Naturally comfortable offices

– a refurbishment project

- Lower summertime temperatures through natural ventilation
- Higher staff comfort and satisfaction
- Lower energy consumption
- Low capital and running costs

GOOD PRACTICE CASE STUDY 308

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INTRODUCTION

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Natural ventilation in offices can improve the thermal comfort of staff. This Case Study looks at the Open University, where an office was refurbished to avoid the need for mechanical cooling or full air-conditioning. It demonstrates how such an approach can:

- lower summertime temperatures through natural ventilation
- increase staff comfort and general satisfaction
- minimise capital expenditure
- reduce energy consumption and maintenance bills
- provide lessons for future refurbishments.

A comfortable office environment is essential for a happy and productive workforce. If an office becomes too hot in summer there is a tendency to assume that air-conditioning is necessary for comfort. This Case Study shows that, with good design, staff in refurbished or new offices can be comfortable in hot weather without resorting to mechanical cooling or air-conditioning. This is supported by on-site staff surveys, and temperature and electricity monitoring.

BACKGROUND

The Open University's administrative offices at Walton Hall in Milton Keynes were built in the 1960s and 1970s. The linked office blocks are two- and three-storeys high with brick walls and concrete floors. The façade is about 60% continuous single glazing in aluminium frames. These large glazed areas result in high losses and draughts in cold and windy weather as well as unwanted solar heat gains when it is warm and sunny. Shortly after the buildings were completed an extra top floor of offices was added under a lightweight steel-framed mansard roof.

In recent years occupation densities and computer equipment have increased, leading to high summertime temperatures which caused discomfort to staff. The University therefore called in consultants to advise them. The suggested options were:

- full air-conditioning or full mechanical cooling
- natural ventilation, with mechanical cooling for the hottest weather
- using natural ventilation and a fabric upgrade only.

At first the consultants advised that air-conditioning or mechanical cooling would be necessary for comfort to be achieved. The University sought a second opinion from experts in natural cooling and passive design because:

- cooling by mechanical means would have increased maintenance and running costs
- staff did not want air-conditioning because this would have meant sealed windows
- the University has a 'green' policy.

The experts confirmed that mechanical cooling was necessary for the lightweight top floor because of its low thermal capacity and poor insulation. However, on the lower floors, tests and computer modelling suggested that acceptable conditions could be obtained if attention was given to:

- window design, for better control of day and night ventilation and a reduction in unwanted summer solar heat gains
- better use of the thermal mass of the building, in particular the concrete ceilings, to moderate internal temperatures and act as a store for night cooling to reduce day temperatures
- reducing heat gains from the lights and from office equipment.

The refurbished building. The new window system on the first floor is the major component in the package of measures employed to avoid mechanical cooling

REFURBISHMENT OF THE DESIGN STUDIO

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The experts recommended a full-scale trial of their proposals on one floor. The opportunity came in 1993 when the design studio changed from being primarily a drawing-board office to a computer-based operation, requiring major refurbishment.

The studio, which prepares the University's publications, has a high occupation density of 9 m^2 per person[1], and a high concentration of equipment that is intensively used. Each person has one graphics workstation with a large screen and in addition one PC is shared between each two workstations. The estimated annual heat gain from this equipment is 27.5 kWh/m^2 (excluding printers and photocopiers) – well above the 15 kWh/m^2 of a typical office of this type[2].

The studio and other offices had already tended to overheat in hot weather; the heat produced by the new equipment in the studio would have made this worse. There was a risk that adopting the natural ventilation solution would not provide comfortable conditions. Nevertheless, it was decided that the design studio would make a good test case and set standards for future improvements in other Open University offices. The University consulted the staff during the decision-making process to give them involvement in the refurbishment process.

The refurbishment scheme was designed in the summer of 1993 and the studio was occupied in January 1994. On the lightweight top floor, natural ventilation could not have provided summer thermal comfort alone, so a cassette-type mechanical cooling system was added (figure 1). The second floor has not yet been refurbished.

Having ruled out air-conditioning, the costs of the other two options – one with mechanical cooling and the other with a new natural ventilation system – were similar. However, the running costs for the naturally ventilated option were considerably lower, because of the absence of mechanical cooling plant, maintenance, and reduced heating costs.

