VENTILATION AND COOLING

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CONTROL of natural ventilated buildings!

(Title)

Feedback On The Design of Low Energy Buildings

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Synopsis

This paper presents results from the monitoring of a low energy building, namely, the Portland Building (University of Portsmouth - UK) during February and July 1997. The BMS Research Group at the University of Portsmouth has instrumented the building so that its performance can be compared with the predictions obtained at the design stage. The Building has been operational since July 1996 and the monitoring exercise commenced in January 1997. Sensors monitor air temperature, air relative humidity and slab temperature in selected areas of the building. Analysis of the data collected shows that the CO_2 and water vapour levels are acceptable during the winter period and that the number of air changes per hour in the office and seminar room under consideration are adequate. The variations of air temperature in July 1997 inside a seminar room are compared with predictions from a simulation exercise carried out using ESP-r (simulation package) at the design stage and found to be in agreement. The underlying work is on-going and aims at providing feedback on the design on naturally ventilated buildings as well as improving the operational control aspects.

1 . Introduction

Building designers in the UK and increasingly in other parts of Europe currently consider natural ventilation as their first option to achieve required indoor conditions. The main reason for this is the concern over energy bills incurred by conventional HVAC equipment. Although natural ventilation might be perceived as an easy alternative, it is not. It requires careful consideration at the design stage even for the simplest building. In many instances, it has to be used in conjunction with alternative strategies (resulting in a mixed mode and/or hybrid system), since it will have been predicted at the design stage that natural ventilation will have difficulty in satisfying all the operational demands; for example a large lecturing theater may necessitate the installation of a conventional HVAC system. This use of mixed technologies makes the problem more difficult as it is the designer's responsibility not to fall into a situation where the overall design is more expensive to run than a conventional HVAC installation.

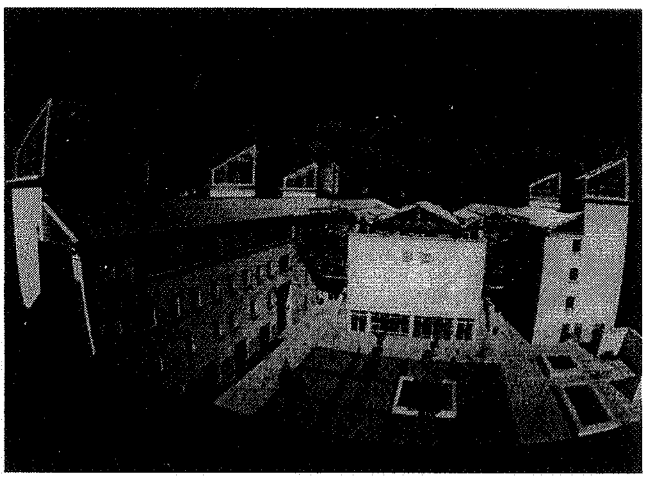

Figure 1. The Portland Building

The main problem associated with natural ventilation is the different requirement between the heating season and summer. In the former case, the concerns are over the maintenance of appropriate ventilation rates to ensure a safe and pollutant free working environment. In the summer the requirement is for high ventilation rates in order to maintain low (with respect to outside conditions) internal temperatures. Increasingly, sophisticated design calculations are called upon to help produce performant naturally ventilated buildings. As a result, there is a growing need for guidance on the design procedures and operation of naturally ventilated buildings. Part of the information required to build up such intelligence will eventually come from monitoring buildings which already implement natural ventilation. This would provide useful feedback for designers and building operators alike. In this context, several schemes are underway to monitor the performance of naturally ventilated buildings [1,2,3] and this paper presents early results from a monitoring exercise being carried out by the authors on the Portland Building [4] on campus at the University of Portsmouth, which is a mixed mode and hybrid building implementing natural ventilation, forced mechanical ventilation and HVAC plants.

