NZS 6703:1984

Code of Practice for INTERIOR LIGHTING DESIGN

Superseding cp 22:1962

NZS6703:1984
Corrigendum No 1 Appended

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COMMITTEE REPRESENTATION

This Standard was prepared under the supervision of the Electrical Accessories and Appliances Sectional Committee (62/-) for the Standards Council, established under the Standards Act 1965. The committee consisted of representatives of the following:

Consumers' Institute
*Department of Scientific and Industrial Research
Department of Trade and Industry
Electric Supply Authority Engineers Institute of New Zealand
Insurance Council of New Zealand
Ministry of Energy
Ministry of Transport
*Ministry of Works and Development
*New Zealand Electrical Contractors Federation
New Zealand Railways Corporation
New Zealand Institute of Electricians
Institution of Professional Engineers New Zealand
*New Zealand Manufacturers Federation
New Zealand Master Builders Federation
Post Office

The Lighting Design Project Committee (62/13), was responsible for the preparation of the Standard and consisted of representatives from the organizations marked with an asterisk (*) above together with three lighting experts.

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AMENDMENTS

Date of Issue	*Description*

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RELATED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS

NZS 4220:1982	*Energy conservation in non-residential buildings*
NZS 6501:1982	*Units of measurement*

BRITISH STANDARDS

BS CP 290:1973	*Suspended ceilings and linings of dry construction using metal fixing systems*
BS 667:1968 (1980)	*Portable photoelectric photometers*
BS 4727:	*Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms*
Part 4 Group 03:1972 (1980)	*Lighting technology terminology*
BS 4800:1981	*Specification for paint colours for building purposes*
BS 5252:1976	*Framework for colour co-ordination for building purposes*
BS 5252F:1976	*Colour-matching fan*

CHARTERED INSTITUTION OF BUILDING SERVICES — LIGHTING DIVISION

(formerly: Illuminating Engineering Society of Great Britain) Delta House, 222 Balham High Road, Balham SW12 9BS, England

CIBS Technical Memoranda TM5	*The calculation of use of utilization factors* (1980)
CIBS Technical Memoranda TM 6	*Lighting for visual display units* (1981)
CIBS Building Energy Code Part 1:	*Guidance towards energy-conserving design of buildings and services* (1977)
IES Technical Report No. 2	*The calculation of utilization factors. The BZ method.*
IES Technical Report No. 4	*Daytime lighting in buildings* (1972)
IES Technical Report No. 9	*Depreciation and maintenance of interior lighting* (1967)
IES Technical Report No. 10	*Evaluation of discomfort glare: the IES Glare Index System for artificial lighting installations (1967). With supplement* (1972)
IES Technical Report No. 11	*The calculation of direct illumination from linear sources* (1968)

IES Code for interior lighting(1977)

ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA

IES lighting handbook(1981)

INTERNATIONAL COMMISSION ON ILLUMINATION

CIE Publication No. 16 (E-3.2) (1970)	*Daylight*
CIE Publication No. 17 (E-1.1) (1970)	*International lighting vocabulary*
CIE Publication No. 29 (1975)	*Guide on interior lighting*

BUILDING RESEARCH ESTABLISHMENT (United Kingdom)

BRE Digest No. 41	*Estimating daylight in buildings — 1 (1970)*
BRE Digest No. 42	*Estimating daylight in buildings* — 2 (1971)

SCIENTIFIC PAPER

LESLIE, S.F., and TRETHOWAN, H.A. A computer file of New Zealand Climate. New Zealand Energy Research and Development Committee, Report No. 21, April 1977.

FOREWORD

This Standard code of practice replaces CP 22:1962, which was based on the 1955 edition of the IES Code. This new Standard utilizes the considerable advances that have been made in the matter of available light sources, improved efficacies, studies of discomfort glare and luminaire design.

Current and predicted energy cost increases require particular attention to energy saving. Properly used, this Standard will enable the designer to achieve maximum energy conservation without sacrificing reasonable standards of visibility. A section on energy saving has been included for this purpose.

The Code is concerned primarily with the lighting of workplaces. However the category classification of lighting installations which is used is applicable also to many recreational and circulation spaces. It must be recognized that other methods of lighting become appropriate where lighting is required to provide for display or to create decorative or architectural effects.

ACKNOWLEDGEMENT

In the preparation of this Standard, material has been used from publications of the Lighting Division of the Chartered Institution of Building Services (formerly the Illuminating Engineering Society of Great Britain), the Illuminating Engineering Society of North America, the International Commission on Illumination and the Building Research Establishment of the UK Department of the Environment. This assistance is gratefully acknowledged.

NEW ZEALAND STANDARD

Code of practice for
INTERIOR LIGHTING DESIGN

1 SCOPE

1.1
This code deals with the design of interior lighting, primarily in workplaces, taking into account both natural and artificial lighting, and relates the lighting to energy use. The code also covers the maintenance of lighting systems and the measurement of illuminance and luminance. While a nearly complete range of interior lighting situations is covered, some buildings have particular lighting requirements which are too specialized to be included. Guidance for the lighting of such buildings is to be found in other publications.

2 REFERENCES

2.1
The full titles of reference documents cited in this Standard are given in the "List of related documents" immediately preceding the Foreword.

