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BEST PRACTICE PROGRAMME

Good Practice Case Study 13

ENERGY EFFICIENCY IN OFFICES

NFU Mutual and Avon Group H.Q. Stratford-upon-Avon

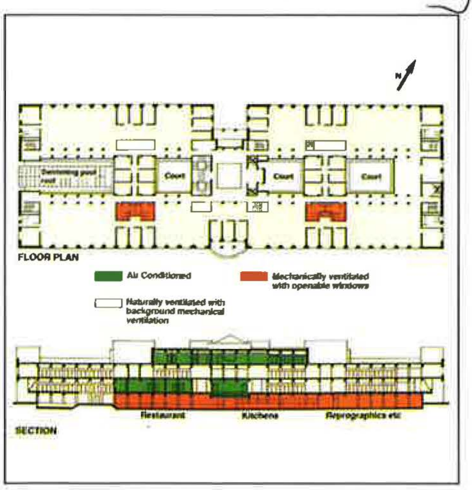
- A new modern head office building without full air conditioning, planned and designed to minimise air conditioning
- Thermal capacity and solar controls help limit summertime temperatures
- Natural and mechanical ventilation with air quality control
- Good daylight plus electronic lighting controls
- Heat recovery from computer suite to swimming pool
- Effective energy management aided by electronic BEMS

The Project

When NFU Mutual and Avon Group decided to move from their congested site in the middle of Stratford-upon-Avon, they had expected their new Head Office on the outskirts to be deep-plan and air conditioned.

However, a staff attitude survey by the Tavistock Institute revealed a preference for daylight, views and openable windows. The multi-professional design team RMJM were therefore asked to reconcile this with an organisational need for a compact internal circulation system. RMJM were also keen to design an energy efficient building.

A three-storey courtyard plan — with a smaller fourth floor for general management — was developed to permit cross-ventilation and to bring light into the centre of the building. The main facades were orientated approximately north and south to maximise the use of daylight and to help limit summertime solar gain and glare.



Earthmoving and a raised forecourt on the north side bring people straight into the core of the building at the first floor level.

Thermal capacity of the facades and floorslabs helps limit peak temperatures, with high ceilings to assist cross-ventilation. Insulation was good for the time of construction, with 0.45 W/m^{2}K fabric, insulated floors and double glazing.

The Result

The building has generally met design requirements. The architectural and planning measures and the use of thermal capacity have provided good daylight and natural ventilation and helped limit overheating. Summertime temperatures are acceptable in spite of more electronic office equipment than was foreseen at the time of design.

The building does not rely upon natural ventilation alone. In the general offices, background mechanical ventilation reduces the need for window-opening, gives additional air movement in summer, and allows excess heat to be exhausted locally and if necessary overnight. The computer suite, telephone equipment room, general management floor, conference rooms and training rooms are air conditioned. Kitchens, stores and WCs are mechanically ventilated.

In response to the attitude survey, a swimming pool is also provided, warmed largely by waste heat from the computers.

The building enjoys low energy costs for a head office of 0.97/ft^2 nett of which nearly half is attributable to the computer room. Lighting energy use of 20kWh/m^2 is particularly low, with good natural light and automatic controls.

Energy Efficiency Office
DEPARTMENT OF ENERGY

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Heating

High efficiency, possibly condensing, gas fired boilers and separate gas water heaters were initially to be used. But in 1979-80 the project was delayed by planning appeal and archaeological excavations and when work re-started, there were restrictions upon gas supplies.

A multi-fuel installation was therefore adopted, with off peak electric hot water storage to meet the baseload, heat recovery from computers and swimming pool, and cast-iron boilers capable of burning either oil or gas.

However, in 1983 the restrictions on gas supply were lifted and gas has been the main heating fuel since occupation. Heating is largely by LTHW to perimeter radiators with TRVs and to air handling units, with a few fan convectors and some underfloor heating in the entrance hall, rear meeting hall, and swimming pool area. There is a multiplicity of separately pumped heating zones.

The two boilers are available year-round under BEMS control, with one being manually isolated in summer. A heat meter indicates an average year-round boiler efficiency of 68%, about the average for 1980's office buildings.

Office Ventilation

Background mechanical ventilation to the general offices is supplied at 2 air changes per hour (4 if necessary in very hot weather) from four separate air handling plants: one for each quarter of the two main floors.

For additional ventilation, the windows have upper inward-opening fanlights and lower double glazed centre-pivot windows: teak on the lower facades and thermally broken aluminium on the courtyard walls.

