Demand Controlled Ventilation as Efficient Means to Achieve Energy Savings in Tertiary Sector Buildings

A. Tissot[1] and M. Archenault[2]
[1] CETIAT, 25 avenue des Arts – BP2042
69603 Villeurbanne Cédex France
[2] ELYO Cylergie, Chemin de la Forestière, l'Orée d'Ecully
69130 Ecully, France

ABSTRACT

Demand-controlled ventilation (DCV) has largely been documented in the literature through field demonstration projects and computer simulation studies. However, in France and in the majority of European countries, the use of this technique is still quite limited. Several partially unanswered questions fuel this paradox:

- What is the impact of DCV on comfort and air quality?
- What are the real energy savings which can be expected?
- How reliable are these systems over the long term and what are the real operational difficulties related to these systems?

This study provides additional field test data to help bring answers to these questions. The study was undertaken by three manufacturers of DCV systems, three HVAC research labs and an energy services company. The study was co-financed by the ADEME agency.

Six tertiary sector buildings were equipped and studied over two 15 days periods. The study quantifies in particular:

- The impact on comfort and indoor air quality both measured and felt by the occupants,
- The net energy savings by comparing them with the real operating parameters in the "before DCV" conditions,
- The difficulties with respect to the installation and maintenance under real operating conditions.

The results provide information useful in better targeting the implementation of DCV techniques as a function of the building type and use.

KEYWORDS

DEMAND CONTROLLED VENTILATION, ENERGY SAVINGS, INDOOR AIR QUALITY

INTRODUCTION

When properly designed and installed, demand controlled ventilation (DCV) can reduce unnecessary over-ventilation that might result if air intakes are set to provide ventilation for a maximum assumed occupancy, particularly where occupancy is intermittent or variable from design conditions. DCV technology is particularly relevant for buildings with a highly variable occupancy such as conference rooms, offices, theatres which require a forced ventilation system when the rooms are at full capacity and almost no ventilation 80 to 90% of the time.

Numerous scientific papers detail the technical aspects of DCV and the potential energy savings which are estimated at up to 80%. In most cases, the system payback is estimated to be as little as a few months to 2 years. In spite of these results, very few systems have been installed in France in new buildings and almost none in existing buildings. As building energy efficiency becomes again a public priority the real impact of DCV on energy consumption and the difficulties encountered by those technologies have to be analysed.

PROJECT OBJECTIVES

Thus the objectives of this study were to determine for several tertiary sector buildings which DCV systems are best suited to each particular application and what are the main difficulties with respect to the installation and maintenance of these systems under real operating conditions. In addition, this study also compared the energy savings resulting from the equipment of DCV.

Presentation of the different partners

The partners in the project team where:

- ELYO CYLERGIE (Elyo's Research and Development Center). Elyo is an Energy Efficiency Services Company, subsidiary of Suez Energy Services.
- Centre Technique des Industries Aérauliques et Thermiques (CETIAT), the French technical centre of heating, ventilation and air conditioning systems manufacturers.
- Comité Scientifique et Technique des Industries Climatiques (COSTIC) research laboratory.
- Centre Scientifique et Technique du Bâtiment (CSTB) research laboratory.
- ALDES (demand controlled ventilation system supplier).
- ANJOS (demand controlled ventilation system supplier).
- ATLANTIC (demand controlled ventilation system supplier).

DESCRIPTION OF THE DCV SYSTEMS USED IN EACH TEST SITE

Two types of DCV systems where used in this study: DCV for which ventilation flow rate is based on indoor CO_2 concentration and DCV for which ventilation flow rate is based on presence of occupants. As a general rule, presence based systems (which detect either presence or activity of occupants through infrared optical detection) are used in small to medium volume rooms (less than $170m^3$) and CO_2 based systems are used in large volume rooms (greater than $100m^2$). The building applications where these different techniques were used are indicated in Table 1.

METHODOLOGY USED TO EVALUATE CHANGES IN IAQ, COMFORT AND ENERGY SAVINGS

The following information was collected from each site during the two 15 days test periods (winter and summer): air flow rates, fan motor intensity, acoustic measurements, occupancy, user satisfaction surveys as well as both indoor and outdoor temperature, relative humidity and CO_2 concentration measurements. Care was taken to ensure that windows and doors were maintained closed during the measurement periods. During a period of 4 days, the actual occupancy was noted down by a permanent occupant. These data were completed or confirmed by way of log books where possible. A user survey was completed by the occupants who were asked to evaluate their perceived comfort and the IAQ upon entering the room and upon leaving the room in terms of odour, noise and sensations of being too hot or cold.

RESULTS

Thermal and Electrical Energy Savings

All results are summarized in Table 1.

