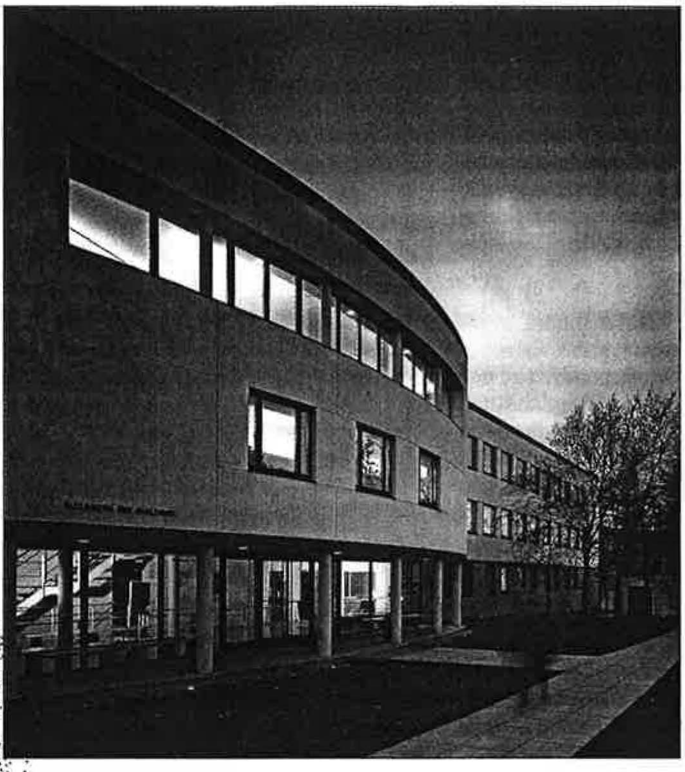
When natural ventilation was all the rage, a novel form of mechanical ventilation was quietly slipping into Britain: the Swedish Termodeck system. One of the first buildings to use Termodeck and other Swedish detailing was an academic facility at the University of East Anglia. How has it fared?

**BY THE PROBE TEAM**



PHOTOGRAPHS: ROBERT GRESHOFF

# PROBE 14: Elizabeth Fry Building

The Elizabeth Fry (EFry) Building, occupied in January 1995, is the most recent low energy building commissioned by the University of East Anglia (UEA). It is the last of a group of new buildings on the western edge of the Norwich campus, which started in the 1980s and includes the Constable Terrace student residences and the Queens Building.

For an in-depth details of the building's construction, readers should look at the original building analysis 'Teaching low energy' (*Building Services Journal*, April 1995)[1].

Basically, the building has a gross floor area of some 3250 $m^2$ (3130 $m^2$ treated floor area) over four storeys. Its north facade is on the site perimeter road, while the south side faces Constable Terrace across a courtyard/ car park.

The top two floors contain 50 cellular offices for about 70 staff. The School of Social Work is mainly on the first floor, with the School of Health Policy and Practice on the second floor. The lower ground and ground floors contain lecture and seminar rooms, bookable by the whole university. For the conference trade, there are also two dining rooms and a small catering kitchen on the second floor.

The position, height and external style of EFry, including its rendered and concrete block external finishes, was very much dictated by earlier buildings on the site. Finishes are of a high quality and more reminiscent of stylish business premises than most academic establishments, even though cost levels were normal at £820/$m^2$. On the north side a curved projection identifies the main entrance, which leads to a pleasant narrow atrium reaching up to roof level. Lecture theatres on the lower ground floor have their own separate entrances on the south side.

### Construction details

The design team has produced a well insulated, tightly sealed and triple-glazed building envelope to meet the client's low energy criteria[1]. This included double-skin blockwork walls with 200 mm insulated cavity, and nylon wall ties to reduce thermal bridging.

All floors including the top floor have exposed structural ceilings made of ventilated hollowcore slabs. The roof has 300 mm insulation, with 100 mm insulation applied to the exposed floor soffits of rooms over the upper ground floor perimeter walkway on the south side of the building.

The windows use low-E, argon-filled triple glazing with an inner sealed unit, mid-pane perforated metal venetian blinds in the outer cavity, and external protective single glazing. These were carefully detailed to minimise cold bridging and air infiltration, and included a heavy-gauge polythene seal to the inner leaf, which was beaded and plastered.

