



probe 1

Tanfield House



Bill Bordass and Adrian Leaman report on how the first building revisited under the PROBE project, Tanfield House, has performed since completion.

To understand the detailed design, readers must refer to the original articles "An assured design"¹ and "Facade of the future"², which appeared in the March 1993 issue of *Building Services*.

Tanfield House in Edinburgh has the honour of being the first building revisited under *Building Services'* post-occupancy project, PROBE, described in full in the July issue. The investigative team performed a variety of tests on the building, measuring actual energy use by the Energy Analysis Reporting Method (EARM) and using the Office Assessment Method (OAM) to determine the building's performance against industry benchmarks.

Owner/occupier Standard Life started in Edinburgh in 1825, now employing some 4500 people, 1300 of whom work in Tanfield House — Standard Life's administrative centre. The client's requirements for maximum flexibility — plus height restrictions on the site in the Valley of Leith — have created a 20 000 m² groundscraper, with just two floors of offices, a roof garden and restaurant above, and 306 parking spaces below. The building contains very deep, open-plan offices (up to 120 m across in places) high coffered ceilings, uplighting, a highly-glazed perimeter and three circular domed atria, each 14 m in diameter. A separate building houses the data centre, to which Standard Life's IT systems are directly linked.

building design

When the building brief was prepared in 1985, concern about poor indoor conditions motivated the client to ask for 100% fresh air ventilation and openable windows. However, mechanical cooling was necessary owing to the building's depth and predicted internal heat gains of 60 W/m².

Main ducts run from 19 air handling units to dampered take-offs at first and ground floors, each with chilled water cooling coils and steam humidifiers, serving vav boxes with 1phw reheat coils. Radial ducts then lead through the 600 mm floor void via take-off spigots and flexible connections to 200 mm diameter floor diffusers.

There is no return ductwork: the air simply drifts up into the three atria and escapes through nine variable volume exhaust ahus, three on each atrium gallery.

Artificial lighting needs are provided by uplighters positioned in the middle of standard cruciform clusters of four desks, plus 150 W metal halide uplighters on perimeter walls, cellular offices and meeting rooms and non-standard workstations.

The uplighting pods originally contained four lamps — 70 W and 150 W metal halide, 150 W tungsten halogen for instant start during the metal halide warm-up period (subsequently removed as background light from circulation routes has proved sufficient) and a 10 W compact fluorescent emergency light.

Sample measurements confirm that the design illuminance level of 350 lux is achieved with the two metal halide lights on. The system provides a good luminous environment, although anti-glare screens on vdu's are used, probably to control reflection off the ceiling coffers.

A Delmatic control system switches both the 100 W and 70 W metal halide lights on at 07.45 h and off at 18.00 h. At 21.00 h all the lights come back on until 05.10 h to allow a small team of cleaners to make their way through the building. Office lighting is therefore on for 20 h or more each weekday. At weekends the lighting operates in response to the recognition buttons only.

Architectural considerations, plus the requirement for both openable windows and air-conditioning, led to a double-skinned facade². But although the building is highly-glazed, daylight at the perimeter is much reduced by the tinted inner glass, the overhanging walkways in the gap between the two skins and limited sky views.

Further glare control is by internal manual roller blinds hung in pairs — occupants can choose between a light opaque and a dark open-weave variety. The blinds are used sparingly, and typically only on the upper parts of the windows on those sides of the building which receive most sunlight.

The 70 W metal halide lamps in perimeter uplighters have daylight-linked photoelectric control: in practice this mainly operates only on facades receiving direct sunlight. Extra

daylight enters through the domes of the three atria with solar control via motorised shading 'sails'. Amazingly, no local switches were provided in cellular offices, toilets or meeting rooms, although four switches were subsequently added to permit slide presentations.

Over recent years the general office provision of one computer terminal per desk has rapidly changed to at least two thirds pcs —some with local printers — with consequential increases in electrical energy consumption. A few people now have two or even three pcs to allow them to consult different databases simultaneously while responding to telephone enquiries. Nevertheless, equipment gain levels in the open-plan office areas are estimated to be just within 15 W/m^2 .

in use performance

During the time since Tanfield House has been occupied problems encountered have been modest, especially for a building of this size and complexity. Particular points are: opening of windows caused severe draughts and noise because the building was under negative pressure. The system has been re-balanced for a slight positive pressure; the building energy management system (bems) was tuned for better usability — for example, each item had its individual time schedule, and these schedules are now shared wherever possible; office equipment heat gains were lower than expected, making the supply air too cold and volumes too small. To combat this, set-points were raised to increase temperatures and volumes. There were also staff complaints of draughts near the floor diffusers, which are nearly all located in circulation routes.



