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A Performance Specification for the Energy Efficient Office of the Future

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CONTENTS

1. Introduction

1.1 Background

The primary objective of the Energy Efficient Office of the Future (EOF) project is to demonstrate the principles of design, construction, and management for a future building that meets the occupants' expectations of a comfortable and healthy environment in an energy efficient manner. To achieve this objective there is a need to identify new or emerging areas of technology, and to refine existing techniques and design practice.

The purpose of the EOF project is to act as a catalyst to accelerate the development of these technologies and techniques and to encourage their replication. As part of this process, a building will be designed and built as an EOF exemplar, which will incorporate some of the new techniques and technologies identified by the EOF Group. The building is intended to represent best practice at the year 2000 and will meet the energy and environmental targets currently anticipated in the early part of the 21st century.

The design approach for the EOF should address the following issues in order to realise design intent and achieve the desired performance from the building:

1. reduce energy loads wherever possible;
2. provide energy input as efficiently as possible;
3. minimise plant operation times - default to 'off' or 'standby';
4. use the simplest solutions that will satisfy the client's requirements and be manageable by the end user.

1.2 Office Energy Use

The strategic approach to the EOF has been based upon an understanding of how the current office stock utilises energy and upon probable future trends. Current total energy consumption of offices in the UK building stock is difficult to evaluate. BRE estimates the energy use of commercial and public sector offices to be 32 TWh (115 PJ) per annum[1.1], over 15% of which is attributable to air-conditioning.

One of the largest single components of energy consumption is lighting, which can account for up to 50% of electrical energy use. Also significant is electrical energy use by fans and pumps, typically 20-30% for an air-conditioned building. When considering the task of improving the energy efficiency of an office building, the reduction of lighting energy use and avoidance of air-conditioning should be targeted to ensure maximum returns.

1.3 Lighting

Lighting control, or more specifically the effective utilisation of daylighting, is a critical factor in any energy efficiency strategy related to buildings. Additionally, lighting controls can have an important role to play in turning the lighting off when the space is unoccupied. The desired result is to reduce lighting energy consumption and the associated heat gains. Results from various field trials have shown that daylight can be poorly utilised even where a building is designed for daylighting. Lighting controls can sometimes be disabled and installations run with lighting on 100% of the time[1.2]. Increasingly, with the wider use of visual display terminals (VDTs) in offices, glare can become a problem and occupants will resort to 'blinds down - lights on' operation to overcome this. The correct design of a control system which allowed sufficient flexibility, coupled with user education, would help to overcome some of these problems.

Any future design must therefore tackle the problem of the provision of an acceptable level of daylighting within the constraint of minimal total energy consumption, considering heating, cooling and lighting energy use. It must provide a control system which is effective in utilising daylight without robbing the occupant of personal control. Visual comfort must also be considered in this strategy, particularly in the case of disabling glare and its effects on the VDT user.

1.4 Air-conditioning

Over the last decade, the use of air-conditioning in offices has increased by a factor of three in the UK, and air-conditioned space now represents approximately 15% of UK office space[1.3]. This increase has been prompted for a variety of reasons:

1 client demand, institutional requirements, and market perception;

2 deeper plan construction;

3 increasing external pollution and noise;

4 higher internal heat gains - principally emanating from small power loads;

5 a spate of hot summers encouraging owners to install air-conditioning equipment.

To developers and letting agents, air-conditioning is seen as a better investment where the market can bear higher rental levels. Conversely, buildings which are naturally ventilated are generally perceived to be less prestigious and hence command lower rental values. Designing for natural ventilation traditionally offers less predictable and precise control over the indoor environment. Recent research at BRE and elsewhere, however, has shown that provided the occupants themselves can exercise a degree of control, they often prefer this to the less user-orientated control structure of conventional air-conditioning installations.

Designing for energy efficiency in future offices must challenge existing conventions and not be thought of predominantly in terms of providing air-conditioning. Consideration must be given to the environmental benefits of improving the building's thermal characteristics, and of applying passive control measures to reduce dependency on air-conditioning. Specialised areas with high heat gains can be grouped and air-conditioned separately from the rest of the building. What might only be a small proportion of the building will therefore not prejudice the rest of the design which may function satisfactorily with a 'heated only, naturally ventilated' arrangement.

1.5 Designing for Comfort

Successful office designs should address the issues of productivity, health and comfort of the occupants at the same time as the energy efficiency of the building. The occupant expectation of a comfortable and healthy environment must not be underestimated since this will be inextricably linked with productivity, although this is almost impossible to show quantitatively. The perception of the quality of the internal environment will be heavily influenced by the occupant's desire to be in control of heating, cooling, lighting and ventilation in the work space. A degree of individual control is seen as essential, so long as it is kept within the constraints of overall effective management to prevent the abuse of environmental systems and energy wastage.

1.6 Passive Design

In order to achieve the objectives listed in 1.1, a design that pursues passive control of the environment is the preferred option. The application of passive solar features to reduce a building's susceptibility to solar gain is essential to minimise, or preferably avoid, the use of air-conditioning. Consideration is to be given in the design to natural wind and buoyancy effects to promote air movement through the building and minimise the energy used by large air handling plant. These technologies are not new but certainly need refinement to enable effective application and integration with the control and management systems of the office of the future.

1.7 Building Plan

Narrow plan construction is demonstrably better suited to the use of natural ventilation and daylighting. In narrow plan construction the application of daylit, naturally ventilated solutions is relatively straightforward. A good design, which is well implemented and managed, will operate with a low energy consumption.