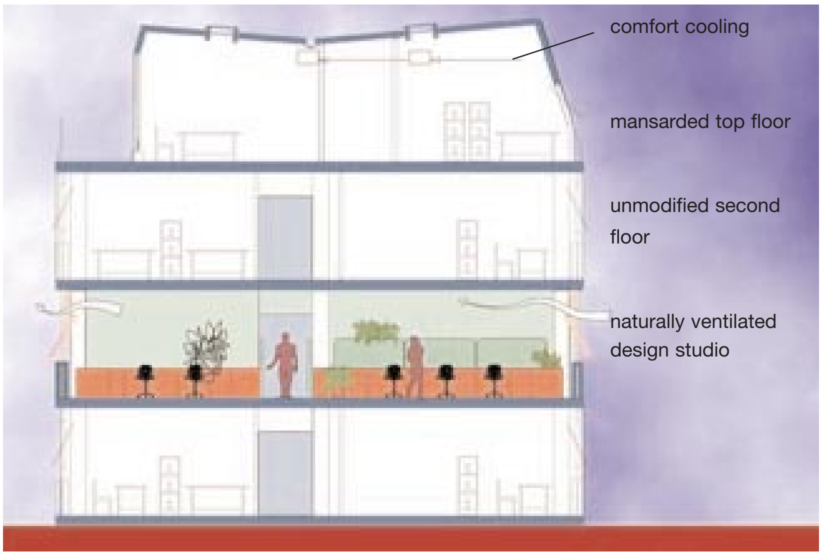

Figure 1 Section through the building

Keeping the design studio cool

As a rule of thumb, offices should not exceed 27°C very often – say for a few hours in the afternoon on not more than 10 working days in a typical year[3]. Simple natural ventilation alone will not keep offices cool throughout the entire summer. The heat gains from people, equipment and the sun must be removed to keep the temperature down. To help minimise the solar gain and remove internal heat gains, changes were made to the windows of the studio.

The low energy refurbishment provides a comfortable working environment. Note the uplighters, low screens and plants

REFURBISHMENT OF THE DESIGN STUDIO

The new window system encourages night air to ventilate the building in hot weather. This cools down the fabric of the building so that it starts off cool the following morning and absorbs excess heat during the day (figure 2). This 'night cooling' needs:

- a method of night ventilation
- a method of allowing night ventilation to cool the structure of the building.

The following measures were adopted to reduce heat gains, improve the studio's thermal storage, and assist heat removal by ventilation.

- The glazed area was reduced, but sufficient window area was left for effective natural daylight and to maintain the impression of a light and airy interior. This was achieved by glazing only four in every seven window bays and fitting insulated panels in the rest, and by providing inter-pane venetian blinds (figure 3). This cut by three-quarters the peak solar heat gain through the smaller window area.

