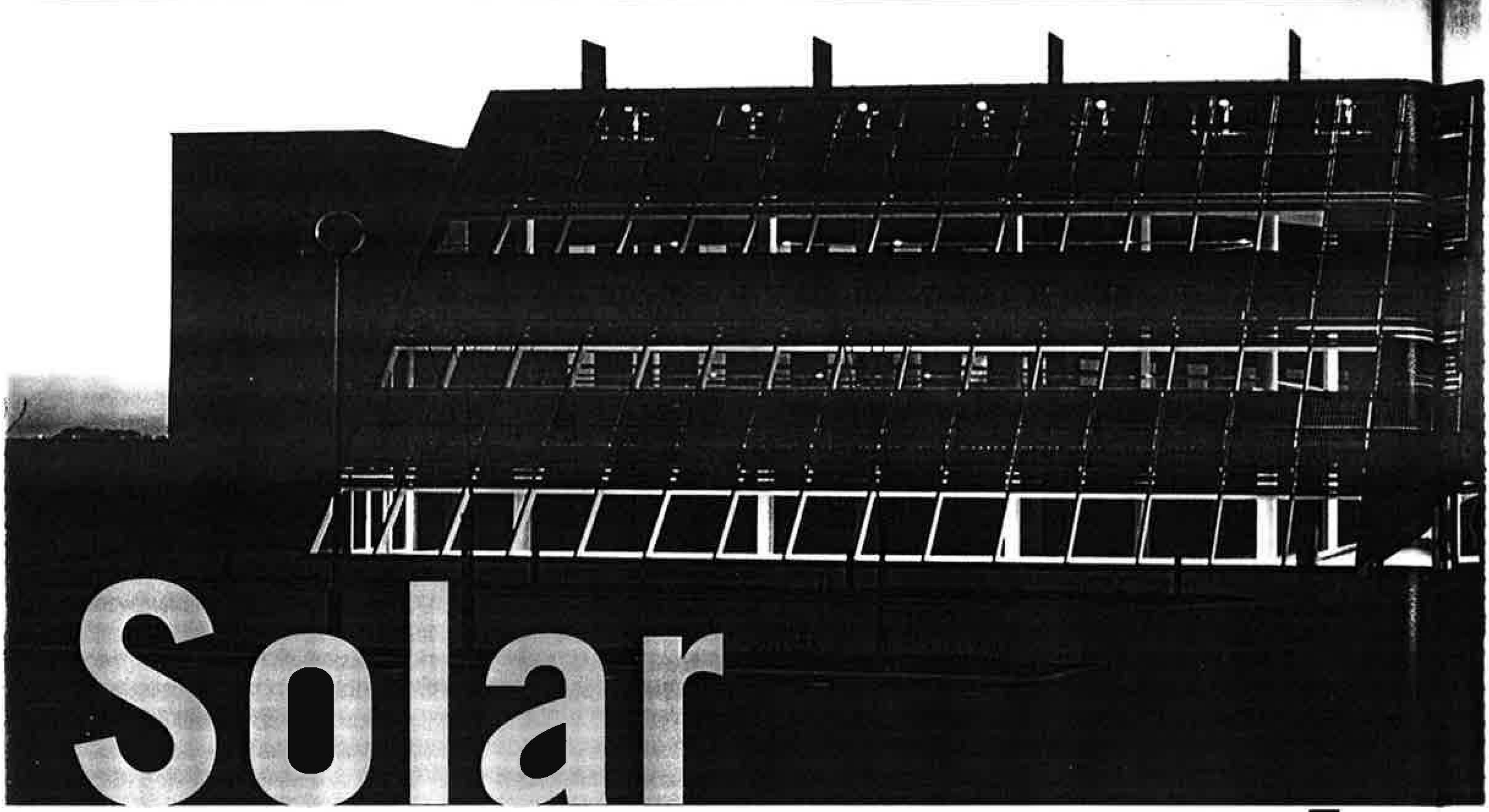


Solar so good

The Doxford Solar Office is claimed to be the first in Europe with an integrated photovoltaic facade and an holistic energy strategy. How has the building performed since completion?

ANDREW PEARSON REPORTS

Not many offices flaunt their energy conservation measures quite so blatantly as the Doxford Solar Office development. But then not many offices can lay claim to generating up to 73 kW of electricity directly from the sun.

No surprise, then, that the building's futuristic facade boasts Europe's largest integrated photovoltaic (pv) wall. But what is surprising, given its credentials, is that the Solar Office is a speculative office development capable of accommodating multiple tenancy.

