Technologies to overcome effects of condensation in exchangers of ventilation units - analysis of monitored field studies

Bart Cremers[*1], Tristan Bakker[1]

[1]*Zehnder Group Zwolle*
Lingenstraat 2
8028 PM Zwolle, The Netherlands
[*] *bart.cremers@zehndergroup.com*

ABSTRACT

Balanced ventilation with heat recovery is an efficient way to maintain low heating demand for ventilation in residential buildings. Laboratory measurements of today's heat recovery ventilation units show high temperature recovery efficiency during standard conditions. In practice, however, the recovery efficiency may decrease due to circumstances that deviate from the standard laboratory conditions.
The present study shows detailed measurements of two field tests with similar balanced ventilation systems installed in houses. One of the houses is in The Netherlands and has a heat exchanger installed (for heat recovery). The other house is in Austria and has an enthalpy exchanger installed (for heat and moisture recovery). During the same period in October and November 2016, various parameters were monitored among which temperatures and humidities of the air streams, extract and supply fan speeds and their corresponding flow rates. Outdoor temperatures vary in the range of 22 °C at the start of the observed period until -2 °C at the end of the observed period. Data is monitored on a 5-minute interval time, and later analysed using the hourly averaged values of the parameters.
From the monitored data, it is shown how the thermal recovery efficiency correlates with other parameters as outdoor temperature, and the combination with the dew point of the extract air. The effects of condensation on fan behaviour is shown for a mass flow balance correcting algorithm, and compared to measurements without correction of mass flow balance. Moreover, the thermal recovery efficiency is shown for the ventilation systems with enthalpy exchanger to compare them with the systems with heat exchanger.
Conclusion of the present study is that a mass flow balance correcting algorithm maintains a high thermal recovery efficiency for a balanced ventilation system, even when condensation occurs in the extract channels of the heat exchanger. Because of moisture transfer, enthalpy exchangers experience no condensation, and therefore show no change in thermal recovery efficiency than heat recovery systems, even when outdoor temperature drops below the dew point of the indoor climate. For the enthalpy recovery units, the thermal recovery efficiency is only a function of ventilation air flow rate.

KEYWORDS

Residential ventilation, heat recovery efficiency, condensation, mass flow balance, enthalpy exchanger

1 INTRODUCTION

Balanced ventilation with heat recovery is an efficient way to maintain low heating demand for ventilation in residential buildings (Cremers, 2012). Laboratory measurements of today's heat recovery ventilation units show high temperature recovery efficiency during standard conditions. In practice, however, the recovery efficiency may decrease due to circumstances that deviate from the standard laboratory conditions.
Maintaining a high thermal recovery efficiency not only safeguards a comfortable supply temperature of fresh air during cold outdoor periods, it also reduces the heating demand for the building further. Using an enthalpy exchanger, the supply of fresh air is maintained not only on a high temperature level, but also on a high humidity level, leading to higher indoor humidity levels, and therefore increasing the level of comfort in the cold season (Cremers, 2014).

2 MONITORING SET-UP

The present study shows monitored data from two field studies with similar balanced ventilation systems installed in houses. One of the houses is in The Netherlands and has a heat exchanger (for heat recovery) installed (see fig. 1). The other house is in Austria and has an enthalpy exchanger installed (for heat and moisture recovery). The monitoring results presented in this work are part of a larger monitoring project of six ventilation installations in The Netherlands, Germany and Austria.

Figure 1: Photograph of the ventilation unit with a heat exchanger in the house in The Netherlands.

During the same period in October and November 2016, various parameters are monitored on a 5-minute interval time, and later analysed using the hourly averaged values of the parameters. The temperatures and humidities are measured with built-in sensors. They are located in the ventilation unit in the outdoor air (ODA), the supply air (SUP), the extract air (ETA) and the exhaust air (EHA). More specifically, outdoor and extract air temperature are measured when they enter the ventilation unit. The supply and exhaust air temperature are measured in the outlet of the fans. Also monitored are the fan speeds of the extract and supply fan, and their corresponding flow rates.
Outdoor temperatures vary in the range of approximately 22 °C at the start of the observed period until -2 °C at the end of the observed period.

