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THE KEIPER METHOD FOR MOISTURE DESIGN IN BUILDINGS

ABSTRACT

This paper outlines a new calculation method for the moisture-control design of common domestic and commercial buildings.

There is a growing interest in correct construction methods for moisture control in building structures. This is a fairly complex subject, further complicated by serious deficiencies in earlier design methods such as the "dewpoint profile".

The Keiper method is both simpler and more reliable than earlier methods and provides more information.

This paper will be useful to all building designers, tutors, and, in some instances, inspectors.

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H. Trethowen
November 1978

The Keiper method for moisture design in buildings

1. Introduction

A need for design for moisture control measures in building structures arise from time to time, and this design has traditionally been carried out by the "dew point profile" method. This is the method set out in many references such as CIBS & ASHRAE Guide Books (1,2) and most textbooks on building. An improved version known as the "Glaser Method" is sometimes used. Unfortunately these methods are not only difficult to use, but also fail for basic reasons to give results that have any relation to the risk of moisture damage.

A new method known as Keiper's method was developed in Germany a few years ago, which is much simpler to use, answers more questions, and avoids the 3 largest of the 5 criticisms to which the dew point profile method is subject. This paper describes the method and discusses some consequences of its use.

2. Moisture control in buildings

To undertake design for moisture control in buildings it is first necessary to understand the basic nature of factors affecting building moisture. It is useful firstly to classify moisture problems into two main groups:

Surface condensation - (or mildew growth) on the visible surfaces of an occupied space.

Cavity condensation - inside the structure cavities, and not visible to occupants.

Surface condensation problems are common in New Zealand dwellings, affecting 25% - 50% of homes. They are controlled principally by occupant habits and although unsightly are not commonly seriously damaging to the structure. Cavity condensation problems on the other hand are rare, affecting only a few buildings per thousand, but can be extremely damaging when they occur. It is to cavity condensation risk that both dew point profile and Keiper methods are addressed.

In New Zealand, the principal factors affecting cavity condensation have been listed, in order of importance (3), as :-

- construction moisture
- evaporation from ground
- induced movement of moist air (from indoors or underfloor space into cavities)
- rain leakage
- vapour diffusion control.

Again it is only the last of these factors which is considered in the dew point profile method. The Keiper method can be used to give in addition at least some idea of the capacity to tolerate construction moisture.

3. The Dew Point Profile Method

An example of a typical application of this method to a light timber wall is shown in Fig.1. In this case the calculation would be taken to indicate a high risk of condensation on the cladding membrane.

The defects in the calculation represented in Fig.1 may be summarised (4) as:-

- equilibrium: The method is not valid unless moisture equilibrium is reached. (The standard calculation of thermal resistance of course also requires that thermal equilibrium is reached before the calculation is valid. The difference is that thermal equilibrium is usually reached in hours or at the most in days, but moisture equilibrium is only reached in months or even years.)

- design conditions: The design conditions chosen, although typical, are defective. In view of the above equilibrium requirement, it is only valid to take mean conditions over the shortest period in which equilibrium might be expected eg, monthly or seasonal average. The choice of peak conditions as in this example, is invalid and unduly severe.

- Construction moisture: The method is unable to deal with the effects of construction moisture, in spite of the observational evidence that far the greatest source of moisture problems is from this cause.

- Linearity: The method assumes that the moisture transfer properties of materials are constant, and the same in both directions. Neither is always true. Some materials do not vary appreciably in these properties, but others can exhibit moisture flow resistance as much as an order of magnitude lower when moist than when dry. Similarly it is not uncommon to find (e.g. in a painted lining board) that the resistance in one direction is quite different to that in the other.

- Hygroscopy: The method takes no account of the hygroscopy of the materials. In particular, wood and wood-based products show very strong hygroscopic effects, giving out or taking up moisture in ways not necessarily dependant on vapour pressure differences. Some macerated paper insulants use fire retardent treatments which are deliquiescent at relative humidities over 75%.

It is only by full understanding of these limitations that misleading predictions can be avoided with the dew point profile method. The Keiper method is not perfect in any of these respects either, but reasonable allowances are made for the first three factors. The Keiper method is no different in respect of the last two factors.

4. The Keiper method

The Keiper method (5,6) is a development of Glaser's method, and is based on a model of the situation as shown in Fig.2. That is, the structure is modelled as a two layer panel, in which any condensation occurs at a plane between the two layers. If there is free water at this plane, then the vapour pressure at that point must be equal to the saturation vapour pressure for the corresponding temperature.

Keiper's method recognises that it is not the onset of condensation which matters, but the seasonal amount. It requires the preparation of overlay charts on which are plotted zones for constant seasonal moisture deposit.

A summary of the derivation (not a proof) is given in Appendix.

