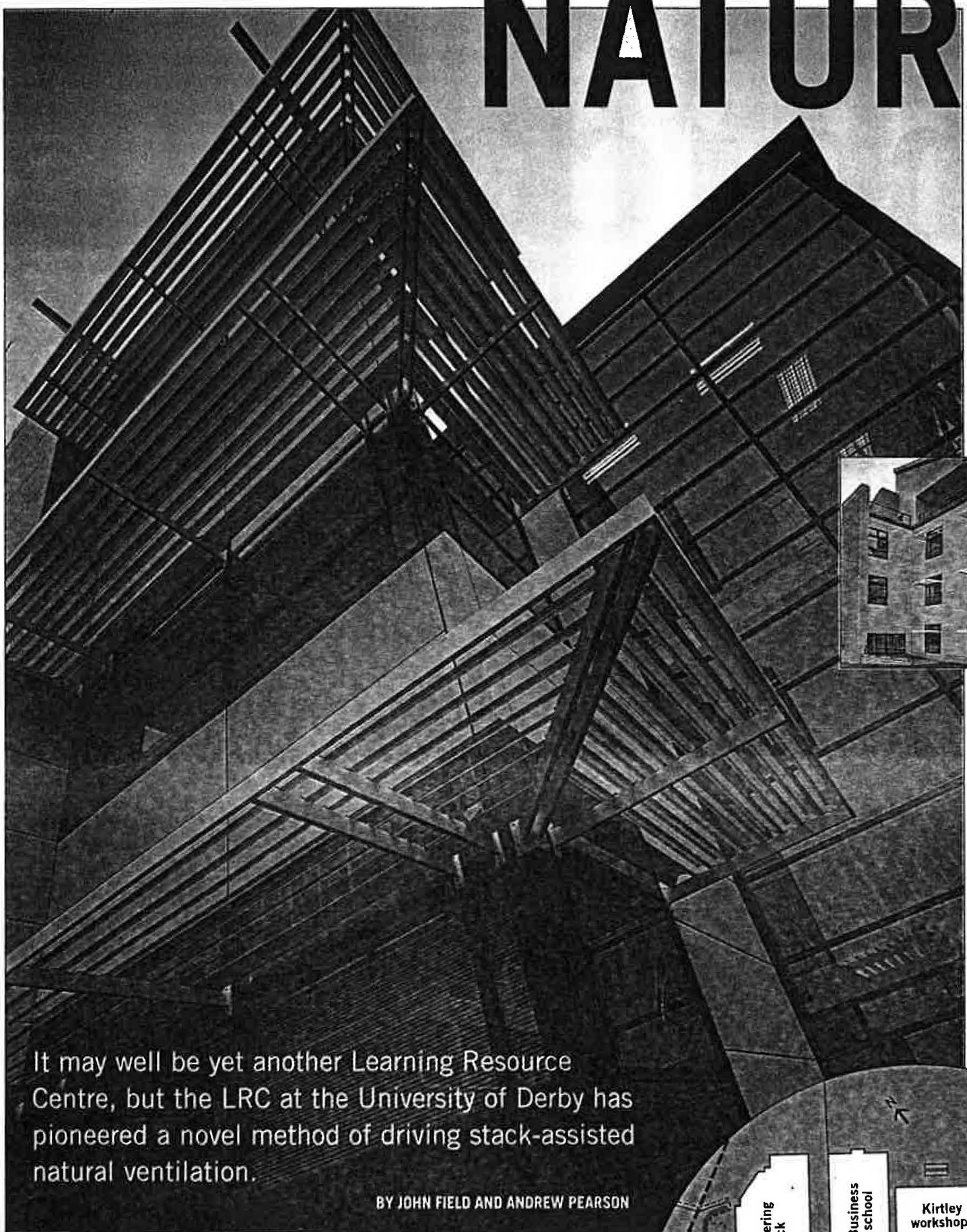
NATURAL



PHOTOGRAPHS: PAUL HARMER

It may well be yet another Learning Resource Centre, but the LRC at the University of Derby has pioneered a novel method of driving stack-assisted natural ventilation.