3 RESULTS AND ANALYSIS

The results are presented mainly in the thermal recovery efficiency as a function of the outdoor temperature. The thermal recovery efficiency based on the supply side is calculated as the temperature change in the supply channel relative to the maximum possible temperature change ($T_{SUP} – T_{ODA}$) / ($T_{ETA} – T_{ODA}$). The thermal recovery based on the extract side is calculated as the temperature change in the extract channel relative to the maximum possible temperature change ($T_{ETA} – T_{EHA}$) / ($T_{ETA} – T_{ODA}$). Unlike for standardized laboratory measurements, both recovery efficiencies are deliberately not corrected with mass flows to see the effect of any imbalance due to possible condensation.

3.1 Heat recovery without mass flow balance correcting algorithm

Heat recovery ventilation units without mass flow balance correcting algorithm are used in many dwellings nowadays. The two fans in these units run in constant fan speed. This means that for a specific flow pre-set as decided by the user (low, medium, high) the fan speed is independent of any change in the air resistance of the system, including ducts and the unit itself. In fig. 2 the thermal recovery efficiency based on the supply side for a unit without mass flow balance correcting algorithm is shown as a reference. This has been monitored in 2014 with a unit that had a commissioned air flow unbalance of 7% (with less extract than supply air) with an average extract air flow of 210 m^3/h. This had the effect, as shown in fig. 2, that for a heat exchanger without any condensation, the thermal efficiency was monitored to be between 85% and 95%.
When outdoor temperature drops below approximately 7 °C, there is a chance that condensation may be formed. Without mass flow balance correcting algorithm, the condensation in the extract channels of the heat exchanger increases the resistance, and therefore the extract flow decreases. This makes the unbalance in condensing cases even larger, which is showed in fig. 1 by a decreasing thermal recovery efficiency, even down to 60%.

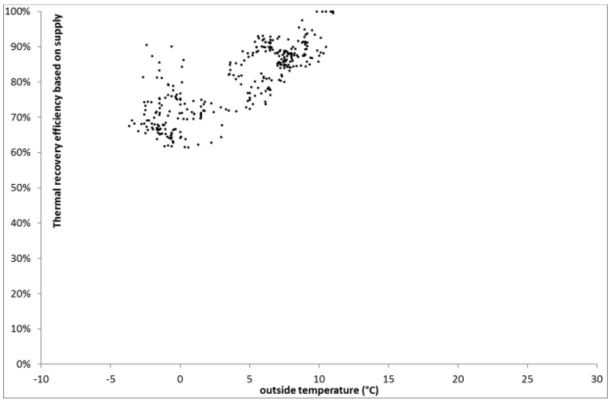

Figure 2: Thermal recovery efficiency based on supply for a heat recovery unit without mass flow balance correcting algorithm.

3.2 Heat recovery with mass flow balance correcting algorithm

Heat recovery units with mass flow balance correcting algorithm preserve the mass flow balance when the air resistance changes in the system because of condensation or even filters accumulating with dust. However, because the occupant changes the flow rate according to his presence and behaviour in the house, the fan percentages itself do not give a clear picture. The ratio between the supply fan percentage and the extract fan percentage gives a clearer picture. Fig. 3a shows fairly constant ratio of 1.15 for outdoor temperature above approximately 10 °C. Apparently in this installation the resistance of the supply side is larger than the extract side, so the supply fan must work harder for the same air flow rate. For outdoor temperature below 10 °C, there is a decreasing trend in the ratio, which - after closer observation of the parameters - comes from the effect that the extract fan percentage increases for colder outdoor temperatures. Although the fan percentages change relative to each other, fig. 3b shows that the mass balance is preserved, noticed by the ratio between supply mass flow and extract mass flow which stays at a value of 1 ± 0.04.