These overlays are supplied to the designer in the form of Figs. 5 and 6. Fig.5 is based on assumed mean winter indoor conditions of 20°C, 50% RH. Few dwellings in New Zealand are kept to mean winter temperatures as high as 20°C, but if they were it is practically certain that the mean RH would be lower than 50%. Fig.6, on the other hand, is based on an argument put forward in ref.4, to the effect that a design vapour pressure difference of 3-5 mbar is appropriate to N.Z. dwellings irrespective of mean indoor temperature.

The use of the Keiper method requires the designer to produce an x-y plot as an overlay to these contours. The fraction of total vapour resistance for each point in the wall is plotted in the "y" direction, against the fraction of total thermal resistance plotted in the "x" direction. Having done this, there are no further calculations, only comparisons with the Keiper overlay diagrams.

Example 1

In Fig.3 is plotted the x-y plot of vapour and thermal resistance for the uninsulated wall indicated in Fig.1. The proportion of vapour and thermal resistances from inner to outer surfaces are plotted 0 to 1 on the y and x scales respectively.

This graph is then overlaid on the appropriate Keiper diagram, Fig.6. Since the two sets of curves do not intersect at all, the Keiper diagram indicates (contrary to Fig.1) that there will be no accumulation of moisture at all. In fact except for brief periods of extreme conditions, this wall would dry throughout winter as well as summer.

5. Cavity Ventilation

It is common for there to be some degree of ventilation of the construction cavities in building structures. It is possible to allow for this by treating the ventilation path as a resistance in parallel to that part of the structure which is bypassed by the ventilation. The resistance of that part of the structure is then replaced by the effective resistance of the two in parallel.

The resistance of the ventilation path is as follows:-

$$\left.\begin{aligned} &\text{Vapour resistance} \quad R_v = \frac{0.48}{r\,l}\ \text{MNs/g} \\ &\text{Thermal resistance} \quad R_t = \frac{0.71}{r\,l}\ \text{m}^2\text{C/W} \end{aligned}\right\} \quad (5)$$

where r = air change rate in the cavity, AC/hr.

l = width of cavity m

With the aid of eqns.5 it is now possible to look at a more complex example.

Example 2

Consider a wall similar to that of Fig.1, but insulated with glassfibre, and also having tiny amounts of cavity ventilation to outside air, from zero to 1 air change/hour.

Keiper diagrams for this are shown in Fig.4. Overlaying Fig.4 on Fig.6 shows on inspection that:

- if cavity ventilation is zero, the $G\Sigma R$ value will reach about 5000. Since the total ΣR is about 5MNs/g this means that the moisture accumulation in one winter is about 1000 g/m^2. If absorbed into timber cladding, this would represent a gain of 10% moisture content for the whole winter.

- Even the most minute amount of cavity ventilation drastically reduces the moisture accumulation. The degree of ventilation considered in this example is too small to have any effect on the insulation value.

- There will be no difficulty in drying off the moisture accumulated, during the following summer. In fact 2-4 times this quantity of moisture could be dissipated, depending on location within N.Z.

The effect of ventilation is a most important factor. The rates of outdoor air ventilation considered in this example must be regarded as trace quantities only. And yet it easily moves the position of the critical lower right knee of the Keiper diagram far out of the risk zone.

It is obvious that similar trace quantities of cavity ventilation by indoor air, would move the critical knee further into the risk zone. In fact, it becomes clear that the conditions actually achieved in the cavity, will be controlled principally by the relative rates of trace ventilation from indoors and from outdoors. The vapour resistance of the materials involved may not matter at all.

6. Initial Drying

On Figs.5 and 6, the limit lines for drying are expressed in terms of the quantity of moisture which can be evaporated during an average summer. No qualification of how this moisture came to be there is made. Therefore it is permissible and useful to regard these as defining the maximum amount of construction moisture which can be handled, if the structure is completed in spring or early summer.

In example 2, the maximum construction moisture which can be handled, according to this method, is about 2kg/m^2 if the building is in Otago or Southland, about 3kg/m^2 in Christchurch and perhaps 4kg/m^2 in most N.I. areas.

Further data on possible drying times is given in Fig.7. This is given in terms of the mean outdoor R.H. during the summer period. It is based on the assumption that free ventilation in summer will lead to equal indoor and outdoor temperatures and relative humidities. But it is also possible to consider other situations. In Fig.7, the relative humidity ϕ can be interpreted as above, or alternatively an equivalent RH can be used as:-

$$\phi = \frac{e_m}{e_s}$$

where e_m = the mean of indoor and outdoor vapour pressures

e_s = mean saturation vapour pressure at the condensation plane during the drying period.

Using this equivalence it is possible to consider situations where, for instances, indoor vapour pressure is kept above outdoor during the summer (increasing the equivalent R.H.) or where solar heating keeps the wall warmer than outdoor mean air temperature (reducing the equivalent R.H.)

7. Conclusion

The use of the Keiper method outlined here offers a still-imperfect but vastly improved method for the prediction of moisture control in buildings.

A set of Keiper overlay diagrams included in this paper allow the method to be used far more simply than dew point profile or Glaser methods. The use of those earlier methods can no longer be regarded as reliable.

