VOLUME FLOW UNBALANCES AND SHORTCUTS IN DECENTRALIZED AND CENTRALIZED VENTILATION UNITS – FIELD TESTS IN RESIDENTIAL BUILDINGS

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Centralized and decentralized mechanical ventilation have become state-of-the-art in modern energy-efficient residential buildings. Calculations for the energy demand of buildings are done with nominal values of the ventilation units, assuming a proper function of the devices. The used ventilation concepts may be divided into two main categories- centralized and decentralized units and both come with advantages and disadvantages in terms of energy efficiency. In Luxembourg, a comprehensive field test has been performed in order to evaluate and compare their performance in practice. It could be shown that ventilation systems often do not meet the expectations. High unbalances in volume flows, high sensitivity to pressure differences and recirculation were measured in several cases. Only a proper installation and balancing of the systems can ensure an energy efficient function.

Key words: ventilation, residential buildings, decentralized, centralized, energy efficiency, user comfort

I. Introduction

As buildings become more and more airtight to avoid unnecessary losses, mechanical ventilation systems have become state-of-the-art to ensure proper indoor air quality and to avoid building damage due to possible moisture damage. Manufacturer argue with very high energy savings and energy certificates are done based on nominal values as input parameters. However, previous studies have already shown that the performance of ventilation units often fall short of expectations [1,2,3]. Examples are insufficient supply and exhaust rates, not properly installed ductwork, shortcuts within the ventilation systems and high noise levels among others. This paper shows the results of measurements of the supply and extract flows and recirculation inside and outside the ventilation unit

II. Objects and methods

Field tests include measurements in 20 single family homes equipped with centralized systems and in total 60 flats where decentralized devices were installed. The decentralized systems, installed directly in the façade of the building, were of two different types. The first type (later named systems A and B) use a regenerative heat exchanger and can only be installed in pairs. Each unit of the pair uses only one fan to deliver air into the volume. While device one is blowing fresh air from outside to inside, the second unit is extracting air from the inside and vice-versa. The leaving air heats up a heat storage mass made of aluminum or ceramics. Every approximate 60 seconds (the exact cycle time depends on the device and manufacturer) the fans switch their blowing direction and the heat stored from the outgoing air can be released to the incoming air. The second decentralized principle (counting for systems C, D and E) is often called “single room ventilation unit”. Each unit can be seen as a small centralized system, since it provides supply air and extract air using a cross-counterflow heat exchanger to recover the heat though the airflows are separated. The centralized systems are equipped with two fans, a heat exchanger and an extended ductwork to transport and distribute the air to the different rooms. All devices come with filters for extract and incoming air.

To address the air flows of interest within the ventilation system, a tracer gas setup was used. Conducting two successive measurements with two different injection points allows determination of the main air flows [4,5].

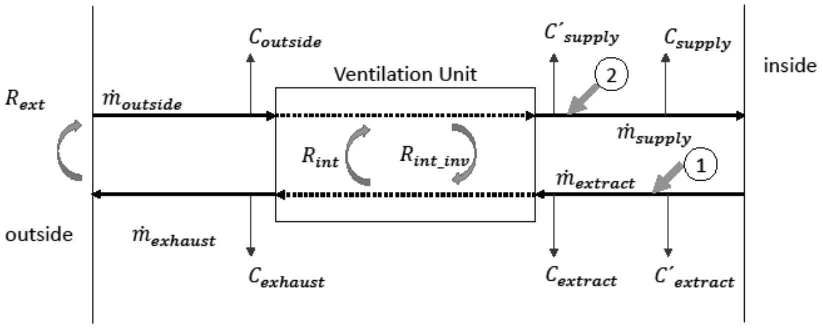

Figure 1: Airflows within the ventilation systems and Tracer Gas sample and injections points.

For this study the two main air flows of interest were supply air flow $\dot{m}_{supply}$ and extract air flow $\dot{m}_{extract}$. The injection point for the first measurement was in the extract duct making it possible to determine $\dot{m}_{extract}$ and the shortcuts ratios R_{ext}, R_{int} and R_{int_inv}.

$$\dot{m}_{extract} = \frac{i_{extract}}{C'_{extract} - C_{extract}} \tag{1}$$

$$R_{ext} = \frac{C_{outside}}{C_{exhaust}} \tag{2}$$

$$R_{int} = \frac{C_{supply} - C_{outside}}{C_{exhaust} - C_{supply}} \tag{3}$$

$$R_{int\_inv} = \frac{C_{extract} - C_{exhaust}}{C_{extract} - C_{supply}} \tag{4}$$

Concentration were recorded until they reached a steady state. For the assessment of the supply flow we inject directly into the supply duct.

$$\dot{m}_{supply} = \frac{i}{C'_{supply} - C_{supply}} \tag{5}$$

Injecting at this spot can be the starting point for measurements of the airflow characteristics within the ventilated volume using principles like the age of air and ventilation efficiency [6] which are part of follow up studies.

