OPTIMUM VENTILATION AND AIR FLOW
CONTROL IN BUILDINGS

17th AIVC Conference, Gothenburg, Sweden,
17-20 September, 1996

PRACTICAL EXPERIENCES WITH IR CONTROLLED SUPPLY TERMINALS IN DWELLINGS AND OFFICES

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1. INTRODUCTION

1.1 DEMAND CONTROLLED VENTILATION

Ventilation is necessary to provide a good indoor air quality to occupants in office buildings but is however a major energy consumer. In that manner, ventilation in itself can contribute to much more than 50% of the energy consumption for heating in well insulated office buildings. Likewise, the general trend in standards to augment ventilation requirements would still increase its energy costs. Thus, it seems obvious that an intelligent control of ventilation in office building allows to obtain substantial reductions of energy consumption.

To a certain extent this is also true for dwellings even if in general ventilation represents a smaller contribution to the energy consumption for heating than in office buildings. In this connection, it should be noted that the increasing requirements regarding insulation of dwellings has for effect to augment this proportion. Demand controlled ventilation in dwellings appears therefore also as an interesting way to achieve energy consumption reduction.

1.2 EXPERIMENTS PERFORMED

This paper presents experiments that were performed in two different environment but are both related to IR control ventilation.

1.2.1 IR CONTROL VENTILATION IN BEDROOMS

The biggest challenge for ventilation is to achieve the best acceptable indoor air quality at the right cost. Two options are already available in dwellings : heat recovery or modulation of the flows according to the needs.

In "normal" conditions, the simple extraction humidity controlled system (one sensor in each room, habitable or technical) is a good economical solution which has proved reliability for more than 10 years.

If the outside conditions need to be improved (noise, pollution, temperature, ...), or if the occupants have particular sensibility to some outdoor pollutants (allergy, asthma, ...), it can be necessary to use a more sophisticated system which blows the air after filtration, preheating, ...

It must be stressed that any treatment of the air has a cost, either through direct energy consumption (preheating, pressure loss, ...) either through maintenance of the systems.

Hence, it seems quite obvious to modulate the flows rather than to give a constant value which is not always necessary but which always needs to be treated.

The main issue is then to find the more accurate detector for the particular need in each room.

The purpose of the experiment in bedrooms described here was to verify that it was possible to detect people through a motion detector, while sleeping, and to adapt ventilation to the occupancy. The idea being that even an eventual lack of ventilation for a short while (a few minutes) is not a problem.

Several nights have been recorded in more than 20 homes, with different occupancies (1 or 2 persons, adults, children) in order to know the frequency of movements and to determine the best parameters for the control of ventilation flows.

The result of these "1001 nights" are presented here and open a big field for products and systems provided that constructive discussions are open with regulation organisations to allow these modulated systems as energy efficient alternative to the "single value strategy" which is often the base of regulations.

1.2.2 Experiments in offices

A first approach for demand control consists in ventilating only the spaces which are effectively occupied. Such a system was studied in detail by BBRI in an occupied office building and forms the subject of a previous publication [1].

A more advanced method would consist in controlling the ventilation as a function of the real indoor air quality in the spaces. This technique seems however difficult to apply in practice since the indoor air quality is determined by a large number of parameters often impossible to evaluate (odours, VOC's, ...).

However, in the event the occupants form the main pollution source in a ventilated space, it is possible implement a demand control strategy based on the occupancy. This can be done by using the carbon dioxide as a tracer of human pollution (see [3]). That technique is quite attractive since it takes into account the number of people in the space as well as the natural infiltration. However, up to the present, it is only appropriate for application in large rooms (classrooms, theatres,...) mainly for a question of cost. Another method is to evaluate the pollution source in space by counting the number of people effectively present and to ventilate accordingly. The AGITO type ventilation terminal is based on this principle. Two terminals were installed in two offices in one of BBRI building in order to evaluate in-situ their performances.

2. Estimation of energy savings by using IR controlled ventilation

In order to provide a quantification of the energy savings that can be made thanks to IR controlled ventilation, some simulations in a well-insulated large office building were performed.