The use of the method shows immediately that the effect of trace quantities of ventilation by indoor or outdoor air is so great that this factor may equal or outweigh the effects of diffusion properties of the materials.

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APPENDIX

Below are outlined the algorithms on which the Keiper overlays are based. Refer to Fig. 2.

The total condensation G formed during the wetting period, is:-

$$G = T\left(\frac{e_i - e_s}{R_{vi}} - \frac{e_s - e_e}{R_{ve}}\right) \qquad [1]$$

where G = total condensation formed g/m²
T = duration of wetting period S
e = vapour pressure N/m²
R = vapour resistance Ns/g

By extensive algebraic processing this can be shown to be equivalent to:-

$$G = \frac{T}{\Sigma R}\left[e_i + e_e - \frac{e_s[T(x)] - y^2 e_e - (1-y)^2 e_i}{y(1-y)}\right] \qquad [2]$$

where y = the fraction of the total vapour resistance on the warm side of the condensation plane.

$e_s[T(x)]$ = the vapour pressure at the condensation plane, which is a function of the temperature $T(x)$ at that plane.

By re-arranging, Eqn.2 can be used to calculate the constant-deposit contours:-

$$e_s[T(x)] = (1-y)e_i + ye_e - \frac{G.\Sigma R}{T}\, y(1-y) \qquad [3]$$

Then for given values of e_i, e_e, $G\Sigma R$, and T, trial values for y can be inserted to lead to corresponding values for x, as in Figs. 5 and 6.

<u>Drying</u>: Similarly, the requires summertime drying period for a given moisture deposit quantity can be shown to be:-

$$T = \frac{G \Sigma R \qquad y(1-y)}{e_s [T(x)] (1-\phi)} \qquad [4]$$

where ϕ = mean outdoor relative humidity during the drying period.