The simplified formula used in all cases to determine the thermal heat losses by ventilation was the following:

$$THL\ (W) = 0.34\ Qv\ (Ti - Te)$$

THL: Thermal Heat Losses by way of ventilation (Wh)
0.34: heat capacity of air ($Wh/m^3 °C$)
Qv: ventilation air flow rate (m^3/h)
Ti: indoor temperature (°C)
Te: outdoor temperature (°C)

The energy savings were calculated by comparing thermal heat losses by ventilation with DCV system with what they would have been without DCV system (i.e. with a constant ventilation flow rate).

Two rooms with very similar geometries were equipped with different DCV technologies. The classroom was equipped with an optical motion sensor and the school canteen was equipped with a CO_2 sensor. Irrespective of the DCV technique used, the results were spectacular with thermal energy savings in excess of 50% in all sites tested.

The operating conditions (running time of the ventilation system, heating intermittence, control strategy) have a strong impact on the energy consumption before and after the DVC equipment, and then on the energy savings due to the technology: in most studied cases absolute energy savings were particularly high because the operating conditions of the buildings were basic.
To determine the energy savings which can be given by DCV, the initial operating conditions of the buildings must be totally known.

Table 1: Summary of results

	Building / Room	Surface / Volume	DCV system	Set points	Nominal / Actual number of occupants (% occupancy)	Thermal energy savings[1] (%)	Electrical energy savings[2] (%)
New Buildings	School / Classroom	60 m^2 / 167 m^3	ALDES MDA-Agito Optical motion sensor acting on the network distribution	Ventilation period as a function of presence (measurement every 10 min)	25 / 15 (60% occupancy)	84% (W)[3]	N/A
	Rehabilitation center / Gym	90 m^2 / 360 m^3	ANJOS NDIR CO_2 sensor acting on the fan voltage	Proportional 750 – 1000 ppm 100 m^3/h<750 ppm 500 m^3/h>1000ppm	20 / 10 (50% occupancy)	51% (W) 51% (S)	45% (W) 59% (S)
	Rehabilitation center / Consultation room	10-20 m^2 / 25-50 m^3	ANJOS ALIZE VISION Optical motion sensor acting on the extraction register	min to max airflow (7.5 m^3/h to 50 m^3/h) re-set every 30 minutes	2 / 2 (100% occupancy)	50% (W) 64% (S)	N/A (W) N/A (S)
	School / Canteen	60 m^2 / 150 m^3	ATLANTIC VARIVENT NDIR CO_2 sensor acting on the fan voltage	Proportional 750 - 975 ppm 220 m^3/h<750 ppm 935 m^3/h>975 ppm	50 / 40 (80% occupancy)	77% (W) N/A (S)	65% (W) 68% (S)
Existing Buildings	University library / Meeting room	32 m^2 / 90 m^3	ALDES MDA-Agito Optical motion sensor acting on the network distribution	Ventilation period as a function of presence (measurement every 10 min)	25 / 1-2 (5% occupancy)	87% (W)[4]	23% (W)
	Superior Court / Courtroom	225 m^2 / 1843 m^3	COSTIC NDIR CO_2 sensor acting on the air intake	Proportional 650 - 1700 ppm <650 ppm 20% open >1700ppm 100% open	150 / 30-40 (30% occupancy)	63% (W) 65% (S)	N/A (W)

[1]: the energy savings are based on an estimated indoor temperature set point of 20°C and account only for the reduction in heat losses through the ventilation system.
[2]: the electrical energy savings are based only on the consumption related to the fans. The consumption related to the sensors/regulators was not taken into consideration in this study. As an indication of the potential impact of a 3W sensor, the annual electrical energy consumption would be approximately 27 kWh.
[3]: (W) winter, (S) summer
[4]: It should be noted that the % occupancy is valid during the hours when the building is open to the public. In some instances the original building ventilation system was being operated 24 hours/day and therefore the energy savings with the new DCV were even more significant than the base case.

Other experimental measurements

Thermal and Hygrometric Comfort

In addition to the significant energy savings obtained in each field test site, indoor thermal and hygrometric comfort was maintained: throughout the measurement periods, no significant user complaints were reported.

Occupancy

Throughout the field tests, the actual occupancy in each building was well below the design occupancy. The low occupancy rates which were identified confirm the interest in demand controlled ventilation systems for these types of buildings. It must be noted that the occupancy rate is almost the same for the different tested rooms.

Indoor Air Quality

The indoor air quality, evaluated as a function of the indoor CO_2 concentration, was also maintained. Levels above 1000 ppm were not reported throughout the field testing both during summer and winter test periods.
The following figure presents the results from the School Canteen during the winter test period in terms of indoor and outdoor CO_2 concentrations and extraction and supply air flow rates during a typical school day. Canteen personnel are present between the hours of 10am and 3pm. The lunch is served from 11:40am to 1:20pm. The two CO_2 peaks correspond to the children entering and leaving the canteen.

