Case study : comparison between a central and a decentral ventilation unit in a school building from the 80's

Paul De Schepper

Thomas More University
Knowledge Centre for Energy
Kleinhoefstraat 4
2440 GEEL
BELGIUM
Paul.deschepper@thomasmore.be

1 ABSTRACT

Ventilation and healthy classes are a recurring problem. Continuously increasing the air flow rate improves the living environment, but is unacceptable in terms of higher costs and energy loss, which is why a different approach is needed. The research question asked in this study is : Is a central ventilation system operating at low power, but combined with a decentralised ventilation system with heat recovery, more economical and energy efficient and at the same time does it provide the premises with a constant and good air quality? A decentralised ventilation system means that space is ventilated according to occupancy and need.
In this case, a university building from the early 1980s is investigated. The building consists of several classrooms and lab blocks and is located in a rural setting. Each block has its own ventilation unit, whereby the fan is switched on/off. The challenge is to save energy while maintaining a pleasant indoor climate. The lesson blocks consist of large (80 people) - medium (40 people) and small classrooms (20 people). The occupation varies between 60 and 85%, but there is never an occupation of 100%. As a result, the entire air flow rate of the pulsed fan is never needed. CO2 measurements show that the current air flow rate is insufficient to meet the comfort requirements. To increase the pulsed flow rate, increases the fan's power, which leads to a considerably higher energy consumption. Furthermore, the increasing air velocity in the ducts can cause more noise pollution and the rising outflow velocity may cause draught problems. Therefore a better solution is needed.
The starting point of this study is to halve the flow rate supplied by the air group - and thus save energy (both thermal and electrical) - and to supplement this with a local ventilation system with heat recovery. In this study the CO2 level will be measured first in three classrooms, then the additionally needed air flow rate will be determined. This additional air flow will be provided by a local ventilation system with heat recovery. A comparison is then made between the two systems, on the one hand, to have the central ventilation system deliver a higher air flow rate resulting in a higher energy cost and, on the other hand, to have the central ventilation system supply a much smaller basic air flow rate and supplement this with a local ventilation system with heat recovery. The end result will then be decisive to the most energy-efficient solution. The estimation is that the system with decentralised ventilation will be the most energy efficient and will give the most comfortable and healthy indoor climate conditions. This study can later on be used for other applications with similar problems, namely offices or schools that do not have 100% occupancy and still want a healthy indoor climate.

KEYWORDS

Comparison centralised and decentralised ventilation

1. energy savings with decentralised ventilation system
2. ventilation strategy in schools/universities

2 INTRODUCTION

In order to ensure a healthy living environment and at the same time to avoid unnecessary consumption, speed-controlled fans based on presence detection or CO2 sensors are now used in new buildings. In existing buildings, on the other hand, the systems often work with fans that can only be controlled on or off. This system is unfavourable for schools because not all classrooms are always fully occupied, which means that the full flow rate is not always required. In this case, therefore, the potential savings will be studied at a university located in GEEL in BELGIUM. The building is situated in a countryside environment and the oldest classrooms date from the mid-1980s. The intention is to have the fan run at only 50% of its full power capacity. A local heat recovery ventilation system provides additional flow when needed.

3 CALCULATION METHOD .

The university consists of several large blocks on a surface area of 44.475 m². Each block has its own air conditioning unit where the air is filtered and then sent to a heat recovery battery. There the air is then warmed up to approximately 2°C above the room temperature. The air conditioning installation only supplies a quantity of fresh air, the rooms are heated by radiators. In this way, the different older lesson blocks are provided with the necessary amount of fresh air.

The study focuses on a classroom with a capacity of 80 students.
In this study, we consider classroom G223 for 80 people as a separate unit. The aim is to measure and calculate the difference in energy consumption between the period when the fan is constantly running at full power and the period when the fan is running at 50% of its capacity, complemented by a local heat recovery ventilation system controlled by a CO2 sensor. If this sensor measures a CO2 value of 800 ppm, the local ventilation system will start to run.

