WINTER HEAT RECOVERY IN VENTILATION SYSTEMS: POTENTIAL AND LIMITATIONS OF SENSIBLE AND TOTAL RECOVERY IN THE EUROPEAN CLIMATES

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Introduction

Ventilation load:

- High performance buildings new or renovated have reduced thermal losses through the envelope.
- Ventilation losses becomes a significant share of the thermal energy needs.
- Envelope air tightness makes mechanical ventilation often necessary.
- Heat recovery systems can be deployed.
Introduction

Humidity control:

- Heat recovery systems in winter mode operation preheat the fresh air by cooling exhausted air.
- Total heat recovery systems also recover water vapor.
- Indoor air humidity is relevant for thermal comfort but can impact on occupants’ performance and satisfaction.
- If dehumidification is then required because of humidity control, heat recovery can be counter-productive.
Introduction

Aim:

• Calculate the potential energy and cost savings from heat recovery in ventilation.
• Contrast nominal and actual saving when introducing humidity control strategies and limitations to heat recovery.
• Map the performance in Europe.
Method

Ventilation cycle:

- OUTSIDE AIR (OA)
- RECOVERY (R)
- MIXED AIR (MA)
- RECIRCULATED AIR (RA)
- EXHAUSTED AIR (EA)
- SUPPLY AIR (SA)
- RETURN AIR (RA)

Heat recovery
Air handling
Humidity control:

$\frac{x_{SA}}{x_{RA}} = \frac{m_L}{m_{MA}}$

$\frac{x_{MA}}{x_{SA}} = \frac{m_L}{m_{MA}}$

$\frac{x_{R}}{x_{RA}} = \frac{m_L}{m_{OA}}$

(steady state moisture balance)
(dehumidification not required)
(dependence on R humidity)
**Method**

**Humidity control:**
\[ x_R \leq x_{RA} - \frac{m_L}{m_{OA}} \]

Specific Latent Load (SLL) = \( \frac{m_L}{m_{OA}} \)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Type of Building</th>
<th>Total W</th>
<th>Sensib. W</th>
<th>Latent W</th>
<th>Latent g/h</th>
<th>Airchange ( l/(s \text{ person}) )</th>
<th>SLL g/( kga )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seated, relaxed</td>
<td>Theatre, Cinema</td>
<td>100</td>
<td>60</td>
<td>40</td>
<td>57.6</td>
<td>5.5</td>
<td>2.4</td>
</tr>
<tr>
<td>Seated, writing</td>
<td>Offices, Hotel, Apartments</td>
<td>120</td>
<td>65</td>
<td>55</td>
<td>79.2</td>
<td>11.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Eating</td>
<td>Restaurants</td>
<td>170</td>
<td>75</td>
<td>95</td>
<td>136.7</td>
<td>10.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Seated, light activity, typing</td>
<td>Offices, Hotel, Apartments</td>
<td>150</td>
<td>75</td>
<td>75</td>
<td>108.0</td>
<td>11.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Slowly walking</td>
<td>Retail store, Bank</td>
<td>185</td>
<td>90</td>
<td>95</td>
<td>136.7</td>
<td>11.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Moderate dancing</td>
<td>Dance Hall</td>
<td>375</td>
<td>120</td>
<td>255</td>
<td>367.1</td>
<td>16.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Heavy activity</td>
<td>Gymnasium</td>
<td>525</td>
<td>185</td>
<td>340</td>
<td>489.4</td>
<td>16.5</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Method

Humidity control:

\[ x_R \leq \frac{x_{RA} - m_L}{m_{OA}} \]

\[ x_R \leq 5.7 \text{ g/kg} \]

\( t_{RA} = 20 \, ^\circ\text{C} \quad x_{RA} = 7.3 \text{ g/kg} \quad \text{SLL} = 1.6 \text{ g/kg} \)

1. SHR:

\[ x_{OA} \leq \frac{x_{RA} - m_L}{m_{OA}} \]
Method

Humidity control:

\[ x_R \leq x_{RA} - \frac{m_L}{m_{OA}} \]
\[ x_R \leq 5.7 \text{ g/kg} \]

\( t_{RA} = 20 \degree C \quad x_{RA} = 7.3 \text{ g/kg} \quad SLL = 1.6 \text{ g/kg} \)

