
APU Learning Resource Centre



Robert Cohen, Adrian Leaman, Darren Robinson and Mark Standeven report on how the Queens Building at Anglia Polytechnic University, the final building in our post-occupancy review series, has performed since completion. To understand the building's detailed design readers must refer to the original article "Making light work", which appeared in the November 1994 issue of *Building Services Journal*.

The Learning Resource Centre (LRC) was the first building commissioned for the new Anglia Polytechnic University (APU), formerly Anglia Polytechnic. Built at Rivermead — an 8.7 hectare disused industrial site in central Chelmsford — the LRC was occupied in August 1994, providing accommodation for 750 work places, a mini TV studio, a conference facility and a cafeteria/bar.

The innovative structure, also known as the Queens Building, is the centre of the University's Rivermead campus.

APU devised the outline brief for the building, including its spatial requirements.

Foremost in the initial brief was the concept of a low energy, naturally ventilated building rather than a fully air conditioned LRC like many recently built by other UK universities.

ECD was appointed as architect on the project, with Ove Arup as environmental, structural and services engineer, Bucknall Austin as quantity surveyor and Esbensen of Denmark acting as independent energy consultant. A Thermie grant was obtained by

including the building as a case study in EC2000⁵, an EC research project managed by ECD.

An intensive design workshop arrived at a credible, naturally ventilated solution comprising sidelighting with light shelves, two atria for core daylighting, a highly insulated thermally massive structure using solar gain, trickle ventilation in winter and stack-driven natural ventilation with night cooling during the summer. The use of low temperature heating distribution and condensing boilers was also established.

A competitive tender for construction was sought on a rigorous performance specification written by the design team. Wimpey was appointed on a detailed design and construct contract to start in June 1993, with ECD and Ove Arup novated to the contractor by the client. Wimpey was under a tight schedule to produce the building within 48 weeks.

Building design

To appreciate the building's architecture and engineering, readers must read the two previous articles published in *Building Services Journal*^{2,3}. Suffice to say that the building's main axis runs from slightly west of north to slightly east of south, on which lie two separate atria providing large quantities of daylight to the building's core. A four-storey library surrounds the south atrium, while a ground floor bar/restaurant occupies the north of the building. The total gross floor area is 6018 m², the treated floor area being 5656 m². Courtesy of the EC Thermie grant, the building is well insulated and thermally massive with concrete framing, waffle-slab floor plates and a brick/insulation/block envelope incorporating mainly triple-glazed, wooden-framed windows. The steel-supported, timber-framed roof boasts concrete infill panels to add thermal mass.

Intermediate floors are of solid concrete, with carpet laid above a thin cement screed. While the floor-to-ceiling height is 3.2 m, the top floor can rise up to 6.8 m, reaching to the concrete infill panels of the pitched roof.

Apart from dedicated servicing of the tv studio, the kitchen, lounge and toilet extracts, the LRC is naturally ventilated via perimeter trickle ventilators in winter, and a combination of opening windows, toplights and atrium roof vents during the summer. Windows can generally be manually opened and closed (although they are fastened shut in the library to prevent book theft), while the toplights and atrium vents are actuator-operated to one of five positions and controlled by the building energy management system (bems) according to sensed external and internal conditions. There is no local override for the actuators, but the motorised actuators have been replaced by manual wormscrew drives for windows serving cellular offices.

Services engineering

The building's heating uses perimeter fin-tubed convectors positioned on the inside of the wall trickle vents, served with 1thw from two gas-fired low NOx condensing boilers with a combined output of 746 kW.

The heating system includes optimum start and compensated flow temperatures, specified to vary flow temperatures between 25°C and 70°C for external temperatures between 20°C and -PC respectively.

DHW for catering and washroom use is provided via two 500-litre storage cylinders. Incoming mains water is preheated using waste heat from the condenser of the bar cellar cooler, the secondary heating coils being served from the gas-fired primary hot water circuit.

The main gas boilers are used for dhw during summer, justified by the significant kitchen hot water loads, the design based on boilers being in condensing mode for the dhw by virtue of a cold feed directly into the primary to secondary plate heat exchanger.

TV studio ventilation is via a packaged ahu with high noise attenuation and twin speed supply and extract fans (with duties of 3.4 and 1.5 W/l/s at high and low speeds) serving very low velocity displacement terminals.

