A ‘use factor’ for HRV in intermittently heated dwellings

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ABSTRACT

When considering the performance of HRV systems, the discussion is generally focusing on the reported effectiveness of the air-to-air heat exchanger. Although some excellent presentations at the AIVC conference in the past have dealt with uncertainties related to the test of that effectiveness, the fact that the heat recovered by the HRV unit might not be useful in an intermittently heated dwelling without room-by-room based demand control is usually not considered. Therefore, the ‘use-factor’ for the recovered heat is quantified in this paper.
The goal of this project was to investigate the performance of heat recovery units in low energy buildings by simulating different buildings under varying conditions. The influence of several parameters on this performance is studied: the type of building, the insulation and airtightness, the ventilation flow rates, the ventilation strategy, the heat exchanger effectiveness, the occupancy pattern and the demanded comfort level.
The results suggest that, although a heat exchanger can have an effectiveness of e.g. 75%, only approximately 40% of the heat in the extracted air is recovered and supplied usefully to the rooms.

KEYWORDS

MHRV, air-to-air heat exchanger, use factor, effectiveness

1 INTRODUCTION

A balanced ventilation system is usually equipped with two duct systems and two electrical fans, displacing the same amount of air. Polluted indoor air is extracted from the wet rooms (i.e. kitchen, bathroom and hall) and fresh outdoor air is supplied to the dry rooms (i.e. bedrooms, living room and study). When an air-to-air heat exchanger (AAHX) is installed between the two air streams, the cold supply air is preheated by the warm extracted air. The use of a mechanical heat recovery ventilation (MHRV) system thereby reduces the heat demand of the building.

MHRV systems can be compared on several levels. Producers of heat exchangers provide an effectiveness of the device, depending on the flow rates. These values can be high, more than 90% (EUROVENT, 2017). This is however a value representing the effectiveness on component level. There can be leakages in the duct system or short circuits between the supplied and extracted air. These unintentional air flows will reduce the efficiency on unit level (Manz, 2001). Also the airtightness of the building will have an influence on the efficiency of the system. It was found in the studies by Binamu and Lindberg (2001), Roulet

(2001) and Dodoo (2011) that the efficiency of the heat recovery drops when the building has a bad airtightness, because no energy can be recovered 66 from air leakages. This observation lead to the inclusion of minimum airtightness recommendations for dwellings equipped with MHRV, e.g. a maximum leakage of 1 ACH50 is recommended in the Belgian residential ventilation standard NBN D 50-001.

Different results were obtained by Juodis(2006), who studied the influence of the building's thermal properties on the effectiveness of the heat recovery. The author defined a balance temperature of a building at which the heat gains compensate the losses. The closer the external temperature is to this balance temperature, the smaller the effectiveness of the heat recovery, because the losses are already compensated by the gains. According to the author, the average annual effectiveness of the heat recovery decreases when a building has more insulation and better airtightness since this reduces the balance temperature of the building.

However, there is more. The approach proposed by Juodis is inherently steady state, while (especially) residential buildings are usually heated according to a dynamic heating pattern and only partially heated. In a building where all rooms have a heat demand, the percentage of the heat in the extracted air that is usefully recovered is equal to the effectiveness of the AAHX. The occupants of a house do not always heat the entire building, but e.g. heat only the occupied rooms. The non-occupied dry rooms will in this case still receive preheated supply air. The heat in this air is recovered by the AAHX, but will not completely contribute to the reduction of the heat demand of the building. It will instead unnecessarily elevate the temperature in the empty rooms and increase the transmission and exfiltration losses to the exterior.

In this paper, we propose the adoption of a 'use factor' that accounts for this effect when the implementation of MHRV is considered. We first propose a definition of this use factor and then show it's effect through the dynamic heat load simulation of an archetypical Belgian detached dwelling.

2 USE FACTOR DEFINITION

For a given case, the total amount of heat that is extracted by the ventilation system, Q_e, and the amount of heat recovered from the extracted air by the heat exchanger, Q_r can be determined as well as the total yearly heat demand, Q. Additionally, the heat demand of the building can also be calculated/measured/simulated when no heat exchanger is installed between the two air streams (or a heat exchanger with an effectiveness of 0%). This heat demand is called Q_0. Likewise, the heat demand Q_1, with a perfect heat exchanger (100% efficiency) between the two airstreams can be defined. Finally, a situation where all ventilation flow rates are reduced to 0m /h can be considered, resulting in the heat demand Q_nv.

