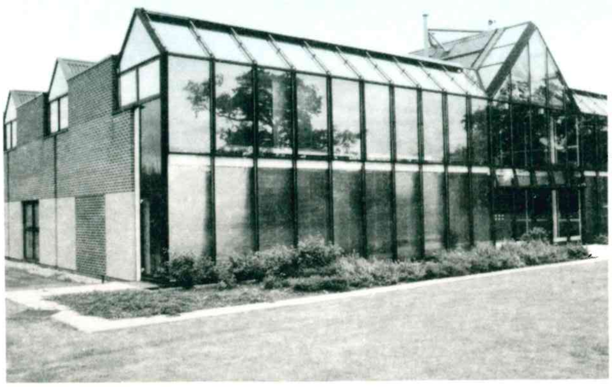
SOLAR ENERGY
A Renewable Energy

SOLAR BUILDING STUDY

Final Report



The JEL Building

ETSU 1160/3

The work described in this report was funded by the Department of Energy and managed by the Energy Technology Support Unit (ETSU) at Harwell. The views and judgements expressed in the report are those of the contractor and do not necessarily reflect those of ETSU or the Department of Energy.

In preparing this report we acknowledge the assistance of the Building Research Establishment, who provide technical consultancy services to the Department of Energy's Passive Solar Design Programme.

"This report is one product of the Energy Performance Assessments project, a programme of field trials in a wide range of occupied buildings, covering the range of UK latitudes and climates.

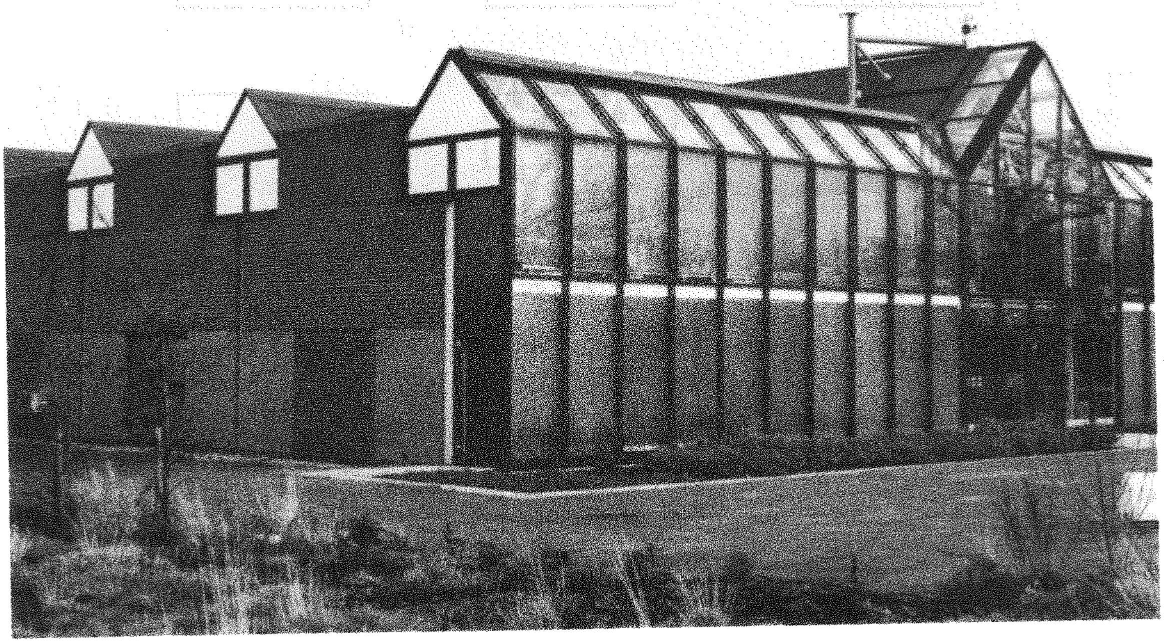
The aim of the field trials is to assess the costs and benefits (energy, financial and amenity/environment) associated with incorporating passive solar principles within building design."

