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Draft for Development

Basic data for the design of buildings: daylight

Projet à développer
Données de base pour la conception de bâtiments: lumière du jour

Entwurf zur weiteren Ausarbeitung
Grunddaten für die Konstruktion von Gebäuden: Tageslicht

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This publication is not to be regarded as a British Standard. It is issued in the Draft for Development series of publications and is of a provisional nature only (see foreword).

It is recommended that this publication should be applied on this provisional basis so that information and experience of its practical application may be obtained.

A review of this Draft for Development will be carried out not later than two years after its publication. Notification of the start of the review period together with a request for

the submission of comments from the users of this Draft for Development will be made in an announcement in the appropriate issue of *BSI News*. Observations which it is felt should receive attention before the official call for comments will be welcomed.

According to the replies received, the responsible BSI Committee will then judge whether the Draft for Development can be converted into a British Standard or what other action should be taken if the interim guidance has proved to be not practicable or not useful.

Foreword

This Draft for Development, which provides a framework for extending and redrafting CP 3 : Chapter 1 : Part 1 : 1964, incorporates changes in approach to the subject of designing for daylight, arising from the need for a more careful consideration of the combined roles of sunlight, daylight and artificial light in the interests of energy conservation. In this last respect the use of natural light is so relevant that it is hoped that this Draft for Development and the parallel DD 67 'Basic data for the design of buildings: sunlight' will together serve to revitalize the combined contribution of skylight and sunlight to the design and quality of buildings.

The integration of artificial lighting sources with daylight has focused attention on the size of view windows, the balance of brightness in the interior and the modelling of form. The study of glare from windows has led to methods by which glare can be predicted. Recommendations are

made for standards of quality and quantity of daylight both in spaces that rely on daylight alone during most working hours, and in spaces in which daylight and artificial light are combined. Recommendations are also made for minimum emergency standards in buildings such as hospitals that, although planned for supplementary artificial lighting, are required nevertheless to function in an emergency using available daylight.

This Draft for Development is concerned with both the theory and practice of the design of daylighting in buildings and thus has a wider scope than that of CP 3 : Chapter 1 : Part 1, which it will eventually replace. For guidance and to facilitate reference, recommendations for all aspects of daylighting in specific types of building are given in clauses 8 and 9.

Draft for Development

Basic data for the design of buildings: daylight

0. Introductory guide

0.1 General. The wide scope of this Draft for Development makes it necessary to stress the fact, already mentioned in the foreword, that clauses 8 and 9 (design guidelines and schedule of recommendations) can be used independently by designers as a direct source of immediately applicable data. The Draft for Development also acts as a reference to the many aspects that explain and supplement these specific recommendations.

To facilitate such reference the contents of this Draft for Development are cross-referenced in this guide under subjects listed under three main headings:

Principles
Standards
Calculation and measurement

References are to clauses (numbers in bold type), figures, tables and appendices of this publication. When reference is made to a bibliographical entry in appendix G (e.g. G.1.13) that entry gives details of another relevant source (e.g. DD 67).

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This publication is a Draft for Development and is therefore not to be regarded as a British Standard. See page 4.

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1. Scope

This Draft for Development is concerned with the design of daylighting in buildings and with the supplementing of daylight by artificial light.

Definitions are given in clause 3. The contents of the body of the text can be summarized under five main headings:

- (a) *Assessment and provision:* clauses 4, 5 and 6, which cover the assessment and provision of daylight, and the design of supplementary artificial lighting.

- (b) *Quality of daylight*: clause 7.
- (c) *Design guidance*: clause 8, giving general guidance and references for specific building types, and clause 9, giving a schedule of recommendations.
- (d) *Urban planning*: clause 10.
- (e) *Appendices*: seven appendices including basic data, methods of calculation, and a bibliography.

2. References

The titles of the standards publications referred to in this Draft for Development are listed on the inside back cover. Sources referred to by number in the text are detailed under the appropriate number in the bibliography (appendix G).

3. Definitions

For the purposes of this draft, the following definitions apply; most have been adopted by the Commission Internationale de l'Eclairage (CIE). For other definitions of relevant terms see BS 4727 : Part 4.

3.1 average daylight factor. The ratio of the total daylight flux incident on the reference plane to the total area of the reference plane expressed as a percentage of the outdoor illuminance on a horizontal plane due to an unobstructed hemisphere of sky or assumed or known luminance distribution.

3.2 building lighting. The light provided to reveal the internal surfaces of a space within a building.

3.3 candela (cd). The unit of luminous intensity. One candela is equal to one lumen per steradian.

3.4 candela per square metre (cd/m²). The unit of luminance. The luminance of a uniform plane diffuser emitting π lumens per square metre.

3.5 CIE standard overcast sky. A completely overcast sky for which the ratio of its luminance L_θ at an angle of elevation θ above the horizon to the luminance L_z at the zenith is assumed to be given by the formula

$$L_\theta = \frac{L_z (1 + 2 \sin \theta)}{3}$$

3.6 contrast. The luminance difference ratio between two parts of a visual field, expressed numerically by a relation such as $(L_2 - L_1)/L_1$ where L_1 and L_2 are the luminances of the two parts of the field.

3.7 daylight. The part of the energy spectrum of electromagnetic radiation emitted by the sun within the visible waveband (380 nm to 780 nm) that is received at the surface of the earth after absorption and scattering in the earth's atmosphere.

NOTE. Radiation received directly from the sun (sunlight) is excluded from this definition.

3.8 daylight contour. A line drawn through all those points in the reference plane that have the same daylight factor.

3.9 daylight factor. The ratio of the daylight illuminance at a point on a plane due to light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky.

NOTE. Direct and reflected sunlight are excluded for both values of illuminance. Daylight factor comprises light received directly from the sky (sky component), light received directly by reflection from

external surfaces (externally reflected component) and light received by reflection and interreflection from internal surfaces (internally reflected component).

3.10 daylight glare index. A numerical index, calculated according to the method described in this Draft of Development, that enables the discomfort glare experienced due to direct view of windows to be assessed, and permissible glare limits to be prescribed.

3.11 externally reflected component. The ratio of the part of the daylight illuminance at a point on a given plane that is received directly from external reflecting surfaces illuminated directly or indirectly by a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere on this sky.

NOTE. Contributions of direct or reflected sunlight to the luminance of external reflecting surfaces and to the illuminance of the comparison plane are excluded.

3.12 glare. The discomfort or impairment of vision experienced when parts of the visual field are of much higher luminance than the remainder.

3.13 illuminance (E). The luminous flux density at a surface, i.e. the quotient of the luminous flux incident on an infinitesimal element of surface containing the point under consideration, by the area of that element. Unit: lux.

3.14 illumination vector (E) (at a point). The vector whose direction is normal to a plane that contains the point and is so oriented that the difference in illuminance on opposite sides of the plane is a maximum and whose magnitude is numerically equal to that difference in illuminance.

Unit: lux.

NOTE. The positive direction of the vector is from the higher to the lower illuminance.

3.15 internally reflected component. The ratio of the part of the daylight illuminance at a point on a given plane that is received from internal reflecting surfaces, the sky being of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky.

NOTE. Contributions of direct or reflected sunlight to the luminances of internal reflecting surfaces and to the illuminance of the comparison plane are excluded.

3.16 lumen (lm). The unit of luminous flux. The luminous flux emitted within unit solid angle (one steradian) by a point source having uniform luminous intensity of one candela.

3.17 luminance (L). The quotient of the luminous intensity in a given direction of an infinitesimal element of the surface containing the point under consideration, by the orthogonally projected area of the element on a plane perpendicular to the given direction. Unit: candela per square metre.

3.18 luminous flux (ϕ). The light emitted by a source, or received by a surface, this quantity being derived from radiant flux (power) by evaluating the radiation in accordance with the spectral sensitivity of the standard human eye. Unit: lumen.

3.19 luminous intensity (I). The quotient of the luminous flux emitted by a source, or by an element of a source, in an infinitesimal cone containing the given direction, by the solid angle of that cone. Unit: candela.

3.20 lux (lx). The unit of illuminance. The illuminance produced by a luminous flux of one lumen uniformly distributed over a surface of area one square metre ($1 \text{ lx} = 1 \text{ lm/m}^2$).

3.21 maintenance factor. The ratio of the daylight factor occurring in an interior, in the average conditions of dirtiness expected in normal use, to the daylight factor in the same interior when window glass and interior surfaces are clean.

NOTE. The maintenance factor is always less than unity.

3.22 mean spherical illuminance. The mean illuminance on the curved surface of an infinitesimally small sphere located at the reference point. (Also known as scalar illuminance.)

NOTE. The mean spherical illuminance takes account of light received from all directions with no obliquity effects.

3.23 modelling index. A measure of the directional characteristics of lighting; the ratio of the maximum to the minimum illuminance received on a vertical plane surface at the object under consideration, rotated about a vertical axis.

NOTE. The directional strength of light at a point is sometimes expressed as a vector/scalar ratio, i.e. as the ratio of the illumination vector to the scalar illuminance (mean spherical illuminance).

3.24 natural light. Term used when the visual and thermal consequences of both direct sun and diffuse sky radiation are implied.

3.25 no-sky line. A line separating all of the points on a given plane, usually the working plane, at which the sky is directly visible from those at which no sky is directly visible, i.e. beyond which the sky component is zero.

3.26 reference plane (working plane). A given plane, often called the working plane, to which interior daylighting is usually referred..

NOTE. Unless otherwise stated, the working plane is assumed to be horizontal and 850 mm above the floor. (Working plane heights are specified in this draft as 750 mm for desks and tables and 915 mm for benches. The reference plane may be specified for planes other than the horizontal, for example in an art gallery it could be a vertical surface at standing eye level, and in a drawing office it might be an inclined surface at 1.5 m above the floor.)

3.27 reflectance. The ratio of the luminous flux reflected by a surface to the incident flux.

NOTE. If the surface reflects non-preferentially in all directions (i.e. it is a perfect diffuser) its luminance is a direct function of the product of the illuminance that is received and its reflectance. This relationship gives rise to the concept of a unit of luminance in terms of equivalent illuminance (or equivalent lux).

3.28 rooflight. A glazed aperture within the zone of the roof structure, normally employed to provide top lighting.

3.29 sky component. The ratio of the part of the daylight illuminance at a point on a given plane that is received directly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky.

NOTE. Direct and reflected sunlight are excluded for both values of illuminance. (A special case of the sky component, when the sky is of assumed uniform luminance and the apertures are unglazed, is known as the sky factor. The sky factor has particular applications in legal requirements and in cases of rights of light.)

3.30 sky factor. The ratio of the part of the daylight illuminance at a point on a given plane that would be received directly through unglazed openings from a sky of

uniform luminance, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky.

NOTE. Direct and reflected sunlight are excluded for both values of illuminance. The sky factor is a pure geometrical ratio and may be defined alternatively as follows: 'The sky factor at a point P on a given plane is $1/\pi$ of the area orthogonally projected on this plane from the surface intercepted on a sphere of unit radius with its centre at P by a cone having as its apex the point P and as its base the contour of that part of the sky visible from P'.

3.31 task lighting (work lighting). The light provided, usually on a particular plane or at certain specified positions within a plane, to enable a particular visual task to be carried out.

3.32 transmittance. The ratio of the luminous flux transmitted by a material to that received.

3.33 uniformity ratio. In this draft, the ratio of the minimum daylight factor at a point on the reference plane to the average daylight factor for the whole room.

3.34 value. The index in the Munsell system of the lightness of a surface on a scale of equal sensation intervals from 0 (black) to 10 (white), the value being approximately related to reflectance by the relation: reflectance = value $\times$ (value - 1) per cent.

3.35 visual field. The full angular extent of what can be seen when the eye(s) regard(s) an object directly ahead, usually the binocular visual field of two eyes.

3.36 window. A glazed aperture in a wall, normally employed to provide side lighting.

4. The assessment of daylight

4.1 Architecture and daylight. The provision of natural light has a significant influence upon the layout and planning of buildings. The most successful designs are those in which the lighting that reveals the form and detail of the fabric is integrated with the lighting that, in an adequate and pleasant manner, illuminates the activities. Light (and colour) may also be used to conceal or surprise.

Vitality in a naturally lit interior arises from the range of brightness visible and the play of contrasts. The contribution of direct and reflected sunlight in this respect is highly important.

The direction of the light and the modelling it imparts to form is likewise of prime importance to our response to natural light. That of sunlight is marked and variable. That of skylight alone will, by comparison, seem constant throughout the day. Most people have a special liking for rooms in which the daylight comes mainly, though not exclusively, from one direction and they prefer the flow of light to be diagonal, as from windows in a conventionally side-lit room. In combination with diffuse (interreflected) light the human face in side-lit interiors is modelled in an agreeable way. This desirable diagonal flow of light is easy to achieve with daylighting and very difficult with artificial lighting. When the daylighting is from rooflights exclusively, the undesirable modelling characteristics of top lighting are just as evident. These are factors to consider in the choice of fenestration.

The technology presented in this draft offers a means by which some of the requirements of natural lighting can be ensured. However, it should not be forgotten that the light received is assessed by human judgement in terms of visual performance, of visual comfort (especially freedom from

glare discomfort), of aesthetic satisfaction and pleasantness, of its revelation of architectural form and of its general suitability for the purpose of the space. These are not matters of daylight alone but of sunlight and view, too. Technically it is convenient to consider the natural lighting of buildings in two stages, (a) design for light from the sky and (b) design for sunlight. Design for sunlight is the subject of DD 67 (ref. G.1.13).

For the architect, however, the design decisions that govern one also influence the other. Daylight and sunlight in a building have in practice to be reviewed together and with matters to do with their thermal consequences and the views sought or afforded by the fenestration. The means of measurement and calculation presented in this draft are concerned in the main with daylight (sky light) with or without supplementary artificial sources but with direct or reflected sunlight ignored. The building designer has to be alert to the broader influences of natural light while making decisions in terms of daylight (sky light) only.

4.2 Components of daylight in buildings

4.2.1 Main components. Daylight in buildings can be considered in terms of three major components:

- the sky component (4.2.2);
- the externally reflected component (4.2.3);
- the internally reflected component (4.2.4).

These three components exclude direct light from the sun, which is the subject of DD 67 (ref. G.1.13).

4.2.2 Sky component. Direct light from the sky that reaches any particular point in a room by an unobstructed path through the glazing.

4.2.3 Externally reflected component. Reflected light from external surfaces, i.e. light that reaches a point in a room through the window but after reflection from external surfaces such as the facades of opposing buildings or from the ground, trees, etc. Light penetrating into a room consists of the sky component and the externally reflected component and, apart from very exceptional circumstances, the former is usually much the greater.

4.2.4 Internally reflected component. Light that reaches a point in a room after multiple reflection from the internal surfaces such as the floor, ceiling, walls, furniture, etc. The lighter the surfaces in the room, the greater will be the internally reflected component. The effect of light surfaces is to increase the total amount of light at a particular point in the room, and consequently to extend the effective duration of useful daylight.

Near windows most of the light is received directly from the sky and the internally reflected component is only a relatively small proportion of the total. Away from the window, however, the internally reflected component may be much the greater part of the total daylight received, and this is particularly so in rooms with light-coloured interior finishes.

The major function of the internally reflected component is to reduce the diversity of light in the room and to soften the modelling. A room with light reflecting surfaces will always appear more uniformly lit than one with dark reflecting surfaces.

