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Title: Applying Night Ventilation Techniques in Office Buildings

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1. Synopsis

In this paper the potential of night ventilation techniques is investigated. Extended real scale measurements have been performed, in three buildings, under free floating and air conditioned operation. Two of the buildings have been studied by using a theoretical model developed in TRNSYS[1] software. Simulation results have been validated by using the measured data. Specific studies concerning the indoor air temperature and the cooling load of the buildings have been carried out in order to identify the influence of night ventilation techniques on the buildings thermal performance. A sensitivity analysis, for various air flow rates during night ventilation, have been performed for one of the studied buildings. The impact of night ventilation on the cooling load (for A/C operation) and indoor temperature (for free floating operation) is studied as well. A significant impact of night ventilation in buildings of high thermal mass is found.

2. Introduction.

Night ventilation is one of the most efficient passive cooling techniques. During summer, night ventilation provides cooling by using the outdoor air to carry away the heat from the building. The efficiency of night ventilation is strongly related with two parameters. The relative difference between the indoor and outdoor temperature, and the rate supply of the fresh air. The lower the outdoor temperature and the higher the fresh air supply, the higher is the effectiveness. Thermal mass of the building as well as the building's interior planning determine the usefulness of night ventilation.

To investigate the cooling potential of night ventilation techniques, extended measurements have been performed in three office buildings, during the summer of 1995 and 1996. In particular, the following three buildings, presenting different characteristics, were studied :

- Office building "Meletitiki Ltd. A.N. Tombazis and Associates" (summer of 1995 and 1996).
- Office located in "University of Athens, Department of Applied Physiscs" (summer of 1996).
- Office located in "National Observatory of Athens" (summer of 1996).

Continuous measurements of the indoor temperature as well as of the air flow rates during the application of night ventilation have been carried out. In the last two buildings the indoor air temperature of the adjusted spaces was also measured.

3. Description of the Studied Buildings and Measurement System.

4 "Meletitiki Ltd" is mainly composed by seven zones as shown in Figure 1, without internal partitions as the building is a unique volume construction. It has a heavy structure and it is ventilated during the night by mechanical and natural means. It is also thermostatically

controlled and cooled by air to air heat pumps. The design air flow rate during night is close to 26 air changes per hour.
Various operational schedules, have been studied both experimentally and theoretically :

- Free floating conditions during day and night without applying night ventilation techniques.
- Thermostatically controlled conditions during the day period (operation of the air conditioning system), without any use of night ventilation.
- Night ventilation followed by a free floating operation during the day period.
- Night ventilation followed by thermostatically controlled operation (operation of the air conditioning system), during the day period.

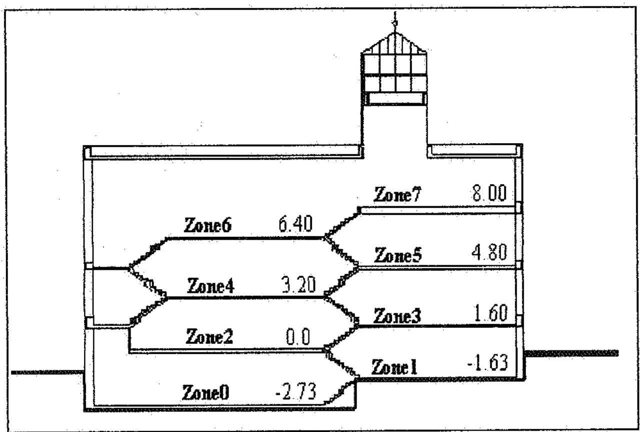

Figure 1. Section of the "Meletitiki Ltd." building showing the different zones and levels.

Night ventilation is achieved mainly through two exhaust fans located on the roof of Zones 6 and 7 over the two staircases. During the night period windows of zones 2, 3, 5 and 7 remain open. The capacity of each fan is close to 25000 m^3/hour. The estimated air flow when night ventilation applied was close to 25 air changes per hour. The mean air flow when fans where off and the windows open varied between 1 to 3 air changes per hour. In the summer of 1995 measurements have been carried out during the summer holidays (July 26th to August 11th). The indoor air temperature was measured in the main zones of the building (zones 2, 4, 6 and 7). In total, indoor temperature was measured at eight different points of the building. Night ventilation has been used for hours between 10pm to 6am. Figure 2 gives the ambient and the average indoor temperature during the experimental period.