ENERGY PERFORMANCE
ASSESSMENTS

ENERGY PERFORMANCE
ASSESSMENTS

THE JEL BUILDING

STOCKPORT



EPA NON-DOMESTIC TECHNICAL REPORT

DATABUILD LTD

4, Venture Way, Aston Science Park, Birmingham

December 1990

ETSU Report 1160/3

Main author: R.Watkins

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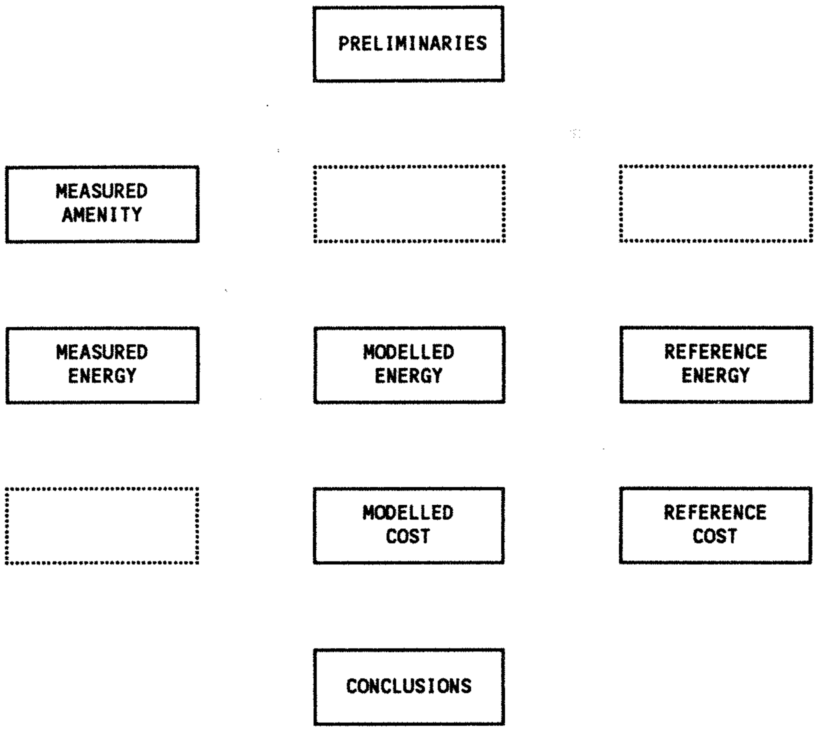
PREFACE

This is the technical report on one of the buildings studied in the Energy Performance Assessment project. The project is sponsored by the Energy Technology Support Unit at Harwell on behalf of the Department of Energy. It aims to accelerate the uptake of designs of low energy passive solar buildings through field trials on occupied buildings. The field trials assess a number of issues as shown in the diagram below; this also indicates the sections of this report. The methodology implicit in the diagram was the result of the first phase of the EPA work. Copies of the technical report, the Solar Building Study and other building reports are available from ETSU, B156, Harwell Laboratories.

The full technical report is summarized in the Solar Building Study which precedes the main text.



Databuild would like to thank all those who have helped with the EPA of the JEL building. In particular, all the staff in the JEL building who have been very helpful while their building has been under scrutiny.

Thanks also go to Roger Francis of Michaelis Francis Le Roith, the architects of the JEL building.

The help received from the Building Research Establishment and others in reviewing the report and methodology is gratefully acknowledged.

The JEL building is currently owned by Thorn Security, a Thorn EMI company.

The work described in this report was carried out under contract as part of the Department of Energy's Renewable Energy Research and Development Programme, managed by the Energy Technology Support Unit (ETSU). The views and judgements expressed in the report are those of the contractor and do not necessarily reflect those of ETSU or the Department of Energy.

Computer modelling work and the evaluation of costs is largely done by YARD and Davis Langdon & Everest, ETSU's Performance Analysis Service and Cost Analysis Service respectively.

SOLAR BUILDING STUDY

EPA SUMMARY REPORT

THE JEL BUILDING

ENERGY PERFORMANCE ASSESSMENTS

Client:
JEL Energy Conservation Services Ltd., but now: Thorn Security Building Management Systems Division.