As debated in [2], large variations of the ventilation requirements can be found in different standards. Two extreme values were chosen in the simulation cases. Firstly, the minimum ventilation requirement for single office in the CEN prENV 1752 (class C, clean building, version 12-94) was used, that is 0.8 l/s.m². Then, a high value of 8.2 l/s.m² was taken which corresponds with the class A of the mentioned proposal for standard with an average pollution emission from the building (for more details see [2]).

An average occupancy of 50% was assumed which is in line with what was measured in the BBRI office building in previous experiments (see [1]).

The other assumptions are:

- 4 facade office building, 20 storeys
- ground dimensions: 20 x 20 m²
- storey height: 3 m
- 30% total glazed area
- Heating system: target value of 20°C, operation from 6:00 to 19:00 during the week
- Ventilation system operation from 6:00 to 19:00 during the week
- Component characteristics :
  - facade: U = 0.4 W/m²K
  - windows: U = 1.5 W/m²K, solar factor = 0.37
  - Roof: U = 0.3 W/m²K
  - Floor: U = 0.4 W/m²K
  - Internal gains : 30 W/m²
- Natural infiltration = 0.2 l/s.m²

The following table gives the simulation results for both ventilation requirements. The energy gain compared with a constant air flow strategy is given as well.

	0.8 dm³/s,m²	8.2 dm³/s,m²
Constant air flow rate during working hours	347000 kWh 43 kWh/m² 100%	2472000 kWh 309 kWh/m² 100 %
50% operation because of occupancy control	252000 kWh 32 kWh/m² 72 %	1283000 kWh 160 kWh/m² 52%
Gains due to presence control	95000 kWh 12 kWh/m² 27 %	1189000 kWh 149 kWh/m² 47%

Table 1 : Predictions of energy demand for heating and relative gains due to demand controlled ventilation in a well-insulated office building

As it can be seen, the impact on the total heating energy consumption is very important. Indeed, it is a fact that ventilation is a large energy consumer in this kind of office building.

It must also be noted that the impact is much larger with the high ventilation requirement because, in this case, the transmission losses are almost negligible compared with the ventilation losses.

Important to mention is also that passing from the low ventilation requirement to the high ventilation requirement translates in an increase of a factor 7 of energy consumption.

3. DESCRIPTION OF THE VENTILATION TERMINALS

3.1 INFRA-RED DETECTION

The principle of the infra-red detection is widely used for alarm purpose. The general principle of a passive infrared detector consists in an electrical signal which varies with the intensity of the heat (infrared wave length). Any modification in the electrical signal is associated to a movement (the waves lengths range of infrared is close to the range of infrared emitted by human body).

This principle has been adapted to the OPTO and AGITO ventilation terminal. There were several constraints such as the installation which can be on the ceiling or the wall, the detection zone unit has to be as accurate as possible to avoid any dead zone. These problems were solved by using a Fresnel lens with 31 view faces facing the room with a 110 ° angle. Moreover the passive infrared detector is a twin-head so the 31 view faces are then doubled. The accuracy of the infrared detector associated with the Fresnel lens is based upon the sum of the length of the borders between the view zone and the blind zone. Thus the number of Fresnel faces time the number of detectors gives here the total accuracy of the system.

3.2 OPTO TERMINAL

The OPTO terminals have the infrared sensor built-in the unit. The electronic card is activated by 4 batteries lasting more than 4 years. When a movement is detected, the electronic card supplies an electric current to the first micro-capsule which switches a micro-valve, blowing down a plastic bag attached to a shutter which then opens and allows the airflow passing. When no movement is detected during 15 min, the electronic card supplies a current to a second micro-capsule which switches the micro-valve, blowing up the bag and closing the shutter. This is instrumental for the batteries to last 4 years, the energy used to open and close the shutter is NOT electric but pneumatic.

3.3 AGITO TERMINAL

The AGITO uses the same infrared detector than the OPTO. The AGITO terminal has a microprocessor activated by a 12 VAC or DC hard wired. The micro-valve is replaced by a micro mixing valve. The AGITO modulate the shutter opening by mixing the pressure of the plastic bag.

