PAPER 8

INFLUENCE OF DIFFERENT PARAMETERS IN INFILTRATION HEAT LOSS

W. DE GIDS

Institute for Environmental Hygiene-TNO
Netherlands

INFLUENCE OF DIFFERENT PARAMETERS ON INFILTRATION AND INFILTRATION HEAT LOSS.

By: W.F. de Gids

SUMMARY

This parameter study with the IMG calculation model for ventilation is an attempt at forming some background for decisions relating to the preparation of a standard in the Netherlands.
From the results one can see that air tightness and the heat loss caused by infiltration cannot be considered as a simple linear relationship.

Publication no.   of the TNO Research Institute for Environmental Hygiene, P.O. Box 214, 2600 AE Delft, the Netherlands.

INFLUENCE OF DIFFERENT PARAMETERS ON INFILTRATION AND INFILTRATION HEAT LOSS.

1. INTRODUCTION

Air infiltration plays an important part in our endeavour to save energy in dwellings.
Designing for minimum air infiltration sounds like a wish.
Considering the words design and minimum air infiltration, several questions arise:

- Where does one start?
  Is it necessary to develop a complete new structural design for minimum air infiltration, or can the normal building practice be improved?
  If improving the normal building practice, what details come first?
- How far must one go?
  There must be a minimum amount of ventilation, but infiltration may not disturb normal controlled natural ventilation.
  Is it cost effective to improve the air tightness of dwellings?
- What are the consequences?
  What are in the first place the effects on infiltration?
  Second, what are the effects on air quality?
  Third, what effects can be expected on man's behaviour as concerns his use of ventilation provisions such as windows, vents and grilles?
  Is adaptation in behaviour neccesary?
- What is the effect?
  Do we save energy and how much?

In the Netherlands a standard on air tightness of housing is in preparation. This paper is an attempt to form some background for decisions.

2. INVESTIGATIONS

2.1 The calculation model

The investigation can be seen as a parameter study with the IMG calculation

model for ventilation and infiltration in buildings.
The principles of this model are described in literature [1]. The mathematical model is a simulation of all air paths in the building. For example, the cracks, joints and seams of windows, doors and other construction details, the grilles, vents etc. intended for ventilation and a mechanical ventilation system can be simulated.
The input data concerning:

- wind pressures
- air temperatures
- characteristics of cracks, joints, seams, vents, windows, ducts and other openings.
- fan characteristics.

2.2 Present situation

The best estimate of the air tightness of houses in the Netherlands is given in figure 1 [2]. The mean value is 0,1 m^3/s at 1 Pa, which means to an air change rate of about 12 at 50 Pa. In figure 2, the floorplan and the cross section of the reference house are shown. It can be considered a typical house in the Netherlands. For this house a model has been made as schematically presented in figure 3. Nine rooms with twenty-four air leakages make up the model. In figure 4, the assumed temperatures in the dwelling are shown. Figure 5 shows the distribution of the air leakage over the outside "shell" or building envelope [3]. With these figures in mind we start our parameter study.

2.3 Parameters

The following parameters have been studied:

- wind velocity (meteorological), 0 - 10 m/s
- wind direction, 0 - 360 °, steps of 20 °
- outside temperature, 0 - 15 °C
- air tightness, retrofitting of floor, roof and internal doors.
- surroundings, a house, exposed to wind.
  a house surrounded in all directions by houses with the same height, a house surrounded by houses with the

same height and flatbuildings up to about 20 m (mild wind climate).

3. RESULTS

3.1 Wind velocity

In figure 6, the infiltration rates and infiltration heat losses are shown for the reference house in the exposed wind situation. Under average weather conditions, 5 m/s and 5 °C, the infiltration through the fabric is about 1 (h^{-1}). The basis or the dutch ventilation standard is 7 dm^3/s per person [4]. Without opening any window, the infiltration has already a large overshoot in relation to the minimum fresh air requirements. An air infiltration rate of 1 (h^{-1}) equals a flow rate of 84 dm^3/s, at a volume of 300 m^3, which is sufficient for 12 persons. The corresponding infiltration heat loss is about 1,3 kW.

Between 0 and 2 m/s, buoyancy effects dominate. From about 5 m/s and up wind effects dominate. Between 2 and 5 m/s the influences of both buoyancy and wind interact.

3.2 Outside temperature

In figures 7 and 8, the air infiltration rate and the infiltration heat loss are plotted against outside temperature. For average weather conditions with a wind velocity of around 5 m/s and outside temperatures of 0 to 15 °C during the heating season, the rate of infiltration can be considered as linear to the outside temperature. For wind velocities lower than 5 m/s and temperatures between 10 and 20 °C, this relationship is non-linear. The relationship between outside temperature and infiltration heat loss can be considered as linear for temperatures lower than 10 °C.

3.3 Air leakage

In figure 9, the air leakage distribution is given after retrofitting the roof. The air leakage is reduced to 57 % of the air leakage of the reference house corresponding to an a_{50} of about 7. Figure 10 shows the air leakage distribution after retrofitting the floor. The air leakage is reduced to 85 % of the reference value. The corresponding a_{50} value is about 10. In figure 11, both floor and roof are retrofitted. The air leakage is 42 % of the reference value, which equals an a_{50} of about 5. These three retrofits are assumed to reduce the original leakage to zero. This seems a bit optimistic. A more realistic air leakage distribution is given in figure 12. The air leakage of roof and floor has been reduced to 20 % of their original value. This leads to an air leakage value for the whole house of 54 % of the reference house, corresponding to an a_{50} of about 6. Comparing the air leakage of such a house to the Swedish standard of $a_{50}<3$, the air leakage of the whole house has to be reduced by that of the natural ventilation ducts (in this case 34), with an a_{50} of about 2,4 as a result.
The results of these retrofits in terms of infiltration rates and infiltration heat loss can be seen in figure 13. The realistic model gives under the average weather conditions (5 m/s, 5 °C) an infiltration rate of 0,5 (h^{-1}) and an infiltration heat loss of 700 W.
In figure 14, the effect of air tight internal doors is shown.
Air tight internal doors give a reduction of the air leakage value up to 20 %. The effect at this level of external leakages is relatively small.

3.4 Wind direction

The influence of the wind direction on the infiltration rate is given in figure 15.
For the house as a whole the variation is rather small. The highest value is about 1 (h^{-1}), the lowest about 0,7 (h^{-1}).
Looking at two opposite bedrooms the effect of the wind direction is impressive.

The low values of infiltration occured with the bedrooms situated at the leeward side. An example of the distribution of air through a dwelling can be seen in figure 16. These effects must be kept in mind when considering retrofits on air leakages. A consequent and conscious use of grilles and vents will be necessary to reach minimum ventilation standards. Enlightenment campaigns to occupants of these houses are necessary to avoid bad indoor air quality situations.