Relative unbalances in percent between supply and extract air flow were calculated as follows:

$$Relative\ unbalance = \left(\frac{\dot{m}_{supply}}{\dot{m}_{extract}} - 1\right) \cdot 100 \tag{6}$$

III. Results

A. *Air flows*

Measured air flow rates for supply and extract of the centralized devices are shown in figure 1.1. The mean supply air flow was 148 m^3/h, the mean extract air flow 156 m^3/h. Unbalances between supply and extract flow were between 22 and -45 % (see fig. 1.2). The decentralized devices were set to an supply airflow of 30 m^3/h while the measured mean supply air flow was 26,3 m^3/h (see fig. 1.3). The mean air exchange caused by mechanical ventilation (without possible in-/exfiltration) was 0.36 1/h for decentralized devices and 0.37 1/h for the centralized devices. These mean air exchange rates can be considered as appropriate for sufficient indoor air quality in residential buildings under normal conditions.

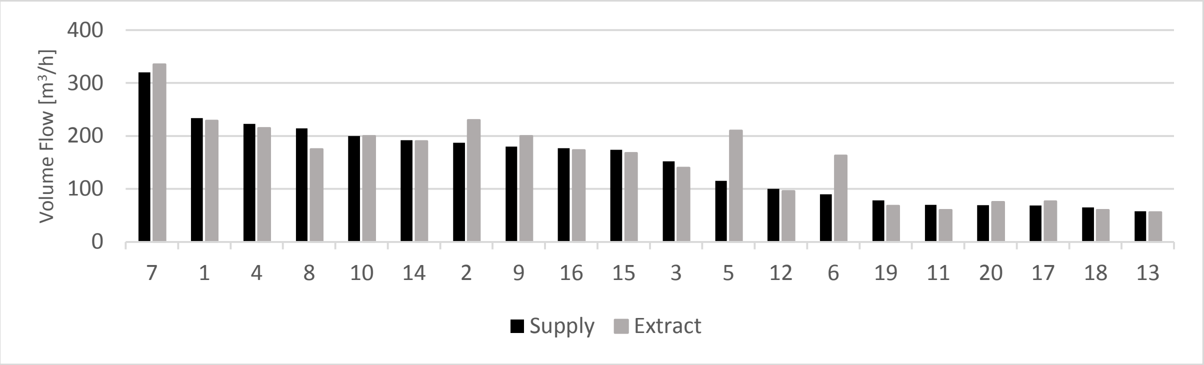

Figure 1.1: Air flows in 20 centralized devices.

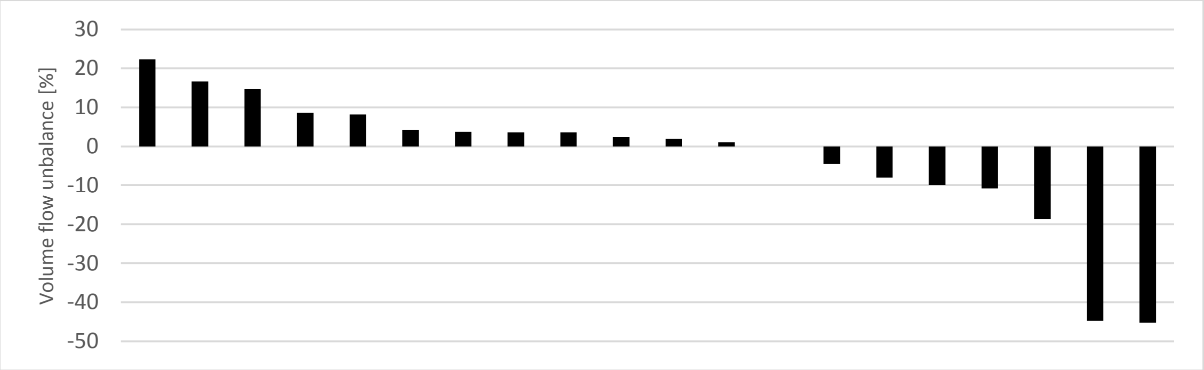

Figure 1.2: Relative flow unbalance in centralized devices.

Decentralized devices showed a much higher unbalance between the supply and extract flows between 60 and -60 % (see fig. 1.4). The mean deviation between supply and extract flow was 20 and -24 %. The buildings were all placed in an urban surrounding with medium to low wind exposure.

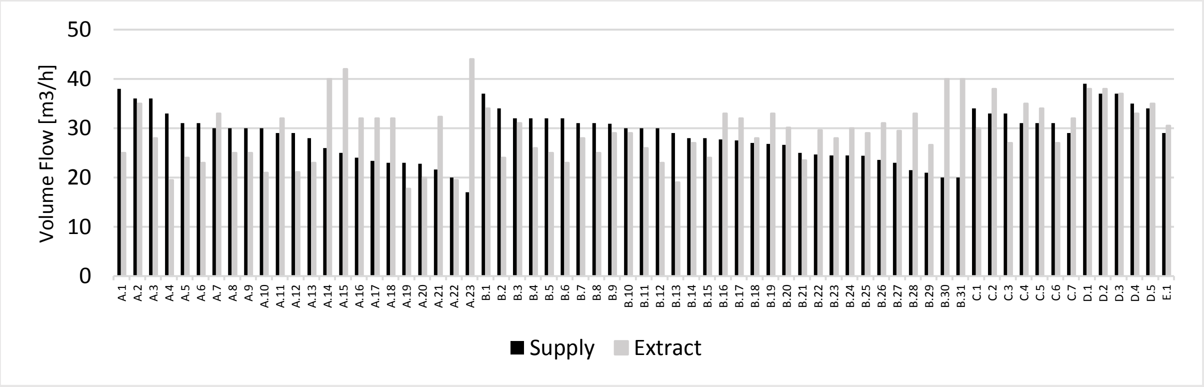

Figure 1.3: Air flows in 67 decentralized devices.

