THE HYGROSCOPIC BUFFER CAPACITIES OF FIXTURES AND FURNITURE

J.L.C.L. Boot
Cauberg-Huygen Raadgevende Ingenieurs BV
Heemraadssingel 70
3021 DD ROTTERDAM
The Netherlands

ABSTRACT

In addition to the hygroscopic capacity of walls, floors and ceilings to absorb moisture, it was thought that fixtures and furniture also acted as a hygroscopic buffer and likewise influenced the moisture balance of a room. Therefore a living-room situation was simulated and measurements conducted to determine the influence, if any, of the fixtures and furniture on the moisture content of the room. The measurements confirmed the supposition under study.
Experiments with water vapour production ascertained the amount of moisture absorbed hygroscopically by the fixtures and furniture. From the experiments the coefficient of water vapour absorption a (m/h), defined as:

$$a = \frac{\text{the quantity of water vapour absorbed by the surface material} \quad (g/m2.h)}{\text{the increase of water vapour concentration in the surrounding air } (g/m3)}$$

is determined. The values were respectively 2.2 and 2.5 m/h for the fixtures and 2.3 and 1.7 m/h for the furniture.

INTRODUCTION

It is presumed that in addition to the hygroscopic capacity of walls, floors and ceilings, fixtures and furniture also act as a hygroscopic buffer and likewise influence the moisture balance of a room.
Little is understood of the scope of the latter role and the rate at which the exchange process takes place in either a semi-furnished of fully-furnished room.
In view of the presumed connection between the relative humidity in the air, especially at peak periods, and the problems of mould and surface condensation, it is considered of importance to understand the hygroscopic buffer effects of fixtures and furniture. Therefore measurements were conducted in a simulated living room.
The study, commissioned by "Netherlands Agency for Energy and the Environment" (NOVEM), was undertaken within the terms of reference of the REGO-programme and constitutes part of the Dutch contribution to Annex XIV (Condensation and Energy) of the International Energy Agency (IEA).

TEST SET-UP.

At present, hardly any published work deals with the extent of the total hygroscopic absorption and/or emission of moisture of fixtures and furniture in a practical situation. It was therefore of initial interest to determine the actual influence on the moisture balance of a room by the hygroscopic buffer capacities of fixtures and furniture. In the second instance an attempt was to be made to indicate the extent to which moisture was absorbed, respectively emitted.

With these objectives in view, the experiment was set up as follows:
A living room is simulated (35 m^3) where all the parameters of importance are registered - temperature, relative humidity, water vapour production, ventilation rate. For accurate water production an "infusion system" is developed with an evaporation capacity of 0 to 1000 gr of water/hour.
The following situations in the "living room" are created:

A. Empty room, no fixtures or furniture; walls, floor and ceiling covered with foil ("zero" hygroscopicity). In theory the moisture buffer capacity of the room is solely determined by the moisture absorption capacity of the air.

B. Semi-furnished room, identical to A with the following additions:
   - carpeting: 100% wool on rubber underlay, 10.3 m^2;
   - curtains : cotton reinforced with synthetic fibre, 4.2 m^2.

c. Fully furnished room, identical to B with the following additions:
   - a settee : velours, upholstered surface 4.5 m^2
   - a armchair : 100% cotton, upholstered surface 2.1 m^2
   - a magazine rack: paper, effective surface 0,2 m^2

Three experiments were conducted to determine the effects, if any, of the hygroscopic capacities of the fixtures and furniture on the room's moisture balance:

1. The temperature of the air in the living room was increased from circa 18°C to 25°C.
   In sit. A the decrease of relative humidity could, in principle, be accredited to the increase of air temperature.
   If, in sit. B. and C., the added elements (fixtures and furniture) really contain hygroscopic storage capacities, the decrease of relative humidity will be lesser due to the (hygroscopic) emission of humidity by these elements than for the situation without any hygroscopic storage capacities.
2. The relative humidity was increased from 40% to 65% by the evaporation of water. How much moisture should be added?
3. A fixed amount of water - 280 gr - was evaporated. What is the resulting increase of the relative humidity?

By determining the loss of humidity through ventilation and moisture absorption by the air, the last two experiments give an indication of the order of magnitude with respect to the amounts of moisture involved in the hygroscopic process.

MEASUREMENT RESULTS

In this paper we only present the combined measurement results. For the complete results of the seperate measurements see Ref. (1).