4.3 Response of the eye to light: adaptation and relative daylight. The functioning of the human eye changes with

the amount of light it receives. The appreciation of sharpness of detail (visual acuity) and discrimination of colour are better in good lighting than in bad, up to the levels of good outdoor daylighting. The relationship between illuminance and visual sensation and visual performance is not linear and it is customary to study daylight quantity on ratio scales rather than linear scales.

The illuminance from daylight throughout the day varies in relation to the elevation of the sun and the cloud cover of the sky. Any measure of daylighting in absolute units can apply only to the particular conditions at the particular time. Daylighting requires some form of measurement that allows for its variability, as well as its influence on visual effectiveness.

The situation is complicated by the manner in which the human eye adapts continuously to a changing light pattern. As the light from the sky changes, the adaptation of the eye keeps pace with the change if it is sufficiently slow. These slow changes in the amount of daylight have therefore only a limited effect upon the visual impression of light quantities. The measure of daylight in buildings commonly adopted is therefore the ratio of the internal light to that available from the sky outdoors. This ratio is called the daylight factor (see 3.9).

4.4 Luminance distribution of the sky: CIE standard overcast sky. In the definitions of the daylight factor and its components (see clause 3) reference is made to 'a sky of assumed or known luminance distribution'. The simplest luminance distribution is that of a sky of uniform luminance, but this bears little resemblance to reality. In practice, design is based upon the fully overcast sky, because this is considered to represent the worst conditions likely to be experienced. The International Commission on Illumination (CIE) takes the standard luminance distribution from the overcast sky as being given by the formula:

$$L_{\theta} = \frac{L_z(1 + 2 \sin \theta)}{3}$$

where

L_z is the zenith luminance, and

L_{θ} is the luminance at the angle θ above the horizon.

With such a sky the zenith luminance is three times that at the horizon.

The occurrence of a fully overcast sky corresponding exactly in luminance distribution to the CIE formula is relatively rare although overcast skies of approximately this luminance distribution are frequent. A sky of uniform luminance never occurs.

The use of the CIE standard luminance distribution has been criticized, particularly on the ground that the most frequently occurring conditions, rather than the worst conditions, should serve as the basis for design. No alternative acceptable proposals have, however, been put forward and it is still generally agreed that the CIE sky is preferable to the uniform sky as a basis for design. The CIE has also proposed a standardized luminance distribution for the clear sky but this is a function of sun position and does not lend itself so readily to design for temperate cloudy climates.

4.5 Duration of daylight. The duration of useful working light in a building is determined by the amount of light available from the unobstructed sky and by the configura-

tion of the glazing and the light-reflecting properties of interior surfaces, which together determine the daylight factor. The relationship is:

illuminance at a point in a building = illuminance available from the unobstructed sky $\times$ daylight factor at that point.

If there is a requirement for a given illuminance, the period of time for which this illuminance will be available during the day and the year will be governed by the availability of light from the sky, since the daylight factor is fixed by the room and the glazing configuration.

Tables of available daylight illuminance from the unobstructed sky (see appendix F) are based on photometric data obtained over a long period. These tables give the mean values of illuminance for any given time of day and year, and also the duration of time for which given illuminances are exceeded.

4.6 Necessary amounts of light: visual adaptation and critical daylight factors. The specification of necessary daylight factors in buildings is determined primarily by the illuminance necessary for a particular kind of visual activity, but is also influenced by other considerations such as maximum tolerable view of sky, and freedom from glare, which will be discussed later.

The amount of light necessary for most industrial and professional tasks, and for many domestic tasks, can be deduced from the established relationships between visual performance, illuminance, and the critical size of detail, contrast, and speed of movement inherent in the task. In the daylighting situation, however, illuminances obtained in this way give only partial guidance to the daylight factor that should be provided in any given situation. In addition to the physiological adaptation process referred to earlier, psychological adaptation also plays a part in the assessment by people of the adequacy of the daylight in a room.

A room with very light walls but with small windows can appear to be much better lit than a room with dark walls and large windows giving a view of bright sky. Because of this complicated adaptation situation, any precise relationship between a recommended daylight factor and the critical detail, contrast and speed of movement of a given task is relatively meaningless unless related to the environment in which the task is being undertaken.

Nevertheless the eye is not totally insensitive to the absolute amount of daylight, especially at the lower and the upper ends of the scale. At twilight or with a heavy passing cloud, for example, the daylight is seen to be inadequate. The response of the eye is then governed by the absolute level rather than by the ratio of the indoor to the outdoor lighting. Again, if the sky becomes very bright, the eye becomes aware of this in various ways and the absolute level becomes of greater significance than the indoor to outdoor ratio.

There is also an upper limit to the amount of light acceptable. There is now ample evidence that people working indoors, on tasks involving large areas of white paper or of similar luminance and contrast characteristics, prefer to work in an illuminance from the daylighting of the order of 500 lx. There is a wide individual variance, but at 1000 lx and above some people complain of 'too much light'. It is advisable to take 500 lx as the norm for work on white paper. This figure, however, can be doubled

or trebled for work on darker objects or the inspection of fine detail.

At the lower end of the scale, individual preferences differ widely, and are greatly influenced by the adaptation conditions in the room. To an individual worker near the window on a dull day, an illuminance as low as 100 lx may be acceptable, but this would not be acceptable at the back of a room remote from the window through which a bright sky could be seen. In the latter case the adaptation conditions are unfavourable and the lighting appears bad. In the former case, typical of a housewife working at the window, the conditions may well be preferable to the alternative of working in artificial lighting.

It will therefore be appreciated that the former practice of determining the daylight factor as a direct function of the illuminance indicated by the critical contrast, detail, and speed of movement inherent in a particular visual task, related to a sky of standard illuminance (usually 5000 lx), ignores many aspects of daylighting design. The schedules given in clause 9 therefore take environmental adaptation as well as performance factors into account.

4.7 Determination of daylight factor

4.7.1 Daylight factor at the design stage. The techniques at the disposal of the designer for the calculation of daylight factor at the design stage group themselves into three processes:

- (a) mathematical formulae, which are of different degrees of complexity and accuracy;
- (b) geometric and graphical techniques, some of which use special projections and others that can be used on scale drawings;
- (c) computer programmes that give numerical or graphical print-out or can be used to plot daylight-factor contours.

The most accurate and complex mathematical formulae for the predetermination of daylight factor are no longer in general use, although they serve as the basis for computer programmes, which are becoming increasingly available, particularly through the work of the Building Research Establishment. Many designers still have no access to computer facilities or do not wish to use them and so the various simplified formulae still have a value in giving a useful approximation to the daylight factor that is accurate for all practical purposes (ref. G.1.15).

The geometrical methods apply primarily to the determination of the sky component (and the externally reflected component) of the daylight factor. Some methods require the window configuration of the room to be drawn on a special plotting web (for example, the well-known Waldram diagram) while others are designed to be used with architects' drawings. The Waldram diagram, though one of the first to be devised, is still in general use and is recommended for many purposes. The diagram is particularly useful for dealing with cases where external obstructions vary in outline and in distance from the window wall. The Building Research Station daylight protractors are a simpler means of determining the sky component to a satisfactory degree of accuracy from scale drawings. These and other methods are referred to briefly in appendix A but reference should be made to a standard text book for the fully detailed treatment necessary to become proficient in the use of these methods as design tools.

The internally reflected component is usually obtained from an empirical formula, such as that based upon the BRS split-flux principle, which treats light entering the room through the window in terms of two components: (a) the light from the sky that is first reflected from the floor and lower parts of the walls and (b) the reflected light from the ground that is first received by the ceiling and reflected from it to other parts of the room. Simple nomograms based upon this formula, the BRS nomograms for internally reflected component, simplify the calculations still further. (See appendix A.)

The use of graphical methods for determining the sky component and the externally reflected component, and the BRS nomograms for determining the internally reflected component, are easily incorporated in the design process. There are, however, methods that enable the total daylight factor to be obtained in one process, accuracy being sacrificed to simplicity by making certain assumptions about the relative magnitude of sky light and internal light. These methods are often sufficiently reliable for many practical purposes.

4.7.2 Photometric measurements. The measurement of the prevailing daylighting in a building (or in a scale model, see 4.8.1) requires the use of specialist daylight photometers. Since the daylight factor is a ratio of the internal to the external illuminances, it is essential that the photometric equipment should measure the internal and the external values simultaneously. Most daylight-factor meters consist of two light receptors one of which is directed at the sky while the other measures the illuminance at a point in the room.

The photometer reading should vary according to the cosine of the angle of light incidence. This usually necessitates the receptor being provided with a cosine-correcting device. The correction is especially important for measurements on a horizontal plane at points in a room far from the window, where the light will reach the receptor at glancing angles.

The receptor measuring the light from the sky should be provided with a device that measures the light from the whole hemisphere of unobstructed sky or enables this to be deduced from the measurement of the light from a restricted part of the sky of known solid angle and direction. It is rarely possible, particularly in a built-up area, to mount the outside receptor in such a way that the view of sky is not obstructed.

The incident light on the outdoor receptor will be about 100 times that on the indoor receptor, and so has to be attenuated optically or electronically in order that the input from each receptor to the evaluating network is of the same order of magnitude.

Both receptors should also be provided with a suitable spectral response correction to accord with the CIE standard visual luminosity function, particularly as the external receptor may be subject to invisible radiation from the sky that is partly filtered through the glazing and so does not reach the internal receptor. These problems are dealt with in detail in the relevant literature.

For accurate daylight photometry, cloud conditions should be stable and readily measurable. A luminance distribution of the sky should be measured before internal measurements commence, and should be checked before, after and

during the series of photometric measurements, any changes in the distribution being noted and taken into account in the final assessment of the data.

Daylight photometry should not be attempted by untrained personnel if repeatable and accurate results are required. Wide discrepancies in measured daylight factors in buildings have resulted from inadequate understanding of the photometric problems.

On the other hand, useful measures, to limited accuracy, can be made using simple equipment like the BRS daylight-factor meter provided the limitations in accuracy are understood and conclusions from the results are not drawn beyond the limits of this accuracy.

4.8 Models in daylight design: artificial skies

4.8.1 Use of models. An intermediate stage between the daylight factor as predicted from drawings, and the photometric measurement of daylight factor in the completed building, is the use of an accurate scale model in which photometric measurements can be made. A scale model of the building is a true optical analogue and can give accurate predictions of daylight factor in the completed building. The accuracy of prediction is related directly to the precision of construction and the faithfulness of the representation of the details of the completed building. Models to be used for visual judgements of the pleasantness and character of the building should be provided with full detail to scale, but models for the determination of the photometric properties of the building do not require purely visual detail. The model should be true to scale, the main internal surfaces should have reflectances corresponding accurately to those intended in the full-scale room, and details such as thickness of walls, sills or reveals, window frames and glazing bars, and overhangs of eaves, etc., all of which affect the quantity of daylighting penetrating the room, should be faithfully represented, but furniture, curtains, pictures on the walls and other small objects of detail can be matched in the photometric model by a simplified representation of the same average reflectance.

The scale of a model to be used for visual appraisal is often critical (a scale of one-tenth is often satisfactory, but the literature should be consulted) in order to ensure an accurate visual illusion, but the scale of a model intended solely for photometric measurements is governed only by the size of the photoreceptors to be used in the measurements. The linear dimensions of the model room should be sufficiently great to ensure that there is no interference by the photoreceptors with the quantity and distribution of light in the model. Satisfactory results are usually obtained provided that the main linear dimensions of the model room are at least ten times the diameter of the photoreceptor. The photoreceptors can either be fixed in a predetermined position in the model, an arrangement that is often convenient when a major change in the configuration of room dimensions or windows is to be tried out, or a single photoreceptor can be mounted on a probe that can be inserted through a suitable aperture in the model and placed in any required position. The measurement positions in the model should be clearly marked beforehand in such a way that accurate location is possible. All photoreceptors for use in models should be provided with the same correcting devices as required for full-scale photometric studies.

4.8.2 Artificial skies. Analogue scale models of this kind can be used for photometric measurements using as the source of light either the real sky (that is, the model is taken out of doors or, in the case of a single side-lit model room, placed up against a window with an unobstructed view of the sky, or with the obstructions actually to be experienced in the case of the real building) or the model can be measured in an artificial sky.

Reference should be made to reference **G.1.14** for details of the design and use of artificial skies.

5. The provision of daylight

5.1 The daylighting of interiors

5.1.1 General requirements. The fenestration of the space should be such that:

- (a) the incoming daylight is of sufficient quantity for the purpose of the space and is suitably distributed;
- (b) the directional characteristics of the lighting are such that modelling of solid objects within the space is acceptable;
- (c) the windows provide a view out from as many working positions as possible;
- (d) any views of bright sky do not cause visual discomfort to the occupants in their normal use of the space.

In this clause the provision of daylight in buildings is discussed in detail and an outline is given of the ways in which fenestrations can be arranged to meet these criteria. A schedule of daylight quantities recommended for various types of buildings is given in clause 9.

Visual discomfort can result from a direct view of bright sky through apertures and it is important that the positions of these are determined in relation to the working positions and the visual activity of the occupants of a space, in order to ensure as far as possible that the direct view of bright sky is limited. Design recommendations for the avoidance of sky glare are given in clause 8 and the schedule of limiting glare indices is given in clause 9.

5.1.2 Side lighting. In side-lit rooms the size and placing of the windows determines the penetration of daylight into the building and the limiting depths of the rooms are governed by this light penetration unless supplementary artificial lighting is to be used. The side lighting provided in rooms with vertically glazed windows in the walls has certain important and desirable qualities. The strong diagonal component of light produces good lighting on the walls, floor and ceiling and pleasing modelling, particularly of the human face. The directional character of the light enables working positions to be selected such that the windows do not come within normal directions of view, the worker does not cast a shadow on his work, and reflections from glossy surfaces are not troublesome. The principal disadvantages are the difficulty of achieving uniform lighting and adequate penetration of daylight to horizontal working positions far from the window.

Rooms in which the depth from window to rear wall is less than the width of the window wall and not greater than twice the ceiling height can generally be lit satisfactorily by windows in one side wall only. In rooms of greater depth, daylighting from one side produces an unacceptably wide diversity of illuminance from areas near the window to those near the back of the room. The marked contrast

within the room and strong shadows give rise to an impression of inadequate lighting that is independent of the absolute amount of light. These harsh contrasts between the front and the back of the room can be considerably modified both in quantity and visual effect by the use of light-coloured finishes on walls and floor as well as the ceiling, particularly in those areas at the back of the room that receive least light. In this way the internally reflected component is maximized, sky glare is reduced by buffering the contrasts at the window, and the higher luminance of the rear portion of the room gives an impression of better lighting out of proportion to the actual quantitative effect.

It is possible to achieve a better quality and distribution of light by means of windows placed in adjacent walls than by unilateral lighting alone. Light from the windows in one wall illuminates the wall surface surrounding the other windows and so reduces sky glare. It will then be more difficult to ensure that no working position in the room suffers from a direct view of the bright sky, but, in general, adjacent side lighting produces a very satisfactory effect with a smaller total glass area than would be necessary with single side lighting. Equal lighting from two opposite sides destroys modelling effects, especially over the middle parts of the room.

The use of high-level windows ('clerestorey' windows) in the wall opposite the main window is almost invariably a source of glare unless designed with considerable care. Supplementary glazing in the roof in the form of a stepped section parallel to the main window wall offers an alternative means of supplementing the daylight with improved uniformity and reduced glass area. This is a technique that has been developed extensively in Scandinavia.