Kitchen and restaurant ventilation is via a packaged ahu with double-effect evaporative cooling powered by twin speed supply and extract fans serving displacement terminals. Extract is via the kitchen cooker hood. A plate heat exchanger is designed to provide up to 50 kW of preheating to the supply air.

Environmental performance

The control system has been designed to provide night cooling of the internal thermal mass via synchronised opening of the perimeter window top lights and atrium vents. There are relatively low densities of office equipment, resulting in an average measured load during occupancy of 2.6 W/m^2 from an installed load of 6 W/m^2 , which reflects the intermittently-used student computers.

The number of degree hours during occupancy that the average space temperature is either above or below a room temperature set-point — regarded as the thermal mass set-point — is logged as the passive heat and cooling gains respectively. At the end of occupancy all perimeter window and atrium actuator-operated windows should be fully opened, and remain so, until the number of degree hours of cooling matches that of heating.

Initially the thermal mass set-point was 22°C , a self-learning algorithm adjusting this between $20\text{--}24^\circ\text{C}$ depending on whether average space temperatures on the following day were less than 21°C or greater than 25°C .

The night purge cycle was only to operate if more than five degree hours of heat gain were registered. During the cycle, windows in each zone would be proportionally closed to ensure average temperatures remained above 18°C . The designer acknowledged his uncertainty in these values by stipulating that all settings should be easily adjustable during the commissioning period.



The library desks. A study carried out by a building physics researcher revealed a rapid reduction in daylight levels away from the perimeter. Hence plans to fit coffer infill panels at the facade and atrium boundaries.

The detailed monitoring commissioned as a requirement of the EC Thermie grant identified that night cooling was not operating during the summer of 1995, even with a calculated 63 degree hours of heating above a set-point of 24°C . Subsequently, a fault was found in the software which was corrected in September 1995, but night purging has still failed to operate satisfactorily, suggesting that commissioning was somewhat inadequate.

During the year July 1995 to June 1996 considerable overheating was experienced, the worst in some zones on the third floor of the library, which experienced over 300 h above 27°C . However, the summer of 1995 was one of the hottest in recent years.

Daylighting and artificial lighting

In spite of its 30 m maximum plan depth, the building has generally high natural light levels from the two atria and the perimeter glazing with twin light shelves. The effectiveness of twin light shelves — which consist of two parallel panes of reflective glass — is questionable as light is reflected into the coffers of the waffle slab ceiling. Measurements also suggest that incoming daylight levels from the perimeter drop rapidly. The original intention was to have a precast floor slab with ribs running perpendicular to the perimeter, but this had to be dropped when no off-the-shelf ribbed system could be identified and design and build costings precluded a bespoke design. Perhaps the choice of light shelves could have been revisited at this point, although they do provide alleviation from sun and sky glare and protect perimeter areas from high altitude solar radiation.

Artificial lighting is from single 36W tubes in luminaires, with category 2 vdu louvres recessed into individual coffers on the exposed ceilings. In library areas, desk-mounted lamps provide additional local task lighting, and suspended fittings are used between bookstacks.

On the top floors wire hung luminaires suspended from the underside of the roof house pairs of 18 W, 2L lamps for general lighting. Overall installed load is measured at 13 W/m². Each atrium has six metal halide projector lamps with capacities of 250 W. The majority of lighting is controlled by a Thorn JEL system incorporating timed, photocell, passive infra-red and manual switching of lighting circuits. Conference room, kitchen, tv studio and plantrooms are all manually switched and independent from the central control.

There are four time-control circuits which enable the lighting circuits, and allow lights to be manually switched. The perimeter lighting has additional input from one of four external wall-mounted photocells according to facade orientation. The photocell output is monitored every two hours and should switch off lighting if levels above a certain value (thought to be 7500 h lux) are sensed.

It is doubtful whether this feature is operating as intended because, from observation, perimeter lights are rarely switched off automatically — this may possibly be due to dirt on the photocells or a set-point which is too high. During the PROBE survey top floor atrium light levels of 45 000 lux were measured on the main stairs where the electric lighting was fully on.