These unusual features required clear explanation to the site workers and special checking of critical details before being concealed by internal finishes. The process benefited from the previous experience of the UEA's Clerk of Works and the co-operation of main contractor Willmott Dixon. The contractor was obliged to meet the airtightness specification by pressure testing at the end of construction (see box "BSRIA pressure test").

The Clerk of Works felt that all went well generally, but would have preferred stainless steel wall ties. The weaker nylon ties had to be fitted at four times the normal density, while the extra bridges across the cavity meant lots of extra cutting and scribing of the mineral wool slabs. The Clerk of Works also thought the gaps so created may have undermined any theoretical benefits attributable to the lower thermal conductivity of the ties.

### Servicing arrangement

The designer considered natural ventilation, but opted instead for the Swedish hollowcore system Termodeck. As a floor slab, this is both a structural component and a means of ducting ventilation through the building[2,3].

EFry was the second UK building (after Weidmuller Klippon Microsystems in West

Malling) to use this technique. By enhancing access to the thermal capacity of the structure, Termodeck offers the opportunity for year-round tempering of incoming fresh air.

Due to its innovative nature, detailed monitoring of the EFry Building's energy and environmental performance between January 1996 and August 1997 has been carried out by Databuild under a joint BRE/BRECSU contract. The BRECSU's report is due to be published shortly.

In the offices and seminar rooms, air is supplied to the hollowcore slabs via stubs from ducts running above suspended ceilings in the corridors. After three passes through the ceiling slabs, the air enters the rooms via annular soffit diffusers. Return air is extracted from behind the ceiling cornice and back to the air handling units (ahus) via the corridor ceiling plenum.

In the main lecture theatres, the air from the ceiling cores is ducted down to wall-mounted displacement terminals. The cores can only handle one-third of the design maximum air volume. The rest is supplied from under the floor, via a damper which is controlled only to open during occupied hours. Return air is again via the cornice.

The windows have inward-opening casements, typically 300 mm wide by 1200 mm high. These are a key element in the mixed-mode approach, giving occupants adaptive opportunity to overcome discomfort.

Four supply/extract ahus are located in four separate plantrooms on the lower ground floor. The ground floor seminar rooms and the first and second floor offices in the west end of the building are served by ahu A. It has a three-speed fan (respectively for offices only, seminar rooms only and both).

The main lecture rooms are served by ahu B, which has a cross-flow heat exchanger with damper-controlled by-pass. The inverter-controlled variable volume fans normally operate at low speed, passing air via the hollowcore. Return air quality is monitored using $CO_2$ sensors, with fan speeds raised and the dampers to the floor voids opened accordingly.

**An IT resource room is located directly above the main entrance, and follows the gentle curve of the elevation. Note the row of annular soffit diffusers connecting directly to the exposed Termodeck slabs.**

AHU C serves two lecture rooms and an adjacent computer terminal room. A constant volume unit, ahu D, serves a variety of accommodation on all floors at the east end.

The heat recovery system for ahus A and D is based on high-efficiency Regenair heat recovery units[2]. These use metal heat exchanger packs to absorb heat from the exhaust air stream.

The airflow between the intake and exhaust ducts is mechanically reversed once a minute, allowing the pack to impart its heat to the incoming air while its twin is being regenerated in the exhaust stream.

Flow reversal (and recirculation if required) is achieved using a set of fast-acting, mechanically-linked dampers. The system claims to recover 85% of the available heat, a figure verified by the monitoring, though the maintenance staff say that it is now closer to 80%, suggesting that the heat recovery packs may need cleaning.

Experience has shown that no additional heater battery power is required at increased volumes: the occupancy gains and the heat recovery is enough. In fact, the design heat loss is only 15 W/m².

### Heating and hot water

Three 24 kW domestic condensing boilers (with 50% standby/reserve capacity) supply a 65°C lphw circuit to the ahu heater coils. During the PROBE survey, with outside air temperatures of 8-9°C, the boilers were not required all day.

Maintenance staff said that the lecture room plant always brings on the boilers first, owing to their less efficient plate exchangers and periods of low occupancy and internal gains.

The boilers are not sized for the (unlikely) event of the heat exchangers being out of service. If they were, they and the heater batteries would have been very much larger, more expensive, and almost undoubtedly less efficient in operation.

The standard Swedish specification for Termodeck includes low-power – often electric – perimeter heaters in each room. In view of the milder UK climate, it was decided to omit them from the EFry Building with a view to revisiting the decision once the building was in use.

To date, the UEA has installed six 200 W electric panel heaters. These are all in rooms with marginally higher-than-average heat losses due to greater exposed external surface area, such as the first floor offices above the ground floor external walkway on the south side.