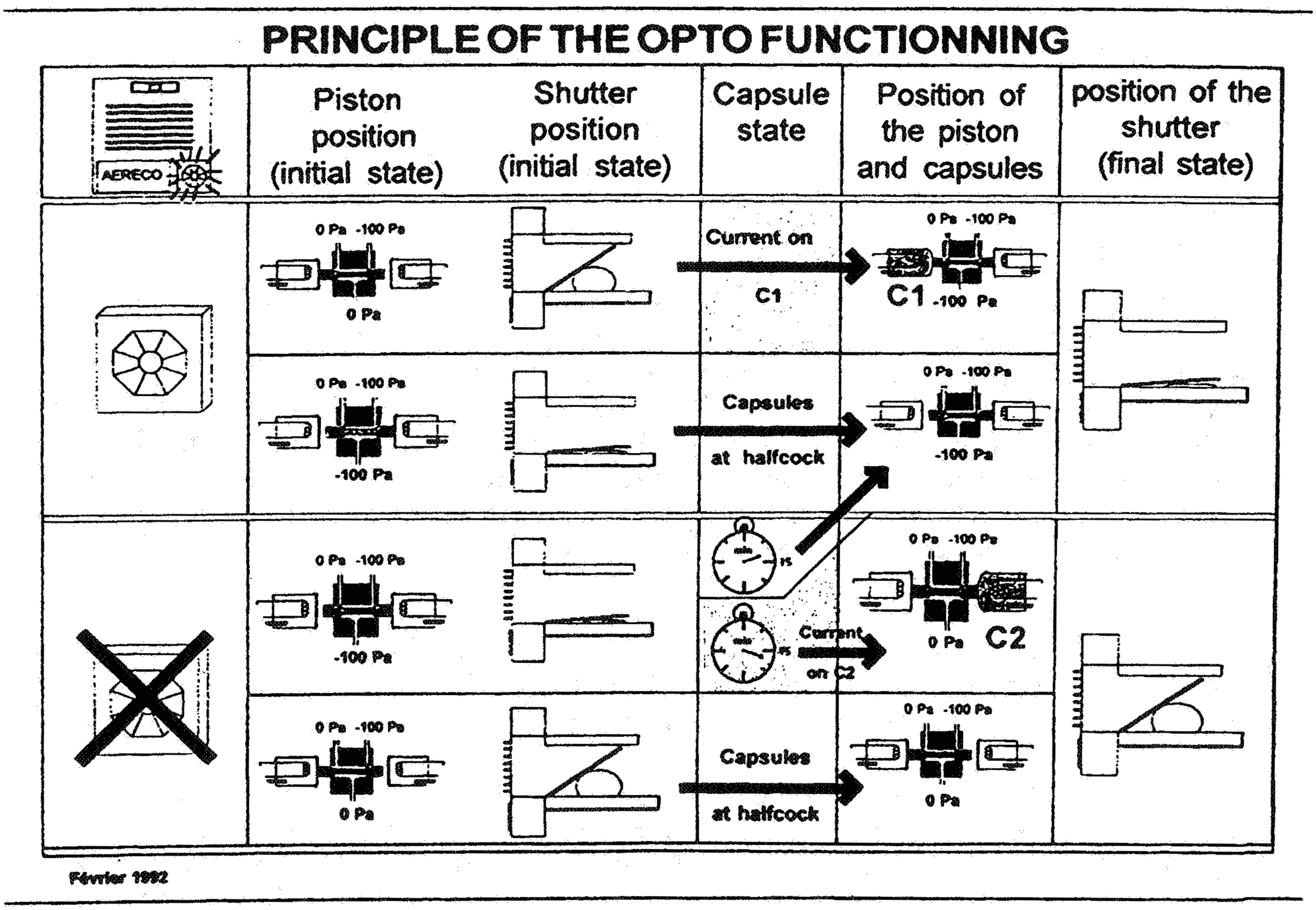
One movement is counted when at least one movement has been detected over a period of 4 seconds. The microprocessor counts the number of the above kind of movements over a period of 3 minutes. It compares this number to a fixed table in order to set the AGITO opening. The AGITO opening can only move from a position to the next or the previous one. Therefore, the AGITO changes its opening only every 3 minutes. It goes never from the maximum to the minimum opening in once but step by step to the minimum. It takes 15 minutes which is equivalent to 60 m^3/h run on during these 15 minutes.

