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Title: **Increased Ventilation Airflow Rate: Night and Day Cooling of an Office Building**

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INCREASED VENTILATION AIRFLOW RATE : NIGHT AND DAY COOLING OF AN OFFICE BUILDING

by Christophe MARTIN - CETIAT

Abstract

This study aims at evaluating the energetical benefits of increased ventilation airflow rate to cool buildings. Different operating modes have been tested :
- increased ventilation airflow rate during the night to take advantage of the building thermal capacity to cool it,
- increased ventilation airflow rate during night and day when the outside air temperature is lower than the inside air temperature.

This three-year study (from 1994 to 1996) has been carried out in 4 steps :
1) bibliographic study to learn results of studies already led in this field;
2) experimental phase on a real building in La Rochelle (France);
3) experimental phase on a real building in Chambery (France);
4) parametric study by numerical simulation.

This paper concerns only the 3rd step of the global study : the experimental phase in Chambery. This experimental study consisted in implementing different working scenarios of increased ventilation airflow rate (up to 10 vol/h) during night and day on a office building. The experiments were carried out during summers 1995 and 1996 and gave us useful information to optimize increased ventilation airflow rate working scenarios, such as :
- solar impact on efficiency,
- working periods in night and day,
- control based on difference between outside air temperature and inside air temperature,
- potential energy savings with regard to energy consumption of the fans.

1 - Experiments

The experiments took place on an office building in Chambery which is located in the south-east part of France, close to the Alps and submitted to a continental outdoor climate. Preliminary experiments were carried out during summer 1995 to assess the performance and to adjust the operating parameters of the system. Based on these results, final experiments were carried out during summer 1996.

1.1 - The building

The building, built in 1992, seems to have a low thermal inertia. The walls are made of metallic beams and siding with fiberglass thermal insulation. The experimental part consisted of the western part of the first floor, constituted of 7 offices : 3 facing north and 4 facing south, as shown in figure 1.

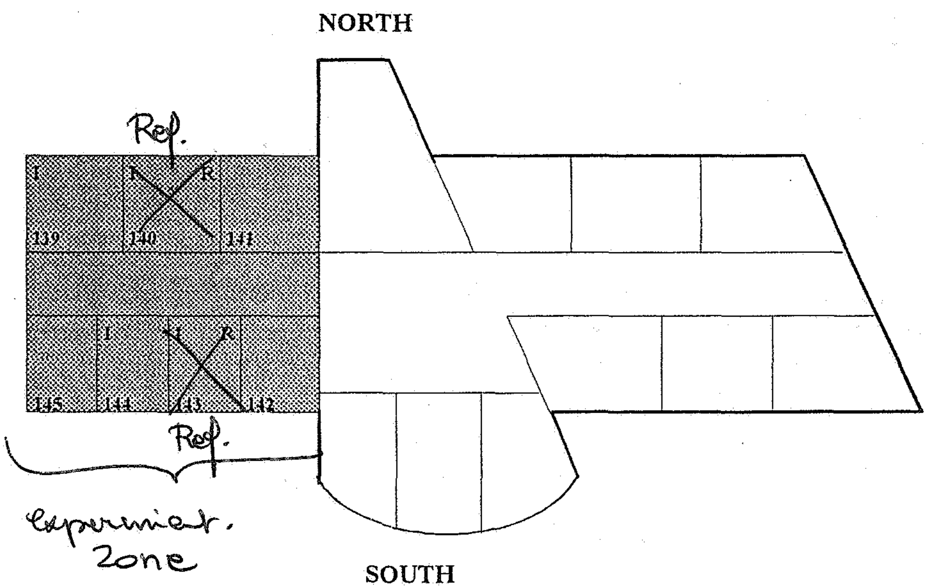

Figure 1 : Experimental building

1.2 - The ventilation systems

The experimental building is equipped with two different ventilation systems : one exhaust ventilation system for sanitary fresh air (0,5 vol/h) and one exhaust and supply ventilation system which was modified to reach airflow rates of about 6 to 10 vol/h. The detailed airflow rates reached in each office are presented in table 1.

