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The BRE low-energy office: a longer-term perspective

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The BRE low-energy office (LEO) was amongst the first buildings constructed in the United Kingdom with the aim of minimising energy use. In practice the building uses only between one-half to one-third of the energy of earlier designs. Experience of the LEO has an important role to play in future low-energy designs because:

- *energy-efficient features associated with the building's design can be fully evaluated because of the very detailed, and long-term, monitoring of the building, combined with extensive on-site expertise; and*
- *the building has already been successfully used to develop and evaluate a number of innovative energy-efficient features. The LEO remains a valuable tool in assessing future design/control strategies.*

In the light of 6 years of operating experience of the LEO, this paper assesses the long-term performance of energy-efficient features incorporated in the building's design. It should be of interest to architects, building managers, building services engineers and surveyors.

INTRODUCTION

The design of the LEO (Figure 1) was finalised in 1978 and incorporated those energy-efficient features which, at the time, were considered desirable to minimise the building's energy use. The design team were constrained by the need to remain within the (then applicable) PSA cost limits, and by the absence of previous operating experience with energy-efficient buildings. Detailed monitoring of the LEO, combined with the availability of on-site expertise, has identified many lessons that can be applied not only to future low-energy designs, but also to more conventional buildings.

In addition the LEO has been successfully used to assess the performance of innovative control algorithms developed at BRE. The performance of one of these control algorithms, 'BRESTART', relative to existing controls has been studied.

REALISED PERFORMANCE

Temperature attainment

An initial failure to achieve target internal temperatures in the LEO on a substantial number of occasions (Figure 2(a)) has been attributed to a combination of inappropriate controls and a level of installed heating system capacity that, in comparison with current design guidance, did little more than match steady-state design requirements[1,2,3]. In order to improve optimum start performance the 'BRESTART'[4] optimum start algorithm was used over the 1984/85 heating

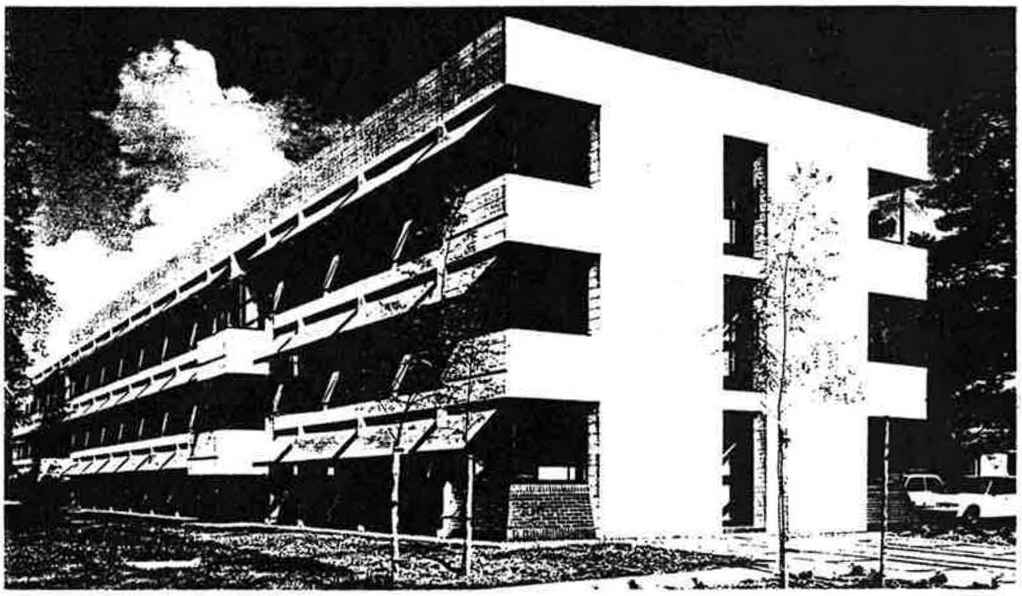

Figure 1
The low-energy office at the Building Research Establishment, Garston

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season. This gave some improvement but, because the heating system lacked capacity, target conditions were still not realised on a significant number of days (Figure 2(b)). During the latter half of 1984/85, control of the ventilation system (which for research requirements was oversized) was integrated with that of the heating system, increasing heating system output during preheat by 30%. Use of an intermittent heating regime througout the heating season therefore became possible[3], resulting in a major improvement in the attainment of comfort conditions (Figure 2(c)). Increasing heating system output also reduced preheat times, and hence energy use.