The Solar Office was built by Doxford International – an Akeler Group company – as part of Phase VI of the 32 hectare Doxford International Business Park development, in the heart of Sunderland's Enterprise Zone. Completed in March 1998 under a fast-track construction programme, the Solar Office has been designed to minimise energy use, with its external fabric replacing a significant amount of the energy that is used.

Central to this is the 66 m-long array of pv cells integrated into the building's envelope. This south-facing pv 'wall' – which plays host to a range of opaque and semi-transparent modules – resembles a granite slab driven into the earth.

Designed by Schüco International, the pv wall – otherwise known as the carapace – stands some 18 m tall, raking back at an angle of 60°. This gradient helps to maximise solar radiation upon the wall panels, while ensuring that glare from the wall doesn't affect the vision of drivers on the nearby trunk road.

In design terms the pv facade is divided centrally with the two wings pulled back slightly at 5°, thrusting the entrance outward toward the main concourse and the car park. Immediately behind the facade is a three-storey atrium, and a full-length internal street.

The pv wall is splintered by three horizontal bands of clear glazing which correspond to the floor levels, the remainder being covered by some 45 000 iridescent pv cells, giving the impression that it has been lightly dusted with glitter. The cells are set out in alternate strips above the clear-glazed panels, with clear glass in between. This is designed to provide a gradation between the transparent sections and the opaque pv panels, while ensuring that occupants' views remain unobstructed.

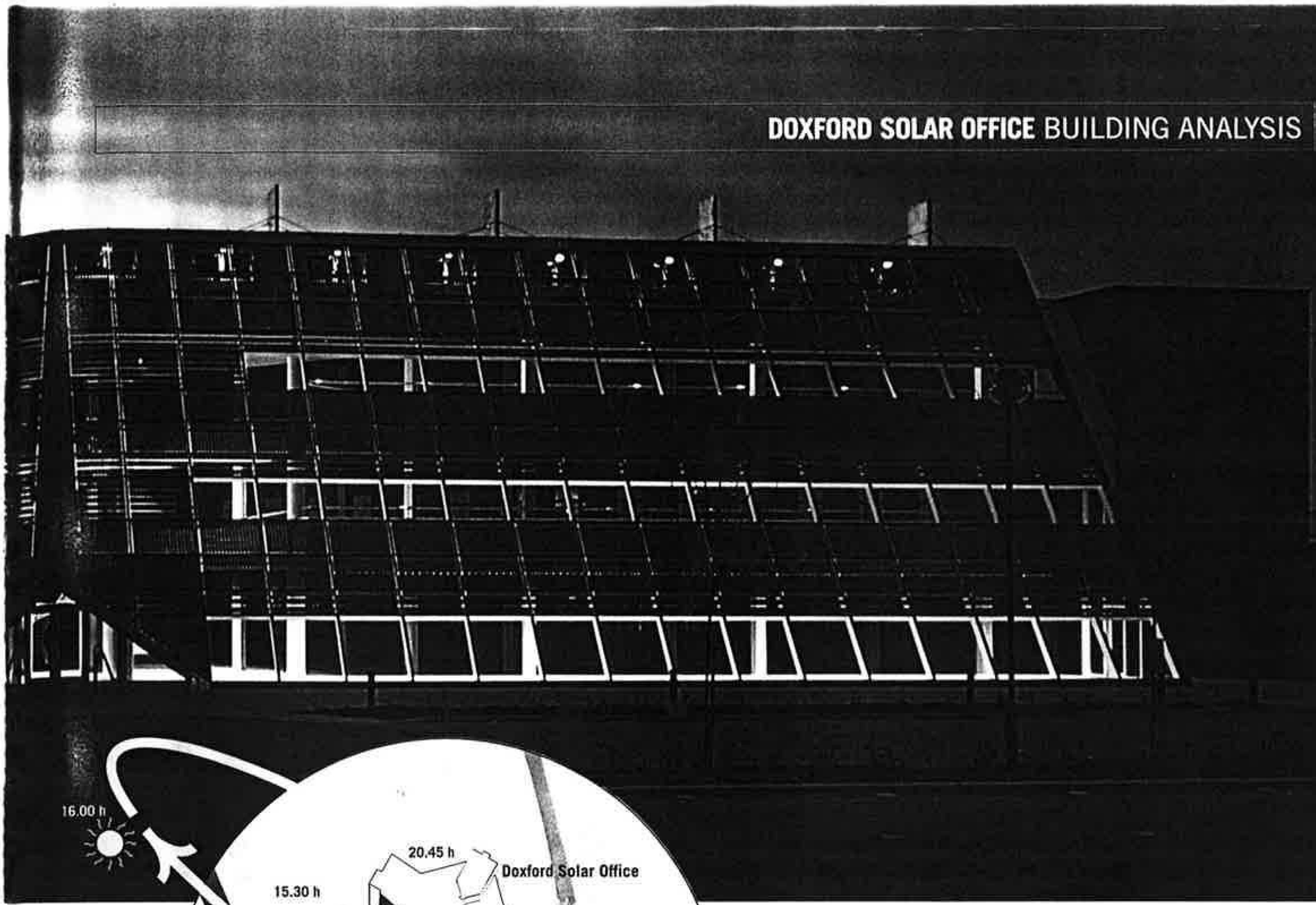
Each pv module consists of 5 mm heat-strengthened white glass, 2 mm cast resin with solar cells, a 4 mm heat-strengthened glass parasol, a 12 mm Krypton-filled void and 6 mm laminated glass with a low-E coating – giving a U-value of 1·2 W/m²K.