The AGITO is easily adaptable to specific requirements.

It is possible :

- to accelerate the functioning (2 minutes rather than 3 minutes)
- to delay the closing of the AGITO by having a 6 minutes sum downward and 3 minutes sum upward
- to leave a minimum opening when nobody is in the room
- to have a non-linear opening versus the number of movements
- to use a special connection to switch a separate routine in the program so over ride the AGITO for a given time for example.

Figure 1 illustrates the operation of the OPTO and AGITO ventilation terminals.



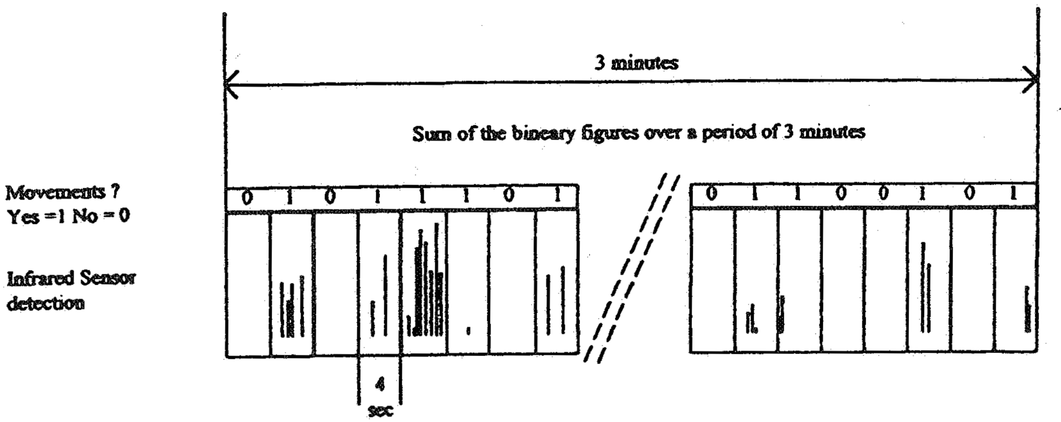


Figure 1 - Operation of the infra-red controlled ventilation terminal

4. EVALUATION OF THE AGITO VENTILATION TERMINAL IN TWO OFFICES

4.1 EXPERIMENTAL SET-UP

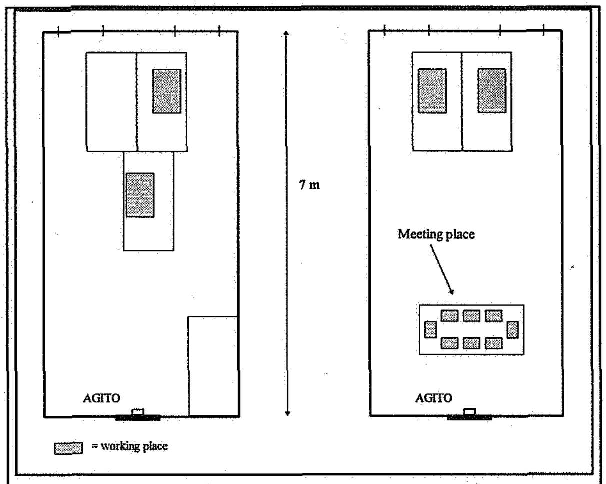


Figure 2 - Rooms with AGITO type ventilation terminals - Top views

As explained, two AGITO ventilation terminals were installed in two office rooms. The following figures show the position of the working places and the AGITO terminals.

It is important to note that the distance between the AGITO terminal and the working places is quite long (excepted for the meeting place). Generally the detector is placed closer to the working place, for example in the ceiling.