BY JOHN FIELD AND ANDREW PEARSON

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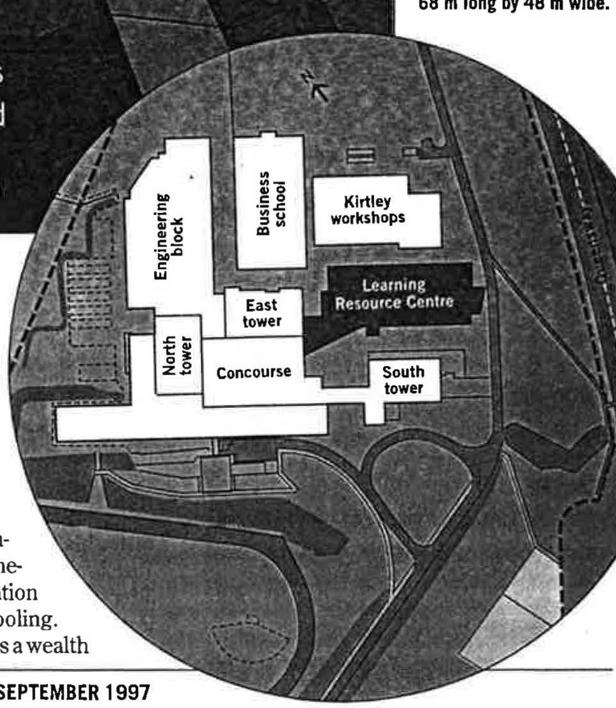


FIGURE 1: Site layout. The Learning Resource Centre is four stories high, with a floor plate 68 m long by 48 m wide.

The Learning Resource Centre (LRC) is becoming a ubiquitous building type, almost defining the low cost, passive solar building of the 1990s. They may be tight, but university budgets have done architects and engineers something of a favour, forcing them to consider low cost and energy efficient building forms robust enough to survive the rigours of the undergraduate horde.

While Derby University's new LRC is no exception, it exhibits a novel approach to stack-driven ventilation that offers a design detail challenging current preconceptions of the atrium form. Linked directly to the busy central concourse area, the building houses traditional library areas, communal pc-user areas and a small amount of administration.

To achieve this the building exhibits classic mixed-mode characteristics, with advanced measures for reducing both cooling and heating loads, and a variety of operating modes including openable windows, mechanical displacement ventilation and a modicum of comfort cooling. This simple description belies a wealth

ASPIRATION

of design effort ranging from back-to-basics strategic appraisals, lateral thinking and sophisticated thermal and wind modelling.

The design, by consultant John Packer Associates, laudably kept to fundamental principles, such as maintaining client support, controlling solar gain and opting for high thermal mass. Lessons from post-occupancy studies have also found their way into the specification, such as devolving services control between large main zones and small sub-zones, allowing natural or forced night cooling and separating services for constant loads by collecting together office machines like photocopiers so that high heat gains and emissions can be dealt with by local extracts. Control strategies are kept as simple as possible.

The building is four stories high, rectangular in plan, with a floor plate 68 m long by 48 m wide (figure 1). Two full-height atriums, topped by glazing, allow daylight into the interior.

Set into the glazed roof is a wind trough for ventilation exhaust. Both atriums are 7·2 m wide, the main atrium is 14·4 m long while the smaller atrium, including a stairway, is 7·2 m long. Two 7·2 m square bays separate the atriums – one of which is a service core containing toilets, communications cabling room and a photocopy booth. The air handling plant room is above these bays on the roof.

Ventilation and daylighting

The building has a 'natural' feel from the light streaming into the central atrium voids, the narrow floor plans, opening windows and lack of plant noise. The facade allows natural ventilation and daylighting, but restricts direct heat gain and glare. It is also designed to have sufficiently low U-values to avoid the need for perimeter heating.

The window units comprise a triple-glazed central pane with a sealed double-glazed outer unit and a horizontal sliding internal tertiary glazing, between which hangs a manually-controllable venetian blind. This arrangement also provides accessibility for maintenance. The upper window is double-glazed with a horizontal centre-pivot and a motorised actuator. This is opened and closed by the building energy management system (bems). The lower section is a 600 mm double-glazed unit.

Between the mid and upper window there is a 1200 mm external brise-soleil and a 600 mm internal light shelf, both louvred, which help to control direct solar gain, glare and daylighting variation in the space. The light shelves are louvred to allow air to filter into the space, rather than drop over the edge of a 'waterfall'. Composite insulated panels complete the facade.