5.1.3 Top lighting. The only method of providing satisfactory daylight in buildings of large span is to provide glazing in the roof. Top lighting is the normal technique used, for example, in large factories. It imposes no constraints on the building area or plan form but can only be used in single-storey structures, on top floors of multi-storey buildings, or partially in multi-storey buildings having internal light wells or voids. It may be the primary source of interior daylighting or it may supplement side windows. In large spaces, top light will inevitably be dominant even when supplemented by side windows.

Top lighting may be used for selective local lighting or as accent lighting on wall surfaces, murals or special displays. It may also be used in stairwells and in escape routes.

The essential principle associated with good top lighting is that it should provide adequate quantity of daylight with minimum diversity (except in accent positions) and without excessive direct view of the sky or penetration of direct sunlight. The roof structure can sometimes be used to form the necessary screening to reduce glare discomfort.

Roof glazing should be sufficient to provide the appropriate level of daylight factor and spaced to give the required uniformity of lighting on the working surface. In general, single-direction arrangements of glazing such as the north-light roof give less uniform distribution of light and this, combined with the stronger modelling, may be unsatisfactory in some industrial buildings. There are several different structural systems and glazing arrangements for factory roofs that give cross lighting, such as the continuous raised

bays or monitors and the equal-pitch shed roof. The glazed surfaces may be inclined or may be vertical. Alternatively there are asymmetric forms of monitor glazing in which the south-facing glazing is of smaller area than that facing north in order to limit the admission of sunlight and to give a directional quality to the light for better modelling. Top lighting can also be provided by individual rooflights set in horizontal or inclined roofs.

Monitor roof glazing may require some form of louvre system or diffusing glass to mitigate the effects of direct sunlight.

The ratio of glass area to floor area for daylighting in factory buildings is determined as a compromise between that required to provide adequate lighting, and the limits set by the loss of internal heat through the poor insulation of single glazing. The ratio of glass area to floor area is usually about 1 to 5 for most factory rooflighting systems but a vertically glazed monitor roof requires a glass area to floor area ratio of about 1 to 3.

Rooflights are more efficient than windows for the lighting of a horizontal working surface. This is because the main component of direct light reaches the horizontal plane at nearly normal incidence, because the glazing can be located closer to the surface to be illuminated, and because under overcast sky conditions the luminance distribution of the sky is such that the zenith sky, which contributes mainly to the top lighting, is about three times brighter than the horizon sky, which contributes to the side lighting. In addition, the effects of external obstructions are usually much less severe with top lighting. As a result top lighting may give up to ten times as much working light on a horizontal plane as side lighting of the same glazed area.

Where top lighting is used in picture galleries and museums it should be designed to provide preferential lighting on the exhibits (and to exclude direct sunlight if this is unwanted), and may require a system of screening if the needs of conservation limit the amount of daylight admitted on bright days. Some examples of art gallery lighting are given in clause 8.

Standard rooflights are a convenient means of admitting daylight to a building, particularly to areas remote from the external walls. Rooflights can add to the flexibility of design and can supplement daylight admitted by side windows, for example where a high degree of uniformity or a dramatic emphasis of light is required on surfaces with architectural or display significance. They should be positioned to admit adequate quantity of light precisely in those areas where it is required, without causing glare discomfort or creating excessive loss of heat or admitting unwanted solar radiation.

The number of rooflights for a given total area of glazing has little or no effect on the quantity of daylight reaching the reference plane, but does influence its uniformity and distribution. Because more uniformity can be achieved with rooflights than with side windows the recommended diversity for interiors lit by rooflights is a uniformity ratio (see 5.2) of not less than 0.7. Where rooflights are used to supplement the daylight from side windows the average daylight factor in the rooflit area should be not less than two-thirds of the recommended average daylight factor from side windows. Examples of the use of rooflighting in association with side lighting are given in clause 8.

5.1.4 Combined side and top lighting. Side windows are desirable in most top-lit buildings, with the possible exception of art galleries and museums, to provide a view. Admission of direct sunlight through windows in east-, south- or west-facing walls can be minimized by using view windows of restricted height. External sun-protection devices such as canopies over the side windows can be used effectively, since the reduction in daylight quantity is of no consequence in comparison with the level of light provided by the rooflighting. In rooms with predominantly side lighting, small rooflights can be used advantageously to supplement the daylight in areas remote from the windows or to provide selective lighting on the work (see clause 7).

Rooflights are especially suited for the lighting of art rooms and laboratories in schools, for example, or to supplement the daylight in project areas remote from the side windows in a deep classroom. In any teaching space where the distance from the side windows exceeds 8 m, judicious disposition of rooflights can enable an appreciable saving to be made in the glass area of the side windows, together with an improvement in lighting distribution and more wall space. A combination of restricted side lighting and supplementary rooflighting may also yield reductions in heat losses and may, with appropriate screening, reduce unwanted solar heat gains.

Rooflights can also be employed on the top floors of multi-storey buildings to provide a higher standard of daylighting with better uniformity than is possible on lower floors lit by side windows alone. Such top-lit spaces are particularly suitable for drawing offices and libraries, in which the character of combined top and side lighting is particularly appropriate and should be utilized to maximum advantage.

5.2 The distribution of daylight

5.2.1 General. The distribution of daylight throughout a room is usually referred to a horizontal surface (the 'working plane') assumed to be at a height of 850 mm from the floor unless otherwise specified. In special circumstances the reference plane may not be horizontal; for example, in art galleries it will be the vertical surface on which the pictures are to be hung while in a drawing office it may be an inclined surface when draughting machines are used. The distribution of daylight illuminance on surfaces other than the conventional horizontal working plane is also of significance; for example, the distribution of daylight illuminance on the walls, together with the interior design of the room in terms of the relationship of the surface reflectances, governs the distribution of brightness and therefore the appearance of the space and the character and quality of the daylighting (see clause 7).

The distribution of daylight illuminance in a room is described in detail by contours of equal daylight factor on a plan drawing of the horizontal working plane, and by graphs for suitable cross sections of the room. Contours of equal daylight factor can be drawn on plan usually corresponding to daylight factors at approximately equal ratio intervals, for example 0.5 %, 1 %, 2 %, 5 %, 10 %, etc., so that the spacing and shape of the contours gives a reliable indication of the distribution of light and of the visual effect. Ratio intervals are chosen because the eye responds logarithmically.

In such an equal-daylight-factor diagram, closely spaced

contours indicate a pronounced and easily noticeable change in the daylight distribution (for example at A on figure 1) while widely spaced contours indicate a more uniform distribution (for example at B on figure 1).

The diversity of the daylight across a room is best shown on a graph of a vertical section through the room, the slope of the curve indicating the degree of diversity. Again, in order that the graph should depict the response of the eye to variations in light, the ordinate scale of daylight factor is logarithmic (see figure 2).

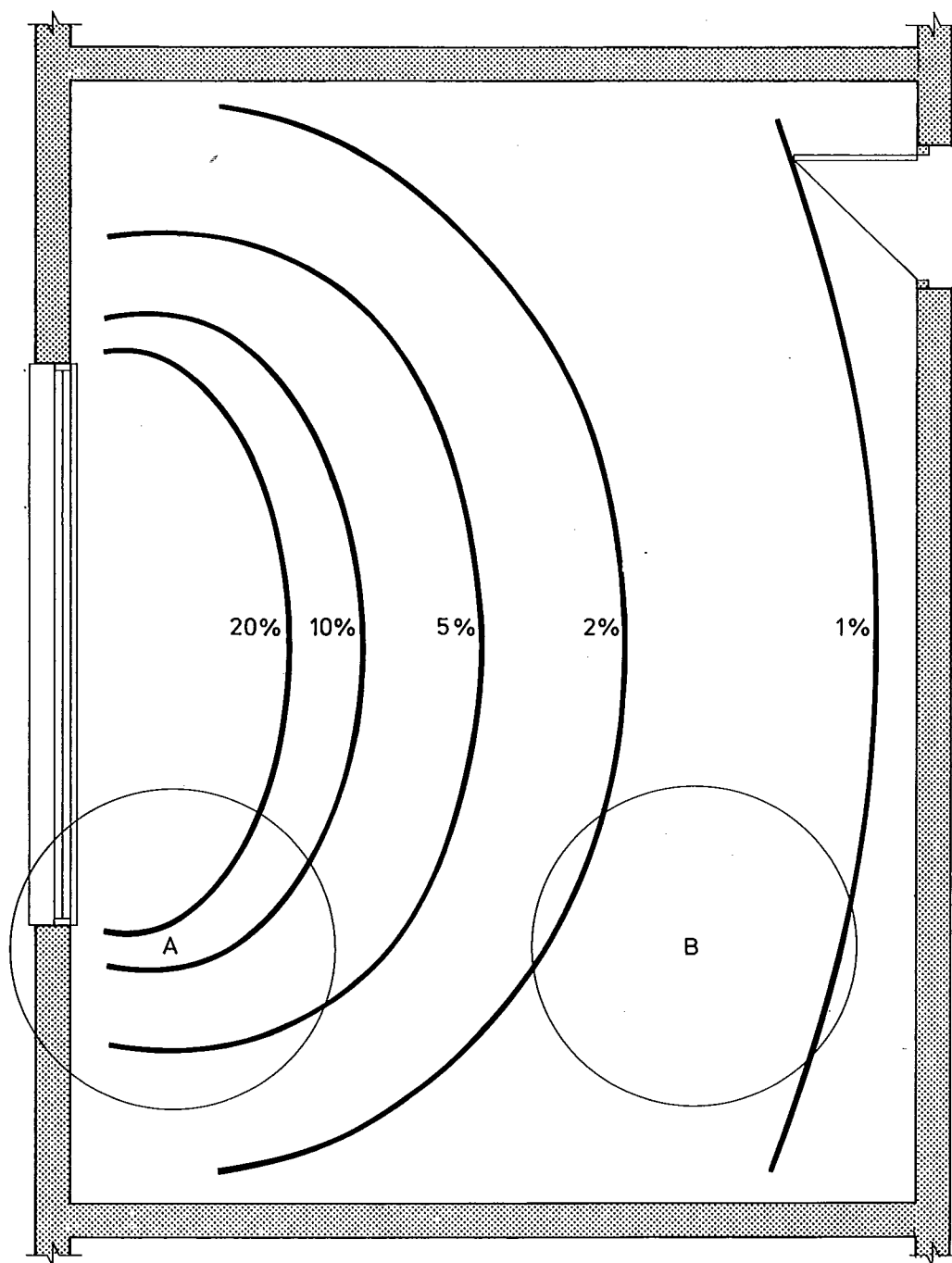
5.2.2 Daylight diversity: the uniformity ratio. A simple

expression of the diversity of daylight in a room is given by the uniformity ratio. In conformity with artificial lighting practice, this is expressed as

$$\text{uniformity ratio} = \frac{\text{minimum daylight factor}}{\text{average daylight factor}}$$

The greater the diversity of the illuminance, the lower will be the uniformity ratio, and in general the higher the uniformity ratio the better the lighting will be judged.

The diversity of the daylight in a room depends upon a number of factors, the most important of which are the position and size of windows or roof glazing, the shape of



A: zone of high diversity of daylight

B: zone of more uniform distribution of daylight

Figure 1. Daylight-factor contours on plan drawing of a room showing the daylight distribution and indicating relative uniformity

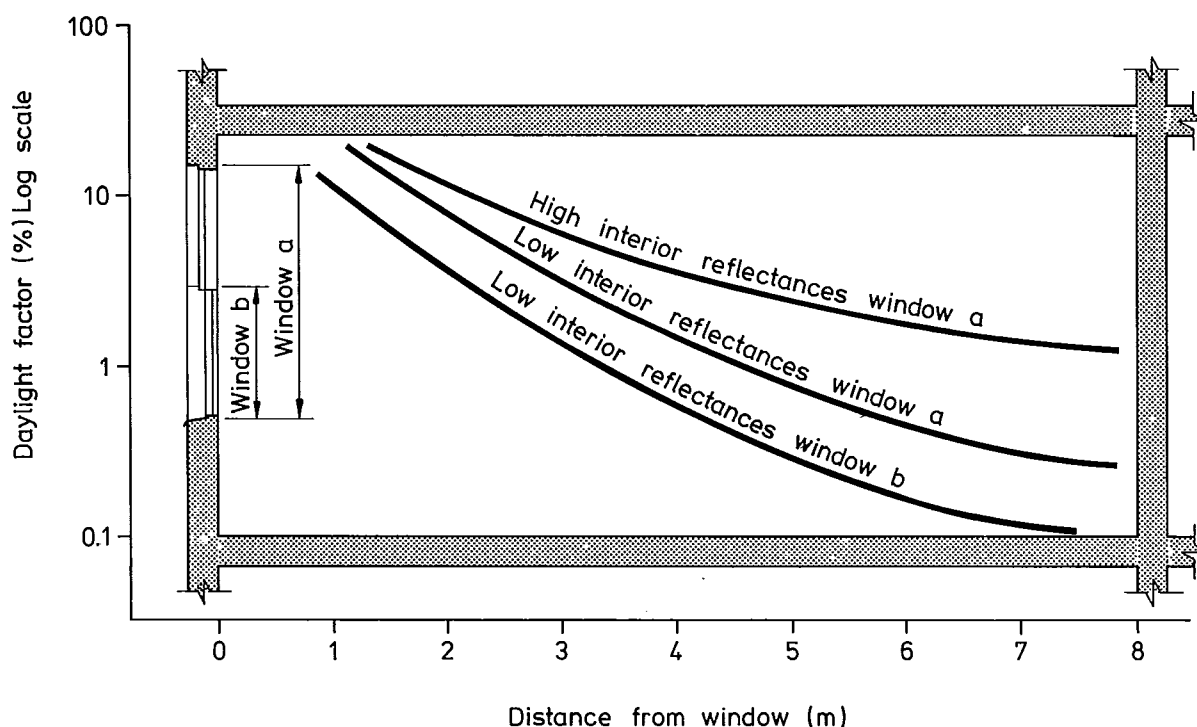


Figure 2. The diversity of daylight across a side-lit room is best shown on a section through the room, the slope of the curve indicating the magnitude of the diversity

the room, the reflectances of interior surfaces, and the luminance distribution of the sky. The aim should be to manipulate these various factors in such a way that both the average level of the daylighting and the diversity throughout the room are appropriate to the type of space or to the activity. In addition (see clause 6) the design daylight factor and diversity will be influenced by the extent to which daylight is to be supplemented by artificial light.

The diversity of the daylight in a room will change with the sky luminance distribution. The standard overcast sky has a zenith luminance three times that at the horizon and so a

diversity based upon this sky will be changed, especially in a side-lit room, if bright sunlit clouds occupy the regions of the sky near the horizon. The standard overcast sky corresponds to something approaching the worst daylighting conditions likely to be experienced, and consequently under most other sky conditions the diversity of daylight in a side-lit interior will be improved. The change in the average daylight factor, however, will be very small and hardly appreciable.

A summary of the relationship between daylight diversity and the activity in a space is given in table 1.