Other issues have also surfaced, most of a relatively minor nature. Intensity of occupation has risen, with more late working. Operating hours of the three main air conditioning zones around the three atria were first extended each day as necessary, but from March 1995 the standard programme was lengthened to 0730–2100 h (and to 1700 h on Saturdays) with optimum start control.

Recently there have been some faults with normally-reliable electrical switchgear and power factor correction equipment (which was increased in capacity after occupation).

These may be a consequence of the change from 'dumb' terminals to pcs, which often have poorer power factors and generate more unhealthy electrical harmonics. The recently-established customer service centre could not access data systems during the three minute, monthly test of the stand-by generator. This was felt to be unacceptable and a new uninterruptible power supply (ups) was installed. The equipment served by this and other ups has low power factors and rapidly fluctuating loads, requiring high kVA ratings in relation to their true power consumption. Heat losses through the highly-glazed perimeter sometimes caused local discomfort during the day and difficulty in achieving comfortable conditions out-of-hours and on some mornings.

It has proved best to leave the 1phw perimeter heating on all the time, under compensated control for each section of facade and with the primary water temperature set back at night from 90°C to 60°C.

The manufacturers are investigating why the chillers lock out in hot weather, well before the specified high condensing temperature (to suit the dry coolers) is reached.

Meanwhile, if the outside temperature goes over 25°C, all the office exhaust units are first run at high speed to improve heat transfer, and then half the vav units are switched off in an attempt to maintain temperature at the expense of air volume.

The horizontal walkways are relatively congested and the vertically-arranged ahus in the shafts by the stairs are reached by zig-zags of cat-ladders and perforated steel walkways. They can be hot on sunny days, draughty on windy ones and require more in the way of frost protection.

In the five years since completion, the flexible rubber couplings between the steam mains and the ahus have perished and several have burst. They are all being replaced with higher-specification flexible connectors with stainless steel braids, plus new isolation valves on either side to allow for replacement when necessary.

energy issues

Energy consumption data were gathered by the facilities staff from commissioning and subsequent performance tests. The operation of key items of plant was also monitored, and readings from all meters were collated.

Subsequently, spot checks of fan, pump and chiller operation and energy consumption were carried out, and a study made of office equipment use. The data collected was then entered into a spreadsheet which reconciled equipment and operational data with metered electricity consumption. Treated floor area was measured from drawings at 19

780 m². On this basis the PROBE researchers are confident that figure 1 gives a reasonable picture.

Annual gas consumption is high at 331 kWh/m² of treated floor area, with that for heating and hot water nearly twice the EEO's good practice level of 124 kWh/m², owing to the 100% fresh air ventilation without heat recovery, long operating hours of the air conditioning and constant perimeter heating.

High consumption for steam humidification alone (estimated at 80 kWh/m² from the annual make-up water consumption) more than covers the excess over the EEO's

'typical' value of 273 kWh/m² for a prestige air conditioned office³.

The standard of 50% ±5% relative humidity (rh) seems unnecessarily tight for an office. A mass balance suggests that, on average, the rh of room air is increased by nearly 10%.

Annual electricity consumption is relatively high for most purposes. Energy used by pcs and terminals is high, but only about 15% are left on overnight. Consumption by printers and photocopiers is reduced because most printing work is carried out in another building. The adjacent data centre uses twice as much electricity as Tanfield House: approximately 55% of consumption for the mainframe computers and 45% for building services.

Refrigeration energy consumption is relatively low owing to the cool Edinburgh climate and free cooling provided by the 100% fresh-air system. The sum in figure 1 includes heat rejection by the reject-only fans, used at night and in hot weather.

Hidden extra energy (26 kWh/m^2) is also consumed by chilled and condenser water pumping, and in extra fan energy consumption by the office extract systems. The resistances of the added filters and heat rejection coils are always present in the exhaust air stream, whether or not heat is actually being rejected.