The o&m manuals state that, if any luminaires identified for corridor lighting or any main lighting are manually switched on, all corridor lighting is switched on until 30 minutes after the last main lighting has been switched off. Discussions with security staff seem to confirm this operation as they manually switch on the atrium projector lamps hourly during the night, which causes all corridor and circulation lights to switch on.

Post-occupancy analysis

As it is part of the longer term plan to establish anew campus, the building is not yet occupied to its full capacity. The third floor of the library is currently used as open-plan office space by 48 accounts staff. Only 166 library workstations from an intended 750 have been installed.

To accommodate the office staff a number of perimeter cellular offices have been installed, affecting the natural ventilation strategy. Several quiet perimeter rooms were also included in the library fit-out. These have high level opening glass louvres to maintain the ventilation link, although manually controlled single-sided ventilation was

the designer's intention.

Students began using the building in September 1994. During the first winter the north of the building experienced underheating problems. Under the terms of the warranty, the contractor increased the primary flow temperature set-point. This helped to reduce the underheating problem, but caused overheating in the southern parts of the building. The underheating could be exacerbated by the external temperature sensor being located on a west-facing wall, which is in full sun from about 15.00 h onwards. Sensor readings are used for flow temperature compensation.

However, detailed investigations revealed that the main cause of the underheating was the insufficient density of fins on the perimeter convectors in the north zone, which were not resized following a cost-saving change in the window specification for that zone from triple to double glazing. To remedy this the contractor is to install an additional radiator system in that zone during the autumn of 1996, after which it will be possible to reset the flow temperature. Low levels of infiltration (0.55 ac/h) suggest leakiness was not a major factor.

Glare from the south-facing top floor windows has had to be counteracted by the application of tinted film to the top lights. Glare is still a particular problem for vdu operators in low winter sun, as the perforated mid-pane venetian blinds transmit some light. However, if the floor were in use for library space these problems might be less serious.

The library vdu terminals have been located under the reading desks, the screen being viewed through a horizontal glazed opening in the desk which reflects any nearby ceiling luminaires perfectly. In addition to discomfort glare from luminaires reflected in desk-mounted vdus, the lowered head and arched back needed to see the screens would seem to be very tiring.

Although there is a sophisticated mains-borne signal lighting controller, which should allow daylight responsive control of perimeter zones and timed switch-off of core areas, it is unclear whether it has ever operated as intended. Local switching is limited to a small number of central grid switches, and occupants can inadvertently switch on all lighting before identifying their required switch. The grid switches also act as a deterrent to anyone wanting to switch off their own lighting.

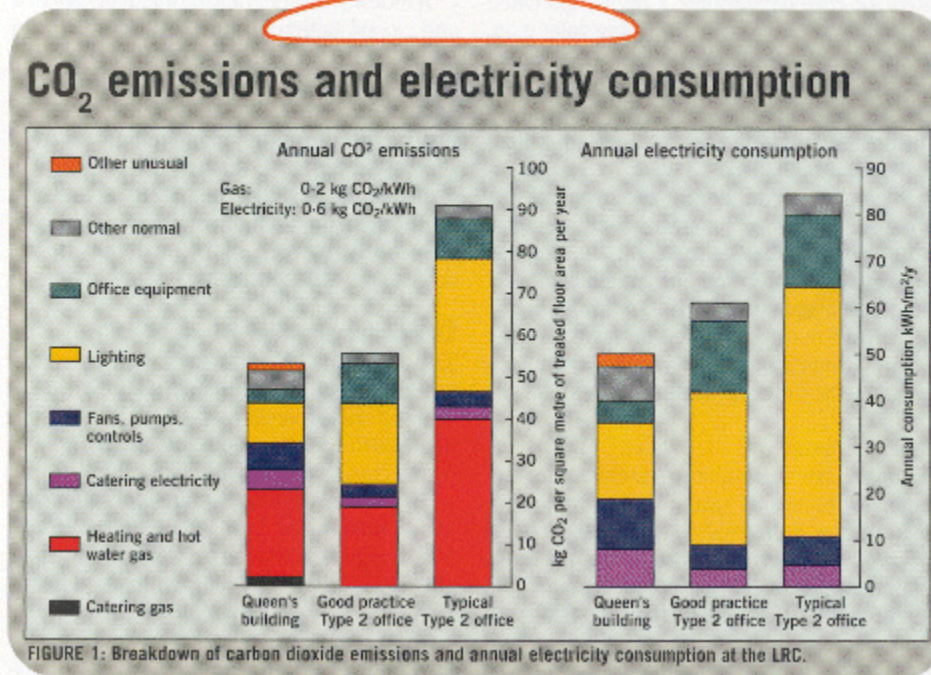
Low Humidities have been measured in the LRC, occupants reporting dry throats and noses. This is a difficulty of tempered fresh air ventilation in a building which has low occupancy levels. The Building Performance Research Unit (BPRU) of APU's construction technology department, and the maintenance staff, intend to experiment with planting and 'leaky pipe' irrigation to raise humidity levels.