The primary focus of the EOF project is to address the issue of extending the application of daylit, naturally ventilated solutions into buildings that would ordinarily require air-conditioning. Examples include the design of energy efficient buildings which are located on sites with high levels of external pollution and noise, and buildings constructed with plan depths in excess of 15 m where conventional heated only, natural ventilated solutions may not work. It should be emphasised that deep plan buildings are not being cited as exemplar low energy buildings, but they do offer greater potential for energy savings which makes them reasonable buildings to target.

However, it must be stressed that the technologies and techniques being considered will be applicable in all buildings. It is of prime importance that the EOF features can be replicated in all construction types: deep plan as well as narrow plan, urban sites as well as greenfield sites.

The features of an EOF building could also be considered for application in major refurbishments. This area of the property market is seen as vitally important in the replication of the energy efficient measures demonstrated in the EOF. In May 1992[1.4] it was estimated that in London alone surplus office space was of the order of 4×10^6 m^2. Of this surplus stock, 49% was in older non-refurbished buildings which may not be occupied again before major refurbishment or redevelopment is carried out.

1.8 The Design Brief for an Energy Efficient Office of the Future

The development of the brief for the EOF will include consideration of the following elements:

1. detailed user needs;
2. selection from a range of appropriate technologies and innovative design ideas (this includes technologies whose prototypes are currently high cost but whose developed production versions could be demonstrated to be cost-effective);
3. maximised passive environmental control, minimised complex HVAC services;
4. energy efficiency considered at all stages, from concept to completion;
5. comfort and health standards to be optimised;
6. buildability;
7. on-site/modular/pre-fab construction opportunities;
8. consideration of the environmental impact of the building on its surroundings and vice versa (this would be covered in detail by an assessment method such as BREEAM);
9. sufficient flexibility built into the design to accommodate medium and long term changes in technology, demographics, climate and future working practices (eg designing for demountable partitioning, highly zoned control systems, modular central and local services);
10. commissioning to appropriately specified criteria;
11. training of building occupiers in the correct operation of the installed environmental systems.

References

1.1 CIRIA, Environmental Issues In Construction, 1992

1.2 BORDASS WT, Integrated Daylight, Solar and Lighting Control in Open-planned Office - opportunity or fantasy, May 1992

1.3 BORDASS WT, How much do offices really need air-conditioning?

1.4 THE DAILY TELEGRAPH/PROVISION, Survey of London Office Floorspace, The Daily Telegraph, 4 August, 1992

2 **PERFORMANCE TARGETS**

The very nature of the EOF building requires it to achieve a superior performance when compared to that of contemporary low energy buildings. The targets set for the EOF in this section are based on:

1. annual energy consumption;
2. greenhouse gas emissions associated with annual energy use.

These two targets alone will not define the success of an EOF. There must also be a consideration of the building total cost-in-use (ie capital, energy and maintenance costs) which would aim to be no greater than that of other contemporary offices.

2.1 **Energy and Cost Targets**

2.1.1 The provisional energy target for the EOF building is an improvement of approximately 30% over current low energy offices (see Appendix A). The annual energy target indicators are shown in table 1 and are expressed in terms of annual energy use per square metre of treated floor area by various end uses.

The target for a building will represent the optimum performance from the building, operating under good control, good maintenance and good management. In order to fully understand the pattern of energy use and realistically judge the performance of the EOF it is important to disaggregate the consumption by end use, eg HVAC, lighting and process loads.

Within process loads one would include computer suite energy, catering, etc. Having a large computer suite within the building could, in some instances, lead to 100 kWh/m^2 or more of additional electrical energy use. This would unfairly weight a single figure energy indicator and hide the building's true energy performance. Therefore it may be best to separate energy use of these process loads from the HVAC and lighting energy use. The interaction in the form of heat gain will however, reduce any space heating energy consumption and increase any mechanical cooling or ventilation energy. These interactions must be accounted for. Probably the most reliable way of accounting for the effects of internal heat gain is to modify the HVAC target with reference to the internal heat gain for a specific building. Where opportunities exist consider the exploitation of process loads.

Two things emerge from this:

1. the target will be building specific, that is taking into account the particular occupancy patterns and activities carried out in that building;
2. the target will be multi-faceted, having components for HVAC loads and lighting energy use.

On this basis the energy target would depend upon the specific characteristics of a given building. The data in table 1 should therefore only be used as an indicator.

Since the limitations of an existing building's construction would naturally restrict the energy efficient measures which could be applied, the energy targets for refurbishment would in general be higher than for new build.

2.1.2 The combination of capital, energy and maintenance costs in a total cost-in-use analysis should be no greater than that of contemporary low energy buildings.

The EOF exemplar building will in all probability use technologies which are in the early phase of development, and hence have prototype plant and materials at high capital cost. An objective judgement will be made in the life cycle costing calculation of the likely reductions in cost once these technologies move into their production form.

TABLE 1 ANNUAL ENERGY PERFORMANCE TARGETS

Based on energy and fuel consumptions from current best practice buildings

Component load	Narrow plan building Gas and electric (kWh/m^2)	Narrow plan building All electric (kWh/m^2)	Deep plan building Gas and electric (kWh/m^2)	Deep plan building All electric (kWh/m^2)
Lighting (2)	10	10	15	15
Fans and pumps (1)	6	3	8	5
Small power(4)	20	20	20	20
Space heating	40	30	40	30
Domestic hot water supply	7	5	7	5
Total electricity	36	68	43	75
Total gas	47	–	47	–
Carbon dioxide emissions (3) (kg/m^2)	34	47	39	52

Note: Floor area based on treated area

Notes

1. 3 kWh/m^2 has been allowed in narrow plan buildings and 5 kWh/m^2 in deep plan buildings for mechanical ventilation during the winter months to guarantee minimum fresh air requirements as required by clause 6.1.5 of the Performance Specification.
2. Lighting energy consumption has been determined on the assumption that automatic lighting control is used with provision for occupant override.
3. The carbon dioxide emission factors used in this analysis are the figures likely to be used in the next revision of BREEAM:

   Electricity 0.62 kg/kWh, Natural gas 0.2 kg/kWh

   It is important to note that these factors account for CO_2 alone and do not take into account the global warming potential of other gases such as methane and NO_x. In order to do this an equivalent CO_2 factor needs to be used for both gas and electricity. There is some disagreement about accurate figures for this.
4. An average small power load of 10 W/m^2 has been assumed (averaged over the occupied period).