## $CO_2$ emissions and electricity consumption data

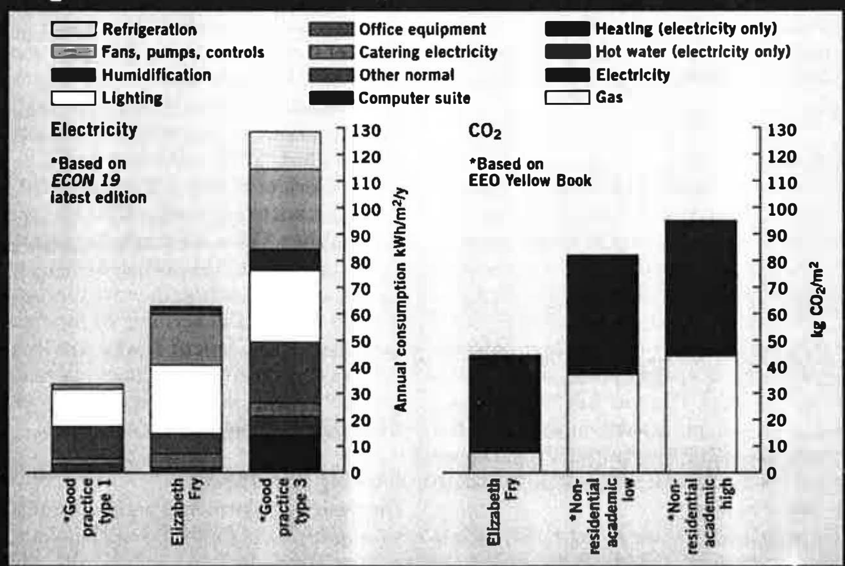



FIGURE 1: End-use energy breakdown at the Elizabeth Fry Building. Total $CO_2$ emissions of 44 kg/m²/y are just over half the low-to-medium academic benchmark of 82 kg/m²/y. This is less than half of the *ECON 19* good practice benchmark for a type 3 office (96 kg/m²/y), and in the good practice bracket for simple, naturally-ventilated offices. Conversion factors are gas: 0·2 kg $CO_2$/kWh and electricity: 0·6 kg $CO_2$/kWh.

### Control issues

The EFry Building was initially fitted with a basic system of stand-alone controls and seven-day programmers. After completion it soon became apparent that the system did not enable the maintenance team to understand how the various systems behaved.

In addition, a number of teething problems were identified, including slab temperature sensors fitted near the inlets to the hollowcores instead of near the outlets as specified.

Aware that in a thermally stable building any reported comfort problems would come too late for corrective action, the UEA opted to incorporate EFry into a new Campus-wide Trend bems system. Replacement Trend outstations feed data back to a supervisor pc in the Estates and Buildings Division offices.

The new bems has allowed the control strategy and settings to be fine-tuned and simplified. During winter and summer the system maintains a core temperature set-point of 22°C. There is no winter/summer switch. Heating plant can operate during the summer if conditions demand, although the extremely stable temperatures mean that this has rarely happened in practice.

For heating there is a 0·5°C deadband below the 22°C set-point, heating being enabled if the core temperature drops below 21·5°C. During hours of occupancy, there is full fresh air with heat recovery if heating is required, the heater batteries only operating (with a 15-minute delay) when heat recovery alone is insufficient. If heating is required outside occupancy hours, the ahus operate on full recirculation.

For cooling, the deadband is 1°C above the 22°C set-point. During occupied hours the ahus operate on full fresh air, but during unoccupied hours after 22.00 h the fans will operate if core temperatures are above 23°C, and when outside temperatures are at least 2°C less than the core temperature.

The facilities team has learnt that the original strategy to provide boost preheat to the slab overnight in winter was seldom necessary. This simply resulted in surplus heat being expelled by the ahus the following day.

### Lighting design

Most room lighting is by high frequency fluorescents concealed beneath the ceiling cornice, normally on both the corridor and the window walls.

However, the penalty of this indirect lighting is reduced efficiency, with relatively high installed power densities of between 15 and 30 W/m², as against a good practice office standard[4] of 12 W/m².

Desktop illuminance levels of 420 lux were measured with lights on and blinds raised, with measured levels of 310 lux with the blinds lowered. This suggests a typical lighting efficacy of around 7 W/m²/100 lux, as against a good practice standard of 3 W/m²/100 lux. In offices, manual pull switches have replaced the original wall switches which became obscured by filing cabinets.

