Leaflet 10

All-electric office of simple design with low electricity consumption

Magnus House, Bridgwater

- Building designed for low heating and lighting energy use
- Good natural lighting to cellular offices
- Domestic-style construction with high insulation levels
- All-electric heating with close electronic control

The Project

Magnus Developments Ltd is a residential developer and builder with a south-western office in Bridgwater. Seeking new premises, it developed a site near the town centre, with its offices on the main frontage and sheltered housing behind.

A requirement for predominantly cellular offices of 1300 m^2 allowed Magnus to adapt its standard residential loadbearing construction for the purpose, giving a cost-effective building without the need for any additional plant and trades on the site.

Applying the same thinking to the heating, Magnus decided to adopt the Electricity Association's Energy Efficient Design (EED) concept, with highly insulated construction (including windows with low emissivity double glazing) and electric heating under central electronic control. This offered simplicity, low capital costs, and made it easy to sub-meter proposed tenants on the second floor.

The Result

The building performs well and the heating system is well-liked, particularly the low maintenance and the individual controls in each office.

High thermal capacity, with masonry walls and partitions, concrete floors and no suspended ceilings, also makes the building comfortable in summer.

Figure 1 External view

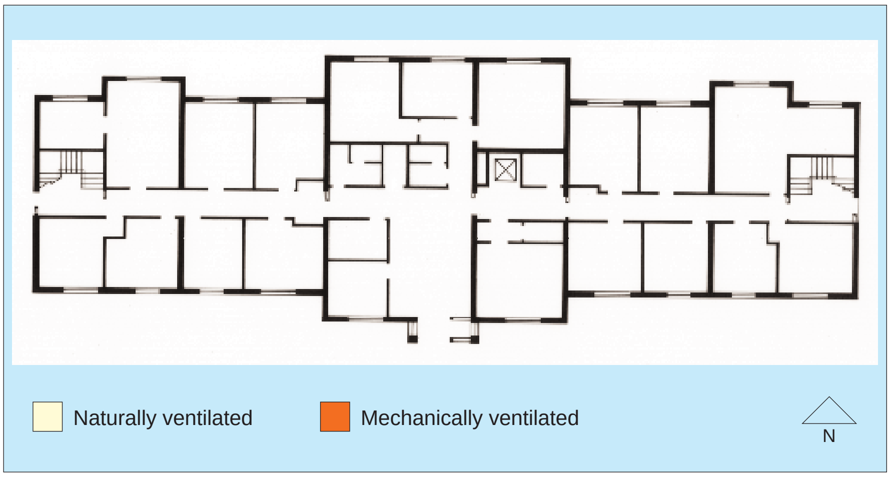

Figure 2 Plan

"Energy efficiency from cost-effective construction"

BEST PRACTICE PROGRAMME
ENERGY EFFICIENCY

Monitored electricity consumption was very low, totalling 71 kWh/m² of treated area per year, including 42 kWh/m² for heating. However, in an average UK location and winter it would have been over 20 kWh/m² higher. Heating consumption is nevertheless 30% below the 'good practice' standard for Type 1 cellular offices given in Energy Consumption Guide 19[1], available from BRECSU at the address shown on the back page. Non-heating consumption is also some 20% lower.

In contrast, heating energy cost when corrected for average location and winter is high, well above the 'typical' levels of Energy Consumption Guide 19[1] and nearly twice its 'good practice' levels, due to the cost of electricity when compared with that of other fuels. Although 43% of heating requirement is met off-peak, high unit rates and Maximum Demand charges by day offset this cost saving. Overall running costs are nevertheless seen as reasonable, as a result of lower initial capital costs and lower maintenance costs, compared with those for conventional central heating.

Carbon dioxide emissions associated with electricity generation for the heating are also higher than 'good practice' levels, but much better than 'typical' levels.

Although energy costs and carbon dioxide emissions exceed 'good practice' levels, valuable lessons can be learnt from the way the low energy consumption has been achieved. Designers will benefit from the good practice techniques used by Magnus House. These can be applied in buildings generally and not just those which are electrically-heated.