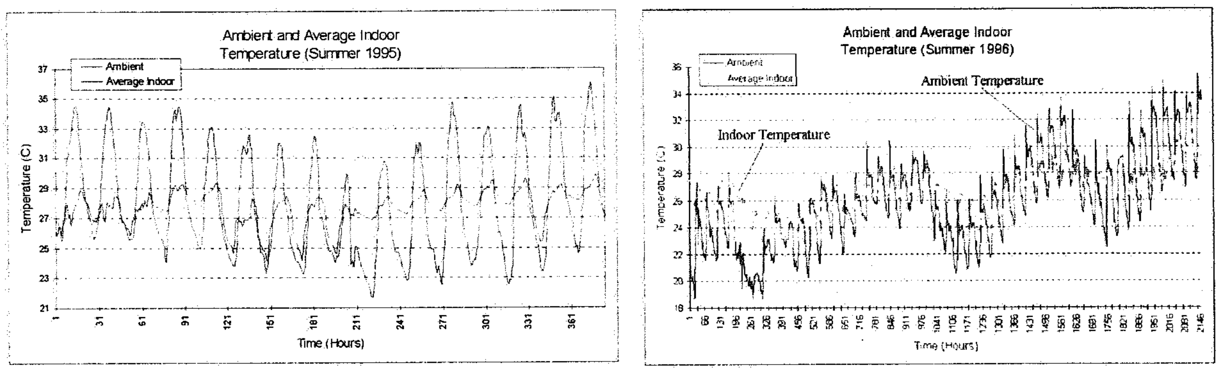

Figure 2. Ambient and average indoor temperature in "Meletitiki Ltd." (Summer 1995 and 1996).

During the summer of 1996 the indoor and ambient temperatures were measured from May 24th to July 8th. Indoor air temperature was measured in zones 2, 4, 6 and 7 of the building. Night ventilation has been applied between 10pm to 6am. Figure 2 gives the ambient and the average indoor temperature during the experimental period.

The office of the "University of Athens", is a room located on the third floor of a six storey building. The building has a light structure and the studied room is cooled by an air to air heat pump. In order to apply night ventilation techniques the two windows of the room were open during the night period. Both windows are located at the same side of the room and therefore the building is single side ventilated. Continuous tracer gas measurements, (constant injection), have been carried out so as to measure the air flow rate. The operational schedules followed for the "Meletitiki Ltd" building, have been also studied, in this building.

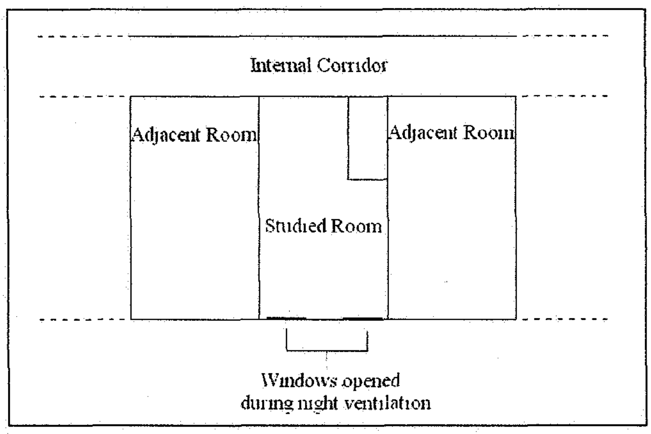

Figure 3. Plan of the office located in "University of Athens" building, showing the location of the studied room.

During summer of 1996 the indoor and ambient temperatures were measured from July 9th to July 23rd. Figure 4 gives the ambient and the indoor temperature during the experimental period of 1996 as well as the corresponding air changes per hour. Night ventilation techniques were applied during twelve nights of the above period.