A south-sloping rooflight in the entrance foyer atrium has motorised external perforated blinds under photoelectric control. During the PROBE survey the blinds remained closed despite overcast external conditions, possibly because control of the blinds may have been overridden by the occupants.

### Energy analysis: electricity

EFry is a non-residential academic building, so the most appropriate yardsticks to benchmark total energy consumption values are in the EEO Yellow Book *Introduction to energy efficiency in further and higher education*[5]. The only relevant yardsticks available for an end-use breakdown of electricity consumption are those in *ECON 19* for offices.

While the EEO Yellow Book benchmark for electricity consumption places low at below 75 kWh/m² and high above 85 kWh/m², the EFry Building falls between the *ECON 19* type 1 (naturally-ventilated, cellular) and type 3 (air-conditioned, open-plan). That said, a type 3 office is more instructive as monitored summertime conditions in EFry are equivalent to or better than an air-conditioned office. The treated floor area of EFry used as offices amounts to a third of the total, so the office benchmarks should be used with discretion.

Total electrical consumption in 1997 was 191 MWh or 61 kWh/m²/y. Consumption was unchanged on the 1996 usage and about 5% up on the figure for 1995, probably due to increased occupancy and equipment levels. The figure of 61 kWh/m²/y is 20% below the good practice figure for academic buildings of 75 kWh/m²/y, and under half that used in a good type 3 office.

End-use breakdown at EFry (figure 1) has been calculated using the normal PROBE reconciliation technique, but where available actual consumption data for loads monitored by Databuild.

Fans, pumps and controls account for about 18 kWh/m²/y, nearly all of this attributable to the fans. The heating and gas-fired hws comprises just one set of run/standby circulating pumps each of 550 W and 275 W respectively which, together with an estimated 1200 h of full-load boiler operation per year, contribute to a consumption of less than 1 kWh/m².

Fan consumption is about 18 kWh/m², half that of a good type 3 office, despite the considerable number of slab night-cooling hours.

## Results from the occupant satisfaction survey

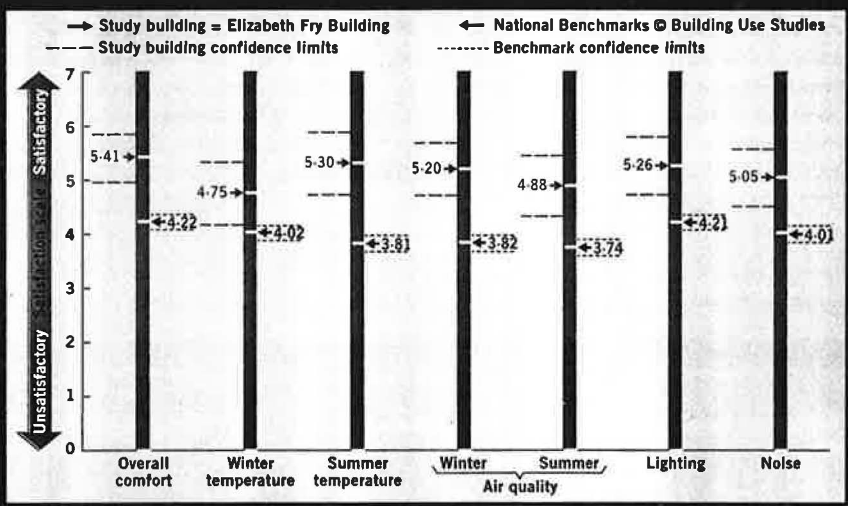



FIGURE 2: Overall satisfaction with comfort conditions at the Elizabeth Fry Building.