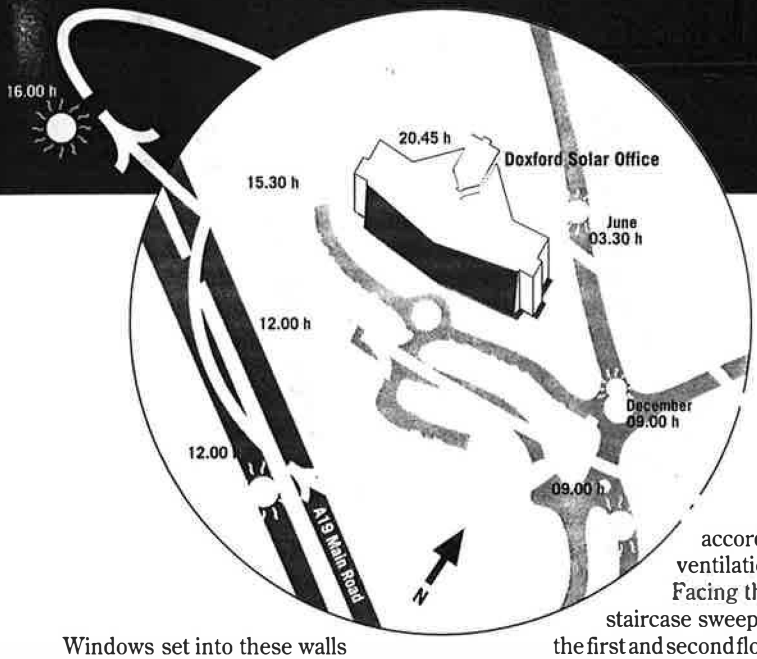
In practice, each of the polycrystalline cells generates direct current. The cells are connected in series, otherwise known as strings, which are in turn connected in parallel with other strings linked to an inverter for conversion to alternating current.

The chimney-like outlines of the rectangular wind baffles are just visible above the pv facade. These braced metal rectangles sit astride a 'wind trough' tucked behind the top lip of the solar wall, forming part of the building's natural ventilation system – of which more anon.

Rather like two sentinels, the building's brick-encased escape stairs border the pv wall's east and west terminations, dissociating it from the building's remaining facades.

When compared with the sparkle of the pv cells, the yellow brick-clad walls to the north, east and west elevations are rather muted.





ABOVE: The 66 m-long inclined facade incorporates a 646 m² array of photovoltaic cells. Total system output since March has been calculated at 11 548 kWh, with an average system efficiency of 7·5%.

LEFT: A south-facing alignment of the building's facade, coupled with an inclination of 60°, has been adopted by the design team to maximise solar radiation.

Windows set into these walls emit daylight to the V-shaped office floors. The windows feature two toplights – one under manual control and one which is opened by building energy management system (bems)-controlled actuators. The lower, glazed section is fixed.

A trilateral entrance porch is cut into the pv facade, entraining visitors into the building's sunlight-dappled central atrium. Once inside, the pv facade's subjugation of the space becomes apparent. Sunlight streams through the clear-glazed wall sections, illuminating the main floor areas.

There is no doubt that the overall quality the pv wall brings to the interior is one of light and space with sunlight trying to force its way in – even through the pv-covered sections.

Designing for daylighting

Two glazed rooflights situated high up in the atrium allow natural light to stream into the building's core. Incorporating actuator-operated windows, which are controlled by the bems, they open and close according to the building's ventilation strategy.

Facing the entrance, a spiral staircase sweeps skywards to serve the first and second floors, its gentle curves emphasising the angular arrangement of the open-plan upper floor balconies encircling the atrium. These are stepped back, allowing daylight to pervade the central office floors.