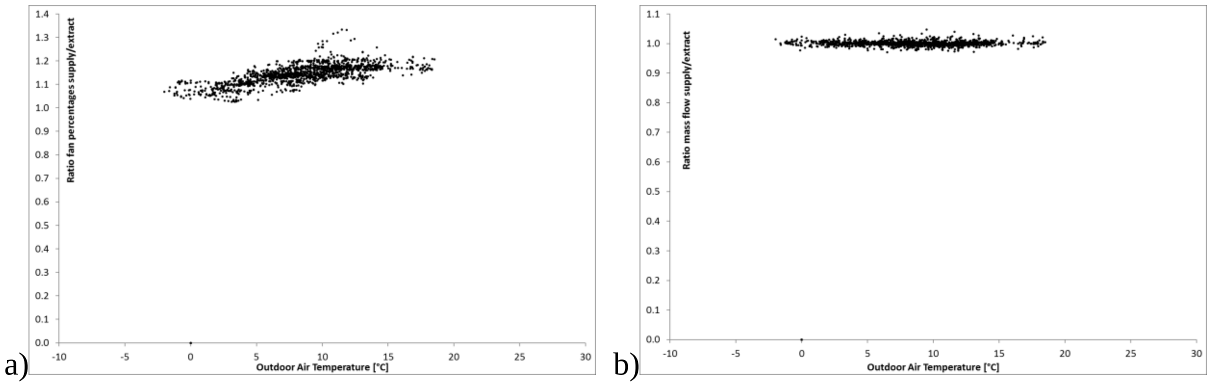

Figure 3: Ratio in fan percentage (a) and ratio in mass flow (b) between supply air and extract air.

The resulting thermal recovery efficiency based on the supply is shown in fig. 4a as a function of outdoor temperature. With the mass flow balance correcting algorithm, there is no effect from any unbalance in the mass flows. Fig. 4a indeed shows that high recovery efficiency can be maintained (above 88% for the temperature range between -2 and 19 °C) for an average flow rate of 180 m^3/h.

It seems however that there is still a trend for the recovery efficiency to decrease when outdoor temperatures get lower. This trend is also observed in two similar ventilation systems during the same monitoring period. However, the decreasing trend is much less than for heat recovery units without mass flow balance correcting algorithm.

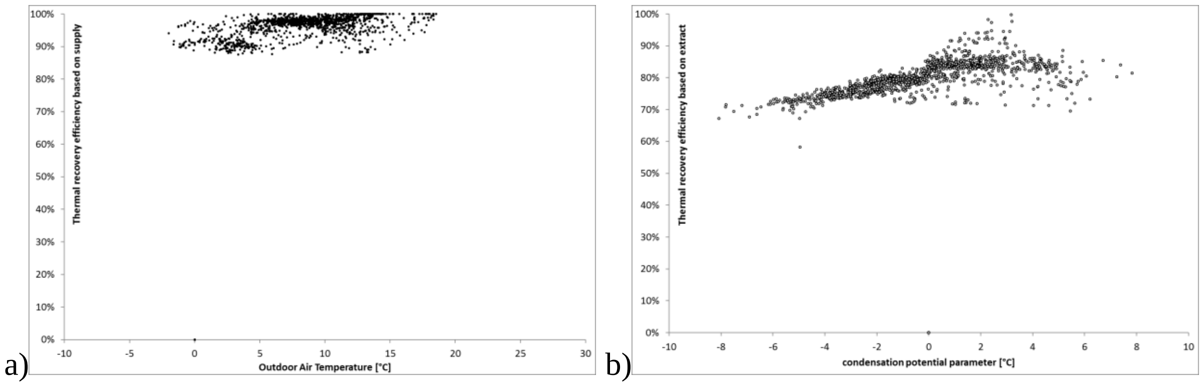

Figure 4: a) Thermal recovery efficiency based on supply as function of outdoor temperature;
b) Thermal recovery efficiency based on extract as a function the condensation potential parameter.
Both are for a unit with heat exchanger and a mass flow balance correcting algorithm.