In BRE's experience a significant number of buildings do not possess sufficient heating system capacity to allow an intermittent heating regime throughout the heating season, and increasing heating system output is not usually an available option. Thus to provide information for the more general situation, use of the ventilation system during preheat was discontinued and during 1985/86 'BRESTART' was further developed to include what is effectively a variable night setback set point. The new algorithm maintains overnight internal temperatures at a level such that use of a preset maximum preheat period should enable targets to be realised[5]. The optimum start performance under this new control regime is given in Figure 2(d). This shows a substantial improvement in performance compared with the original optimiser. When such a control regime becomes available commercially it should improve the attainment of targets in buildings that are currently intermittently heated but do not possess sufficient heating system capacities. It should also allow greater freedom in future over heating system sizing, although the implications of sizing on energy use need to be fully assessed.

Energy use

Table 1 illustrates energy use and internal temperature over the first 5 years of occupancy. High energy consumption during the first year can be attributed to commissioning trials. The lowest energy consumption figures are those for 1982/83 — the period covered by the initial report on the LEO[1]. Energy levels increased during 1983/84, a period when the building was not being intensively monitored, ie the building's operators no longer received feedback from monitoring work. Over the last 2 years energy use has returned to levels similar to those for 1982/83, even though there has been an improvement in the attainment, and level, of comfort conditions. This can be attributed to the use of the new control and heating regimes, which allowed a more consistent, and energy-efficient, control over the building.

LONG-TERM VIABILITY

Initial monitoring of the building[1] gave an immediate assessment of the performance of energy-efficient measures included in the building's design. In order to determine whether or not the performance of these measures has been maintained (or even improved) the building's performance has been continuously monitored. In several areas it has been found that the longer-term performance of energy-efficient measures has been sub-optimal. Lessons that have been learnt from such experience are not confined to future low-energy building designs alone.

Thermostatic radiator valves

When functioning correctly, thermostatic radiator valves (trvs) have been found to utilise extraneous gains successfully. However, the longer-term performance of trvs has proved disappointing. Initially, trvs failed frequently owing to a combination of design and installation faults (eg see Figure 3), and even when replaced by an improved design, some trvs continued to fail. Because of failure, or tampering by occupants, by June 1985 some 40% of trvs were effectively disabled, and a significant number remain so.