Behind the staircase, two eight-person lifts stand to attention, passively awaiting their first passengers upon building occupation.

Flexibility in the building services provision

The truncated promontory at the rear of the office floors houses the service core, which is fitted-out with both wcs and showers. With flexibility very much in mind, provision has also been made for a goods lift, loading and lorry access. Along with the atrium, this is the only area of the building to have undergone fit-out, the remainder having been delivered to shell and core.

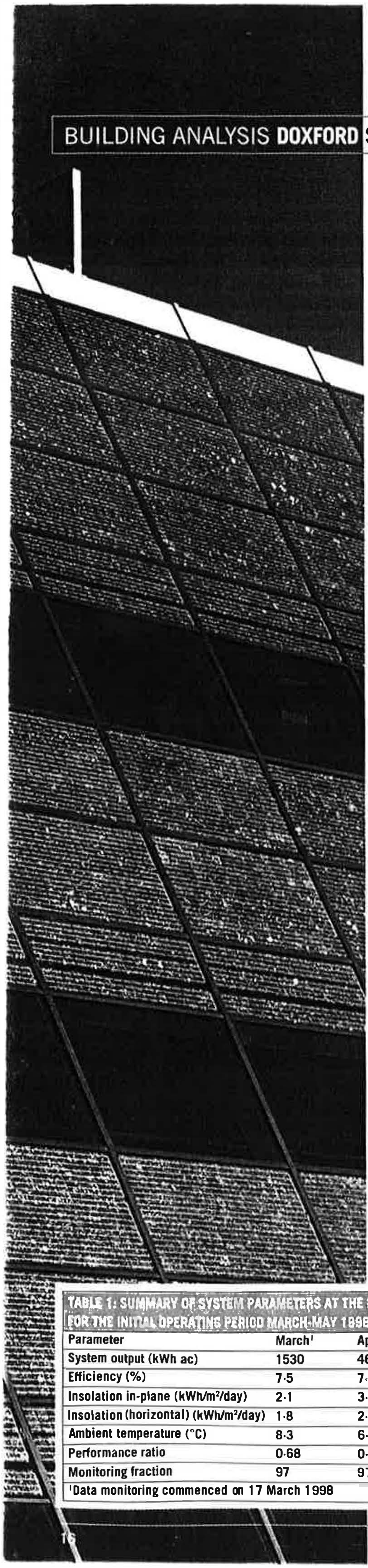
As a speculative development, the Doxford Solar Office has been designed for letting either as a single corporate facility or for subdivision: this will be on a floor-by-floor or half floor basis.

Flexibility is also in evidence in terms of the building services provision. The building is capable of running under natural ventilation (with night-time cooling), but can also accommodate a traditional displacement ventilation system, a mixed-mode system or even a four-pipe fan coil set-up.

In its 'natural' mode, the system is primarily wind/stack-driven and takes full advantage of the site's exposed, windy location close to the North Sea. A wind trough surmounted with baffles runs the full length of the facade. As the wind drives across the trough, a negative air pressure is created immediately outside the series of high-level vents regardless of the wind direction. This reduced pressure encourages airflow out of the vents.

This, in turn, encourages air to be drawn in through the north-facing windows on the opposite side of the building, and across the 11-15 m-wide floorplates, keeping the interior cool. At the base of the pv wall, bems-controlled openings permit additional stack-driven air to rise up behind the pv cells, keeping them cool and aiding overall performance[1].

In its pre-let condition, the provisions made for flexibility in servicing the offices are immediately apparent. A 450 mm empty void awaits a raised floor, while the rough-finished concrete soffit lies ready for finishing, using ei-



"This building makes the leap from building-as-

ther a suspended ceiling or a finishing screed, depending upon tenant selection.

If, however, a night-cooling strategy were employed then exposed thermal mass becomes important. A steel frame supports the precast concrete floors and, since a raised floor is necessary to fill the void whichever system is used, the ceiling's finish becomes all important.

Clearly, a suspended ceiling will effectively blanket the concrete soffit, whereas a thermally-linked finish would work most effectively – something a prospective tenant will have to consider.

Should a future tenant opt for an underfloor displacement ventilation system, the 450 mm floor void could be used either to house distribution ductwork or as a pressurised plenum served from roof-mounted air handling units. In the same manner, fresh air ductwork for the fan coils (assuming that they are floor-mounted) could also be run in the void.

Initial building performance

The main objective in terms of the building's environmental design was to find a symbiosis between the pv modules' requirement to remain cool for maximum output and the facade's need for thermal insulation as part of the building's low energy enclosure.