Storage of daytime heat in thermal mass has been optimised by exposing both the concrete slab soffit and also the floor, which is carpeted but not raised. Air through the windows or from the perimeter displacement ventilation terminals passes across the floor plates, into the atria and rises to roof level, where it either exits through the motorised louvres in the ridge wind trough, or is pulled into a large plenum at the inboard end of each void to be extracted via the air handling units (ahus) (figure 2).

As the top floor misses out on the exposed concrete soffit, it has the potential to suffer from overheating. Design measures to offset this include a porous egg-crate acoustic ceiling to allow air to pass freely into the pitched roof void, and an increased air change rate by dint of mechanical ventilation.

Night ventilation is possible either naturally or using the mechanical system. Initially, night ventilation will be controlled on a simple schedule of duration against average preceding day temperature. Due to the building's low external temperature balance-point, at which heating is no longer required, the initial schedule shows some night ventilation even at 0°C external temperature.

Mechanical systems

The building has a large control dead band in which natural ventilation operates. Mechanical systems run outside this band. The building is split into four zones, one at each corner, separately served by dedicated, multi-function ahus.

Using techniques derived from swimming pool ventilation systems, the ahus include a flat plate heat recuperator and a heat pump operating between inlet and extract air streams. An lphw coil can supplement heating input or provide standby for an out-of-service heat pump. Three motorised dampers allow normal air flow, recuperator bypass or 90% recirculation for the pre-occupancy period.

Mechanical ventilation is designed for 5 ac/h except for the top floor which is designed to 6 ac/h. Supply ductwork distribution is extremely compact, with short runs to the external vertical ducts feeding directly into vertical wall voids on each floor. These serve as a local plenum for the displacement ventilation terminals.

The plantroom is used as a fresh air plenum and there is virtually no return air ductwork:

Category 2 luminaires suspended from the coffered ceiling at 3·6 m centres provide 350 lux on the working plane in the main occupied areas.

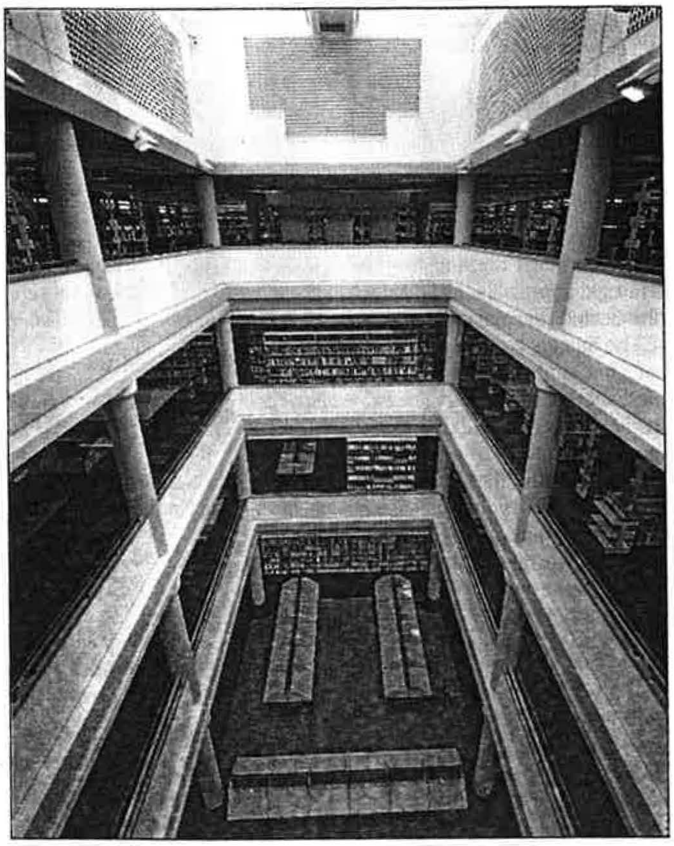
the atrium-top air return plenums are adjacent to the plantroom and short exhaust air ducts pass through the roof. The ductwork is in Koolduct which has integral phenolic insulation. This meant that the ductwork could be installed in tight spaces without applying any insulation afterwards.

The duct pressure is low at only 150 Pa, but pressure drops within the ahus are probably higher than average because of the recuperator and the extract air heat pump recovery/reject coil. Against this, the system has avoided the need for a dry or wet condenser.