2.1.3

Variations should be made to the provisional targets given in table 1 to account for buildings: where air-conditioning is essential; which have high business machine usage; or with different patterns of use.

As already noted, those buildings that have high small power and computer consumption can add in excess of 100 kWh/m^2 to the total electricity consumption. This component of energy use does not reflect on the buildings' thermal characteristics or energy efficiency, although there will be some effect on heating energy consumption. These 'process' loads must be identified in the target as not contributing to the measure of energy efficiency of building or system.

2.2 Greenhouse Gas Emissions

The carbon dioxide production related to energy use in the EOF building should be commensurate with levels indicated in table 1, expressed as kg CO_2 per square metre of treated floor area.

Ideally it would be possible to account for all the greenhouse gas emissions that are associated with building energy consumption by using a CO_2 equivalent factor which accounted for the global warming potential of other gases contained within each fuel, such as methane and NO_2. There are problems associated with deriving these figures, and hence they have not been used here. Further information can be obtained from an ETSU study[2.1] which accounts for fuel extraction, processing, transport, generation, distribution and utilisation. However this study is now several years old and has not been updated.

2.3 Energy Content of Building Material

2.3.1

It is important to consider the effects of durability, maintenance, repair, decoration, and expected life of a building in embodied energy calculations.

Embodied energy (the energy used to produce and transport building products) is an important component of the total energy use related to buildings and construction. However, there is no generally accepted methodology for calculating the embodied energy of building products, so at present any values of embodied energy should be viewed with caution. In a wider context it should be remembered that embodied energy is unlikely to be the most significant environmental effect associated with a building product.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
2.4	**Renewable Energy**	The use of renewable energy sources will allow the energy and emission targets to be met more readily. Government policy is to stimulate the development of new and renewable energy sources wherever they have prospects of being economically attractive and environmentally acceptable, in order to contribute to: **1** diverse, secure and sustainable energy supplies; **2** reduction in the emission of pollutants; **3** encouragement of internationally competitive industries
2.4.1	The application of renewable energy sources should be considered as part of the energy supply strategy for the EOF. Primarily this will concern the use of solar energy to heat, cool, light, and produce power for the building. Other forms of renewable sources should be considered if they can be demonstrated to be practicable, and appropriate to the size of the building.	
2.4.2	Photovoltaic solar systems can be considered for incorporation into the facade or roof elements to provide electrical power for loads in the building, with surplus power exported to the grid.	The economic application of these systems depends on the scope for displacing conventional cladding and roofing materials. Only a small number of pilot schemes exist at present. The costs of photovoltaic systems are currently high, but are expected to fall.

References

2.1 EYRE NJ, MICHAELIS LA. The impact of UK electricity, gas and oil use on global warming. ETSU, 1991

3. THE INTERNAL ENVIRONMENT

3.1 Thermal Comfort

In the selection of design criteria for the EOF, occupant health and comfort is paramount, but due consideration must also be given to the ramifications for energy usage.

3.1.1

Summer Internal Criteria

The building should be designed not to exceed a dry resultant temperature of 28°C for more than 1% of the year and not to exceed 25°C for more than 5% of the year. Air movement in a naturally ventilated building may be used to offset higher dry bulb temperatures, but the air velocity should not exceed 0.8 m/s for cooling. If the moving air is lower in temperature than the bulk air condition then an air movement limit of 0.2 m/s should be used.

Application note: The meteorological data used for the overheating analysis shall be from a 'sample' year. To determine the sample year, rank the last 20 years according to average daily mean temperature (using June, July and August only). Once ranked, designate the mid year of the upper quartile the sample year.

For conditions where the supply air is above 23°C (summertime) the higher velocity limit will apply.

3.1.2

The current guidance on thermal comfort provided in the CIBSE Guide, Volume A[3.1] should be used to select a design dry resultant temperature. If the space is likely to suffer from excessive air movement or variations in relative humidity, ISO 7730 should be consulted[3.2].

Application note: The use of a predictive model such as the predicted mean vote (PMV) method[3.2] is imperfect in a naturally ventilated building. The adaptative model[3.3] is likely to be preferable. However, as this is not yet sufficiently developed, the CIBSE method[3.1] is an intermediate measure. Note that the sensation of comfort will depend on a number of other factors that are not so readily quantified, not least the effects of individual occupant control which is simple and responsive. The validity of thermal comfort models, including the PMV and adaptational models, in predicting comfort temperatures in naturally ventilated and air-conditioned buildings is discussed in BRE conference proceedings[3.4].

3.1.3

Within the context of 3.1.1 and 3.1.2, vertical temperature gradients should be limited to no more than 3°C through the occupied zone[3.2], and a maximum radiation asymmetry of 10°C for a cold vertical surface, 5°C for a warm ceiling.

