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## Gardner House PROBE 7



Bill Bodass, John Field and Adrian Leaman report on how Gardner House, the penultimate 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 "Looking radiant", which appeared in the June 1994 issue of *Building Services Journal*.

Like many clients, the Homeowners Friendly Society (HFS) wanted its new headquarters building to be fresh and comfortable, with easily maintained low energy services and flexible artificial lighting and IT systems. In order to achieve this, the HFS called for the use of air conditioning, largely to suit perceived market demands and to meet predicted office equipment heat gains of up to  $30 \text{ W/m}^2$ .

Unlike many clients, however, the HFS was prepared to entertain a more novel method of air conditioning, namely chilled beams and displacement ventilation, a system promoted by the services consulting engineer on the project, Hoare Lea & Partners. Using setbacks, the slope of the site and a partially-buried lower ground floor, the

ground-hugging building — called Gardner House — looks smaller than its  $4300 \text{ m}^2$  gross ( $3800 \text{ m}^2$  treated) floor area. The stone-clad ground floor is largely a deep, open-plan office with a central 6 m by 6 m rooflight.

A first floor courtyard is surrounded by a corridor and largely cellular offices and meeting rooms. The sealed double-glazed windows are grey-tinted, with approximately 35% total light transmission. Manually operated internal Venetian blinds are used in order to control glare.

The first floor also contains a boardroom plus an adjacent dining room and kitchen. The main staff dining area on the lower ground floor is largely served by vending machines. On certain days, and with increasing regularity, its small all-electric catering kitchen also provides some simple hot dishes for about 25% of the 120 staff.

The lower ground floor also contains a  $230 \text{ m}^2$  materials and archive store and a  $60 \text{ m}^2$  computer room with an uninterruptible power supply and two packaged dx air conditioning units.

A plantroom in the pitched roof contains gas-fired modular boilers, dhw calorifiers heated from the boiler circuit, heating pumps and kitchen supply and extractor fans. Self-regulating electric trace heating tape is left permanently on to keep the dhw distribution system up to temperature.

The plantrooms are rather cramped, more characteristic of speculative rather than owner-occupied buildings, or perhaps the late engagement of the services engineers. Some parts — including the reheater control valve — are virtually inaccessible.

## Overall building performance

HFS is full of praise for the design team, but feels that the contractor did not pay enough attention to coordination. In particular, a key person was moved on several months before the building was completed and a promised building services coordinator never materialised. Consequently, there was a loss of quality and coordination and the building services commissioning suffered in the final rush. The bems is still not resolved to the client's satisfaction, and the expected level of operator training has not yet been delivered.

Although the building gives a very good overall impression, there has been one major problem: a lack of airtightness. This affects control and makes the building cold in windy weather, particularly on the first floor which is more exposed and has a shallower plan. The initial omission of some insulation made matters worse.

To help in identifying the weak points and to improve airtightness, the BSRIA commissioned a series of tests which revealed a normalised air leakage rate at 50 Pa of some  $27 \text{ m}^3/\text{h}/\text{m}^2$ . Although only a little above typical levels for post-1990 UK air conditioned offices, this is five times the rate recommended by the BSRIA for air conditioned and low energy buildings<sup>2</sup>. The leakage at Gardner House equates to a massive  $9 \text{ m}^2$  hole and a mean winter infiltration rate of about 1 ac/h in still air and 2 ac/h at 10 in/s wind velocity.

The first tests revealed major leakage at the eaves and at the cills to windows and curtain walling. Disappointingly, remedial measures reduced infiltration by less than 10%.

Attention then turned to the windows themselves. Tests by the manufacturers and BSRIA confirmed that large amounts of air could pass through labyrinthine paths in their hollow aluminium sections, and particularly up the mullions. *In-situ* foam filling and mastic sealing was carried out in the summer of 1996, and results of further pressure tests are awaited.

Recent research by the BRE and BSRIA suggests that airtightness cannot be taken for granted, as confirmed by Gardner House and other buildings studied under the PROBE programme. Its effect on comfort and energy performance is also proportionately greater in today's well-insulated buildings, owing to their relatively low-powered heating.

In order to raise temperatures in cold, windy weather, the supply air temperature has been raised and slightly compensated, varying from 23°C in cold weather to 21°C in hot weather. In any case, even without the excess air infiltration there are indications that the intended supply air temperature of 19°C might have been regarded as uncomfortable.