Total fan power of the main ahus is 13·4 W per m^2 of floor area. Inverter-controlled variable speed fan drives and volume control dampers in sub-zones should ensure that average fan power is much lower.

The displacement ventilation system supplies air at between 19-24°C, which allows extensive use of free cooling from ambient air (which is below 19°C for most of the year), and minimises the energy expended on non-optimal dehumidification. Heat pump operation in heating mode is assisted by the low supply air temperature, use of the outgoing air stream as the heat source and preheating of the incoming air by the recuperator before it reaches the heat pump heating coil.

If recuperation or heat pumps are not required, the extract fan is held off and air is extracted naturally via the roof louvres.



Detail of the glass-topped main atrium. Note the plantroom intake louvre directly underneath the pitched roof.

The heat pumps provide base heating load, with two Hamworthy high efficiency, low thermal mass gas boilers to provide top-up and stand-by heating capacity. LPHW is used for the coils in the ahus, and a small number of radiators equipped with thermostatic radiator valves link to the concourse.

Inverter-controlled secondary pumps are carefully matched with two-port valves on three of the ahu coil circuits, leaving three-port control on the fourth coil index run to maintain 25% flow – necessary as a minimum pump duty to maintain pump self-cooling. Hot water is provided by a local electrical heater in the service core of each floor.

The lighting design

Category 2 luminaires suspended from the coffered ceiling at 3·6 m centres provide 350 lux on the working plane in the main occupied areas. These units are centrally switched and dimmed in banks by a central controller to avoid nuisance turning-off of luminaires. There is no local occupant override.

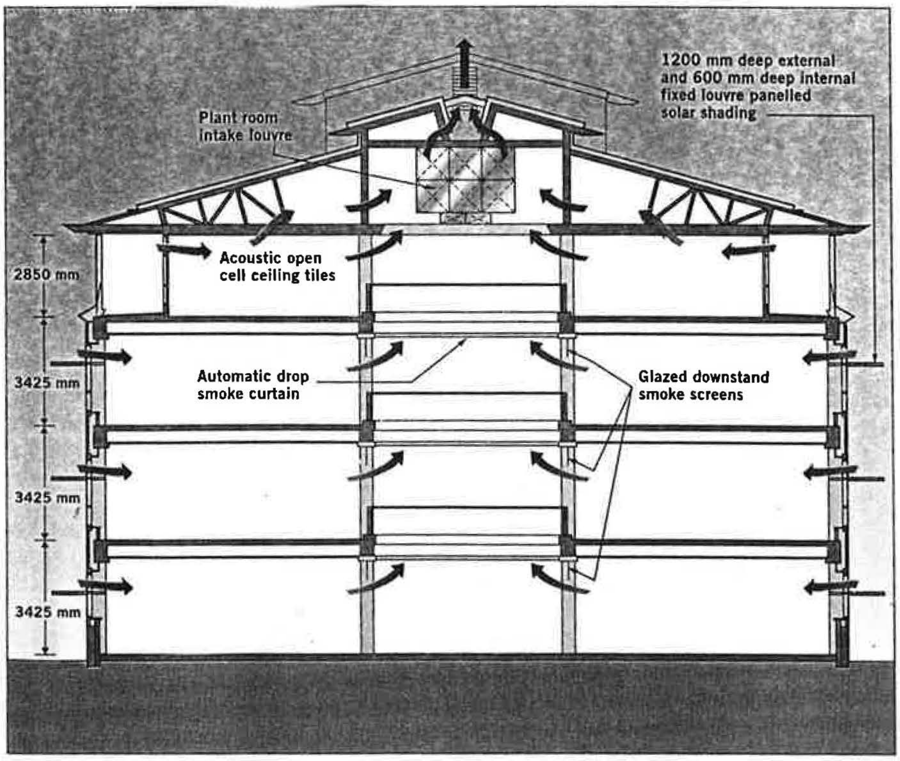
The central lighting controller uses only a single, three-sensor, roof-mounted light detector which can identify magnitude and directional properties of external ambient light. To commission the control system, lighting will be set up to maintain light levels in the various zones, based on external conditions, and will then be refined in use.

All luminaires are provided with a switched live circuit in addition to the normal dimmed circuit so that individual lights can be rewired to be held on during occupancy if, for example, partitions or other special circumstances make the local dimmed lighting regime inappropriate. The atriums are lit by mercury halide up and downlighters.