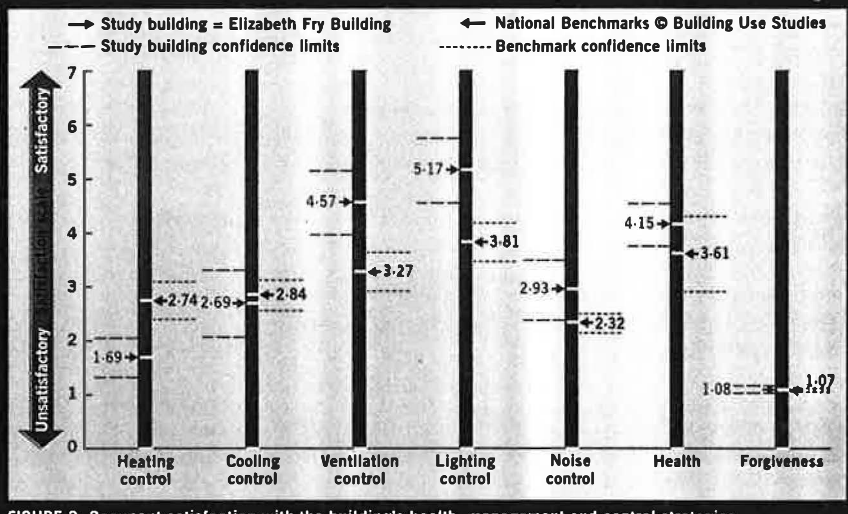



FIGURE 3: Occupant satisfaction with the building's health, management and control strategies.

Installed fan power for the two main ahus is 5·2 kW for ahu A (three-speed) and 7 kW for ahu D (fixed speed). This amounts to a total of 12·2 kW, providing a supply volume of 5·5 m³/s, equating to a specific fan power of 2·2 W/litre/s. This is similar to the *ECON 19* good practice level of 2 W/litre/s, though well above the low-energy target of 1 W/litre/s. Commissioning results confirm this figure, with specific fan powers of 2·2 and 2·3 W/litre/s respectively for ahu A (at high speed) and ahu D.

The two ahus serving the lecture theatres have a total installed power of 10·4 kW and supply rates of 3·2 m³/s, giving a specific fan power of 3·3 W/litre/s at full speed. In practice, the variable speed drives on these ahus ensure that the fans rarely operate at more than half speed (and usually less).

The significant energy saving potential of variable speed drives is revealed from the individual fan consumption monitored for BRECSU. Equivalent annual full-load operating hours (calculated by dividing the annual fan consumption by the installed fan power) for the fixed-speed ahu D is 4300 h.

As expected, this is longer than the total occupied hours of 2500 h/y due to considerable hours on during summer nights for slab cooling, in addition to shorter periods topping-up the heating during unoccupied periods in winter.

The ahus with variable speed drives serving the lecture theatres run for only 130 h and 600 h at full-load equivalent, despite running all 2500 occupied hours and for night cooling. The fan laws and efficient drives offer huge energy savings with variable speed control.

At 26 kWh/m²/y, lighting consumption is similar to a good type 3 office, but nearly double that for a good type 1 cellular office. Installed lighting loads are at typical (for a type 3 office) rather than good practice levels, averaging 20 W/m² in offices and 12 W/m² in corridors.

Total consumption reflects the long operating periods of lighting in circulation areas which is manually key switched during security rounds at the start and finish of each day, together with the unnecessary lighting of unoccupied seminar and lecture theatres.

Some use of daylight or occupancy-sensed light switching in communal areas and lecture theatres could reduce the lighting consumption significantly. This was cut from the original specification.

The catering kitchen on the first floor is used relatively infrequently to prepare refreshments and serve meals (cooked elsewhere). The staff common room includes an electric hot water boiler for making tea and coffee, and many offices also have kettles. Hence the electricity use for catering is 5 kWh/m²/y.

The six 200 W retrofitted electric panel heaters account for 0·2 kWh/m²/y, while the local electric water heaters account for 1·7 kWh/m²/y. The estimated electricity consumption of office equipment is 8 kWh/m²/y. Each office has a pc and a printer, with two IT rooms providing a total of 25 pcs for students.

Office equipment densities are generally low. Over the whole treated floor area, average installed load density is 4 W/m², much less than might be expected in a type 3 office.

There is no mechanical refrigeration at EFry, the extended operating hours of the fans to achieve night cooling of the Termodeck being the closest comparison. Despite this, comfortable conditions are achieved with typical office internal heat gains of about 40 W/m² (considerably more than this in the lecture theatres and seminar rooms when occupied).

Interestingly, using data from Databuild's technical report, the coefficient of performance (heat removed/electricity input) of the additional night ventilation used for fabric cooling can be estimated as 5·8. This strategy also benefits from using night rate electricity, which is both cheaper and less $CO_2$ intensive.

**Energy analysis: gas**

Office areas are normally occupied between 08.00 h and 18.00 h weekdays, but the building is open for use between about 07.00 h and 23.00 h depending on the security rounds. Seminar and lecture theatres can be booked up to 22.00 h, seven days a week. All cleaning takes place between 18.00 h and 21.00 h.