Application note: For mainly sedentary activity this will be the vertical temperature gradient measured between 0.1 m and 1.1 m. For mainly standing activity this gradient will be measured between 0.1 m and 1.8 m.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
3.1.4	For general office applications standard design recommendations for humidity limits would apply - ranging between 40% and 70% for air-conditioned spaces. For naturally ventilated spaces a free swing in humidity conditions is an inherent characteristic of the design. However, humidity control in these spaces will require consideration in view of recent HSE legislation affecting environmental conditions in the workplace[3.5, 3.6].	Excessively low humidity levels can be experienced in winter. To date, the studies of low rh (< 30%) have been inconclusive, although there are concerns about its effects on the respiratory tract and about the incidence of static electricity. Health and Safety (Display Screen Equipment) Regulations 1992, have called for reasonable humidity levels to be maintained in all buildings where VDTs are used. The Regulations came into force for new installations on 1 January 1992 and will apply in existing buildings from December 1996.
3.1.5	The decision on the external design condition is one that is influenced by the client, based on the acceptable level of risk in maintaining the desired internal environment.	The decision to use, for example, a winter design condition which is only exceeded for say 1% or 2% of the winter hours will depend upon the need to maintain design conditions weighed against the capital expenditure of building and systems used to guarantee them.
3.2	**Visual Environment**	
3.2.1	Standards for the EOF visual environment will follow the recommendations laid down in the CIBSE Code for interior lighting, 1994; CIBSE Lighting guide LG3: Areas for VDTs; and CIBSE Applications Manual AM2 Window Design.	Specify the use of high efficiency lighting equipment. Attention should be paid to occupant requirements and preferences as well as energy efficiency when considering both the lighting itself and the control systems.
3.2.2	Consideration should be given to the integration of high efficiency task lighting with scheme lighting to reduce overall installed loads.	
3.2.3	Highest possible daylight factors should be aimed for within the constraints of minimum total energy consumption considering aggregated use of lighting, cooling and space heating energy. BS 8206 Part 2 gives recommendations on satisfying the requirement for a 'view out'.	Note that daylight itself is an example of a 'renewable' energy option. Design features to be considered include orientation, layout, glazing areas, etc.
3.2.4	Attention should be paid to the lighting strategy to be used in common 'unowned' areas.	A recent (as yet unpublished) study has shown that lighting in common 'unowned' areas such as corridors and atria is frequently on when the space is unoccupied or well daylit. Additionally, corridors are often overlit. They do not need illuminances as high as office work areas, but have often been carved out of the floor of a building which has been uniformly lit over its entire area.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
3.2.5	Provision of sun screening and solar protective glazing should be assessed in the same fashion as indicated in 3.2.3 (see also 3.2.6).	
3.2.6	Measures should be taken to ensure visual comfort, particularly avoidance of glare at the perimeter.	The use of light shelves, mirrored louvres and prismatic glazing, whilst not appreciably improving daylighting levels deep within an interior, can assist in achieving comfort conditions by providing shading near to the perimeter.
3.2.7	The application of solar protective glasses, where it is deemed necessary, should be considered with the following restrictions. **1** Solar control glass and clear glass should not be used in circumstances where both can be seen simultaneously. Where opening windows containing tinted glass are used for ventilation purposes, the size and position of the openings should be such that reference to unmodified daylight is minimised (see 2). **2** Where tinted glass is used in sealed units the light transmission should be maximised, paying particular attention to the choice of tinted glazing where colour matching tasks are undertaken. The total energy needed for heating, cooling, and lighting purposes should be considered when specifying solar control glazing.	
3.2.8	The lighting installation should satisfy three basic requirements: **1** safety and security; **2** suitability for task; **3** visual comfort.	Visual comfort of the installation will be assessed to ensure the well-being of the occupant - checking lighting flicker and glare, aesthetic impressions of internal finishes, etc.
3.2.9	In order to realise savings from maximising daylighting, automatic lighting control should be considered with the facility for occupant override.	For an office, flexible manual control with time switching can often be as effective and cheaper than photoelectric control. The use of an energy efficient dimming system should be considered where appropriate.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
3.3	**Aural Environment**	
3.3.1	The design recommendations given in Section A of the CIBSE Guide[3.1] should be followed in the control of noise and vibration within the EOF building.	
3.3.2	In naturally ventilated buildings openable windows/vents should only be used where they can provide adequate insulation against external noise.	
3.3.3	Design conditions should also be observed in relation to the operation of business machinery within the space, eg printers, plotters, photocopiers. Measures shall be taken, where spatial layouts are known at design stage, to protect occupants from noise and vibration, eg separation of equipment from occupied space (see also 6.2.2).	Health and Safety (Display Screen Equipment) Regulations 1992 call for noise emanating from workstations not to distract attention or disturb speech.

References

3.1 CIBSE Guide Volume A, Chartered Institution of Building Services Engineers, 1986

3.2 ISO 7730. Moderate thermal environments determination of the PMV and PPD indices and specification of thermal comfort, 1984

3.3 HUMPHREYS MA, Adaptive model - Outdoor temperature and comfort indoors, Building Research and Practice, March/April 1978 pg 92-107

3.4 OSELAND NA, HUMPHREYS MA, Thermal comfort: past, present and future, Building Research Establishment, 1994

3.5 HSE, Health and Safety (Display Screen Equipment) Regulations 1992

3.6 Healthy Work Places, CIBSE Guidance Note 2, 1993

4. **PASSIVE ENVIRONMENTAL CONTROL**

4.1 **Ventilation**

A central objective of the project is to produce a building that operates with a low energy consumption. In this respect it is preferable to have a naturally ventilated environment rather than one that requires the complexity and associated high energy use of an air-conditioning system.

Conventional air-conditioning systems have the disadvantage of having significant fan and pump energy requirements for the distribution of air and water around the building – on large all-air systems this can represent the largest single component of electrical energy consumption. The pursuance of the naturally ventilated option is therefore considered central to the project. This approach offers an inherently low energy solution that if replicated would lead to a significant reduction in UK energy usage in office buildings.