Avoiding false ceilings and raised floors is commendable but possibly ambitious in these times of obsession with electronic communication, especially in a building where many areas could be occupied at 3 m^2 per desk, each with a high-end pc. The approach merits close attention.

Lighting is suspended from the coffered ceiling which provides lateral downstands running across the building. There is no service void within the ceiling construction, unlike the BRE's Environmental Building where the waveform ceiling conceals lateral service runs.

Here, lighting and fire detection cable access is drilled through from trunking running in the floor above: every floor has four longitudinal trunking runs each incorporating three or four 100 mm by 50 mm compartments. The three compartments are for small power, data



BELOW, FIGURE 2: Cross-section of the building showing the ventilation strategy. Air through the windows or from the perimeter displacement ventilation terminals passes across the floor plates, into the atria and rises to roof level. Here, it either exits through the motorised louvres in the ridge wind trough or is pulled into a large plenum at the inboard end of each void to be extracted via the ahus.

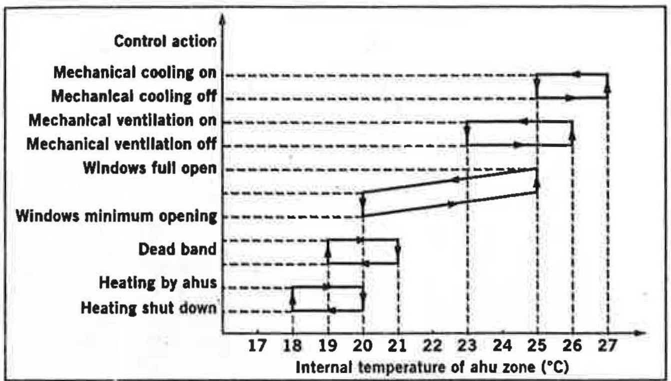


FIGURE 4: The environmental control strategy is based on a cascade of operating modes.

and controls runs throughout, the fourth is included when there is a need for fire detection and alarm wiring.Floor trunking is flush in the floor screed, connecting to cast-in conduits through the planks to luminaires and fire detectors below. The trunking is designed so that no desk is more than 2 m from a trunking run.

The library desks run laterally (across the longitudinal trunking runs) and have a simple but effective cable management arrangement which means that only one end of a linear desk has to sit over an outlet.

An exposed ceiling and floor has resulted in savings of possibly £30/m^2, giving a probable net cost saving over a traditional floor-and-ceiling treatment, but with an increase in internal mass for internal conditions.

Roof vents

For the natural ventilation strategy to hold up on this hilly and windy site, the roof vents had to encourage extraction with negative wind pressure in all conditions. The initial design for a traditional 'bee hive' section would require motorised, wind-dependent opening and closing of the louvres (figure 3). This design requires double the total louvre area.

Various designs were investigated by the simulation specialists with Professor Tom Lawson of Bristol University. One option included baffles placed in front of these louvres, but these were not acceptable to the architect.

Finally, the idea emerged of a slot in the roof ridge, which the wind would blow over, maintaining an area of negative pressure in the slot regardless of wind direction. But the problem of how to control the opening remained: bottom pivot windows admit rain, top pivot windows obstruct the slot. A motorised louvre system was the final choice, one which also satisfied smoke extract requirements.

A detailed fire strategy was developed in association with Colt International. Although there is no active fire fighting, 1 m glass downstands assist with smoke control on the sides of the atriums. These glass partitions only occur on the longitudinal axis – at either end of the atriums there are full-height, motorised fire curtains.

During a fire the bems is programmed to co-ordinate the smoke control response, involving closing of the windows on the affected floor while driving them open on other floors. The full-height void curtains stay retracted on the fire floor, and are dropped closed on other floors to reduce smoke ingress. Roof vents are released 'open' for smoke exhaust.

Thermal simulation

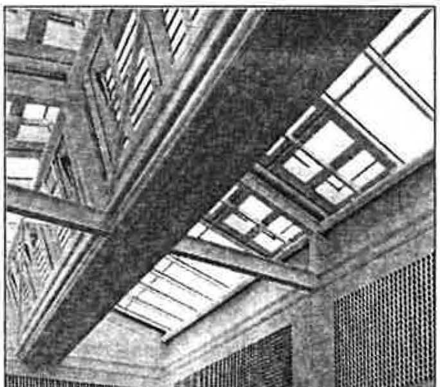
The designer has maintained a beneficial relationship with thermal simulation specialists. The contact came about through the Energy Design Advice Scheme (EDAS) which also pays half the costs of simulation work. EDAS provided the names of several potential specialists, but Cathy Ho at Building Simulations provided the required pragmatic approach.