For the experiment with warm-up of air in the living room, see Fig.1, the development of relative humidity (RH) in the furnished situations (sit. B and C) was decidedly tardier in comparison to the empty room (sit. A); a clear demonstration that moisture emission had occurred due to the addition of fixtures and furniture.

The difference between the RH development in the empty room ("hygroscopic zero situation") and a theoretically calculated RH development cannot reasonably be explained.
Similar differences have been noticed in comparable experiments conducted by Künzel (Ref. (2)). However they have been attributed to a temperature interdependent change in the water vapour absorption of the wall surfaces. In this connection, if the water vapour absorption coefficient "a" is calculated for the foil, values are produced (a = 0.3 and 0.5 m/h) which are on the same scale as those for a apparently comparable material such as linoleum (a = 0.43 m/h).

The development of the relative humidity when increased from 40 to 65%, see Fig. 2, demonstrated that moisture absorption took place as well as water vapour production.
Absorption is greater and therefore the increase of RH slower as more fixtures and/or furniture are added.

In the experiment with evaporation of 280 gr of water the pattern of development of RH, see Fig. 3, illustrates that the presence of fixtures and furniture causes it to increase only slightly, otherwise the case if the room is empty. This also implies a less steep "gradient of RH development" than in the case of a empty room.

From the measurement results we can conclude that the fixtures and furniture effect the moisture balance of the room. In conjunction with current methods (see Ref. (3)), the water vapour absorption coefficient a (m/h) is used, for a more detailed quantification of the effects. This coeffient is defined as:

$$a = \frac{\text{the quantity of water vapour absorbed by the surface material} \quad (g/m2.h)}{\text{the increase of water vapour concentration in the surrounding air} \ (g/m3)}$$