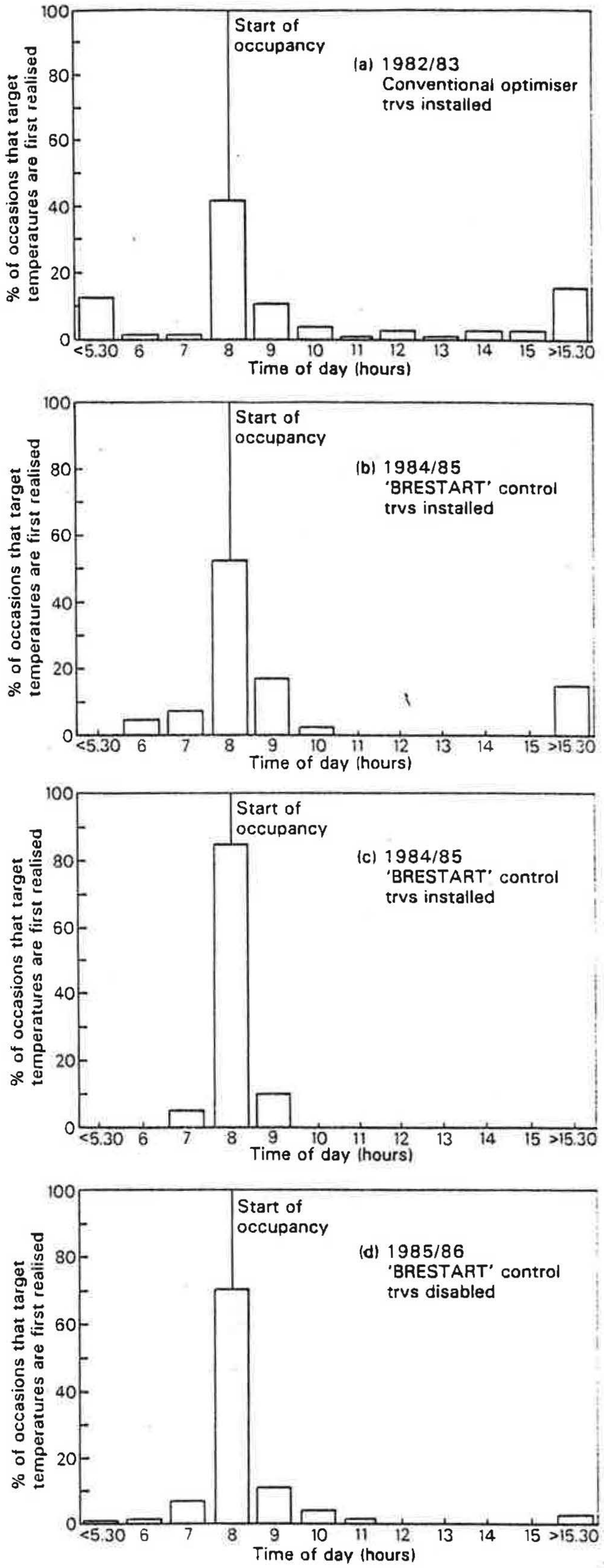

Figure 2 Optimum start performance: (a) 1982/83 heating season, old heating regime; (b) 1984/85 heating season, old heating regime; (c) 1984/85 heating season, new heating regime; (d) 1985/86 heating season, old heating regime, new control regime

In the LEO, because of the characteristics of the installed optimiser and trvs, trvs were found to affect optimum start performance adversely by reducing emitter output during

Table 1 Energy consumption and environmental conditions in the BRE low-energy office, 1981—86

	Heating season				
	1981/82	1982/83	1983/84	1984/85	1985/86
Gas consumption (degree-day corrected; October to April; MJ/m²)	524	460	530	476	476
Internal temperature at the start of occupancy (°C)	—	18.6	18.4	19.1	19.3

preheat as target temperatures were approached. This made the attainment of target temperatures less likely. During 1985/86 this effect was limited by adjusting trv and optimiser set points to minimise the interaction between them.

This work illustrates the importance of having an integrated controls strategy, and the need for tight on-site supervision to ensure that correct installation practices are observed.

External blinds

The external blinds are an important design feature of the LEO. They protect the building from overheating in the summer, so allowing window size to be optimised on the south face of the building (45% of facade) by balancing fabric heat losses with solar gain and the availability of daylight. Control of the blinds, other than outside the occupancy period and at high wind speeds, has been left to the occupants.

In practice there have been on average seven blind failures a year to date, there being an increase in failure rates with time. Rectification of faults, combined with a requirement for regular maintenance (eg to recalibrate and check control instrumentation such as anemometers) has proved expensive, and has made a significant contribution to the overall running costs of the building.

Given the costs incurred in both the installation and later maintenance of the external blinds, it may be thought appropriate that if window size is to be optimised in future designs then the likely costs associated with solar protection should be considered in design calculations. In addition, as a matter of prudence, the availability of maintenance resources should be evaluated to check that such features can be easily maintained.