2 . The Portland Building

The Portland Building (Figure 1) was built to house the Environment Faculty at the University of Portsmouth. It was commissioned during the summer of 1996 and is being monitored by the authors as part of an exercise aimed at assessing the effectiveness of the ventilation process and developing model based solutions to assist in the operation of the buildings. The Portland Building has been described by its designer, Professor Sir Colin Stansfield Smith as "...'a hands on laboratory' for experiencing a whole host of issues that can moderate and control an internal environment.", it is felt to be a valuable teaching aid for students to learn about natural ventilation and the factors which affect it.

The building is L-shaped and has five energy towers which provide staircase access, as well as house the electric ventilating fans and boilers for the under-floor heating. These towers are capped with glazed tops with controllable openings to take advantage of the effects of solar irradiance and the wind. The towers are linked to plenums on the different floors, and allow the air displaced by the stack effect to cross ventilate some of the rooms in the building; the air is discharged to the outside at the highest point in the towers through the motorised windows. The ventilating fans are used in extreme situations (summer time) where the stack effect alone is not sufficient. The Portsmouth BMS Research Group has, in conjunction with the BRE, instrumented sections of the building located between Towers 4 and 5 as described in the following section.

(under floor heating system!)

3 . Instrumentation

In order to assess the performance of the building from the comfort and ventilation points of view it was necessary to install required sensors in offices, corridors, rooms and towers. The monitored area in the building is shown in Figures 2 and 3. The emphasis was placed on measuring temperature both inside the space (air) and of

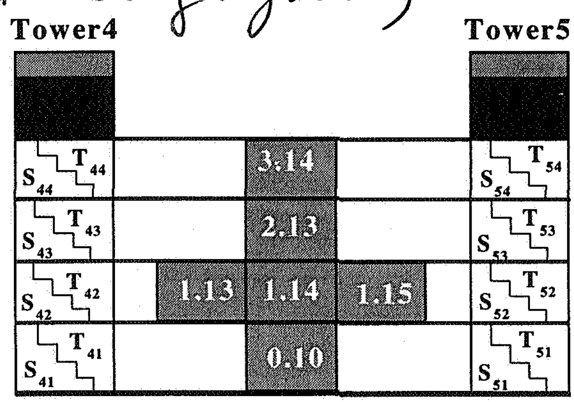

Figure 2. Portland Building - V-section

season). Air temperature inside Room 0.10 displays rapid oscillations on Thursday which can be explained by the fact that the two occupants in this office used a fan heater with a built in thermostat hence the temperatures oscillations.

February 97- Air CO_2 and water vapor content

Next, we look at the indoor air quality. Since the activities carried out inside the office and the seminar room are those undertaken by sedentary occupants engaged in clerical type work, it is reasonable to consider CO_2 and water vapour air content as comfort indicators.