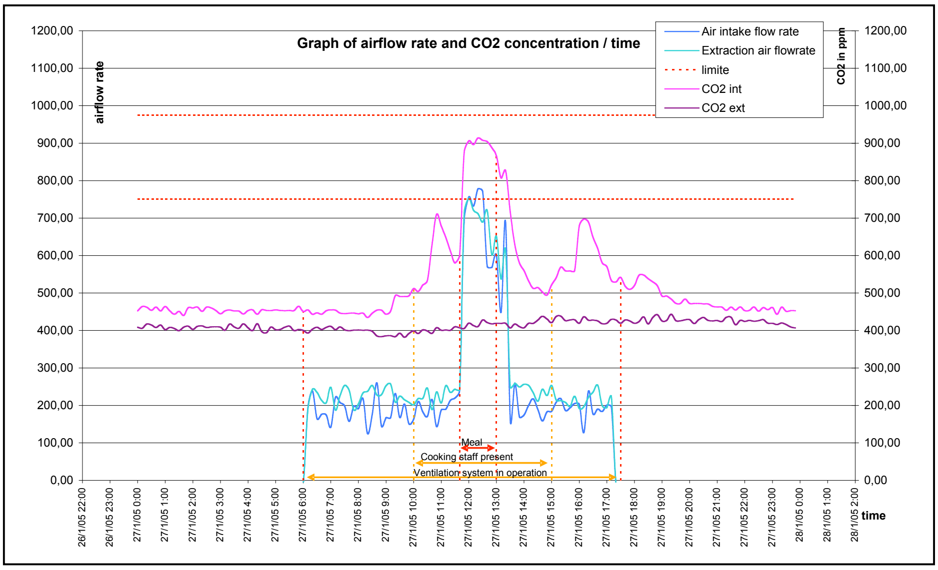

Figure 1 : School canteen indoor and outdoor CO_2 and air flow rate measurements

User satisfaction surveys

A survey was completed by the users who were asked to evaluate their perceived comfort and the IAQ upon entering the room and upon leaving the room in terms of odour, noise and sensations of being too hot or cold. Throughout the different sites tested, 118 user surveys were completed. Of those surveyed, in terms of perceived IAQ and comfort, 89% reported it as being good, 6% reported it as being average and 5% reported it as being poor.

Difficulties encountered and observations made during the installation and maintenance of these systems

Precaution should be taken to ensure a proper seal especially when installing CO_2 sensors in ducts. No problems were identified when installing wall mounted CO_2 sensors.

A thorough evaluation of the existing system must be completed before installing DCV systems to ensure that the existing system was installed and is operating as designed. Setting up the control strategy for DCV systems integrated within existing HVAC systems can be a rather complex task and therefore should be completed and maintained by on-site energy services personnel.

Optical motion sensors do not require any particular maintenance. However, CO_2 sensors must be calibrated periodically. Slight sensor drift was noted on several sites especially after power outages or after having been dismantled and re-installed after several months of being unused. A complementary study is underway to evaluate the reliability of NDIR CO_2 sensors.

Punctual CO_2 measurements were carried out at different locations in the courtroom. CO_2 measurements were taken with two different CO_2 sensors. No CO_2 stratification was highlighted.

CONCLUSIONS

The field testing of several DCV systems, allow the following conclusions to be made:

- Indoor thermal and hygrometric comfort was maintained: throughout the measurement periods, no significant complaints from the occupants were reported.
- The indoor air quality, evaluated as a function of the indoor CO_2 concentration, was also maintained. Levels above 1000 ppm were not reported throughout the field testing both during summer and winter test periods.
- Irrespective of the DCV technique used, the results were significant with thermal energy savings in excess of 50% in all sites tested. The relative energy savings related to DCV depend on the initial operational conditions of the building.
- The building's energy management personnel must be implicated in the maintenance of DCV systems to ensure their reliability.

References

Demand Controlled Ventilating Systems, Sensor Tests - P Fahlen, H Andersson, S Ruud - Swedish National Testing and Research Institute, Boras, 1992, SP Report 1992:13, ISBN 91 784 8331 331 X, 148 pp + apps.

Modulation de débit, Rapport final – A-M Bernard, M. Blazy, CETIAT Report NTV 2000/071, septembre 2000

NTV 2002/111 – Modulation des débits de ventilation, caractérisation des performances – Rapport final – A-M. Bernard, M. Henninot, JG. Villenave, CETIAT, décembre 2002

La modulation de débit de la ventilation dans les locaux tertiaires, la valorisation des enjeux énergétiques dans la future réglementation thermique, via la préparation d'avis techniques – Rapport final ADEME – M. Archenault, M. Barbat, M. Blazy, P.Haenel, D. Labaume, N. Nicholson, A. Tissot, N. Viala, JG. Villenave, février 2006