Booking sheets are used by the Estates team to adjust plant time schedules via the bems supervisor for the week ahead. Lecture theatres are generally only used during normal hours, while seminar rooms are regularly used during evenings and weekends.

Unfortunately, EFry does not have pulsed output utility meters and so cannot be monitored automatically. However, manual weekly meter readings have been taken since the building was occupied in January 1995.

Gas is used for space heating and hws in the main toilets and the catering kitchen. Unusually (and commendably) the gas supply to the hws boiler is separately metered.

As far as the EEO Yellow Book is concerned, low annual gas consumption would be below 185 kWh/m² and high above 220 kWh/m². During the 1997 calendar year, actual heating gas consumption at EFry was 96 MWh or 31 kWh/m² /y. Gas used for hws generation was 4·2 kWh/m²/y. Normalised for standard weather conditions of 2462 degree days, the gas used for heating in 1997 was 33 kWh/m²/y.

The total normalised gas consumption for 1997 was 37 kWh/m²/y, which is one fifth of the academic building low benchmark, under half the lowest *ECON 19* good practice benchmark[5]. Exemplary by any standard.

Gas consumption for heating has fallen significantly since the EFry's occupation, demonstrating the benefit of fine-tuning. The normalised figures for 1995 and 1996 were 73 kWh/m²/y and 53 kWh/m²/y. Gas for hot water has reduced since occupation from 5·6 kWh/m²/y in 1995 and 4·9 kWh/m²/y in

## DESIGNERS' FEEDBACK

From our point of view, we are of course extremely pleased to see the combination of very low energy use and good comfort conditions coming out of the PROBE investigation, *write Andrew Ford and Richard Brearley*[1]. Elizabeth Fry is one of those buildings where everybody's efforts have combined in a positive manner.

The idea of low energy was introduced powerfully at the very first design team meeting. A panel of independent experts assembled by Fulcrum openly discussed all the issues with the architect and the rest of the design team.

From this point on, the design team understood the issues and took on board fully the design implications of the desire to achieve comfort without air conditioning.

These ideas included keeping the building surfaces very close to normal room temperatures, and the avoidance of any very high or very low temperature heat sources.

Easily reached openable windows were also regarded as vital to provide contact with the outside. This is as important for the sound of birds and voices as it is for fresh air and control over temperature.

Avoidance of draughts, accidental air leakage, good thermal insulation and limiting excessive glazing were also major objectives.

From the services engineer's perspective, it was important to restrain from installing anything that might be avoided and keep everything to the minimum size calculated for the building rather than the plant. Termodeck allows this because of its immense capacity to even out fluctuations.

Termodeck, two years study and monitoring by BRE plus regular feedback sessions between users, designers and monitoring contractors enabled faults to be identified. It also ensured that energy use fell constantly from its initial very low level with no inconvenience of the occupants due to the nature of the heat sources.

The most serious problem we faced was the capital savings made at the project's inception. This removed the front-end control interface which subsequently limited feedback on the controls. Such feedback is essential in a building whose inherent characteristic is to respond to changes over days, not minutes.

[1]Richard Brearley Dipl Arch RIBA is an architect with John Miller + Partners, and Andrew Ford CEng MCIBSE is a partner at Fulcrum Consulting.

1996, despite an increase in building usage. Water consumption during 1996 and 1997 has remained steady at about 880 $m^3/y$ (280 litres/$m^2$/y). If attributable only to the 70 office staff, this equates to a maximum of 12 $m^3$/person, which is comparable to good practice office use of 10 $m^3$/person/y.

The true figure will inevitably be less than 12 $m^3$/person, due to the variable number of other building users. The UEA has also installed some urinal flushing controls.

### The occupant survey

Analysis of the survey results concentrates on the office staff responses, which can be compared to the BUS dataset benchmarks, *writes Adrian Leaman*. Questionnaires were completed by a total of 41 staff members. Respondents were a mix of administrators, academics and researchers, 50% of whom work a five-day week at EFry.

An unusually high proportion of people are partial occupants of the building. A high proportion (51%) of staff had been at their present workstation for less than a year, while 31% had been in the building for less than year. Some 76% of staff have a window seat, which reflects the cellular office environment.

EFry stands out in achieving exceptional conditions across a wide variety of key criteria. On overall comfort, winter and summer air quality and lighting, the occupancy scores are the highest in the Building Use Studies (BUS) dataset (figures 2 and 3). In all other criteria EFry comes in the top 20%. It is only the second building in the PROBE studies to achieve better overall comfort in summer than winter. Another PROBE building – Gardner House – has radiant cooling, but its airtightness problems affected winter conditions more than in summer.