This study demonstrates that high insulation and good electronic control are cost-effective and indeed essential if electricity is to be used efficiently for heating in small office buildings.

Construction

In an electrically-heated building, energy has to be managed effectively, requiring good controls and higher than average levels of insulation. The measures at Magnus House include:

- partial fill 35 mm cavity wall insulation batts as well as the 150 mm insulating blockwork, with plasterboard on dabs internally;
- a suspended floor with 50 mm insulation underneath;
- pitched roof insulation with 150 mm of mineral wool;
- thermally broken and well-sealed aluminium tilt-and-turn windows with low emissivity double glazing.

The simple construction with concrete floors and wet plaster finishes is interestingly airtight, reducing heat losses to a minimum.

The calculated conduction heat loss from the building under design conditions was 13.6 W/m² – under half the level which would satisfy the 1990 Building Regulations and considerably lower than the ventilation heat loss of 24 W/m².

Magnus Developments Ltd report that cost savings in relation to conventional wet central heating more than paid for the extra insulation measures. While detailed cost figures are not available for this project, independent studies for the Electricity Association and BRE confirm that the claim is reasonable.

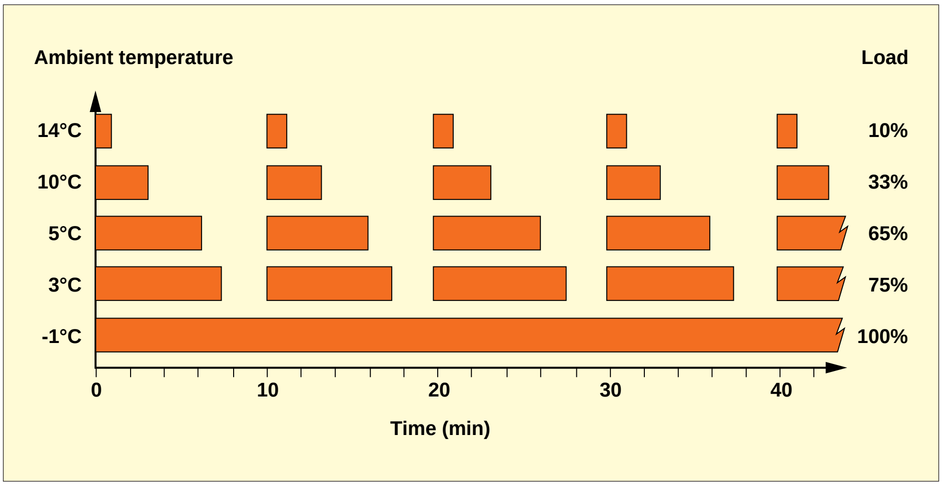

Figure 3 Compensation by proportional load cycling

Heating System

There are electric panel heaters in each office, night storage heaters at the bottom of the two stairwells, and a fan storage heater in reception. Each panel heater has its own built-in thermostat. The night storage heaters have separate built-in charge and output controllers.

Heating Controls

The panel heaters are arranged in seven zones: the north and south orientations on each of the three floors and the common areas. A 'Johnson MP 1000' electronic controller with proportional load control provides each zone with independent:

- time control with optimum start/stop;
- outside temperature compensation by 'proportional load cycling' (altering the amount of time during which electricity is supplied to the heaters in each zone);
- zone temperature feedback.

The supply of electricity to each zone is also 'staggered' in order to stop peak loads coinciding and thus avoid adding to electrical Maximum Demand charges (see figure 3).

Although the panel heaters were not off-peak storage devices, over 35% of the electricity used was purchased at the low night rate (from midnight to 7am) and used to warm up the building prior to occupancy. With the three night storage units included, 43% of the electric heating was off-peak.

The room thermostats were initially freely adjustable throughout their range, but people tended to overreact and alter the settings, giving problems of both over and under heating at the start of the following day. Tamperproof high and low limit stops have since been brought into use, improving both performance and user satisfaction.

