrac{\beta \cdot S \cdot r_v \cdot Ta}{V \cdot P_{sat}}$; $\delta_m = \dfrac{\beta \cdot S}{\rho_{ms} \cdot V_m \cdot \alpha}$

$\beta = \dfrac{h' . P_{sat}}{r_v \cdot T_a}$: by definition, coefficent β is a surface exchange coefficient reduced to the average water content of the material. It is highly dependent on surface mass exchanges and includes vapour diffusion between the surface and the heart of the material, whence its dependence on the thickness of the material (very few experimental values are presently available) [kg water.m^{-2}.sec^{-1}] ;

α : coefficient α is an intrinsic characteristic of the material. This mean value represents the slope of an absorption isothermal unit (hysteresis of the phenomenon is not taken into account) [kg water/kg mat. sec./degree of relative humidity] ;

r_v : constant of perfect gases for water vapour (r_v = 461,51 J. K^{-1}.kg^{-1}) ;

T_a : ambient temperature [K] ;

V : volume of the room [m^3] ;

V_m : volume of the material [m^3] ;

ρ_{ms} : mass per unit of volume of the dry material [kg/m^3].

1.2 - Vapour exchanges with the walls

Diffusion phenomena in the walls have been neglected for the surface exchanges in the first layer of the materials so as not to over-complicate the model and maintain reasonable "computation times".

The walls are thus considered as furniture from the point of view of vapour transfers.

With a simplified model at hand allowing relative humidity inside premises to be computed while taking account of the absorption effect of the furniture and the walls, an attempt has been made to validate this model experimentally.

2 - METHODOLOGY OF EXPERIMENTAL VALIDATION

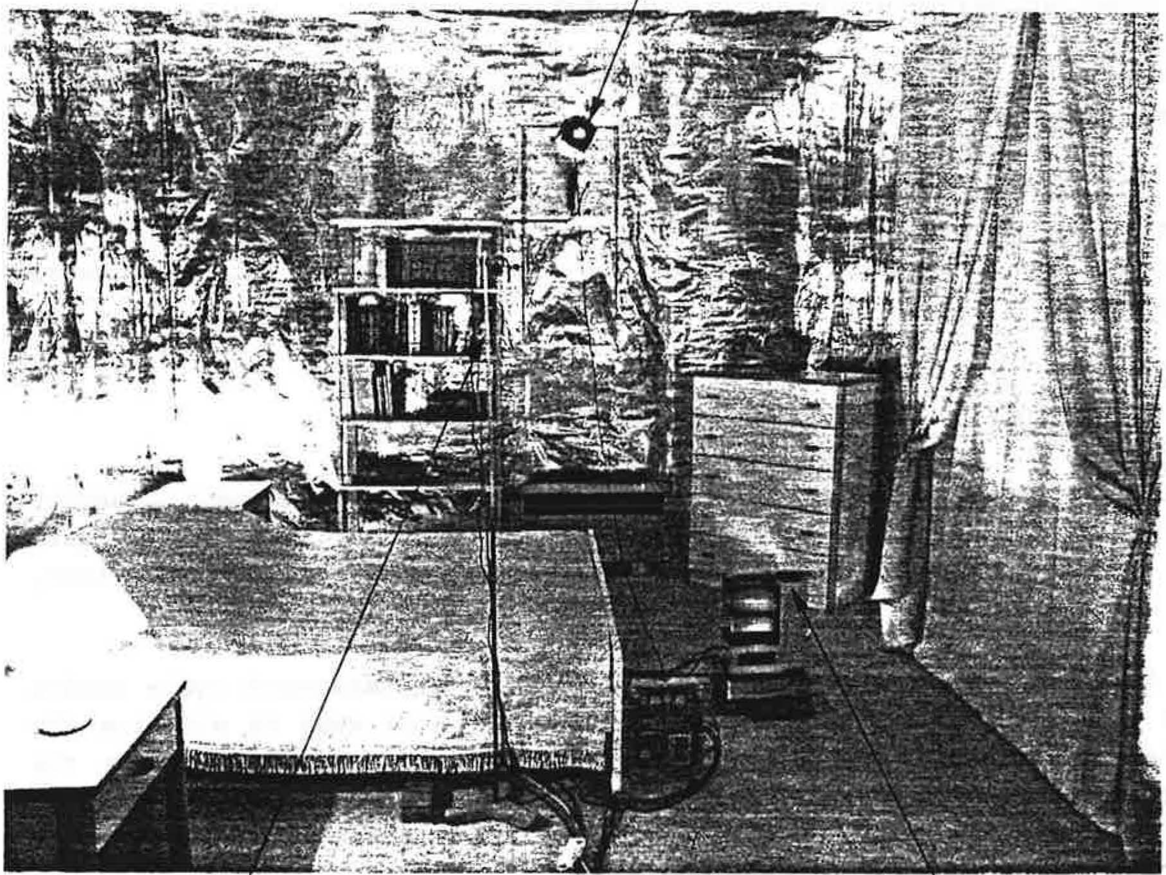
As indicated earlier, there are few materials whose mass transfer coefficients α and β are known. An attempt has thus been made to aggregate and identify these coefficient numerically, separately for the furniture, the wall facing out and inside partitions.

Availing, for each test described below, of a measurement cycle scaled over several 24 hours periods, an attempt has been made to minimise the difference between "measured and calculated" values so as to deduce the optimum values of computation parameters. These parameters are coefficients and δ entered in equation (1) as well as the initial water volume (M_m) contained in a piece of furniture or a wall.

This search, using the least squares method, for the minimum error has covered the value of the vapour flow exchanged between ambient air and the internal masses over the first periode of the measurement cycle.