Ultimately, the design team has opted to minimise winter heat loss by incorporating sealed double glazing rather than take the ventilated cavity or single glazing options at the cost of cell performance reduction.

Monitoring of the pv system began in March this year, and will continue for two years under DTI/ETSU funding. The 646 m^2 array of pv cells is split into four subarrays – two large and two small – each side of the entrance. The two large subarrays are rated at 35·6 kW each, while the two small arrays are rated at 0·94 kW each. Individual subarrays are being monitored separately, while embedded thermocouples monitor the temperature of the modules (see box "Photovoltaic system parameters").

In addition to further monitoring of the pv arrays, measurements will be made of the following: air temperature in the office space and atrium, humidity levels in the offices, electrical loads, gas usage and wind speed and direction, along with monitoring the opening of all vents once the space is occupied.

Data from the pv system is to be recorded as ten-minute averages, and then relayed directly to the Newcastle Photovoltaics Application Centre at the University of Northumbria.

Currently, the monitoring information is displayed on a touch screen located in the

PHOTOVOLTAIC SYSTEM PARAMETERS

The photovoltaic (pv) system was commissioned in March 1998, with full monitoring of performance data commencing later that month.

System performance through to the end of May 1998 is shown in table 1. The total system output since monitoring began on 17 March has been calculated at 11 548 kWh, with an average system efficiency of 7·5%. This efficiency has been calculated using the total pv module area, making no allowance for variation in cell density across the facade.

For a system of the same rating using modules of the highest density, this would correspond to a system efficiency of 7·8%. This is only a small correction, since almost 70% of the modules on the system are full density, with a conversion efficiency of around 11·5%.

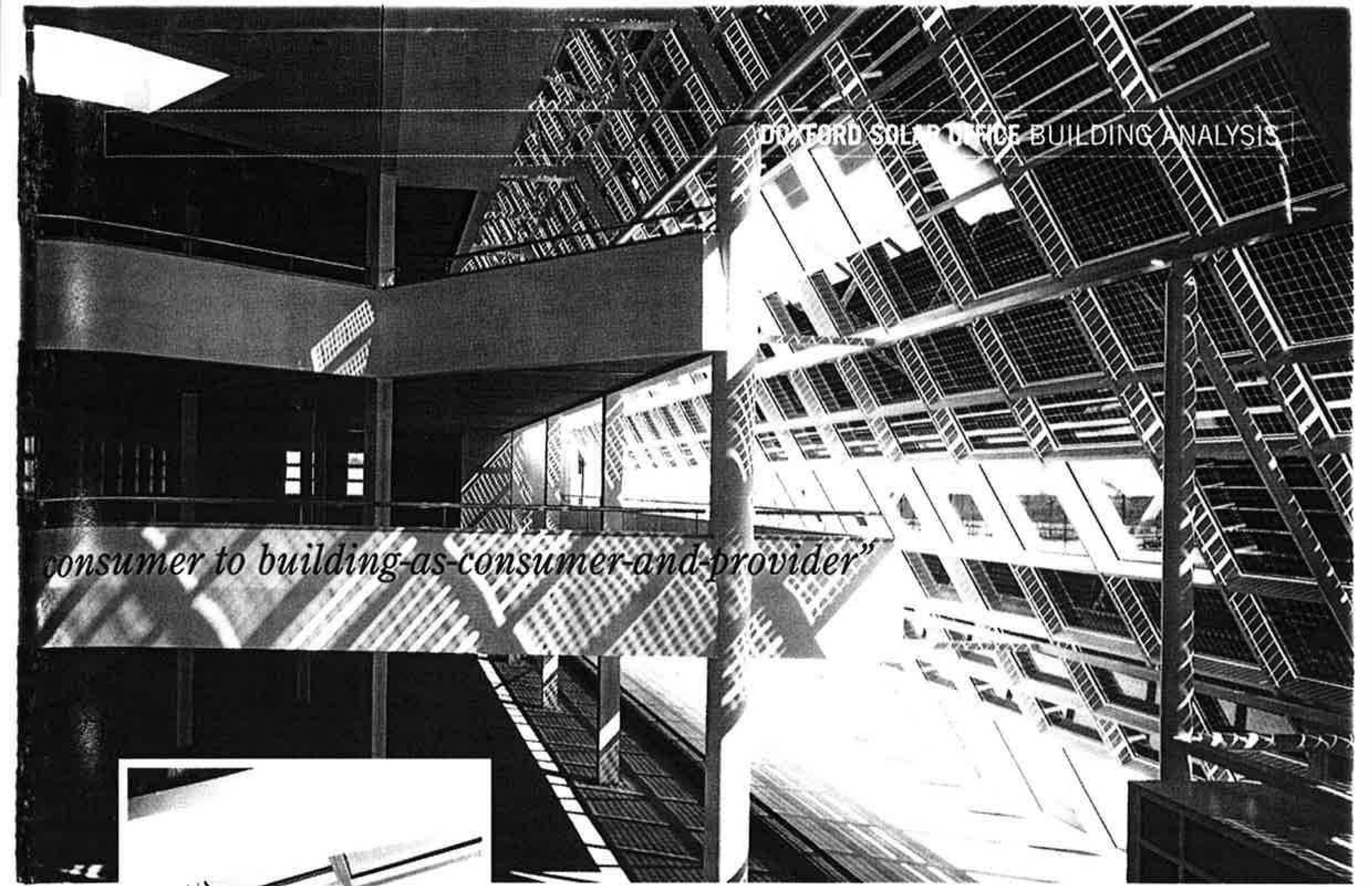
The performance of each pv subarray is also being measured, with the two large subarrays so far showing consistently higher efficiencies than their smaller counterparts.

