

The third PROBE investigation has focused on the performance in use of the Cheltenham & Gloucester Chief Office, located in Bamwood four miles from Gloucester city centre. The building was completed in 1989, and provides hq accommodation for some 930 staff (700 at initial occupation) at a density of approximately 17.5 m^2 nett per person.

The company's general management, the deeds and the main computer systems are based here, together with other hq activities such as marketing, network services, treasury, dealing and legal departments. A full-time team of six staff is employed to run the building.

C&G needed a building quickly. As a result the building is fairly repetitive and straightforward. In many ways this has proved to be no bad thing, though there are a few surprises including the absence of a basement, the relatively poor use of potentially premium space on the top floor and a lack of storage space.

The four storey steel-framed structure of symmetric plan form has a central full height

atrium with a 60% glazed barrel-vault which breaks the otherwise deep floor plan. This provides attractive internal views, circulation and meeting areas. The gross floor area measures 19900 m², the nett lettable area 16 390 m².

services design

Full details of the building's design appeared in the May 1990 issue of *Building Services*, and readers are urged to refer to that article for the detailed services description.

However, in basic terms the services installation is as follows.

The ground, first and second floors are air conditioned in four quadrants relating to orientation, each with a separate main air handling unit (ahu) serving a vav system. A compensated 1phw circuit serves perimeter convector heaters beneath each window. The third floor areas such as the boardroom, training area, restaurant and kitchen are served by five constant volume ahus, with 1phw zone reheat. The main plant on the third floor is rigorously modular, with each of the four ahus having a separate gas-fired steam generator for its humidifier, which seems a mite excessive.

The three packaged, air-cooled chillers are externally mounted in a south-east facing third floor roof compound, and provide chilled water to a common header. The computer suite is serviced separately. Three gas-fired 1phw boilers on the ground floor are equipped with dilution flue fans which exhaust via the roof.

Main office lighting is from twin 24 W fluorescent tubes in 450 mm square bespoke luminaires, while corridor lighting is from compact fluorescent downlights. A variety of low voltage lamps and uplighters provide added interest, and the majority of lighting schedules are controlled from the Trend bems. The lighting scheme won the commercial section of the 1990 National Lighting Awards.

The original design was for a general cooling load of 55 W/m², with 110 W/m² capacity for hotspots, and an additional 15-20W/m² lighting load. The small powerload is estimated at 15 W/m² of office area, and the corresponding annual consumption is 28 kWh/m².

Office equipment distribution varies considerably between departments. Some have desktop mainframe terminals, others have single pcs and some have two pcs. Printers and fax machines are fairly evenly distributed between groups of 12 to 20 workstations. Photocopiers are similarly distributed.

in-use performance

The four main vav ahus supplying the office areas are programmed via the Trend bems to adjust supply temperatures between 18°C in winter and 12°C in summer. Free-cooling is exploited for air temperatures at or below 11°C, a temperature determined through experience.

C&G's operators have minimised the vav terminals' control range to between 30-70% of fully open to reduce the occurrence of draughts and cold air dumping. The passages in the open-plan areas tend to be over-supplied with air to maintain sufficient cooling in areas of high occupancy. Extract is through the ceiling luminaires, and predictably C&G has had problems purchasing replacements for these bespoke items.

Owing to the close control of the heating boilers, leakiness in the building envelope (which has been improved since occupancy but not eliminated) and low occupation densities, the vav system has been unable to heat the second floor executive offices

satisfactorily. To counter this the perimeter flow temperatures in quadrant one are uncompensated and executives have electric fan heaters. This is considered a simpler and more cost-effective solution than longer boiler operating hours.

The five dedicated ahus serving the training, boardroom and restaurant areas variously supply two or three zones. In the training area uncomfortable changes in temperature can be experienced between rooms as empty rooms in the same zone are overcooled when 1phw for the zone reheater is not available in mild weather.