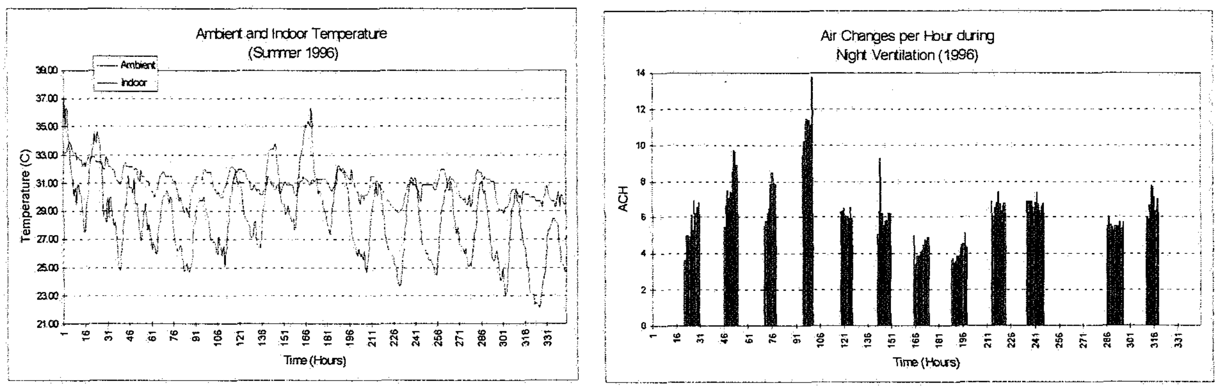

Figure 4. Ambient temperature, indoor temperature and the corresponding air changes per hour during night ventilation in "University of Athens" (Summer 1996).

The office located in "National Observatory of Athens", is a room located on a one storey building. It is composed by one zone (Figure 5). It is a non air conditioned building having a very heavy structure. Night ventilation is applied and measured the same way as in the previous building.

weekt nt ; vermoeden dat by hoge airflow → geen contact tussen massa & lucht !!
ventilation effectiveness

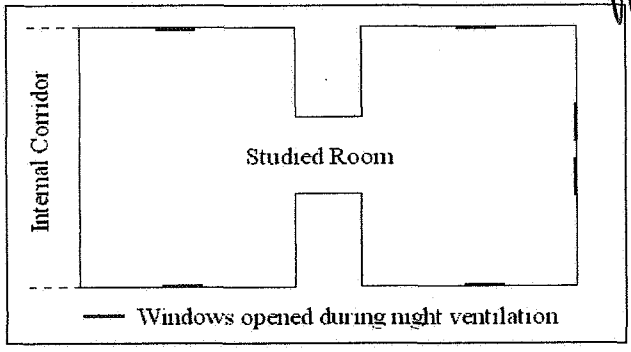

Figure 5. Plan of the office located in "National Observatory of Athens" building, showing the location of the studied room.

During the summer of 1996 the indoor and ambient temperatures (three temperature sensors) were measured from September 7th to September 18th. Figure 6 gives the ambient and the average indoor temperatures during the experimental period of 1996 as well as the corresponding air changes per hour achieved during the night. Night ventilation techniques were applied during twelve nights of the above period.

10 - 17 ACH/hr !

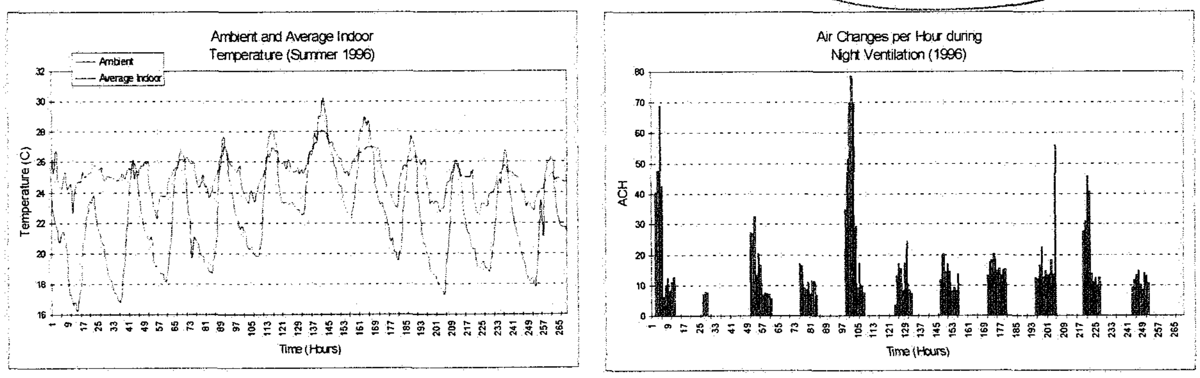

Figure 6. Ambient temperature, indoor temperature and the corresponding air changes per hour during night ventilation in "National Observatory of Athens" (Summer 1996).