The thermal simulations provided the designer with confirmation that the traditional methods for design assessment and sizing have worked. They also allowed quantitative evaluation of overheating risk. Such exercises provide an improvement in understanding general principles. Here, for example, the simulations showed that most upward ventilation occurred mainly through the larger unobstructed atrium rather than the smaller atrium which includes a stairway.

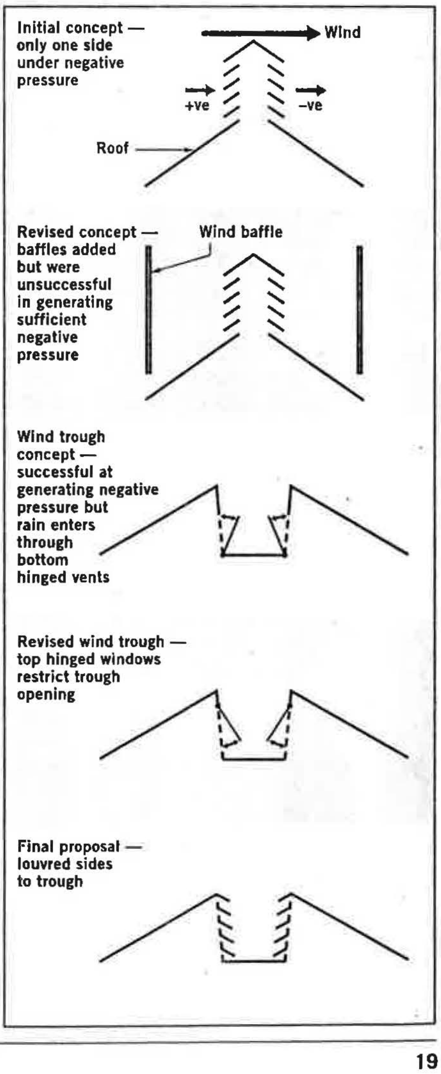
The fire strategy required that a permanent 1 m glass downstand be hung from the ceiling around the central atrium voids, so a computer simulation was run to identify whether the downstands would ruin the natural ventilation paths and cause warm air to stack up in the occupied areas. Fortunately, the effects were deemed acceptable.

Simulation was also used to assess the overheating risk for various design strategies, the number of hours per year that internal dry resultant temperature exceeded 25°C and 27°C being calculated for the various design options. Investigations were carried out for a high and low-IT area, with mechanical ventilation in both cases.

Heat gains in the high-IT area were taken as 6 W/m^2 for lighting, 20 W/m^2 for occupants and 30 W/m^2 for equipment loads. Mechanical cooling reduced the hours above 25°C from 370 h to 200 h in the high-IT area on the second floor, and from 120 h to zero in the low-IT area. This was taken to make a strong case for mechanical cooling – 120 h being deemed acceptable for the low-IT areas, but not 370 h in high-IT areas.



ABOVE AND, RIGHT, FIGURE 3: Various designs were considered for the roof vents. A motorised louvre system was the final choice, one which also satisfied smoke extract requirements.



John Packer Associates has striven to answer the important questions, but the $64 000 question remains – can the university run the building as it is intended? After all, this is no small, lightly-loaded building so there does not seem to be a dream ticket solution: it is difficult to see what more could have been done to reduce loads and avoid the occasional need for mechanical ventilation or cooling other than extreme fixes like interseasonal cooling storage.

Although there have to be some temperature limiting systems, you don't want these to work all the time, and you don't want them all to work together except in very testing conditions. A sequence or cascade of operating modes is required, with an associated control strategy.

Even getting the natural ventilation to work needs an overview: unless the occupants have been watching too many episodes of the *X-Files* and have developed an eerie "gestalt" in which everyone knows and takes account of what everyone else is thinking – not a normal characteristic of undergraduates.

The approach taken has been to simplify the overall control sequence and use more transparent proportional control logic where possible rather than full PID logic, which is trickier to set up and to assess in use.