Table 1. Lighting and fenestration of spaces

Nature of lighting the space	Nature of space		
	Sparsely occupied spaces or spaces without fixed working positions	Densely occupied spaces or spaces with fixed working positions	Special interiors, e.g. art galleries, libraries
Principally daylit space with night time artificial lighting	An even distribution on horizontal surfaces is desirable, but not essential; dark zones should be avoided so as not to reduce the flexibility of space usage	Care should be exercised in the daylight distribution. The ratio of daylight factors between adjacent working positions should not exceed 1.5 to 1	Detailed examination and control of illuminance distribution on vertical and horizontal surfaces within controlled limits will be necessary
Daylit space with some permanent supplementary artificial lighting	The distribution of daylight throughout the space is less critical but the pattern and level of daylight will influence the appropriateness of the supplementary artificial lighting	Daylight distribution to provide a general background illuminance where the selective lighting of the task is by artificial lighting. Greater variation in distribution is tolerable	The integration of daylight and artificial light will require detailed knowledge of the daylight distribution
Artificially lit space with windows provided principally for view	The extent and position of glazing designed primarily to provide an adequate and useful view of the outside	The extent of intervening furniture and the exact location of the working positions will require careful siting of view windows	The provision of view windows should be made with the nature of the visual task in mind. Distraction from critical visual tasks and unwanted daylight on vertical surfaces should be considered

5.2.3 Reflected daylight

5.2.3.1 Design considerations. Reflected daylight can add substantially to the quantity of useful light in a room, and can influence its quality even more markedly (see clause 7).

In order to gain the greatest quantitative advantage, surfaces that receive the highest proportion of incoming light, such as the floor near the window, should have the highest reflectance compatible with other considerations. Visual effect, however, may gain most by the provision of light surfaces in those parts of the room remote from the window that receive least light and would otherwise look dark and gloomy.

Reflected daylight in a room is determined by the average reflectance of all the room surfaces. Some surfaces may be dark and some colourful, and local effects of highlight or of shade can be designed for visual effect or for room character, provided the average reflectance is kept high.

A high proportion of reflected light helps to improve daylight distribution by adding a more or less constant component of light all over the room and so reducing the diversity. The effect is most marked in single side-lit rooms and of greatest benefit at working positions far from the windows. Good planning of the internally reflected light can be used to compensate to some extent for the deficiencies in the daylight distribution in a room where non-visual requirements (for example the need for wall storage space in a school room) dictate a window arrangement not compatible with the desired daylight distribution. The planning of surface reflectances and of internally reflected light is of greater value in daylighting design than in artificial lighting design because, due to structural limitations, there is much less freedom in the positioning and spacing of the windows than there is in the placing of artificial light sources.

5.2.3.2 Reflected light and redecoration. It is important to realize that the dependence of the daylighting design upon the contribution of internally reflected light calls for continuing control over the decoration of the room. A redecoration programme that reduces surface reflectances generally, or upsets the balance of surface reflectance distribution in relation to the windows, will have a much more serious effect upon both the level and the diversity of the daylighting than it would in a room relying primarily upon the artificial lighting, or in a space such as a top-lit factory where reliance in the daylighting design has been placed primarily on the direct light from the sky.

5.2.4 Average and minimum daylight factor

5.2.4.1 The design recommendations in CP 3 : Chapter 1 : Part 1 were based upon the need to achieve daylight illuminance over the whole room adequate to the performance of specific tasks, and were therefore expressed in terms of minimum daylight factor.

The use of the minimum daylight factor alone as the criterion for interior daylighting gives no indication, without a full knowledge of the fenestration and of the interior reflectances, as to whether the daylighting in the room as a whole will be satisfactory. Two rooms of similar shape, the one provided with large windows and interior surfaces of low reflectances, the other with smaller windows and interior surfaces of high reflectances, can have the same minimum daylight factor at comparable working points in the room, but the distribution of lighting in the

second case would be judged to be generally more satisfactory than the first.

While the full specification of daylight can only be given by complete data on the distribution of illuminance and of luminance in a room, an improvement in the information contained in the specification of the daylighting is achieved if two quantities, the average daylight factor, and the uniformity ratio (minimum/average) are given. This is the procedure adopted in this Draft for Development. There is the additional advantage that this form of specification corresponds to artificial lighting practice and so enables comparisons to be made. This is of particular value in spaces to be lit partly by daylight and partly by supplementary artificial lighting. It has the further great advantage that it enables an approximate calculation of window area to be made directly from the specified value of averaged daylight factor and room reflectances.

The average daylight factor in a room can be calculated by the formula:

$$\text{average daylight factor} = \frac{\text{total incident light flux on working plane}}{\text{outdoor illuminance} \times \text{area of working plane}}$$

and methods of calculation are described in A.7.

Tables are given (see appendix A) for the computation of the glazed area necessary for side lighting and for top lighting to achieve various values of average daylight factor.

A schedule of recommendations for desirable daylighting levels is given in clause 9 in terms of average daylight factor together with a limiting daylight uniformity ratio as determined by the activity in the room, the location of the glazing, and the availability of artificial lighting to supplement the daylight, either spacially or temporarily or both (see clause 6).

5.2.4.2 It is usual in practice to define the minimum daylight factor as that occurring at the worst-lit point in the working area. The particular significance of the minimum daylight factor arises in spaces where specific visual tasks of known difficulty (in terms of critical contrast, detail, and speed of movement) have to be undertaken in daylight without the benefit of supplementary artificial lighting. Such conditions arise where colour judgement (for example clinical judgement in a hospital) has to be made under natural daylight and are likely to occur more commonly in buildings where energy economy is practised.

The tables of recommended daylighting (see clause 9) give recommendations of average daylight factor and of diversity (uniformity ratio) that in effect define the minimum also:

$$\begin{aligned} \text{minimum daylight factor} &= \\ \text{average daylight factor} &\times \text{uniformity ratio.} \end{aligned}$$

The illuminance resulting from a given minimum daylight factor is given by:

$$\begin{aligned} \text{illuminance} &= \\ \text{minimum daylight factor} &\times \text{outdoor illuminance.} \end{aligned}$$

The illuminance resulting from a given daylight factor is thus continuously variable, in relation to the variations that occur in outdoor illuminance. The resulting illuminance as obtained from the above formula can be compared with that necessary for the given visual task, as laid down in the relevant specification (Building Regulation, code of

practice, etc.) in terms of the percentage of normal working hours for which this value is exceeded, e.g. an outdoor illuminance of 5000 lx is exceeded for about 85 % of normal working hours (see table 31).

5.3 Special methods of daylighting

5.3.1 General. Daylighting technology provides a number of refinements for improving the quality of daylighting under special conditions. Diffusing glasses and tinted glasses are available that can both, under appropriate conditions, improve daylight quality in rooms and usefully ease glare situations, but it should be borne in mind that glare discomfort may arise when diffusing glasses are used if they are exposed to direct sunlight; working positions should be arranged to avoid direct view.

5.3.2 Diffusing glass. Diffusing glasses scatter the light incident upon them and so do not redirect it at any particular angle. They can, however, be used to achieve some improvement in distribution in obstructed situations where the view out is of no importance. Diffusing glasses act as secondary light sources in that they become bright when light falls upon them, unlike clear glass which transmits light from the sky without modification. The luminance of diffusing glass depends upon the degree of diffusion and upon the amount of incident light. Diffusing glass should be placed as near to the outer face of a building as possible.

Some diffusing glasses have slightly lower light transmittances than clear glass and therefore admit less light to a room. Their function is to provide a better distribution of daylight within the building. These glasses serve a number of other useful purposes. They can be employed in situations where privacy is essential as, for example, in examination or treatment rooms in hospitals, or bathrooms in dwellings, admitting daylight without permitting a view into the interior from outside, or they can be used to mask an unpleasant view. Special forms of diffusing glass, in single or laminated form, are used effectively to diffuse sunlight, particularly in rooflights. Other applications of special glasses include decorative uses such as the employment of plain or coloured glass blocks.

5.3.3 Selectively transmitting glasses (solar control glasses). The use of tinted or solar control glass has particular value in situations of continuous very bright sky. The use of these glasses for windows has become more common, particularly in buildings that have been provided with glass curtain walls, where the control of glare and of solar gain is required. Light transmission is reduced at all times and the use of these glasses should be carefully evaluated in relation to energy conservation in addition to internal environmental requirements. Glare can be reduced by the use of tinted glass in windows but the penetration of useful daylight to the deeper parts of rooms will be reduced and such a technique should not be used in other than shallow rooms if the intention is to rely on daylighting without an artificial lighting supplement. The use of tinted glasses is therefore likely to be confined to designs with some form of supplementary artificial lighting, or where special attention needs to be given to the reduction of visual and thermal discomfort. The visual function of the tinted glass is to enable a balance of brightness to be obtained between daylight and artificial light without resort to high illuminances from the artificial lighting system. It is very often possible to achieve this without tinted glass by careful

design of the daylight as indicated in this Draft for Development.

The use of selectively transmitting glasses in combination with appropriately designed artificial lighting and heating systems can produce energy-efficient buildings whilst retaining the visual benefits of the window. Such glasses modify the colour of the light and so may affect the accuracy of colour judgement. This modification may be so small in most situations to be unnoticed and of no operational significance, but there may be a need to modify the colour qualities of the supplementary artificial lighting to be used in conjunction with such glasses. Where accurate colour discrimination is essential the use of tinted glass is not recommended. Opening windows with tinted glazing can cause disturbing visual contrasts when they are opened.

5.4 Safety lighting. Escape routes in buildings can, in many cases, be daylight. Many buildings are required by law to provide emergency artificial lighting, but in some cases this can be supplemented by daylight. The average daylight factors recommended for circulation areas and staircases are applicable (see clause 9) but, where these areas are remote from windows and are designed to be artificially lit, a basic safety standard of 0.1 % minimum daylight factor should be provided to enable the building to be evacuated in emergency and in event of failure of the artificial lighting, and to permit certain critical visual tasks to be undertaken. It is important that fenestration designed to provide safety daylighting should not be obstructed by black-out or other blinds or curtains.

6. Supplementary artificial lighting

6.1 Principles. The design of deep open-plan offices and multi-storey factories, and more recently of landscaped offices and open-plan schools, has been influenced by the progressive development of fluorescent light sources. These types of building are all dependent upon permanent artificial lighting for their successful operation but also rely upon windows for an outside view.

The design of the artificial lighting supplement in a daylight interior is governed by several factors. First, there is the necessity for the artificial lighting to supplement the illuminance available from daylight to a level adequate for efficient and comfortable vision; the artificial lighting should 'top up' the daylighting to the necessary illuminance. This aspect of supplementary lighting has always been well understood and raises few problems.

The other aspect of artificial lighting in a daylight interior appears at first to be a paradox. If there is a marked diversity in the daylighting, as in a deep side-lit room, the higher the levels of daylighting in the areas near the window, the higher, not the lower, is the amount of artificial lighting supplement necessary in order to achieve a satisfactory overall visual result. This paradox was shown experimentally, justified theoretically, and subsequently validated in practice. It holds true whenever the sky can be seen through windows to a degree sufficient to influence the adaptation of the eye. The higher this adaptation level, the less bright the remoter parts of the room will appear. The artificial lighting supplement is necessary to bring the apparent brightness of these interior areas to a level where there is a satisfactory balance of brightness with the areas of the room near the window and with the sky as seen through the window.

6.2 Quantity and diversity

6.2.1 General. Where the average daylight illuminance in an interior is inadequate for the activities taking place within it, artificial lighting is used to supplement the task lighting and the lighting of the room in general. In other cases artificial lighting is used to modify the diversity of the daylighting in deep side-lit rooms.

Where these conditions arise, the artificial lighting should be so designed in relation to the daylighting in quality, quantity and method of control that overall energy consumption is kept to a minimum both for the lighting and heating of the space. By separating task lighting from building lighting it is possible to correct gloomy interiors that otherwise have sufficient task lighting, for example by lighting walls preferentially so that a minimum amount of energy is consumed.

Where the task lighting needs to be supplemented, the control should be arranged so that selective and logical switching is possible, or photoelectric dimming devices should be used, again in order that a minimum amount of energy is used.

6.2.2 Top-lit spaces. Top-lit spaces such as factories or offices are usually provided with roof glazing to give an average daylight factor of about 5 % and a uniformity ratio approaching the acceptable value of 0.7 (see clause 5). The average daylight factor of 5 % arises partly from lighting considerations, and partly because, if more glazing is installed than is necessary to give this level of daylight factor, losses of internally generated heat through the roof glazing become a serious problem. In addition, if the glazing is not of a north-light type of design, solar heat gain may also be unacceptable at certain times of the year.

A daylight factor of 5 % provides an illuminance of 500 lx or more for about 70 % of the working year. This level of illuminance is adequate for most visual tasks likely to be undertaken in industry. Such daylighting therefore needs to be supplemented only during those times of the year and the day when the illuminance from the 5% daylight factor falls below the acceptable level. There may be an opportunity to use photoelectric control to limit the use of supplementary lighting to these times.

6.2.3 Side-lit spaces. Side-lit spaces require different principles in the design of the supplementary artificial lighting system. The main purpose is to reduce the diversity of the lighting by selective illumination of the spaces remote from the windows.

When the sky is visible through windows on or close to the normal line of sight or when people habitually and frequently look up from their work and see the bright sky through the window, this very largely determines visual adaptation. Those parts of the room remote from the windows that are less well lit appear subjectively to be darker by comparison, and the photometric measurement of the prevailing lighting in these darker areas is not a reliable guide to the visual judgement of the adequacy of the lighting.

In addition there is a feeling of deprivation that results from working in an apparently dark part of the room when others can be seen to be working in the brighter parts near the window. This sense of deprivation, which has been noted by architectural psychologists and given some prominence, should be taken into account in considering the overall design of the lighting of the building.

The design of the artificial lighting supplements in a side-lit room requires, in theory, a lighting system that illuminates selectively those parts of the room receiving less light from the window, and that varies in quantity with the brightness of the sky as seen through the window. The aim is to achieve, not a uniform illuminance, but rather a gradation of illuminance from the window area towards the remoter parts of the room that is consistent with visual expectations of unilateral daylighting. If the artificial lighting supplement swamps the daylighting, the desirable characteristics of side lighting, (see clause 5) particularly as regards modelling, will be lost and the overall result will be less acceptable. The aim should be to reduce severe contrasts while retaining the visual character of the side lighting.

In practice these principles are modified. A distinction can be made between the needs of individuals in dwellings or small offices and the needs of people in large offices and in public buildings such as schools and hospitals. Refinements of design and even individual control will be welcome for those in dwellings or small offices. In public buildings simplicity of operation may take priority but even so a space may be enhanced, and at the same time fuel may be saved in the interests of energy conservation, if consideration is given to the selective illumination of walls and of other areas, priorities being established by the use of the space and by the daylighting conditions. It is not always an economic solution to provide an overall uniform illuminance either for daytime supplementary lighting or for night-time lighting. Selective switching and the use of photoelectric switching and dimming should be considered in order to get the maximum effect for the minimum consumption of energy.

For uniform illuminance conditions, the average level of the supplementary electric lighting depends on the daylighting condition and on the nature of the work being illuminated but should be not less than 300 lx, otherwise the space will appear gloomy and poorly lit on dull days and after nightfall. A range of 300 lx to 500 lx correlates with an average daylight factor of between 3 % and 5 %. These figures are only guides and should be related to the daylighting design, the fenestration and the view outside. Recommendations are given in clause 8.

An extension of the supplementary lighting principle is the technique employing limited window areas (commonly vertical slit windows that give a limited view but yield maximum daylight penetration for the available glazing), supplemented by an illuminance of about 1000 lx or more from permanent artificial lighting throughout the room. In such a design the windows perform a minimal service, and the space is effectively lit permanently by the artificial lighting. The main criterion is the thermal performance of the external building envelope (walls and windows) rather than the visual considerations. In a deep building, however, considerable energy may be required to remove the heat from the lighting and other sources even in cool weather, or perhaps distribute it to perimeter areas.