The high air quality scores and good summer freshness at EFry seem to demonstrate the benefit of full fresh air ventilation, but without the penalty of high gas consumption. There were some comments of smells and smoke drifting from room to room, possibly owing to eddies in the return air ducts.

Exceptional lighting scores add weight to the argument that indirect lighting and electric light levels of 300-400 lux are well liked by most occupants. The wide range in adaptive opportunities to adjust electric and daylight levels (confirmed by the high perceived control of lighting) must also contribute.

Such high scores raise eyebrows. The overall score for comfort is exceptional, but this may be slightly helped by the cellular layout, which offers privacy, security and control.

Statistical analysis also reveals that part-time occupants rate conditions more highly than full-time occupants of buildings, though not enough to negate the findings. Scores from the full-time staff at the EFry building are also very high.

There are some problems, though. Sun glare through the perforated blinds was reported on the south side, with gloomy ceilings when the lights were off. When lights are on, the cornices reflect on computer screens. The electric lighting and daylight are easily con-


FIGURE 4: The air leakage rate of the Elizabeth Fry Building plotted on the BRE/BSRIA database.

## BSRIA pressure test

The Elizabeth Fry Building (EFry) was initially pressure tested by the BSRIA Fan Rover in December 1994 to check that the airtightness met the performance criterion for the building, *writes Tom Jones*.

The building was required not to exceed 1 ac/h at a test pressure of 50 Pa. The test result then was 0·97 ac/h @ 50 Pa (equivalent to 4·2 $m^3/h/m^2$ of envelope area), which met the criterion.

For the PROBE study, the BSRIA replicated the 1994 pressure test on Sunday 8 February 1998 in order to establish the current airtightness and identify any features leading to reduced airtightness.

The building was tested with all ahus sealed. The building volume was given by the UEA to be 13 280 $m^3$, and the envelope area 3107 $m^2$. The test revealed a slight deterioration in performance, with an air leakage index of 6·53 $m^3/h/m^2$ at 50 Pa with the external doors unsealed, and 6·23 $m^3/h/m^2$ with external doors sealed (figure 4). This included sealing the air handling plant and external doors with polythene sheet and tape.

Although higher, the figure compares well with the BSRIA's recommendation that airtightness of a low energy building should be better than 5 $m^3/h/m^2$ at 50 Pa.

To investigate the possible sources of the deterioration, the BSRIA also conducted a full smoke test of the building. Smoke was observed egressing:

- ☐ at stairwell roof level at both ends of the building;
- ☐ from the access hatch to the roof;
- ☐ around the windows;
- ☐ at door thresholds and from the revolving door;
- ☐ into the tank room on the roof (it is believed that the lift shaft ventilates into this room).

Smoke emitting from the windows was from around the frames and the opening light of the windows. This air leakage is greater than would be expected for triple-glazed windows and for a building with an

Air leakage through an end stairwell.

Air leaking through the seals of the revolving door serving the main entrance.

airtightness specification of less than 5 $m^3/h/m^2$.

The air change rate for this type of building with spring temperatures and an average wind speed would be expected to be less than 0·15 ac/h. This degradation of the air seal is likely to increase this air change rate to 0·22 ac/h.

The BSRIA has undertaken measurements on 14 office buildings which have been constructed with an airtightness specification of less than 5 $m^3/h/m^2$ @ 50 Pa. The average value for all was 5·7 $m^3/h/m^2$, while the average value for the top ten of these buildings was 4·1 $m^3/h/m^2$, the same as the airtightness value achieved by the EFry Building back in 1994.

The average for office buildings tested by the BSRIA without an airtightness specification was 21·8 $m^3/h/m^2$, with the worst being an air-conditioned office building at 40·1 $m^3/h/m^2$. The best office building tested was 2·78 $m^3/h/m^2$, and the best superstore was 1·65 $m^3/h/m^2$.

Tom Jones runs the BSRIA Fan Rover. This pressure test was carried out as part of the BRE/BSRIA/*Building Services Journal* collaboration on improving building airtightness.

trollable in most rooms by manual switches, dimmers and mid-pane venetian blinds.

Though relatively low on the satisfaction scale, the score for noise is within the top 5% of the buildings on the BUS database. This must also reflect the comparatively quiet nature of cellular offices. Although there is evidence of noise breakout from the offices to the corridor, it seems that the closed door is generally adequate to contain normal noise levels, at least within the offices.