Further analysis of condensation effects has been focused on the thermal recovery efficiency based on the extract. In fig. 4b it has been expressed as a function of the condensation potential parameter (outdoor temperature minus dew point of extract air). It is likely that condensation will take place when this condensation potential parameter is below zero, and the more negative it is, the more condensation can be formed.

Fig. 4b shows that for negative values of the condensation potential parameter, the thermal recovery efficiency based on the exhaust deviates from the positive values, and shows a decreasing trend for more negative values. This is a clear indication that condensation in the heat exchanger is hindering the thermal transfer between the two air streams in the heat exchanger, and therefore the recovery efficiency is going down. The water in the exchanger decreases the area for an efficient heat transfer. Because mass balance is still preserved (see fig. 3b), the decrease in recovery efficiency is much less than for units without mass flow balance correcting algorithm.

3.3 Enthalpy recovery

Enthalpy recovery units have an exchanger which not only transfers heat, but also moisture. The moisture is transferred in vapor form through microscopic channels in the foils of the enthalpy exchanger. Because of the moisture transfer, condensation is not likely to be formed in these exchangers.

Fig. 5 shows the thermal recovery efficiency based on the supply as a function of outdoor temperature. The hourly averaged values appear as two distinct, nearly horizontal lines, and a lower line made up of occasional dots.

The two distinct lines show that the recovery efficiency for a unit with enthalpy exchanger is not a function of the appearance of condensation anymore (in fact, there is no condensation). The recovery efficiency remains only a function of the flow rate as set by the end user. The highest line (approximately 95%) corresponds to a set flow rate of 100 m^3/h and the other horizontal line (approximately 90%) corresponds to a set flow rate of 160 m^3/h.

The other dots in the graph - below 70% - belong to circumstances where heat recovery is not needed (e.g. when a comfortable indoor temperature has been reached, outside the heating season), and therefore the recovery efficiency is automatically gradually decreased by activating a bypass mechanism.

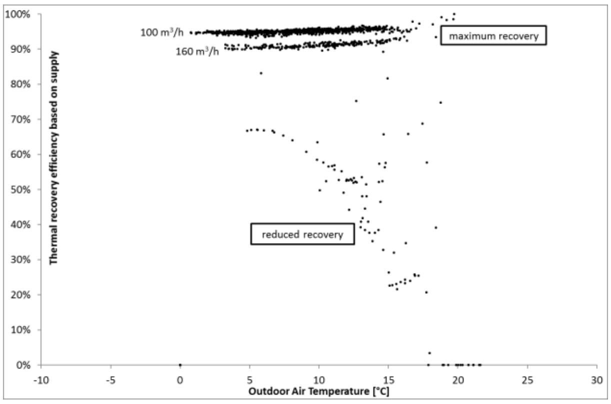

Figure 5: Thermal recovery efficiency (supply) against outdoor temperature for a unit with enthalpy exchanger.

4 CONCLUSIONS

Conclusion of this study is that a mass flow balance correcting algorithm maintains a high thermal recovery efficiency for a balanced ventilation system, even when condensation occurs in the extract channels of the heat exchanger. Although the condensation hinders the efficient area for transfer of heat through the foils, it has no effect on the balance between extract and supply air stream anymore. Therefore, thermal recovery efficiency stays above 88% (compared to monitored values down to 60% for units without mass flow balance correcting algorithm).

Because of moisture transfer, enthalpy exchangers experience no condensation, and therefore show no change in thermal recovery efficiency, when outdoor temperature drops below the dew point of the indoor climate. For the enthalpy recovery units, the thermal recovery efficiency is only a function of ventilation air flow rate.

5 REFERENCES

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