6.3 Supplementary artificial lighting and window design.

The design and shape of windows to be used with a permanent supplement of artificial lighting will depend very much upon the need for adequate view of the outside, and on the depth of penetration of daylight.

These two considerations may be in opposition. Deeper penetration of daylight can be achieved by the use of tall

windows, because the upper parts of the glazing are the most efficient in admitting daylight to the room, and the direct sky light that results has a major effect upon the modelling.

Experimental studies of windows in rooms with permanent supplementary artificial lighting indicate that the shape of the window should be related to the nature of the view outside, that is, if the outside view is mainly horizontal, as may be the case in rural areas, wide windows are preferred to tall windows. If on the other hand, the exterior view is vertical, e.g. tall buildings or trees, tall windows are preferred. (See clauses 7, 8 and 9.)

6.4 Reduction of glare. Supplementary artificial lighting in a room not only provides additional working light, but also reduces sky glare by buffering the brightness of the sky seen through the windows. By a combination of window design and a suitable choice of distribution of artificial lighting, glare can very largely be eliminated from supplemented lighting installations. This is discussed in greater detail in clause 7.

6.5 Colour characteristics

6.5.1 Design considerations. The colour appearance and colour rendering properties of the artificial light sources used to supplement daylight should be chosen in relation to the activities to be undertaken in the room and the likely continuation of the use of the room after normal daylight hours. The light from a fluorescent lamp or discharge lamp does not have the continuous spectrum characteristics of daylight, and so the colours of objects and surfaces may be distorted to a greater or lesser extent from the familiar appearance of the same objects by daylight. The colour appearance of a light source, and particularly a discharge lamp or fluorescent lamp, may not necessarily give an indication of its ability to render colours, and this is a further problem.

The colour characteristics of fluorescent lighting have been the cause of critical comment over the years, but continued improvements have reduced the frequency and level of complaint. Fluorescent lamps with a colour appearance and with colour-rendering characteristics reasonably like those of natural daylight are now available. 'Colour corrected' discharge lamps are also available and are sometimes used where colour rendering is not so important, as for example in industrial interiors.

In a room illuminated by daylight and having an artificial supplement, the differences between the colour characteristics of the artificial lighting and the daylighting, since they are seen simultaneously, tend to be accentuated; if these differences are too great complaints may arise, particularly in the case of visual tasks where colour judgement is critical, such as clinical examination in a hospital.

There are three general situations that call for three different choices of fluorescent lamp. The choice is governed by the need to achieve a compromise between lamps having the desirable colour characteristics and lamps with higher luminous efficacy but having less satisfactory spectral quality.

6.5.2 Non-critical colour judgement. Where colour judgement is not critical, for example in offices, schools and some factories, the choice of fluorescent lamp can give some priority to the needs of economy. An adequate match of the appearance of the artificial lighting installa-

tion with that of the sky visible through the windows is given by the type of lamp commercially designated 'daylight-type'; this is also reasonably satisfactory, if not the best choice, for use as the night-time lighting system when daylight fades. 'Colour corrected' mercury fluorescent lamps have also been used in some industrial situations.

6.5.3 Critical colour judgement. The choice of fluorescent lamp for situations where accurate judgement of colour is essential, for example in art galleries, laboratories, some factories, print rooms, etc., should be related to the colour-rendering requirements of the particular task. This choice will often be of the type that has a correlated colour temperature of 5000 K to 6000 K. Commercial designations are given in clause 8. The appearance of the lamps is distinctly 'cold' and such lighting is not suitable for use after dark unless the installation is designed to ensure that the bare lamps are not visible from any normal direction of viewing. The choice of decorative treatment in the room and of lighting units themselves should compensate for the cold effect. A few 'spots' of filament wall lighting can greatly improve the appearance. In general, the higher the colour temperature of the lighting, the higher is the illuminance needed to produce an acceptable appearance. When the illuminance is severely limited for reasons of conservation (see 8.5.4.2) this may mean that daylight alone gives a 'gloomy' appearance to the scene, hence the need for some added light of lower colour temperature (from incandescent lamps).

6.5.4 Hospitals. Hospital buildings are a special case, because for clinical reasons the colour appearance of patients is of major importance. The type of fluorescent lamp to be used has to have colour-rendering characteristics that enable the clinical staff to recognize colour change in patients' skin. Experimental studies of the problem indicate that clinical staff can work satisfactorily in certain types of fluorescent lighting that have good colour-rendering characteristics.

It is important that the same type of lamp should be used in all interrelated spaces, such as wards, treatment rooms and corridors, where clinical observations may have to be carried out by the medical staff. Lamp replacement has to be carried out strictly in accordance with the original specification. (See also 8.2.12, 8.2.13 and table 6.)

7. Quality of daylight

7.1 Aspects of quality. Many of the factors that govern lighting quality can only be discussed in general terms, and the factors governing the quality and quantity of the light in interiors cannot be analysed entirely separately. A distinction can sometimes be made between those aspects of lighting quality that affect visual comfort and those that relate more to the pleasantness of appearance and the character of the room. A room can be designed to be visually comfortable but it can also appear dull and characterless. A room that is bright, cheerful, and pleasant at first sight may be uncomfortable to work in over a period because of excessive contrast or glare. It is part of the skill of the daylighting designer to emphasize, where appropriate, one attribute as against another, or to achieve the best compromise between conflicting attributes.

Visual comfort and pleasantness of appearance are both governed by the distribution of brightness (luminance) in the room, by the directional qualities of the light as judged

by the position of windows relative to the observer, by the modelling, shadowing, and texture of objects and surfaces, and by the richness and texture of coloured surfaces. Both aspects of lighting quality are also influenced by the presence of sharp contrasts in the room, either between neighbouring surfaces or between the interior of the room and the view of the sky or the exterior landscape through the window, but the influence is not necessarily the same. Sharp contrasts that are small in scale add to the liveliness and the interest of the scene, but when large in scale can cause people to experience sensations varying from mild irritation to acute discomfort from glare or even serious disability to vision. The design of dramatic lighting effects is very likely to introduce a degree of visual discomfort that may be of little consequence in a building used for social purposes, but may be totally unacceptable in a school, factory, office, or hospital; the designer should determine the scale and degree of contrast appropriate to the circumstances. The aspects of lighting quality that are best understood are dealt with here as follows:

- directional properties (7.2);
- luminance (brightness) distribution in interiors (7.3);
- glare (7.4);
- design of the space and disposition of windows (7.5);
- colour and lighting design (7.6).

Each of these aspects has to be discussed separately but it is essential not to lose sight of their high degree of interdependence.

7.2 Direction of lighting

7.2.1 Modelling and shadows. Lighting that comes equally from all directions as, for example, outdoors in snow on an overcast day, gives 'soft' modelling, and on any numerical index scale of modelling would be represented by some terminal figure (for example, zero modelling or 1:1 modelling index). Such a modelling character would not necessarily be 'bad', and might be judged pleasant and flattering to the human face in certain circumstances. Light that comes strongly from one direction only in an otherwise dark room would give rise to 'strong' modelling that would have a value towards the other extreme of a modelling index scale. Modelling of this extreme character would be judged 'harsh' but might be desired for certain dramatic purposes. It is impossible in discussing modelling from daylighting to use terms such as 'good' modelling or 'bad' modelling without stating the context.

7.2.2 Vector-scalar ratio and vertical illuminance modelling index. When lighting consists of a single dominant source, such as the sun, and a secondary large-area source, such as the sky, a formula may be devised in which the main parameters are the relative magnitudes of the dominant direct component of illuminance and the secondary diffuse component, together with the direction of the dominant source relative to the object being modelled and the direction of the observer's view. However, in most interior daylighting situations the modelling arises from the interplay of directional light from several large sources, which may be windows in different walls, or rooflights, and more diffused light received at the object by reflection from surfaces in the room. In such circumstances the directional component is difficult to specify in visual, rather than in engineering, terms.

Two forms of modelling index have been put forward for

use in daylighting situations. One, the vector-scalar ratio, employs the mathematical concept of an illumination vector in relation to the mean spherical illuminance at the object under consideration (ref. G.1.19).

The other modelling index relates the maximum to the minimum illuminance received on a plane surface at the object, the plane rotating about an axis to the situation. This is usually a vertical axis, and so the modelling index is the ratio of the maximum to the minimum illuminance on a vertical surface rotating about a vertical axis at the modelling point.

Neither of these forms of modelling index is fully satisfactory, but the second is simpler to operate. The vector-scalar ratio correlates well with the subjective judgement of modelling in simple cases where the directional light comes from the same general direction, but it is at variance with the operation of the eye as an analysing instrument; the eye simultaneously perceives and evaluates separately the effects of light coming from sources of widely differing direction, whereas the vector concept synthesizes the light from such different directions into one single vector. Because of this fundamental limitation, critical in daylighting situations, and because of the need for sophisticated photometric equipment in operating it in practice, the vector-scalar ratio is less suitable for recommendations in a code of practice than the vertical illuminance modelling index.

Although the vertical illuminance modelling index (see also appendix C) gives useful guidance to the designer on the distribution of windows that will achieve modelling for his purpose, it cannot give him a figure that will tell him whether the modelling will be 'good' or 'bad'. It will, however, quantify preferences in relation to the needs of the situation.

A distinction needs to be made between modelling and cast shadows. Modelling occurs when the lighting of an object varies over its surface because different parts receive their light at different angles of incidence. Cast shadows occur when the light on the surface is interrupted by an obstruction between the surface and the major source(s) of illuminance. Modelling can occur without cast shadows, while strong cast shadows can occur with very little modelling. In practice they usually occur together as a result of directional lighting.

Modelling and cast shadow both reveal solid form. In very diffuse lighting there is little modelling; shadows are soft and solid form is not well revealed. A large window will produce strong modelling and soft shadows, particularly if there is a high internally reflected component. A small window in a room with dark walls will give strong modelling and hard shadows, because of the lack of 'fill-up' light from the internally reflecting surfaces.

Guidance cannot be given on preferences without stressing that modelling which is satisfactory, or preferred, for one situation such as a school, may not be acceptable in a room of very similar proportions but with an entirely different use, such as a hospital.

There is some consensus of opinion, however, that people in the ordinary course of daily work like the kind of modelling that results from light with a strong component coming from somewhat above the horizontal, such as comes from a window in a side wall, provided there is sufficient diffuse light from internal reflecting surfaces to reduce the

harshness of the modelling. Generally acceptable modelling in side-lit rooms results if the modelling index (ratio of maximum to minimum vertical illuminance) lies between 2:1 and 5:1. It is one of the satisfactory characteristics of good side lighting that the modelling does not vary dramatically over different parts of the room. Even though the daylight factor may vary by about 5 to 1, the modelling index will remain fairly constant, so that the appearance of people does not change as they move about the room.

Modelling from top lighting is regarded as flat and dull and unflattering to the human face. The modelling of the human face will change as people move around the room, standing first directly under a rooflight, and then in a position between lights. This objection also applies to all forms of lighting set in the ceiling, whether natural or artificial.

The direction of lighting and the direction of view of the object should be well separated, so that both the modelling and the cast shadows can be seen. Objects viewed from the same direction as the source of lighting tend to have a flat appearance.

7.2.3 Modelling from supplementary artificial lighting and windows. The modelling given by side daylighting combined with supplementary artificial lighting will depend upon the way in which the artificial lighting is integrated with the daylighting. Three different forms of supplementary lighting have been used: (a) supplementary lighting placed near to the window, and so emphasising the modelling effect, (b) supplementary lighting placed at the back of the room, acting in opposition to the modelling from the window, and (c) lighting distributed uniformly over the room, introducing a top lighting modelling character in addition to the modelling from the window. Current practice favours, for reasons of engineering convenience, this third form of supplementary lighting with uniformly distributed artificial light sources that serve as the night-time lighting after daylight hours. (See also 6.2.3.)

If the uniformly distributed artificial lighting system is too dominant, it will override the preferred modelling from the windows, except in a limited area near them. A reasonably satisfactory result will often be achieved in a side-lit room designed to an average daylight factor of 3 %, with uniformly distributed additional artificial illuminance of about 300 lx. If the average illuminance from the artificial lighting alone exceeds 500 lx, much of the modelling quality will be lost on dull days.

The other two forms of supplementary lighting lend themselves to more refined design and enable the modelling effects to be enhanced or modified with some degree of precision, using as a numerical design guideline the vertical illuminance modelling index or, in the case where the supplementary lighting comes from the same direction as the light from the window, the vector-scalar ratio.

7.3 Luminance (brightness) distribution in interiors. The visual quality of a daylighting installation is influenced by the distribution of brightness in the room more than by any other single factor. The subjective brightness appearance is governed not only by the photometric luminance, but by the adaptation conditions, which include the visible sky and the lightness and colour of the surfaces in the room as they are seen. The photometric luminance is determined by the distribution of incident illuminance and the directional reflectance properties of

the surfaces in the room. There is therefore a complex relationship between subjective and objective factors.

Visual comfort is affected by the distribution of brightness in the immediate visual field, and by the brightness of the environment as it is seen when people look up from their work.

The surroundings should not be brighter than the work. The greatest visual comfort results when the work is slightly brighter than the immediate surroundings, which in turn should be slightly brighter than the room in general (the so-called 10:3:1 ratio). This ideal distribution of luminance is relatively easy to achieve in a small room lit by artificial lighting, but in large rooms lit by daylight some compromise with the ideal is necessary. If the room in general is to be bright, and light surfaces are to be used on the walls, the only way in which the work can be made brighter than the surroundings is by selective lighting, by taking the work to the window in a side-lit room, or working under a rooflight in a top-lit room (see 5.1.4). In rooms with limited occupancy this is easy but in larger rooms in public buildings with fixed occupancy it may not be convenient or possible.

Fortunately the luminance ratios for maximum visual comfort are not critical, and much can be achieved by the positioning of work places and by the suitable choice of reflectances in and around the work, for example by using light grey rather than black table tops for working with white paper, and avoiding the use of white table tops.

The desired distribution of luminance in the window wall can be achieved by the techniques mentioned in clause 8. The major requirement is for splayed reveals of high reflectance, which serve to grade the contrast between the interior of the room and the sky. The window walls should be of as high reflectance as is compatible with the other requirements of the interior lighting.

7.4 Glare

7.4.1 Glare discomfort and disability. Areas excessively bright in relation to the rest of the visual field give rise to glare. This situation can cause disability to vision, as with a very bright sky light at the top of a flight of stairs or a window at the end of a relatively dark corridor; or it can give rise to discomfort without at the same time reducing vision. On a very dull day the sky seen through a large window may cause no glare discomfort, yet it may inhibit the view of objects around the window, as can be easily demonstrated by holding the hand in front of the eyes to screen the window. Conversely, in a well-lit room on a very bright day, the sky seen through the window may cause acute discomfort without noticeably reducing vision. The disabling effect is due to certain physiological factors, including the scattering of light in the eye, while the discomfort effect is due to other physiological factors, including interaction in the neural pathways to the brain and the consequent influence on the pupillary neuromotor system.

Both forms of glare are associated with excessive contrast and unfavourable distribution of luminance in the visual field. In addition, the discomfort effect is directly related to the absolute luminance irrespective of whether there is unfavourable contrast present. In a particular room a distribution of luminance that is comfortable on a dull day may be very uncomfortable on a bright day.

In addition to the discomfort and disability effects from glare in a fixed direction of view, consideration has also to be given to what is called 'successive glare', i.e. glare that arises temporarily when looking up from the relatively dark work towards the bright window.