During occupancy hours in winter, the damper settings of the fresh/return air dampers in each ventilation plant are controlled by Horiba carbon dioxide sensors to maintain good air quality without excessive heat loss. In fact, with the offices declared no-smoking, the minimum air quantity normally suffices.

Swimming Pool

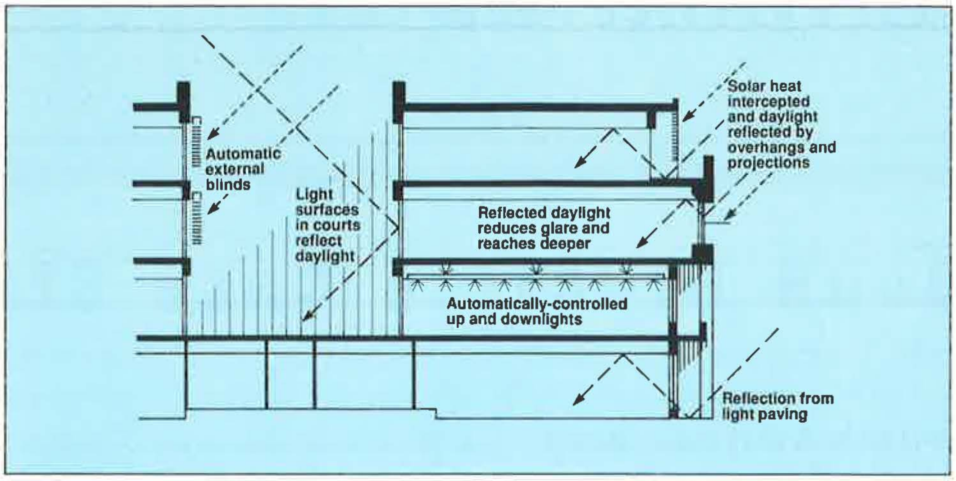
Swimming pool water is filtered, ozone treated, and heated by computer waste heat, with an auxiliary heater battery from the LPHW system.

Swimming pool changing room ventilation includes recirculation: the return air is dehumidified using an electric heat pump whose reject heat then warms the supply air. Any surplus heat is transferred to domestic hot water pre-heat.

Other Ventilation and Air Conditioning

The General Management suite on the top floor has comfort cooling by a local fresh-air and fan coil system, with the adjacent private dining rooms and meeting rooms on full fresh-air systems operated on demand only.

The 120-seat conference room on the upper ground floor has an independent all-air system, as does the adjacent suite of training rooms. All the above systems obtain LTHW from the central boiler plant and chilled water on separately pumped circuits from a 120kW reciprocating chiller in the main plant room, which has an air-cooled condenser.



Lighting principles

Kitchens, Restaurant, Stores, Reprographics, and workshops have independent full fresh air mechanical ventilation systems. Toilets have mechanical extract ventilation, with make-up from the adjacent office areas.

Computer Suite Air Conditioning

The computer suite has six packaged air conditioning units: two water-cooled and four air-cooled, plus an air-cooled mainframe water chiller.

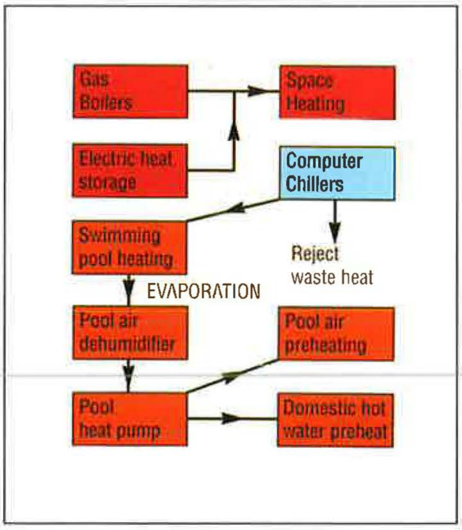
Reject heat from the water-cooled units heats the swimming pool; any surplus is rejected through an air-blast cooler.

Domestic Hot Water

Three separate hot water calorifiers supply the kitchen, the swimming pool changing rooms and the centrally located toilets. The more remote toilets at the ends of the building have local electric water heaters. Cold water supplies to all calorifiers are pre-heated by surplus heat from the swimming-pool.

HVAC Controls

The controls are largely from Satchwell's Keyboard range, supervised and optimised by a BAS 700 Building Energy Management System (BEMS) which also does electrical maximum demand control.



Heat flow schematic

Lighting

The windows were designed to provide optimum daylight, ventilation and contrast control without excessive summertime solar gains. A high level hopper for draught free cross-ventilation also brings daylight deep into the space, assisted by a 'light shelf' to scatter light onto the ceiling. The low level centre pivot window has projected sunshades and mid-pane venetian blinds on the south side. Exposed south and west-facing windows in the courtyards have external motorised venetian blinds.