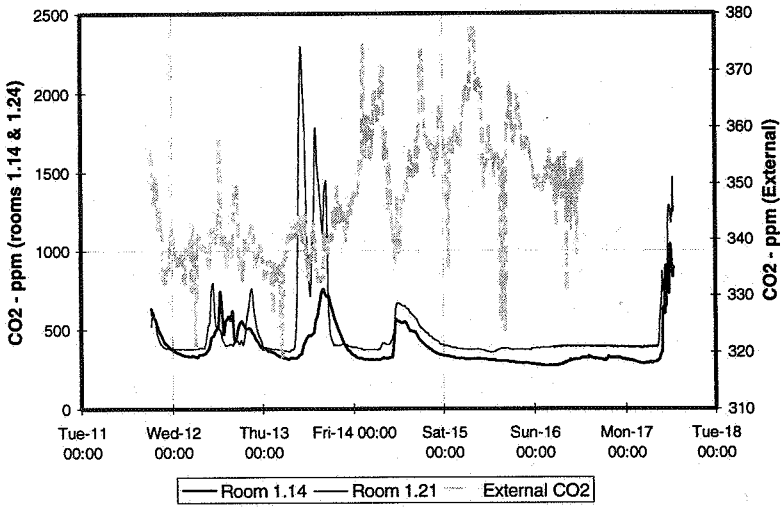

Figure 5. CO_2 concentration variations

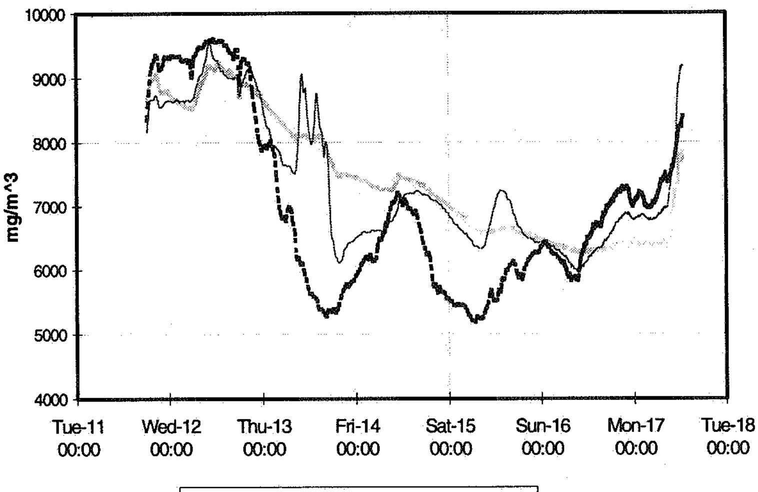

Figure 6. Water vapour content variations

Figure 5 shows the variations CO_2 content indoors (rooms 1.14 and 1.21) and outdoors. The latter remains fairly constant throughout the week at an average of ≅350 ppm. The indoor CO_2 concentration varies with occupancy as discussed in [5]. The high levels attained in 1.21 (seminar room) on Thursday are due to a class being held in it on that day. The levels are still under 3000 ppm which is below the recommended maximum level of 5000 ppm. Figure 6 shows the variations of water vapour content indoors and outdoors. Again the effect of occupancy can be clearly seen on Thursday-13th. A visual inspection of the graph shows the internal water vapour content is affected in a similar way by the external water vapour variations and the input from occupants, whereas the indoor CO_2 in the seminar room 1.21 rises to about 5 times its normal level while a class is being held inside it. The suitability of the CO_2 and water vapour levels for occupants is discussed in detail in [5]. Correlation analysis was carried out to assess quantitatively the influence of external CO_2 and water vapour content on internal air contents. Figures 7 and 8 show the correlation between the internal (cross ventilated seminar room) and the external water vapour and CO_2 air content. We can see that in the case of the water vapour content the behaviour of the external content is more influential than any other source (occupants), whereas in the case of the CO_2 content the correlation is not as well defined as in the case of water vapour. This is because the effect of occupancy takes a few hours to dissipate and is in proportion larger than the effect from the occupants on the internal water vapor content. The

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the walls (structural). Room R_C is at the centre of the monitored section and the rooms on either side, below, above and across the corridor from it are also being monitored.

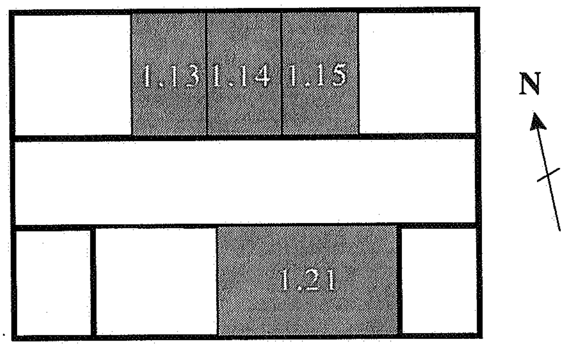

Figure 3. Portland Building - H-section

On the first floor (room R_C and adjacent rooms) the relative humidity was also measured. The information from these sensors is continuously recorded at 5 minute intervals. In addition to this, the ventilation rates in Room R_C (single sided ventilation) and the seminar room R_S across the corridor from it, have been monitored by the BRE in February 1997 (as described in [5]) and more recently in July 1997 using tracer gas (SF6) techniques. Besides this continuous monitoring it is hoped that in the near future funding will be secured to carry out a subjective analysis of comfort conditions by circulating questionnaires among the building occupants.