The environmental control strategy is based on a cascade of operating modes (figure 4). As internal temperature rises above the dead band, the windows are progressively opened, then mechanical ventilation is brought on until the cooling is finally introduced and windows closed. The sequence is reversed, but at lower set-points as temperatures fall. If internal temperature falls below the dead band the mechanical ventilation with heat pump heating is brought on.

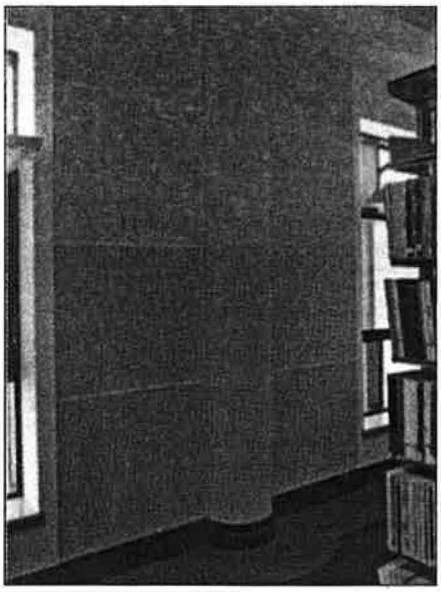
An element of local control is often cited as an important factor in widening occupants' tolerance of internal ambient conditions, but in this building it was judged inappropriate because of the transient nature of most users. Implementing the declared policy of rapid response to complaints should go some way to achieving the same effect, but while the occupants have been given control of the crucial mid-pane blinds, they haven't been given control of the local lighting, so it will be interesting to see both the occupants' tolerance and the eventual operating regimes of the building once it's occupied.

There seems to be plenty of scope for permanent or seasonal low-power mechanical ventilation, with cooling on demand for the odd week or month. This is certainly not what is currently intended. It would require effective but less technically proficient building management, and could still be low energy for the given internal heat gains. In theory this approach retains the cascade control sequence, but adds an element of time-hysteresis to the mode changes of around one week.

One could argue that successful natural-feel local controls would remove a substantial workload from a facilities team, who should provide rapid response anyway. The counter argument is that suitably arranged, automatic controls can also reduce the workload. One Bridewell Street[1] and Tanfield House[2] are reported examples of buildings which depend successfully on quick response rather than local control.

Persistent reference to basic design principles, linked with an awareness of recent feedback from buildings in use has produced a building with a sound design basis and many novel but not overly technical features, one which promises happy occupants and low energy use.

The latter is dependent on successful implementation of the operating strategy which still requires significant commitment from the facilities management team. This commitment has been strongly expressed by the client, so there is every chance the designer's intentions will be fulfilled.



The ventilation system supplies air at between 19-24°C through a series of displacement terminals.

University of Derby Learning Resource Centre

Client
University of Derby
Architect
David Lyons and Associates
M&E consulting engineer
John Packer Associates
Structural engineer
Alan Brough Associates
Quantity surveyor
Rex Proctor & Partners
Main contractor
Higgs & Hill
Electrical contractor
N G Bailey
Mechanical contractor
Markham Engineering
Commissioning contractor
Commissioning South West

Mechanical suppliers
AHUs: Mercury Climatic
Anti-vibration mounts: Allaway Acoustics
Boilers and burners: Hamworthy Heating
Ceiling diffusers: Gilberts
Coolant: R22
Computer room ac: Mitsubishi
Above-ground drainage: Caradon Terrain
Ductwork: Koolduct
Extract fans: Roof Units
Displacement terminals: Displacement Design (Lindab)
Flues: Eagle Fabrications
Louvres: LBJ Fabrications
Pumps: Wilo Salmson
Pressurisation: Hamworthy
Radiators: Zehnder
Sound attenuation: Allaway
Valves and strainers: Crane
Tanks: Dewey Waters
Toilet extract: Roof Units
Water treatment: Garny Plant
Water heaters: Heatrae Sadia

Electrical suppliers
BEMS, controls and motor control centres: MSI
Cable management and floor boxes: Arena
Communications: IBM
Electrical accessories: MK
Fire alarm/detection: Kidde
Lifts: Schindler
Lighting controls: Leax
Luminaires: Moorlite
LV switchgear: Crabtree
Power busbar: Barduct
Trace heating: Trace Heating