The entrance lobby to the building has been reconfigured to increase the lobby size and also improve the draught stopping performance of the automatic sliding doors.

Previously the opening sensors of both doors covered the same space between the doors, causing both to be open simultaneously. This measure would appear to have been only partially successful.

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Energy consumption

APU has a team responsible for property management of its whole estate. Detailed monitoring of the building's energy and environmental performance was undertaken by the APU's own BPRU over a 12 month period from July 1995 to June 1996 as a requirement of the Thermie grant.

The Trend bems has been configured so that every four days it saves the hourly records of each of the building's 150 sensors, the resulting data being automatically transferred to a customised spreadsheet program. In addition, detailed measurements of daylight factors and ventilation flows have been made, and a spot check of the infiltration rate in the library area carried out using tracer gas.

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Occupancy survey results

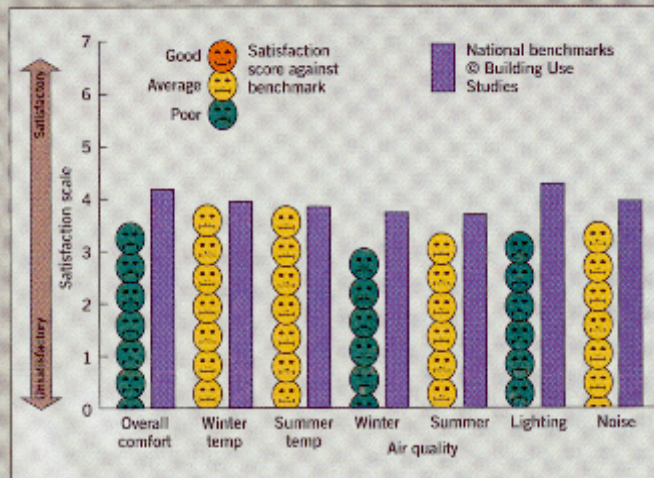


FIGURE 2: Overall satisfaction scores compared with national benchmarks.

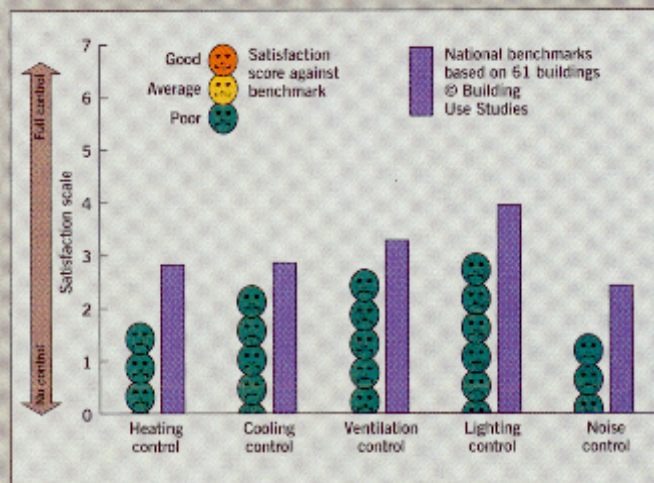


FIGURE 3: Occupancy satisfaction with control strategies.

That said, the building's systems have been largely left to operate as commissioned. Control systems for the lighting in particular have yet to be fully exploited for their energy saving potential in what is a very well daylight building.

APU's property manager has provided funding for another year's interpretation of the monitored data, the objective being to further iron out any teething problems and learn how best to operate the building.