4 . Discussion and analysis of data collected

4 . 1 . Winter Period

February 97- Space temperatures

Figure 4 shows the variations of air temperature inside single side ventilated offices on four floors and external air temperature. A visual inspection shows a good correlation between the latter and the indoor room temperatures. As can be seen, room 3.14 is the most sensitive to weather variations. This is explained by the fact that the offices on the top floor are heavily glazed and obviously more subject to the wind cooling effect (solar irradiance in the summer

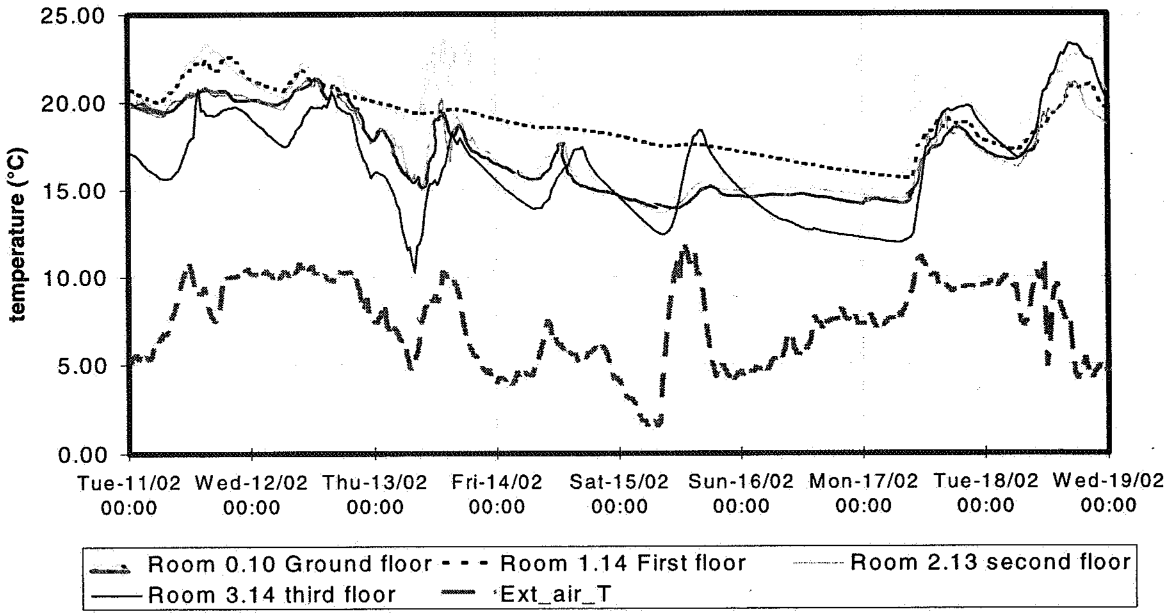

Figure 4. Air temperature on different floors.

computed correlation between the CO_2 and water vapour levels inside the room spaces shows that for room 1.21 (seminar room) the correlation is close to 1, but that for room 1.14 it is in the region of 0.5. This can be justified by the fact that the input in terms of water vapour from one occupant in the office does not show itself as strongly as in the case of a class.