4. Simulations and Theoretical Studies for the "Meletitiki Ltd" building (Summer 1995).

In order to evaluate the performance of night ventilation techniques and to analyze the experimental data, simulations of the thermal performance of the building have been performed using the TRNSYS software, during the measurement period of the summer of 1995. An additional air flow model based on the network approach has been coupled to TRNSYS to simulate air flow through internal and external openings under natural and forced air flow. The basics of the model as well as the validation procedure and results are described in (2). It should be noticed that during the above measurement period the building was under free floating conditions and without internal gains.

The simulated as well as the measured temperatures for zones 2, 4, 6 and 7 and for the whole measurement period, are given in Figures 7 and 8, respectively. As shown, the agreement between all simulated and measured values is satisfactory for all the possible operational conditions. The average difference between measured and simulated temperatures is close to 0.4 C. Thus it was assured that the developed theoretical model of the building represents accurately the thermal behavior of the building under all the studied conditions.

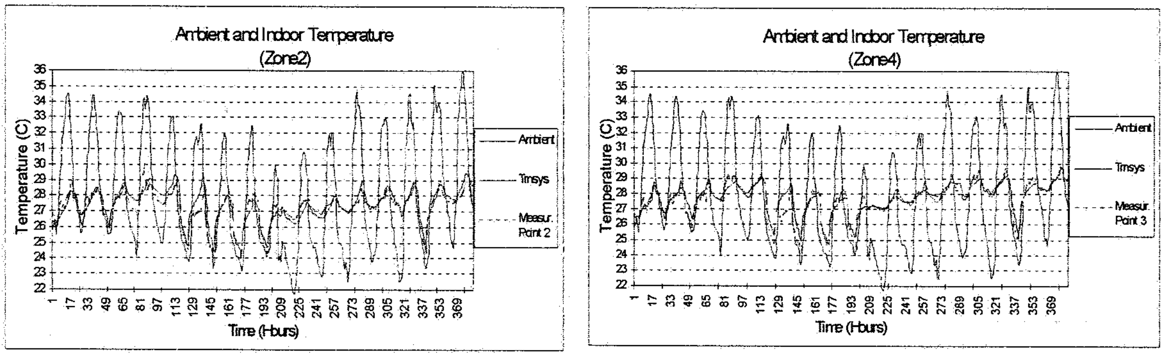

Figure 7. Measured, simulated and ambient values of the air temperature, for Zones 2 and 4.

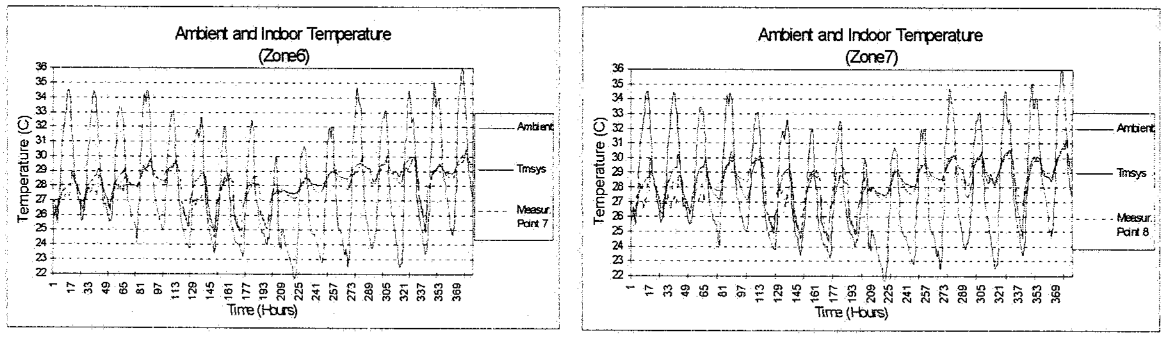

Figure 8. Measured, simulated and ambient values of the air temperature, for Zone 6 and 7.