Insulation

The use of thermal imaging, combined with visual inspection of cavities using an endoscope (Figure 4), indicated that most cavities were either incorrectly filled or have not retained the insulation material used (polystyrene beads). Work is under way to identify, and subsequently rectify, the causes of the loss of insulation, before the cavities are refilled.

Lighting controls

The lighting control system installed in the LEO was based on the use of external photoelectric sensors, combined with simple automatic time switching. The selection of this control system was made at a time when little guidance was available on the choice of lighting controls.

Disconnection of the lighting controls in the LEO had a minimal effect on electricity consumption. This finding is

Figure 3 Inspection of some failed thermostatic radiator valves from the low-energy office revealed the presence of a significant quantity of hemp and swarf, indicating poor installation practices

Figure 4 Inspection of cavities with an endoscope invariably revealed a lack of insulation. In the worst cases up to one-third of the insulation was absent

predicted by, and has added further confidence to the use of, *BRE Digest* 272[6] on lighting control schemes, written subsequent to the building's design, which recommends that the only lighting control strategy likely to be economically justifiable for buildings similar to the LEO (ie those providing predominantly cellular accommodation) is one based on simple time switching.

Window locking in winter

The ability to lock windows in the LEO during winter was incorporated into the building's design in order to minimise air infiltration. In practice the locking of windows proved difficult because it was never quite certain when they should be locked (there is no definite summer/winter changeover date) and occupants preferred having the option to open windows, so locking of windows was discontinued. Experience has indicated that so long as internal temperatures are tightly controlled to 19.0°C, occupants seldom take up the option to open windows in cold weather as this lowers internal temperatures below acceptable comfort levels.

Building management system

The building management system (bms) in the LEO was installed to act as a monitoring system to enable an assessment of the performance of the building to be made[1]. Even though the system did not perform any control functions, the experience in operating it is still relevant to prospective bms users.

The bms in the LEO has proved generally reliable in operation, suffering only hardware failures some 5 years after its installation. However, since the bms installed in the LEO is no longer in production, the replacement of failed items has proved both time consuming and expensive. Prospective purchasers of bms should realise the long-term problems associated with the maintenance and repair of such systems after they have gone out of production. Such problems can be minimised by selecting manufacturers with a good long-term record of supporting their older bms systems[7].

FUTURE WORK

Under design conditions (−1°C), the average office in the LEO requires something like 1 kW to match steady-state heating requirements. Although insulation levels in the LEO were high by the standards of 1978, by today's standards they are not unusual. Improved insulation levels, undertaken as part of a refurbishment option, could halve fabric heat losses. With even a moderate level of adventitious heat gains combined with this level of heating requirement there may well be cost advantages for selecting a 'micro-decentralised' heating system[8,9] (eg individual electric heaters in each room) rather than a more traditional centralised wet heating system. As a trial scheme, insulation levels in four rooms in the LEO have been improved (predominantly by installing double glazing incorporating low-emissivity glass with argon fill, combined with an aluminium frame with thermal break). Initial results show that the use of individual electric heaters in these rooms provided much tighter internal temperature control than was the case under the centralised heating system, and that most (70%) of the electrical demand for heating in these rooms occurred during preheat. It is planned to refurbish all of the LEO to evaluate more fully the benefits of a decentralised heating system when installed throughout the building.

Because of the level of monitoring in the LEO, combined with the presence of on-site expertise, the LEO will continue to provide an important test facility to develop and assess new control and design strategies.

CONCLUSIONS

This assessment of long-term performance of the energy-efficient features incorporated in the design of the LEO has underlined the importance of:

- the need, and subsequent application of, appropriate design, installation, commissioning, and operating guidelines;
- an integrated approach to the design and provision of building services and control systems, considered in the context of the building fabric and other parameters such as occupancy patterns;
- long-term performance monitoring to ensure that energy efficiency is maintained; and
- the need to consider the implications for long-term performance of energy-efficient measures of the operating environment of the building (eg what maintenance resources are likely to be available).

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