The state of both AGITO ventilation terminals was measured in parallel with the real occupancy in both rooms. In addition, the carbon dioxide concentration was recorded in the office with two working places.

4.2 MEASUREMENT RESULTS

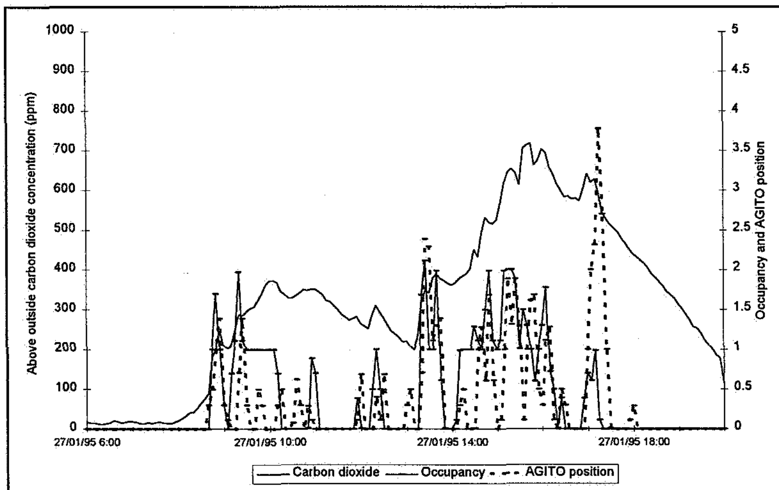


Figure 3 - Two working places room - Above outside CO_2 concentration, real occupancy and AGITO terminal opening position on the 27[th] of January 95

The following figures show the measured values (AGITO opening position, real occupancy as well as the CO_2 concentration in the two working place room) for one typical day chosen in the measurement period. It must be noted that the AGITO opening position corresponds with the number of "detected" people in the ventilated space, i.e. the number of people corresponding with the number of movements observed according to the conversion table programmed in the terminal. The outside CO_2 concentration has been subtracted to the CO_2 concentration measured in the room.

It has to be added that the AGITO opening position and the real occupancy were measured every 2 minutes while the CO_2 concentration was recorded each 5 minutes. In order to perform the analysis, all the 2 minutes measurements were averaged on a 5 minutes period which explains that not entire occupancy values or opening positions are observed on the following figures.

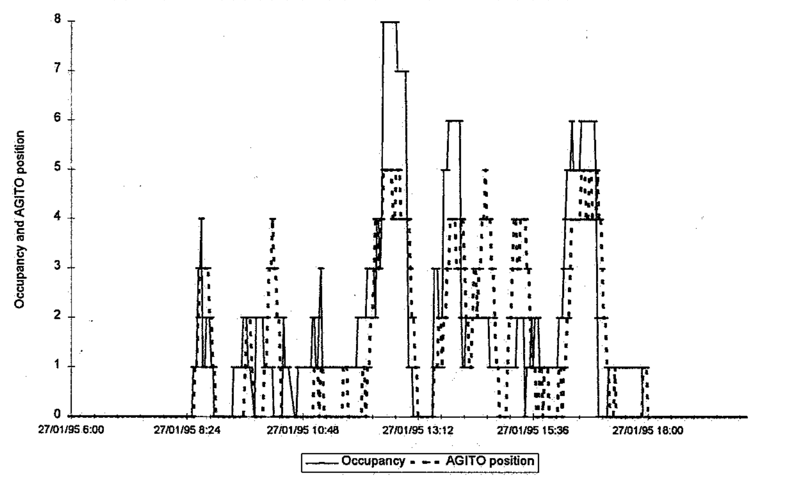


Figure 4 - Meeting room - Real occupancy and AGITO terminal opening position on the 27th of January 95

The observation of the measured data calls for several comments.