Table 1 : Airflow rates in the offices

N° office	Floor area [m²]	Room volume [m³]	Sanitary exhaust ventilation system [m³/h]	Increased supply airflow rate [m³/h]	Increased exhaust airflow rate [m³/h]	Total exhaust airflow rate [m³/h]	Total exhaust airflow rate [vol/h]
139	23,35	65,38	33	280	360	393	6,0
140	23,65	66,22	33	0	0	33	0,5
141	22,80	63,84	32	355	390	422	6,6
142	16,80	47,04	24	450	480	504	10,7
143	17,65	49,42	25	0	0	25	0,5
144	17,65	49,42	25	415	440	465	9,4
145	17,35	48,58	24	425	310	334	6,9

The offices n° 140 (north) and 143 (south) are not connected to the increased ventilation airflow rate system and were considered as reference to assess the effects of increased ventilation airflow rate.

The sanitary exhaust ventilation system works permanently when the increased ventilation airflow rate system is controlled by a BMS (Building Management System).

1.3 - The instrumentation

Four offices were instrumented : the two reference offices (140 and 143) and two offices (139 north and 144 south) with increased ventilation airflow rate. Three temperature probes were installed in the middle of each office at 1.00, 1.50 and 2.00 m from the floor.

One air temperature probe was installed in the inlet duct of the air handling unit (used to generate the increased exhaust and supply airflow rate) and one in the outlet duct.

A measurement station was already available on the roof of the building, for recording the outdoor conditions (air temperature and solar intensity).

The BMS was equipped with probes and recorded the outdoor air temperature (with a probe on the north side of the building), the minimum inside air temperature (with one air temperature probe in each office), the supply air temperature and the operating status of the increased ventilation airflow rate system.

1.4 - The scenarios

Different scenarios were carried out to assess the potential energy savings of such a system. Working limits were selected to manage the increased airflow rate ventilation system. It could only work when the difference between the minimum inside air temperature and the outdoor air temperature was greater than 2 °C.

The three different experiments carried out during summer 1996 are described in table 2.

Table 2 : Experimental periods carried out during summer 1996

Period	Scenario
August 14 to 18	No increased ventilation airflow rate : reference period
August 19 to 26	Increased ventilation airflow rate when it is allowed without time limit
September 1 to 9	Increased ventilation airflow rate when it is allowed only during the night from 8 pm to 8 am

During all these different periods, the sanitary exhaust ventilation system was working permanently.

2 - The results

The records showed that there were no significant differences between the three air temperature probes of an office or between the different outdoor air temperature probes.

2.1 - Period without increased ventilation airflow rate

During this period, it seemed obvious that the different offices had a different behaviour : the air temperatures in the offices facing north were lower than those facing south. Even on the same side, offices 143 and 144 showed differences because of different exposure to sun : office 143 could benefit from the shadow of the projecting middle part of the building. Nevertheless, the evolution of these differences seemed to be similar from one day to the other and it was decided to define an average evolution on 24 hours as shown in figure 2. It was necessary to take into account these differences to understand correctly the effects of increased ventilation airflow rate during the other periods.

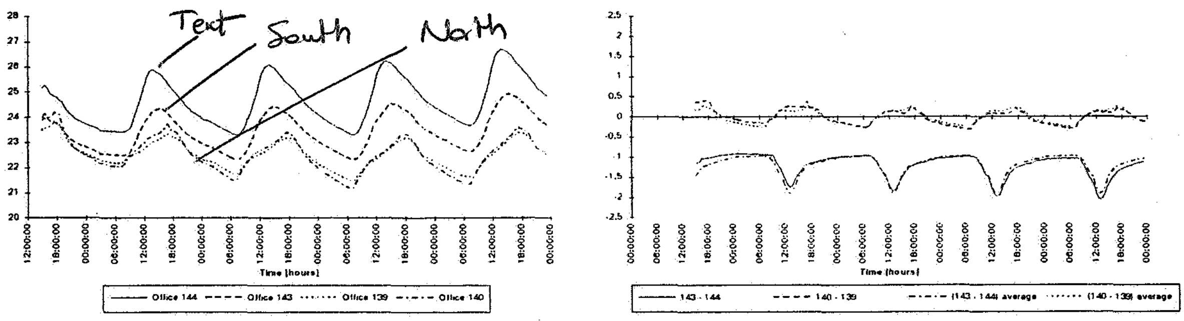

Figure 2 : Inside air temperature evolution during the period without increased ventilation airflow rate

2.2 - Period with increased ventilation airflow rate during the night

During this period, increased ventilation airflow rate system worked only during the night from 8 pm to 8 am when the difference between the outdoor air temperature and the minimum inside air temperature was greater than 2 °C.