In addition, floor supply temperatures have been reported to vary locally by up to 3°C, particularly after the building has cooled down overnight, and with some air infiltration to the floor void. As there is no recirculation or heat recovery the air needs heating, even on summer mornings.

The building cools rapidly and tends to be cold in the morning. In cold weather a 'hot flushing' programme has been adopted from 06.00 to 07.30, where the AHUs operate with the heater battery valves full open. In very cold weather the heating and air conditioning is also run on Sundays. In addition, five electric fan heaters are used in exposed perimeter rooms on the first floor, plus another in the ground floor accountants' offices.

The temperature of the 1phw perimeter trench heating is compensated centrally and operates during programmed hours whenever the outside air temperature is below 16°C, even in summer. It is also zoned locally for each of the eight main facades. On sunny days, however, the facade temperature sensors could cut off 1phw to the zone too soon, and their cut-off points have had to be raised to 35°C, except on the north side.

There have been difficulties in obtaining the intended amount of humidification. A low of 40% in the offices in winter and a high of 60% in summer was intended, but during the first winter rh levels sometimes fell to nearly 30%, leading to staff complaints, particularly from contact lens wearers.

When investigated, the canisters of the electrode boilers were found to have been rapidly degraded by salts and corrosion, and were operating well below their design output (canisters are now replaced twice a year). However, the replacements have not provided the full specified output, a problem which has been attributed to the low conductivity of the soft local water.

Meanwhile the rh set-point has been raised, but this leads to wasteful operation at times when humidification is not really necessary. Excessive summertime dehumidification has also been reported on occasions, perhaps a consequence of control faults.

The PROBE team discovered serious control instabilities: on a warm day (outside air temperature 25–26°C) the main air handling plant cycled over a half-hour period from full cooling, via full cooling plus reheating, full reheating with no cooling, to full reheating with humidification and back to full cooling.



**Smoke released during the BSRIA's pressure tests showed severe leakage at eaves, cills and via the window system. Gardner house is not unusual though - the UK has an epidemic of new buildings which are not airtight.**

This not only wasted energy for heating, cooling and humidity control, but also caused (typically) a 2°C swing in the temperature of the air emerging from the floor, and consequent hunting of the chilled beam controls.



## Environmental systems performance

The office was reportedly the first in the UK to use full fresh air displacement ventilation with ventilated chilled beams recessed into the ceiling. Conditioned fresh air is supplied from the floor void at 3 ac/h via Hesco displacement diffusers and extracted via slots in the planked ceiling.

As is usual with today's modern office, most staff members have a pc. However, at present the occupancy of the office areas is only about 60% of their design capacity of  $10 \text{ m}^5$  nett per person, so the density of equipment is relatively low. The provision of printers and photocopiers is also relatively modest. As a result, equipment heat gains average some  $7 \text{ W/m}^2$ , with local pockets rising to some  $12 \text{ W/m}^2$  well below the design capacity of  $30 \text{ W/m}^2$ .

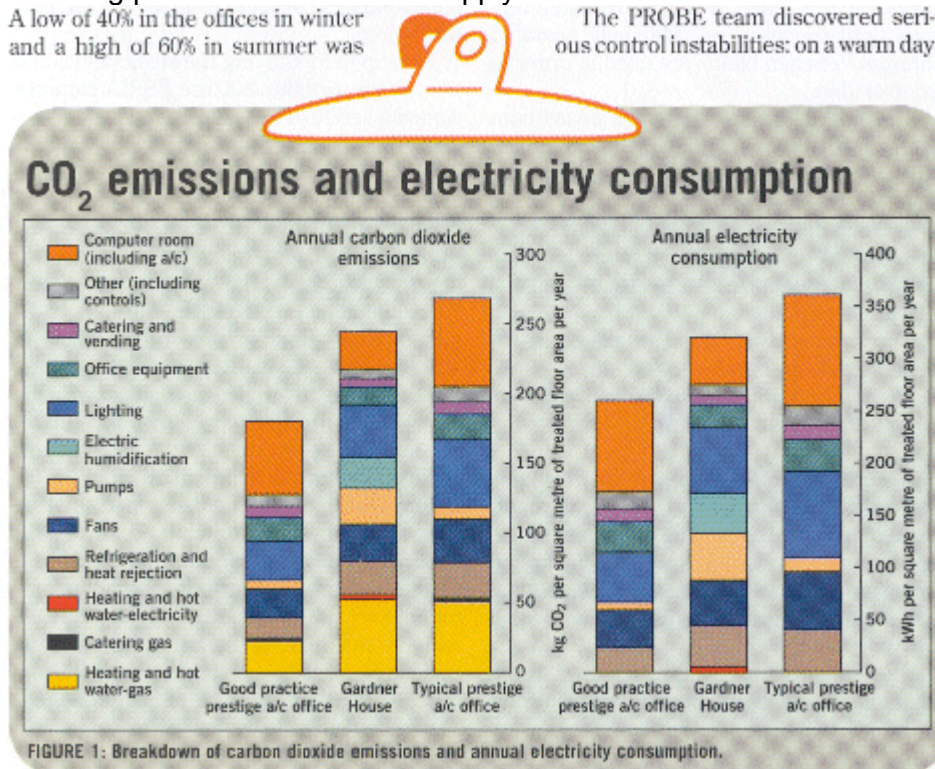
Control of the chilled beams was initially poor. Many control valves sludged up and had to be taken out and cleaned, probably a consequence of the hasty completion and commissioning. Although the problem has not recurred, initial blockages such as these are frequently reported.