4.1.1 In order to avoid or reduce the dependency on air-conditioning in the EOF building, the use of passive control features will play a major role. The building envelope should become the dominant climate modifier leaving minimal work for the environmental services, thus allowing for simplification of these installations.

Care needs to be exercised with the design of passive measures. For example, passive solar heating is one area where careful consideration is needed to achieve successful operation, without impairing thermal comfort and indoor air quality, see also 5.3.3.

Daylighting applications generally prove most successful because the physics of lighting distribution is less complex than thermal analysis. However, field trials on daylighting and artificial lighting control have highlighted the need to specify appropriate and reliable automatic control systems[4.1].

As a general point, passive measures are usually successful where a full analysis has been carried out not only under peak loads but also through the transitional seasons.

4.2 **Thermal Mass**

Provided significant night ventilation can be ensured, the use of thermal mass to attenuate heat gain is seen as essential and a prerequisite for the successful operation of naturally ventilated solutions in high heat gain buildings.

The use of building mass might range from active systems where 'coolth' is stored in floor/wall slabs on night purge cycles, to the judicious use of thermally heavy internal finishes in the space. The passive thermal mass approach would require the selection of heavyweight internal finishes to attenuate heat gain in the space. This might be achieved, for example, by exposing the slab soffit.

4.3 **Controllable Solar Shading**

Controllable sun screening is desirable to prevent solar transmission in summer but should also be capable of allowing transmission of daylight to minimise the use of artificial light energy under overcast conditions.

Care must be exercised in the design and control of such systems to ensure that, where possible, the user has an override facility. Case studies have shown that removing user control causes irritation and a significant reduction in occupant tolerance to the internal environment.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
4.4	**Permanent Solar Shading**	
	Permanent sun screening features such as deep window reveals or overhangs can be used as an alternative.	Reduced daylighting can be minimised by selecting tall aspect windows. When considering a number of devices ensure that the resultant combination does not create a 'gloomy' atmosphere.
4.5	**Building Orientation and Form**	
	Consideration should be given to the role of form and orientation in minimising energy consumption by:	It could be beneficial to arrange the building plan and zone the services to make maximum use of the solar gains.
	1 minimising summer and intermediate season solar gain;	
	2 maximising useful winter solar gain;	However, it is important to account for glare from low angle winter sun.
	3 reducing the building's sensitivity to the wind, where appropriate;	
	4 considering a compact simple form to minimise the surface to volume ratio, and selecting the appropriate percentage of glazing.	To find the optimum building form the need to maximise daylighting and use natural ventilation (where possible) will also need to be considered.
	Large flanking walls facing prevailing winds and funnel-like gaps between buildings should be avoided. Consideration should also be given to site topography and tree planting, as well as building height, roofline, and form.	

References

4.1 INTERNATIONAL ENERGY AGENCY SOLAR HEATING AND COOLING TASK XI, Passive and Hybrid Solar Commercial Building, 1991

5 HVAC SYSTEMS

5.1 Ventilation

The design of a naturally ventilated environment in buildings which would normally require air-conditioning is the primary focus of current EOF development resources.

The extension of naturally ventilated solutions to both new build and refurbishment is one of the main aims of the project.

5.1.1

The design of naturally ventilated environments should be considered for urban sites where noise and pollution usually require the application of air-conditioning.

The introduction of outside air adequately filtered and without resorting to mechanical fan energy requires some research. Filtering will not remove fumes unless charcoal filters are used.

5.1.2

'Mixed-mode' operation of natural ventilation with limited mechanical ventilation or air-conditioning would be an acceptable solution where internal heat gain precluded the use of passive measures alone.

Mixed-mode operation can involve any combination of natural, or mechanical ventilation, or air-conditioning. Examples could be operating the entire building on air-conditioning during peak summer conditions and natural ventilation at other times of the year. An alternative could be air-conditioning those areas experiencing consistently excessive heat gain, leaving the rest of the building to be naturally ventilated.

5.1.3

Adequate airflow should be achieved throughout the building to provide a standard of indoor air quality defined by 6.1, where possible with the use of natural or passive ventilation.

The application of solar assisted ventilation via solar chimneys, wind towers and atria will be considered as these are design solutions that can promote adequate airflow in deep plan buildings without resorting to fan energy use.

These measures for improving airflow in deep plan buildings are not new, but will require refinement for application in future buildings.

5.1.4

The fabric leakage of new build or major refurbishment should satisfy the requirement of permitting 5 m^3/hr per m^2 of permeable envelope at a maintained pressure difference of 25 Pa. The area of envelope will include facades, roof and suspended floor if used[5.1].

Although adequate fresh air is required for ensuring the health and well-being of occupants, excessive quantities of infiltration air will cause discomfort and high space heating energy consumption. In low energy design a philosophy should be adopted of trying to achieve a tight building envelope and then providing adequate ventilation in a controlled fashion. The airtightness standard quoted here would typically represent an uncontrolled infiltration rate of $^1/_4$ ac/h.