So far, the large subarrays have shown average efficiencies of 7·8%, compared with 6·1% for the small subarrays. About a third of the observed difference can be assigned to the density of cells, 60% of the strings of the small subarrays being composed of semi-transparent modules.

TABLE 1: SUMMARY OF SYSTEM PARAMETERS AT THE DOXFORD SOLAR OFFICE FOR THE INITIAL OPERATING PERIOD MARCH-MAY 1998

Parameter	March[1]	April	May
System output (kWh ac)	1530	4607	5411
Efficiency (%)	7·5	7·4	7·7
Insolation in-plane (kWh/m²/day)	2·1	3·2	4·1
Insolation (horizontal) (kWh/m²/day)	1·8	2·9	4·1
Ambient temperature (°C)	8·3	6·1	10·7
Performance ratio	0·68	0·68	0·68
Monitoring fraction	97	97	85

[1]Data monitoring commenced on 17 March 1998



ABOVE: The pv wall in relation to the lettable area. The nature of the sunlight penetration will require close control.

Rooflights incorporating actuator-operated windows open and close as part of the ventilation strategy.

Solar Office's atrium, although it is hoped that the same information will soon be made freely available on the Internet[2].

Temperatures of the pv modules are also being recorded to assess their performance as part of a double-glazed unit. In May this year the operating temperature reached 27°C, although further monitoring is needed to assess the reduction in the units' performance. According to Akeler Developments, the units are performing slightly better than expected.

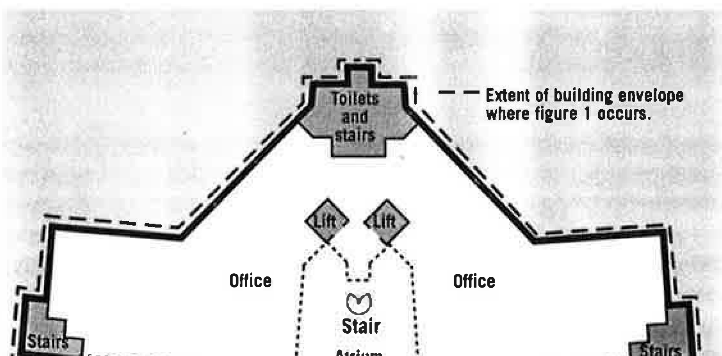
Airtightness

Construction quality appears to be excellent, so perhaps it should be no surprise that the building has achieved an exceptional air leakage result of 3·7 $m^3/h/m^2$ of enclosure at a pressure of 50 Pa. This result is all the more impressive given that current best practice has been set at 5 $m^3/h/m^2$, while the building's target leakage level was 10 $m^3/h/m^2$.

Exceptional results like this are no accident: they are the outcome of hard work and close attention to detail – this building being a very good example.

Minimising infiltration loss was intrinsic to the building's low energy strategy. Stuart Borland, technical director of Building Sciences, worked with Studio E Architects on the infiltration issues. The result was an air barrier formed principally by the plasterboard dry wall lining. Importantly, care had to be taken where the hollow Bison floor beams abut the brickwork facade (figure 1).

The tripartite Schüco windows on the north, west and east elevations were also designed



Detail of the 1285 m² ground floor. The Solar Office can be used as a single corporate facility, or subdivided on either a floor-by-floor or half-floor basis. The minimum suite size is 530 m².