Based on nameplate rating, the specific fan power of the office vav units is relatively high (typically 5 W/litre/s for supply and extract combined), but the average power drawn is 35% or less of this figure.

The vav units run light for two reasons: lower heat gains than in the brief and a partial displacement effect which reduces the cooling requirement. On a July afternoon at an external temperature of 20°C the average air change rate was only 3.1 ac/h . However, owing to the very long running hours, annual fan energy consumption is slightly above typical levels.

All supply air was originally heated to 17°C , only to be cooled back down again on the floors. The preheat temperature is now 16°C and the minimum floor supply temperature 17°C (13°C and 14°C respectively when the outside air temperature exceeds 16°C).

Alternative variable temperature schedules - which would reduce reheat requirements — were defeated by the slow response of the vav units. The supply air fans serving the perimeter gap have also been disconnected.

Energy consumption for pumps is three times the typical level due to 24 h operation of 1phw pumps for perimeter heating and, most importantly, the constant running of the main chilled water and condenser pumps for heat rejection from the communications room and substations.

At 13 W/m^2 in the offices (and no more than 16 W/m^2 elsewhere), the installed load of the lighting is well under the $20\text{-}25 \text{ W/m}^2$ of the typical 19gos prestige office, particularly as the tungsten halogen lamps have been removed from the uplighters. Occupancy-sensing light control is also now used in the lifts.

The long running hours in the large open-plan offices coupled with the overnight cleaning regime (and little local control) means that annual energy consumption is only just below typical, although currently the management is geared towards providing an excellent service with less emphasis on economy — an approach borne out by the results from the energy and occupancy surveys — and with specific improvements to particular areas.

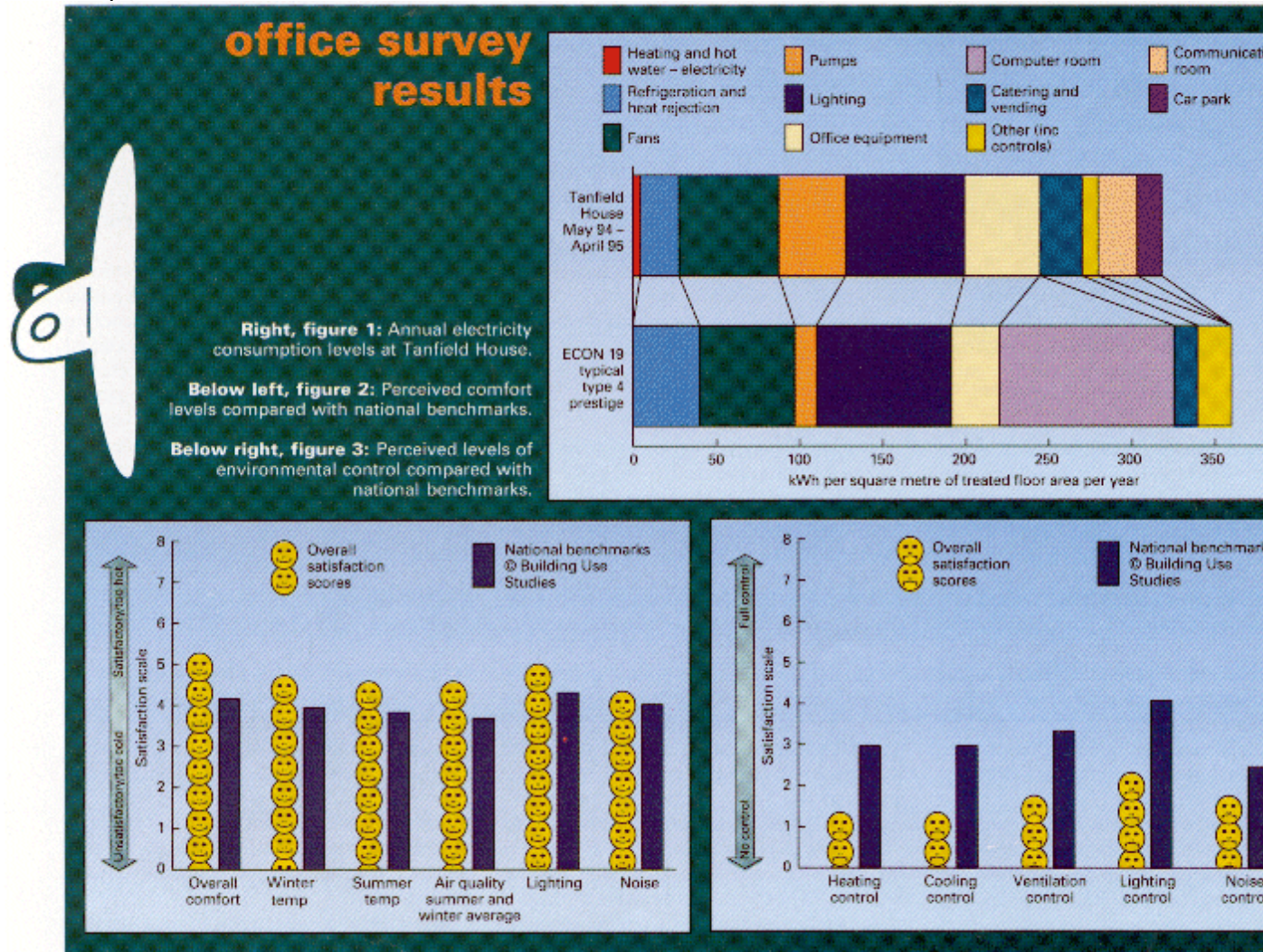
Future energy saving plans include disconnecting the heat rejection from the central system serving the communications room and substations and redirecting it to air-cooled condensers in the car park immediately underneath. This would halve the building's pump energy consumption. The transformer and ups will be cooled on a free-cooling system largely replacing the current air-conditioners, with the excess heat dumped into the car park.

