October 1990

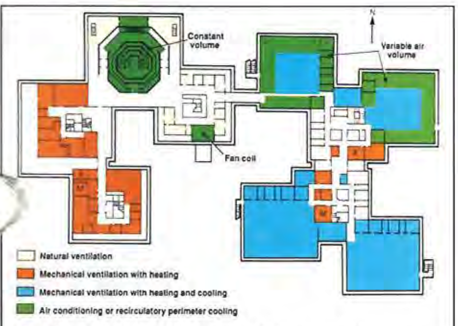
BEST PRACTICE PROGRAMME

Good Practice Case Study 17

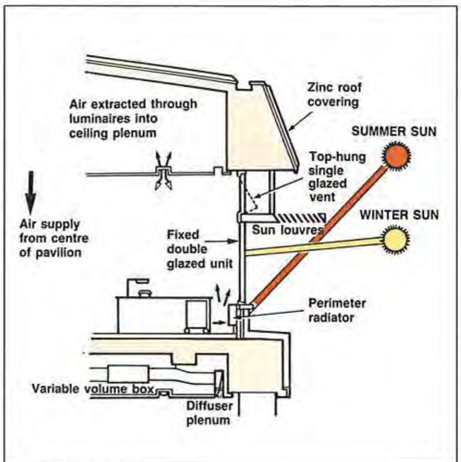
ENERGY EFFICIENCY IN OFFICES

1970's Civic offices designed and managed for low energy consumption

Hereford and Worcester County Hall, Spetchley Road, Worcester



Hereford & Worcester County Hall First floor plan



- Thermal capacity of fabric designed to reduce and delay summertime heat gains.
- Comfort cooling available but only operated as and when required.
- Good natural lighting with summertime solar protection.
- Automatic photoelectric and timed lighting controls.
- Good energy performance sustained for over ten years.

The Project

Hereford and Worcester County Council wanted new offices with an internal environment comparable to full air-conditioning, but able to survive power cuts by making good use of natural light and ventilation. This design requirement has also produced an energy-efficient building.

To reduce the need for lifts, the main offices are on two upper floors, with a lower service floor in parts. Good daylight and views are afforded by continuous perimeter windows around linked office "pavilions", each 25 m by 25 m, with rooflights on the top floors.

Although designed before mandatory insulation levels, the roof has a U-value of just under 0.6 W/m^{2}K and the aluminium-framed windows are double-glazed except for some openable and fire-resistant elements, where costs were too high.

The windows are solar-protected by overhangs and projecting louvres and the brick-clad concrete structure has thermal capacity. This combination delays the entry of summertime solar heat gains until after the occupied period, and reduces the need for mechanical cooling. The roof is steel-framed with zinc covering over 200 mm aerated concrete slabs, which provide thermal mass (delaying the arrival of solar heat gains) and insulation.

The Result

The first phase was completed in 1977. It includes the Council Chamber, a lecture theatre, and areas for council members, social and civic activities.

The subsequent planned phases of the development have not materialised although some much smaller buildings have been added, particularly the County Record Office. This has left the centralised site heating and cooling services oversized, but has not markedly increased running costs in this instance.

BEST PRACTICE PROGRAMME

Energy Efficiency Office
DEPARTMENT OF ENERGY

(R5)
C1/Sfb 1976 (81)(Y2)

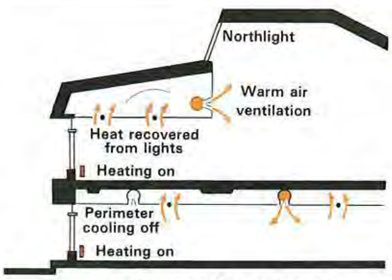
Since the building was completed, the Council has been able to reduce energy consumption further by good management and minor alterations. Heating and electrical energy use fell annually from 1977-82, though subsequently electricity consumption has increased owing to growth in electrical office equipment, and particularly a new computer.

The annual energy consumption (excluding computer room) of 183 kWh/m^2 of treated floor area is well within the CIBSE Energy Code Part 4's "good" level of 195 kWh/m^2 for a naturally-ventilated office. However, although this building enjoys both natural and mechanical ventilation and summertime comfort cooling, it has been economical because systems run only as the weather and local requirements demand rather than continuously.

Office HVAC System

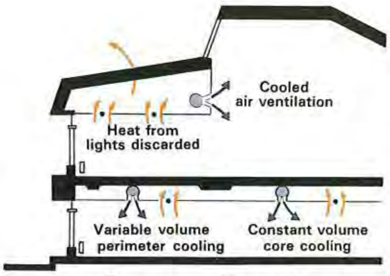
Many air-conditioning systems operate most efficiently in peak summer and winter conditions. In spring and autumn — when heating needs can often be met by solar and internal heat gains and cooling by natural ventilation — they are often less economical.