In order to investigate the influence of night ventilation to indoor temperature, the building was simulated under the above conditions but without night ventilation. Figures 9 and 10 give the indoor air temperature with and without night ventilation for free floating operations. This comparative approach has clearly shown that under free floating conditions, application of night ventilation techniques contributes to decrease the next day peak indoor temperature of the building, up to 2.5 °C. It should be noticed that under air conditioning conditions the corresponding temperature decrease was close to 1 °C.

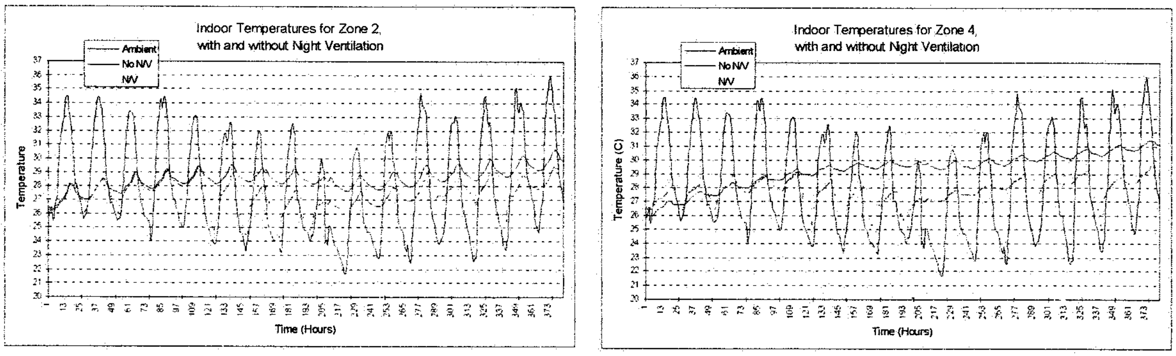

Figure 9. Indoor temperature with and without night ventilation, for Zone 2 and 4.

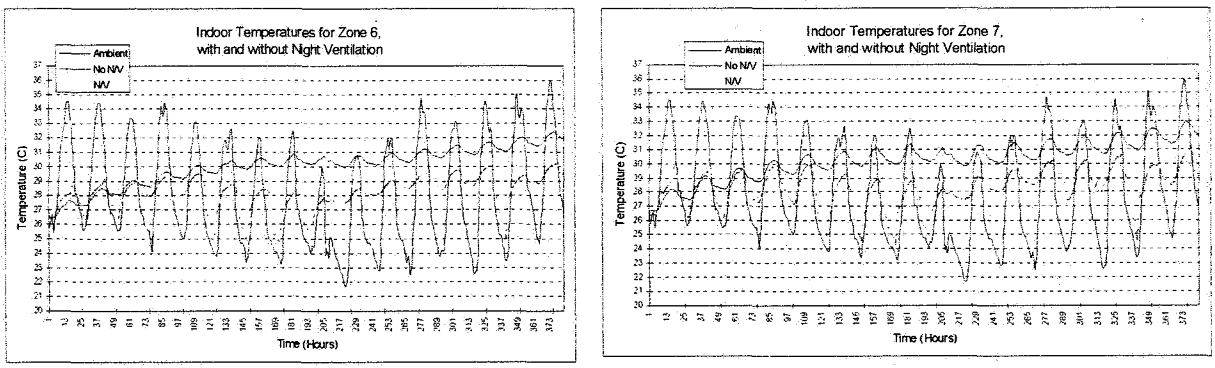

Figure 10. Indoor temperature with and without night ventilation, for Zone 6 and 7.

In order to investigate the cooling potential of night ventilation techniques and to examine the impact of the various possible air flow levels, simulations have been performed under air conditioning conditions with and without night ventilation. The previously mentioned validated TRNSYS model, is used. Simulations were carried out for a complete summer period, (May to September), and for 5, 10, 20 and 30 air changes per hour. The building was considered to be under thermostatic control between 9 a.m. to 7 p.m., while night ventilation is applied between 10 p.m. to 6 a.m. Simulations have been performed for an indoor set point temperatures of 27 C.

