VENTILATION ASPECTS OF A LOW ENERGY HOUSE

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Abstract

The paper presents the ventilation and infiltration results obtained from a low energy house in N.Ireland. A mechanical ventilation system with a heat recovery capability is installed in the house, to complement the high thermal insulation levels. The annual energy savings due to heat recovery are calculated, as well as the ventilation and infiltration losses. Ventilation is shown to be sufficient to avoid moisture build up within the house, and provides a pleasant living environment. Also the daily behaviour of the mechanical ventilation system, and the heat recovery system are investigated, showing a larger than anticipated contribution of cooking to heat recovery.

Introduction

The house from which the following ventilation and infiltration results have been taken, was designed and built by a local insulation manufacturer, to demonstrate how space heating demands can be reduced by the use of specialist building techniques.

The house has a number of innovative energy saving features. A unique polystyrene based roof, and external polystyrene wall insulation, create a highly insulated building envelope, around a massive internal structure. Space heating is supplied from an electrically heated water storage boiler to underfloor pipes dowmstairs, and to conventional radiators upstairs. Heat distribution to each room in the house is individually controlled by a central computer. A mechanical ventilation and heat recovery system, incorporating an air to air heat exchanger was installed to complement the very air-tight and extremely well insulated building. The main living areas have a southerly aspect , to benefit from solar gain, through windows fitted with low emissivity glass. Temperatures have been monitored at a large number of points over the last two heating seasons to study the thermal performance of the building structure.

Fresh air needs.

It was realised that in order to utilize the house's high level of insulation to its full potential, the natural infiltration would have to be kept to a minimum. Before and during the first heating season the house was pressure tested several times. The infiltration rate was estimated from the air change rate at 50 Pa, using equation 1.(1)

$$Q_{inf}=Q_{50}/20\ (h^{-1}) \qquad (1)$$

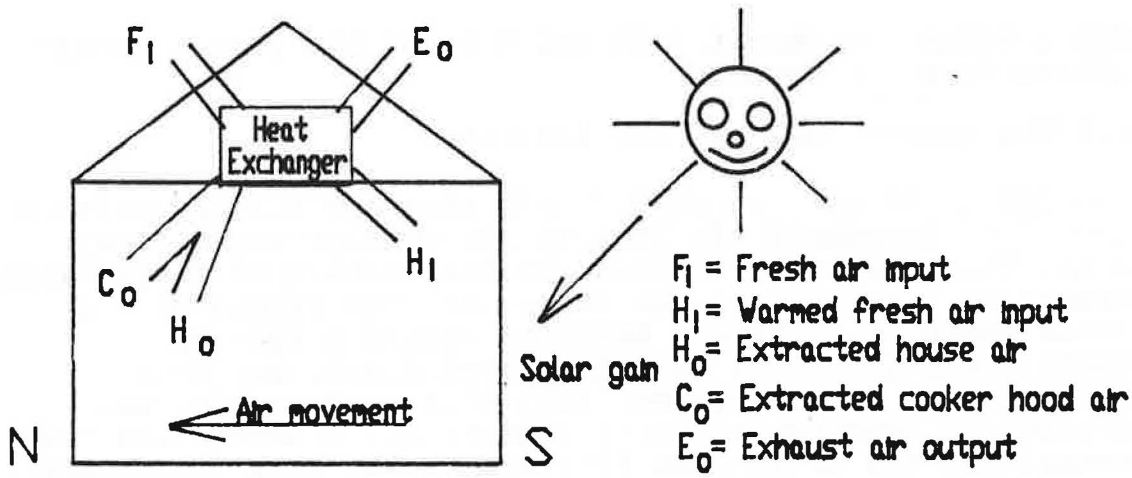
Improvements were made to the air tightness until a figure of 0.2 air changes/hour (ac/h) was achieved. This is equivalent to 36 litres/sec (l/s)of fresh air, very near to the low limit for a healthy environment (8 l/s per person (2)). The mechanical ventilation system provides an extra 0.3 ac/h, bringing the total air change rate to 0.5 ac/h. This reduces the risk of condensation, which can become a major problem given the very damp climate in N.Ireland.

Throughout the two year monitoring period, a number of moisture readings were taken in the building fabric, to determine the effectiveness of the ventilation system, and to test for interstitial moisture build-up. Although there was variation in the humidity in the roof and walls, levels never approached the stage at which condensation might occur. Actual moisture levels in the rooms were not continuously monitored, but a combination of lack of condensation and occupier satisfaction suggests that the ventilation is sufficient.

The mechanical ventilation system

In order to distribute the heat supplied by the underfloor heating system, concentrated in the south side of the house, and any solar gain which enters the house, air extraction and input points are designed to bring air from the warmer south side to the cooler north side (Figure 1). Air is extracted from northern rooms and passed through the heat exchanger before output through an exhaust duct. The replacement fresh air from outside is passed through the heat exchanger and released into the south side of the house. However this does not give a homogeneous distribution of air temperatures throughout the house. The thermal mass of the internal structure means that much of the floor heat and solar gain are stored, leading to wall and floor temperature differences of up to 3°C between the south and north sides of the house. This obviously affects the air-temperatures in the different rooms, which cannot be totally equalized by the forced northerly air movement. Heat losses

FIGURE 1. The mechanical ventilation system.



through fabric and infiltration cause a reduction in temperature before the air is extracted, leaving extracted air temperatures 1-2°C less than the 17°C average air temperature in the house.

Energy aspects

The mechanical ventilation system is also responsible for quite considerable energy losses from the house. The heat exchanger recovers energy from the extracted air stream, comprising air from the living space and also from the cooker hood, (H_o and C_o), and exchanges it to the incoming fresh air (F_i), as shown in figure 1.