At Worcester the office HVAC System incorporates heating, mechanical ventilation and cooling, but is designed to operate in three separate modes; the most efficient mode being selected by the building engineer according to outside and inside conditions and occupant requirements.



Winter Operation

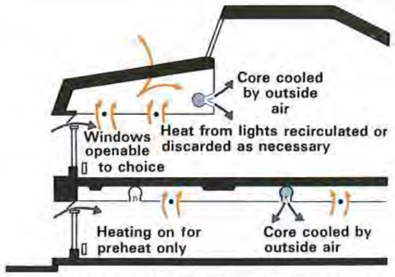
In winter, the offices are mechanically ventilated by warm air, while perimeter radiators offset the fabric heat losses. Heat from the light fittings is exhausted or recycled as appropriate.



Summer Operation

In hot weather, cooling from the central chilled water system is made available to the central mechanical ventilation plant and to local recirculatory variable-air-volume systems for the perimeter offices on the lower floors.

Design calculations predicted that refrigeration would be required for about 50 days in an average year: in practice it is used much less; typically only when outside temperatures are above 25°C.



Spring/Autumn Operation

In spring and autumn, the building is designed to be "free-running" with perimeter heating off and the ventilation recirculating or discarding exhaust heat as required.

Separate air-handling plants for each cluster of offices, the civic suite, and the Council Chamber, allow equipment to be controlled in relation to the changing patterns of activity. Chilled water is also supplied to local fan-coil units in some internal rooms.

Computer Room Air Conditioning

The present computer — installed in 1987 — is rated at 75 kW and is cooled by a local air handling unit which takes low temperature hot water and chilled water from the site mains. This reliance on central systems might well have been uneconomic as frequently the computer room is the only load in operation. However, the situation is less severe here than on many other sites as the computer only runs for 15 hours a day, 5 days a week, and the buffer capacity of the generously sized and well insulated mains helps reduce wasteful plant cycling.

Telephone Exhcange

The telephone exchange is an early electronic system based on a mainframe computer with close-control air conditioning. It runs continuously, and its energy consumption is very high by modern standards. A new exchange was installed in October 1989 and energy consumption is expected to fall.

Lighting

Lighting is largely fluorescent, with twin-tube recessed fittings to a design illuminance level of 500-600 lux.

An automatic system — with local ON/OFF over-ride switches — controls the office lights according to time of day and natural light level. Timed OFF occurs three or four times a day, but photoelectric switching can be annoying and is now used in summer only.

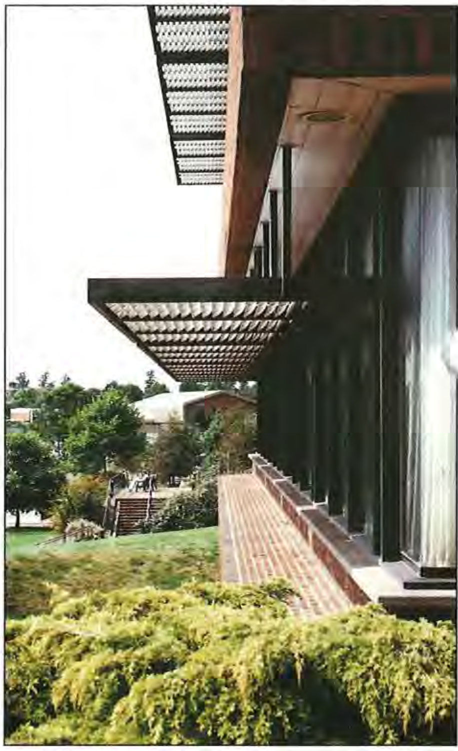
The automatic control has under-performed partly because the continuous perimeter windows create an expectation of high levels inside, and partly because the lights are switched in groups — with all switches for each area in one panel — so there is a long walk when the lights go off. Although the switches are now labelled, people tend to switch everything on but are much less likely to switch anything off for fear of inconveniencing others.

Energy Management

The original Satchwell Autoscan central monitoring system has allowed the engineer to keep a watch on environmental conditions, plant operation, and energy consumption, and to optimise the use of the installation. An electronic building management system now under consideration would give further savings.

Close control and manual supervision has allowed gas consumption to be cut from 138 kWh/m^2 of treated floor area in 1979 to 98kWh/m^2 in 1987/88.

By diligent operation and by replacing tungsten decorative lighting with compact fluorescents, electrical consumption was also reduced by 25% from 1978 to 1982. However, it has since risen owing to the addition of new buildings and equipment, and has now returned to the first year's level of 106 kWh/m^2 of treated floor area.



Typical office windows with overhangs and sunscreens.