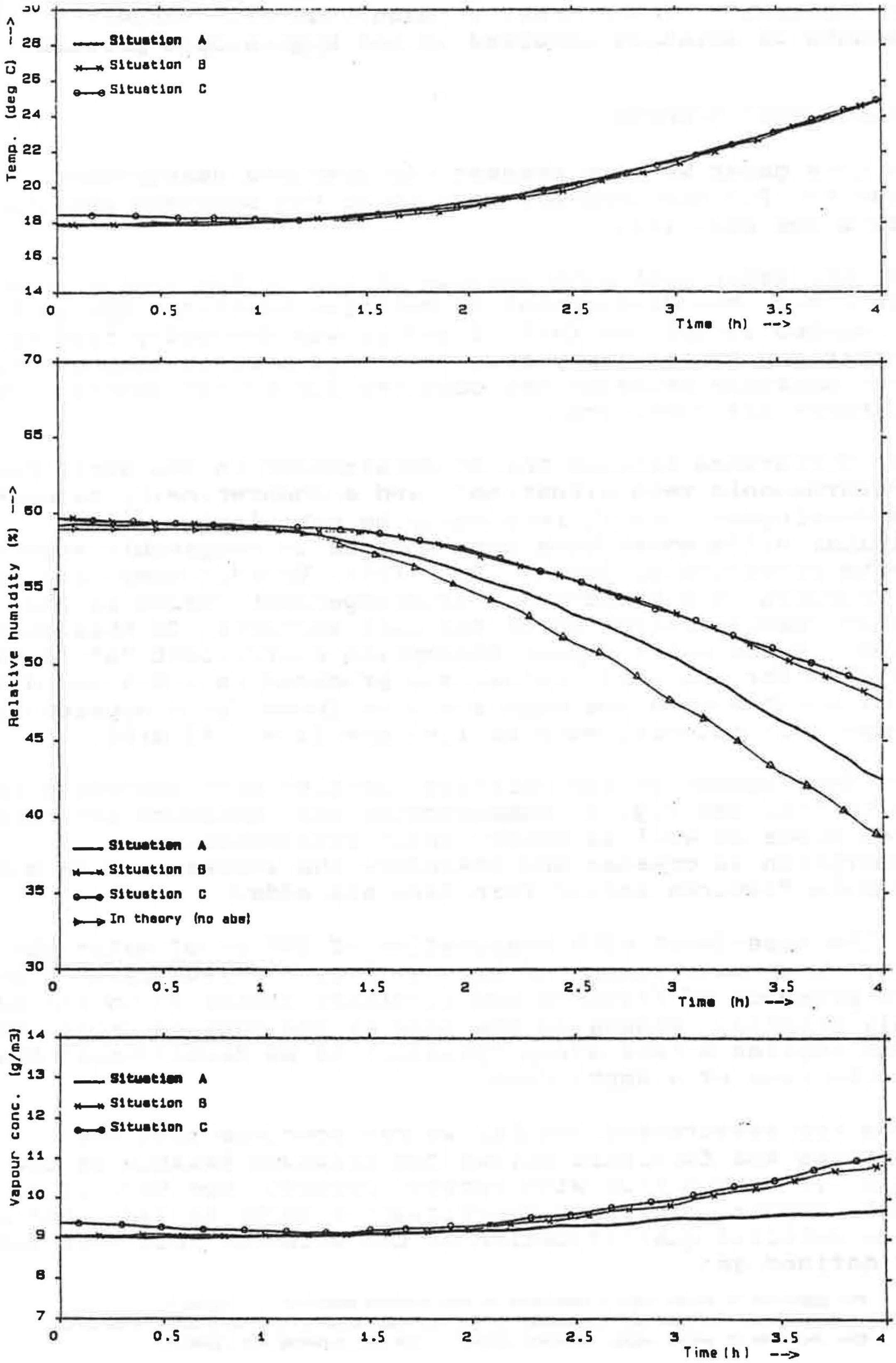

FIGURE 1. Temperature, relative humidity and water vapour concentration as a result of the warm-up of air in the empty (A), the semi-furnished (B) and the fully-furnished (C) room. (Conditions: ventilation rate 0,07 h^{-1}).