3.5 Surroundings

The effect of the surroundings on wind exposure and on infiltration rates is shown in figure 17. This figure teaches us, that the effect of surrounding buildings in an absolute sense is more important for leaky houses then for air-tight houses.

4. DISCUSSION

In the figures 18 and 19, the infiltration and infiltration heat losses are plotted against relative air leakage. These results are calculated in the situation with all windows closed, a wind velocity of 5 m/s and an outside temperature of 5 °C. As can be seen from figure 18, there is no linear relationship between air infiltration rate and air leakage [5]. If there is no leakage in the floor the relative air leakage is 85 % and the air infiltration rate is 0,7 (h^{-1}). Reducing the air leakage through the roof to zero gives a relative air leakage of 57 % and also an air infiltration rate of 0,7 (h^{-1}). The corresponding infiltration heat losses are 900 W and 1000 W, respecively . The higher heat loss applies to the lower air leakage !
The reasons for this are :

- distribution of air leakage over the building envelope in relation with
- distribution of air pressures over the building
- temperature distribution in the house.

The overall conclusion of this consideration must be:

Different retrofits with the same effect on air leakage can have complete incomparable effects on air infiltration and infiltration heat loss.

5. CONCLUSIONS

1. The effects of wind velocity and temperature difference on infiltration are both non-linear. However, within certain limits and with some inaccuracy they can be considered linear (figures 6,7 and 8).

2. Under average weather conditions, 5 m/s and 5 °C, the air infiltration exceeds the minimum fresh air requirements, even in a mild wind climate (see figures 6 and 17).

3. Because wind direction is a predominant factor for the infiltration rates of individual rooms conscious behaviour is neccessary to reach minimum ventilation standards (see figures 15 and 16).

4. Under average weather conditions, 5 m/s and 5 °C, the infiltration heat loss can be reduced from 1300 W in the reference situation to 700 W in the realistic model situation (see figure 13).

5. It seems possible to reach reasonable air leakage values by improving normal building practice in the Netherlands (see figure 12).

6. There is neither a simple linear relation between air leakage and air infiltration rates, nor between air leakage and infiltration heat loss (see figures 18 and 19).

6. REFERENCES

[1] Gids, W.F. de. Calculation method for the natural ventilation of buildings.
IMG-TNO, publication no. 632, Delft, 1977.

[2] Schippers, P.J. and P.J.J. de Jong. Luchtdichtheid van woningen. Bouwfonds Nederlandse Gemeenten, Hoevelaken, 1980.

[3] Gids, W.F. de, B. Knoll and J.C. Phaff. Toepassing en consequenties van een meetmethode voor de luchtdoorlatendheid van woningen. Stichting Bouwresearch, Publ. B2-17, Rotterdam, 1981.

[4] NEN 1087.
Ventilatie van woongebouwen.
Nederlands Normalisatie Instituut, Rijswijk, 1975.

[5] Gids, W.F. de. Problems and consequences of the pressurization test for the air leakage of houses.
Air Infiltration Centre, Proc. 1-80, Bracknell, 1981.

7. NOMENCLATURE

7.1 Symbols

C	Air leakage coefficient	(m^3/s at 1 Pa)
v_{met}	Meteorological wind velocity	(m/s)
a	Air infiltration rate	(h^{-1})
V	Volume	(m^3)
Q	Infiltration heat loss	(W or kW)
T	Standard deviation	(-)
n	Number	(-)
a_{50}	Air infiltration rate at 50 Pa pressure difference	(h^{-1} at 50 Pa)

7.2 Abbrevations.

INF	Infiltration
MET	Meteorological
L	Living-room
B	Bedroom
BR	Bathroom
K	Kitchen
Bo	Boiler