Building Team

Architects:	RMJM and Partners, London
Mechanical Services:	Edwards and Partners, Maidenhead
Electrical:	Pinto and Partners, Hampton in Arden
Main Contractor:	Espley-Tyas
Mechanical Services:	How Group Southern
Electrical Services:	Mann Egerton Electrical

Building Details

Offices and civic accommodation completed 1977, with later small extensions

Floors: Main offices — 3, Civic areas — 2 plus basement support services.

Gross floor area	23600 m^2 254000 ft^2
Treated floor area	19750 m^2 212600 ft^2
Nett floor area	15550 m^2 167400 ft^2
Linked pavilions —	highly glazed perimeter.
Typical number of occupants	1050

Typical hours of use: 8-6 weekdays plus 2-shift and occasional weekend computer use.

Fabric

Fabric	U-Value (W/m^2K)
Walls — varies, average about	1.0
Glazing (clear double and single) average	4.3
Roof (with high thermal capacity)	0.6

Heating

Medium temperature hot water (MTHW) site heating mains fed from central boiler house with dual fuel steel boilers 2 x 1465 kW. Local controls supported by Satchwell Autoscan central monitoring system. Perimeter radiators and local fan-convectors.

Hot Water

2 local calorifiers fed from MTHW system.

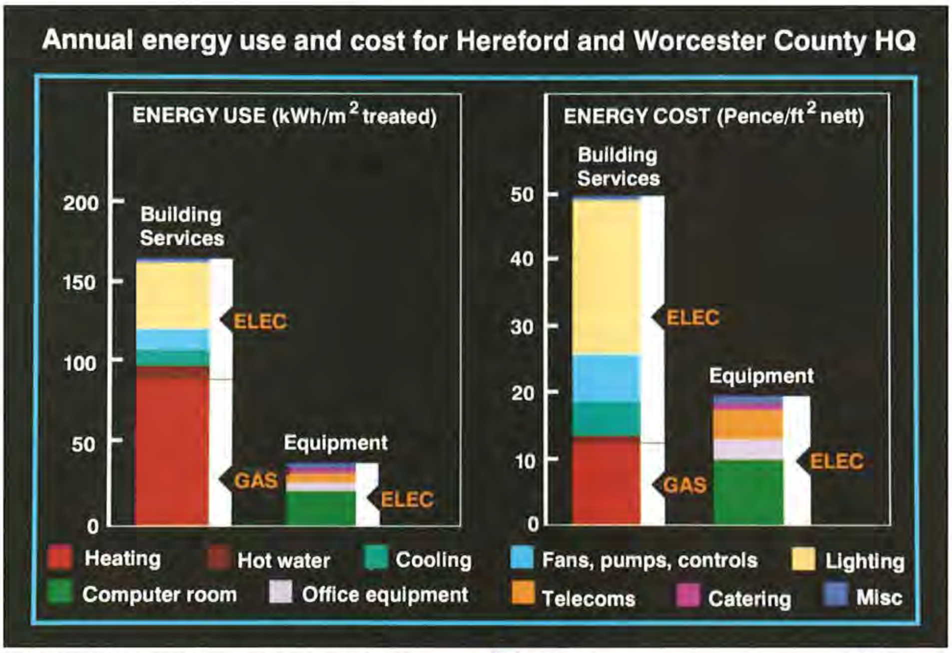
Ventilation and Cooling

Mechanical ventilation by local plant for most areas, with tempered air supply. Supplementary natural ventilation to offices from openable windows. Cooling from central chilled water supply (4 reciprocating compressors) for offices, council chamber and computer room. Self-contained air-conditioning for telephone exchange.

Lighting

Good daylight to perimeter. Rooflights to top floors. Delmatic lighting control system.

Typically 500-600 lux 32 W/m^2



Analysis of Energy Use and Energy Cost

From May 1987 to April 1988 (2433 degree days) 1,952,500 kWh of gas and 2,062,500 kWh of electricity were consumed. Excluding the computer room's electricity consumption, the total of 183 kWh/m^2 of treated area is well within the CIBSE Energy Code 4's "good" category of less than 195 kWh/m^2 for a naturally-ventilated office of this size and only two-thirds of the level for air-conditioned office.

The diagram above gives a detailed breakdown of energy use and cost. Although consumptions are similar, the annual cost of electricity dominates: £93,500 as against £21,750 for gas, or 56 and 13 pence/ft^2 nett respectively.

Heating — 90 kWh/m^2

Heating energy use is low, even in comparison with some recent gas-heated low-energy buildings. Sound design and good management shows that good efficiencies are possible in spite of the operational difficulties and distribution losses which often occur with a central boiler house and site heating mains.

Hot Water — 8 kWh/m^2

Energy use is low for a centralised system which relies upon central heating boilers. This relates partly to distribution from local calorifiers, and partly from running the boiler for only 1 hour per day in summer, which has proved enough.

Cooling — excluding computer 10 kWh/m^2

Chiller energy use is modest for an air-conditioned building but rather high in relation to the actual demand, owing to the losses which arise in circulating chilled water to the dispersed plant and particularly the computer room.