The degree of airtightness should be verified by leakage testing whenever possible.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
5.2	**Alternatives to Mechanical Cooling**	
5.2.1	In a building where the heat gain characteristics are such that the natural ventilation solution has no chance of sustaining acceptable comfort conditions throughout the year, alternative means to conventional mechanical cooling should be considered.	
5.2.2	The use of evaporative cooling on an indirect basis should be considered. The supply water can be cooled through a conventional cooling tower.	Indirect systems are preferred to direct arrangements because with direct systems there are inherent problems of evaporating water droplets in the supply airstream. These include the microbiological contamination of the water supply and high space humidities in summer. In an indirect system the exhaust air stream is humidified and cooled. This coolth is then transferred to the supply air via a high efficiency heat exchanger.
5.2.3	If the site allows, groundwater may provide a viable cooling source, offering a more stable source temperature than that achieved with evaporative cooling.	The temperature of the groundwater should be approximately 10°C if water is abstracted from well depths of between 5 m and 50 m. This would be outside the depths where geothermal gradients are effective. Site conditions limit this application, but assume 50% of England may be suitable. Wales and Scotland, however, mostly consist of hard rock through which water extraction is difficult.
5.2.4	In addition to groundwater cooling sources, surface water (rivers, lakes, docks, etc) offers a possible alternative depending upon site location. The environmental impact of using such sources for heat rejection must be fully evaluated.	Temperature fluctuations in source water will naturally be greater – summertime maximum would reach approximately 20°C, but the cooling effectiveness should be greater than that offered by evaporative cooling techniques. Note that the use of surface water and groundwater are subject to the approval of the local authorities.
5.2.5	In this context, the preferred means of cooling distribution is by water circuits feeding chilled ceilings, cooling panels, etc. Care must be taken to consider the need for dehumidification due to the presence of a low temperature surface.	A prime aim in the design of the EOF is to avoid distributing large volumes of cooled air, thus avoiding the use of significant quantities of fan energy. The cost-effectiveness of this approach is dependent on the area of the building having air-conditioning. Chilled ceilings, cooling panels, etc use water as the medium for cooling distribution and obviate the need for high volume air distribution systems. If only a small part of the building requires cooling, the benefits may be marginal if demand can be met with decentralised units.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
5.2.6	For buildings with a dehumidification requirement, desiccant driers provide an alternative to vapour compression and absorption refrigeration machines.	The cost-effectiveness of this approach must be considered with the choice of the heat source required to 'regenerate' the desiccant.
5.3	**Space Heating and Related Issues**	
5.3.1	The level of insulation used in the EOF building should be selected on the basis of minimising total energy consumption and total cost-in-use. Due recognition of the building's internal gains should be made, and the effects on energy use for cooling, fans and pumps, as well as space heating, should be considered.	The Building Regulations Part L specifies maximum thermal transmittance values for the building envelope. Improvements to this standard of insulation must be made with reference to the total cost-in-use and total energy consumption based upon the resultant heating and cooling loads.
5.3.2	Space heating systems should be selected on the premise of providing the lowest total cost-in-use solution. To comply with the performance target (see Section 2) the total cost-in-use shall be no greater than that of contemporary low energy buildings.	In buildings that have low annual heating energy consumptions (<50 kWh/m^2) the application of low capital cost systems should be a consideration. A number of system based solutions have demonstrated their effectiveness (based on total cost-in-use), when designed and operated correctly, in existing low energy designs. **1** Decentralised gas boiler plant with low cost (ie at domestic rates) distribution systems. **2** Low cost small-scale CHP having acceptable payback periods with 3000 hrs/year at full load operation. **3** Highly insulated buildings coupled with direct electric heating. **4** Heat pump technology for heating, cooling and heat recovery applications.
5.3.3	The application of either active or passive solar energy for the provision of either heating or hot water would require the inclusion of thermal storage in order to match the availability to building demand more readily.	The application of passive solar heating would arrange to use the building form and fabric to admit, store and distribute incident solar energy. Careful consideration is needed of the quality of the internal environment which results from such arrangements. Active solar collectors coupled with thermal storage offer potential. Storage media that have been used successfully include water, rocks, and phase change materials. Costs and benefits have to be assessed very carefully, however.

References

5.1 E PERERA, LM Parkins, Airtightness of UK Buildings: Status and Future Possibilities, BRE, 1992

Further reading

BRE DIGEST 399, Natural Ventilation in non-domestic buildings

BORDASS WT, BROMLEY AKR, LEAMAN AJ, IP 395 Comfort control and Energy Efficiency in offices

BORDASS WT, ENTWISLE MJ, WILLIS STP, Naturally Ventilated and Mixed-Mode Office buildings: opportunities and pitfalls

6	**HEALTH ISSUES**	
6.1	**Quality of the Internal Environment**	
6.1.1	The perception of the quality of the internal environment is dependent upon both physiological and psychological factors; both areas will be considered in the EOF design.	Traditional parameters such as thermal, visual and aural comfort are reasonably well understood. However, the effects of airborne pollutants and occupational stress are not so well understood - there are many questions with very few specific answers.
6.1.2	The specification of internal finishes and furnishing should be made in accordance with COSHH regulations on exposure limits to volatile organic compounds (VOCs), gaseous pollutants, dust and fine fibres defined in HSE note EH/40. Within these requirements, the targets should be minimum emissions.	Building materials emit a variety of gaseous pollutants, such as VOCs and solvents; each a controlled substance under the COSHH regulations. Generally the concentrations are individually less than the prescribed exposure limits but their collective effect is still unknown.
6.1.3	To comply with 6.1.2, data on emission rates of gaseous pollutants, VOCs, solvents, dust and fine fibres must be sought from the building material manufacturer.	
6.1.4	Dilution ventilation is not the preferred solution. Other control strategies should be tried first. Where dilution ventilation is chosen, outdoor air should be used to dilute concentrations of indoor pollutants. The setting of an adequate ventilation rate can be undertaken at two levels, depending upon the amount of information available about the nature of the indoor air contaminants. **1** Providing a basic outdoor air rate per person; accounting for body odour and/or cigarette smoke but ignoring other sources; eg off-gassing from furnishing and fittings. Minimum outdoor air rates with no smoking - 8 l/s per person, with heavy smoking - 32 l/s per person. Consideration should be given to segregation of smoking areas from non-smoking areas within the building. **2** Providing an outdoor air rate to dilute known pollutants to acceptable concentrations (see 6.2). This method can only be used if material specification is known, the rate of generation established and combined with safe exposure limits for those pollutants.	In the Government's response to the House of Common's Environment Select Committee 1991 enquiry on indoor pollution its view on environmental tobacco smoke was that non-smoking should be considered the norm, and smoking areas should be segregated from the rest of the building. With ventilation systems incorporating recirculation it is important to separate those systems treating smoking areas from those treating non-smoking areas.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
6.1.5	An upper level of 800 ppm of CO_2 is suggested for the EOF internal environment. Ventilation rates set on this basis must also be referred to 6.1.2 and 6.1.4 and the higher rate used in the control of indoor pollution levels.	Carbon dioxide concentration is a useful indicator of the general levels of indoor air pollution and ventilation effectiveness because it is a gas which can be monitored to an appropriate level of accuracy. Achieving 800 ppm of CO_2 with ambient concentrations of between 300 and 400 ppm would require a fresh air rate of approximately 8 l/s per person.
6.1.6	In the control of particulate contaminants (if necessary) a filter grading specification of EU5 to EU7 is recommended (Eurovent 4/5 standard of filter testing and filter classification).	
6.1.7	It is generally accepted that psychological factors influence the occupants' health and well-being in a building as much as physiological effects. The following factors can influence the design: **1** the desire to have control of one's own environment; **2** the preference to be close to a window. It is essential that building users are informed of any limitations in environmental control. Equally, although thermal, visual and aural comfort parameters may be satisfied, the aesthetics of the internal space still require assessment, eg use of tinted glazing, ambience of the space, etc.	
6.1.8	Further information can be obtained on sick building syndrome and indoor air quality from a report produced for the HSE[6.1].	