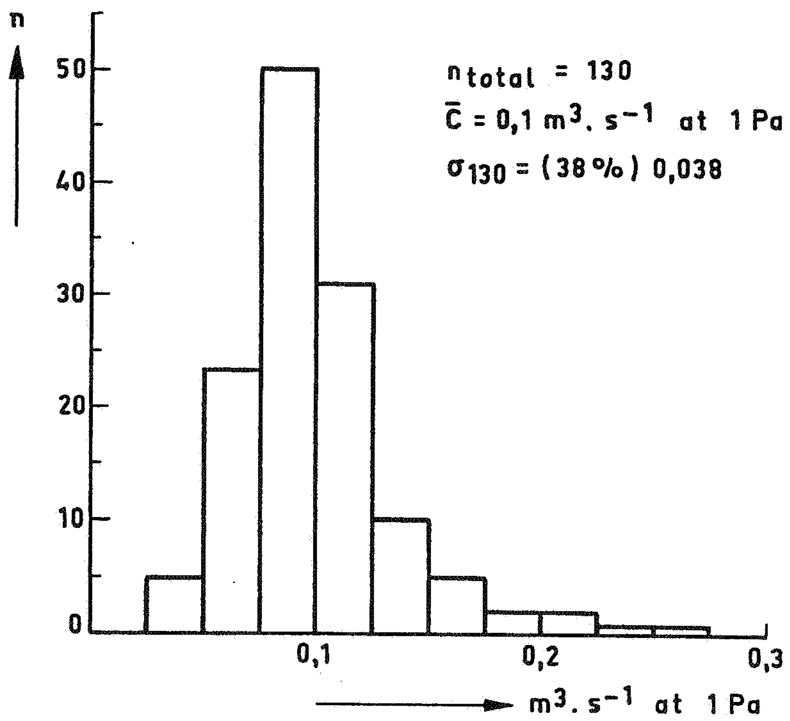


Figure 1 Distribution of air leakage for 130 dwellings in the Netherlands

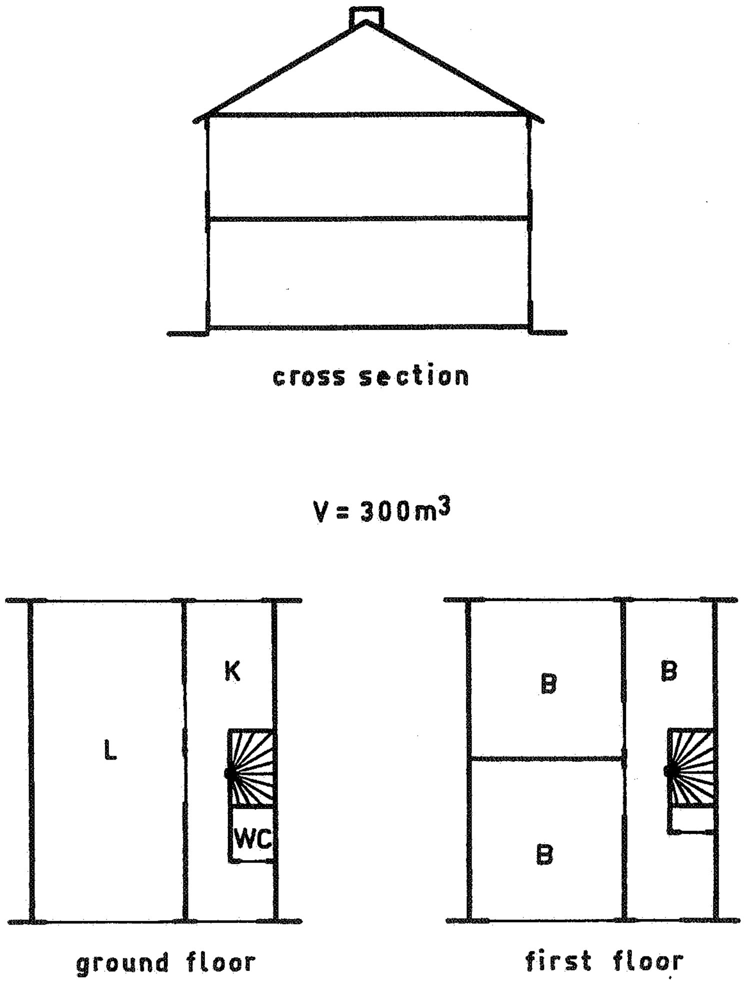


Figure 2 Floorplan and cross section of the reference house

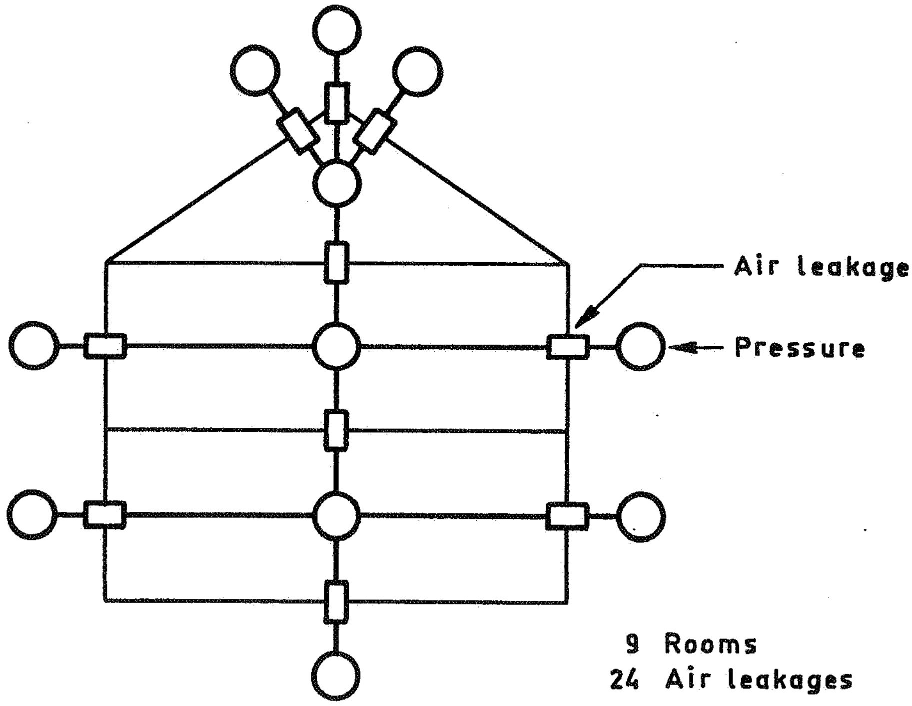


Figure 3 Scheme of the model

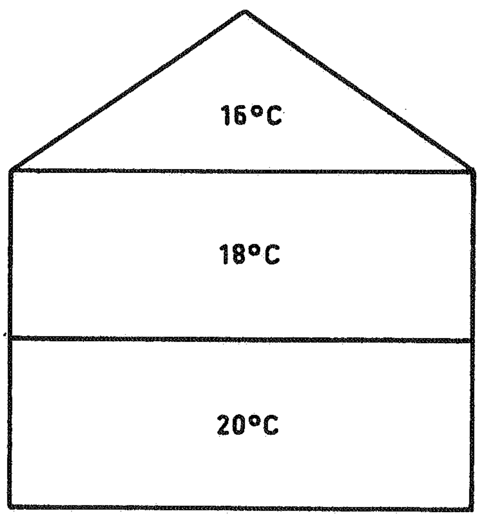


Figure 4 Temperature distribution in the dwelling