Fans, Pumps and Controls — 13 kWh/m^2

Energy use is low for the extent of the system, and results from local plants, low-pressure distribution, and short running hours through good energy management.

Lighting — 44 kWh/m^2

Lighting energy use is disappointing given the good daylight and automatic controls. Reasons include:

- the lighting technology is some 12 years old — a modern installation would require about half as much power.
- extra artificial light is needed to offset glare from the continuous windows
- light switches are not sufficiently local to be convenient.

This offers scope for further energy savings.

Computer Room — 20 kWh/m^2

Energy use is low for the size of installation because the equipment and its air conditioning is switched-off at night.

Office Equipment — 5 kWh/m^2

Hereford and Worcester has less electronic office equipment than many commercial head offices and its energy use is consequently modest.

Telecoms — 8 kWh/m^2

Energy use is high because the telephone exchange runs constantly and is of an old design based on mainframe computer equipment and requiring full air conditioning. The new exchange is expected to use perhaps one-fifth of this.

Catering — 4.5 kWh/m^2

2.5 kWh/m^2 — gas

2.0 kWh/m^2 — electric

This energy is largely used by the canteen to serve about 150 hot meals a day.

Miscellaneous — 1.5 kWh/m^2

This includes the printing department and the lifts, whose energy use is modest in this low-rise building.

User Reactions

Users are generally happy with heating and ventilation. They like the views out and the ability to open windows, switch lights and adjust radiators in some areas. However, there is overheating in some areas where summertime cooling was omitted as an economy measure and this may now be replaced.

The heavy roof construction, overhangs and projecting sun screens have helped reduce summertime solar gain and peak temperatures, and hence the need for the cooling systems to operate. The "natural" environment also makes people more tolerant of higher summertime temperatures than in a sealed building, and this has caused the mechanical cooling to be used less than the designers predicted.

Satisfaction with daylight and sunlight is not as high as had been hoped:

- The overhangs and sunscreens are deliberately designed to admit winter sun and help reduce space heating requirements. However, since no internal blinds are fitted, problems arise from glare and low sun.
- Although daylight levels in themselves are often sufficient to meet illuminance requirements, there are some complaints of "dimness", which probably arise from the contrast between inside and outside as seen through the continuous band of windows. The electric lights are therefore on more than anticipated, improving visual comfort by reducing contrast. The photoelectric controls initially also switched the lights off too frequently, leading to complaints. This situation offers several lessons and opportunities for further energy savings.

General Appraisal

Hereford and Worcester County Hall was one of the buildings completed in the mid-1970s which challenged the then-conventional wisdom that large offices had to rely on deep planning, artificial lighting, full air-conditioning and small windows to reduce heat loss and solar gain.

By having a heating, ventilation and cooling system which operates differently at different times of the year, it offers the advantages of a controlled environment — cooled if necessary — when the climate is hostile, but allows a more "natural" environment in mild weather.

This "selective" approach has proved successful as the analysis of energy costs shows. This success owes just as much to the conscientious operation, maintenance and management of the building and plant as to its design features. For example, the Council Chamber is only air-conditioned on days when it will be occupied (otherwise only background heating runs), the chilled water system does not run when the computer is off, and perimeter lights are held-off on bright days.

The low heating costs are particularly interesting in view of the central boiler-house being positioned some distance away from the offices, and designed to serve planned extensions which have never been built. Good management and well-insulated, accessible mains have kept losses to a minimum.

Although, for various physiological and operational reasons, daylight has not been used as much as hoped, the fact that lighting energy use is as low as in many comparable modern buildings is creditable given the age of the installation. Modern lights would be much more efficient and indeed the twin-tube perimeter lights are now being upgraded using new high-efficiency Silverlux reflectors to give a similar light level with a single tube.

Main Conclusions

Hereford and Worcester demonstrates that low-energy buildings do not have to rely on sophisticated heat recovery and energy-collection systems, and that the intelligent use of the external environment can be an energy-saving benefit. If heat gains from new electronic office equipment do increase substantially, then the design still has the flexibility to cope.

Part of the energy-savings result from matching the running hours of local plant (particularly for the council suite) to patterns of occasional occupancy, and this would not be characteristic of many commercial buildings. Many civic offices — or conference suites in commercial offices — could also benefit from this flexibility.

As new technologies are introduced, such as the new telephone exchange, further lighting upgrades, an electronic building management system, and replacement chillers, the energy performance of the building services should become even better.

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

Rooflit top floor office core.

Perimeter offices. Note that the band of lights towards the window is off under automatic control.

All case study analysis in this series are based on at least one year's measured fuel consumption and cost. Further breakdowns 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 co-operation of the owners, designers managers and the occupants of the case study building is gratefully acknowledged.

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