Total electricity consumption, calculated to be 50 kWh/m^2 is respectable (figure 1), and is partly accounted for by the building's low occupancy and student pcs which are not used intensively.

At 16 kWh/m^2 , the electricity consumption for lighting compares very well with the good practice figure of 32 kWh/m^2 , but might be lower still if the available daylight was fully

exploited by the lighting controller, and clearer local manual light switches were provided.

Due to some confusion between British Gas Transco and British Gas Trading, only to three gas meter readings have been taken by the suppliers in the two years since building occupation. However, the BPRU has taken monthly readings of the supply at 12.00 h on the first of the month between July 1995 to June 1996.

These figures show an actual total gas consumption of 115 kWh/m^2 . When corrected for standard degree days and extended occupancy, this gives 108 kWh/m^2 inclusive of catering and hot water gas usage of 11 kWh/m^2 and 10 kWh/m^2 respectively.

Excluding catering use, the normalised figure of 97 kWh/m^2 for heating and hot water is very close to the 95 kWh/m^2 yardstick for a good practice Type 2 office. This respectably low annual consumption has been achieved despite the raised flow temperatures adopted to counter the underheating in the conference room, and also in spite of the relatively low internal heat gains from both occupants and equipment.

Occupancy issues

The standard PROBE questionnaire, with an additional question on perceived health within the building, was distributed to the building's 95 staff. 83% were returned. A separate single page questionnaire was completed by 109 library users probing their perceptions of environmental comfort, productivity and health.

63% of staff were female, 72% were aged over 30. 14% had worked in the building for less than one year and 29% had been in their present work area for under a year. 87% were in the building four or five days a week, while 90% worked a 7-8 h day. 65% spent more than five hours a day working on screen.

35% of staff worked around the northern atrium in a mixture of open-plan and enclosed perimeter offices. 41% worked in areas surrounding the southern atrium, while another 25% worked in other small open-plan areas. 38% of staff had window seats.

Against national benchmarks, overall comfort of staff at APU was significantly lower than the mean (figure 2). Perceived temperatures in winter/summer and air quality in summer were no different to the benchmarks, although winter air quality was less satisfactory.

The more detailed environmental questions suggest that temperatures in winter and summer are higher than the norms, but temperature fluctuations and draughts are average and, if anything, slightly stiller. The survey confirmed winter humidity problems with significantly drier conditions than the norms, although summer was no different. Paradoxically, air quality in both winter and summer was perceived as being stuffier but more odour-less than the norms.

The survey found that library users rate the building much higher than the staff. Overall, staff find lighting to be less satisfactory than the benchmarks, with average levels of daylight but more sun and sky glare than normal. They consider there is too little artificial light, but glare is average.

Noise levels were average, comments indicating localised problems such as between floors in the atria and vehicle noise via the automatic opening of top lights.



Top floor atrium light levels of 45 000 lux were measured on the main stairs when the atrium lights were on.

CONSULTANTS' FEEDBACK

Being highly supportive of the PROBE initiative, we offer the following designer feedback on the APU Learning Resources Centre, *write Chris Twinn and John Daggart.*

With regard to design and build novation, the ACE terms of appointment do not include any allowance for lengthy vetting of numerous post-tender contractor alternatives. Proper allowance for this must be made because splitting any cost saving does not cover even a fraction of the involvement in checking out unfamiliar suppliers.

For example, beware of alternative supplier cost savings that conceal a change from triple to double glazing.

In addition, it is essential that the client retains a representative who can identify building services systems as fully functioning prior to building occupation. The poor reputation that systems gain at handover lingers long after the snags are rectified. The ability to hand-hold the client as he first occupies his building is also considerably reduced as the designer is contractually distanced from him.

In energy consumption terms we are very content with the building's performance levels so far. Not only is it using less than two thirds of the air conditioned alternative, but it has defaulted to a 'good' standard in spite of systems not functioning to their full intended potential. Even now, the building appears to have the lowest consumption of any of the current generation of Learning Resource Centres. It is encouraging to see the client's desire to trim the systems over the next couple of years to make use of the full capabilities of the design.

It is also interesting to relay the comments made by the occupants, such as: how do the venetian blinds work, and how do you throttle individual heaters? It is a pity the user group presentations evaporated and that the user notes have been diverted to the o&m manual.