With these concepts, assuming flow rate and effectiveness are constants, the ratio of Q_r and Q_e are equal to the test effectiveness η_1.

$$\eta_1 = \frac{Q_r}{Q_e} \quad (1)$$

A second effectiveness, η_2, is defined as the ratio of the useful recovered heat (Q_0 -Q) to the heat recovered by the heat exchanger (Q_r) or the fraction of the recovered heat that has been usefully supplied to the rooms. This is nothing other than the use factor described above. The heat that was not usefully supplied (e.g. supplied to a non-heated room), is then represented by 1-η_2.

$$\eta_2 = \frac{Q_0 - Q}{Q_r} \quad (2)$$

Alternatively, a third effectiveness, η_3, is defined as the ratio of the useful recovered heat (Q_0 - Q) to the extra heat loss incurred by adding ventilation without heat recovery (Q_0 - Q_nv).

$$\eta_3 = \frac{Q_0 - Q}{Q_0 - Q_{nv}} \quad (3)$$

The use factor for the MHRV is then defined as the ratio of η_3 en η_1.

3 USE FACTOR VALUES FOR AN ARCHETYPICAL DWELLING

The effect of the use factor defined above is illustrated on an archetypical Belgian detached dwelling, of which the floor plan is shown in figure 1. The total volume of the dwelling is 379 m3 and the gross floor area is 137 m2. TRNSYS was used to simulate the building and calculate all room temperatures and heat demands. The study was limited to the Belgian climate, and only the heating period was taken into account.

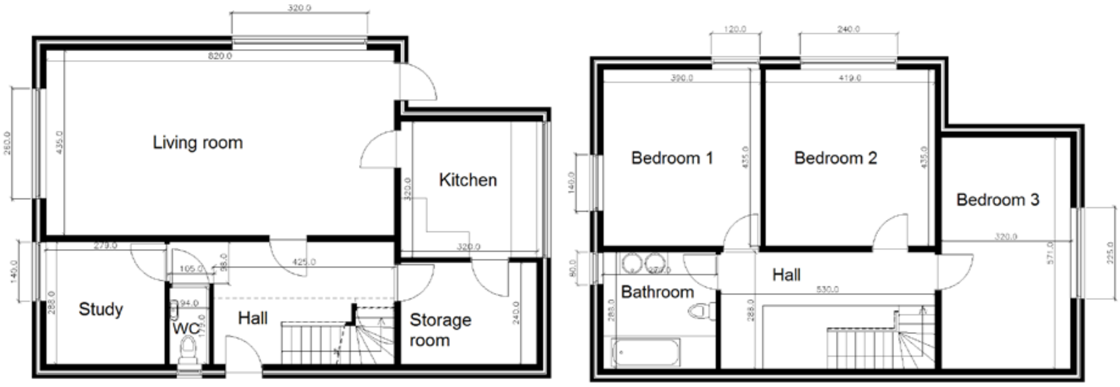

Figure 1:Figure caption

Table one lists the results for η_1, η_2, η_3 and the alternative use factor based on η_3 for this case study dwelling under different general energy performance levels of the building envelope (including insulation and airtightness), expressed as the total annual heat load per square meter of floor area.

Table 1: Table Caption

EP level	**η_1**	**η_2**	**η_3**	**UF (η_3)**
60 kWh/m a	0,75	0,50	0,56	0,75
30 kWh/m a	0,75	0,52	0,64	0,86
15 kWh/m a	0,75	0,49	0,74	0,99

There is a large difference in values obtained for the two alternative definitions of the use factor. The use factor based on the amount of usefully supplied heat to the room,η_2 can be as low as 50%. This means that less than 40% of the heat extracted by the ventilation system is actually supplied usefully to the rooms of the dwelling. The use factor based on the saved heating demand at the building level is much higher and more dependent on the overall energy performance of the envelope.

Both approaches are valid but should be used in different contexts. From the perspective of the operational assessment of the MHRV unit, the first approach is a good measure of the cost-benefit balance, operational cost and return on investment that is to be expected. The second approach relates to the expected impact on the annual heat load calculation.

η_2, in contrast to η_3, is correlated to the occupancy rate of the dwelling (assuming that heating patterns and occupancy are correlated). This is due to the fact that η_2 is a ratio of heat fluxes at the unit level (Q_r) and at the room level (Q_0 – Q), while η_3 is only a function of room/building related parameters.

The improvement of the energy performance of the building envelope causes the temperature throughout the dwelling to be more constant over time and uniform with respect to the different spaces, therefore reducing the effect of intermittent dynamic heating. Similarly, the second use factor increases substantially with decreasing flow rate, since the denominator (the increase in annual heat load due to ventilation) decreases more rapidly than the nominator because the temperature redistribution that is cause by the circulation of air is smaller.

Both use factor definitions are independent of the test effectiveness of the AAHX (η_1).

4 CONCLUSIONS

This paper proposed two alternative definitions for a use factor for the performance assessment of MHRV ventilation. It shows that, based on a simulated case study for an archetypical Belgian detached dwelling, although a heat exchanger can have an effectiveness of e.g. 75%, only as little as 40% of the heat in the extracted air is recovered and supplied usefully to the rooms.

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