Office lighting is fluorescent, with semi-recessed fittings in cellular offices and corridors and suspended upward and downward-facing units elsewhere. The downward fitting gives most of the light while the upward ones are for decorative effect and for VDU users. Elsewhere there is a mixture of fluorescent, high intensity discharge, and some tungsten and tungsten-halogen decorative lighting.

The artificial lighting level is relatively low at 350 lux, with additional task lighting available where required. This level of light has proved to be adequate.

Lighting Controls

Lights are controlled centrally by a system by ECS Ltd., plus local over-ride switches in each bay. Downlights are controlled singly or in pairs and uplights in larger groups. Different 'coding plugs' can be inserted into local controllers to designate the channels to which each group should respond.

Lighting controls have proved worthwhile. Typically no more than half the lights are on during working hours. Perimeter daylight control works well in most areas but flexitime makes lunchtime off unacceptable, as was end of day off in the toilets.

The ECS controller is installed in the security office to simplify out of hours use, and for that reason it also controls the electric water heaters in the toilets. Control of vending machines was also intended but did not work in practice.

Other Systems

There are two passenger lifts, one goods lift, a food hoist and a fountain. A large restaurant with gas/electric kitchen serves about 400 hot meals per day.

Building Team

Designers (all skills)	RMJM Ltd.
Builder	Turriff Construction.
Mechanical installation	Drake & Scull
Electrical installation	N G Bailey

Building Details

Purpose built office, completed early 1984.
Floors: Upper and lower ground + two above.

Gross floor area	14610 m^2 157250 ft^2
Treated floor area	12850m^2 138350ft^2
Nett floor area	9870m^2 106200ft^2
Typical number of occupants:	600

Typical hours of use: 8am-6pm weekdays plus some weekend work and evening and weekend swimming pool use.

Fabric — U-value (W/m^{2}K)

Walls (stone with part cavity fill)	0.45
Roof (concrete + extruded polystyrene)	0.40
Windows (aluminium or timber double glazed, with clear glass), average	3.00

Solar protection: mid-pane venetian blinds and overhangs. Motorised external blinds to exposed part of courtyards.

Heating

Modulating multi-fuel boilers 2 x 1 MW
Alternative off-peak electric hot water storage 4 x 9000 litre, 75kW, 120°C. Constant-temperature LTHW to air plant; compensated to heating zones.

Hot Water

3 LPHW storage calorifiers average 1350 litres each. Pre-heat calorifier 1500 litre. 8 local 3 kW toilet immersion heaters.

Ventilation and Air Conditioning

Offices mechanically ventilated to 2 ach (4 if necessary in summer), with openable windows. Top floor air conditioned with minimum fresh air and fan-coils. Separate comfort cooling systems for management dining, board room, conference room, training rooms and computer suite. Mechanical ventilation to restaurant, kitchen, stores, reprographics and toilets. Swimming pool heat recovery heat pump. Reciprocating air-cooled chiller 120kW.

Lighting

Suspended ceiling-mounted fluorescent up and down-lights in offices 350 lux 14 W/m^2.
Variety of different sources elsewhere.
Good daylight generally.

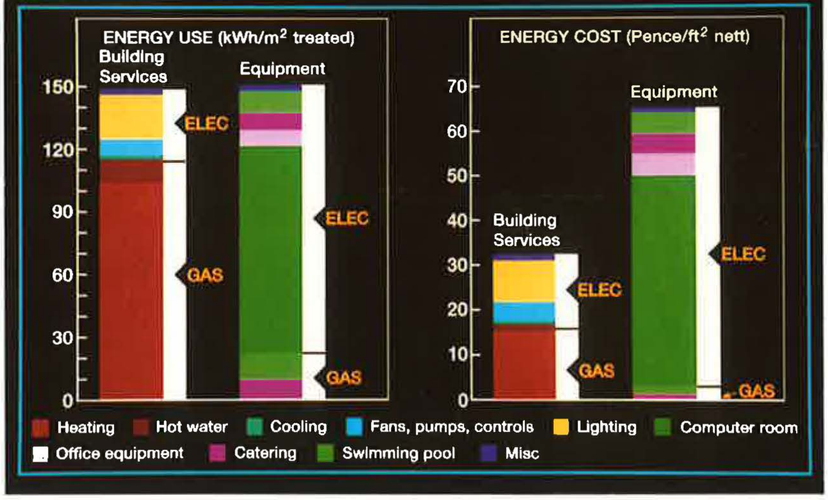
Energy Management

Local electronic controls with central Satchwell BAS 700 supervisory system. Automatic lighting controls by ECS Ltd.