Architect
Michaelis Francis Le Roith

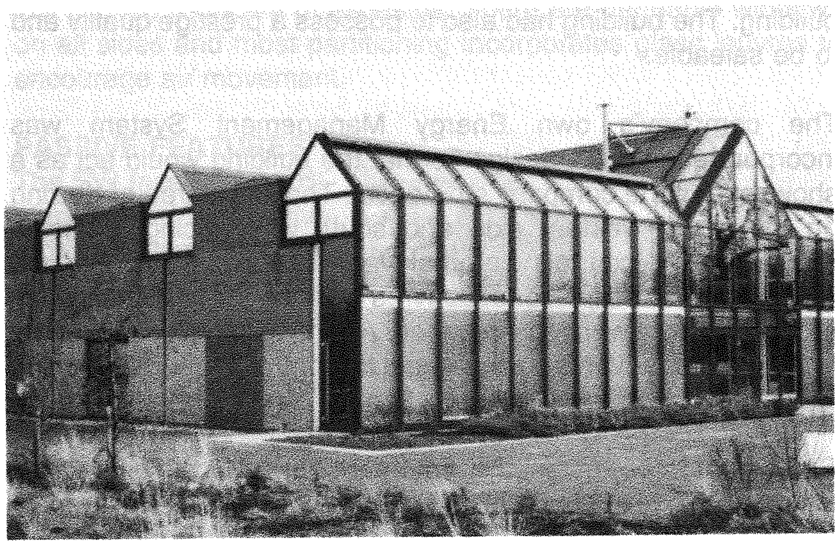
Building Type:
Office & Factory

Solar Features:
100% SW glazing and SW facing rooflights

Location:
Semi-urban, Stockport, Greater Manchester

Date Occupied:
1983

Size:
Gross Floor Area 2087m^2



In the heating season the sun provides heating energy equal to that from the gas boilers.

Total annual energy use is low at 140 kWh of delivered energy per m^2 gross floor area.

Despite solar blinds the building over-heats, particularly during the summer.

The overall cost of the building is near the mean of purpose built steel framed buildings. However, the capital and maintenance costs of the solar blinds have provided a significant cost penalty.

Air quality was criticized by many occupants.

Anti-stratification fans in the production area are not used. This has undermined part of the design and is a cause of discomfort in first floor offices.

EVALUATIONS

ENERGY	★★★★
SOLAR DESIGN	★★
AMENITY	★★
COST	★★★

These ratings are based on 10 months monitoring, interviews, questionnaires, and modelling studies. Five stars indicate an excellent standard, three an average, and one a poor standard.

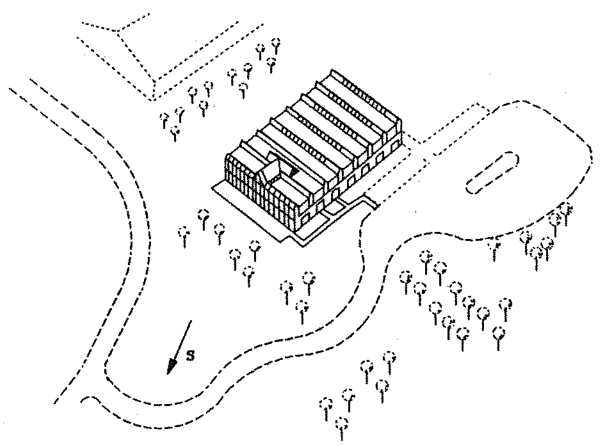
THE BUILDING

DESIGN

In 1982 the then JEL company commissioned a purpose-built new headquarters. The building had to be low energy to reflect the company's commitment to energy efficiency. Passive solar features were allowable if they would help to bring about the aim of halving the energy consumption compared with a conventional building. The building had also to possess a prestige quality and to be saleable.

The company's own Energy Management System was incorporated into the design so that the building would act as a showcase of the company's products. The large area of glazing on the south western side and south west facing rooflights required solar controls (internal venetian blinds and external roller blinds) to be included. Louvres beneath the rooflights in the production area were also planned. A lighting control system was to have taken advantage of daylight by controlling the fluorescent lighting.