Some room temperature sensors were affected by cool air streams from the air conditioning, a problem largely resolved by taping-over the lower ventilation holes of those sensors. Others were affected by heat rising from nearby pcs. Here, the equipment was relocated or control settings were altered.

A few people have objected to the floor air supply. Diffusers were moved further away from their desks (most were in corridor zones anyway). Others closed the dampers below the floor grilles, creating a domino effect of further closures and complaints elsewhere. All the dampers have now been removed, which appears to have caused no balancing problems because the supply air is ducted to each structural bay.

A low of 40% in the offices in winter and a high of 60% in summer was

The PROBE team discovered serious control instabilities: on a warm day



## Lighting and lighting control

The offices are lit by 36 W PL-C lamps to provide a nominal 500 lux. In the open-plan office, additional 26 W compact fluorescent uplighters attached to the columns add some visual interest.

There is a high degree of lighting control, complete with occupancy sensors, photocells, and some — but not many — local switches and infra-red controllers. This is centrally managed by a Philips IFS control rack and attached supervisory computer. Both this and the Satchwell hems currently have fairly unfriendly menu-driven user interfaces which are regarded as non-intuitive and tedious to use. No doubt they could be tailored, but this would require time and money.

Lighting operation is broadly as follows. Lamps in the ground floor open-plan office are time-switched to come on at half-brightness at 07.00, with increase to full brightness at 08.30. The lighting drops to half-brightness at 18.00, and goes off at 20.15. Outside these times manual switches allow lights to be switched to full brightness, either dropping back or switching off after two hours.

Although there is one switch for each 6 m by 6 m bay, these are clustered in groups of four or eight and so tend to be switched all at once. There are no off-switches, so if the setup is wrong there is no manual override (although some parts of the office have occupancy sensors with a two-hour time delay).

Lights in the cellular offices, corridors, toilets and dining room are controlled by occupancy sensors, usually with a 15-minute time delay. Lights on stairs and in the reception area are manually switched, and usually on during daylight hours.

Lights in meeting rooms are operated by hand-held infra-red controllers. As the buttons are not labelled there is a tendency to switch on more lamps than is necessary.

Nearly all luminaries are dimmable via the central system, with those at the perimeter also controlled by local ceiling-mounted photocells. The adjustable control setting is typically 600 lux with a 50% margin, so in rising daylight the lamps stay at full brightness until illuminance levels reach 900 lux and then dim down progressively. With a falling light level, a level of 600 lux is maintained.

Daylight availability at the perimeter is reduced by the tinted glass and the Venetian blinds. In order to maintain a consistent appearance to the building, the management has instructed the staff not to raise the blinds but only to tilt them. The blinds are normally left in a horizontal position, but when glare occurs they tend to be shut rather than finely adjusted. Maintaining the Venetian blinds in a consistent position also helps to avoid any long-term damage to them.

The perimeter lights often seemed to be on more than might have been anticipated, but spot measurements of typically 800-1000 lux were consistent with the control setting, after allowing for hysteresis. In some areas occupant complaints of insufficient light had caused the control setting to be raised — normally to 900 lux (ie dim-down at 1450 lux). There appeared to have been two principal reasons for this: reflections from the Venetian blinds onto the ceiling which confuse the photocells, and increasing contrast as external light levels rise.