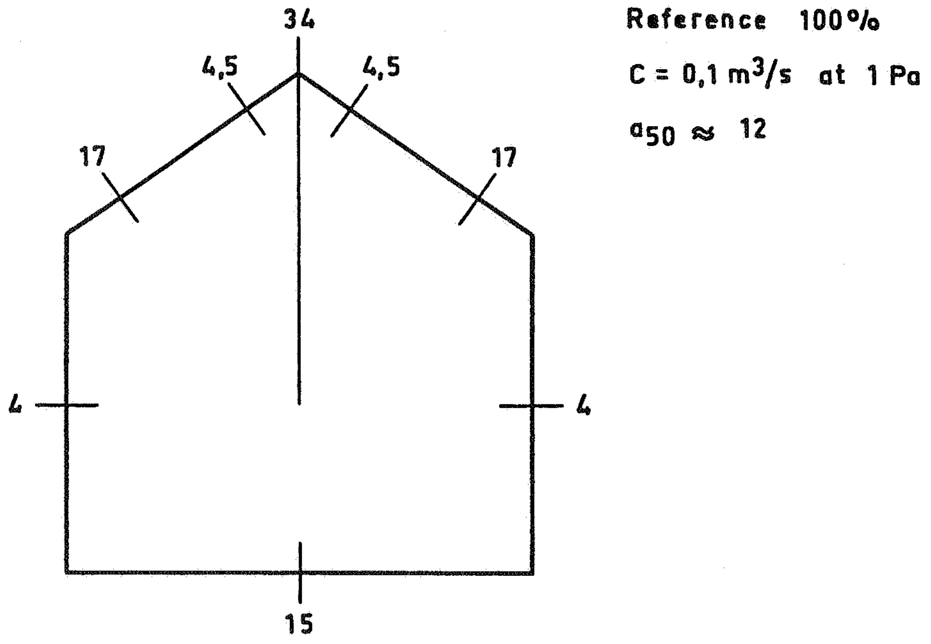


Figure 5 Distribution of air leakage

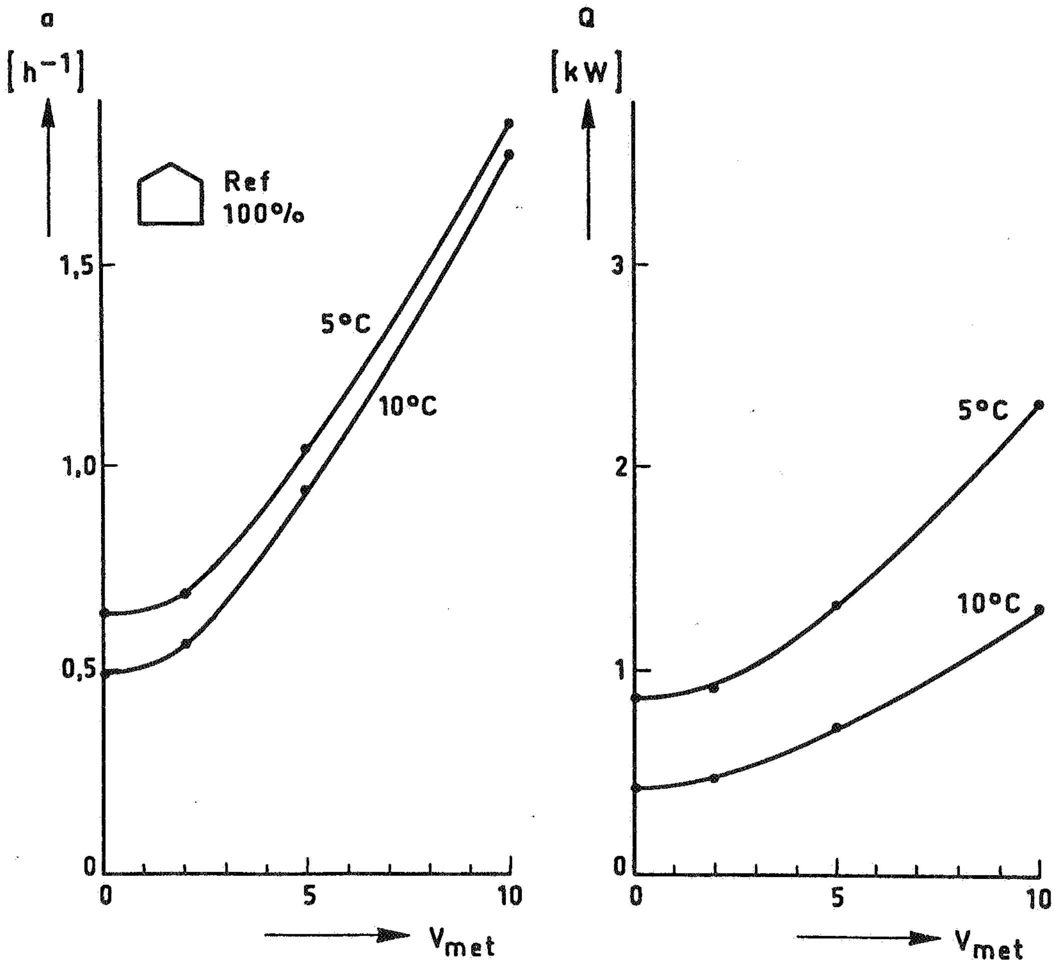


Figure 6 Infiltration rates and infiltration heat losses versus windvelocity

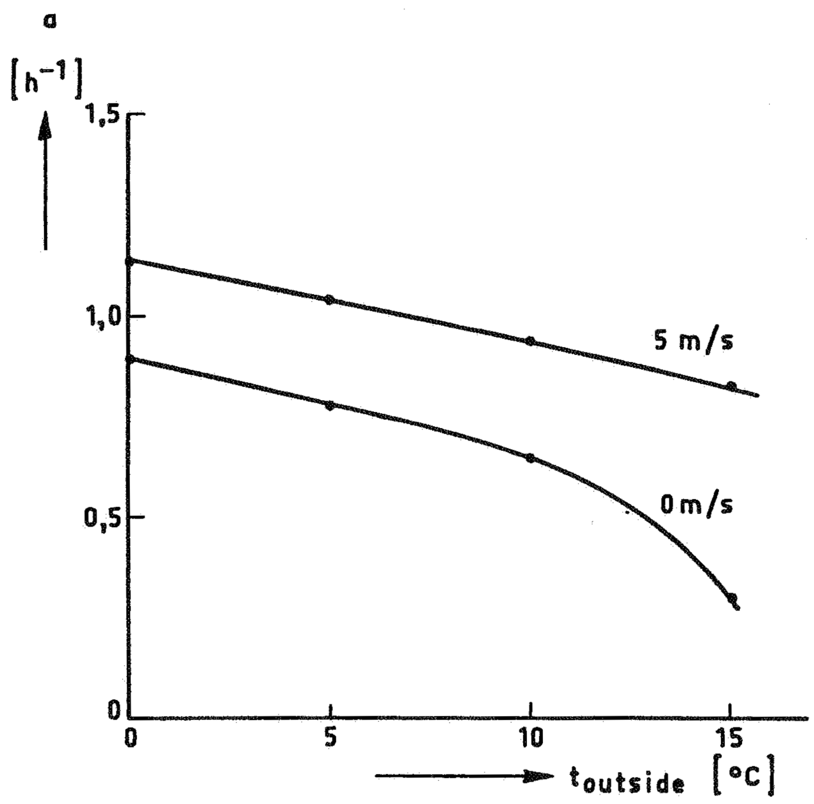


Figure 7 Infiltration rates versus outside temperature

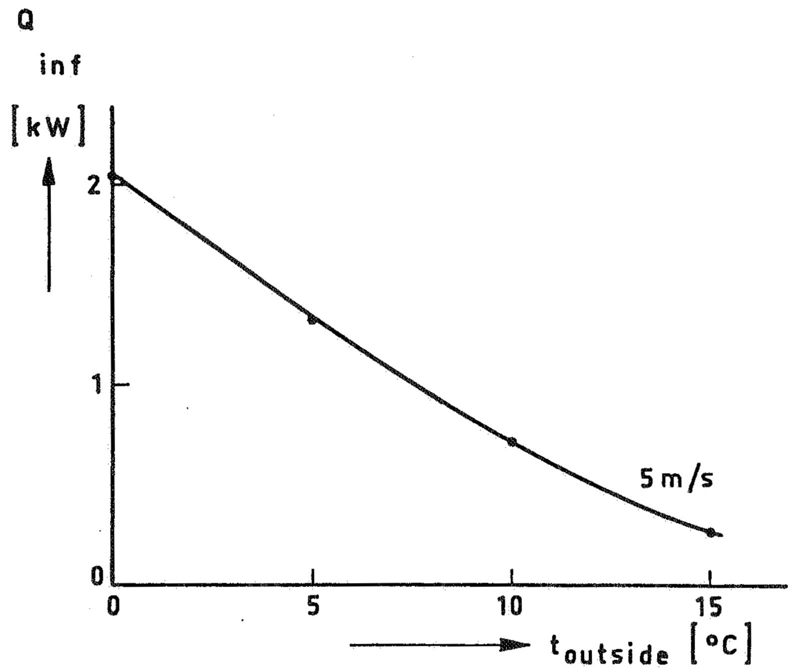
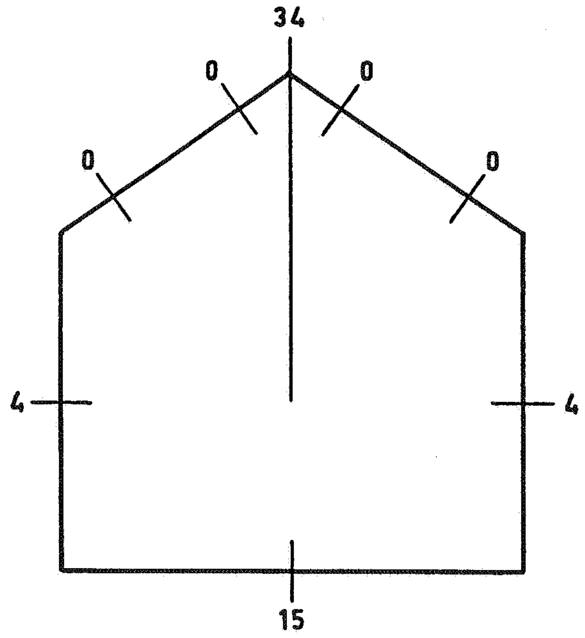