Main-frame computing and network file servers are cooled by 12 packaged air conditioning units in service corridors surrounding the computer suite, the heat being rejected by three banks of dry coolers. Free cooling is obtained by passing the glycol through a free cooling coil in each unit. If additional cooling is required, the compressors will operate, rejecting heat into the glycol circuit. Step control of pairs of the 30 modular fans try to maintain a minimum glycol flow temperature of 12°C, which means in practice that all fans operate for air temperatures above 9°C.

In the first summer of operation there were just two banks of dry coolers and eight air conditioners, and water had to be sprayed by hand on the dry coolers to avoid overheating. An additional bank was added to the roof compound that winter which solved the problem.

One major concern to the operators is that, despite twin substation supplies to the glycol pumps, there is only a single (albeit separate) substation serving the entire computer suite air conditioning. Any pipework problems would also be troublesome since there is only one glycol circuit — a questionable design choice.

In the original design, the communications rooms were initially unserviced and relied on local vav units for fresh air. However, this required 24-h operation of a main ahu, and the operators have now installed local dx coolers to operate out-of-hours.

An Emerson ups supplies the computer suite. There is non-synchronous control of the two generators so parallel operation with mains supply is not possible. It was a management decision not to install such control on the basis of high capital cost.

However, with early evening pool prices currently rocketing to over £1/kWh, this could be re-evaluated.

Although the lighting scheme won a National Lighting Award, during the first two years the controls were the source of several problems, not least the random connections to grid switches which subsequently required rationalising according to the office layouts. The office lighting is toggle-switched from gangs of wall-mounted switches, controlling alternate pairs of luminaires. Labels are now used to identify a toggle switch with the luminaire.

The central lighting control provides timed sweeps to switch down to 50% at 17.30 h and again at 18.30h, and at 21.30h a sweep to 10% for security. A useful touch is the colouring of the switch toggles—red for circulation, white for lobbies and metallic for the rest.

The atrium is lit by 150 W metal halide downlighters suspended beneath the roof glazing, and by metal halide uplighters which wash the white plaster of the lower barrel vault of the ceiling. While the downlights are on permanently to ensure lighting of the dark granite atrium floor, the uplighters are manually switched by the receptionist based on an assessment of outside light levels. However, during both site visits these lamps remained on all day.