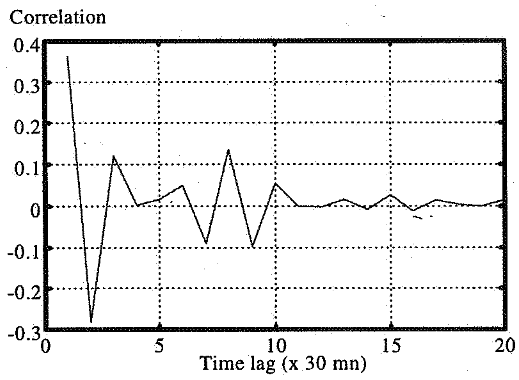

Figure 7. Correlation between outdoor and indoor air CO_2 content (seminar room).

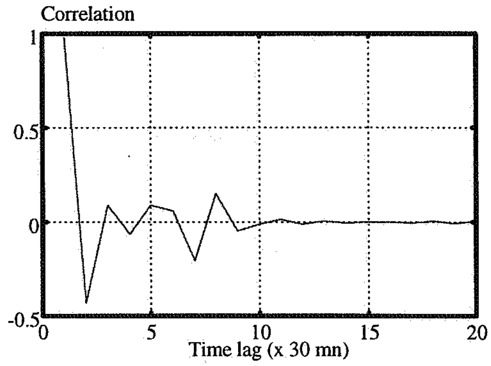

Figure 8. Correlation between outdoor and indoor air water vapour content (seminar room).

February 97- Air change rate

Analysis of the correlation between wind speed and direction and the number of ach in the rooms monitored is described next. Figure 9 shows the number of air changes in rooms 1.14 (office) and 1.21 (seminar room). The wind data (speed and direction) for the same period is shown in Figure 10. Visual examination of the curves does not reveal any obvious correlation, therefore, the correlation was computed using the data and is shown in Figure 11. As can be seen the data is uncorrelated. The number of air changes inside the monitored spaces seems to be independent of the variation of wind characteristics. However, the period covered is too short to draw any definitive conclusions; longer monitoring periods might show some dependence between the wind and rate of ventilation. Correlation was also calculated to identify any dependence between tower differential air temperature (between top and bottom of tower) but showed no conclusive results. The large peak in the ach in the seminar room (1.21) on Thursday night is thought to be due to a window left open overnight. The average rate of ventilation for Thursday (9am-5pm) was calculated to be 8 l/s for the office (room 1.14 with one occupant) and 17 l/s per person in the seminar room (room 1.21 - assuming 20 occupants). This shows the effectiveness of the cross ventilation process over the single side equivalent. Although on the border line in the case of the office space, the figures are acceptable and should be higher in the summer.

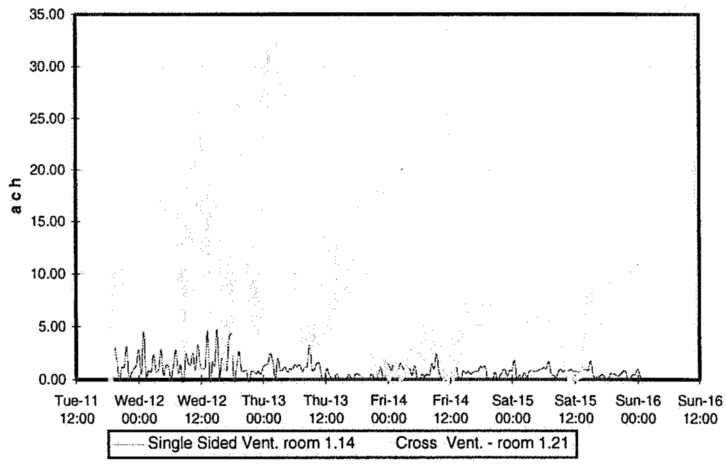

Figure 9. ach in office (1.14) and seminar room (1.21)