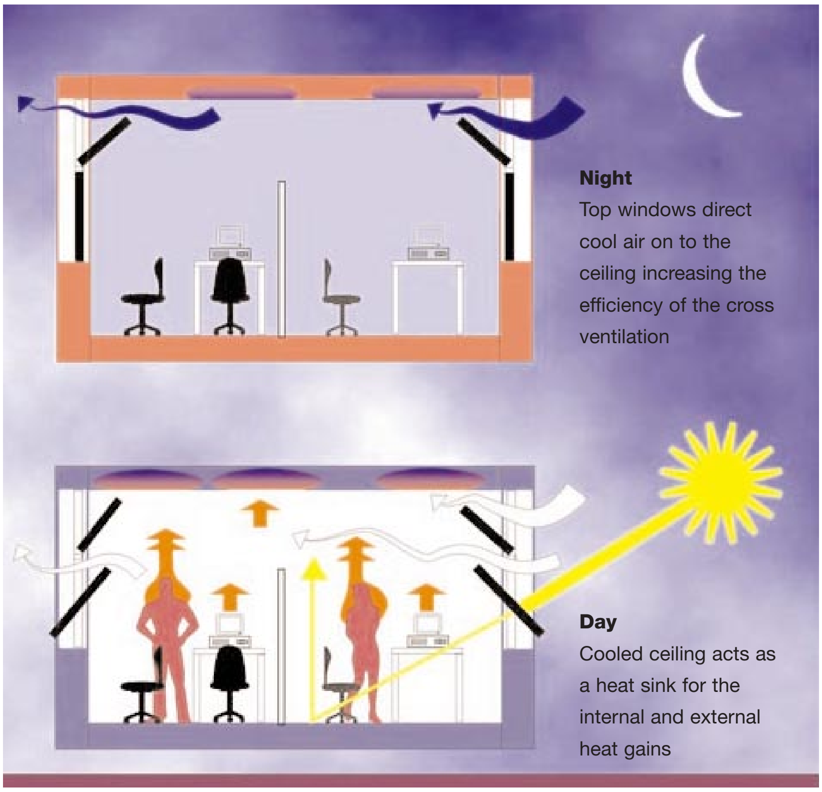

Figure 2 Night air cools the mass of the building to absorb daytime heat gains

Figure 3 The upper and lower elements of the new windows are readily adjustable by the occupants

- The area of openable windows was increased, and adjustable centre-pivot windows were provided. These improved daytime ventilation and were lockable to provide secure ventilation positions which did not compromise office security.
- High-level windows were added to improve cross-ventilation and to provide further secure night ventilation. The inward-opening design helps to direct air on to the ceiling to remove heat from it overnight.
- The insulating ceiling tiles were removed to expose the concrete ceiling, which was then finished with acoustic plaster.
- A low-energy lighting scheme was chosen that included uplighting with better controls, individual high/low/off switching at the workstations and separate lighting control for the corridors. The uplighters and new ceiling finish also give an open feel to the studio.
- Low-energy electronic graphics equipment was purchased.
- Photocopiers and shared printers were sited in a separate room with a small extract fan, to help keep their heat out of the main office area. This also reduced occupant exposure to fumes from the equipment.
- Furniture layout was planned to allow for easy access to window and blind controls for all room occupants.

THE RESULTS

Other measures

Other measures were introduced to improve the ambience of the studio as part of the general refurbishment.

- Improved layout of the desks created groups of workstations divided by low partitions.
- Plants were introduced and walls were painted a neutral colour to give a cool relaxed atmosphere.

Window design

Figure 4 shows the new window system. The windows of the studio feature:

- timber frames for insulation and a warm, natural internal appearance
- externally aluminium-clad frames for low maintenance (no cleaning)
- venetian blinds between the inner and outer panes for low maintenance and more effective solar heat rejection
- simple and readily adjustable controls which are easily accessible in the middle of each bay
- durability
- off-the-peg standard product for economy.

THE RESULTS

During the summer of 1995, which was unusually hot, energy consumption and temperatures were monitored in the:

- refurbished first floor studio
- unmodified second floor
- mansarded top floor with its mechanical cooling system for comfort.

At the same time, staff on all three floors were asked to fill out questionnaires, at monthly intervals from August to October, on perceived comfort over the preceding two weeks. They were also interviewed. In November they completed a final questionnaire to gauge their overall perceptions of comfort to their workspaces, and the refurbishments. The analysis of the supporting data for this Case Study and technical guidance on how to achieve summertime comfort will be the subject of a Best Practice General Information Report (GIR 48)[4].

Figure 4 The windows in the design studio allow control of cross-ventilation:

(a) closed – triple glazing provides good insulation

(b) open but secure – on summer nights partially open windows direct cool air on to the ceiling

(c) fully open – on summer days to create pleasant air movement within the studio

THE RESULTS

Results of temperature monitoring

At low air speeds a small sphere (or globe) responds to the surrounding temperatures in a similar way to the human body, making the globe temperature (Tg) a good index of thermal comfort. Globe temperatures were monitored at various points on each floor.

Figure 5 is a graph of globe temperatures on the three floors during a hot four-day period. The table on page 7 summarises key results, showing that:

- in spite of the greater internal heat gains in the studio (see below) it has cooler daytime temperatures than the second floor
- peak temperatures in the studio are lower than the peak outside temperature, an effect of cooling, particularly by the exposed ceiling
- at night and at weekends (the first two days in figure 5), the studio is the coolest of the three floors, confirming the effectiveness of the passive cooling measures.

Energy use by office equipment

Energy consumed by equipment in the studio was 58 kWh/m^2 per year, which compares with 20 kWh/m^2 on the second floor and a benchmark of 16 kWh/m^2 for an open-plan 'type 2' office (see Energy Consumption Guide 19 'Energy efficiency in offices. A technical guide for owners and single tenants' (ECON 19)). This shows that the equipment heat gains in the studio are about three times higher than normal levels for typical offices.