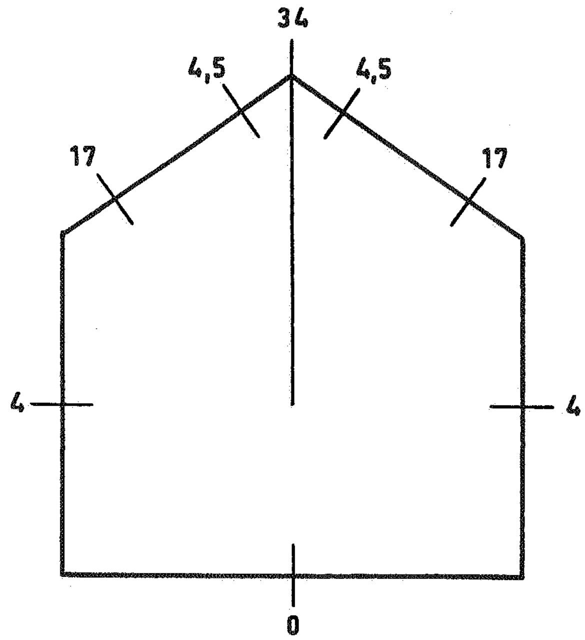


Figure 8 Infiltration heat losses against outside temperature



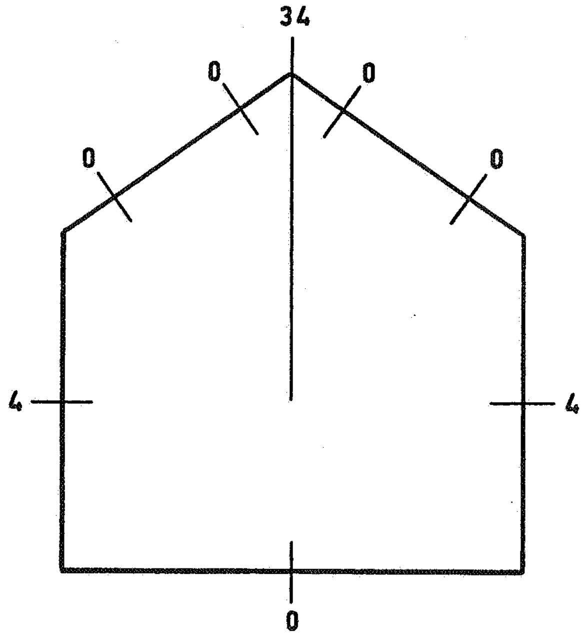
57 %
$a_{50} \approx 6{,}8$

Figure 9 Air leakage distribution after retrofitting the roof



85 %
$a_{50} \approx 10$

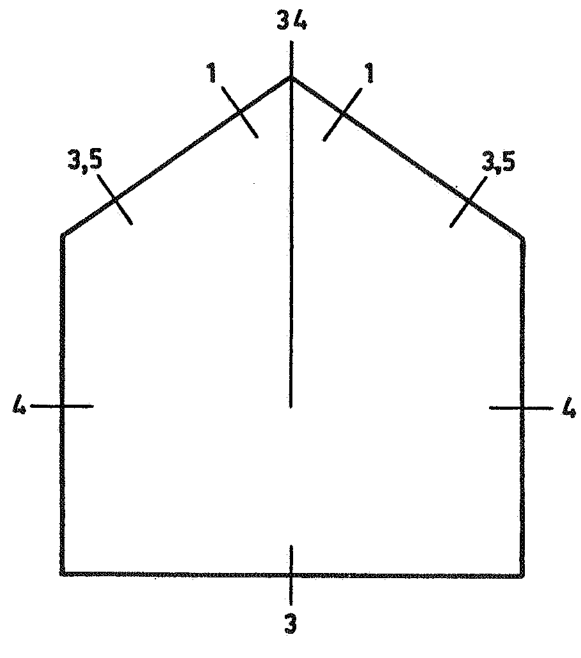
Figure 10 Air leakage distribution after retrofitting the floor