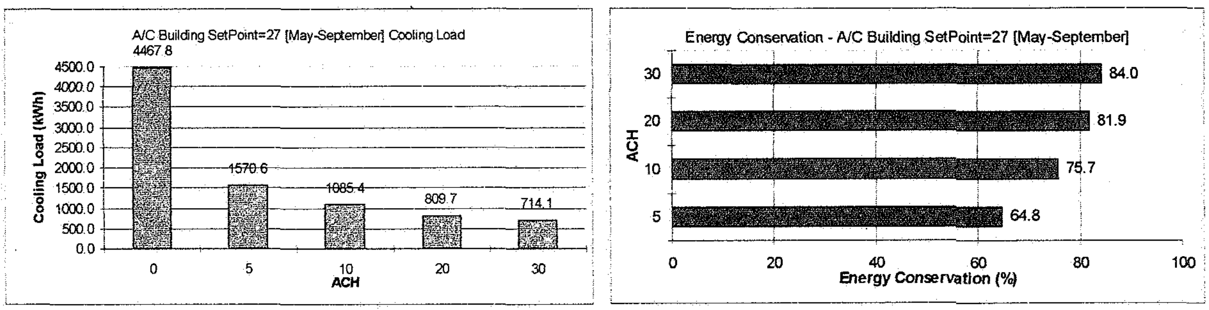

Figure 11. Cooling energy and energy conservation due to night ventilation (set point 27C).

Figure 11 gives the obtained results for the studied scenarios. The absolute value of the cooling load as well as the corresponding energy savings for cooling are given. It is found that the expected energy conservation, for this specific building, varies between 65 to 84 percent when air flow rate varies between 5 to 30 ACH. As clearly shown, the higher the air flow rate, the higher the calculated energy conservation due to night ventilation.

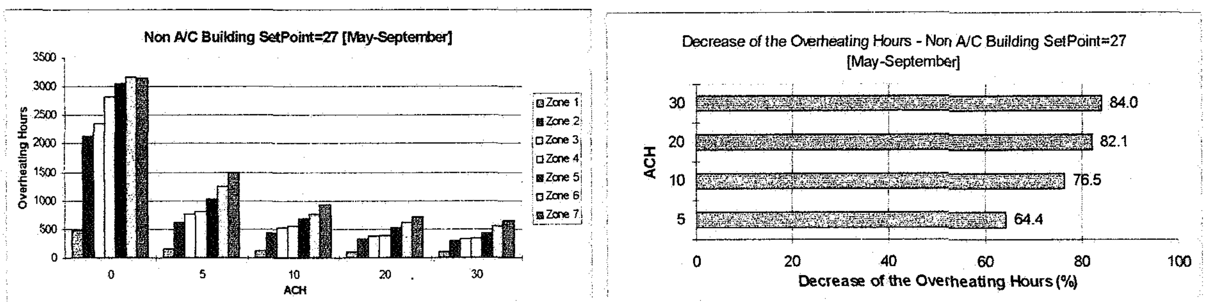

Figure 12. Number and decrease of the overheating hours (set point 27 °C)

To investigate the potential of night ventilation techniques, to improve indoor comfort conditions when A/C systems are not in use, the building was simulated under free floating conditions. In this case the number of hours for which indoor temperature exceeds 27 C were calculated (Figure 12).

5. Simulations and Theoretical Studies for the "University of Athens" building (Summer 1996).

Simulations of the thermal performance of the building, during the measurement period of the summer of 1996, have been performed using the TRNSYS software. The measured air flow rates during night ventilation (Figure 4) have been used in all thermal model. In contrast with the previous building, the present was occupied during the experimental period. The simulated as well as the measured indoor temperatures are given in Figure 13. As shown, the simulated and measured temperatures are almost identical. The average difference between measured and simulated temperatures is close to 0.3 C.

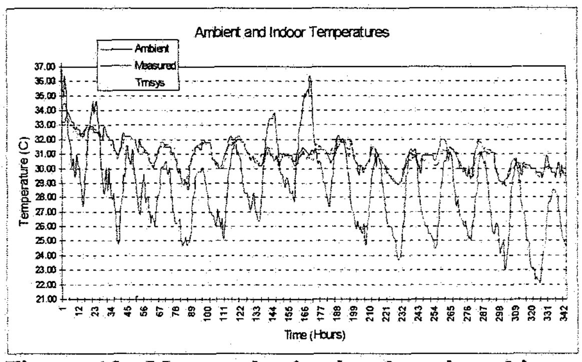

Figure 13. Measured, simulated and ambient values of the air temperature.