Energy use by lighting

The lighting consumed 27 kWh/m^2 per year, which is better than the good practice benchmark of 32 kWh/m^2 given in ECON 19, although not as good as had been hoped by the designers. The reason is that the lights were on for longer than had been expected because:

- the orientation of the computer screens meant that sometimes blinds had to be shut to reduce glare
- the blinds, once lowered, tended not to be raised
- people tended to switch on lights, and to leave them on more than necessary
- poor automatic time control allowed lights to remain on until 9pm.

Savings due to the refurbishment

The new windows are estimated to have reduced the heating fuel consumption of the office by more than 50%, saving about 90 kWh/m^2 of gas (18 kg CO_2/m^2) per year[5]. The new lighting and controls have saved about 20 kWh/m^2 of electricity (14 kg CO_2/m^2) per year.

The amount of electricity saved by avoiding air-conditioning depends on the system and its intensity of use. The comfort cooling on the top floor appears to use about 30 kWh/m^2 (21 kg CO_2/m^2) although many air-conditioning systems use far more than this.

Total savings of carbon dioxide were 53kg/m^2 per year with a cost saving of £2.63/m^2 per year* in addition to savings due to lower maintenance.

* Energy costs for 1995: gas @ 0.55p/kWh; electricity @ 4.27p/kWh

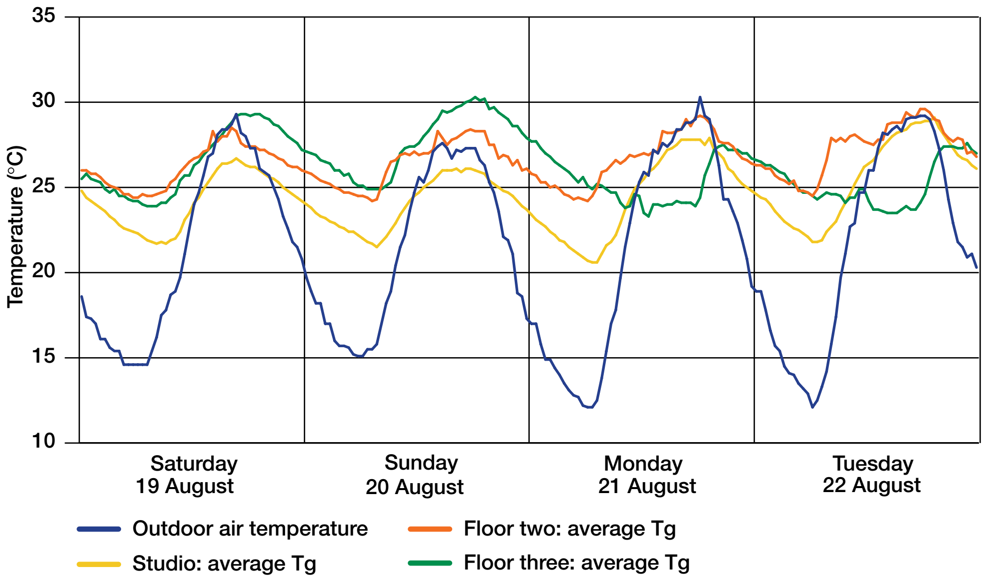

Figure 5 The graph compares the globe temperatures on three floors of the building during a period of hot weather in 1995. At weekends the comfort cooling on the third floor is switched off, which is why the third floor temperature peaks at about 30°C, even when the building is unoccupied. Night-time cooling alone would be inadequate in these conditions. Contrast this performance with that of the other floors, in particular the studio.

OTHER LESSONS

Results of the occupant surveys

Studio staff were pleased with their office, especially its lighting layout and 'airy feel'. Ninety-five percent of studio staff thought that the refurbished studio was better than the offices on other floors of the building. Staff found the refurbished studio to be more comfortable than the unchanged second floor. When the outdoor temperature is high (ie, a peak of more than 25°C, exceeded in a normal year on only 1% of days), the top floor, which is mechanically cooled, was considered to be more comfortable. At other times, the other floors were considered to be at least as comfortable as the top floor. Studio staff were content in hot weather because they regard the refurbishment as pleasant and well planned, and higher temperatures are acceptable in such circumstances.