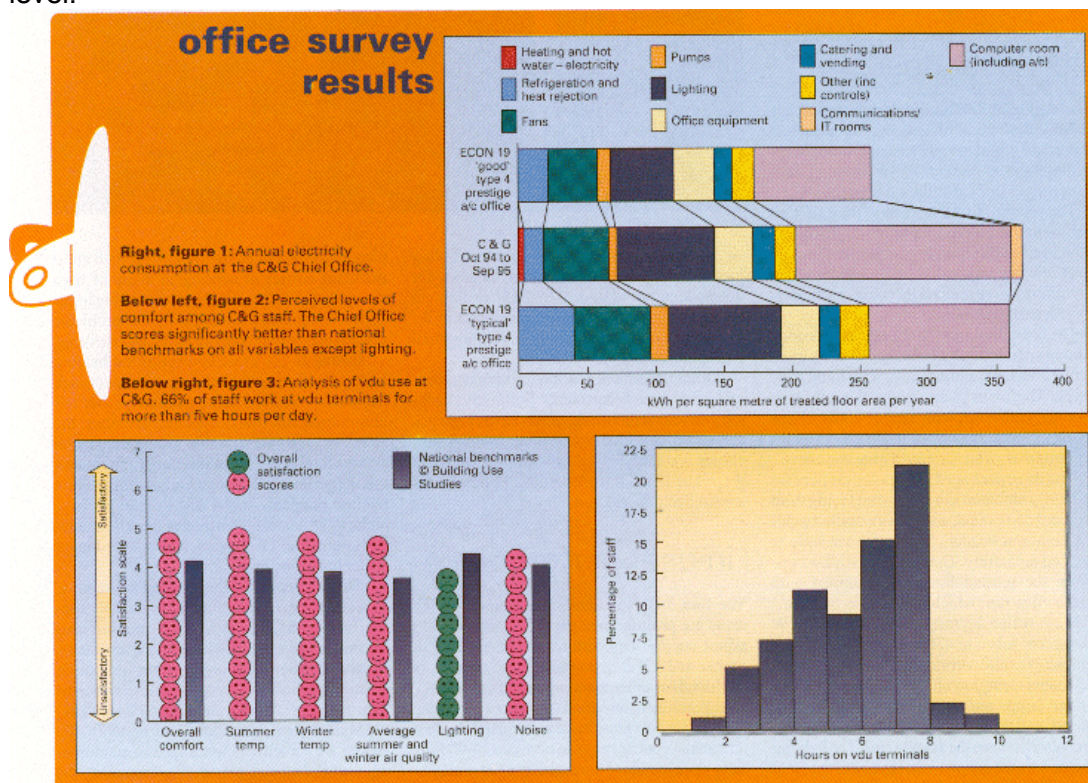
energy issues

There is no formal energy monitoring and targeting programme. Although zonal electricity sub-meters were installed, they are not used. This is largely because they are

on a quadrant-by-quadrant basis, and not seen to relate to specific systems or the building's current space plan.

However, electricity consumption has been very stable since the building was occupied. The daily electricity consumption of 16 MWh varies little with season, except in high summer when the chillers operate much harder and consumption rises to 20 MWh/day. Half-hourly consumption data for representative winter and summer days shows that there is a background load of 550kW on a winter bank holiday which rises to 960 kW on a summer Friday.

The annual electricity consumption figure of 369 kWh/m² is virtually identical to the typical benchmark in *Energy Consumption Guide 19*¹ of 36kWh/m² (figure 1). However, a greater proportion of the total is attributable to the computer suite and less to building services, putting many elements of the building services closer to the good practice level.



Electrical consumption by chillers and condensers is better than good practice levels owing to the effective use of free cooling by the well-controlled (and in hindsight somewhat oversized) vapplant, and the economical running and sequencing of refrigeration plant.

For fans, consumption falls right between typical and good practice. However, given the over-sizing, the expected economies of vav system fans with variable frequency drives on low speed operation have not been achieved. To provide the right volumes of air and avoid draughts, the vav supply temperatures have been raised. This means greater volumes of air in order to satisfy a given cooling requirement, and therefore more fan power.

Considerable savings over good practice levels have been made for the pumped circuits as the pumps are not left running continuously, but are only operated when there is a genuine demand for heated or chilled water.

In spite of a modest installed power density and a relatively sophisticated control system,

lighting energy consumption is only 13% below typical levels owing largely to long running hours and relatively little beneficial use of daylight, which is due to the need to use curtains to control solar glare. The client is now considering the use of presence detectors in office areas as a way to reduce lighting energy consumption.

Estimated energy consumption by the computer air conditioning is reasonable given the intensity of C&G's data processing operation, but not particularly low, and it is not certain that the glycol 'free' cooling is giving substantial economies in annual energy consumption. At 10°C outside, the temperature of the glycol returning to the computer suite was about 10°C above ambient, offering limited free cooling.

At higher outside temperatures, there would be no energy saving while electricity will still be consumed parasitically (in relation to air-cooled condensers) by extra fan power to pull air through the glycol and heat rejection coils, plus pump power to circulate the glycol.

The building is on a pool price half-hourly tariff which ranged from a monthly mean inclusive charge (excluding vat) of 3.5 p/kWh in July 1995 to 9.2 p/kWh in January 1995. During the day prices peak between 16.30h and 19.00h and the cost of electricity during this 2.5 h period accounts for 40% of weekday unit charges for the building. For example, on atypical January weekday, unit charges increased from a daily average of about 5 p/kWh to 40 p/kWh.