6.2 **Hazardous Substances**

6.2.1 The COSHH regulations define the need to control these substances, with occupational exposure limits defined in the HSE document EH40 (see also 6.1.5).

These are mandatory requirements to which the EOF design must comply. This would be in addition to the requirements laid down in the Control of Lead at Work Regulations and the Control of Asbestos at Work Regulations where individual exposure limits are addressed. Recent studies in buildings have revealed a vast array of internally generated air pollutants - aromatics, ketones, halogens, esters, alcohols, phenols, aldehydes, epoxides and aliphatic hydrocarbons. These are termed collectively as volatile organic compounds (VOCs), and where individually their concentrations are generally less than occupational exposure limits, their combined effects are still little understood.

6.2.2 Dust and fine fibres are addressed in EH40. However, exposure limits for paper and toner dust (found around photocopiers and laser printers) require clarification.

Application note: Grouping of such equipment in areas which can be treated separately from the rest of the office area minimises cost on mechanical ventilation plant and alleviates noise intrusion identified in 3.3

6.3 **Radon**

If the EOF building is located on a site identified by National Radiological Protection Board (NRPB) as being in an area where high levels of radon have been observed, advice should be sought from the NRPB, BRE or DOE on the prevention of infiltration and limiting exposure levels.

Application note: Radon is a naturally occurring radioactive gas found in small quantities in soil and rock and permeates its way into buildings by infiltration where concentrations can be high. Radon decays into other radioactive isotopes called radon daughters which if inhaled will be deposited in the lung. Exposure to radon and its decay products is believed to increase the risk of developing lung cancer. BRE guidance is available.

References

6.1 RAW GJ, Sick Building Syndrome: A review of the evidence on causes and solutions, HSE Contract Research Report 42/1992. HSE Publishing.

Further reading

RAW GJ, BRE IP 3/94 The importance of indoor surface pollution in sick building syndrome.

7 BUILDING ENVIRONMENTAL IMPACT

7.1 BREEAM Assessment

The EOF building, when assessed under BREEAM[7.1], should achieve a categorisation of at least 'very good'.

The BREEAM categorisation will depend not only on the number of credits accrued, but also on their distribution related to global, local and internal environments. As a rule of thumb a rating of no less than 27 credits should be achieved out of the 42 available.

7.2 Refrigerants and Insulant Blowing Agents

The Montreal Protocol 1987, to which the UK is a co-signatory, will govern the use of CFCs, HCFCs and halons in the building design. The principal areas affected are in the use of the compounds as refrigerants in air-conditioning systems, as 'blowing' agents in the production of insulants, and halons used primarily in fire control installations.

The Montreal Protocol was revised in May 1990 and again in November 1992 to accelerate the phase-out of CFCs and halons, with a complete ceasing of CFC production by 1 January 1996 and halon production by 1 January 1994. Production of HCFCs will be phased out by 2030.

Since then EC regulations brought forward CFC phase-out to January 1995. There is also a proposal to phase out HCFCs by 2015. The use of halons in fire protection should be avoided.

7.2.1 Refrigerants should be used that have an ozone depletion potential (ODP) of zero. HCFCs such as R22 and R123 may only be used as an interim measure where there is no suitable zero potential alternative.

Substitute refrigerants for R11 and R12, R123 (HCFC) and R134a (HFC) respectively are now available. New equipment designed for use with these new refrigerants is also available. R123 has a particularly low occupational exposure limit and therefore requires care in use. Refrigerant detection equipment should be considered. HFC-based substitutes for R22 are becoming available and some new equipment could be used with them.

7.3 Absorption Refrigeration

An alternative to the use of vapour compression machines using HCFCs and HFCs is the use of absorption cycle chillers.

The absorption machine might be coupled with a combined heat and power set to improve the overall thermal efficiency.

References

7.1 BREEAM/New Offices, Version 1/93, Building Research Establishment

8 QUALITY IN BUILDING DESIGN

8.1 The first priority in preparing for overall quality is the early establishment of formal representation for the client in order to:

1. develop a good brief in a systematic manner, from the very first decisions concerning any proposed project;
2. maximise the possible integration between design and construction.