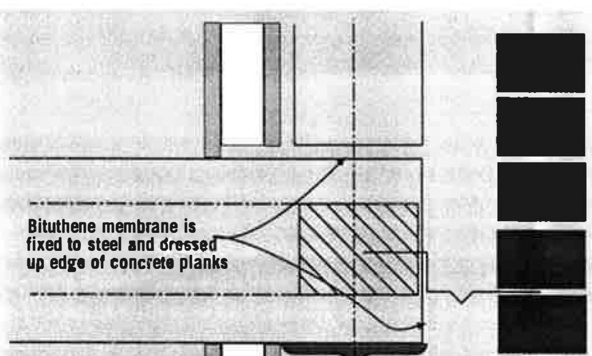


FIGURE 1: Section through the floor/wall junction. Workmanship on the roof junctions had to be well above average.

with a special channel on all four sides to ensure their airtight installation. "Initially, we were in awe of the pressure testing requirement because the specification made it look difficult," said David Scorer, area director of main contractor Bowmer & Kirkland, "especially given the building's original form".

This was the first air leakage test they had been involved in on the Doxford International Business Park, so Building Sciences was retained to regularly visit the site during the construction phase.

"There was a lot of time spent sweating over drawings and details even before work started on site," said Scorer. "Overall, it must have cost us about £30 000 to meet the airtightness specification". Not cheap, then, but the end result has been well worth it.

Innovative design

Ten years ago a speculative office building such as this would have been air conditioned. Even today, with ever-increasing levels of environmental awareness, it still takes a forward looking developer, such as Akeler, to break away from ingrained real estate values.

However, Akeler's far sightedness was aided by the additional cost of the environmental measures (£1·5 million) being covered by the European Regional Development Fund.

The building's architect, David Lloyd Jones of Studio E Architects, believes the Solar Office is "making the leap from building-as-consumer to the building-as-consumer-*and*-provider"[3]. This idea must be generally adopted, he argues, if any real impact is to be made towards the drive for sustainability.

If future tenants opt for the low energy ventilation strategy then it follows that the building's environmental impact will be considerably less than many comparable speculative office developments. However, its success as a low energy office will hinge on tenant commitment, possibly by adapting their way of working to ensure the environmental systems' success.

Currently, the Doxford Solar Office stands empty, awaiting its first occupant. It would be a real tragedy if the building's low energy potential is not fully exploited, both in terms of its environmental credentials and tenant feedback from working in such a building.

The Solar Office, Doxford International Business Park, Sunderland

Client
Akeler Developments
Architect
Studio E Architects
Executive architect
Aukett Associates
M&E consulting engineer
Rybka Battle
Structural engineer
Whitby & Bird
Main contractor
Bowmer & Kirkland
M&E contractor
N G Bailey

Mechanical suppliers
AHUs: Eurocell
Boilers: Hamworthy Heating
Ceiling diffusers: Halton
Control valves: Trend
Dampers: Waterloo Air Management
Drainage (above ground): Terrain
Ductwork: Beacon Industrial Services
Extract fans: Roof Units
Floor grilles: Wade
Flues: Hamworthy Heating Products
Insulation system ductwork and pipework: Beacon Industrial Services
Pumps: Grundfos Pumps
Pressurisation: Boss
Radiators: Acoustics and Envirometrics
Sound attenuation: Allaway Acoustics
Strainers and valves: Hattersley
Water treatment: Fernox
Water heaters: Solectra

Electrical suppliers
BEMS and controls: Trend (via Clover Controls)
Electrical distribution: Groupe Schneider
Electrical accessories: MEM Delta
Fire alarm/detection: Gent
Lifts: Kone
Luminaires: Concord
LV switchgear: Groupe Schneider

External design conditions
Winter: -4°C/sat
Summer (non ac): 23°C db

Internal design conditions
Winter: 21°C minimum
Summer (non a/c): 26°C (maximum) dry resultant temperature (not to be exceeded for more than 2·5% of the year)

U-values (W/m²K)
Photovoltaic wall: 1·2

Structural details
Slab thickness: 200 mm
Clear floor void: 450 mm
Floor-to-ceiling: 2700 mm (3300 mm clear)
Ceiling zone: 600 mm
Live load: 5 KN/m²
Dead load: 4 KN/m²

Occupancy
Offices: 1 person/10 m²

Energy targets (gfa)
Building energy consumption: 85 kWh/m²/y
Fabric leakage: 3·7 m³ per m² of envelope @ 50 Pa

BREEAM rating: Yes (Excellent)

Engineering data
Gross floor area (gfa): 3819 m²
Net usable area: 3601 m²
Atria: 218 m²