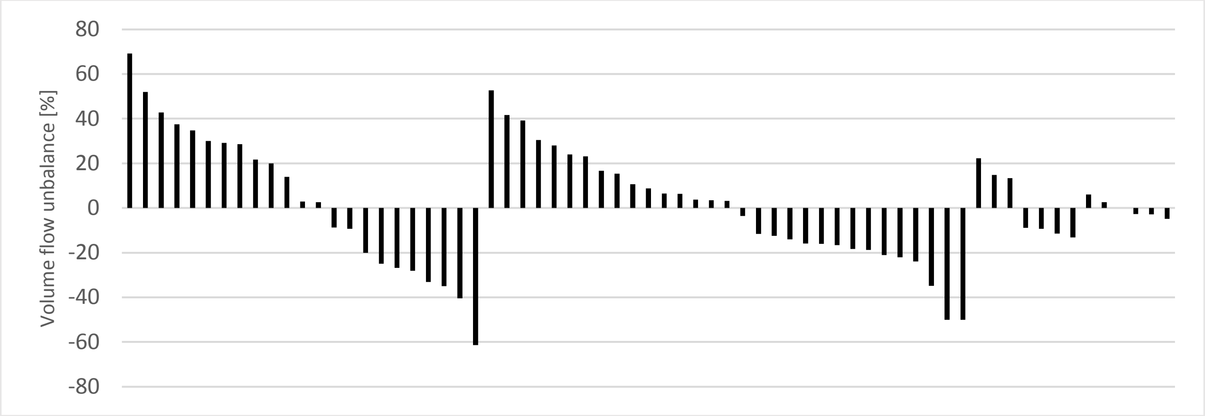

Figure 1.4: Relative flow unbalance in decentralized devices.

Measurements of the sensitivity to pressure differences confirmed these findings. A pressure difference of 5 Pa between inside and outside lead to deviations of the supply and extract flow of the decentralized devices between -55 % and 25 % for system A and B and -15 % to 20 % for system C. E.g. a device of system A or B beeing set to a volume flow of 25 m^3/h was actually delivering about 31 m^3/h supply air and extracting 12 m^3/h air.

In table 1.1 the results of the recirculation measurements are shown. External recirculations were in most cases caused by inlets and openings placed too close to each other outside the building and unfortunate wind directions may even increase the recirculation of exhaust air to the air inlet outdoor. Decentralized devices showed low internal but high external recirculation. Inlet and outlet on the outside are placed close to each other, resulting in external recirculation. Usually internal and external leakage is not noticed by the user and simply leads to reduced air quality due to a reduced fresh air supply. In this case it is necessary to increase the volume flow, which leads to higher power consumption of the fan and higher noise levels.

	Centralized devices	Decentralized devices
R_{int}	4 %	1 %
R_{int_inv}	2.5 %	0.5 %
R_{ext}	3 %	11.5 %

Table 1.1: Shortcuts in Ventilation devices – Mean Values.

The noise level, in most cases, is the limiting factor, especially for decentralized devices. While decentralized systems B, C, D and E were able to deliver an airflow of 30 m^3/h at noise levels around 25 dB(A) (at a distance of 1 meter), the maximum volume flow of system A at this noise level was only 15 m^3/h, possibly resulting in decreased indoor air quality. In this case, the user can only choose between good air quality at high noise levels or low noise levels at low air quality.

IV. Summary

Field measurements have shown real values for centralized and decentralized ventilation units and revealed shortcomings of the performance of the devices. High unbalance between supply and extract flow can lead to draught risk, lower heat exchange rates and in-/exfiltration, resulting in performance losses. These systems were hydraulically badly balanced system or showed high sensitivity to pressure differences between inside and outside. Especially the sensitivity of decentralized units to weather induced pressure difference has to be taken into account and should be object of further measurements to describe their heat exchange rate over a longer period. The external recirculation rate for centralized and decentralized units could be reduced by an increased separation of in- and outlet which should be part of further experimental investigation. Shortcuts in general can increase the specific fan power and result in a reduced indoor air quality. Only a well-balanced and installed system can lead to good overall system performance.

Nomenclature

$\dot{m}$	mass air flow rate (kg/s)
$\dot{I}$	tracer gas injection rate (kg/s)
$\dot{V}$	volume flow (m^3/h)
C	tracer gas concentration (expressed in air in parts per million (ppm))
R	shortcut ratio expressed in %

Subscripts

outside	outside air
supply	supply air
exhaust	exhaust air
extract	extract air
ext	external
int	internal
int_inv	internal inverse

V. Literature

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