(1) The energy loss through the ventilation system

The net energy loss rate via the mechanically ventilated air is calculated according to equation 2. The input air stream (H_i) includes both the recovered energy and the power consumption of the fans.

$$VLs=P.Cp((Q_{co}.T_{co})+(Q_{Ho}.T_{Ho})-(Q_{Hi}.T_{Hi})) \qquad (2)$$

This was calculated for hourly values of outside air temperatures over a two month winter period and used to produce a regression equation predicting the energy loss due to ventilation over two 191 day heating seasons.

Year 1 Ventilation energy loss=998 kWh
Year 2 Ventilation energy loss=933 kWh

These values represent 7.1% and 6.7% of the yearly energy losses from the house.

(2) The energy loss via infiltration

The infiltration rate of 0.2 ac/h accounts for approximately 130 m^3 of household air lost to the outside world every hour. This has to be replaced by the heating of a equivalent amount of generally cooler fresh air. The figure of 0.2 ac/hr quoted earlier was measured within a year of completion, and could have increased since, due to a reduction in air-tightness. Also high wind speeds, the unrecorded openings of outside doors and windows, and the occasional use of an open fire means that this figure must be regarded as a minimum.

The infiltration energy loss rate is given by equation 3:

$$ILs=Q_{inf}.P.Cp.(17.0-T_{air}) \qquad (3)$$

Year 1 Infiltration energy loss=2284 kWh
Year 2 Infiltration energy loss=2184 kWh

These values represent 16.2% and 15.6% of the yearly energy losses from the house.

(3) The heat recovery achieved

Table 1 shows the energy that would be lost through infiltration and ventilation without heat recovery (A), and the savings due to heat recovery (D). Columns (B) and(C) show the actual energy losses with heat recovery.

TABLE 1. Energy savings due to heat recovery.

Year	Energy loss no recovery (A)	Energy loss infiltration (B)	Energy loss ventilation (C)	Energy recovered from ventilation (D)
Yr 1	5710	2284	998	2428
Yr 2	5460	2184	933	2343

Units: kWh/heating season

These figures translated into percentages of total ventilation and infiltration energy, become:-

Non-recovered ventilation energy loss (C) =17.5%
Non-recoverable infiltration energy loss(B) =40.0%
Recoverable ventilation energy (D) =42.5%

If the infiltration rate is above 0.2 ac/h, the actual energy saved would remain the same, but the total energy losses via infiltration and ventilation would increase.

The economic assessment of these figures is dependent on local energy supplies and prices. In N.Ireland, the Economy 7 tariff prices energy used during 7 night-time hours at a third of the price of day-time energy. This encourages energy to be stored for use during the day, either using thermal bricks or as in this case water as the storage material. Using the cheaper tariff, the cost savings amount to £54 and £51 for the two years. However because the fans have to run 24 hours a day, the energy used is charged at the higher rate for 17 hours, resulting in annual running costs of £30. Thus the net annual saving attributable to the heat recovery system is only £20-£25. This is not sufficient alone to justify the installation, which in this case cost £1000. However, given the relatively small overall space heating cost, it can account for a sizable amount (20%) of the total energy savings.

Details of the heat exchangers performance.

At different periods during the year, and at different times of the day, the rate of energy exchange from the extracted air (H_o+C_o) to the fresh air (F_i) varies. Energy is lost from the extracted air and exchanged to the fresh air which has then gained energy. The main influence upon this exchange is the temperature of the fresh air input, and both the energy lost across the exchanger and the energy gained, show good correlations with fresh air temperature,(-0.94 and -0.78). The correlation figure of 0.78 for the gained energy, is somewhat dependant on the varying temperature of the cooker hood extracted air (C_o). This varies considerably more than the air extracted from the remainder of the house, due to the close proximity of the heated floor, and the influence of cooking activities. During periods when this cooker hood air is at a higher temperature, the energy gain actually exceeds the energy loss. This effect could be accounted for by greater fan speeds selected when cooking, and also by the increased amounts of moisture in the extracted air resulting from cooking. Once this air is cooled in the heat exchanger there is a release of latent heat. The majority of this will be absorbed by the fresh air, being the cooler of the two air streams. This is confirmed by the temperature increase in the incoming fresh air into the house.

Conclusions

The inclusion of a mechanical ventilation system in a highly insulated and very air-tight building is a necessity for healthy human habitation. In terms of energy saving, the inclusion of a heat recovery capability would take many years to pay-back its initial cost. The 'problem' is that the N.Ireland climate is too warm for the heat exchanger to work at high efficiencies. However, if a building is built to the high thermal standards and high air tightness that we hope will become the norm in the future, it becomes essential to include a mechanical ventilation system, preferably with heat recovery. The extra capital investment must be considered as an essential additional cost in the thermal upgrading of the building.

Nomenclature

Q_{inf} = Infiltration rate (h^{-1})
Q_{50} = Air change rate at 50 Pa
Q_{Co} = Air flow rate in C_o (m^3/s)
Q_{Ho} = Air flow rate in H_o (m^3/s)
Q_{Ho} = Air flow rate in H_o (m^3/s)
P = Air density (kg/m^3)
Cp = Specific heat of air (J/kg/K)
TC_o = Temperature of cooker air (C)
TH_o = Temperature of house air (C)
TH_i = Temperature of warmed fresh air (C)
T_{air} = Temperature of the outside air (C)
ILS = Energy loss due to infiltration (kW)
VLS = Energy loss due to ventilation (kW)

References

(1) AIVC Applications Guide 1986
(2) CIBS Guide 1986