To analyse the results of the experiments, the difference in inside air temperatures between the ventilated offices with high airflow rates (139 and 144) and the reference offices (140 and

143) had to be taken into account. The normal air temperature difference between the ventilated offices and the reference offices noticed during the period without increased ventilation airflow rate had to be substracted. Finally, an average evolution on 24 hours was necessary to reach a conclusion on general tendancis. Figures 3 and 4 show the different steps of this procedure.

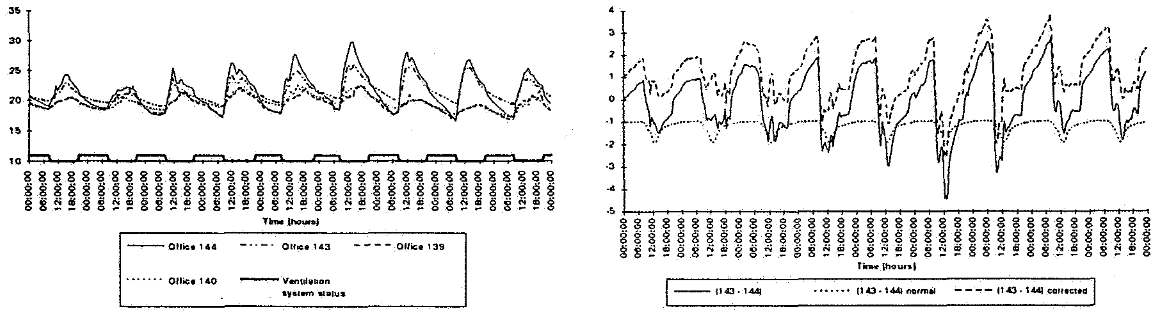

Figure 3 : Inside air temperature evolution during the period with increased ventilation air flow rate during the night

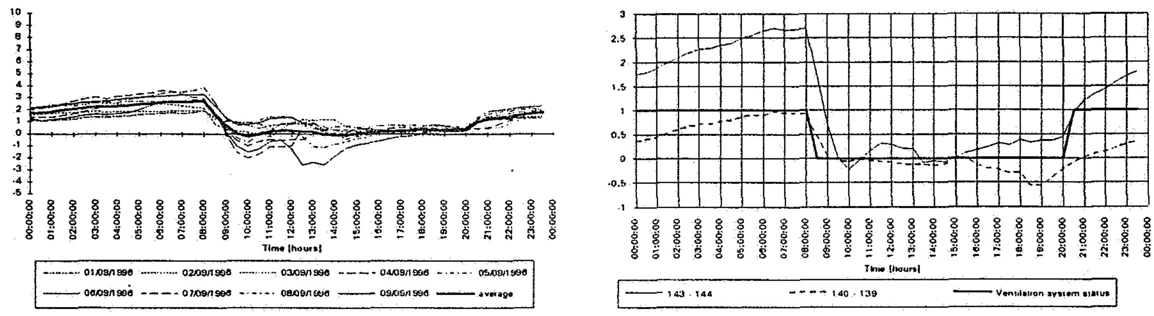

Figure 4 : Average inside air temperature evolution during the period with increased ventilation air flow rate during the night

Figure 4 shows that the inside air temperature difference between the ventilated offices and the reference offices increases when the increased ventilation airflow rate system is working, but as soon as it stops, the inside air temperature difference between the offices decreases very quickly and reaches zero in less than one hour. This can be explained by the very low thermal inertia of the building.

For this case, it appears that increased ventilation airflow rate during the night is not profitable.