Solar heat received in the south western offices was to be distributed to the rest of the building, if appropriate, by fans.



DESCRIPTION

FORM

A two storey rectangular building contains a double height production space which is flanked by two storeys of offices and other cellular accommodation. Management and sales areas are on the SW side; R & D, training and other support functions are on the SE and NW perimeters. The centre of the building is devoted to production and stores and delivery access is through the NE entrance.

Site Data
Latitude 53.2°N
Altitude 100m

Climate Data

Annual:

1988 degree days:	2246
20 year average d.days:	2369
External temperature:	12.8°C
Total solar radiation on horizontal:	945 kWh/m²

October to April inc.:

1988 degree days:	1871
20 year average d.days:	1995
External temperature:	6.0°C
Total solar radiation on horizontal:	278 kWh/m²

Techniques used to optimize benefits were:

- Anti-stratification fans in the production area were to have reduced the temperature gradient, but these are now disabled because they are noisy and draughty.
- Double glazing was used throughout the building.
- The building was divided into three zones for space heating.
- Insulation levels used were higher than contemporary ones.
- Draughtproofing and tightness of construction were emphasized.
- The EMS was to have controlled the use of artificial lighting, so as to take advantage of the large area of glass on the SW side and over the production area.

THE BUILDING

Dimensions:
Floor to ceiling height: variable, from 3m to 7m.

Surface Areas, m²:

Plan area:	1350
Roof area:	1633
Walls inc. glazed side:	798
Windows (NW & SE):	71
Windows (NE):	0
Rooflights (plan area):	118
SW façade:	175
Atrium windows:	45

Volume, m³:

Gross:	9800
Heated:	9000
Atrium:	260

U Values, W/m²/K:

Floor:	0.4
Walls:	0.3
Glazing:	2.9
Roof:	0.2

Envelope Heat Loss, kW/K:

Transmission:	2.0
Infiltration & ventilation:	1.3

Glazing Properties:
Double glazing:

U Value:	2.9 W/m²/K
Daylight transmission:	76%
Solar transmission:	73%

Space Heating:
Installed Capacity:

Heated areas:	79 W/m² heated

Design Condition:

Internal temperature:	21°C

Lighting Installed Capacity:

Total:	8.5 W/m² gross

Design Condition:

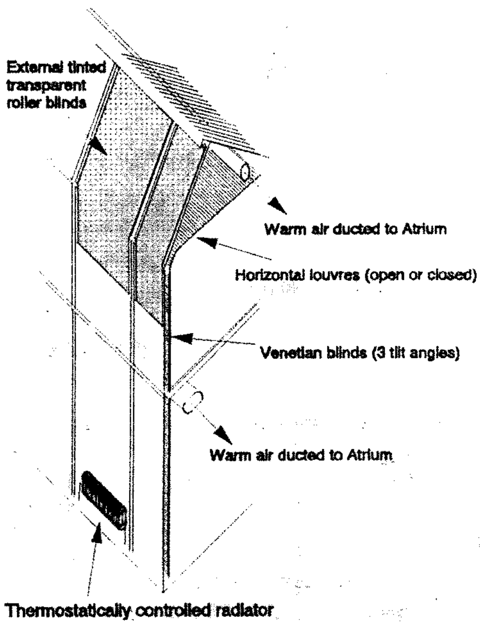
Background:	300 lux
Task lighting:	1000 lux

CONSTRUCTION

A steel frame supports a triangular lattice roof which has an 18m clear span in the centre and 6m cantilevers at either end. Bricks clad all but the SW façade. 75mm of rockwool lies behind these. The first floors are made of pre-cast pre-stressed concrete planks and the ground floor made of reinforced concrete with edge insulation. Triangular roofs are of PVC coated metal and low pitched roofs are of asbestos. There are openable windows on all sides and most partitioning incorporates glass louvres to encourage air movement.

PASSIVE FEATURES

The SW façade is 100% glazed and extensive rooflights face SW. The EMS can activate solar controls to reduce solar gain. External transparent tinted roller blinds can descend from the apex of the roof to the ground floor ceiling level. Internal metallized venetian blinds can be rotated to reflect away the sun, as can horizontal louvres on the first floor.