7.4.2 The control of glare. Sky glare can be controlled by the use of blinds, curtains, etc. over the window and by refinements (see 7.4.4) in the design of the fenestration and of the supplementary artificial lighting. Systematic design control is aided by the use of the glare index, which is derived from work at the Building Research Establishment and elsewhere. An extension of the CIBS (IES) glare index is used in the Draft for Development for the tabulation of glare indices from windows and from rooflights. Recent work has examined the factors that influence glare in practical situations and is reported in a supplement to CIBS Technical Report TR4, *Daytime Lighting in Buildings* (ref. G.1.22). The research has led to a simplified approach to glare prediction for vertical side glazing. Limiting levels of glare index are detailed in clause 9 and tables for the determination of the daylight glare index are given in appendix B.

The control of glare in daylighting supplemented by artificial light is complex. The glare from the windows can be reduced by an increase in interior luminance resulting from the artificial lighting supplement, but additional glare may be caused by the view of the artificial lighting installation. The addition of the glare components from the daylighting and from the artificial lighting will depend upon both the absolute levels of glare and the relative levels from the two systems. If the glare from the daylighting is excessive, it will be difficult or impossible to mitigate it by the design of the supplementary artificial lighting. If the artificial lighting gives a high degree of glare, little improvement will result from the presence of the daylighting. However if both installations separately give only a moderate degree of glare, the two combined will probably give a better rather than a worse result.

7.4.3 Blinds and louvres. There should be no difficulty in controlling glare from accessible windows. Adjustable blinds or curtains, if well designed, maintained and used, are capable of controlling excessive sky brightness. Glare control by blinds should only be required on bright days. No permanent control is necessary or desirable but, in some situations where blinds may be misused, fixed louvres or permanent screens are sometimes recommended. Such devices, however, reduce the amount of light admitted at all times and are undesirable in rooms that rely exclusively on daylighting. Permanent louvres in the upper parts of the window, designed in conjunction with a rational form of permanent supplementary artificial lighting can give very comfortable lighting throughout the year while still providing a satisfactory view out and a dominant daylighting character on all but dull days. Instead of permanent screens, the upper sections of the windows may be glazed with glass of neutral colour and of low light transmittance.

7.4.4 Refinements of design: contrast grading. The detailed design of the window and the window wall can influence the degree of glare discomfort. Glare is reduced if there is a gradual, rather than a sharp, change in the luminance of the boundary between the sky and the interior. Careful design of the window and the use of light colours on adjacent surfaces can grade the contrast between the interior and the

sky by providing an intermediate zone of luminance between that of the sky and of the room (the principle of 'contrast grading').

Examples of methods of fenestration designed to reduce glare are given in clause 8. One of the most useful techniques is the provision of light-coloured splayed reveals to the window. Tapered glazing bars between the panes of glass in the window have a small but useful effect, but the number and cross section of glazing bars should in any case be reduced wherever possible. Examples of methods of fenestration designed to reduce glare in specific circumstances are also given in clause 8.

Artificial lighting directed on to the window wall to raise the luminance of the window surroundings is good in principle but often unsatisfactory in practice. Lighting used for this purpose should have a spectral quality closely similar to that of daylight and the light sources should be concealed from all normal directions of view to prevent them becoming additional sources of glare or visual conflict.

7.4.5 Systematic control of glare

7.4.5.1 The discomfort glare index. The discomfort glare index is a mathematical expression relating the subjective sensation of discomfort to the physical parameters of the lighting situation, in particular the luminance of the window, the average luminance of the room interior surfaces and the direction of the source of glare in relation to the normal direction of viewing. Limiting values of the discomfort glare index can be set such that the degree of discomfort is within acceptable limits as judged by the occupants of the room. Such a judgement depends not only on the critical nature of the visual task, but also on the degree of mobility of the occupants, and the length of time during which they experience the condition.

The limiting glare indices derived for differing activities do not ensure that everyone will be satisfied. Visual conditions in a room are not constant and differ with location and direction of view. Also there will always be individuals particularly sensitive or insensitive to glare. The limiting glare indices are set to try to ensure that, on average, not less than 85 % of the general population will find the degree of glare acceptable in a particular situation.

7.4.5.2 Determination of daylight glare indices. The calculations of the daylight glare index for side windows and roof glazing are described in appendix B. The following summary is a short guideline to the procedure.

Rooms lit from one side only should be considered separately from rooms lit by rooflights. For the latter the methods and tabulation of glare constants are given in appendix B.

The glare index for any space is a direct function of the luminance of the sky and of the solid angle subtended by the window at a particular viewing position within the room. The luminance distribution of the CIE standard overcast sky modified for the transmittance of the window glass, is used for the calculations. The glare index is an inverse function of the average adaptation effect, which is a function of both the luminance of the room surfaces and the luminance and apparent size of the window.

As the glare index for any space is a function of the sky luminance and the average reflectance of the room interior surfaces, a reduction in glare index can be achieved by

raising the reflectance of the surfaces and/or introducing screening of the window.

7.4.5.3 *Combined side daylighting and artificial lighting.*

In rooms lit by side daylighting and uniformly distributed artificial lighting, a single value of glare index appropriate to the whole room (as in the exclusively daylight situation) may not apply. Some compromise with a highly complex situation will be necessary. In a room lit by side daylighting alone, a change in the viewing position with distance from the window produces a relatively small change in the degree of glare, because with a greater distance from the window, although the apparent size of the glare source is less, the adaptation luminance also decreases because more of the darker areas at the back of the room come into the visual field. The two effects tend to counterbalance each other.

In the supplemented lighting situation the distribution of light in the room is more nearly uniform; in the presence of the artificial lighting supplement, therefore, glare discomfort due to the window decreases with distance into the room. However, if the artificial lighting is arranged, as is customary, in rows parallel to the window, more lighting fittings come within the field of view as distance from the window increases. There is therefore an increase in discomfort glare due to the artificial lighting towards the rear of the room. A zone of changeover occurs, on one side of which the window is the dominant source of glare discomfort, and on the other side of which the lighting fittings are the dominant source. This zone of uncertainty changes with the sky luminance, the zone receding from the window as sky luminance increases.

In general lighting practice, the complexities of glare from mixed lighting are resolved by the procedure described in appendix B. The daylight glare index is calculated to comply with the limiting glare index listed for the activity/space schedule of clause 9. The artificial lighting glare index is calculated separately to comply with the glare index limit for the artificial lighting alone, since the artificial lighting installation will be used by itself during the hours of darkness. Provided that the daylighting glare index and the artificial lighting glare index each meet their respective limits as set out in the schedule, the degree of glare will be acceptable also when both lighting systems are in operation together.

7.5 Design of the space and disposition of windows

7.5.1 *General.* The appearance and character of a room depend to a great extent upon the fenestration. In many cases decisions about windows are the most influential that the designer makes on both the internal character and the external appearance of a building.

Historically, window design was conditioned by technological limitations and contemporary problems exist which, when properly considered, can be equally constraining. For example, external traffic noise, reduction of solar gain, prevention of heat loss and energy conservation all point to different constraints that will condition overall size and shape.

7.5.2 *Windows and the view outside* (see also 6.3). An adequate view out should always be provided unless the activity to be carried out in the space is itself a reason for not doing so. Where permanent supplementary artificial lighting provides the major component of the lighting, the window will serve primarily to give the occupants a means of visual communication with the exterior.

Windows can provide visual relaxation, satisfy a need to see the sunlit landscape and the changing lighting effects caused by atmospheric conditions, and can also provide a sense of orientation, to relieve feelings of isolation and claustrophobia.

The shape and size of a window should be related to the view. If there is an interesting view the window should be designed so that as many people as possible inside the room can enjoy it.

The most important factor is the area of window, especially in a room lit partly or predominantly by supplementary artificial lighting. There is a critical minimum window area below which the window ceases to perform the proper function of providing a view. Table 5 gives recommended minimum window areas that have been determined experimentally to provide a satisfactory view out for the different indoor activities classified 1 and 2 and cross referenced to tables 6, 7 and 8. The areas are related to the depth of the space from the window wall and are expressed as percentages of the external wall. Satisfaction with the window area is affected by the distance of the observer from the window. Decreases in window area below the values given in the table are not recommended. The values given are not rigid design rules, but rather guidance to give the designer some means of reconciling the need for reduced fenestration (e.g. for heat energy conservation) while still providing sufficient window area to avoid dissatisfaction.

7.5.3 *Window shape.* The choice of window shape in rooms provided with supplementary artificial lighting is partly dependent upon the view outside and partly on the sizes, proportions and functions of the interior, (see 6.3). There is some evidence that horizontal windows are more generally satisfying than vertical windows, the exact shape and location being dependent on the elevation of the skyline. There appears to be a general requirement that a wide view of the skyline or horizon should be seen, together with some sky above and some landscape below, because cloud patterns and the landscape are both of interest and together complete the scene.

Window sill heights will depend on the requirements of equipment. Window head heights commonly range from 1.8 m to 2.4 m, but depend on the view outside. Requirements are less precise for fully obstructed views. Particular types of buildings may have their own requirements; for example, hospital patients are said to welcome windows to floor level in order to be able to appreciate outdoor activity, and in many school rooms teachers stress the value of visual and physical connection with the outside.

The lateral continuity of the view should not be disrupted. A number of smaller windows may not be as satisfactory as a single larger one if there is an interesting view outside, and if the intervening wall sections are wide. Satisfaction with windows of similar area decreases with an increase in both mullions and the number of elements making up the window. The relation of the view window to movement by occupants about the room and the movement or changes that may occur in the outside scene should be taken into account.

A bay window or a corner window offers a wide angle of view, provided people have the freedom of movement to take advantage of it.

7.6 Colour and lighting design. Colour harmony and colour

preference, though having an influence on the visual character and appearance of a daylight room, are nevertheless outside the scope of this draft (see ref. G.1.12). The need to provide high average reflectances in a room to enhance the internally reflected component of daylight does not preclude the use of strong and even dark colour. Areas of attraction or dominant interest can be created by the use of strong colour provided the average reflectance over the whole room is maintained at the requisite value. In practice this is not difficult to achieve. The function of surface finish in contributing to lighting of good quality through the selection of colours with suitable reflecting characteristics is important, and has been taken into account in BS 5252 and the derived standards including those for paint (BS 4800), vitreous enamel (BS 4900), plastics (BS 4901), sheet and tile flooring (BS 4902), and external cladding colours for building purposes (BS 4904).

Many aesthetic considerations such as the choice of colour to produce a 'warm' or 'cold' colour character affect the selection of colours of a particular hue and chroma. This selection should be related to the spectral quality of light in the room, the same colour treatment giving a different result in a north-facing room as compared with a south-facing room, because of the difference in the spectral quality of the light; even greater care should be exercised if the room is to be lit by artificial lighting, supplementary by day and entirely by night.

The appearance of surface colours may be affected by highlights and shadows. Colours in shadow are likely to appear darker and greyer, in Munsell terms reduced in value and chroma. Since surface texture is less visible in shadows the colour tends to appear luminous, an effect that can be accentuated by the use of dark or strongly saturated colour in shadowed areas. Alternatively the depth of shadows can be reduced by raising the value of the shadowed colour. Further data on the effects of highlight and shadow on surface colour appearance is given in a Building Research Station study published in *Die Farbe* in 1955 (ref. G.1.11).

8. Design guidance

8.1 General. Basic principles of daylighting have been described in previous clauses. This clause is concerned with the application of these principles to specific activities occurring in various building types. The information is given in the form of design notes expanding the tabulated data given in clause 9. These notes are neither exhaustive nor exclusive. They are included for guidance and are illustrated by sketches and photographs of particular examples.

Lighting for different kinds of activity demands careful discrimination. This can often be aided by considering the lighting of the building and the lighting of the task. In some spaces, e.g. a lecture hall, there is no distinction, while in others, e.g. a workshop, there is a distinction that it would be bad practice and bad economy to ignore.

A room where there are only a few difficult tasks that need special lighting should not be lit to a uniformly high illuminance. Selective lighting on the special task areas provides a better solution visually at less capital and running cost. The distinction between task lighting and building lighting should be appreciated as should their

integration. They are both part of lighting design as opposed to mere provision of illumination.

Basic visual requirements for particular types of building and activity are discussed in 8.2 to 8.5, the types being dealt with in four main categories:

1. Work places
2. Reception and circulation
3. Residential spaces
4. Other spaces

8.2 Category 1: work places

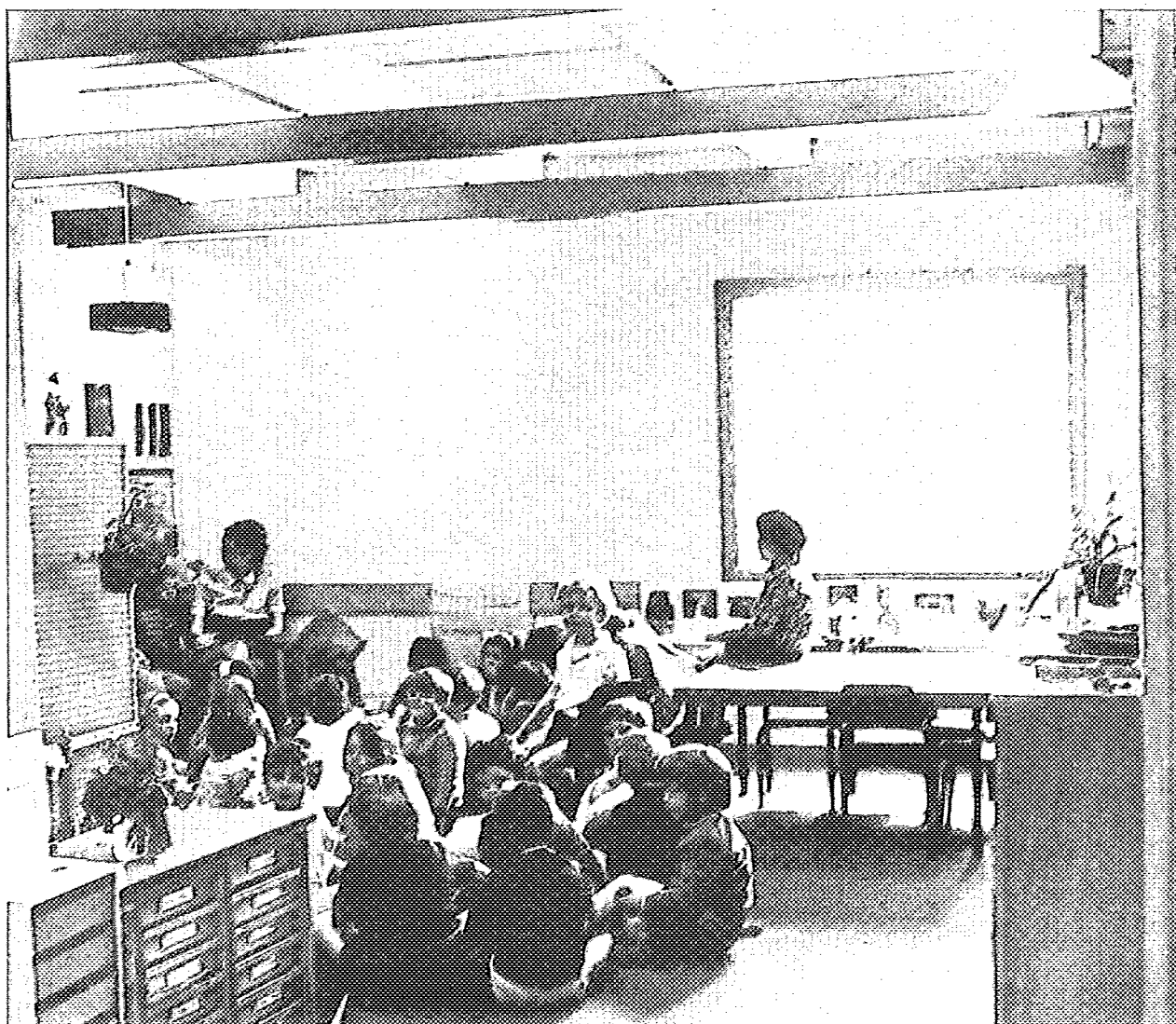
8.2.1 General teaching spaces

Activity/spaces	References	Building types
Formal teaching and seminar rooms, deep (open) plan teaching spaces	<i>The Education (Schools Premises) Regulations</i> , 1981 (ref. G.1.19) <i>Guidelines for Environmental Design and Fuel Conservation in Educational Buildings</i> , DES Design Note 17 (ref. G.1.16) <i>Colour in School Buildings</i> , DES Building Bulletin 9 (ref. G.1.17) <i>Lighting in Schools</i> , DES Building Bulletin 33 (ref. G.1.18)	Schools Colleges Universities Hospitals (teaching)

Daylight should as far as possible be the main source of light in teaching spaces and should only be permanently excluded in special circumstances. Daylight is particularly valuable in schools for young children where the hours of use are comparatively short and artificial lighting is only required for a very short time during the winter season when natural light fades before the end of the school day.

