Smart ventilation toward an assessment of airflow imbalance and supply temperature set-points

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KEYWORDS

Smart ventilation, Continuous commissioning, Digitalisation, Heat recovery, Automatic balancing

1 BACKGROUND

Many countries have mandated the use of mechanical ventilation with heat recovery to limit heat loss in residential buildings. Nearly all these devices use temperature sensors to modulate bypass dampers and adjust heat recovery. These controls track a reference temperature for the supply or return air while maintaining exhaust temperatures above freezing. As a result, nearly all air-handling units (AHUs) come equipped with temperature sensors before and after the heat exchanger for both airflows. As Figure 1 indicates, these temperatures are often labelled 'outdoor' (or 'intake'), 'extract' (or 'room'), 'inlet' (or 'supply') and 'exhaust'. Nearly all AHUs indicate the position of the bypass damper around the heat exchanger, and if the AHU has a heating coil, the data will indicate the temperatures before or after the coil as well as its valve opening position. Using some basic knowledge about the physical design of the heat exchanger, data analysis can indicate the physical flows of heat and mass in the system. After applying several filters to the data, an energy balance can indicate the balance of airflows and required adjustments to the fan speeds to improve this balance. For most AHUs, these controls operate autonomously, but nearly every unit provides a potential communication link via Modbus, BACnet, KNX, or internet API. For this research, we used an API to access data from 40 apartment-level AHUs and developed a novel method to assess their performance with regards to airflow balance and supply temperature configuration.

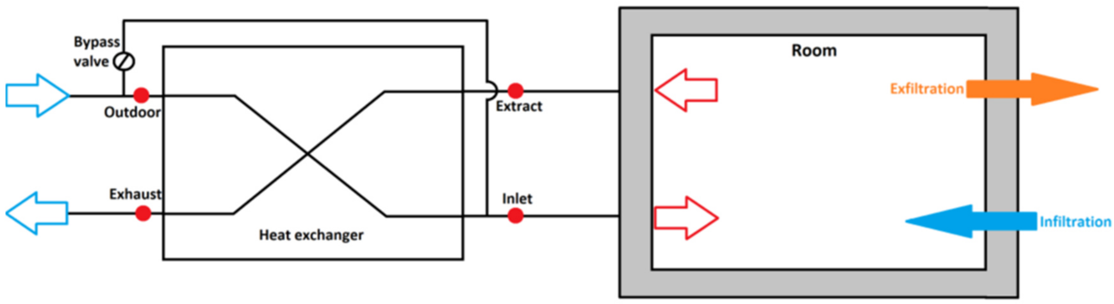

Figure 1. Common data from a residential AHU with a plate heat exchanger.

2 METHODS

Firstly, we aimed to assess the control signals and regulation of the bypass damper. The bypass has two main purposes: (1) avoiding overheating during the summer by partially bypassing heat recovery if the supply air temperature exceeds its set point, and (2) avoiding freezing in the exhaust side of the heat exchanger when the humid exhaust air could drop below 0°C. We analysed the average position of the heat recovery bypass during the heating season to see if any AHUs bypassed heat recovery excessively. If the bypass percentage is non-zero but still consistently low, it may be that the AHU is using a too-low supply air temperature set point, which could be increased. If the bypass percentage is consistently high in the heating season, it indicates an error leading to insufficient heat recovery. Secondly, we aimed to indicate the balance of supply and exhaust airflows using the AHU data, as most building regulations require balanced airflows (i.e. $Q_{exhaust} = Q_{supply}$) to minimise heat loss. The temperature increase in the supply air will roughly equal the temperature decrease in the exhaust air if the supply and exhaust airflows are equal under certain conditions. That is, the bypass must be fully closed, with no condensation in the exhaust, while assuming roughly similar air densities. As Equation 1 shows, the ratio of the mass flow rates is inversely proportional to the ratio of the temperature changes, where T is temperature, $\dot{m}$ is mass flow, ρ is density and Q is airflow:

$$\frac{(T_{supply} - T_{outdoor})}{(T_{indoor} - T_{exhaust})} = \frac{\dot{m}_{exhaust}}{\dot{m}_{supply}} = \frac{\cancel{\rho_{exhaust}}}{\cancel{\rho_{supply}}} \cdot \left(\frac{Q_{exhaust}}{Q_{supply}}\right) = Capacity\ ratio, Cr \qquad (1)$$

Therefore, we assessed the balance of airflows ($Q_{exhaust}/Q_{supply}$) from the temperature changes of both airflows ($(T_{supply} - T_{outdoor})/(T_{indoor} - T_{exhaust})$). We then balanced the airflows by adjusting the fan signals. A fan's airflow is proportional to its speed (according to the fan affinity laws), and fan speeds are often proportional to the control signal, so we simply balanced the airflows by scaling the fan signals according to the capacity ratio in Equation 1.

3 MAIN RESULTS AND CONCLUSIONS

The overall analysis revealed errors during commissioning leading to poor performance and energy losses. Most of the AHUs received low supply air temperature set-points, leading to unnecessary heat recovery bypass for much of the heating season. After increasing the setpoint to eliminate this constant slight bypass, we gathered data and plotted the average bypass percentage during the next winter period. As Figure 2 shows, the bypass damper was open for more than 48% of the winter period in nine apartments. This revealed an error, where the supply air temperature sensor was not installed in the supply duct, so the sensor was measuring the temperature of the apartment air. All other sensors were hardwired into the AHU, but the supply air temperature sensor required installation to allow for a heating coil, leaving open the potential for this error. We subsequently analysed the balance of airflows in all other apartments. The indicator for the balance of supply and exhaust airflows, herein called the capacity ratio, revealed significant imbalances. As Table 1 shows, at least seven apartments had capacity ratios of 0.81 or less. We used the indicator and the proportional relationship between fan signals and airflows to obtain a scaling factor for the supply fan signal. With this scaling factor, we targeted a capacity ratio of 0.95. As Table 1 indicates, the scaling successfully balanced the airflows, obtaining a capacity ration between 0.93 to 1.00, likely reducing infiltration.

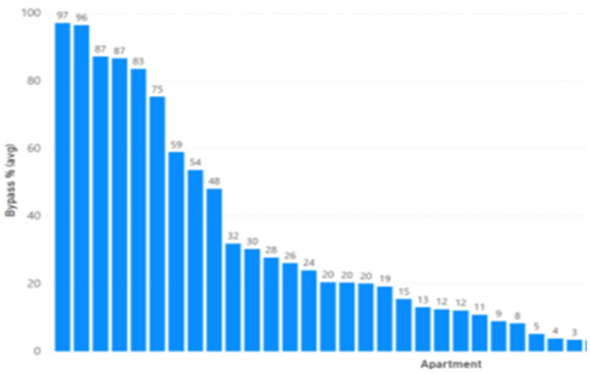

Figure 2. Average bypass percentage for each apartment in the winter period.

Table 1. The improvement of the capacity ratio before and after applying the new fan settings.

Anonymised Apartment	Capacity ratio before	Capacity ratio after
C1	0.72	1.00
C5	0.79	0.95
C10	0.78	0.93
E0	0.78	0.97
E1	0.81	0.95
E2	0.70	1.00
E4	0.65	0.95