SERVICES

A 150kW gas boiler heats perimeter radiators in three independent zones and provides hot water to a heater battery. The main fan housed in the latter draws sun-warmed air from the atrium, heats it and discharges it into the production area at high level. There are four anti-stratification fans here designed to pump air from the ceiling level down to floor level. However, they are not used.

Most artificial lighting is provided by 58W fluorescent tubes providing 300 lux. The production area uses high pressure sodium lamps providing 300 lux. Task lamps are also used to give 1000 lux. No artificial-lighting control system has as yet been installed, though this is planned and all wiring for this was done when the building was erected.

Local electric multi-point storage heaters provide hot water.

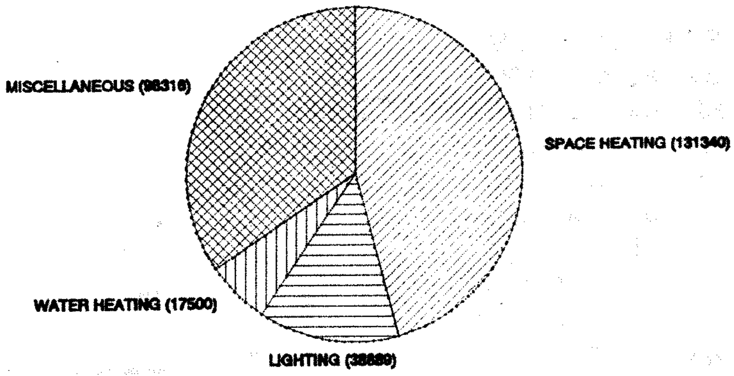
PERFORMANCE

ENERGY AND ENVIRONMENT

All annual data come from monitoring in 1988. The pie diagram shows actual monitored data. The table shows the same data normalized for degree-days; gas use has been normalized to the long term degree-days for the site.

ENERGY

THE USE OF DELIVERED FUEL IN 1988 (Jan to Dec), kWh



FUEL TYPE	USE	NORMALIZED DELIVERED FUEL, kWh/year	
		TOTAL	PER m² GROSS FLOOR AREA
GAS	SPACE HEATING	138533	66.4
ELECTRICITY	LIGHTING	38889	18.6
	WATER HEATING	17500	8.4
	MISCELLANEOUS	98316	47.1
	TOTAL	154705	74.1
TOTAL ENERGY USE:		293238	140.5

The total energy use of 140kWh/m^2 gross floor area/year is low. The high miscellaneous use corresponds to plant such as a chiller for a computer, a desoldering machine, a "soak" testing room, a small amount of catering, photocopiers and many computers.

The total fuel use is much lower than conventional buildings. For comparison, the BRE Low Energy Office consumes the same total delivered fuel. However, 88% of the LEO's energy use is gas (the rest electricity) while the JEL building's split is about even. The JEL building therefore consumes 60% more primary energy (354 kWh/m^2 gross/year compared to the BRE LEO's 221 kWh/m^2 gross/year). The BRE LEO does not have a production area, with high miscellaneous electricity use.

The trend in energy consumption, since the building was first occupied, is for gas consumption to drop and electricity use to increase. The increase in electricity use (which is twice the decrease in gas) is probably accounted for by the stepping-up of production since the factory was built in 1983.

Electricity use does not vary much throughout the year. The ratio of on to off-peak is similarly fairly constant at 4:1.

Off-peak electricity is used for some water heating and for the overnight part of the "soak testing" of circuit boards that the company makes. (Boards are placed in a room that is heated to 50°C.)

Two electric fans are used to move warm air from the SW side of the building. A 0.75 kW fan can draw air from the SW offices into the atrium. A 1.5 kW fan (the "main fan") can draw air from here through a heater battery and pass it to the production area. Air can also be extracted from the atrium to outside by the main fan when it is too warm. The electricity used by these fans is quite small as a proportion of the total annual electricity use - about 1%.