Analysis of Energy Use and Energy Cost

The diagrams above show breakdowns of annual energy use and cost. From September 1987 to August 1988 (2363 degree days) 2,084,000 kWh of electricity and 1,763,000 kWh of gas were used (162 and 137 kWh/m^2 of treated area) at a cost of £0.78 and £0.19 per ft^2 nett. The situation in 1989 was very similar. Under half the energy costs are attributable to normal building services, the rest arising in the computer room, swimming pool and kitchens. Electrical power factor correction was added in 1986. Excluding the computer room and swimming pool, energy consumption of 179 kWh/m^2 is within the CIBSE Energy Code part 4's good category of 195 kWh/m^2 for naturally ventilated offices.

Annual energy use and cost for NFU Mutual and Avon Group Head Office



Heating — 103 kWh/m^2 (15 p/ft^2)

Although modest, this figure is higher than for some comparable Case Study buildings, for three main reasons:

- The high thermal capacity — deliberately so to limit peak temperatures and the need for air conditioning.
- The low internal heat gains, particularly from lighting.
- Extra air heating requirements associated with mechanical ventilation.

The heat source design for multi-fuel flexibility also gives lower boiler efficiencies and higher primary distribution losses than for single purpose equipment.

Hot Water — 12 kWh/m^2 (2 p/ft^2)

11 kWh/m^2 gas
1 kWh/m^2 electric

This is not unreasonable for the type of system, serving a restaurant and changing rooms, but suggests that the heat recovery system made only a small contribution.

Cooling — 2 kWh/m^2 (1 p/ft^2)

The low metered figure for the chiller confirms good thermal performance and effective energy management.

Fans, Pumps and Controls — 8 kWh/m^2 (4 p/ft^2)

This low figure in relation to the complexity of the building arises from the decentralised air handling plant, low duct pressure drops, zoned pumping, and effective time control via the BEMS.

Lighting — 20 kWh/m^2 (10 p/ft^2)

This very low figure for a head office building reflects the good levels of daylight coupled with well managed automatic and local controls.

Computer Room — 98 kWh/m^2 (47 p/ft^2)

Even though its air conditioning is quite efficient, the computer room is alone responsible for over 60% of the building's electricity consumption.

Office Equipment — 9 kWh/m^2 (4 p/ft^2)

8 kWh/m^2 of this arises from PCs, terminals, photocopiers etc. in the general offices (about 260 screens in all outside the computer room) and 1 kWh/m^2 from the reprographics area.

Catering — 18 kWh/m^2 (6 p/ft^2)

8.5 kWh/m^2 gas
9.5 kWh/m^2 electric

This is largely accounted for by the submetered supplies to the main kitchens, plus 3 kWh/m^2 for the vending machines, which have to be left on all the time to work reliably.

Swimming Pool — 22kWh/m^2 (6 p/ft^2)

13 kWh/m^2 gas
9 kWh/m^2 electric

While energy costs — which include ozone water treatment — are modest for the size of the pool, demands for heat outside normal office hours can not always be met by the computer and sometimes require the boiler to operate at low efficiency. A new small boiler for such duties is under review but has not proved cost effective to date.

Miscellaneous — 6 kWh/m^2 (3 p/ft^2)

This figure includes telecommunications and their air conditioning (3 kWh/m^2), external lighting (under automatic intruder detection control and so does not have to stay on all night), fountain and lifts (1 kWh/m^2). Lift use and energy consumption is very low owing to the building's low rise and raised entry point.

User Reactions

The building concept works well in environmental and energy terms, and the design intentions have been achieved. However, there have been a number of detailed problems from the occupant's point of view:

- Low angle winter sun through the upper parts of the south-facing windows initially caused glare which was cured by fitting louvre blinds.
- Automatic control of the courtyard blinds proved unpopular in the cellular offices and is now only used at night and in high winds, with occupant-operated control otherwise.
- The upper fanlight is not as easy to operate as the designers hoped, so the lower windows tend to get opened first instead. If the fanlight is opened it is less likely to get shut at the end of the day.
- The thermostatic radiator valves work well in the cellular offices but are less successful in the open areas where perimeter casings also make them very difficult to reach.
- While the lighting controls have been reasonably successful, and provision was generous for the date of design, NFU would prefer one controller for each lamp, with all coding plugs accessible without having to remove access panels, or better still addressable by computer.
- The main offices have no fire doors, but instead large hinged panels are held back magnetically. This has assisted the circulation of air as well as people, leading to draughts in places, requiring room temperatures to be raised slightly.