The wide range in pool prices and a recent peak of £1.10/kWh (17.00 h—17.30 h) on 7 December 1995 provide a strong incentive to manage demand during these periods, even though consumption falls during these high cost half-hours due to falling occupancy.

The annual average unit price including uplift costs was 5.5 p/kWh (excluding vat) which does not compare well to a competitive contract price. In general, pool tariffs only generate a large saving if demand is outside the expensive periods, or a pro-active approach to monitoring pool prices and demand is taken. With different synchronous controls the standby generator could be operated when supplied electricity costs exceed those of the generator.



Gas is used to supply 1phw, kitchen hot water and steam humidifiers serving the four main ahus. Detailed gas consumption data are only available from March 1992 to March 1994, after which C&G changed gas supplier and the readings became very irregular, with some missing, many estimated and some meaningless (a widespread problem related to the recent deregulation of gas supply).

In 1994–95 gas consumption was 101 kWh/m^2 of treated floor area. After adjusting to standard weather conditions, the normalised consumption of 135 kWh/m^2 is close to the 132 kWh/m^2 good practice level (figure 1). After deducting 8 kWh/m^2 for catering gas, about one-quarter of the remainder is attributable to the gas-fired steam humidification and the rest to space heating. Unfortunately, there are no sub-meters either for the kitchen or for the humidifiers.

The edge-of-town location and the large number of car parking spaces favour staff who commute by car. An analysis of staff travel to work shows that at $334 \text{ kWh/m}^2/\text{y}$, annual commuting energy for the building is over three times its gas consumption, similar to a previous study of a British Council office in Manchester².

Space heating consumption is relatively low for an air conditioned office. Here, the boilers are tightly managed and only operate when the vav systems really need them. On one particular autumn day with temperatures between 8°C and 10°C the boilers were only used for morning boost, recirculation maintaining internal temperatures. This is at some expense to comfort, in particular an absence of 1phw zone reheat in the boardroom and the training suites when the boilers are off, along with a general shortage of heat in the management suite.

Incidentally, the boiler flue dampers are no longer used, the occupier relying on the burner dampers for sealing. This is an interesting alteration to the design rationale and

based on evidence that products of combustion were resulting in the flue dampers seizing open.

Initially the main reception was cold and draughty. A lobby was added in August 1991 with two 5 kW above door electric air curtains replacing the original non-fanned convectors. At the same time six 3 kW electric heaters were fitted in the panelling all around the reception. All these are time-controlled from the Trend bems and have local thermostat control.

The hws storage calorifier for the kitchens was originally supplied from the 1phw boilers in winter and electric immersion heaters in summer. Following a recent energy saving programme the calorifier is now served by a 39 kW gas-fired boiler.

At some 30 kWh/m², estimated gas consumption for office humidification is relatively high owing to the amount of free cooling adopted and a low limit setting of 44% rh in the return air duct, which could perhaps be reduced to the design level of 40% or even lower.

the staff survey

A standard PROBE questionnaire was distributed to 75 staff on the first floor. 96% were returned. An additional question was added to identify the effect of the new out-of-town location on staff commuting distances and times.

96% of people work a normal five day week, and 86% spend between seven-eight hours in the building. 78% spend more than six hours at their desk, making the population relatively sedentary (figure 2). 66% work at vdu terminals for more than five hours per day. The staff are relatively young, with 58% under 30. Some 28% have window seats which is unusually low in modern offices. 63% are women.

Overall the building is perceived to be comfortable, and temperatures and air qualities in winter and summer perceived to be quite satisfactory (figure 3). Despite this, and the fact that the operators have restricted the damper opening ranges, roughly 25% of the sample reported frequent cold draughts. There were also many comments about excessive solar gain and inadequate blinds.