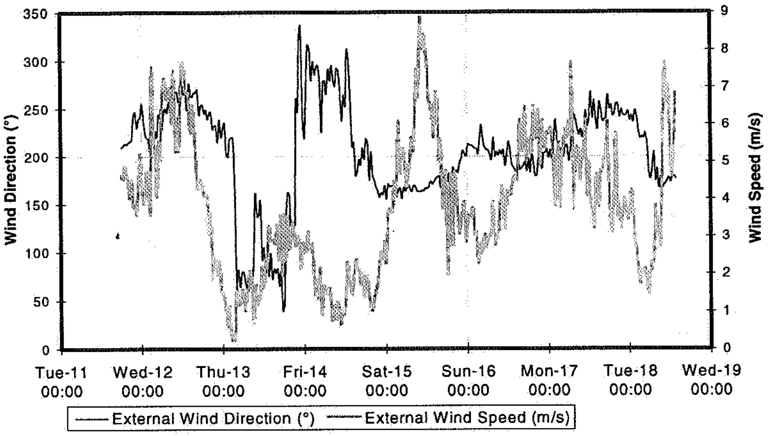

Figure 10 . Wind data

4 . 2 . Summer period

July 1997 - Maximum air temperature.

At the design stage The ESP-r package was used to carry out several simulations in order to predict the performance of the Portland Building under extreme conditions and also in order to determine parameters such as the maximum openable area for the vents at the top of the towers. One of the predictions made was that the air temperature inside the studios during the month of July would not exceed 25°C for more than 13 hours during working time, that is 9am to 8pm, Monday to Friday. Figure 12 shows the variations of air temperature in seminar room 1.21 during the month of July 1997. Inspection of the data revealed that the air temperature in this room exceeded the 25°C threshold only by a maximum of 0.5°C for just over 24 hours during the working month, which confirms the predictions made at the design stage. Figure 13 shows the variations or the air temperature in room 3.14 (top floor) during the same period and here the air temperature inside room 3.14 exceeded 25°C for more than 55 hours during the working month by a maximum of 3.2°C. In this case one must bear in mind that this room was possibly unoccupied and that the windows could have been closed at all times thus making ventilation rate

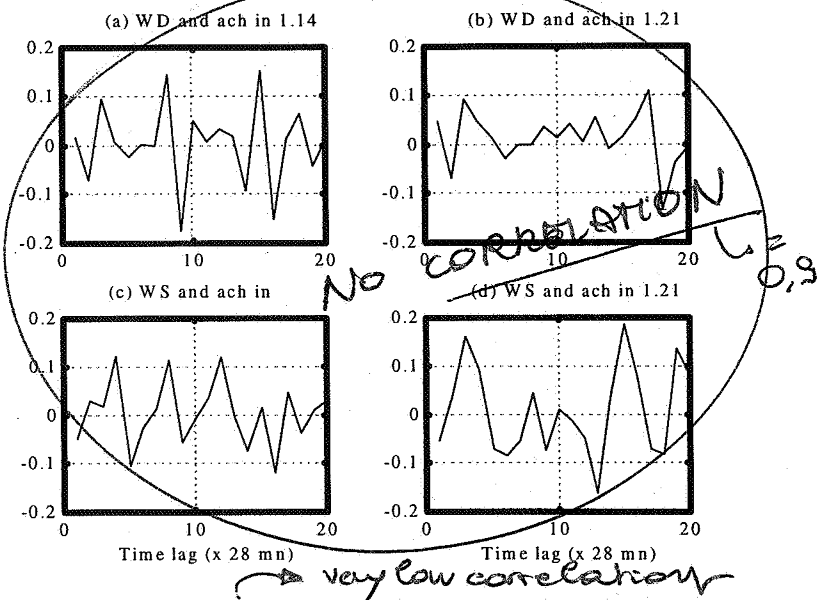

Figure 11. Correlation analysis of ach and wind data.