<u>2.3 - Period with increased ventilation airflow rate without time limit</u>

During this period, the increased ventilation airflow rate system worked without any time restriction when the difference between the outdoor air temperature and the minimum inside air temperature was greater than 2 °C.

In order to analyse the results, a calculation procedure similar to that used in section 2.2 was adopted. Figure 5 shows directly the average inside temperature difference between the ventilated offices and the reference offices on a 24-hour period.

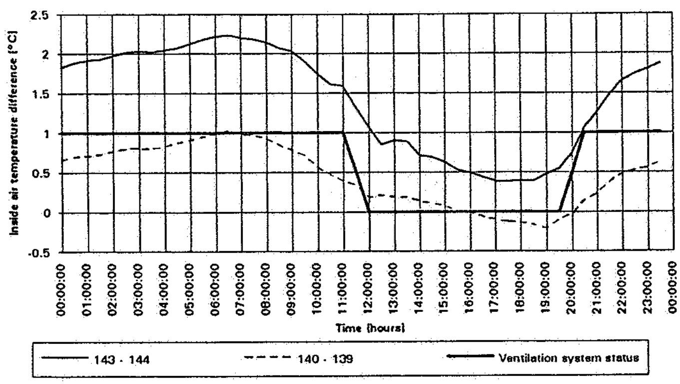

Figure 5 : Average inside air temperature evolution during the period with increased ventilation air flow rate without time restriction

With this scenario, the increased ventilation airflow rate system worked until 12.00 and the inside air temperature could be lowered by 2 °C in the southern offices and by 1 °C in the northern offices. Moreover, previous results showed that it was not necessary to ventilate the building all night and it could be possible to optimize the working scheme to start the ventilation system only 4 hours before the occupied period.

To evaluate the energy savings potentiality, an index was defined as follows :

$$I_{ji} = \int_{8h00}^{20h00} (T_{ref} - T_i)dt$$

Iji : temperature gain index for office n° i
Ti : inside air temperature of the office n° i
Tref : inside air temperature of the reference office associated to the office n° i

Figure 6 shows the evolution of Iji with the solar intensity and the outdoor air temperature.

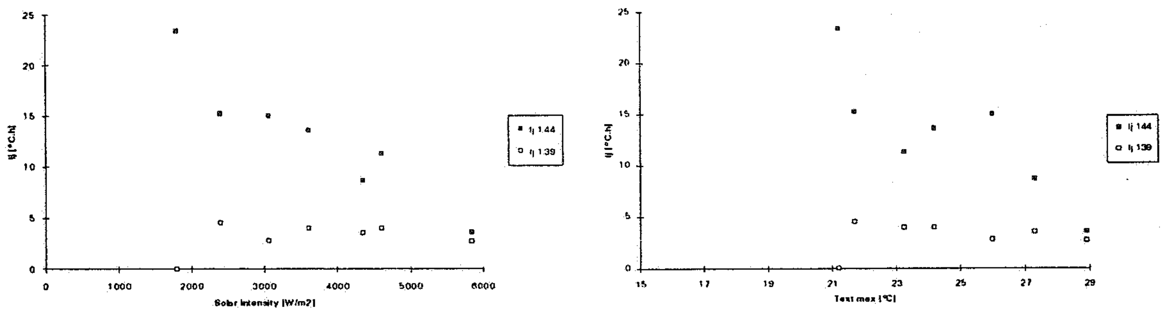

Figure 6 : Evolution of Ij with solar intensity and maximum outdoor air temperature

It appears that the nothern offices are less sensitive to the outdoor climate conditions. For the southern offices, the lower the outdoor air temperature and the solar intensity are, the higher the temperature gain index is.

2.4 - Influence of outdoor temperature

To optimize the working scenario of such a system, it was necessary to take into account the evolution of the inside air temperature of both the ventilated offices and the reference offices against outdoor air temperature.