The vav fans normally operate at low speeds at which eddy-current drives are not efficient, giving high motor currents and low power factors for the duty. This places

demands on cables, switchgear and central power factor correction equipment. The heavy drives also complicate maintenance, particularly in the staircase riser ducts where access is tricky. Alternative inverter drives have been considered, and may be used to replace any units which fail.

the staff survey

The standard questionnaire developed for PROBE by Building Use Studies (BUS) in consultation with the BRE was used at Tanfield House for the first time. It was given to a sample population of staff in typical parts of the two open-plan floors. Remarkably, out of the 120 questionnaires handed out, all but one were returned.



Nearly all the staff in this building are clerical. Most work five (sometimes six) day weeks, with a seven-hour day the norm. Of those staff surveyed, 55% were women and 12% men aged under 30, and 14% were women and 19% men over 30.

Compared with BUS' database of UK offices, Tanfield House is in the top 10% of UK office buildings for perceived overall comfort, lighting, temperature and air quality during both winter and summer months (figure 2). Perception of noise was poorer, but still in the top 30%, which is good in view of the exceptionally deep-plan space.

The most common reported problems were distractions (especially when on the telephone) caused by the voices of nearby people (particularly those not in the

respondent's working group), and from other telephones ringing.

Perceived levels of control for heating, cooling, ventilation, lighting and noise were much lower than national benchmarks, not surprising for a building with few facilities for switching and personal control (figure 3).

While the openable windows were felt to make things slightly better overall, few people actually used them. This was either due to lack of awareness, or from being too far away from the windows to experience any effect.

Draughts were also reported as only the lower sashes could be opened, while some occupants reported being discouraged from opening them either by neighbours or management. One staff member said that what came "in wasn't real air" — perhaps a consequence of the plant room environment in the gap.

Most people preferred the uplighters to ceiling-mounted lighting, although several found full brightness created glare and they welcomed the facility which allowed them to switch off one lamp. Many occupants were unaware that they could do this, or found the degree of control insufficient.

Low perceived individual control is compensated for by rapid and thoughtful management responses to complaints or requests for adjustments. Since all occupants have a computer terminal, maintenance requests are by e-mail, using a standard procedure. Maintenance staff respond to the request rapidly (usually the same day), define the problem, carry out the adjustment or repair and sign off 80% of jobs within three days. Respondents clearly appreciate the effectiveness of the response and the trouble taken: up to 34% had used the e-mail facility, 64% of these rated speed of response as fast or very fast and 70% rated the outcome as effective or better.