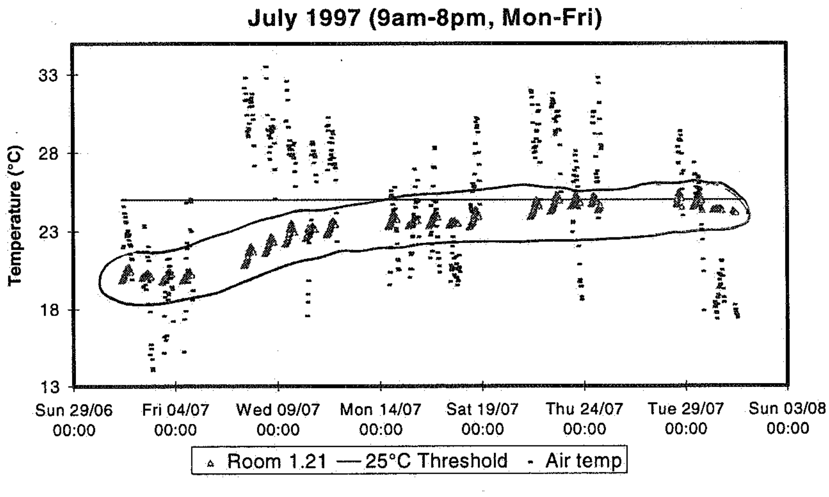

Figure 12. July 1997 air temperature variations room 1.21

minimal if not non-existent.

5 . Conclusions

The paper presented initial feedback on the performance of a naturally ventilated building, namely the Portland Building at Portsmouth University (UK). Winter data suggest that pollutant levels inside are well within the suggested limits. A correlation analysis confirmed the effect of occupancy on CO_2 and water vapour level, but no correlation was found between wind speed and the number of air changes per hour in either of the monitored rooms (office or seminar room). Finally the room air temperatures for the month of July 1997 were checked against a prediction made at the design stage and it was found out that on the first floor temperature hardly rose above the threshold of 25°C, but that on the third floor in room 3.14 the temperature was higher (maximum 3°C) than the threshold for just over 55 hours. A possible explanation for the latter could be the fact that the room is not occupied during the summer and that the windows could have been closed during most of the month. The monitoring of the Portland Building by the BMS Research Group at the University of Portsmouth is ongoing and the collected data is still being analysed and will be published in the near future.

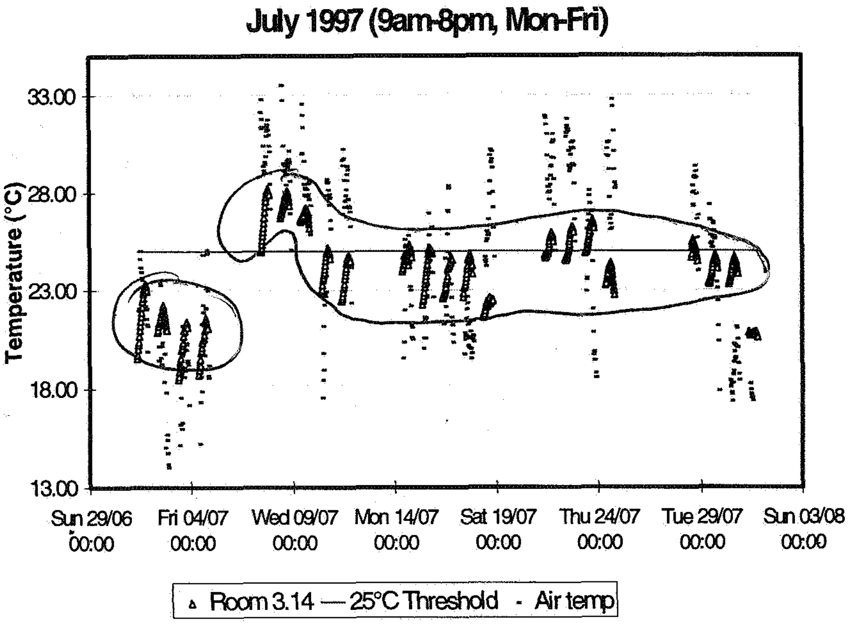

Figure 13. Air temperature variations room 3.14

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