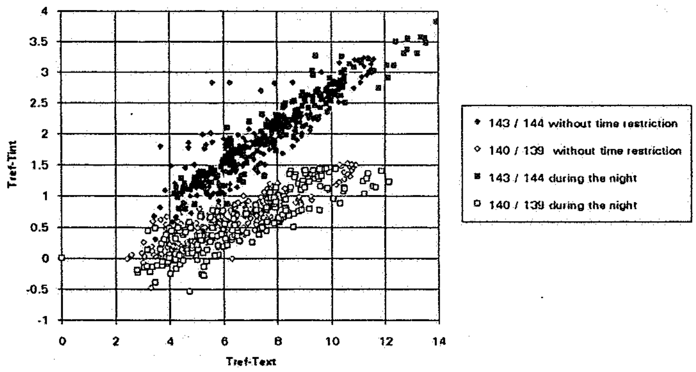

Figure 7 : Inside air temperature difference between reference offices and ventilated offices against air temperature difference between inside air temperature of reference offices and outdoor air temperature

Figure 7 shows that the tendance is the same for the northern offices and for the southern offices but the effect is much more important for the southern offices. For both cases, it appears not profitable to start the high ventilation airflow rate system for an air temperature difference between inside air temperature and outdoor air temperature lower than 4°C.

A theoretical coefficient of performance (COP) was defined as :

$$COP = \frac{\int \dot{M} C_p (T_r - T_s) dt}{2 \times P_{abs}} \quad \text{with } P_{abs} = \frac{Q_v . \Delta P}{\eta}$$

$\dot{M}$: mass airflow rate,
C_p : specific heat capacity of air,
T_r : exhaust air temperature,
T_s : supply air temperature,
P_{abs} : electrical power of the fans (hypothesis exhaust = supply),
Q_v : volume airflow rate ($\dot{M} = Q_v . \rho$, with ρ : specific mass of air),
ΔP : pressure losses,
η : efficiency of the fan.

Figure 8 shows the evolution of the COP with realistic values for the parameters : Q_v=1980 m^3/h, ΔP=300 Pa and η=30 %.

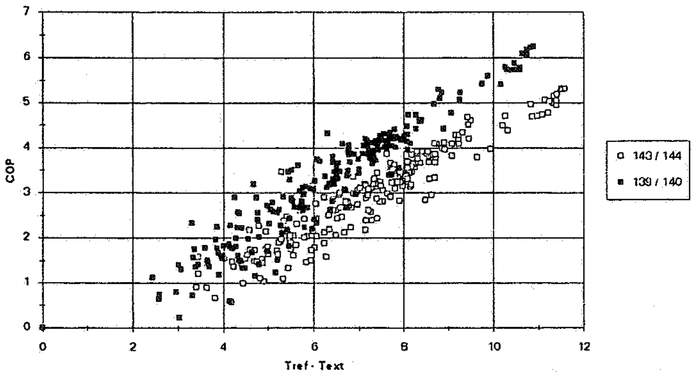

Figure 8 : COP evolution with air temperature difference between inside air temperature of the reference offices and outdoor air temperature

A profitable system should have a COP greater than 1. Figure 8 shows that the difference between the inside air temperature of the reference offices and the outdoor air temperature must be greater than 4 °C, which is in accordance with the previous conclusion. Obviously, with a simple exhaust system, the COP of the system would be multiplied by two (only one fan electrical consumption).

3 - Conclusion

This following conclusions can be drawn from the experiments :

- the northern and southern offices present the same tendancis but the southern offices seem to be more sensitive to the outdoor conditions;
- since the thermal inertia of the experimental building is low, it is not useful to let the system work all night, but just a few hours before the occupied period;
- the efficiency of this system decreases when the solar intensity and the outdoor temperature increase. It is then important to take care of sun protection on the southern wall of the building;
- to be profitable, the system has to work only when the air temperature difference between the indoor and outdoor is of 4 °C at least;
- to be profitable, the increased ventilation airflow rate system has to work without time restriction during day-time. Such an operative scheme allows it to work until 11.00 am and to reduce the inside air temperature by 2 °C in the southern offices and by 1 °C in the northern offices;

As a conclusion, in this case, this increased ventilation airflow rate system seems to be interesting in term of energy savings in mid-season (spring and autumn), when the solar intensity is not to high and when the outdoor air temperature is reasonably low.

Acknowledgements

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