In order to investigate the impact of night ventilation on the indoor air temperature, comparisons with simulation results of non night ventilated configuration have been performed. In both cases the building was considered as thermostatically controlled. Application of night ventilation techniques was found to decrease the next day peak indoor temperature of this building by 0.1 up to 0.2 °C (Figure 14).

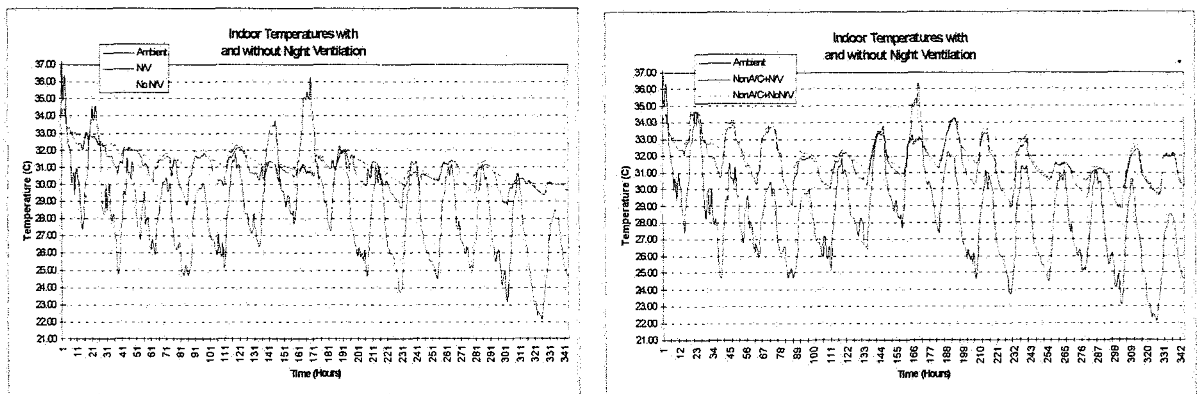

Figure 14. Indoor temperature with and without night ventilation (A/C and non A/C operation)

It is concluded that the use of the air conditioning system, the high internal gains and the low thermal mass of the building decrease the efficiency of night ventilation techniques. In a second attempt, the building was simulated under free floating conditions. Figure 14 gives the indoor air temperatures with and without night ventilation, when the A/C system is not in use. As shown the influence of night ventilation on the thermal performance of the building is not important. The application of night ventilation decreases the next day peak indoor temperature of the building by 0.1 to 0.3 C.

6. Conclusions

Night ventilation techniques have been applied in three real scale office buildings, of different mass, ventilation and layout characteristics (in Athens, Greece). The "Meletitiki Ltd" building has important thermal mass and it was studied during a period of very low internal gains, and non operation of the air conditioning system. On the contrary, the "University of Athens" building has a light structure and it was studied when internal gains were important and the air conditioning system was in use. The two cases are extreme conditions and in a way they indicate the limits of the potential of night ventilation techniques.

It was found that in the "Meletitiki Ltd", application of night ventilation techniques decrease the next day peak indoor temperature of the building, during free floating conditions, up to 2.5C, while under A/C conditions the corresponding temperature decrease was close to 1 C. Sensitivity analysis has shown that under A/C conditions, the expected energy conservation, for this specific building, varies between 65% to 84% when the air flow rate varies between 5 to 30 ACH respectively. It is shown that the higher the air flow rate, the higher the calculated energy conservation due to night ventilation. Under free floating conditions, the expected decrease of overheating hours varies between 64% to 84% when the air flow rate varies between 5 to 30 ACH respectively.

In the building of the University of Athens, night ventilation decreases the next day's peak indoor temperature of the building during A/C conditions by 0.1 to 0.2 C, while under free floating conditions the temperature decrease is 0.1 to 0.3 C.

In conclusion, night ventilation techniques when applied, may contribute to decrease considerably or not the cooling load of A/C and improve or not the comfort levels of free floating buildings. The exact contribution of night ventilation for a specific building has to be calculated as a function of the building characteristics, the climatic conditions, the applied air flow rate and the assumed operational conditions.

7. References

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2. M. Bruant, A.I. Dounis, G. Guarracino, P. Michel and M. Santamouris
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