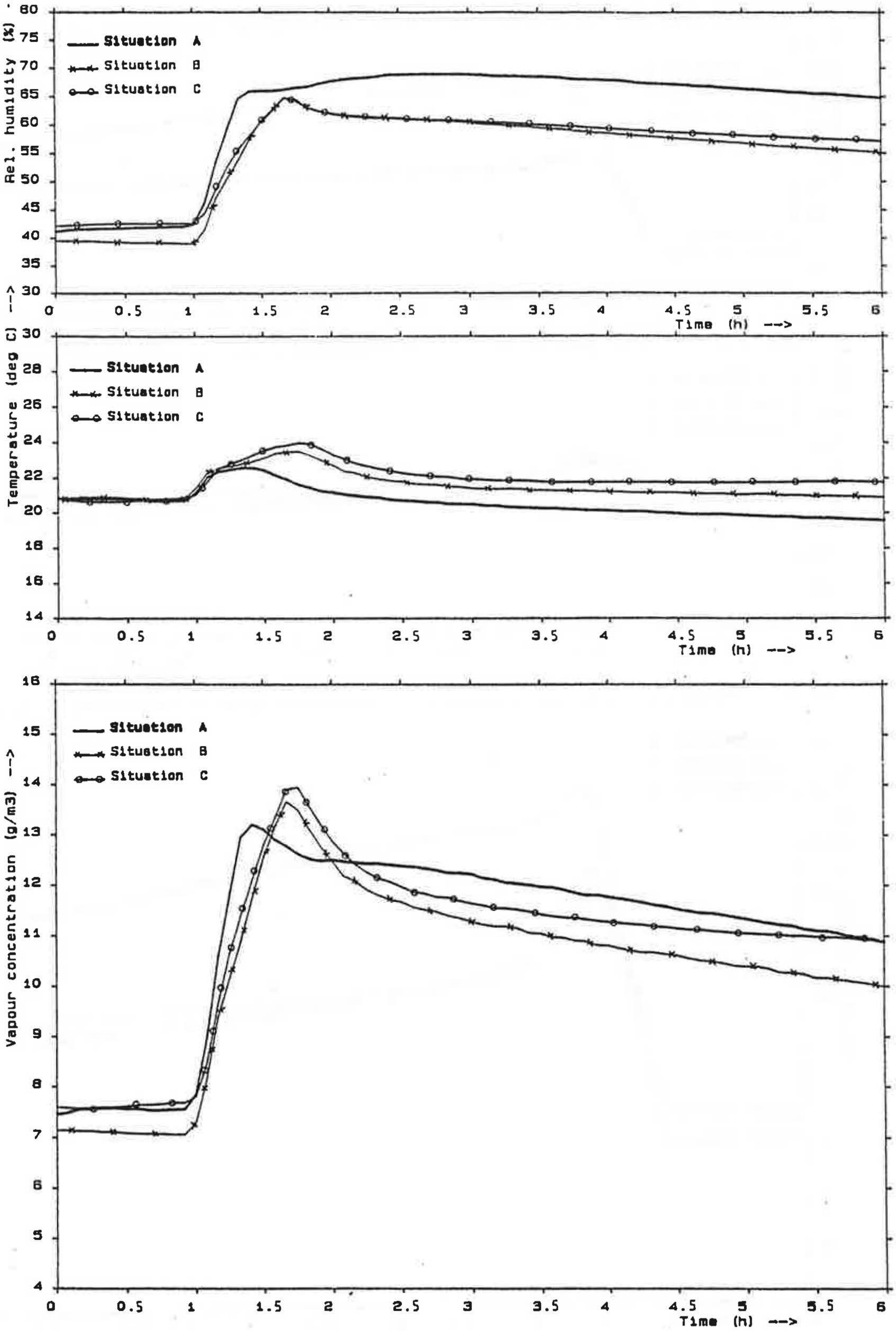

FIGURE 2. Temperature, relative humidity and water vapour concentration as a result of the increase of the relative humidity from 40 to 65% in the empty (A), the semi-furnished (B) and the fully-furnished (C) room. (Conditions: ventilation rate 0.07 h^{-1}; evaporation rate 600 g/h; no condensation)