Perceived control over heating is lower than the benchmark – not unexpected as there are no radiators or anything to adjust (except windows and doors). The Termodeck system maintains very stable temperatures so the consequence of lower control is only important when discomfort occurs. This can be relieved by responsive action, as at EFry where a handful of perimeter panel heaters were fitted in the affected rooms. Winter temperatures are regarded as being on the cool side.

The mechanical ventilation seems to work well in the background, with on-demand boost from openable windows. However, some offices had only one window and a few occupants commented that it was not always possible to use it without causing draughts – more choice would have been preferable.

Discomfort of some sort was reported by 72% of staff, which is not the lowest but still much better than benchmark (84%). Only 28% had ever requested a change to the heating, cooling or lighting systems: a very low figure, also indicating high satisfaction levels.

EFry is one of the rare buildings where users give it unprompted praise – "I love it. It combines a sense of tranquillity with aesthetic delight".

**By any standards the occupant survey results are excellent, one of the best seen by BUS in over ten years of similar studies. EFry is thus likely to become a role model for future** building design and management

The PROBE 14 Team comprised Mark Standeven, Robert Cohen, Bill Bordass and Adrian Leaman.

The PROBE Team extends its thanks to Martyn Newton and Norman Buck of the UEA Estates and Buildings Division for their help during the PROBE site visits, and to BRECSU for access to the Databuild monitoring reports. Thanks also to Tom Jones and Nigel Potter at the BSRIA for conducting the pressure test and air leakage audit.

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PROBE is a research project conducted by *Building Services Journal* and managed by HGa Consulting Engineers. The PROBE research is co-funded under the Partners in Technology collaborative research programme run by the Department of the Environment, Transport and the Regions.

## Key design lessons

**Energy performance** at EFry is excellent. High levels of insulation, an airtight envelope and triple-glazing obviated the need for perimeter heating. Highly efficient heat recovery has shown that internal gains within such a well insulated building envelope are often sufficient for the heating requirement, even on full fresh air.

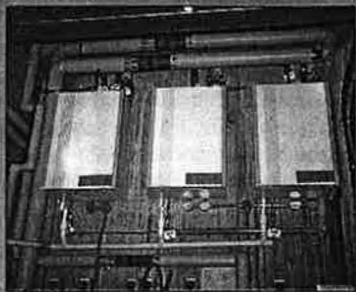
**Ventilated hollowcore slabs** have produced very stable and comfortable temperatures (winter and summer), as good or better than those in air-conditioned buildings, without the use of mechanical cooling. Avoidance of conventional heating and cooling services has helped this low energy approach to be built within normal UK academic budgets.

**Construction supervision** by the client, the design team and the contractor, along with careful detailing and specification, ensured that the pioneering design was not compromised. Special attention was paid to making the design requirements clear to the contractor, and critical details such as window reveals were inspected before concealment by wet trades.

**Controls** were initially a problem, proving insufficient for monitoring and operating the building. The UEA decided to install a site-wide bems, and co-operation between the building's managers, the controls specialist and the design team produced a well-configured, user-friendly system with a simpler control strategy: you need to know more to be able to do less.

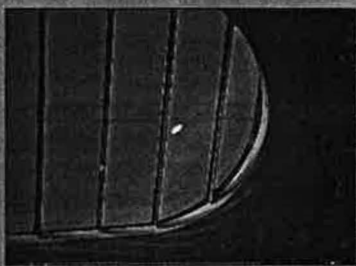
**Aftercare** Careful and persistent commissioning and handover during the first two years of occupation has ensured that design intent has been fully achieved in practice. This is in stark contrast to many buildings, which proves the value of "sea trials" for buildings of any originality or complexity.

**Occupant comfort** is exceptional. The provision of good ventilation without major fluctuations in temperature, modest electric lighting levels and the opportunity to fine tune local conditions has ensured that users are rarely uncomfortable.



The total normalised gas consumption for the Elizabeth Fry Building in 1997 was measured at 37 kWh/m²/y, one fifth of the academic building low benchmark.

The heat recovery systems for two of EFry's air handling units use high-efficiency heat exchangers. These are claimed to recover 85% of the available heat, a figure verified by the monitoring.



The rooflights above the stairs show a slight tendancy towards air leakage.

Some areas were initially underheated, like this first floor corner room above a walkway.

Note the clear and concise labelling of the building controls.

PHOTOGRAPHS: BILL BORDASS