Domestic Hot Water

Hot water is from three electric multipoint heaters, one per floor for the toilets and one for the two kitchens. Time controls are not fitted although they could have given further economies by avoiding night and weekend operation and made better use of off-peak electricity. However, savings would have been relatively small and setting the clocks could have an additional problem for management.

Figure 4 A typical office

Ventilation

Ventilation is natural through windows except for the toilets, which have mechanical extraction. No air-conditioning is present or necessary, in spite of high densities of electronic equipment in several rooms. The ingress of noise and dirt through open windows was not seen as a problem.

Lighting

Natural lighting is good, supplemented by twin-tube, high frequency, surface-mounted fluorescent fittings with prismatic diffusers generally, and low brightness louvres in computer areas.

Compact fluorescent fittings are used in corridors, WCs and interview rooms. 150 watt metal halide uplighters with 25 watt tungsten-halogen wall washers are used for decorative effect in reception and in two other rooms. All lights are controlled by local manual switches, which are very effectively used by occupants, though unfortunately lights near the windows are not switched separately from those inboard. Lights in most stairwells, corridors, WCs and in many offices were off during survey visits.

Other Systems

Two small kitchens, one with a vending machine, are used primarily for hot drinks. The one low-speed lift is used rather more than might be expected, as it is centrally located, while the stairs are at the far ends of the building only.

Building Team

Designers: Magnus Developments Ltd

Heating and lighting advisers: SWEB

Builders: Magnus Developments Ltd

Electrical installation: Rodney Fry

Building Details

Purpose-built office completed 1988

Floors: ground + 2 under pitched roof

Gross floor area: 1310 m² 14 100 ft²

Treated floor area: 1290 m² 13 900 ft²

Nett floor area: 950 m² 10 200 ft²

Typical number of occupants: 60

Typical hours of use: 8am-6pm weekdays

Fabric U-value (W/m²K)

Walls: brick exterior, cavity, insulation, lightweight block & plasterboard 0.30

Roof: pitched, tiled with 150 mm mineral wool over ceiling 0.25

Windows: aluminium low emissivity double glazed with thermal breaks 2.2

Floors: screed and insulating board over suspended concrete slab 0.35

Solar protection: trees on the south side

Blinds: vertical louvre blinds throughout internally

Heating

Electric panel heaters total 77 kW in seven zones with central optimum start and zone temperature-limiting control, using a Johnson MP1000 electronic control unit. Electricity is only supplied to the heaters for a timed burst every ten minutes, the burst length being controlled by the ambient temperature (see figure 3). 2 × 17.6 kWh night storage heaters in stairwells and 1 × 33.3 kWh storage fan heater in reception.

Hot Water

3 × 3 kW electric storage water heaters, one for the toilets on the top floor and both kitchens, and one on each of the two lower floors for the toilets only.

Ventilation

Natural ventilation with mechanical extract to toilets only.

Lighting

Good daylight to cellular offices. Surface mounted twin-tube fluorescent fittings with high frequency control gear typically 700 lux. Office installed load averages 17 W/m².

Compact fluorescent lights in corridors and WCs. Metal halide uplighters in the reception and board room. Room by room light switches only.