In secondary schools, colleges and universities, where the hours of use are longer or where relationships between various activities often demand larger, more complex interrelated spaces, requirements are more varied. Daylight, again, is appropriate for most activities in this category but, where it is not feasible to use daylight as the sole source of daytime illumination in teaching areas, well integrated artificial light can be used to supplement the available daylight (figure 3). In these circumstances, window areas should be not less than the minimum recommended for view purposes in relation to the depth of the space. (See table 5 and DES Design Note 17, ref. G.1.16.) The Department of Education and Science recommended that the lowest level of maintained illuminance at any point on a working plane should not be less than 150 lx. This is to allow for the use of tungsten filament lighting in schools for younger children as the recommended minimum illuminance of 150 lx is acceptable for most tasks involved in nursery and primary schools, and selective lighting can be provided on tasks that are visually exacting. In teaching spaces for older children and adults, where permanent artificial lighting provides the major illumination for the task, the illuminance should be not less than 300 lx and with exacting tasks may need to be about 500 lx (see clause 9). Interiors with levels of less than 300 lx from fluorescent lighting usually appear dull.

When the main view is across the space, e.g. towards a chalkboard, and movement by the occupants is restricted, a daylight glare index of 21 should not be exceeded. In informal teaching situations this may be relaxed to 23. An artificial lighting glare index of 16 should be met when the main view is across the space, e.g. towards chalkboards and display surfaces and in teaching spaces for further education. In less formal situations the glare index for the artificial lighting may be relaxed to 19.



Thorndown Junior School, St Ives, Cambridgeshire. Architect: Huntingdon and Peterborough County Council Architect's Department. Photograph by, and reproduced by permission of, Ralph Hopkinson, Newton Watson & Partners, Environmental Design Consultants.

NOTE. An example of a school designed with minimum window area to reduce the passage of noise from low-flying aircraft. Note the integration of permanent artificial lighting and structure

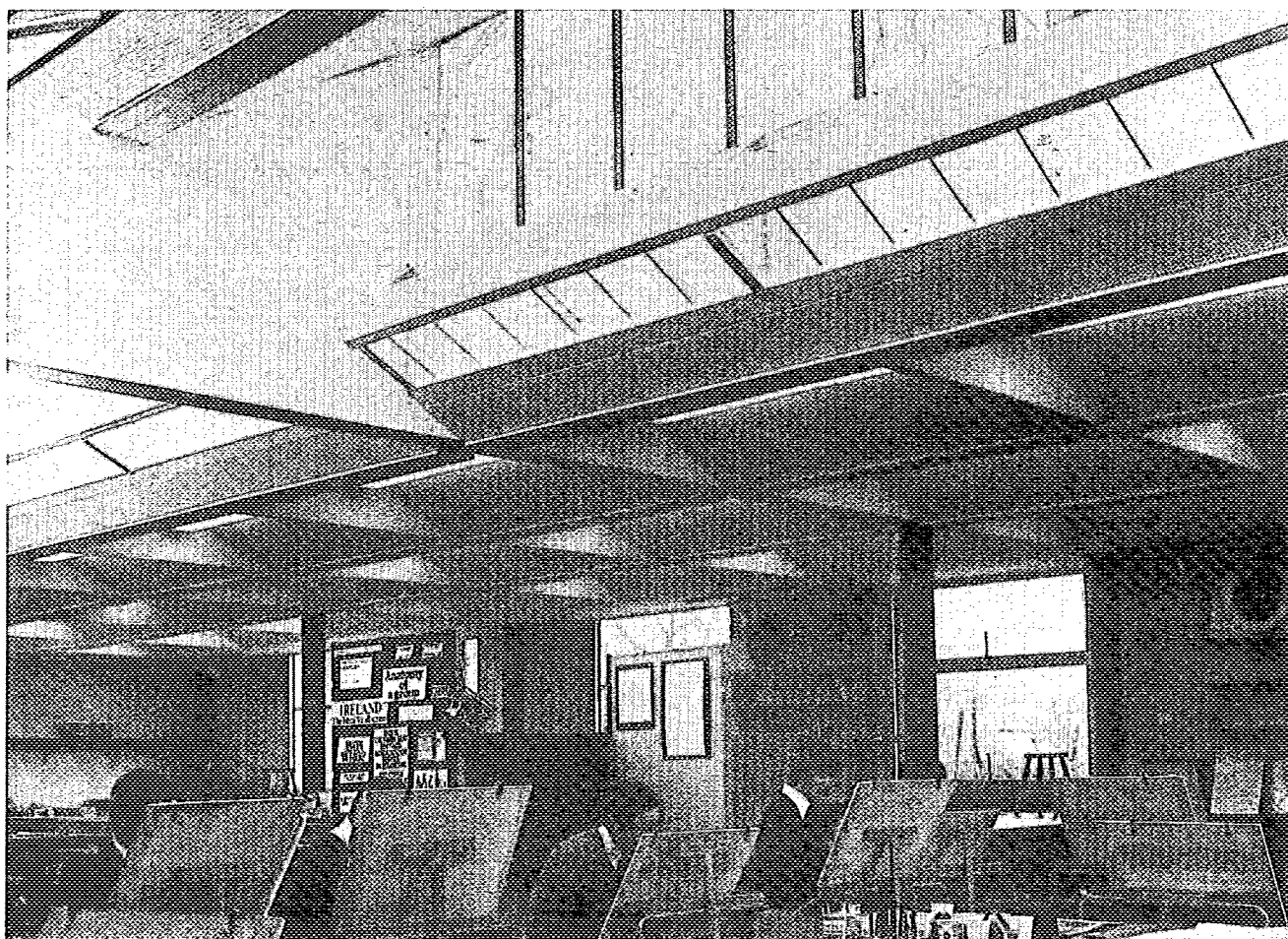
Figure 3. Classroom lighting

Provided the minimum requirement for view out is met by well-positioned windows, additional daylight may be provided by rooflighting carefully integrated with the artificial supplement (figure 4). In teaching spaces of unusual or indeterminate shape, or where the main view window is located at one end of the space, the admission of light through a window in an adjacent wall will assist a satisfactory distribution of daylight and will help to reduce glare. Window walls should be of a light colour with a reflectance not less than 60 % (i.e. Munsell value 8 or above) although on bright days some form of glare control such as window blinds may be necessary.

Selective lighting should be provided on visually exacting tasks remote from windows. Contrasts of luminance greater than 10 to 1 should be avoided in juxtaposed areas. Desks and worktops with a reflectance of 25 % to 30 % (Munsell value 6), i.e. about one-third of that of white paper, are best; the finish should be matt.

Selective lighting is usually also necessary on the chalkboard or display wall, of 500 lx to 1000 lx. This is best achieved with artificial lighting for use by day as well as at night with directional luminaires giving a controlled light distribution.

Reflections on chalkboards or other surfaces should be avoided by careful positioning of the directional lighting and the immediate surroundings to the chalkboard should be of moderately low reflectance (30 %). In some circumstances it is possible to use rooflights to provide the emphasis lighting on display areas but these and any artificial lighting luminaires used for highlighting display surfaces should be so placed as to prevent direct view of the sky or bare lamp from normal standing or sitting positions, and should be correctly offset to give reasonable uniformity on vertical display surfaces.



Langleybury School, near Kings Langley, Hertfordshire. Architect: Hertfordshire County Council Architect's Department. Photograph by, and reproduced by permission of, Ralph Hopkinson, Newton Watson & Partners, Environmental Design Consultants.

NOTE. The main source of daylight is from carefully designed rooflights giving good light over the whole area. The windows are positioned to give selective views. Note the integration of artificial light into the structure.

Figure 4. School art studio lighting

8.2.2 Lecture theatres and examination halls

Activity/spaces	References	Building types
Lecture theatres	<i>CIBS Lighting Guide:</i>	Colleges
Examination halls	<i>Lecture Theatres</i>	Schools
	(ref. G.1.21)	Universities
		Hospitals (teaching)

The advantages and disadvantages of glazing in lecture theatres and examination halls should be carefully considered. A sense of deprivation is experienced if natural light is excluded and this could be important where occupants, e.g. teaching staff, may have to spend long periods in the space. Some visual relief by a window is beneficial, and in any lecture theatre or hall that depends solely upon artificial lighting, provision should be made for the possibility of central or local power failure. The safety standard of 0.1 % daylight factor should be provided in the main circulation and exit areas and the fenestration that admits this light should not normally be subject to black-out. There is no optical reason for total black-out because projectors are available that provide adequate illuminance even for colour slide projection in conditions of minimum daylight, and a low level of background lighting is desirable for note taking. A daylight factor of 0.1 % is recommended to meet safety needs and to enable the space to be

evacuated in the event of an emergency unless emergency artificial lighting is provided.

If windows are provided, visual and aural distraction from outside should be avoided and sunlight should be excluded with shading devices where necessary. Undue brightness contrasts between the sky and the window walls should also be avoided. Black-out facilities will be needed and, for avoidance of contrast and for a more pleasant effect, a light-tight opaque material having a surface reflectance similar to that of the window wall, rather than a black surface, should be used.

8.2.3 Music rooms

Activity/spaces	References	Building types
Music rooms and music practice rooms	<i>Lighting in Schools,</i> DES Building Bulletin No. 33 (ref. G.1.19)	Educational buildings Recreational buildings

If side light is to be employed, music rooms for performance and regular practice should be planned so that the light from the windows falls on to the music stands, and the direction of view of the musicians should be parallel to the windows. As music-room windows are often sealed and double glazed and consequently restricted in size, or have to be positioned so that unwanted sound is not transmitted to other rooms, the best solution may be to

design a supplementary lighting scheme in which the artificial lighting provides the working illuminance at the piano or on the individual music stands, while the windows provide a view out only.

Glare should be avoided and the furniture so arranged that the conductor or teacher will not be silhouetted against a bright area. In some cases local lighting on the music stand may be necessary and tungsten lamps can be used to highlight teaching aids and provide a more intimate character to the spaces.

8.2.4 Art and craft rooms

Activity/spaces	References	Building types
Art	<i>Lighting in Schools,</i>	Schools
Craft	DES Building Bulletin	Colleges
Needlework	No. 33 (ref. G.1.18)	Factories
		Offices
		Recreational buildings

Work in art and craft studios is varied, and the disposition or direction of the daylight is not necessarily related to any one particular layout or direction of viewing. Full daylighting is difficult to achieve with vertical glazing in the walls alone and particularly if this is restricted to one wall. Top lighting in one form or other is necessary to supplement the light in all parts of a studio remote from windows. The main daylight can be from rooflights or high-level ('clerestorey') windows provided that view windows are introduced where possible. This allows freedom to arrange the vertical glazing to achieve the most stimulating view out without having to be too concerned about its daylighting contribution. Reflectances should be kept high, say ceilings 70 %, walls not less than 50 %, and it is most important that the reflectance of the floor should be high and the window properly screened to avoid direct sun penetration and high sky glare.

The modelling effect of side daylighting should be utilized in art areas where form and textures are of importance, e.g. sculpture, pottery. Where studios cannot be suitably lit by rooflights alone, artificial lighting may be used solely in conjunction with view windows or it can be integrated with rooflights for use when daylighting falls below a certain level.

Accurate colour rendering is important in these areas. The type of fluorescent lamp to be used in the supplemented areas (or for night-time use) should preferably be 'colour matching' whose spectral characteristics are close to daylight (CCT 6500 K). When energy conservation is important, a possible but less satisfactory alternative to the 'colour matching' fluorescent lamp is one of the recently developed higher efficiency tri-band lamps of 'cool' or 'intermediate' appearance. The lamps should be fully integrated into the ceiling or structure and should not be visible from any normal direction of viewing.

The general supplementary artificial lighting should provide an illuminance of 300 lx to 500 lx on the task, and wall and display areas should be brightened by the use of tungsten filament lamps, screened from direct view, providing an additional 100 lx.

Similar activities to those mentioned above that also require good daylighting or good colour rendering are weaving, dressmaking, graphic design, printing and paint manufacture. Any project areas where colour work starts under

daylight and continues under artificial light, say in spaces that have considerable use after work or school hours, also need well-integrated lighting and good colour rendering. Parts 1 and 2 of BS 950 specify spectral distribution properties of sources for colour examination and inspection.

8.2.5 Workshops (teaching)

Activity/spaces	References	Building types
Woodwork	<i>Lighting in Schools,</i>	Schools
Metalwork	DES Building Bulletin	Colleges
Engineering (teaching)	No. 33 (ref. G.1.18)	Training centres
		Recreational buildings

The lighting of teaching or training workshops should be consistent with good industrial practice (see 8.2.12). Daylighting can provide the general lighting during the daytime, either exclusively or in conjunction with supplementary artificial lighting. The daylight can be determined by the illuminance requirements of the visual tasks, or it can be designed entirely from the point of view of amenity, view out and visual comfort.

Daylight design may not be compatible with the need for flexibility in teaching methods and the resultant spaces. In practice it is probably best to provide good general lighting rather than to attempt to relate the lighting to a specific task as the activities are likely to change a good deal. If the work is all of one kind, the daylighting or the combined lighting can be designed to be more specific. If the tasks are varied and have differing lighting requirements it would be wrong to design the workshops or workshop complex for the requirements of the most difficult task. Either the work can be zoned in such a way that the difficult task is undertaken in the areas of greatest daylight or, more satisfactorily, additional local lighting can be provided for those tasks that require more than the average illuminance.

In single-storey buildings, it is best to provide a uniform level of daylight by rooflighting. An average daylight factor of 5 % can be attained without the excessively large areas of glazing that give rise to problems due to excessive solar heat gain and discomfort from direct sunlight during the summer, and that cause cold down draughts and loss of internal heat in winter.

In multi-storey buildings and workshop complexes of very deep plan the preferable solution is side lighting and view out combined with a matched supplement of artificial lighting from fluorescent or colour-corrected discharge lamps designed from the start to serve as the work lighting. Sky brightness seen through windows will to some extent affect adaptation and will certainly act as a distraction if the interior illuminance is not high enough. The aim should be to provide illuminance both on the working plane and on the surroundings to provide an environmental brightness of not less than one-twentieth of that of the visible sky.