In the first phase, we halved the speed of the fan drive motor and then we've measured the CO_2 in the classroom with a capacity utilisation of 80% with the following results :

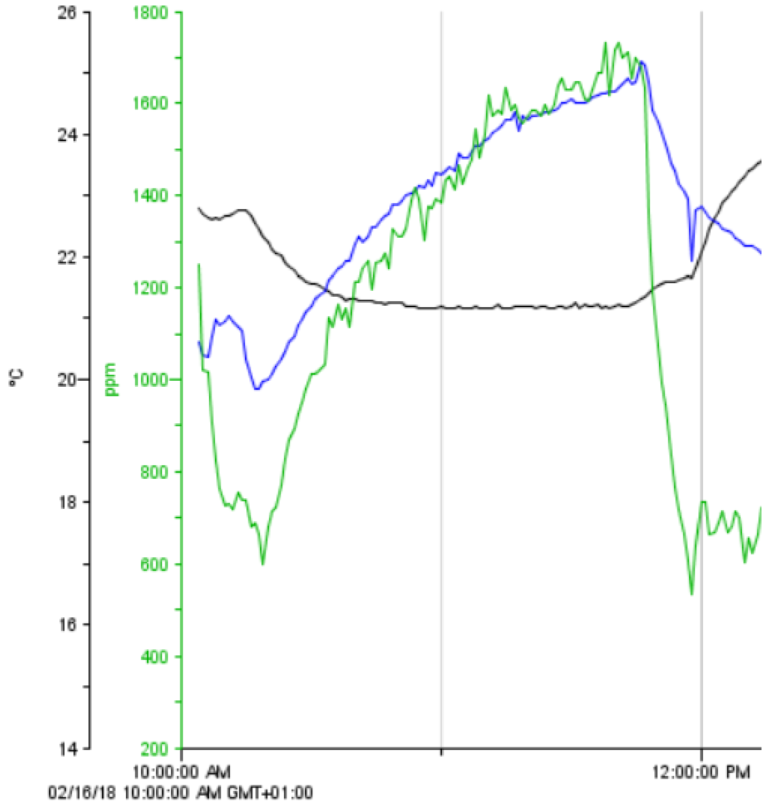

Figure 1 : CO_2 (green line)

At the end of the previous lesson at 10.00 a.m. a short intensive ventilation was carried out. A starting point of 600 ppm was measured, which rises quickly to a value of 1700 ppm at the end of the lesson. This result was to be expected.

For a room of 80 people, an air flow of 2400 m^3/h is required, based on a necessary amount of fresh air of 30 m^3/h per person. ASHRAE gives a recommendation of 25 m^3/h but Flemish regulations require a flow rate of 30 m^3/h. Because the classroom is considered as a separate unit in this study, we calculated the resistance of the channels and of the air intake vents from the main branch. This resistance is 180 Pa over approximately 10 m channel length and with two wall air vents.

According to the formula:

$$P = \dot{V} * \Delta p \qquad (1)$$

that means a capacity of 120 W. For a 1.5-hour lesson block, this corresponds to an energy consumption of 180 Wh. Assuming an acceptable fan efficiency of 70%, we calculate an energy consumption of 257 Wh for a fan at constant full capacity. On the other hand, we calculate the energy consumption at a halved flow, supplemented by a local ventilation system that is activated when the CO_2 in the room exceeds a limit of 800 ppm.

Through the proportionality rules we deduce that a halving of the flow corresponds to a decrease of the power of 2^3. Instead of 120 W, the fan will still have a consumption of 15 W, which means an energy consumption of 32,14 Wh for the duration of 1 lesson block. The characteristics of a local ventilation system of 1200 m³/h indicate a power requirement of 260W.

The next question to be examined is when a concentration of 800 ppm will be reached in the classroom.

