Comfortable indoor climate

The human body can sense a temperature difference of about 1.5 °C. The maximum temperature difference between in- and outdoor, for which the comfort level has to be sustained, is set at 30 °C. The required ventilation rate of fresh air for health is 150 m^3h^{-1}. Heating by the fresh air (an efficient DC) fan is about 0.5 °C. This results in a maximum allowable temperature difference between the fresh air leaving the recuperator and the room air of 2 °C.

The temperature effectiveness of the recuperator therefore has to satisfy:

ε = realized temperature difference / maximum temperature difference =

$$(30 - 1.5 - 0.5) / 30 = 93 \qquad [\%] \qquad (1)$$

The heat capacitance flow (product of the air mass flow and the specific heat capacity) is:

C = airflow [m^3s^{-1}] * specific density [kgm^{-3}] * specific heat capacity [Jkg^{-1}] =

$$150 / 3600 * 1.23 * 1002 = 51 \qquad [WK^{-1}] \qquad (2)$$

The temperature effectiveness of a recuperator under mass balanced flow is:

$$\varepsilon = kA / (kA + C) \qquad (3)$$

In which kA, the heat exchanging capacitance, is the product of the heat transfer coefficient (k [$Wm^{-2}K^{-1}$]) and the heat-exchanging surface of the recuperator (A [m^2]). From (1), (2) and (3) it follows:

$$kA = \varepsilon / (1 - \varepsilon) * C = 650 \qquad [WK^{-1}] \qquad (4)$$

The quality of the heat transfer is the ratio (also called the Number of Transfer **U**nits) of the heat exchanging capacitance with the heat capacity flow:

$$kA / C = \mathbf{NTU} = 13 \qquad [-] \qquad (5)$$

The relative humidity has to stay between 40 and 50% for a good comfort level at 21 C. Therefore a maximum of 5 g water per kg air is needed to humidify the indoor air, during times of heating the ambient air. At the required 150 m^3h^{-1} the moisture m_l, that has to be recuperated, is:

$$m_l = 150 * 1.23 * 5 / 1000 = 0.92 \quad [kgh^{-1}] \quad (6)$$

Part of this moisture is produced by the inhabitants. At 0.06 kgh^{-1} per person this adds up to 0.15 kgh^{-1} for the average 2.5 persons. The effectiveness of the moisture to be recuperated is:

$$\varepsilon_l = (0.92 - 0.06) / 0.92 = 85 \quad [\%] \quad (7)$$

For dehumidification a maximum outdoor condition is taken at 35 C and 85 % RH. Therefore 25 g of water has to be removed per kg air, resulting in:

$$m_l = 150 * 1.23 * 25 / 100 + 0.15 = 4.8 \quad [kgh^{-1}] \quad (8)$$

With 100 % effectiveness of the recuperator only 3.1 kgh^{-1} can be removed, so the enthalpy (both sensible and latent heat) recuperation has to be as high as possible. For a further reduction, cooling is needed.

As the production of moisture inside can vary, a control system for the moisture recuperation is needed.