There are certainly aspects we would strive more strongly for next time around, such as more local light switching when block switching was asked for, resisting the choice of vdu stations with inherent susceptibility to glare and the design control of task lighting robustness and its provision in staff areas.

Then again hindsight is indeed a wonderful thing. At what point does imposing one's experience become excessive designer ego?

Chris Twinn is an associate with Ove Arup & Partners. John Daggart is a director of ECD Energy and Environment.

The LRC is worse than the norms for control of all environmental characteristics (figure 3). However, there is no difference in the quickness of response of all characteristics except noise, which is less quick and reflects the fact that there is little one can do to reduce noise travelling between atrium floors, or that coming through an automatically opened window for which there is no local override.

59% of the staff surveyed have requested a change to the heating, lighting or cooling systems, 40% of them being happy with the speed of the response and a poor 30% happy with the effectiveness. This is probably the key to the slightly disappointing performance of this building.

The lack of on-site facilities management (many duties seen to be carried out by well-meaning but under-trained security staff) means that problems are not logged or diagnosed effectively, leading to sub-optimal action by maintenance contractors, which means that slow response to complaints is inevitable.

The university has underestimated the management resources needed to run a building of this type effectively. One staff comment sums up the situation concisely: "All requests are met by 'that's the way the building has been designed' or 'that's a personal preference'", which indicates a lack of understanding, indecision or shifting the blame. Off the eight PROBE buildings, APU has the highest proportion (97%) of staff reporting some sort of discomfort on the overall environmental questions. The worst areas for discomfort are those that have been converted to office space from other uses: the cash office and ground floor store room, for instance. There appears to be no difference in overall comfort between the purpose-designed atrium offices and offices in the library light well which are located in space originally intended for library use. Interestingly, comfort conditions are better on the top floor despite higher summertime temperatures.

Staff at APU report a decrease in productivity of -5.6%, putting the building in the 30th percentile of the benchmark data. However, APU falls between the 40th and 60th percentiles on all the main reference benchmarks except productivity, making the performance fairly average overall.

With improvements to a few key elements — such as a manual override to the automatic top lights and proper commissioning of the lighting and night cooling controls — there is no reason why the LRC could not perform well above average.

Key design lessons

Low energy design APU has pioneered a natural ventilation approach for its LRC, and has achieved considerable energy savings compared with an air conditioned alternative – often the norm for such buildings. As a naturally ventilated building, it matches the good practice yardstick for that building type: the heating and hot water gas consumption was measured at 97 kWh/m² and electricity consumption was 50 kWh/m².

Procurement The design and build option with the design team novated to the contractor seems, in general, to have ensured that the design concept was maintained. However, there are some instances where cost considerations overruled the design team and the quality of commissioning and o&m manuals is poor. Triple glazing in the conference room was changed to double glazing as a post-tender cost saving, but the consequential effect on the heat emitter sizing was not identified at the same time.

Thermal performance In its first two summers of operation top floor temperatures have been excessive, although night cooling has yet to operate as intended. External solar shading above the windows on the south and south west facades could have alleviated excess solar gains. It seems there is real potential for night cooling to provide a considerable benefit if it can be made to operate properly.

Daylighting The twin mirrored-glass lightshelves are cumbersome and ineffective in enhancing light levels deep into the space. Once it was known that the flat ceiling slab was going to be replaced by a waffle slab, the use of such expensive light shelves might have been reconsidered. Single opaque versions of the same dimensions might have provided sufficient protection against glare and direct solar radiation in perimeter areas.

Lighting control A controller was installed which should switch lights off according to defined time schedules. However, the system originally specified was changed by the design and build contractor without any appraisal by the m&e consultant. The



Daylight levels from the perimeter drop quickly, probably due to the waffle slab.



The external air temperature sensor exposed to the sun.



The second floor, showing the circulation lighting on despite good daylighting from the north atrium.



Between June 1995 and July 1996, zones on the third floor experienced 300 h above 27°C.



References

¹Future buildings, *Building Services Journal*, 3/96.

²Twinn C, "A buoyant line of thinking", *Building Services Journal*, 1/94.

³Bunn R, "Making light work", *Building Services Journal*, 11/94.

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