SPACE HEATING

During the heating season, about one third of the energy needed to maintain comfort temperatures within the building is provided by the heat from the sun. Another third is supplied by internal gain from electrical appliances and the final third from the gas heating system. The solar displaced gas is a substantial amount of energy; it would have cost about £1800 at 1989 prices.

The EMS has an optimizer to control the pre-heating of the building to the target temperatures, ready for start of work at 08.30. Over a year, about 45% of gas is used during the pre-heat period, when there is little or no solar gain.

Energy used for space heating by gas is low at 66 kWh/m^2 gross/year. The temperatures demanded in the offices are about 21°C and a few degrees higher in the large production area. Temperatures often rise above 26°C in the summer months. Heating in the monitored year of 1988 was off from 13th May to 26th September.

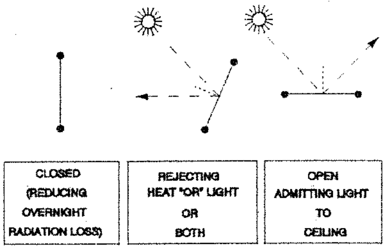
LIGHTING

The estimated lighting energy is low though about three times that of the BRE LEO. It is similar to that of another low energy building, the South Staffordshire Water Company's headquarters. Although the design of the building envisaged the EMS controlling lighting throughout the building no system was in fact installed, despite all necessary wiring having been done. This may be remedied in the future. Manual switching is the only control over artificial lighting at present.

Lights are normally switched on by the first person in and switched off at the end of the day by the cleaners.

The EMS does control incoming daylight in the south western offices, in two ways. The internal venetian blinds will rotate so as to reflect light back out of the building if the internal light level at ceiling level on the first floor rises above 9000 lux. This action is also triggered if the temperature rises above 22°C. The horizontal louvres overhead on the first floor will close on the same light trigger, but are not triggered by temperature.

The internal venetian blinds on the SW side can adopt three positions, shown below in cross-section.



They are closed automatically overnight to reduce heat loss. Modulation of all blinds takes place very quickly, in seconds. This can be rather abrupt for those workers near the SW windows.

PASSIVE SOLAR FEATURE

The passive solar feature is the large amount of glazing forming the south western façade, together with rooflights. It is really a hybrid solar building as it depends on electric fans to distribute the heat from the SW offices to the rest of the building.

To illustrate the evidence for how much the sun affects the JEL building, the monthly use of space heating energy can be plotted against the intensity of the sun in the same months. Two factors have to be allowed for. Because outside temperature varies we use the amount of space heating energy used for each degree centigrade that the building is warmer than outside. Because sunnier months are often warmer months (and so less energy would be used anyway for space heating) we look at the amount of solar energy available for each degree centigrade of temperature difference. (Space heating energy here includes contributions from internal gains as well as gas.)

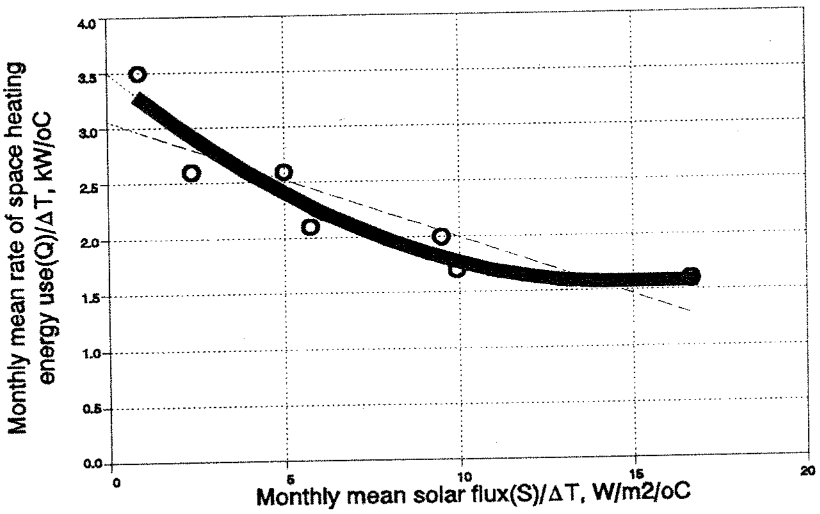
Substantial heating energy is saved through solar displacement. However, the large amount of glazing presents a potential for displacing lighting energy. This is not realized because of the lack of any automatic artificial lighting control.