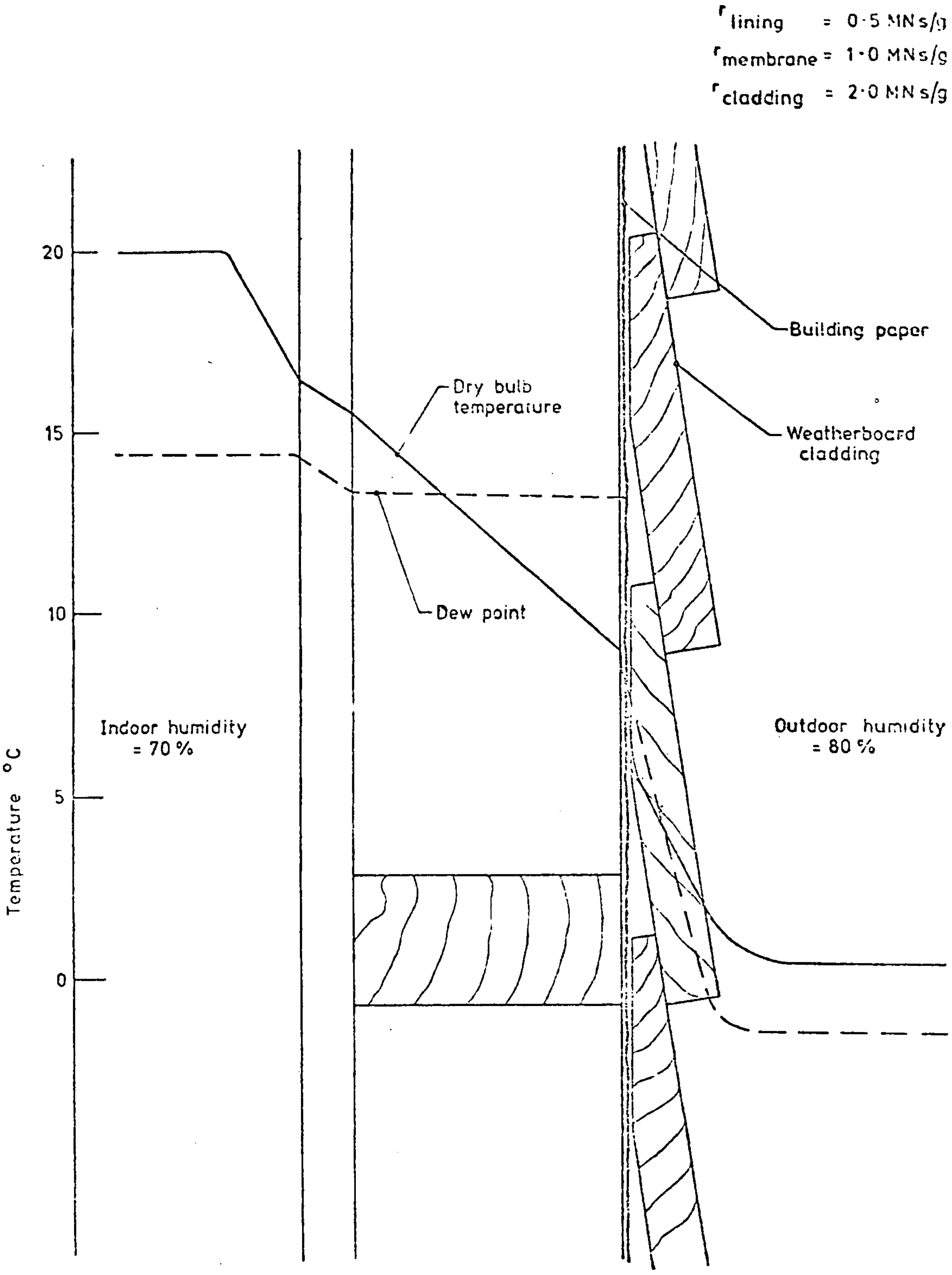

FIG. 1 DEW POINT PROFILE

For traditional timber wall, with zero cavity ventilation.

Illustrating the application of the traditional condensation risk calculation – indicating in this case a serious condensation risk on building paper and cladding

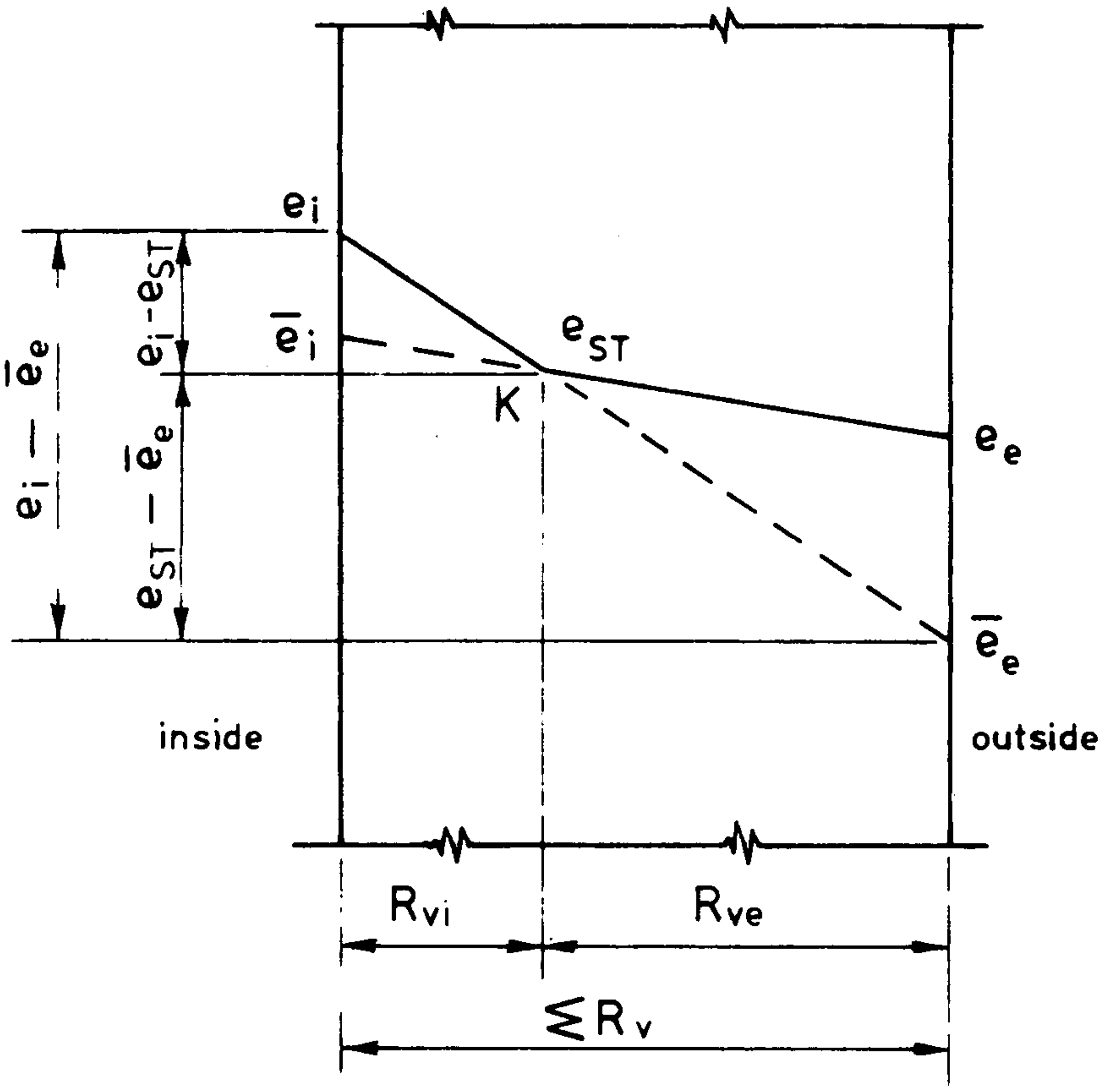

FIG. 2 GLASER MODEL
Vapour pressure distribution through wall with a condensation plane