1. SHR:
   \[ x_{OA} \leq x_{RA} - \frac{m_L}{m_{OA}} \]

2. THR:
   \[ x_{OA} \leq x_{RA} - \frac{m_L}{m_{OA}} \times (1-\varepsilon)^{-1} \]
Method

Humidity control:
\[ x_R \leq x_{RA} - m_L / m_{OA} \]
\[ x_R \leq 5.7 \text{ g/kg} \]
\[ (t_{RA}=20 \text{ °C} \ x_{RA}=7.3 \text{ g/kg} \ SLL = 1.6 \text{ g/kg}) \]

1. SHR:
   \[ x_{OA} \leq x_{RA} - m_L / m_{OA} \]

2. THR:
   \[ x_{OA} \leq x_{RA} - m_L / m_{OA} \times (1-\varepsilon)^{-1} \]
Method

Humidity control:

\[ x_R \leq x_{RA} - \frac{m_L}{m_{OA}} \]
\[ x_R \leq 5.7 \text{ g/kg} \]
\[ (t_{RA} = 20 \degree C \ x_{RA} = 7.3 \text{ g/kg} \ SLL = 1.6 \text{ g/kg}) \]

1. SHR:
\[ x_{OA} \leq x_{RA} - \frac{m_L}{m_{OA}} \]

2. THR:
\[ x_{OA} \leq x_{RA} - \frac{m_L}{m_{OA}} \ x \ (1-\varepsilon)^{-1} \]
\[ \text{or} \]
\[ \varepsilon \leq 1 - \frac{\Delta x}{(x_{RA} - x_{OA})} \]
Method

Calculation:
Energy and cost savings in ventilation have been determined:
• Hourly weather data for a whole representative year for 66 climates in Europe
• Different values of SLL (from 0.8 to 2.4 g/kg)
• Nominal effectiveness for sensible and total heat recovery: 70 %
• Seasonal efficiency of 0.8 for the gas water heater
• Costs charged per kWh for natural gas referred to final domestic users
• Outcomes represented on Geographic Information System (GIS), averaging the results for all the cities in the same climatic zone according Köppen-Geiger climate classification
Results

Sensible heat recovery – w/o limitation

SHR cost savings

Total heat recovery

THR cost savings
Results

Sensible heat recovery – controlled SLL = 0.8 g/kg
Results

Sensible heat recovery – controlled SLL = 1.2 g/kg
Results

Sensible heat recovery – controlled SLL = 1.6 g/kg
Results

Sensible heat recovery – controlled SLL = 2.0 g/kg
Results

Sensible heat recovery – controlled SLL = 2.4 g/kg
Results

Sensible heat recovery

SHR cost savings – w/o limitations

47.0 kgh

Total heat recovery

THR cost savings

color scale from less than 2 EUR (l/s)^{-1} to more than 16 EUR (l/s)^{-1} in steps of 2 EUR (l/s)^{-1}
Results

SHR cost savings – controlled SLL = 1.6 g/kg

Sensible heat recovery

SHR cost savings

Total heat recovery

THR cost savings

Introduction

Method

Results

Conclusions

color scale from less than 2 EUR (l/s)$^{-1}$ to more than 16 EUR (l/s)$^{-1}$ in steps of 2 EUR (l/s)$^{-1}$
Results

Total heat recovery – w/o limitations SLL 1.6 g/kg
Results

Total heat recovery – controlled SLL 1.6 g/kg
Results

THR cost savings – w/o limitations SLL 1.6 g/kg

color scale from less than 2 EUR (l/s)^{-1} to more than 30 EUR (l/s)^{-1} by 2 EUR (l/s)^{-1}
Results

THR cost savings – controlled SLL 1.6 g/kg

Color scale from less than 2 EUR (l/s)^{-1} to more than 30 EUR (l/s)^{-1} by 2 EUR (l/s)^{-1}

Sensible heat recovery

SHR cost savings

Total heat recovery

THR cost savings

Introduction

Method

Results

Conclusions
Conclusions

Findings

• Sensible and total heat recovery increase with duration and severity of the winter climatic conditions, from southern and Mediterranean climates to the northern regions
• Nominal heat recovery without control strategy is much higher for THR than for SHR - from two to three times - depending on the SLL
• SHR is reduced by the control strategy from 5 to 65 %, from Nordic to Mediterranean climates and from low to high SLL
• THR is more affected than SHR, with a reduction from 10 to 93 %, from Nordic to Mediterranean climates and from low to high SLL
• Costs follow a similar trend, with some variations due to the national energy prices, which may be different in countries with similar climates.
• Preliminary results: steady state, and winter
THANK YOU FOR YOUR ATTENTION!

ANY QUESTIONS?

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