Because the base load of electricity use is high, less use can be made of the heat from the sun. Such internal gain also exacerbates problems of over heating in the summer.

PERFORMANCE

These values have been converted to a rate of energy use (W or kW/°C) and plotted below. The figure illustrates how the rate at which energy must be supplied to this building to keep it one degree warmer than outside decreases in months when there's more sun per degree centigrade of temperature difference.

The Reduction in Space Heating Energy as the Availability of Solar Energy Increases



THESE MEASURED MONTHLY DATA SHOW THAT INCREASING AVAILABILITY OF SOLAR ENERGY/ΔT IS STRONGLY RELATED TO A DECREASE IN THE USE OF SPACE HEATING ENERGY/ΔT.

AMENITY

The success of the design in saving energy has been accompanied by penalties in the occupants' comfort. Over-heating in the summer months has caused great discomfort , particularly to those working on the SW side on the ground floor. During the ten months' monitoring there were 72 days when the temperature in a ground floor office exceeded 26.5°C. (42 of these days were outside the summertime.) Air quality was widely complained of by occupants who answered a questionnaire and this is probably owing to the tightness of construction and to the disabling of the fresh air intake on the air heating system. This disablement also meant that it was no longer possible to use the main fan for overnight summertime cooling.

BUILDING COST

Designing for the sun did not significantly increase capital costs. The cost of the building was £477/m^2 (adjusted to 1989 prices) and this lay near the mean of a sample of costs of purpose-built factories and offices with mixed facilities that were considered for comparison. (The BRE Low Energy Office building cost £700/m^2 at 1989 prices.) The blinds were expensive and the external ones in particular require maintenance three or four times a year by an outside contractor. This is a significant cost to set off against the money saved on energy.

The graph on the left shows how the rate at which heat was used for each degree centigrade of difference between the internal and external temperature DECREASED as the rate of solar energy falling on the building per degree ΔT INCREASED. The strength of this relationship is a measure of how passive solar the building is.

Two regression lines have been fitted. The first assumes a linear relationship; the second more describes the data as measured. The linear fit provides an average or seasonal value for the effect of the sun on heating energy. The curved fit roughly describes the reduction of the effective solar aperture with the increasing availability of sun per degree ΔT.

The gradient of the line gives the solar aperture, and the intercept (with the Q axis) the heat loss coefficient. The solar aperture is a notional equivalent flat area facing a particular direction that receives the same solar energy as the whole building has effectively absorbed. (In the case of the curved (fitted quadratic) line, the gradient at the steepest point has been taken for the information below - at its intercept with the y-axis.

Linear fit:
r^2=0.70 (n=7)
Heat loss coeff.: 3.06 kW/°C
Solar aperture: 100 m^2

Quadratic fit:
r^2=0.90 (n=7)
Heat loss coeff.: 3.51 kW/°C
Solar aperture: 250 m^2

These calculated heat loss coefficients compare well with the theoretically predicted heat loss coefficient of 3.3 kW/°C.

The solar apertures may be compared with the 220 m^2 of glass on the SW façade and 118 m^2 projected area of rooflights facing SW - 338 m^2 in all.

Some aspects of amenity are conclusive: summer over-heating and poor air quality. However, questionnaires were received back from less than half the workforce and this undermines the confidence in some other conclusions. The following were also reported: glare and winter under-heating in the production area; noise from equipment; dislike of the effect of the solar controls (blinds) on the working environment in the SW offices.

EVALUATIONS

The star ratings are evaluations based on all of the information gathered during the period of study, and are brought together here to give a comprehensive judgement of the building. Five stars indicate an excellent standard, three an average, and one a poor standard.