The pre-set blinds in the ground floor rooflight do not appear to have taken account of all oblique sun paths, and at certain angles there have been glare problems which have been partly resolved by rearranging furniture. As the rooflight also leaked initially and is a source of air infiltration, HFS's management feel that it could have been omitted.

## Energy consumption

During 1995-96 the electricity has been on a simple day-night tariff, similar to the

domestic Economy 7. This has worked well — the cost per average unit is considerably less than with the previous year's maximum demand tariff, and less than in many comparable buildings.

In the year to June 1996, annual electricity consumption per square metre of treated floor area was a little below the typical benchmark for an air conditioned head office<sup>3</sup>. However, after allowing for the computer room and restaurant — both smaller than average — energy use by building services is above the norm (figure 1). This is disappointing in view of the relatively low occupation density of the building and the application of innovative services.

At 38kWh/m<sup>2</sup> for humidification, estimated consumption is high owing to unnecessary operation, particularly in summer. While 40 kWh/m<sup>2</sup> for refrigeration is similar to typical, consumption is high in view of the low occupancy densities and internal gains. Reasons include extended hours of chiller operation, even in winter, and often with simultaneous heating, even in summer.

When cooling is called for, both chillers operate along with their pump sets, although spot checks suggest that only one is ever necessary, even in high summer.

The measured specific fan power of the office ventilation system is just over 4W/l/s for supply and extract combined. Although not an unreasonable figure, it is well above today's suggested targets of 1.5 W/l/s or less for an energy-efficient installation, and gives an installed power of some 12 W/m<sup>2</sup>.

Owing to the long running hours, the annual fan energy consumption of 45 kWh/m<sup>2</sup> is between good practice and typical levels for all-air systems and has not reaped the potential benefits of static cooling.

considerably less than with temperature is just over 4 W/m<sup>2</sup>  
 maximum demand tariff, for supply and extract

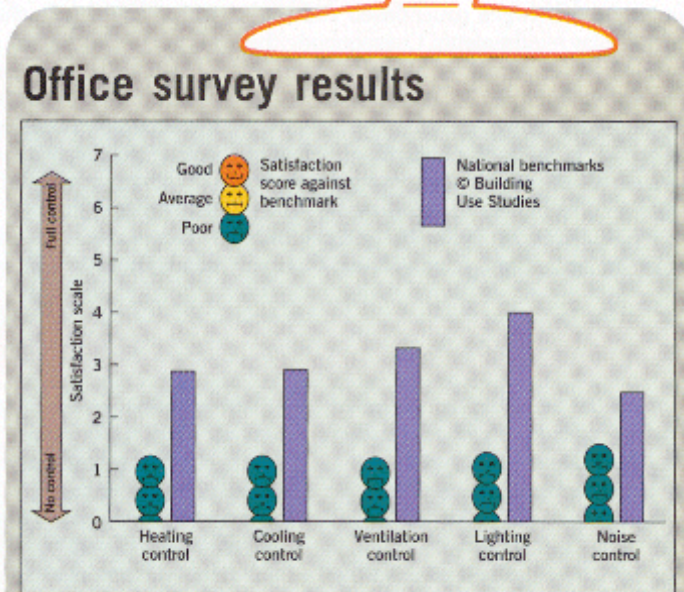


FIGURE 2: Overall satisfaction scores compared with national benchmarks.

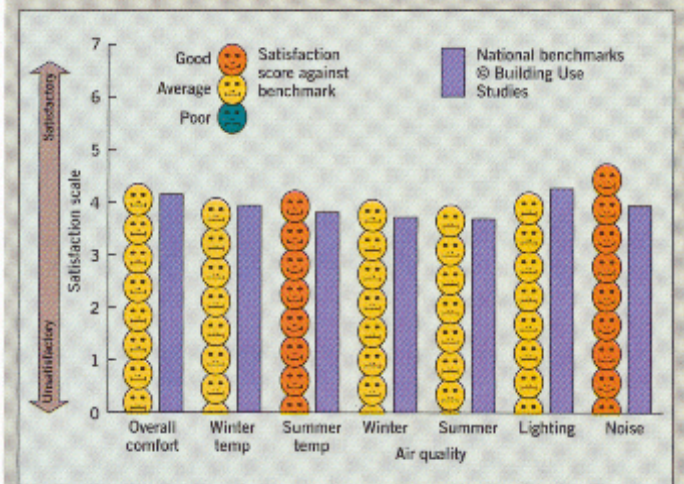


FIGURE 3: Occupancy satisfaction with control strategies.