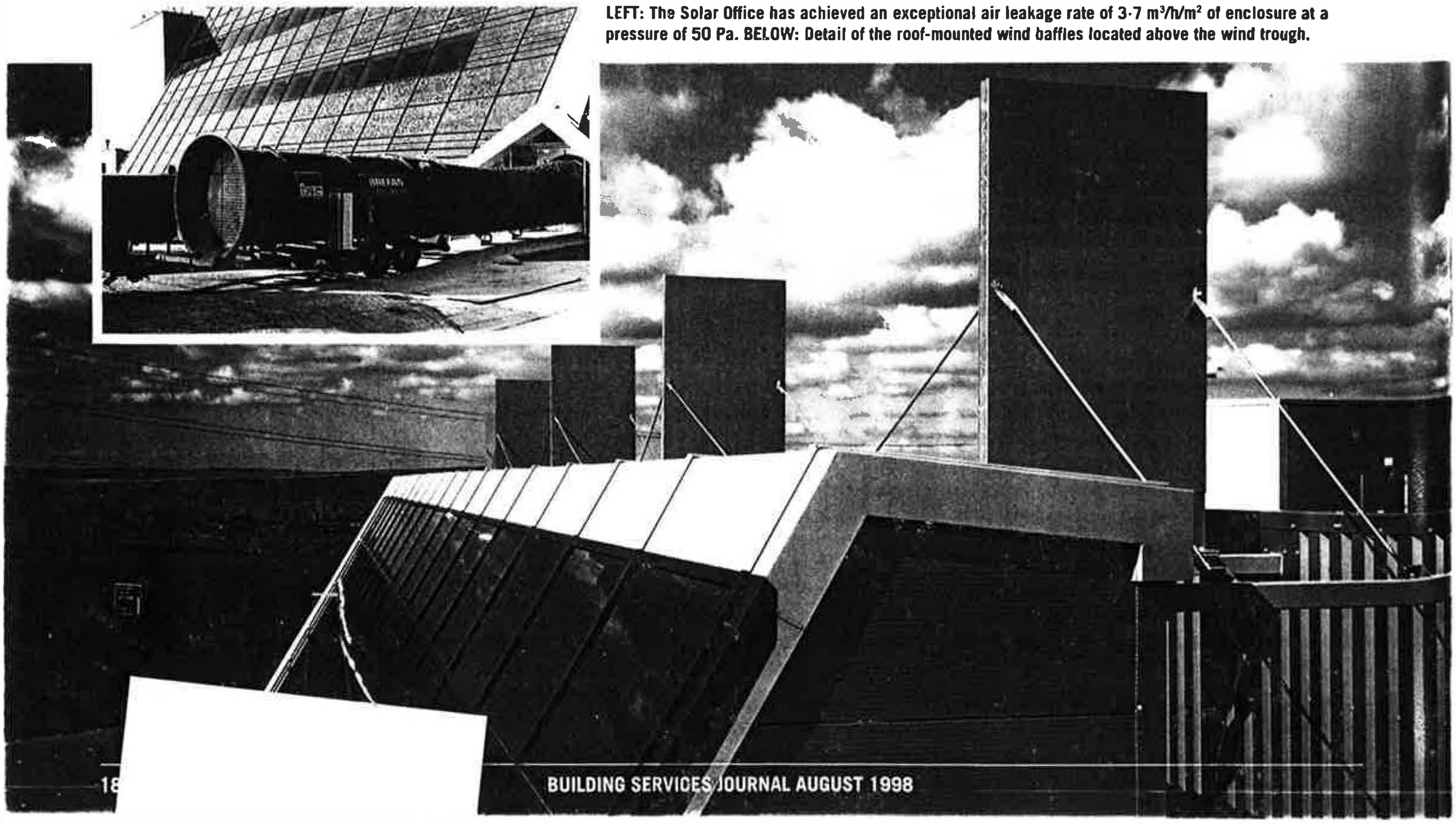
Loads
Equipment: 25 W/m²
Lighting: 15 W/m²
Occupancy: 7 W/m²
Solar gain (winter): 10 W/m³

Lux levels
Office: 300 (design)

Electrical supply
73·1 kW photovoltaic array (55 000 kWh/y expected)

References

[1]Pearson A, 'Generating design', *Building Services Journal*, 7/97.
[2]Information on the Doxford Solar Office is available on the Internet at www.akeler.co.uk/doxford/schuehle/menue.htm.
[3]Lloyd Jones D, *Architecture and the environment: bioclimatic building design*, Laurence King Publishers, 1998 (ISBN 1-85669-103-9).



LEFT: The Solar Office has achieved an exceptional air leakage rate of 3·7 m³/h/m² of enclosure at a pressure of 50 Pa. BELOW: Detail of the roof-mounted wind baffles located above the wind trough.