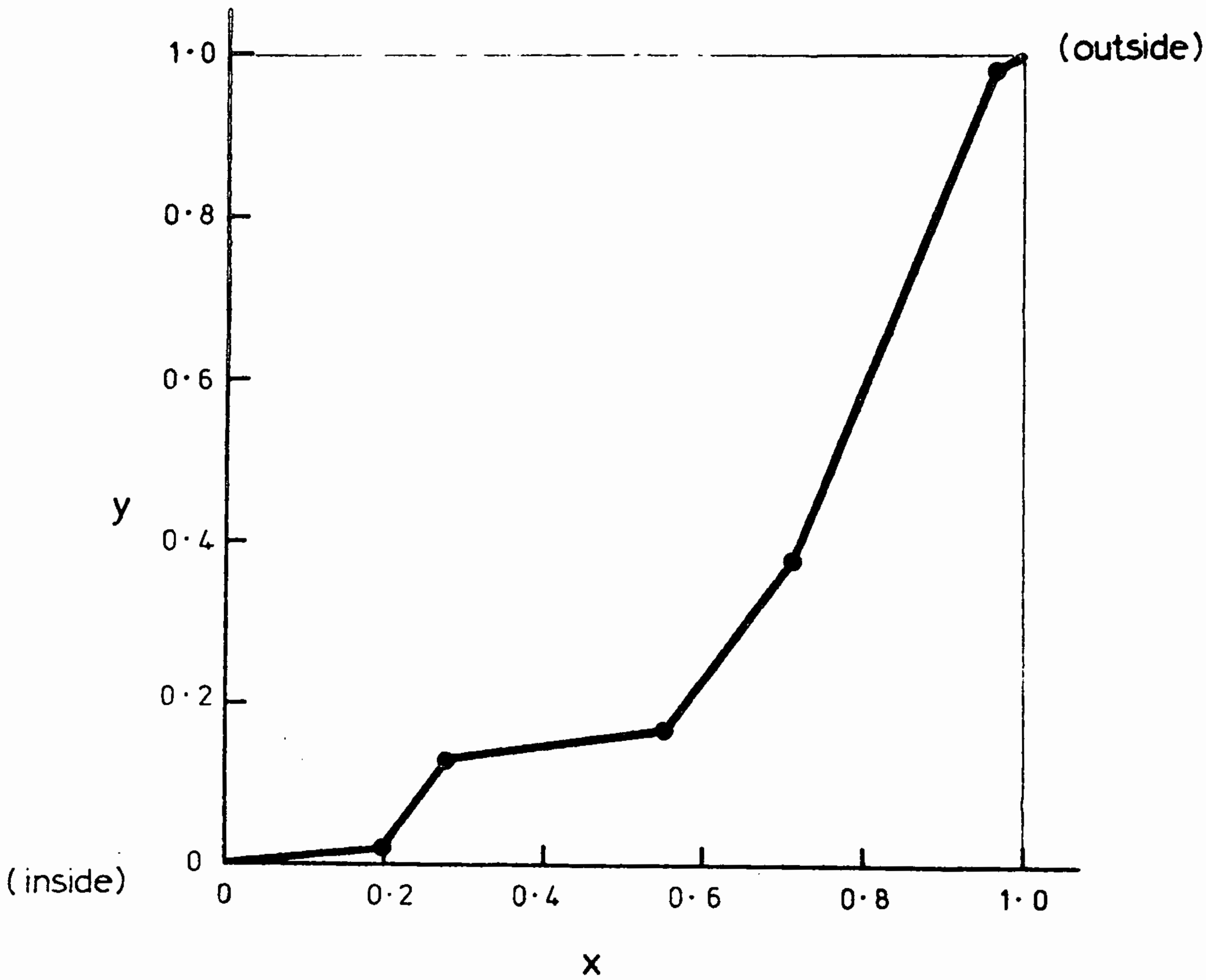

FIG.3 KEIPER DIAGRAM FOR UNINSULATED WALL

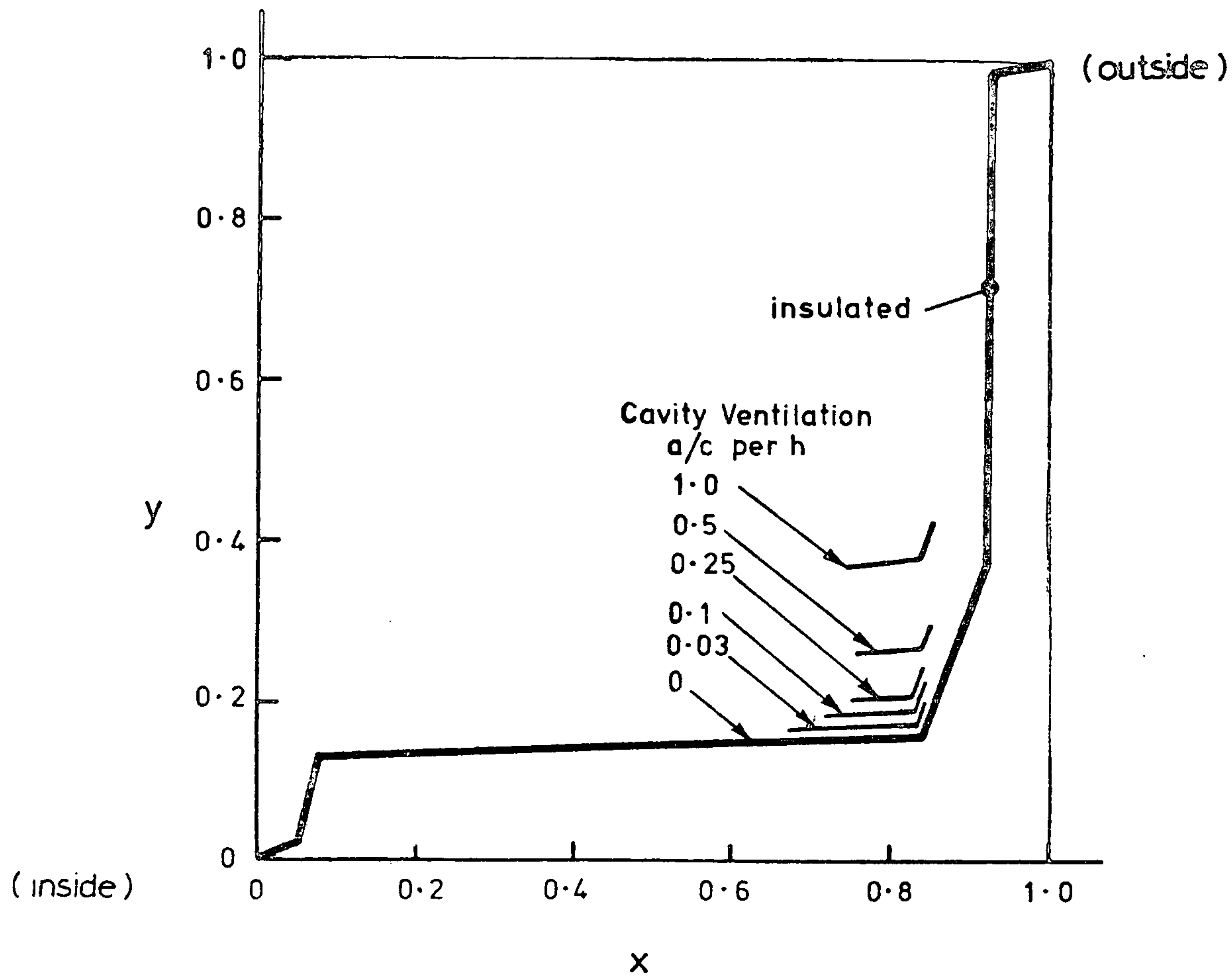

FIG.4 KEIPER DIAGRAM FOR INSULATED WALL
(with cavity ventilation)