ENERGY ★★★★

This rating is given for the whole building. It has a very good normalized energy consumption of 140 kWh/m^2/year of delivered energy. This is about the same as the similarly sized BRE LEO. It also satisfies or is much better than a range of standard energy performance indices. Even if almost zero solar gain were received, the annual energy use would still be categorized as good (the best category given) by the CIBSE Energy Code Part 4's Energy Performance Indicators.

SOLAR DESIGN ★★

The building was designed to be striking and to be low energy through reducing heat loss and increasing solar gain. All have been achieved. However, controlling the solar gain requires complex services and these have proved insufficient to cope with the level of gain in summer. The external roller blinds are unreliable. Simulation modelling has suggested that the SW façade could be only 50% glazed and still maintain space heating performance.

AMENITY ★★

The majority of respondents liked the building itself much better than the environment it gave to their workspace. There was a common dissatisfaction with thermal comfort in summer, air quality and the ease with which temperatures could be controlled. Lighting levels were mostly thought to be adequate, except in the production area in Winter.

COST ★★★

The JEL factory is more expensive than a traditional factory, but good value for an office. The company were well pleased with their new headquarters. The cost of the solar rejection devices (about 4% of the total building cost) is high, but they are integral to the design which allows solar gain to displace about £2000/year worth of gas use (in 1989 prices). However, maintenance costs of the blinds must reduce the savings by half.

COMPOSITE ★★

The JEL building performs well in energy terms and its total cost is average. However, the design was ambitious and the 100% glazed south western façade causes problems; solar controls are essential, but, even when they are working, they are inadequate. The design yielded an appropriate image, but also resulted in excessive over-heating and costly blinds' maintenance.

ASSESSMENT

CONCLUSIONS

The design of the JEL building satisfied the client's brief; to provide a low energy prestige headquarters that could display the company's products. The low energy consumption is impressive, and a substantial part of the total energy need comes from the sun. Of all the energy that contributes to space heating in the heating season, the sun provides roughly one third. Electricity and gas each provide another third.

The impressive performance has not been achieved without penalty. Air quality has suffered and over-heating can be a severe problem affecting many workers.

The building's cost was typical for its type: good value for an office: dearer than a factory. However the blinds were costly to install and are costly to maintain. The design relies on blinds and other services to try and maintain comfortable working conditions. These have proved insufficient.

LESSONS & RECOMMENDATIONS

The comments below are extracted from the full technical report on the monitoring of the JEL building.

1. This design of direct gain building requires services to be more reliable than is realistic. The bold design to capture so much heating energy from the sun has brought with it other problems.

2. Subsequent direct gain designs should have reduced glazing, be orientated more towards the east, and avoid moveable external blinds. The latter are very problematical.

There are several things that can be done to improve conditions:

3. The main fan should be used to force-dump warm air during the summer. This facility is currently not used.

4. The fresh air intake dampers should be re-enabled. This would help to improve the air quality and would allow the main fan to be used overnight to bring in cool air into the production area to reduce over-heating later in the day.

5. Consideration should be given to modifying or replacing the four anti-stratification fans in the production area, so that they can be used again.

6. The solar control devices should be operated at weekends for the benefit of occupants who work then, and so that the building is cooler on Monday morning, during the summer.

FURTHER INFORMATION

EPA Technical Report on the JEL building, available from ETSU.

The building's designers, Michaelis Francis Le Roith, Bay 8, 16, South Wharf Rd., London.

Architects' Journal, Building Study on the JEL building, 13th July 1983, and further comments in the 14th November 1984 issue. The Architects' Journal, 9 Queen Anne's Gate, London.

ETSU Renewable Energy Enquiries Bureau: Telephone: 0235-432450.

Solar Building Studies are summary reports of the Energy Performance Assessment project. This is funded by the Department of Energy through its Energy Technology Support Unit at Harwell. The R & D is carried out by Databuild (Birmingham) and UWCC (Cardiff). The views contained in this document are those of the authors. The EPA of the JEL building was carried out by Databuild (Birmingham).

The co-operation and assistance of all those concerned with the building reported here is gratefully acknowledged: owners, designers and occupants.

THE JEL BUILDING, STOCKPORT

EPA NON-DOMESTIC TECHNICAL REPORT

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