- In general the AGITO terminal seems to react to the presence of people in the ventilated space and to follow more or less the occupancy variation.
- However, it appears that the AGITO terminal sometimes underestimates or overestimates the real occupancy (see Figure 3 and Figure 4). On this subject, it should be reminded that the occupancy detection is based on the integration of movements in the room during a 3 minutes period and that, as a consequence, the occupant behaviour can strongly impact on the number of people "seen" by the terminal. Moreover, the detector is quite far from the working places (excepted the meeting place) which probably makes the detection more difficult.

The following figures give the average opening position of the ventilation terminal in function of the real occupancy. The number of recorded samples is also indicated for each point.

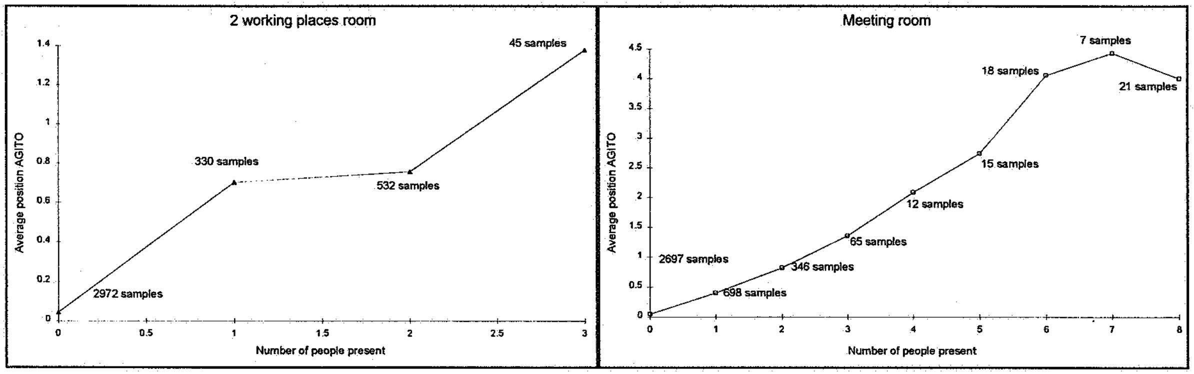


Figure 5 - Average opening level versus occupancy

It can be seen on Figure 5 that the relation between the average AGITO opening and the real occupancy is quite linear when the occupancy is low. As previously mentioned, the lowest the number of samples, the lower the representativity which, with the fact that the AGITO terminal are limited to 5 people occupancy, gives reasons why deviations from the linear relation are observed for high occupancy values.

It is interesting to observe that the relation is similar in both rooms expected for the high occupancy values in the meeting rooms and for an occupancy of 1 person in the two working place room. This last deviation is difficult to explain and could be due to a bad measurement of the real occupancy. The average behaviour is given by the following formula relating the AGITO terminal opening to the real occupancy:

Eq. 1 $$\text{Average opening position} = 0.5 \times \text{number of people} \quad [/]$$

The measurement points corresponding with real occupancy value higher than 5 and an opening position of 5 were removed to proceed to the analysis since the terminal is limited to 5 people. However, this affect not strongly the result since a very few points are concerned.

It should be said that the reaction time of the AGITO terminal does not influence this last analysis since the delay at the opening of the terminal (when more people are detected) is compensated by the delay at the closing of the terminal (when less people are detected).

It can be concluded that the number of people detected by the AGITO terminal is on average the half of the real occupancy. The reason why the occupancy is underestimated could be the long distance between the working places and the AGITO detector. It is therefore advisable in such configuration either to lower the detection level of the terminal or to place the detector closer to the working places.

4.3 CONCLUSIONS

- The AGITO terminal seems to react to the presence of people in the ventilated space and to follow more or less the occupancy variation. However, the occupancy estimated by the sensor was on average only the half of the actual occupancy. This is probably due to the long distance between the occupants positions and the infra-red sensor.
- Therefore a special attention should be paid to the sensor location when installing these terminal. In the event the sensor cannot be placed close to the occupants (in renovation for example), the conversion table of the terminal could be adapted to take account for the distance.