42%

$a_{50} \approx 5$

Figure 11 Air leakage distribution after retrofitting floor and roof



54%

$a_{50} \approx 6{,}4$

a_{50} without ducts = 2,4

Figure 12 Realistic air leakage distribution after retrofitting floor and roof

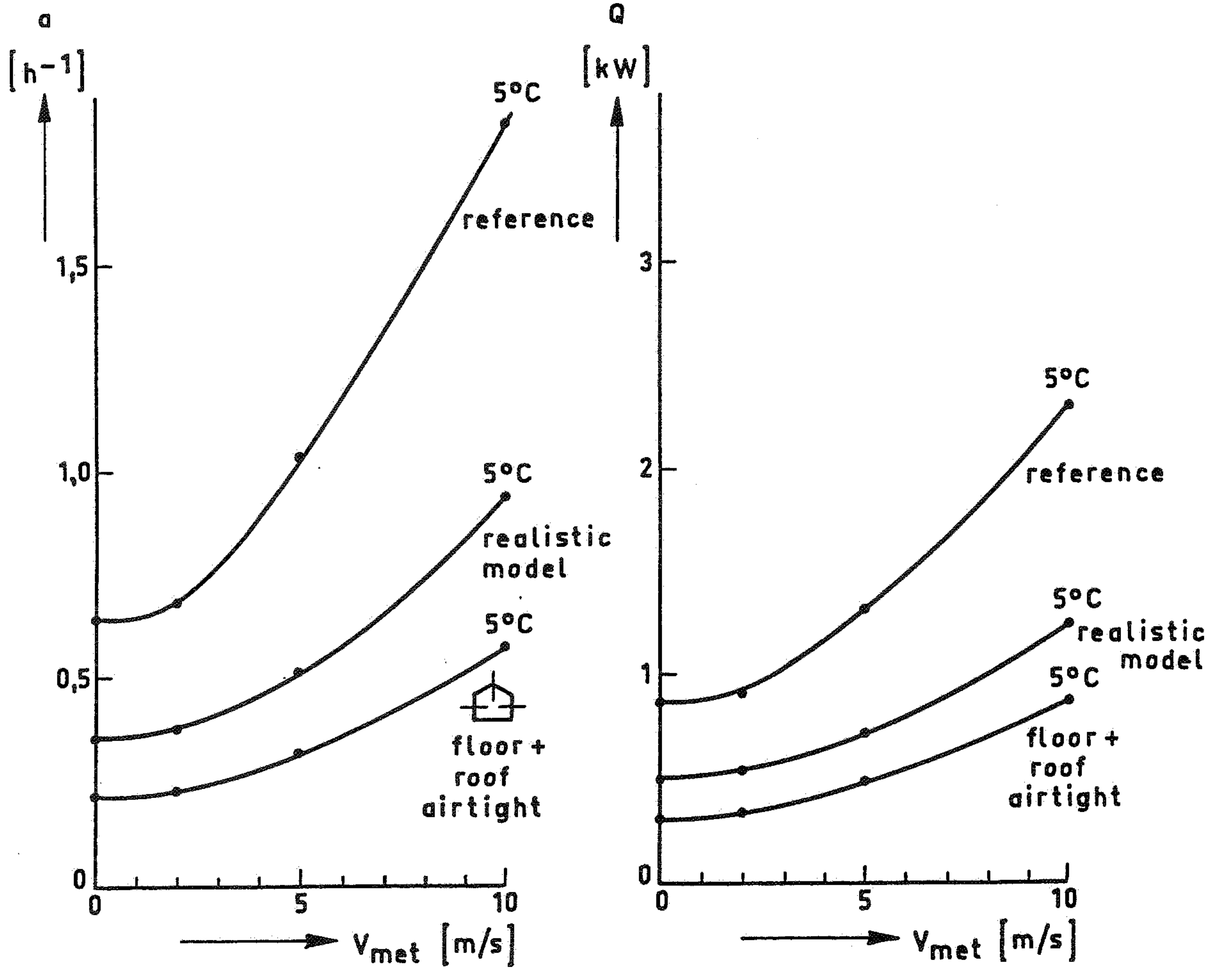


Figure 13 Infiltration rates and infiltration heat losses versus windvelocity for different retrofits

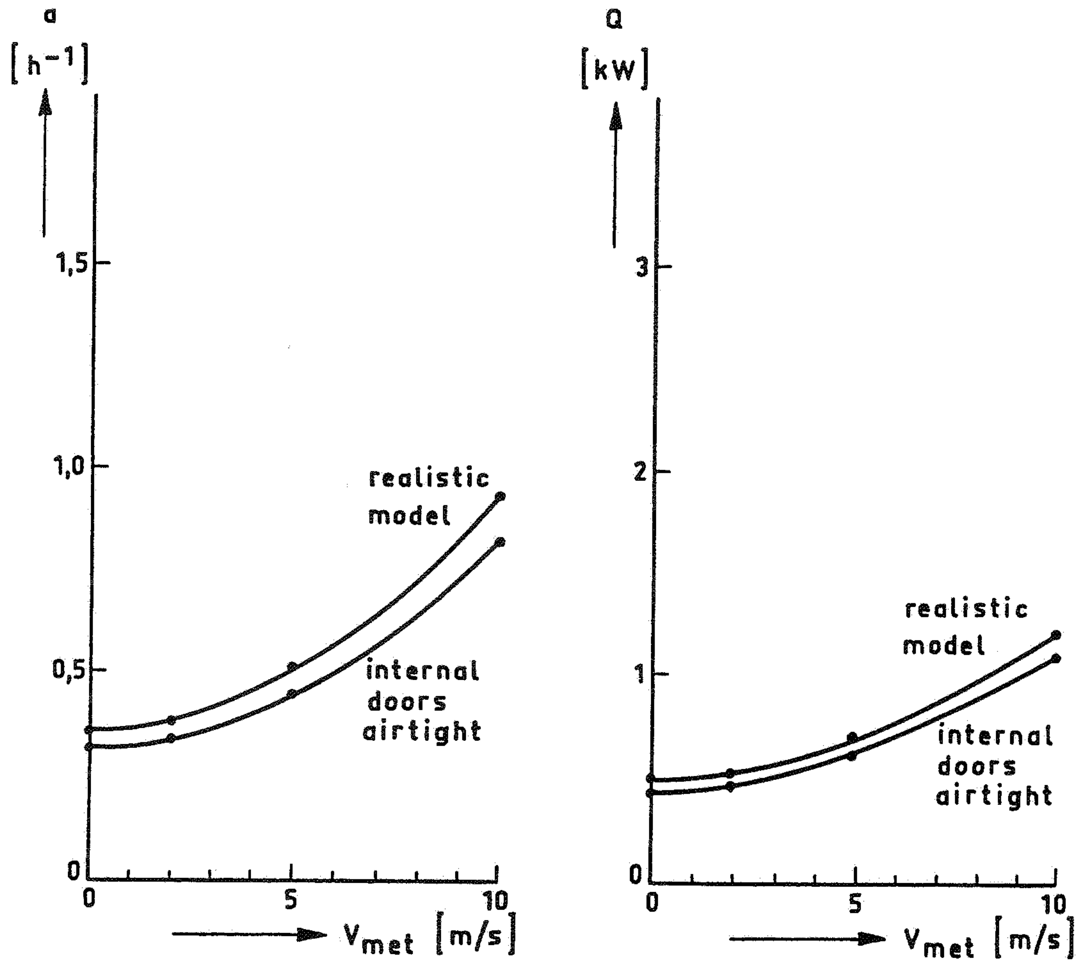


Figure 14 Effect of airtight internal doors on infiltration and infiltration heat losses