Contract details
Tender date: 16/11/95
Tender System: Competitive
Form of contract: JCT 80 nominated subcontract
Contract period: 3/96-4/97
National Engineering Specification: No

External design conditions
Winter: -3°C/sat
Summer (non a/c): 26°C db
Summer (a/c): 26°C db, 19°C wb

Internal design conditions
Winter: 19°C min
Summer (a/c): 22±3°C
Circulation/toilets: 19°C min

U-values (W/m^{2}K)
Walls: 0·36
Floor: 0·2
Roof: 0·25
Glazing: 1·7 average

Structural details
Slab thickness: Gull wing T-beam 100-550 mm
Floor-to-soffit: 3700 mm (average)
Live load: 5·0 KN/m^2
Dead load: 9·0 KN/m^2

Occupancy
General areas: 1 person/4 m^2
Meeting rooms: 1 person/3 m^2

Noise levels
Offices, open areas: NR30
Toilets and circulation: NR35
External breakout limits: 55 dBA at plant louvre

Energy targets (gfa)
Heating (gas): 40 kWh/m^2/y
Hot water: 5 kWh/m^2/y
Fans/pumps: 15 kWh/m^2/y
Refrigeration: 8 kWh/m^2/y
Small power: 20 kWh/m^2/y
Lighting: 18 kWh/m^2/y
Lifts: 0·2 kWh/m^2/y

BREEAM rating: No

Engineering data
Gross floor area: 6666 m^2
Net usable area: 5600 m^2
Plantrooms: 160 m^2
Offices: 252 m^2
Computer room: 26 m^2
Atria: 460 m^2
Services risers: 1·2% gfa

Loads
Calculated heating load: 0·3 MW
Installed heating load: 2 @ 0·2 MW including standby heater battery
Calculated cooling load: 0·43 MW
Installed cooling load: 0·35 MW
Fan power: 3·2 W/litre/s, 13·4 W/m^2
Gross building load: 65 W/m^2 design cooling load
Equipment: 30 W/m^2 maximum
Installed lighting load: 10·5 W/m^2
Occupancy: 20 W/m^2
Solar gain (summer): 4·5 W/m^3

Ventilation
Scheduled supply air temperature: 19°C-24°C
Room temperature: 19°C minimum, 25°C maximum
Fresh air: 100% minimum (18 litres/s/person)
Maximum recirculation: 90% (preheat only)

Filtration EU category: EU7

Primary air volumes
2 ahus at 7·2 m^3/s
1 ahu at 8·4 m^3/s
1 ahu at 5·1 m^3/s

Distribution circuits
LTHW: 82°C flow, 71°C return
DHWS: 60°C flow (local electric)
Constant temperature: 82 °C

Refrigerant
AHU heat pumps: R22
Computer room: R22

Electrical supply
460 kW supply

Lighting
Types: Fluorescent
Lighting load: 58 kW
Efficiency: 3·0 W/m^2/100 lux

Lux levels
Offices: 350
Computer room: 350
Toilets: 350
Stairs: 350
Circulation areas: 350

Lifts
1 x 8 person @ 0·63 m/s

Costs
Total cost: £4·76 million
Building services total: £1·36 million
Total net cost
Building: £714/m^2
Services: £204/m^2

Mechanical services cost (£/m^2 gfa)
Heating system: 5·85
Air conditioning and ventilation: 77·28
DX cooling systems: 2·30
Gas installation: 0·41
Thermal insulation: 3·49
BEMS mechanical installation: 0·18
Soil and waste: 3·11
Cold water systems: 1·73
Domestic hot water services: 0·98
Dry riser installation: 0·83
Sundries: 0·52
Preliminaries: 1·58

Electrical services (£/m^2 gfa)
LV distribution: 3·31
Lighting: 32·42
General power: 10·24
Fire alarm system: 8·24
Data wireways: 1·20
Mechanical wiring: 5·26
Lightning protection: 0·46
Earthing and bonding: 0·52
Sundries: 1·70
Fire engineering: 8·25
Preliminaries: 1·16
Data wiring: 11·10
BEMS: 18·00
Lift: 3·62

References

[1]EEO Best Practice Programme, *Good Practice Case Study No 21.*

[2]Bordass B and Leaman A, 'PROBE 1: Tanfield House', *Building Services Journal*, 9/95.