The building operators have set up a complaint help desk which staff can ring up to report any aspect of building operation. The operators consider that they provide a fast and effective response to most complaints, but that comfort expectations are sometimes unrealistic, expecting staff to be sensible and wear warmer clothes before complaining about being too cold. However, requests for changes to the heating, lighting, ventilation or air conditioning were made by 60% of staff, of whom 75% felt the response was satisfactory.

Overall lighting conditions were perceived to be worse than Building Use Studies benchmarks, while artificial lighting levels were considered too high and natural light levels too low (figure 3). Glare from the sun and sky was also considered a problem. Twelve occupants added comments complaining of glare from bright lights, reflections and sky causing discomfort.

Little has been done to combat solar gain and glare — the elevations are the same in all orientations and such overhangs as there are seem to be more stylistic than functional. The basic window design and the absence of any glare control measure other than translucent curtains first caused problems (until the curtains were doubled-up), and curtains are closed a lot.

maintenance issues

Three sets of operation and maintenance manuals cover the hvac system, the electrical

system and the bems. The hvac manuals were the first to be completed, roughly nine months after occupation. The electrical and bems manuals were not produced until snagging was almost complete which resulted in significant additional problems. Often the operators had to work with 'as-designed' drawings which did not necessarily correspond with the installation.

Inadequate pre and main filters were specified for the main ahus. Dust particles regularly disabled duct airflow sensors, which caused significant cold dumping in the affected areas. The situation has been remedied by upgrading the filters and retaining stocks of spare sensors.

The plant room drainage channel leaked after completion, an irritating defect from the client's point of view. Proper welding and mastic sealing was a contractor's remedial action point.

The diesel generators have shown an unfortunate trait in use — as the fans draw generator power and do not operate instantly, a large cloud of diesel smoke is expelled on start-up. This has caused passers-by to call the fire brigade, and current practice is to position a member of staff prominently when the units are tested.

key design lessons

Initial occupation Snagging took about two years. There was poor information and software and the as-fitted drawings were said to be dreadful. In common with many recently completed air conditioned buildings, the facade was very leaky particularly in the executive areas, and required extensive improvements under contractor warranty. The main reception was initially cold and draughty and since occupation a lobby and additional electric heaters have been installed to improve comfort.

Air conditioning The main problems have been complaints of draughts which have several origins, but whose prime cause is probably explained by the fact that internal heat gains are considerably lower than anticipated at the briefing stage. This has been tackled by reducing the range over which the vav controllers operate, and compensating vav supply air temperature in accordance with outside temperature, an act which increases fan energy consumption.

Lighting Despite a prizewinning lighting installation there have been many teething problems and it is still not popular with occupants. For repairs and alterations facilities management finds the non-standard fittings a nuisance. The electronic lighting controls seem to have delivered less than might have been promised, partly owing to the use of grid-switches for the office lighting, and to what seems to be an unfriendly front-end.

Heating The C&G Chief Office is comfortably warmer than the average building in spite of the tightly managed boiler plant, the switching off of the perimeter heating system in mild weather, the lower room set-point (21°C instead of the more typical 23°C) and the consequential low return air temperature. However, a more detailed analysis of the survey responses reveals that a significant minority do report cold winter temperatures.

Humidification Humidification from the compact systems with gas-fired steam generators is much more economical than that from electrode boilers, which not only incur a CO₂ penalty but also tend to operate most in cold weather when electricity prices are high. However, the reason for the ruthless modularity, in which two steam generators are virtually side-by-side, is somewhat dif-



The reception now has electric heaters behind the panelling to improve comfort.



The atrium is lit by 150 W metal halide uplighters which, as they are switched from the main reception desk, tend to remain on all the time irrespective of daylight levels.



The occupant survey revealed that artificial lighting levels were too high, and natural light levels too low...



perhaps due to no external solar shading or

References

¹Energy Efficiency Office, *Energy Consumption Guide 19*. EEO. October1991.

²Environmental comparisons. *The Architects' Journal*. 21 September1995.

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