The survey showed that occupants who perceive their desired environmental conditions are met quickly also report increased perceived productivity at work. At Tanfield House the effect appears substantial: with a difference of 10% in perceived productivity between those reporting rapid and slow response. Good perceived control over cooling and ventilation appeared to be of particular importance for staff productivity, although this did not apply to heating, lighting or noise.

From a management perspective the building is a success. It provides the quality of space and flexible working environment that Standard Life was looking for.

The building's technology needs quite a lot of looking after, but Standard Life has employed seven facilities engineering staff and the job is done well, as confirmed by the occupant survey and the rapid and comprehensive responses given to the PROBE investigators' comments.

Although deep-plan buildings are now unfashionable, at Tanfield House the problem is solved with panache. Occupant comfort and satisfaction is unusually high for a building of this kind, owing to the combination of design and management measures. With less management attention, a building of this kind could easily spiral into decline.

However, Tanfield House's energy consumption is high. Standard Life gives priority to service, and regards its energy costs as perfectly reasonable in relation to its payroll and the tens of billions of pounds worth of funds it has to manage.

While the economic sense of this attitude is clear, there is scope for more energy efficient plant, such as condensing boilers, inverter drives, high frequency lighting and systems with lower air and water pressure drops, as well as heat recovery in the office air conditioning system.



key design lessons

Design assumptions Much of Tanfield House's energy consumption occurs when there is little real demand, particularly outside normal occupancy hours, and would not have been picked up in design calculations.

Lighting Full lighting does not need to be switched on automatically in the morning, even in cellular offices and wc cubicles where occupants are quite capable of making up their own minds.

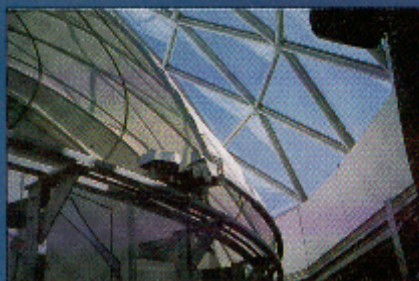
Air conditioning Standard Life was advised to keep air conditioning on out-of-hours for health and safety reasons. But this policy is questionable given the energy and environmental cost, the large volume of air in the space, and the openable windows.

Air and water transport The chosen mode of heat rejection has increased condensing temperatures, reduced refrigeration efficiency and has necessitated extra fan energy to force exhaust air through filters and coils whether or not heat rejection was needed.

Humidification It is best to avoid installing systems like the one used at Tanfield House where small local demands mean using large systems, for example the relationship of the communications room with the central chilled water system.

Glass walls In theory, glass-walled buildings may achieve an economical energy balance but, in practice, when hvac systems are switched off, greater heat losses and gains and less thermal stability may cause certain areas to become uncomfortable more quickly. The response is earlier starts or extended running (particularly for systems which also suffer instability on start-up) with the potential for major increases in energy consumption. In open-plan offices, energy savings from daylight can be disappointing due to problems with glare or unsuitable lighting controls.

Pumping In June 1995, on average two of the 32 refrigeration compressors were running, but 100% of the chilled and condenser



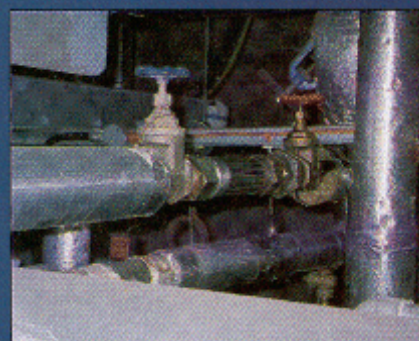
Detail of the motors that operate the solar sails in each of the three atria.



Filters and heat rejection coils in the extract system always mean high pressure drops.



Although the building is highly glazed, daylight at the perimeter is much reduced by the tinted inner glass, the overhanging walkways in the gap and limited sky views caused by planting.



References

¹Corcoran M, 'An assured design', *Building Services*, March 1993, pp13-17.

²'Facade of the future?', *Building Services*, March 1993, p43.

³Energy Efficiency Office, *Energy Consumption Guide 19*, EEO, October 1991.
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