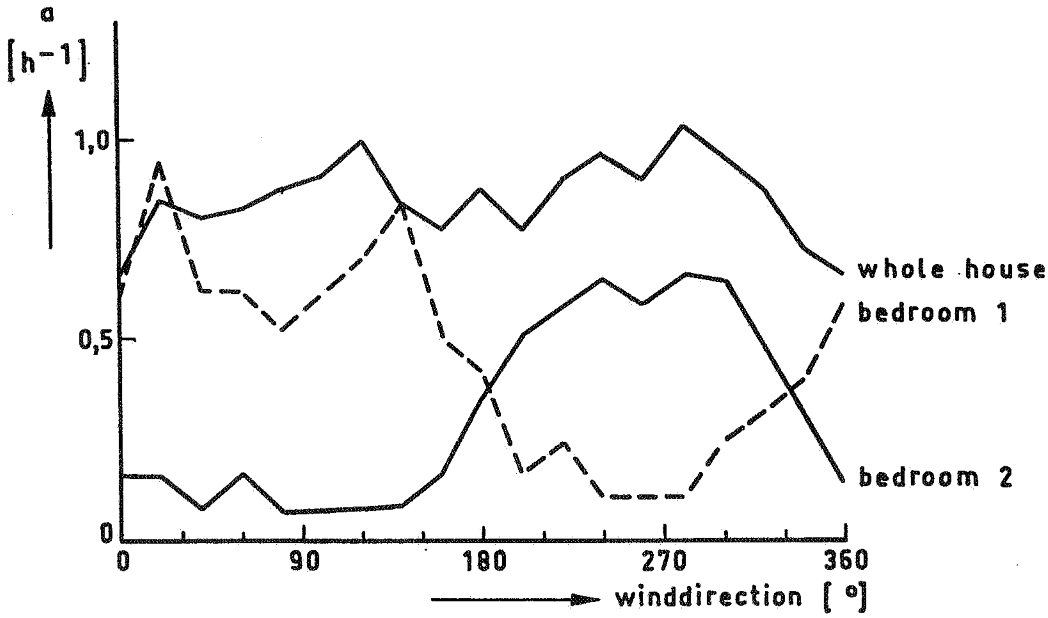


Figure 15 Infiltration rates versus winddirection for the whole house and for two opposite bedrooms