Extended running hours make pump energy consumption of 42 kWh/m<sup>2</sup> extremely high in relation to typical levels, let alone good practice<sup>2</sup>. Unfortunately, this trait is common in 1990s air conditioned buildings, viz the PROBE studies of Tanfield House and Aldermanbury House. Too much equipment defaults to on, regardless of need. Given the advanced technology of high frequency, occupancy-sensing, dimming and computerised lighting management it is disappointing that lighting energy consumption of 63 kWh/m<sup>2</sup> is one-third more than the good practice benchmark. There are three main reasons for this. The design illuminance level of 500 lux, although the recommended institutional standard, is rather higher than the 300-400 lux often chosen in many offices today as a reasonable compromise between paper-based and computer display requirements. Consequently, the installed power density of some 18 W/m<sup>2</sup> is also higher than the 12-15 W/m<sup>2</sup> regarded as good practice today.



Second, in spite of — and to some extent because of — the occupancy sensing, too many lights tend to default to on. However, since most luminaires are dimmable and centrally programmable, there is considerable scope for greater economy once operational experience and confidence has been gained.

Individual local adjustment of dimming might also be considered: in some buildings this has proven to be very successful for both occupant satisfaction and energy efficiency, with many people choosing illuminance levels in the 200-300 lux range.

At 21 kWh/m<sup>2</sup> consumption by office equipment is only two-thirds of typical, owing to the low occupancy density of the building and the use of relatively new, reasonably efficient equipment, most of which is switched-off routinely overnight.

Gas is also on a quasi-domestic tariff, with quarterly bills and only one annual meter reading, the rest being estimated. This has made it impossible to do a thorough degree-day analysis, although some meter readings taken by HFS's facilities manager have been very helpful in filling in major gaps and constructing a performance profile.

After allowing for degree-day correction, the gas consumption of 271 kWh/m<sup>2</sup> of treated floor area is about typical. There are four main reasons for this: the high air infiltration rate, a full fresh-air system of 9 m<sup>2</sup>/s (at the current occupancy level of 120 people this equates to 75 litres/s/person), extended running hours of ventilation and the control instabilities.

The set-point adjustments, additional hours of operation, 'hot flushing' and extra humidification have caused both gas and electricity consumption to be over 20% higher in 1995-96 than the previous year. However, this operating regime is possibly more liberal than necessary, and potentially it should be possible to make reductions of up to 30% in building services energy consumption by careful attention to control and energy management.



**The occupancy-sensed lighting control in corridors and perimeter rooms was generally liked by occupants, although a minority expressed dissatisfaction at gloominess caused by the policy of lowered blinds.**

## **Occupancy issues**

The standard PROBE/Building Use Studies (BUS) questionnaire was given to 86 staff, a



100% response being obtained.

While most people quite liked the floor air supply, 35% disliked it usually because of draughts, coldness and variability. People were generally neutral about the chilled beams although 25% disliked them for various reasons, for example for being “too cold”. When seated for a time, the PROBE team experienced wafts of cool air, probably the direct and indirect result of the supply air temperature fluctuations. This felt refreshing, but had the PROBE team been sedentary all day our view might well have been different.

The occupancy-sensed lighting control in corridors and perimeter rooms was generally liked. Although most people were happy with the daylight-linked dimming at the perimeter, there was a dissatisfied minority. Gloominess was also mentioned — anecdotal comments suggest that this may be a reaction to the automatic dimming. Based on seven general questions, the scores for overall comfort, winter temperature, lighting, and summer and winter air quality are not significantly different from BUS’s benchmark norms from 55 buildings. However, occupants regard summertime temperatures as significantly more comfortable.

The noise score is also better than average, though this might be partly a consequence of the low occupation density. Noise break-out from mechanical plant was mentioned by a few occupants on the first floor.

VDU screen glare was also mentioned, particularly from bright spots above the wall-mounted and column-mounted uplighters, and from their lamps at some angles. Remarkably, however, in 11 of 16 more detailed questions, occupant perceptions differed significantly from the norms. The building is perceived as colder and draughtier in both winter and summer, but surprisingly also stuffier. Further discussion suggested that this might be a comment on the fluctuations and on conditions during hot flushing. The building was also reported to be drier and more variable in temperature in summer (but not in winter) and much less smelly than average, both winter and summer.