5. THE USE OF THE OPTO TERMINAL FOR VENTILATION OF BEDROOMS

5.1 EXPERIMENTAL SET-UP

The recording of movements during the nights in bedrooms was achieved through the same motion detectors used in the OPTO terminal. The detectors were placed in different locations in the rooms, in possible positions for a ventilation terminal, "looking" in the direction of the bed. Two detectors were used at each time, at different locations, to verify the variability of response in the same conditions of sleeping. (A previous experiment had shown the reliability and repeatability of 16 detectors in the same place, looking at the bed, but with small differences in the angles).

In order to avoid the saturation of the memory we used "reduced movements" : a "reduced movement" is a period of 4 seconds in which at least 1 movement occurs:

If 1 or more movements occur during this period, the counter is set to 1 and kept to this value.

Each recorded value is the number of "reduced movements" detected in a 3 minutes period. The maximum value is thus 45 (3*15 reduced movements) (which value is very rarely attained as it implies quasi continuous detection for more than 3 minutes).

A full day gives 480 values. Eight nights (and days) were recorded at each campaign and transferred to a PC for storing and analysis. More than 1000 nights have been recorded from the beginning of the experiment.

5.2 MEASUREMENT RESULTS

5.2.1 TYPICAL DETECTION PATTERN

Following figures show typical detection pattern as recorded in two different bedrooms during the night. One can observe that a lot of movements are recorded during the night although during some periods the sensor "does not see" the sleeping people anymore.

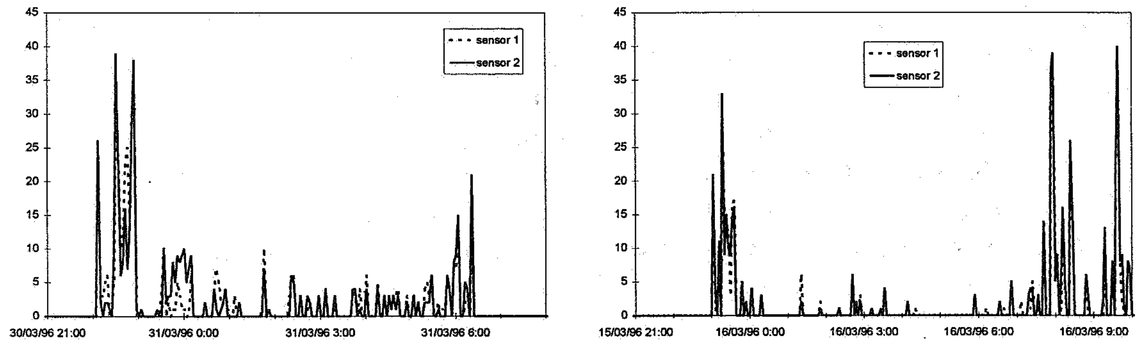


Figure 6 - Typical infra-red detection pattern in bedrooms

5.2.2 WHAT DELAY SHOULD BE TAKEN FOR SWITCHING OFF THE VENTILATION?

As illustrated by the previous figures, there are periods during which sleeping people are not making any movement that can be detected by the sensor. Therefore, the delay for switching off the ventilation after last detection must be chosen with care. Indeed, a too long delay would diminish the energy gain that can be obtained thanks to the IR control and a too short time constant would result in a unacceptable air quality. The intention is to study in detail the large amount of data recorded so as to determine on a statistical basis the optimal delay. The outcome of this study will be proposed for publication at the next AIVC conference.

6. GENERAL CONCLUSIONS

Simulation of demand controlled ventilation based on IR detection in a large well-insulated office building showed that substantial energy savings can be obtained.

The study of the AGITO terminal in two offices showed that the device is able to adapt the flow rate as a function of the real occupancy. It was highlighted that a special attention must be paid to the sensor location.

A large amount of data on the detection of occupancy in bedrooms during nights were collected. A first analysis of these measurements shows that it could be possible to control ventilation on the basis of infra-red detection. However, the time constant of the terminals must be chosen with care. A statistical analysis of the measurements will occur next year so as to determine optimal time constant.

ACKNOWLEDGEMENTS

This research project was partly financed by the Commission of the European Communities in the framework of the CONVENT project. The authors would like to express their gratitude to the sponsoring organisation.

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