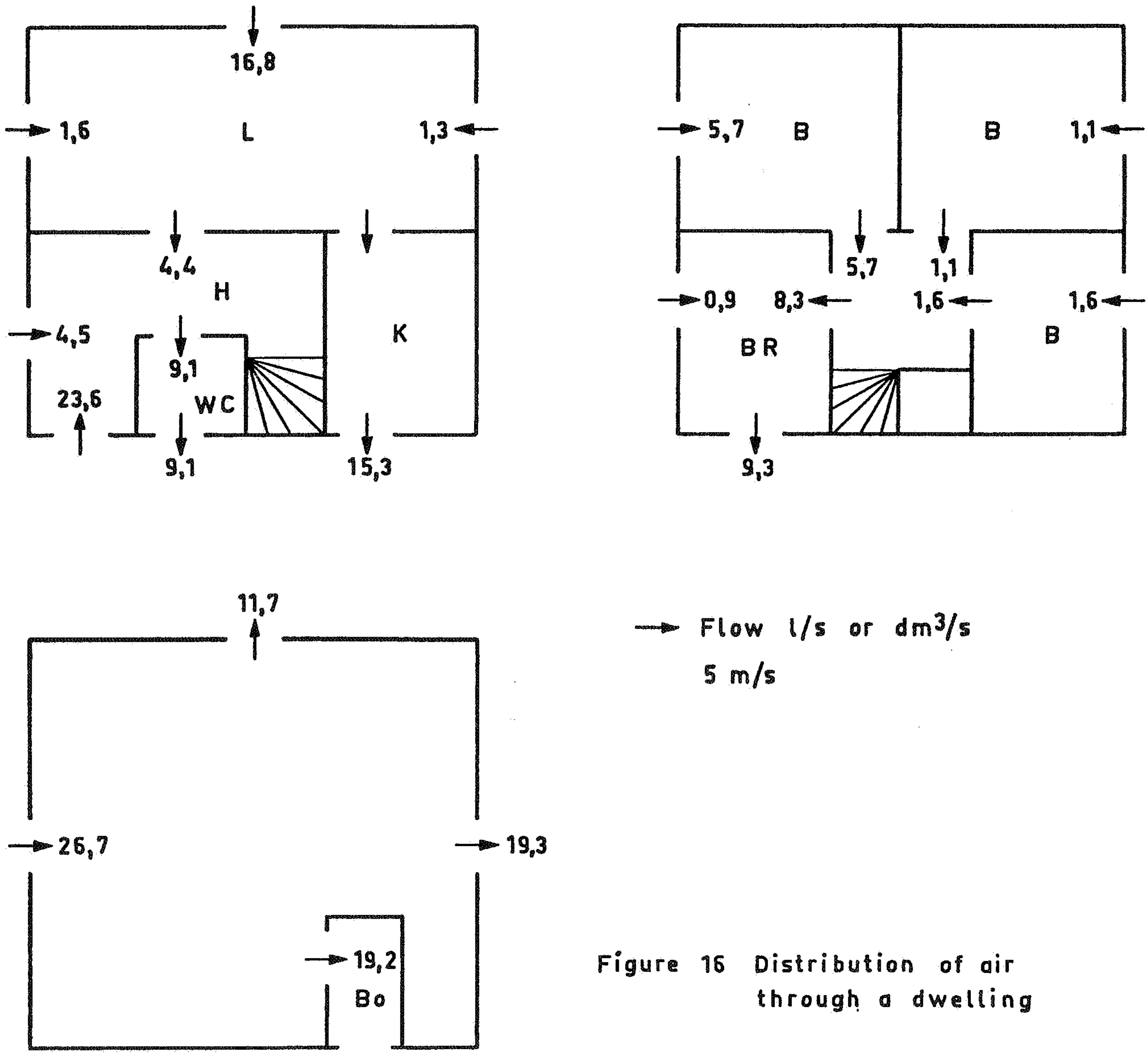


Figure 16 Distribution of air through a dwelling

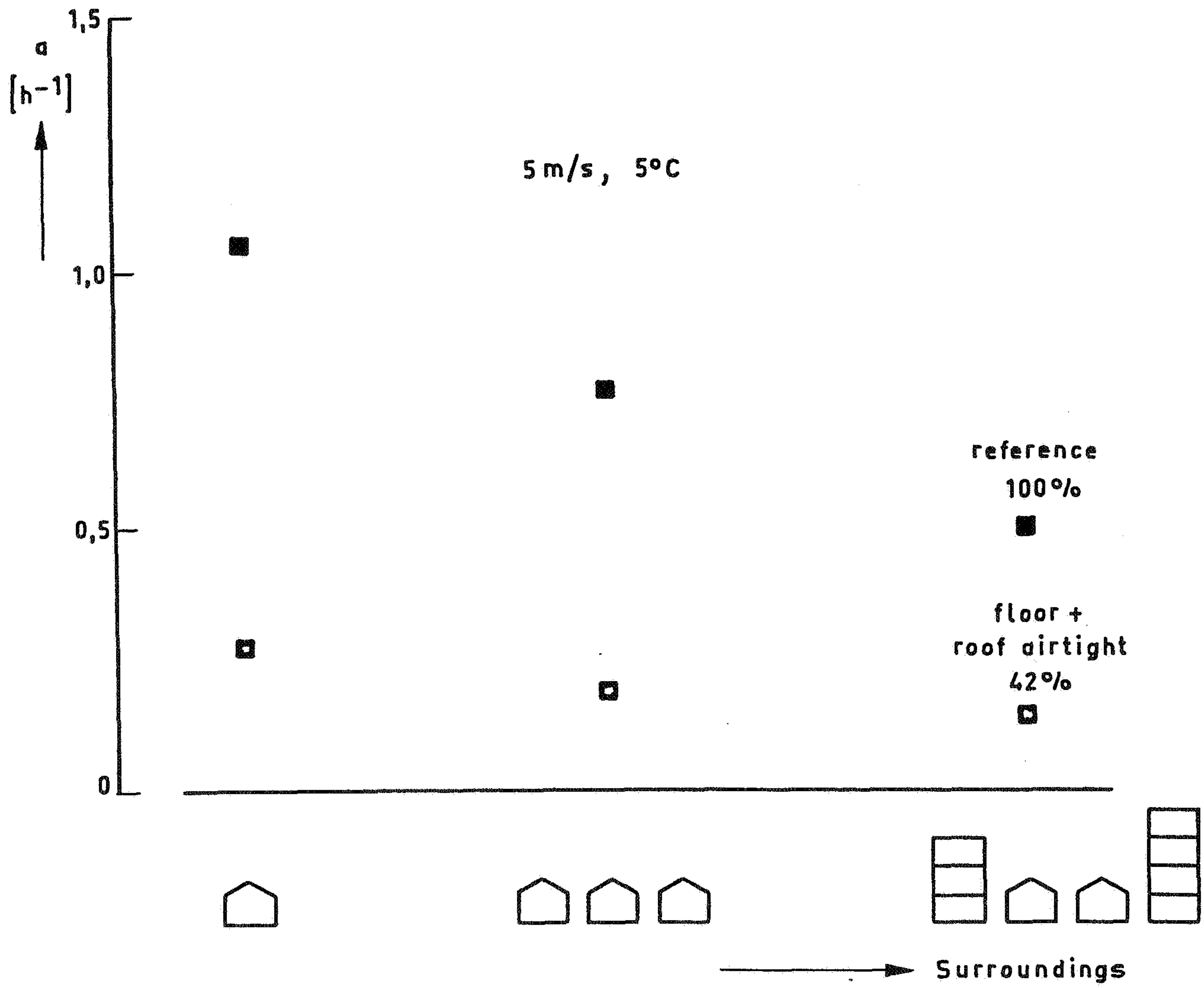


Figure 17 Relative effect of surroundings on infiltration rates

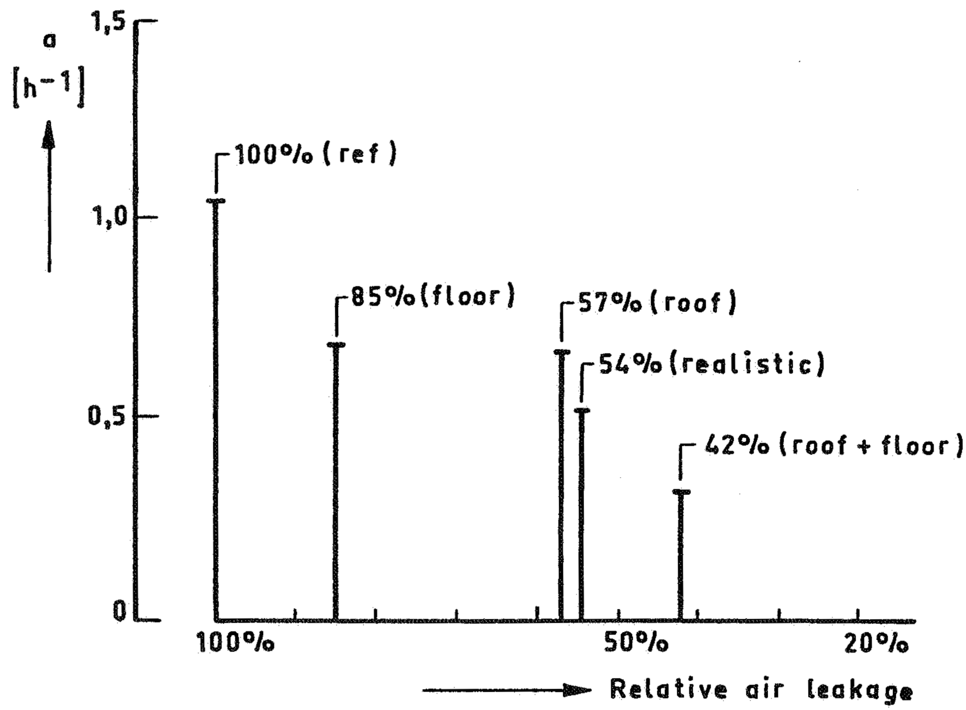


Figure 18 Relative air leakage against infiltration rates

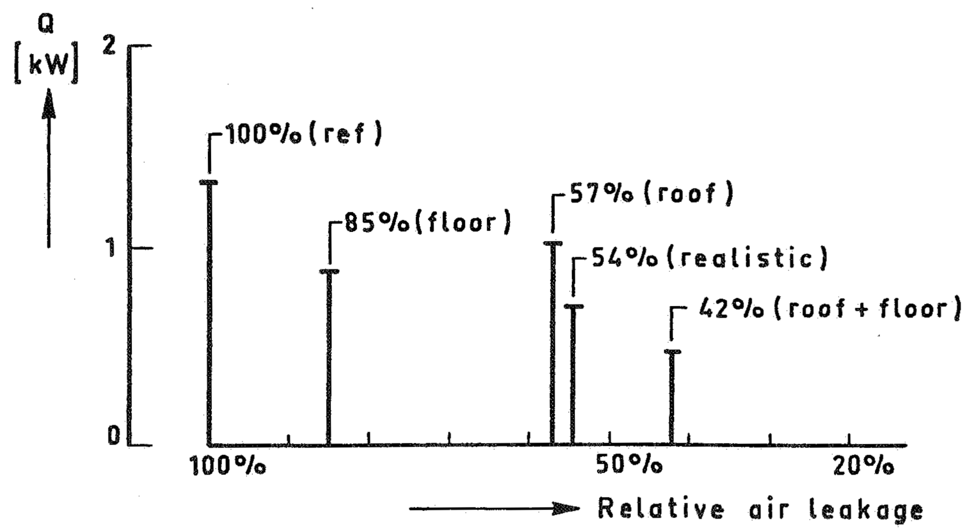


Figure 19 Relative air leakage against infiltration heat losses