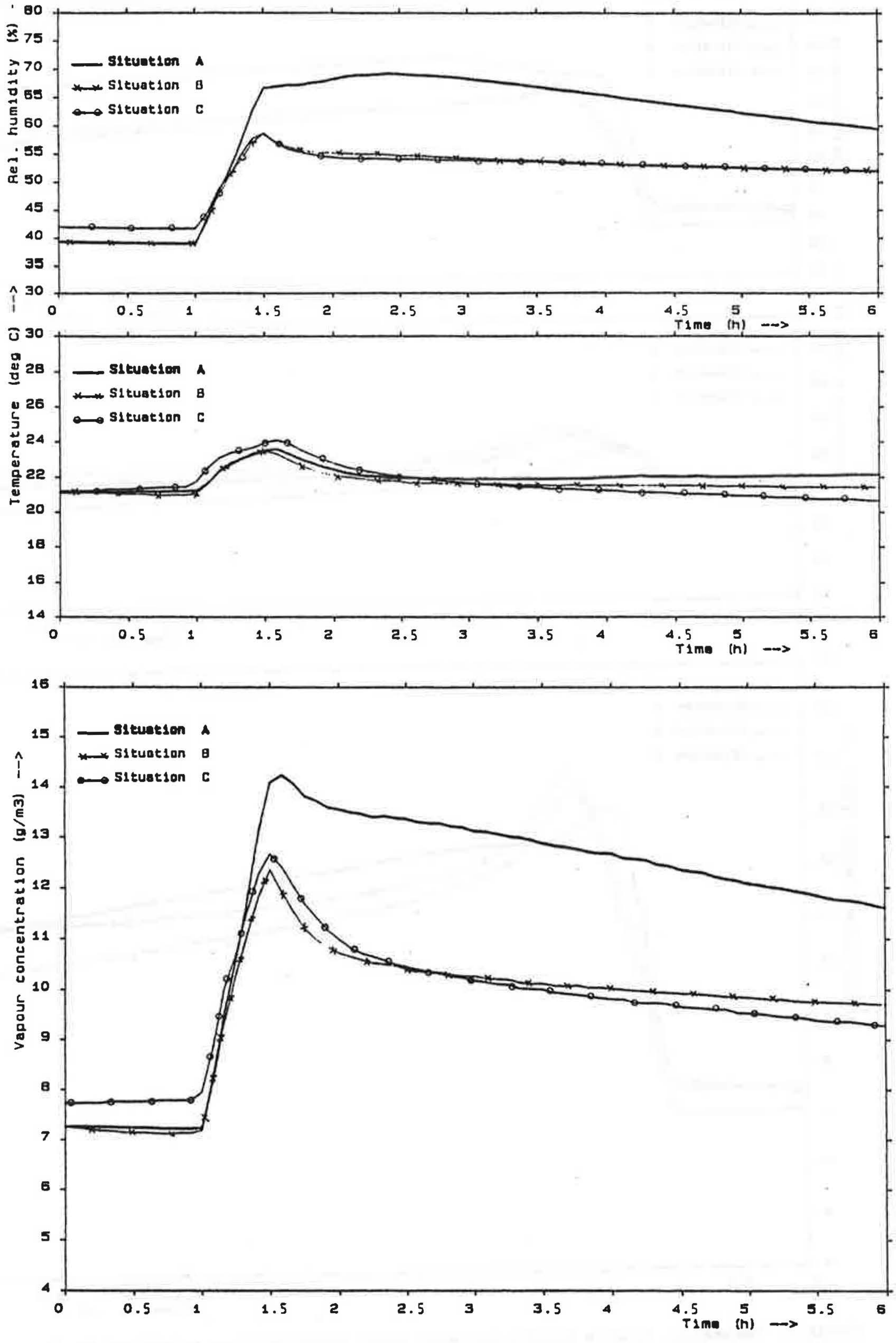

FIGURE 3. Temperature, relative humidity and water vapour concentration as a result of the evaporation of 280 g of water in the empty (A), the semi-furnished (B) and the fully-furnished (C) room. (Conditions: ventilation rate 0.07 h^{-1}; evaporation rate 600 g/h; no condensation)

Thus the development of water vapour concentration in a room plus simultaneous moisture production can be expressed as:

$$Ct - Co = \frac{Q}{a.A + n.V} \left(1 - \exp\left(- \frac{a.A + n.V}{V} . t\right)\right)$$

In which:

Ct	=	water vapour concentration at time t	(g/m^3)
Co	=	water vapour concentration at commencement of humidification (moisture production)	(g/m^3)
Q	=	water vapour production	(g/h)
a	=	water vapour absorption coefficient	(m/h)
A	=	moisture absorption surface	(m^2)
n	=	ventilation rate	(h^{-1})
V	=	volume	(m^3)
t	=	period of duration from commencement of humidification	(h)

The water vapour absorption coefficient of the fixtures and/ or furniture can be calculated on the basis of the pattern of development of the water vapour concentration measured during the period of moisture production. Table 1 gives the water vapour absorption coefficients as calculated from the measurements. The different values for fixtures and furniture have been determined from the extra absorption with respect to the earlier situation. The values derived here for fixtures and furniture are of the same order of magnitude as some building materials as plaster board (a = 2.29 m/h), cellular concrete (1.97) and lime and cement plaster (1.70); see Ref. (2).

Table 1. Calculated water vapour absorption coefficients (at 21°C).

Situation	Material	Water vapour absorption coeff. (m/h)	
		on the increase of RH from 40 to 60%	on evaporation of 280 gr of water
A	only foil	0,3	0,5
B	fixtures	2,5	2,2
C	furniture	1,7	2,3

In the water vapour absorption coefficient moisture absorption on the surface is given as a function of change of the absolute moisture content of the air although, in fact, the hygroscopic absorption and emission is primarily caused by modifications in the relative humidity. Therefore the choise of the coefficient to describe hygroscopic buffer capacity is not an optimum one. In this study the quantity was chosen to conform with usage in existing publications and the numerical values used for other (building) materials.

However further study should be worthwhile for a more suitable quantity which could also be used to predict the effects of certain hygroscopic materials on the moisture balance of a room. The analogy between non-stationary heat transport to material surfaces and non-stationary interchange of moisture to surfaces could lead to such a quantity; analogous to the coefficient of heat penetration b ($J/m^2.K.s^{0,5}$) a coefficient of water vapour absorption b' ($kg/m^2.s^{0.5}$) could well be defined. The further study would have to decide whether such a quantity is usable and under which conditions.

REFERENCES

(1) Boot, J.L.C.L.; Plomp, A.N.J., The hygroscopic buffer capacities of fixtures and furniture. Cauberg-Huygen Raadgevende Ingenieurs BV. Report 5018-1 (1989).

(2) Künzel, H., Die Feuchtigkeitsabsorption von Innenoberflachen und Inneneinrichtungen. Berichte aus der Beuforschung, Heft 42 (1965).

(3) Künzel, H., Auswirkung mangelnder Feuchtigkeitsabsorption in Raumen. Berichte aus der Beauforschung, Heft 79 (1972).