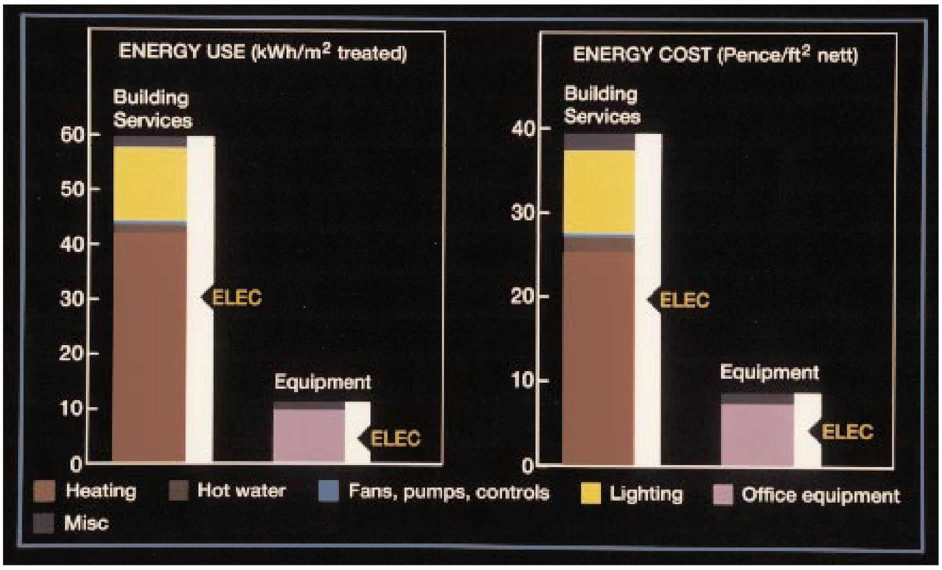

Figure 5 Annual energy use and cost for Magnus House

Energy Consumption

The diagram above shows the breakdown of annual electricity use and cost in the year from May 1989 to April 1990.

92 000 kWh of electricity were consumed during the period at a cost of £6700 or 48 pence per square foot (p/ft²) nett. Of this just under 54 000 kWh, costing £3600, was attributable to the electric heating system.

The actual energy consumption of 71 kWh/m² of treated area is well within the 'good practice' standards of Energy Consumption Guide 19[1], but actual costs are little better than 'typical'.

Heating **42 kWh/m²** **26 p/ft²**

The low electricity consumption for heating – in an office with relatively low internal heat gains from lighting and other sources – verifies the EED concept. However, the period was relatively warm (1563 degree-days), when compared to the 20-year Severn Valley average of 2078 and the national norm of 2462 degree-days. Under these more severe conditions, consumption could be expected to rise to 55 and 65 kWh/m² respectively.

Such higher consumption would produce heating costs of 35 and 40 pence/ft² respectively, even though 43% of the electricity used for heating was off-peak. Such costs are high in relation to the 'good practice' standards of Energy Consumption Guide 19[1] and above even 'typical' levels. The average cost per kilowatt-hour was 6.7 pence, of which an estimated 2.8 pence was for apportioned Maximum Demand and Availability charges.

Hot Water **2 kWh/m²** **1.4 p/ft²**

The electric hot water system is simple and economical.

Fans and Pumps **0.4 kWh/m²** **0.3 p/ft²**

This low figure is for the toilet extract system only.

Lighting **13 kWh/m²** **10 p/ft²**

This relatively low figure – similar to that in the BRE Low Energy Office described in Good Practice Case Study 62[2] – reflects good natural lighting and the effective use made of local light switches in cellular offices. Occupants are also in the habit of switching off unwanted lights; during the survey most of the corridor lights were out in spite of low natural light levels, and lights in toilets were usually off.

However, the low figure also reflects low occupancy rates, with about 15% of the office space vacant and a similar proportion occupied by staff who are often out on site.

Consumption could have been reduced by around 40% if lights closer to the windows had been switched independently and the offices lit at 700 lux had been lit less brightly to say 300-500 lux.

Office Equipment **10 kWh/m²** **7.5 p/ft²**

Office equipment comprises typically one screen per three persons, a minicomputer, a computer-aided design system with two workstations, electronic telephone exchange, a dye-line printer, and four photocopiers.

Miscellaneous **4 kWh/m²** **3 p/ft²**

This section includes the lift (1 kWh/m²), external lighting (1.5 kWh/m²), the vending machine and the kitchens.

User Reactions

For the first few months of occupation in Autumn 1988, the building was thought to be somewhat cold and damp due to: drying-out, controls not yet fully calibrated, and staff reaction as a result of their previous rather overheated building. Following this initial period, user reaction to the heating has been good and the individual temperature control of each heater is well-liked. The only slight problem has been a fairly slow response to heating if a room has become chilled, as can happen if a window has been left open or a thermostat turned down too low. Occasional complaints that the heaters were cold also occurred when they had legitimately turned themselves off because the room was up to temperature.

Summertime temperatures have been acceptable, and much more comfortable than in Magnus' former building, showing the benefits of thermal capacity in reducing peak temperatures.

