HEAT LOSSES DUE TO WINDOW OPENING BY OCCUPANTS

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Introduction

Conventional heat loss calculations assume that the heat losses can be based on some form of an equation which multiplies the sum of the fabric and ventilation heat losses by the difference between inside and outside air temperatures, with the assumption that a standard ventilation rate of 1,0.75 or even 0.5 air changes per hour may be implied. (See figures 1 & 2).

Brundrett [1] has shown why this latter assumption must now be challenged in the light of the increasing proportion of heat lost by ventilation as insulation of the fabric is increased and in the light of actual consumptions (Fig. 7 op.cit). This paper attempts to quantify the ventilation heat losses which arise due to window opening behaviour on the part of the occupants.

The reason for the studies on which this paper is based arose from the results which were obtained at one of the sites in the Better Insulated House Programme described by Campbell [2], where it was found that the mean energy consumption in the 19 highly insulated houses was not statistically significantly different from that in the 23 normally insulated houses although conventional heat loss calculations indicated that a difference of some 18-21% could be expected. This lack of difference could not be wholly accounted for by the slightly higher whole house mean temperatures obtaining in the highly insulated houses, and further studies were instituted to examine; window opening habits, infiltration ventilation rates, and ventilation rates arising from the opening of windows. [Lee [3]]. In conjunction with these studies an analysis of the relationships between the indoor air temperatures in the various rooms and outside air temperatures was undertaken.

Findings

The findings from these supplementary studies produced nothing which had not been reported elsewhere e.g. Dick & Thomas [4], Brundrett [5] and Dickson [6], with the exception of the final finding which would appear to be site specific. These findings are summarised below

(i) The number of open windows is related to the outdoor air temperature and only slightly modified by wind speed.

(ii) The whole house ventilation rates within the houses were related to the number of open windows and to wind speed - and hence, by the above, related to outdoor air temperature.

(iii) The windows most usually opened by the occupants were first floor bedroom windows.

(iv) Indoor temperatures were related to outdoor temperatures, the relationship being most marked in the case of first floor bedrooms.

(v) The bedroom temperatures in the highly insulated houses were markedly higher than those in the normally insulated houses and accounted for most of the whole house mean temperature differences between the two groups.

(vi) The occupants of the highly insulated house group demonstrated a greater propensity to open windows than the occupants of the normally insulated house group.

The fact that each aspect could be related either directly or indirectly to outside air temperature made it apparent that it would be possible to examine the relationship between outside air temperature and ventilation heat losses occurring as a result of the window opening behaviour with due allowance being given to the variations in indoor temperature to outdoor temperature obtaining in both the test and control groups, to see whether these losses could account for the lack of difference in energy consumption between the two groups.

Results

Fig. 3 indicates the results of the window opening study and superimposed are the results of the studies by Dick and Thomas [4] and Brundrett [5] giving the number of open windows versus outdoor air temperature.

Fig. 4 indicates the relationships established between the whole house ventilation rate and the numbers of open windows based on the studies of Lee [3], Dick and Thomas [4] and Dickson [6].

By combining the data sets illustrated in the preceding figures it is possible to arrive at an assessment of the variation in ventilation heat losses as a result of opening windows. The results of these assessments are presented in Figures 5 to 7 for each of the investigators for a wind speed of 4 m/s for both test and control groups.

By summing the above ventilation losses and the fabric losses the total heat losses can be obtained and the results of these summations are presented in Figures 8 to 10.

Figure 11 presents the variation of total space heating consumption that was actually measured, with outside air temperature.

Discussion

Billington [7] proposes that casual and solar gains may be of the order of 2 kW or 40 - 48 kWh/day. This proposal has been used to obtain, along with the total space heating consumption figures presented in Figure 11, a measure of the total heat input. This total heat input is then compared to the total heat losses from Figure 8 and the comparison presented in Figure 12.

Although there are discrepancies, especially at the higher outside air temperatures, it is encouraging to note that this form of treatment of the data produces a heat loss prediction which has a shape similar to that of measured heat input curves and approximates in magnitude to the consumption. In addition it indicates why there was no statistical difference between the heating requirements of the two groups of houses in the study and demonstrates quite clearly that excess ventilation by open windows can easily negate the benefits of increased insulation.

While care was taken to ensure accuracy of measurements on site, time prevented a complete study of all the variables affecting the window opening/ventilation rate relationship. The relationship is not so simple and straightforward as might be implied from Fig. 4 above. Obviously degree of shelter; position of open windows relative to the wind direction and to one another; arrangement of opening of internal doors will all affect the ventilation rate even at constant wind speed and direction. Nor would it appear that, all other things being equal, the relationship is necessarily a smooth function. Lee and Dickson both report on a large increase in ventilation rate within a room at even the smallest window opening with an increase in the rate as the window is opened further which is not necessarily pro-rata with the increase in opened area.

Conclusions

This paper has attempted to demonstrate a modification to the calculations of total heat losses by taking into account both the opening of windows and the fact that mean house temperatures are likely to decrease as the outside temperature decreases. It has also attempted to highlight the need for further study of the factors governing the ventilation rates in houses arising from the tendency of occupants to open windows.