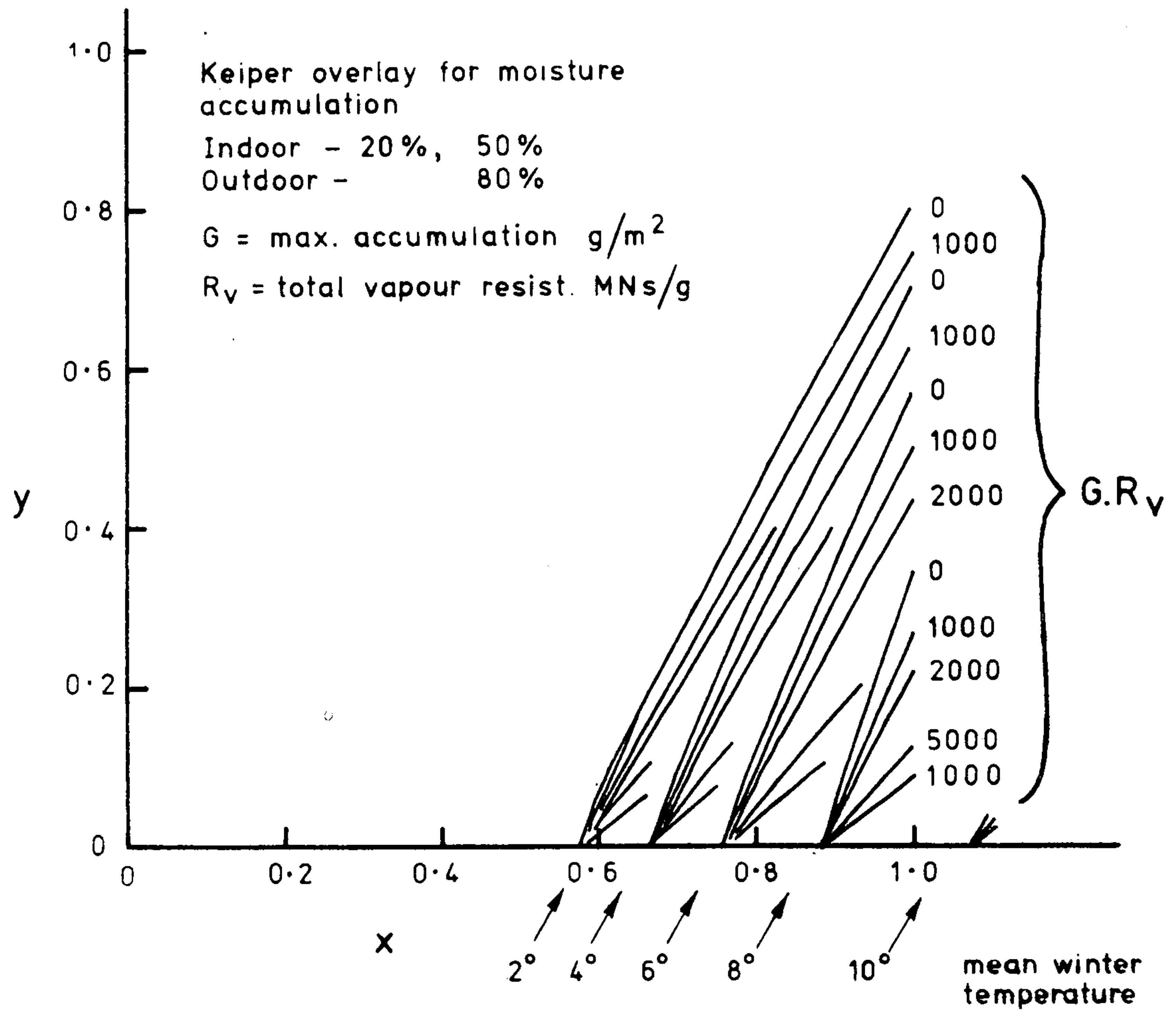

FIG. 5 KEIPER OVERLAY FOR 50% INDOOR R.H.