To calculate when the CO2 level in the classroom reaches a value of 800 ppm, we use the formula below:

$$c \;=\; \frac{q}{n.V} \cdot \left[1-\left(\frac{1}{e^{n.t}}\right)\right] + \frac{(c_0 - c_1)}{e^{n.t}} + c_1 \qquad (2)$$

c = carbon dioxide concentration in the room (m^3/m^3)
q = carbon dioxide supplied to the room (m^3/h)
V = volume of the room (m^3)
e = the constant 2.718.....
n = number of air shifts per hour (1/h)
t = time (hour, h)
c_i = carbon dioxide concentration in the inlet ventilation air (m^3/m^3)
c_0 = carbon dioxide concentration in the room at start, t = 0 (m^3/m^3)

This calculation learns that after about 20 minutes the limit of 800 ppm is reached. The local fan will thus provide the additional ventilation flow for one hour and ten minutes. The energy consumption then amounts to 1.17 h * 260 W = 304 Wh. Together with the consumption of the central fan (32.14 Wh), this means a total consumption of 336.14 Wh, which is more than if the central fan were operating alone (257 Wh). This is in line with expectations, but the premises never have an occupancy rate of 100% . As soon as the occupancy rate falls, the profits of the decentralized system start to appear.

Table 1: energy use

Occupancy Rate	Number of persons	Total air flow (m³/h)	Air flow decentral unit (m³/h)	Power (W)	Time (h)	Energy use (Wh)
90 %	72	2160	960	170	1,3 h	221 Wh
80 %	64	1920	720	105	1,2 h	126 Wh
70 %	56	1680	480	53	1,1 h	58 Wh
60 %	48	1440	240	48	1 h	48 Wh

An occupancy rate of 90% means a presence of 72 people. If we assume that each person emits 0.05 m³/h CO2, we can calculate from equation 2 how long it takes to reach a CO2 concentration of 800 ppm in the room. For a 90% load factor, it will already be reached after 0.2h - at which time the decentralised unit will start operating. The decentralized unit must then provide an additional flow of 960 m³/h corresponding to a power of 170 W during 1.3 h. This means an energy consumption of 187 Wh. Together with the energy consumption of the central fan, a total energy consumption of 219 Wh is reached, which is already slightly lower than the consumption of the central fan running at full load.

The table below summarises the results with other occupancy rates.

Table 2 : Energy gains

Occupancy rate	Energy consumption decentralised unit Wh	Energy consumption central unit Wh	Total energy consumption Wh	Difference Wh
100 %	304 Wh	32,14 Wh	336,14 Wh	+ 79 Wh
90 %	221 Wh	32,14 Wh	253,14 Wh	- 3,86 Wh
80 %	126 Wh	32,14 Wh	149,14 Wh	- 107,86 Wh
70 %	58 Wh	32,14 Wh	90,14 Wh	- 166,86 Wh
60 %	48 Wh	32,14 Wh	80,14 Wh	- 176,86 Wh

The dates of occupancy of the premises show that, for more than 75% of the time, the premises have an occupancy rate of less than 80%. According to these calculations it is certainly profitable to reduce the speed of the central fan to 50% and to combine it with a decentralized unit with CO_2 control.

In the next phase, these calculations will have to be substantiated by practical measurements. During the next school year an airmaster will therefore be installed in the classroom and practical measurements will be taken. In addition, an economic analysis will be carried out to determine whether the profits from this energy saving are sufficient to justify the additional costs of purchasing and installing a decentralised unit within a reasonably acceptable payback period.

4 CONCLUSIONS

The starting point of this case study was the consideration that in a school environment, where ventilation is already realized by a central fan with on/off control, it is too expensive to replace it by a decentralized unit. Classrooms in universities are almost never occupied for 100%, which means that there is always an oversupply of air flow at full rate, which costs energy. On the other hand it is not advisable to stop or to limit the use of the existing central ventilation system. This study wants to be a first theoretical step to justify the replacement.
It has been calculated that at capacity utilisation rates of 80 % and less, profits are already significant. Further measurements and further economic analysis are very much needed to reach the right decisions.

5 REFERENCES

Website : https://www.engineeringtoolbox.com/pollution-concentration-rooms-d_692.html