The tilt-and-turn windows are not universally liked, providing insufficient fine control of ventilation – particularly when the office doors are open – and swinging-in over the window sills. Friction hinges, plus stays or trickle ventilators at the window heads would have improved the situation.

The good daylight is appreciated but, at 700 lux, several occupants considered that the artificial light levels were unnecessarily high — overriding rather than supplementing the daylight. In a few fittings one tube has been disconnected but this is not possible in others that have twin-tube control gear.

The management much appreciate the simple installation, flexibility and low maintenance requirements and costs of the electric heating, and are very happy with the low fuel and maintenance bills generally.

General Appraisal

Naturally-ventilated cellular offices are inherently low energy consumers, as discussed in Energy Consumption Guide 19[1]. The low energy use of Magnus House owes as much to its type as its design and technology.

The design features, particularly siting, construction, orientation, insulation, fenestration, daylighting, and thermal capacity have all worked well.

The heating system is simple, reliable, and takes up less space than traditional wet systems. Effective controls minimise waste of expensive electricity, and also give local control to individual occupants.

Problems during drying-out are not unusual in highly insulated buildings owing to their: better airtightness, low capacity heating system, and insulation (which may be damp initially). Designers and owners should recognise that additional heating and ventilation may often be necessary for the first few months.

The low lighting energy consumption is characteristic of cellular offices with good daylight and a switch by the door. Although bettering the 'good practice' levels of Energy Consumption Guide 19[1], further reductions of up to 40% might have been obtained if lower artificial light levels, say to the PSA standard of 350 lux, had been specified, and lights by the windows had been separately switched, possibly with capital cost savings as well.

Figure 6 Interior photograph

Main Conclusions

Comparing Magnus House with Energy Consumption Guide 19[1] benchmarks for other 'Type 1' naturally-ventilated offices, delivered energy consumption is well below the 'good practice' level both for the raw data and after climate correction to show how the building would perform in a typical place and year. Heating is the primary origin of the low consumption for three main reasons: better insulation, good control and a high utilisation efficiency of electricity on site.

However, generation losses in electricity production raise its unit cost substantially and account for the heating fuel cost of 26p/ft^2, admittedly in a high tariff area but for a very mild winter. This should be compared with 15p/ft^2 (including electricity used by pumps and ancillaries) for a 'good practice', double-glazed gas heated office without the extra insulation.

Desk studies and Magnus House's experience suggest that the extra fuel costs are affordable owing to the lower capital, maintenance and replacement costs. Increased user satisfaction from local control may also give productivity gains, but such controls are not unique to electrical systems. Energy costs could be reduced further by improved thermal insulation, but this is a fine balance usually with higher initial capital costs.

The higher carbon dioxide production from UK electricity generation is of concern for the global environment. On this basis, Magnus House only lies between 'good practice' and 'typical' as shown in table 1.

For small electrically-heated offices, where simplicity of construction and operation is paramount, Magnus House demonstrates that the high levels of insulation and the good electronic control necessary to make the most efficient use of electricity are practical and affordable. For responsible use of energy, they should now be provided as a matter of course.

References

[1] Energy Consumption Guide 19. Energy Efficiency in Offices. A technical Guide for owners and single tenants. EEO, October 1991.

[2] Good Practice Case Study 62. Energy Efficiency in Offices. BRE low energy office. EEO, February 1993.

Fuel type	Energy use in kWh/m^2			Carbon dioxide emissions in kg/kWh		
	Typical	Good practice	Magnus House	Typical	Good practice	Magnus House
Fossil fuels	200	95	0	46	22	0
Electricity	48	37	95*	34	26	68*
Total				80	48	68*

*Degree-day corrected figures.

The table above compares electricity use and carbon dioxide emissions associated with Magnus House with typical figures for type 1[1] cellular naturally ventilated offices.

Table 1 Energy use and carbon dioxide emissions

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For buildings-related projects: Enquiries Bureau, BRECSU, Building Research Establishment, Garston, Watford, WD2 7JR. Tel 0923 664258. Fax 0923 664787.

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