Staff in the building as a whole regard the studio as the most desirable of the three floors. However, people sitting further away from the windows were significantly less happy with their control over temperature, ventilation and daylight. The survey also found that people in the centre of the room experience draughts both in summer and winter due to cool air from the 'hopper' windows.

OTHER LESSONS

While the natural cooling approach is relatively straightforward, not everyone is familiar with how to make the best use of the system. The surveys revealed scope for improved understanding by occupants and management.

- Optimal use must be made of the windows to maximise the cooling effect, but not to cause over-cooling leading to discomfort.
- Cleaning and security staff should be told not to close the upper windows (or the lower windows in their secure night ventilation positions) when it is hot.
- Staff should understand the importance of the use of daylight to minimise the need for electricity. Controls tend to be left in inappropriate positions (for example, blinds closed and lights on) and they should be reset regularly (for example, blinds could be opened each morning).
- Occasional briefing/discussion sessions should be held for occupants, with a card or leaflet explaining the system and how to make the most of it. This will encourage a greater level of awareness of energy issues, and simple habits that people can develop to minimise avoidable waste.

On the technical side, the following improvements could be considered:

- provide remote control of the upper windows to permit adjustment by people some distance away from them
- provide controls for night-opening of windows to ensure that the building is not over-cooled at night
- include automatic dimming control of the lights close to windows so that electric light is used only as necessary.

Temperature measurement	**Globe**		**Air**	
Floor	Studio	Second	Top	Outside
Maximum weekday temperature °C	27	29	25	28
Maximum weekend temperature °C	26	28	30	28
Corresponding minimum night temperature °C	22	24	25	15

The table shows mean maximum and minimum temperatures on the three monitored floors over eight consecutive hot days, with outdoor air temperatures shown for comparison. The weekend temperatures represent the building performance when it is unoccupied, ie has minimum internal heat gains and the comfort cooling on the third floor is switched off.

CONCLUSIONS

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The Open University has shown that, through a holistic approach to office refurbishment, it is possible to provide a comfortable working environment in summer using natural ventilation. This has achieved the University's objective of avoiding the use of air-conditioning or mechanical cooling in spite of relatively high internal heat gains from people, lights and equipment. It also provides a model for future refurbishments.

The natural cooling approach:

- improves the internal ambience
- reduces summertime temperatures to levels that are acceptable to the staff
- provides a higher quality environment overall by spending money on new windows rather than mechanical plant
- results in replacement of elements of the buildings which were performing poorly, and had reached the end of their useful lives, with new, better-looking and lower-maintenance items
- avoids the energy and maintenance costs of the alternative comfort cooling plant
- reduces heat losses and heating energy consumption
- increases the University's environmentally responsible, passive, low energy options in future refurbishments.

REFERENCES

[1] **British Council for Offices**. Specification for Urban Offices ISBN 0952 4131 08. Available from the British Council for offices, c/o The College of Estate Management, Whiteknights, Reading RG6 2AW, 1994

[2] **Department of the Environment**. Energy efficiency in commercial and public sector offices (ECON 19). London, DOE, 1991

[3] **The Builder Group**. 'A comfortable future?' by Dr Robert Cohen in: Building Services (CIBSE Journal) *Vol 15 No 9 page 35-36*. September 1993

[4] **Department of the Environment**. Passive refurbishment at the Open University (GIR 48). (In press)

[5] **Department of the Environment**. Introduction to energy efficiency in offices (EEB 6). London, DOE, 1994

FURTHER READING

Building Research Establishment. Natural ventilation in non-domestic buildings, BRE Digest 339. BRE, Garston, 1994 (available from the BRE's publisher, CRC Publications. Tel 0171 505 6622)

In addition to those listed elsewhere in this Case Study, the following Energy Efficiency Best Practice programme documents may be of interest. They are available from BRECSU Enquiries Bureau (contact details below).

General Information Reports

30 A performance specification for the Energy Efficient Office of the Future.

31 Avoiding or minimising the use of air-conditioning. A report from the EnREI Programme.

Good Practice Guide

118 Managing energy use. Minimising running costs of office equipment and related air-conditioning.

The Government's Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

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General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting, etc.