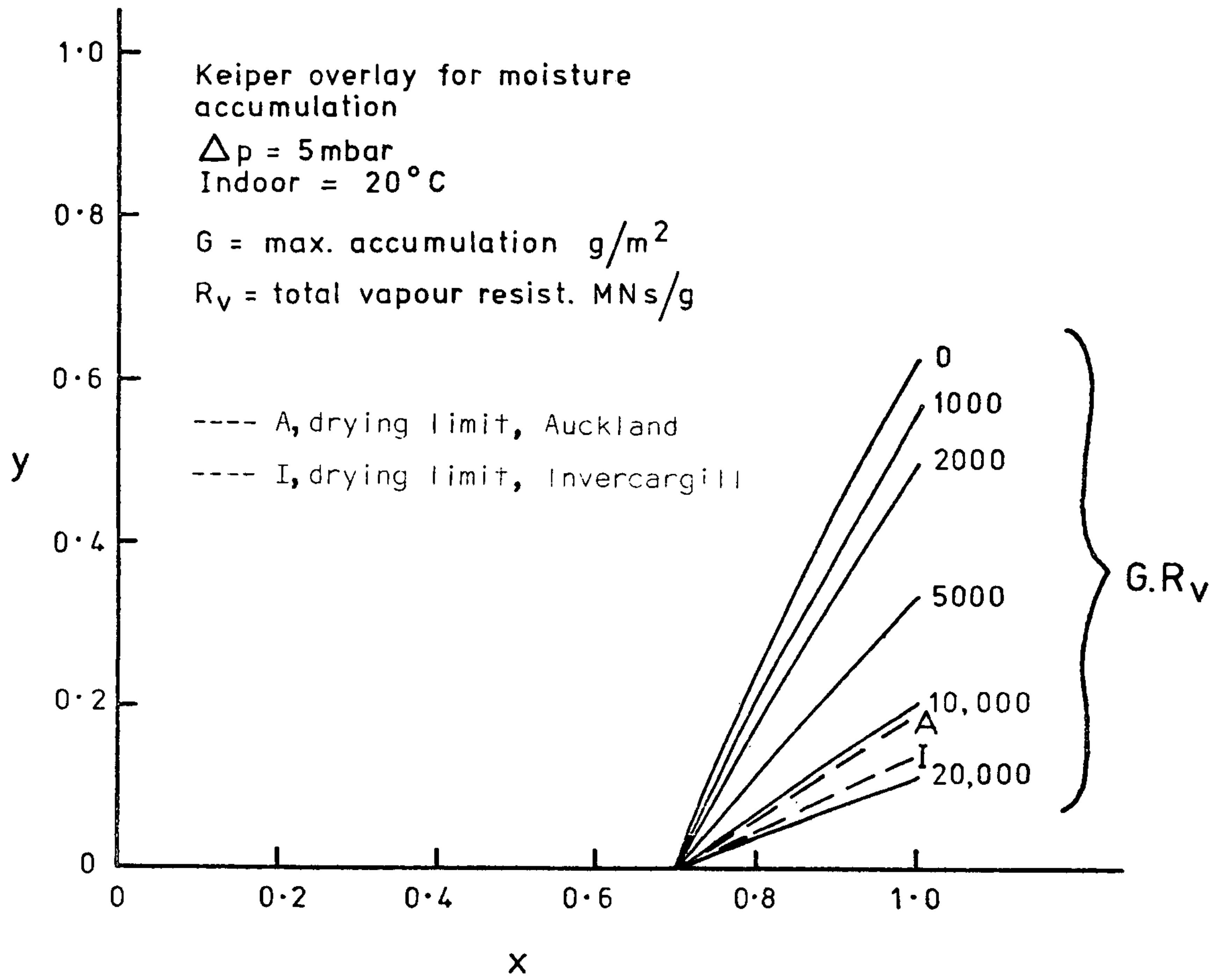

FIG.6 KEIPER OVERLAY FOR 5 mbar V.P. DIFF.

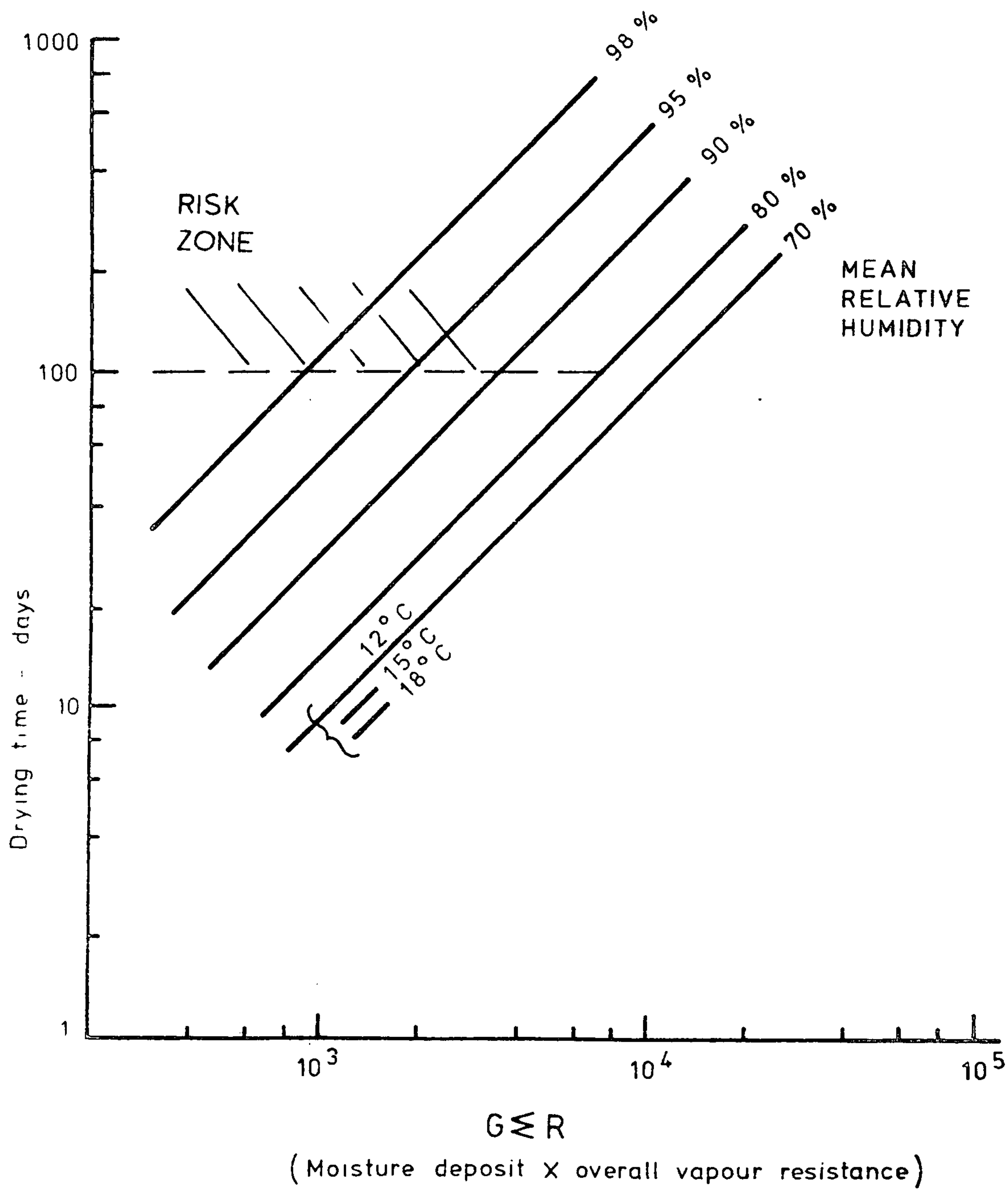

FIG. 7 DRYING TIMES FOR VARIOUS CONDITIONS