References

[1] Brundrett G.W., Window opening in houses: and estimate of the reasons and magnitude of the energy wasted. E.C.R.C. Report, No. ECRC/M801, March 1975

[2] Campbell P.M., The better insulated house programme. E.E.C. Report No. EUR7419, March 1982.

[3] Lee H.S. A field study of natural ventilation in better insulated houses. Edinburgh, August 1982.

[4] Dick J.B. and Thomas D.A., Ventilation research in occupied houses. J.I.H.V.E. 19 306 - 326, 1951.

[5] Brundrett G.W. Ventilation: a behavioural approach. Energy Research 1, 289 - 298, 1977

[6] Dickson J. Ventilation with open windows. E.C.R.C. Report No. ECRC/M1329, April 1980.

[7] Billington N.S., Thermal insulation and domestic fuel consumption. Building Services Engineer, 23-24 April 1972.

Fig. 1. Gross daily heating requirements for the highly insulated (test) houses and the normally insulated (control) houses based on a constant internal temperature of 18°C and a fixed ventilation rate of 0.75ach.

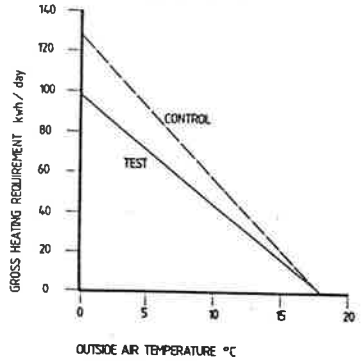


Fig. 2. Gross daily heating requirements for the test and control houses based on a fixed ventilation rate but with an internal temperature varying with outdoor air temperature.

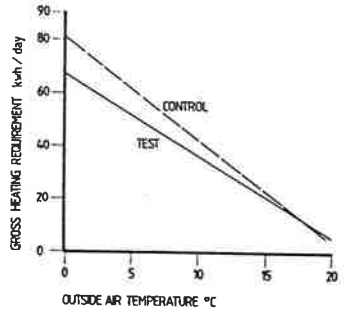


Fig. 3. Relationships between number of open windows in a house and outdoor air temperature.

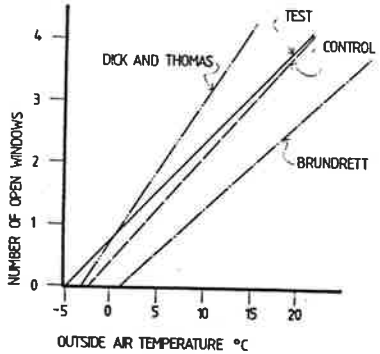


Fig. 4. Relationships between ventilation rates and number of open windows at varying wind speeds based on data from three sources.

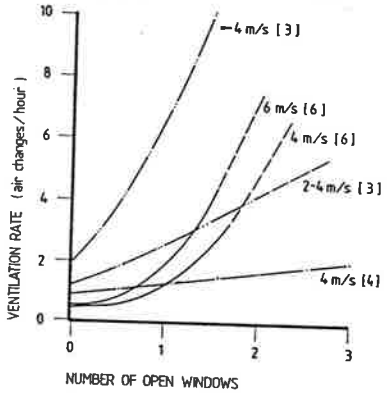


Fig. 5. Variation of ventilation heat losses with outside air temperature based on data from Lee (3) for wind speeds of 2-4 m/s for both test and control houses, including allowance for different mean house temperatures.

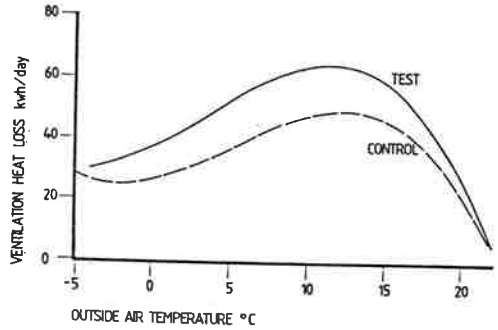


Fig. 6. Variation of ventilation heat losses with outside air temperature based on data from Dick & Thomas (4) for a wind speed of 4 m/s for both test and control houses, including allowance for different mean house temperatures.

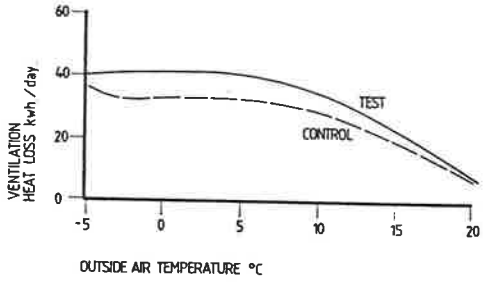


Fig. 7. Variation of ventilation heat losses with outside air temperature based on data from Dickson (6) for a wind speed of 4 m/s for both test and control houses, including allowance for different mean house temperatures.