Local lighting, in the form of individual fittings attached to machines or mounted near machines, should be provided where work is to be carried out that is of special visual difficulty or for safety reasons demands careful visual attention.

Lighting from discharge lamps (including tubular fluorescent lamps) can cause stroboscopic effects in machinery in motion (see *CIBS Code for Interior Lighting*, ref. G.1.20).

8.2.6 Laboratories

Activity/spaces	Reference	Building types
Laboratories	<i>The Design of Research Laboratories</i> (ref. G.1.28) Appropriate sections	Education buildings Hospitals Factories Offices Research establishments

Large modern laboratories buildings include rooms of different size and type, from small single-person rooms to the very large open areas associated with pilot-scale development research that, so far as daylighting is concerned, are closely analogous to factory buildings (see table 6, under 'activity' 8.2.12).

The smaller conventional laboratory (i.e. a room with serviced benches) presents a special daylighting problem in that it may be necessary to house visual tasks of widely varying difficulty and the nature of these may change over comparatively short periods of time. It would not be practicable to specify natural lighting that would allow all of these visual tasks to be performed everywhere, but it is possible to assess the proportion of the range of visual tasks that can be performed with given amounts of light and to recommend averages that will cater for a high proportion of the range. Tasks requiring more light can be taken to better-lit parts of the room or local artificial lighting should be provided. It is recommended that such laboratories should have average daylight factors of 1 % in supplemented situations and 5 % for rooms with a large proportion of top lighting.

In addition to the multiplicity of changing tasks within the standard research laboratory 'cell' unit the emphasis of the work can change as the direction of the research shifts, and it is usual for the fenestration of such a building to take account of the need for demountable or moveable partitions (figure 5).

Laboratories for teaching tend to be less flexibly arranged, although even here there is a tendency towards less formality than has been the practice hitherto. However, benches containing sinks generally need to be linked to services that are fixed and it is less easy for students to move over to a window to gain better light. Where possible, top daylighting with rooflights carefully designed to cut out glare and solar gain is a good solution for schools: in other situations good side lighting with an artificial supplement is appropriate.

8.2.7 Staff and common rooms

Activity/spaces	References	Building types
Staff rooms Common rooms	Offices, Shops and Railway Premises Act, 1963 <i>CIBS Code for Interior Lighting</i> (ref. G.1.20)	Educational buildings Hospitals Offices Factories etc.

The design of a staff room is a compromise between a living room and a work room, and between privacy and the need for a view out. Windows, preferably in adjacent walls, with adjustable blinds (for privacy) are the best solution, together with local lighting. The placing of tables near the windows, and sitting areas (with local lighting) away from the windows is a reasonable arrangement. Some part of the local lighting may be of a movable domestic type if appropriate.

In slightly larger spaces, such as common rooms, the requirements will be similar but there should be more scope for varying the arrangement of the furniture for different functions. Lighting, textures and colours should serve to provide a relaxed character in contrast to surrounding working areas (see 8.4.2).

8.2.8 Offices: general

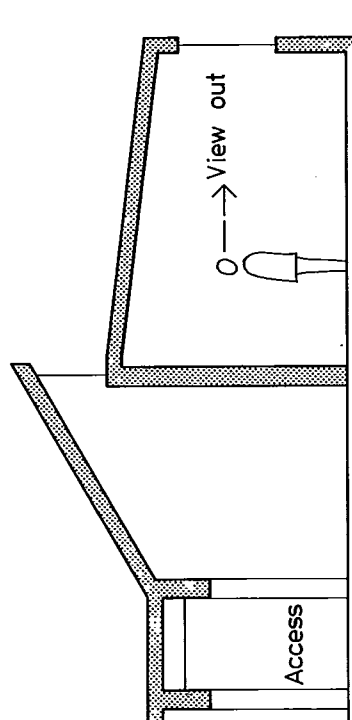
Activity/spaces	References	Building types
Offices	Offices, Shops and Railway Premises Act, 1963 <i>CIBS Code for Interior Lighting</i> (ref. G.1.20) <i>Daytime Lighting in Buildings</i> , CIBS Technical Report TR4 (ref. G.1.22)	Offices Educational buildings Factories Hospitals Banks Insurance buildings Post Offices Libraries etc.

Where daylight is intended to be the main working light in a large space it should be well distributed throughout. In single-occupancy offices, where the occupant may position his desk as he pleases, this is not so important but in multi-occupancy offices, staff working at positions some distance from the windows may feel deprived regardless of the physical quantity of light. The distribution of the daylight is therefore as important as its quantity.

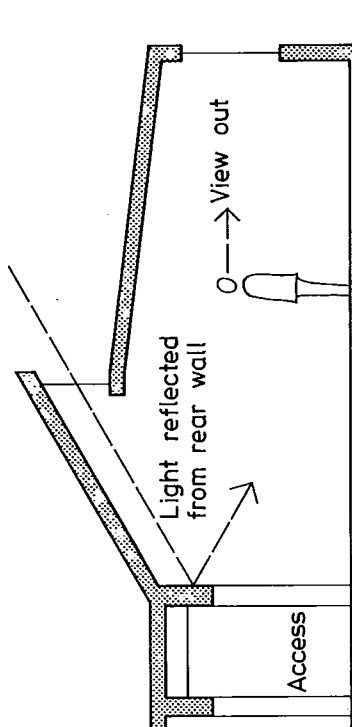
Daylight should come from as wide an angle as possible. Daylight from small windows is highly directional and throws hard shadows. If such directional light comes from a wrong angle in relation to the work, e.g. from a window on or near the line of sight at the work, it can be a cause of visual strain and can lead to discomfort and dissatisfaction and is liable to result in inaccurate work.

The lighting should be suitable in terms of both illuminance and directional characteristics. The modelling that the lighting gives on the human factor is important, and should be moderate in strength with the main direction arriving at an angle between the vertical and the horizontal. These recommendations call for some compromise because high illuminance is most easily provided by top lighting, while the directional and modelling properties require some form of side lighting. Acceptable office lighting from side windows alone can be achieved in rooms in which the working places farthest from the window are located not more than 1.5 times the height of the window head (actual glazed area) above the floor.

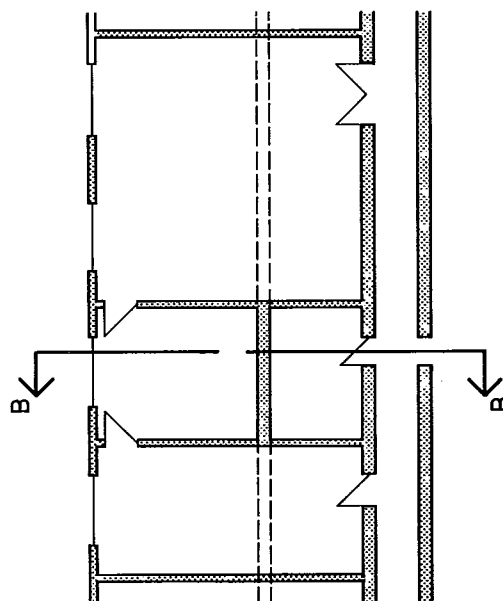
An average daylight factor of about 5 % is recommended; this is a value that appears to allow most office workers to work at their desks without the need for artificial light except on dull days. Daylight at this level cannot be easily achieved by side lighting and very large windows cause excessive contrasts and glare. In single-storey offices daylight can be provided by rooflights, recessed and screened to prevent direct sun penetration where it is not wanted. All glazing in offices, whether in the walls or the roof, should be provided with blinds or curtains so that the daylight can be controlled both in quantity and in direction. If in a wholly daylit office the working daylight is provided by rooflights there should also be sufficient window area to meet the requirements for view (see table 5) because people who are engaged in work of great visual concentration require the visual relaxation of an external view.



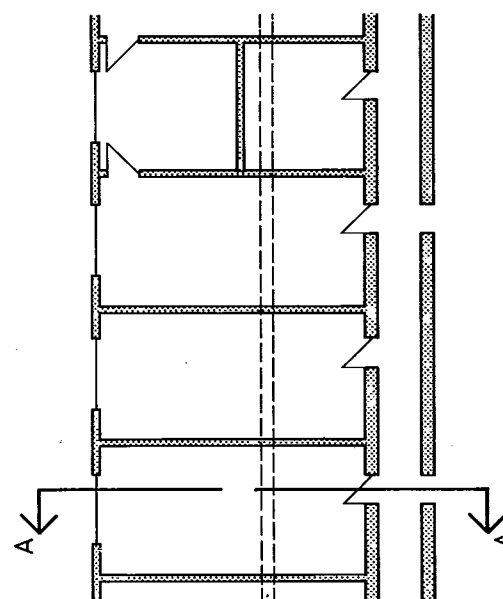
Section A-A



Section B-B



Plan



Plan

Figure 5. The natural lighting of a 'flexible' research laboratory unit showing the use of a vertically glazed rooflight to light deep-plan and internal rooms

Because of the need to make the fullest use of site space in urban areas, multi-storey, deep-planned office buildings are common and have no facility for rooflighting, except on the top floor. The only way in which good lighting can be achieved in these deep spaces is by proper integration of daylight and artificial light. Sufficient daylight should be admitted through windows to make a significant contribution to the character of the office, while the illumination on the working surfaces is predominantly artificial.

Windows in these very deep offices, although providing only a small component of daylighting, give visual release and contact with the outside, and avoid a sense of isolation. Although the daylighting on horizontal desks remote from windows may be minimal there will still be considerable daylighting on vertical planes, which will modify the dominant downward component from the artificial lighting and greatly improve the overall effect.

Adequate view out is achieved in an office in which the window area is between 15 % and 30 % of the external wall, depending on the depth of the office from the window (see table 5).

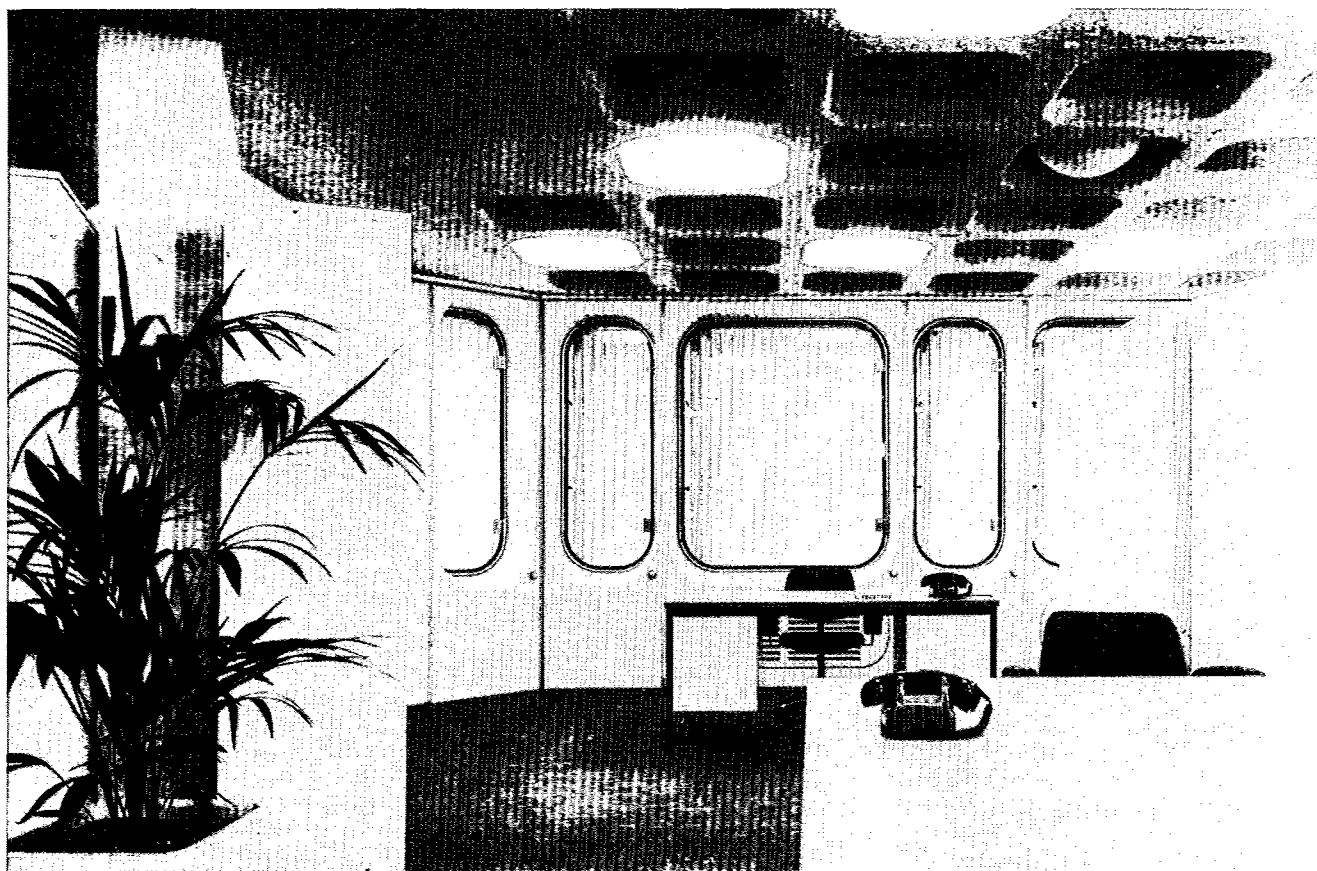
Artificial lighting of about 500 lx is satisfactory and gives a balance of brightness between the daylit areas near the windows and the artificial-supplemented area, where the daylight factor may be as low as 1 % (see table 6, under 'uniformity ratio'). The artificial lighting installation should be integrated into the building fabric in such a way that the occupants of the space are unconcerned that they are

working in predominantly artificial light (figure 6). The general illuminance from the artificial lighting may however be lower than this (e.g. 300 lx) if desk lighting is used to provide at least 500 lx on the work.

Direct glare from bright sky seen through windows (see 7.4) or from light fittings should be controlled (table 6, under 'glare indices') and unwanted reflections from polished or semi-gloss surfaces in offices can be avoided by sensible placing of work stations in relation to windows and light fittings. Careful selection of surface finishes should be made to help to draw attention naturally to important areas.

Local lighting on the task in addition to the general lighting is recommended as it can help to avoid any sense of monotony or dullness in the overall scheme. Selective lighting of the window head can also help to reduce brightness contrast with the sky. On the brightest days some controlling device (blinds, etc.) will be needed on the windows. The design of daylighting should aim particularly at reducing the possibility of glare (see clause 7, in particular 7.4.5).

The office design technique known as 'landscaped office' may encompass a very extensive area without permanent or full-height partitions. Indoor plants and decorative features supply the landscaping and view windows around the perimeter of the space are essential to give some visual access to the outside world. It is claimed that uniform lighting throughout such a space permits complete freedom



Metal Box Co. Ltd, Reading. Architect: Llewelyn-Davies Weeks. Photograph by Henk Snoek Photography & Associates, and reproduced by permission of Llewelyn-Davies Weeks, Architects, Planners and Health Services Consultants.

NOTE. The photograph shows integration of artificial light sources into coffering of structural slab in a deep-plan multi-storey building.

Figure 6. Office lighting

This publication is a Draft for Development and is therefore not to be regarded as a British Standard. See page 4.