Application note: A basic requirement in the application of any technology is the allocation of responsibility for arranging the conditions under which quality can be achieved. Quality is defined as conformance with requirements: these include, but are not limited to, those laid down in the building specification.

8.2 There are two processes involved in improving design and construction integration that deserve the continuing further attention of the design and construction team:

1. a continuing improvement at the design stage in response to the general needs of construction planning;
2. a related improvement in design stage response to the 'sequencing' of each item of specialist or trade work.

Application note: It is important to use design decisions to influence 'timing' in the installation of most fully finished products, so as to minimise or eliminate subsequent damage.

8.3 The design should seek to maximise improvements in defining the needs of specialist and trade contractors.

Application note: These improvements tend to involve better collaboration with specialists in relation to detailed design. Detailing must deal not only with the technology itself, but also with the interfaces with other building components.

9 BUILDING MANAGEMENT AND MAINTENANCE

9.1 Building Management

Realising the designer's intent for an energy efficient building depends greatly on the management of the building and its services. Good designs may never reach their potential if management is poor. It is vital that the EOF design is able to facilitate effective management[9.1].

9.1.1 The environmental services should be sub-metered to allow the use of lighting, fans and pumps, space heating, hot water supply, etc to be distinguished. (It is probable this would be linked with the BMS.)

Application note: Sub-meters provide a greater insight into how a building is using energy, and a measure of the energy efficiency of the building fabric and services. Sub-metering will allow excessive consumptions to be diagnosed more readily.

9.1.2 The heating, ventilating and air-conditioning services should be zoned to accommodate partial occupancies.

Application note: The zoning of the environmental services in this fashion will allow single floors or parts of those floors to function out of hours without activating the services for the entire building. The central plant must be able to accommodate reduced loads, ie operate at good part-load efficiencies.

CLAUSE	RECOMMENDATION	APPLICATION NOTE
9.1.3	Provision should be made for the monitoring of environmental control and operational hours of plant and system.	Vagaries in control and sloppy management of plant operation hours can add significantly to annual energy consumption. Practically, such provisions will be achieved in the BMS which will monitor and indicate alarm conditions when these parameters have slipped out of acceptable limits.
9.2	**Building Management Systems**	
9.2.1	Centralised monitoring of energy use is seen as essential for the EOF building. Any departure from specified energy targets must be detected by the BMS and an alarm situation indicated.	The intention is to develop this area of BMS monitoring to include a knowledge-based element with a diagnostic facility that will identify cause and remedy.
9.2.2	Consideration should be given to the application of BMS with a field bus arrangement for load management of electrical energy use appropriate to achieving minimum energy costs within the commercial tariff structures.	Although the central goal is to achieve a building, with passive control measures and hence a simplification of HVAC services, the building would still benefit from centralised monitoring and control of heating, ventilation, lighting and management of electrical loads. The BMS will also play a vital role in facilities management.
9.3	**Maintenance**	
9.3.1	Generally, materials and plant will deteriorate over the life of a building, and this rate of deterioration will be influenced by the level of maintenance provided.	
9.3.2	Adequate space and access should be provided for maintenance of the building fabric and its services. Due consideration should be given to the need to check, adjust, clean and replace building and system elements.	Space and access provisions should take into account the need for efficient site installation, commissioning and future maintenance.
9.3.3	Provision should be made for achieving a high level of hygiene in the building and its services over the building's life.	Space and access are required to ensure cleaning can be effectively carried out. This would include cleaning of finishes and furnishing, air ducts, stacks, etc, minimising dust, fine fibres, etc in accordance with 6.1.2.
9.3.4	A fully defined fabric services inspection and maintenance programme needs to be in place at the take-up of occupancy. Operation and Maintenance manuals should be planned and organised to meet the overall requirements of owner and occupier.	The key to the successful operation of a building lies in an understanding of how the building and services are supposed to work. A clear and concise statement of the function and control of systems needs to be given in the O&M manuals. This should define the design space conditions, implications of plant deterioration or failure, and resources required for proper preventative maintenance.

References

9.1 BREAAM Version 4/93, Existing Offices, Building Research Establishment

APPENDIX A

Table A1- Performance Parameters of Contemporary Low Energy Offices

Ref	Description	Annual Energy Consumption kWh/m² of treated floor area							CO_2 produced (kg/m²)
		Lighting	Small Power	Fans and Pumps	Refriger-ation	Heating	Total Electricity	Total Gas	
1	GFA 2500 m² TFA 2240 m² Heated only, natural vent, Gas condensing boilers	46	6	7	—	70	78	77	83
2	GFA 2980 m² TFA 2830 m² Heating and some a/c, natural vent, Modular gas boilers	49	21	3	6	69	96	69	96
3	GFA 23 600 m² TFA 19 750 m² Comfort cooling, mechanical and natural vent, Dual fuel boilers	44	5 20 computers 8 Telecoms	13	10	90	104	101	110
4	GFA 17 840 m² TFA 13 600 m² Air-conditioned and free cooling, Gas boilers	39	9	22	8	75	177	100	170
5	GFA 2460 m² TFA 2380 m² Refurbishment - natural vent and some mechanical vent, Gas boilers	16	2	8	—	164	30	164	62
6	GFA 3525 m² TFA 2860 m² Heated only, natural vent, light shelves Gas boilers	18	11	9	—	93	52	109	68
7	GFA 1309m² * Heated only, natural vent, Highly insulated, Direct electric panels	13	22	—	—	46	80	—	67
8	GFA 634m² * Heated only, natural vent, Highly insulated, Direct electric panels	36	14	—	—	36	85	—	71

Where

GFA – Gross Floor Area

TFA – Treated Floor Area

* – energy consumption expressed in terms of kWh/m² of gross internal area