General Appraisal

The architectural design has worked well to give low energy costs.

Daylight is good and generally even and glare-free, reducing the need for supplementary artificial lighting.

The window detail works well for daylight but needs further refinement for ventilation and low-angle sun control.

The suspended lighting, with separately controlled upward and downward lights, works well and gives occupants a useful degree of choice. This was liked by users.

Although the lighting controls have not achieved their full potential, the low lighting costs demonstrate that they are having a worthwhile effect.

The relatively high insulation of the fabric has made an impact on heating energy consumption. However, attention to plant and control design and to ventilation systems would probably be even more beneficial.

However, the use of thermal capacity has been very effective, with the building exhibiting a higher degree of thermal stability than had been calculated, the hottest parts peaking at only 27°C in the abnormally hot summer of 1989. Similarly, the building cools down very slowly in winter. Paradoxically this may increase heating energy use in relation to a more lightweight building, as more heat is lost during unoccupied periods than if the building cooled down more rapidly, but this is a small price to pay for avoiding refrigeration.

Energy use and carbon dioxide savings. Degree-day corrected figures.

	Energy use kWh/m^2 treated			CO_2 savings kg/m^2
	NFU Case Study	Typical naturally ventilated	Difference	
Gas	128	200	72	14
Electricity	55	79	24	20
	Energy use kWh/m^2 treated			CO_2 savings kg/m^2
	NFU Case Study	Typical air conditioned	Difference	
Gas	128	273	145	29
Electricity	55	255	200	166

The tables above compare fuel and electricity use (excluding that for the computer room and swimming pool) with typical figures for both naturally ventilated open plan offices and fully air conditioned prestige offices (see Energy Consumption Guide no. 19). It also shows how the implied savings translate into reductions in CO_2 emissions.

The mechanical ventilation has improved comfort conditions but at the expense of some additional fan power and heat losses through additional ventilation and an extended heating season. It has not yet been extensively used for removing excess heat overnight, giving further potential to accommodate additional heat gains from office equipment. High-speed summer ventilation has seldom proved necessary and is somewhat noisy: variable-speed controls are now being considered.

Heat recovery from computer to swimming pool has been effective but has caused some concern by increasing the scope for an equipment failure affecting the computer. NFU would now require all heat recovery items to be duplicated or immediately by-passable. Heat recovery from swimming pool to domestic hot water is disappointing but an equipment fault was recently found which may help account for this.

Main Conclusions

NFU demonstrates that it is not essential for a modern head office on an open site to be fully air conditioned, if the building shell is designed as an effective climate moderator. A 'mixed mode' design, with both natural and mechanical ventilation and some local air conditioning, has proved effective and has reduced both capital and running costs, allowing more of the budget to be spent on fabric. In spite of the computer, swimming pool and heat recovery systems, building services accounted for only 27% of the construction cost, compared with typical figures of over 30% in most air conditioned offices.

The decentralised air handling and pumping systems — together with good energy management — have proved effective in reducing energy costs but the consequence is rather more items of plant than strictly necessary. More modern variable volume techniques might have achieved similar results with less hardware.

The design team initially anticipated that the offices would require some refrigeration in summer, but computer modelling indicated that this would not be necessary with good thermal capacity, solar gain control, daylighting, and low-capacity mechanical ventilation. However, at that time the allowances made for office equipment heat gains were smaller than today, when more contingency provision for refrigeration would probably be made.

The growing energy use by the computer suite is the exact opposite of the expectation at briefing-time that network developments would cause central computing requirements to diminish. If this trend had been correctly anticipated, either 'free' cooling or heat recovery from condenser air to office ventilation might well have been appropriate.

Short Notes on the Measurement of Floor Area

Gross	Total building area measured inside external walls.
Nett	Gross area less common areas and ancillary spaces. Agent's lettable floor area.
Treated	Gross area less plant rooms and other areas (eg stores), not directly heated.

PRECISE DEFINITIONS ARE AVAILABLE ON REQUEST

All Case Study analysis in this series are based on at least one year's measured fuel consumption and cost. Further breakdown into sub-headings is by a combination of sub-meter readings, on-site measurements, and professional judgement. The technique of apportionment is the same for each Case Study and all quoted building areas have been re-measured for the project.

This study has been carried out by the Davis Langdon & Everest Consultancy Group and William Bordass Associates. The cooperation of the owners, designers, managers and the occupants of the Case Study building is gratefully acknowledged.

Further information: Enquiries Bureau, Building Research Energy Conservation Support Unit (BRECSU) Building Research Establishment, Garston, Watford, WD2 7JR. Tel No. 0923 664258 Fax No. 0923 664097