3 - EXPERIMENTAL VALIDATION IN A REAL CASE OF A FURNISHED ROOM

The aim was to check that a first order model can point up vapour exchanges between the air and internal masses, both for the furniture and the walls. To this end, phenomena have, in a first stage, been dissociated by water-proofing the wall with tinfoil (see photograph below).



Experimental furnished cell

After satisfactory completion of initial comparisons of "Measurements and Computations" conducted on furniture alone, the second phase of the study has consisted of removing the tinfoil protection to secure the real conditions of a room.

Figure 1 presents the comparison of vapour flow measured (following an indirect method) and then calculated for the room in real conditions.

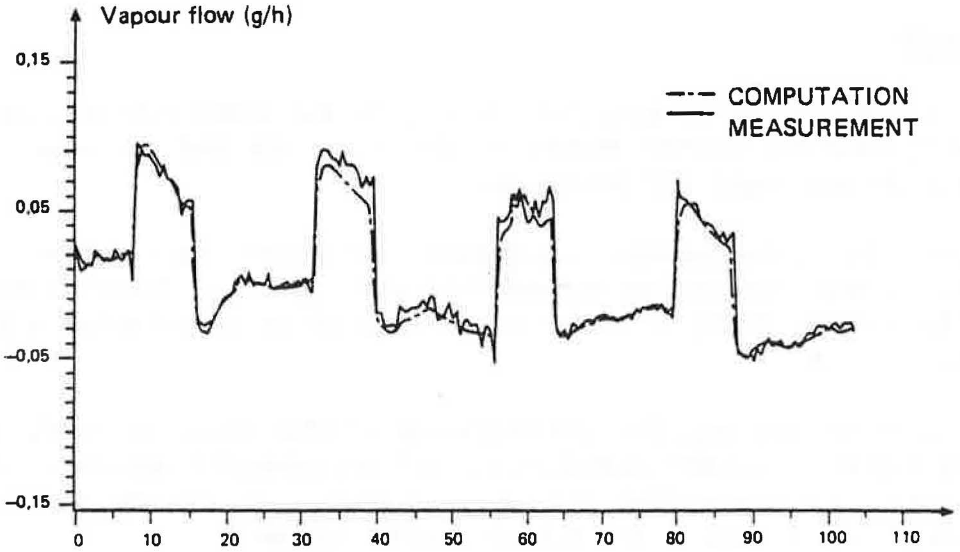


Figure 1 – Flow of water vapour exchanged with the furniture and the walls.

Finally, and this was our objective, figure 2 shows how important it is to take hygroscopic inertia phenomena into account for the computation of relative humidity inside premises.

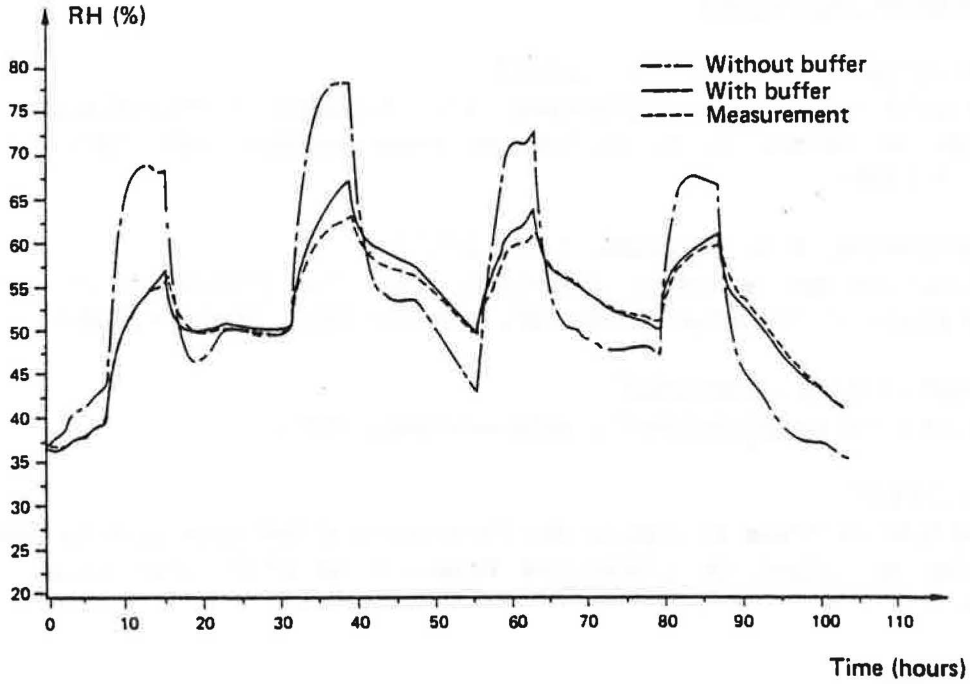


Figure 2

4 - CONCLUSION

Relative humidity inside premises can only be estimated with accuracy by taking the hygroscopic buffer formed by the furniture and the walls into account in a thermal model for buildings.

Although the experimental validation presented here gives some credibility to the computation method followed, it would nevertheless be desirable to extend it to a different configuration of external weather conditions.

It would be interesting, for the follow-up of this study, to confirm the adequate consistency between calculations and measurements observed over a period of more than three days and, in particular, to include a sequence involving major variations in the external water volume.

It is nevertheless encouraging to observe that a first order model gives quite a good portrayal of hygroscopic inertia in a dwelling room and that this formulation is easy to integrate into an aggregate thermal model for buildings.

Refer to reference [1] for more details.

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