Hence the fairly typical overall perceptions conceal a variety of compensating changes for the better and for the worse. Overall, staff report self-assessed productivity gains averaging 2% — a good result, in the upper quartile of buildings studied by BUS. Perceived levels of control for heating, cooling, ventilation, lighting and noise were all low in relation to national benchmarks, all at a 99-99% level of statistical significance. For ventilation and lighting, the responsiveness of the system to occupants’ needs was also significantly less quick. While such responses are not unusual for an air conditioned building with few facilities for switching and personal control, the scores are remarkably and consistently low.

It appears that while seeking reasonable conditions, the design approach has totally removed the individual forgiveness and tolerance which comes from being able to exercise choice. This has been exacerbated because discomfort occurs more frequently owing to the lack of airtightness and possibly the temperature fluctuations. Some people commented that they missed being able to open a window or a blind.

## CONSULTANTS’ FEEDBACK

The PROBE article on Gardner House and the preceding six buildings studied to date represents a welcome opportunity for our industry to obtain feedback on the product that we produce, writes *Ian Durbin*.

The Gardner House scheme, with its then ground-breaking use of displacement ventilation and static cooling, is of particular interest. The biggest single issue that has affected the building since its completion is the lack of integrity of the building facade, and the effect on the performance of the engineering systems.

The magnitude of the problem was shown during the BSRIA pressure tests when smoke was released to identify the air leakage paths. To see so much air and, in direct correlation,

energy being leaked through what one would ordinarily view as a solid, airtight structure was staggering.

Indeed, it could well be argued that all engineers and architects should view such a test to highlight the effects of not getting it right.

Infiltration levels were obviously very high, and on the first floor where the amount of curtain walling was greatest, the building could not cope.

To overcome these problems the mechanical systems were modified outside the limits that were originally envisaged. Raising the supply air temperature, introducing 'warm flushing' routines early in the morning, the knock-on effects on humidification and running plant for almost 24 h per day have undoubtedly had a major effect on energy consumption figures and indeed the overall level of occupant comfort.

With the building leakage down to a manageable level, and the engineering systems reined back, it would be interesting to return to the building in a further years' time and see how the undoubted benefits of the static cooling and displacement ventilation systems have been delivered.

Ian Durbin is a services engineer with Hoare Lea and Partners consulting Engineers.



### Key design lessons

**Overall** Gardner House is on a fine site and has an aura of cleanliness, freshness and good quality. Sadly, the poor airtightness and associated loss of temperature control has caused problems in delivering comfort conditions, and where occupants do not have the means to adjust conditions they are less tolerant of any discomfort. In summer the room temperature set-points are rigorously kept at 21-22°C, even though many occupants regard them as cold.

**Airtightness** The lack of airtightness has very clearly undermined both occupant satisfaction and energy efficiency. As a widespread phenomenon, this is related to the trend to prefabricated construction and insufficient attention to the sealing of adjacent components.

**Air conditioning** Occupants' perceptions of the chilled beams and displacement ventilation are generally about average, although a smoke pencil showed that the fluctuations in supply air temperature caused air to rise from the floor diffusers at the peak – not surprisingly as it was very close to room temperature. At the trough the air spread out more. There was little stratification.

Smoke tests also showed that some of the air from the chilled beams spread out and re-entered the ceiling void, although checks of exhaust air temperature showed little evidence of chilled air short-circuiting into the extract system.

**Lighting** Lighting energy use is disappointingly high, given the high frequency control gear, occupancy sensing and daylight-linked dimming. This is due to blinds being closed more than necessary and occupancy sensors either turning lights off sometimes two hours after spaces are vacated or turning on unnecessarily through sensing someone simply passing by. There is no local switching that would enable local dimming of the lighting.

**Plant areas** Although the main supply and extract plants are adjacent, there is no heat recovery. However,



Tests revealed Gardner House to have an air leakage rate of 27 m<sup>3</sup>/h/m<sup>2</sup> at 50 Pa.



The open-plan offices, with the rooflight in the foreground. The rooflight gives little sense of light and space to the large ground floor office, partly because the plane of the downstand baffles is maintained.



Deliberately underexposed photograph to show the glare from the uplighters.



The main air handling unit. The reheater control valve is behind here somewhere...



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## References

<sup>1</sup>Bunn R, "Looking radiant", *Building Services Journal*, June 1994.

<sup>2</sup>Booth W B, Jones O J and Potter N, "Air leakage of office buildings", *Technical Note*, August 1995.

<sup>3</sup>*Energy Consumption Guide 19* (ECON 19).

The PROBE team acknowledges the help of Gardner House facilities manager Derek Barnes and the HFS staff.