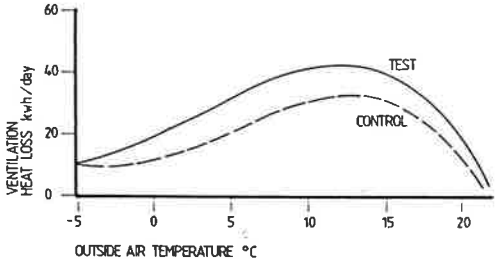


Fig. 8. Variation of total heat losses with outside air temperature based on ventilation losses in Fig. 5 for test and control houses including allowance for varying mean house temperatures.

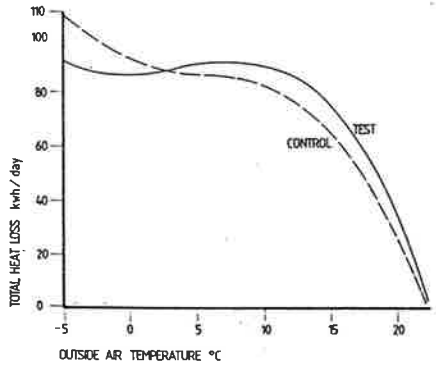


Fig. 9. Variation of total heat losses with outside air temperature based on ventilation losses in Fig. 6 for test and control houses including allowance for varying mean house temperatures.

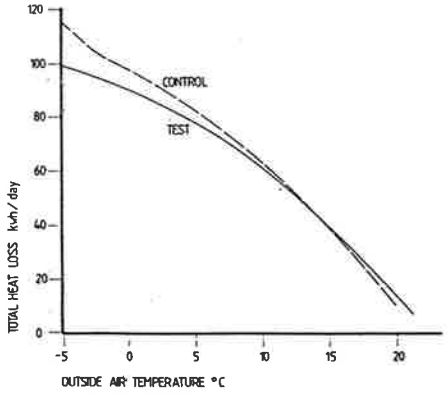


Fig. 10. Variation of total heat losses with outside air temperature based on ventilation losses in Fig. 7 for test and control houses including allowance for varying mean house temperatures.

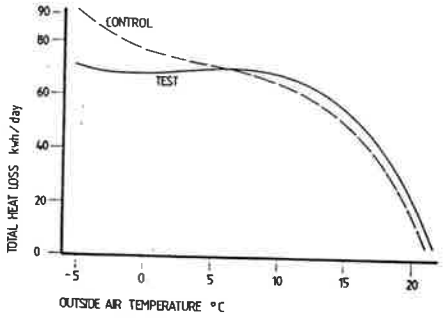


Fig. 11. Variation of energy consumption with outside air temperature.

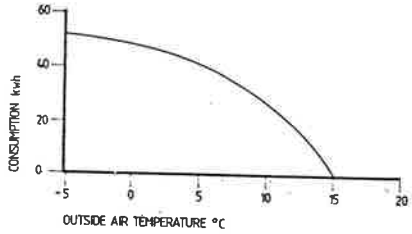
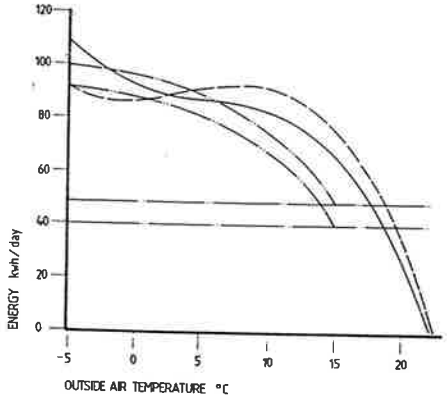


Fig. 12. Comparison of total heat losses (Fig. 8) and total energy input.



SUMMARY

R.A. Mutch: Heat losses due to window opening by occupants. This paper examines the excess ventilation losses arising from window opening behaviour by occupants and using data from a number of sources relates these losses to the outside air temperature. These excess ventilation losses alter the shape of the total heat loss predictions and bring these more into line with the energy consumptions measured. Excessive ventilation by open windows is shown to negate the benefits of increased fabric insulation.

RESUME

R.A. Mutch - La perte de chaleur causee par l'ouverture des fenetres par les occupants. Dans cet article, on examine les plus grandes pertes de ventilation qui sont causees par l'ouverture des fenetres par les occupants de maison et, employant les donnees prises de plusieurs sources, on etablit un lien entre ces pertes et la temperature d'air a l'exterieur. L'augmentation de la perte de ventilation change toutes les predictions au sujet de la perte de chaleur et les font conformer plus a la consommation de l'energie mesuree. La ventilation excessive par les fenetres ouvertes reduit les benefices de plus de calorifugeage de la structure.

KURZFASSUNG

R.A. Mutch - Warmeverlust durch Offnen von Fenstern. Die vorliegende Studie befasst sich mit der durch das Offnen von Fenstern bedingte Verlust von Raumwarme. Aus verschiedenen Quellen gewonnene Daten werden in einen Bezug zur jeweiligen Aussentemperatur gestellt. Diese Raumwarmeverlust wirkt sich auf die prognostizierten Gesamtwarmeverlustwerte und lassen diese eher in ein Verhaltnis zu den gemessenen Energieverbrauchswerte bringen. Es wird erwiesen, dass eine ubermassige Luftung durch Fenster-Offnen die durch erhohte Isolierungswerte gewonnenen Vorteile negiert.