2.2
Where any other Standard named in this Standard has been declared or endorsed in terms of the Standards Act 1965, then —

(a) Reference to the named Standard shall be taken to include any current amendments declared or endorsed in terms of the Standards Act 1965;*or*

(b) Reference to the named Standard shall be read as reference to any Standard currently declared or endorsed in terms of the Standards Act 1965 as superseding the named Standard, including any current amendments to the superseding Standard declared or endorsed in terms of the Standards Act 1965.

NOTE — The date at which an amendment or superseding Standard is regarded as "current" is a matter of law depending upon the particular method by which this Standard becomes legally enforceable in the case concerned. In general, if this is by contract the relevant date is the date on which the contract is created, but if it is by Act, regulation, or bylaw then the relevant date is that on which the Act, regulation or bylaw is promulgated.

3 DEFINITIONS

3.1
For the purposes of this code, definitions given in the following list apply. Some of these definitions are simplified versions of the more formal definitions given in the CIE International Lighting Vocabulary. SI units are defined in NZS 6501.

ASYMMETRY-CONTROL DISTRIBUTION (ACG) means a classification given by numbers 1 to 8 relating to axial and transverse intensities of asymmetrical luminaires, for the purpose of establishing the glare index. See supplement to IES (GB) Technical Report No. 10.

BZ (BRITISH ZONAL) SYSTEM means a system for classifying luminaires according to their downward light distribution. See CIBS Technical Memoranda TM5.

COLOUR ADAPTATION means the adaptation of the eye to the colour of the prevailing light.

COLOUR APPEARANCE means the colour of a light source as seen when it illuminates a white surface.

COLOUR RENDERING means the ability of a light source to show objects in their natural colours — those revealed by daylight.

CONTRAST means, subjectively, the difference in appearance of two parts of a visual field seen simultaneously or successively. The difference may be one of brightness or colour or both. Objectively, the term means the luminance difference ratio expressed numerically by such relations as:

$$\text{contrast} = \frac{L_2 - L_1}{L_1}$$

DAYLIGHT FACTOR means the daylight illuminance on the working plane expressed as a percentage of simultaneous planar illuminance due to the unobstructed standard overcast sky.

GLARE means the discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.

ILLUMINANCE (E) means the luminous flux falling onto unit area of a surface. The unit is the lux. (1 lx = 1 lm/m^2)

ILLUMINANCE, DESIGN SERVICE, means standard service illuminance modified for the requirements of a given situation.

ILLUMINANCE EFFICACY means the performance of the lighting installation in converting electrical energy into lumens on the work surfaces.
It may be expressed as:

$$\frac{\text{calculated service illuminance x area}}{\text{electrical load}} \quad \text{lm/W}$$

ILLUMINANCE, INITIAL means the illuminance due to an installation of new luminaires with 100 h aged lamps and clean room surfaces.

ILLUMINANCE, MEAN SPHERICAL means the average illuminance over the whole surface of a very small sphere.

NOTE — This may also be called SCALAR ILLUMINANCE.

ILLUMINANCE, PLANAR means the average illuminance over the surface of a plane.

ILLUMINANCE, SERVICE means the average illuminance through the life of an installation, taking account of light losses.

ILLUMINANCE, STANDARD SERVICE means the service illuminance recommended for standard conditions.

LAMP, DISCHARGE means a lamp in which light is produced by an electric discharge through a gas, a metal vapour, or a mixture of the two.

LAMP, HALIDE means a discharge lamp using metal vapour and the products of the dissociation of halides.

LAMP, FLUORESCENT means a tubular discharge lamp in which most of the light is emitted by a layer of fluorescent material that is excited by ultraviolet radiation from the discharge.

LAMP, INCANDESCENT means one in which light is produced by a filament heated by the passage of electricity.

LAMP LIFE means the average useful life of a type of lamp stated in hours. According to application, useful life may be defined by a stated proportion of lamp mortalities or of lumen depreciation.

LIGHT-LOSS FACTOR means the ratio of design service illuminance to initial illuminance.

LIGHT-OUTPUT RATIO means the ratio of the total light output of a luminaire under practical conditions to that of the lamp or lamps under ideal conditions.

LIGHTING, DIFFUSED means that in which the flux comes from many directions, none of which predominates.

LIGHTING, DIRECT means an installation in which the greater part of the flux from the luminaires reaches a surface directly.

LIGHTING, DIRECTIONAL means that which is designed to illuminate a task or surface predominantly from a preferred direction.

LIGHTING, GENERAL means that which illuminates the whole of an area without provision for special requirements.

LIGHTING, INDIRECT means an installation in which all or the greater part of the flux reaches its object only after reflection from some other surface.

LIGHTING, TASK means that which is provided for, and largely confined to, a working area such as a desk or a machine.

LUMINAIRE means an apparatus which controls the distribution of light from a lamp or lamps fixed in it, and which connects them to the supply circuit.

LUMINAIRE, PROOF, means a luminaire able to withstand the particular hazards of a given application. The term includes "proof" and "tight" luminaires as defined in BS 4727 Pt 4 Group 03, and corrosion-resistant luminaires.

LUMINANCE means the intensity of light coming from a surface in a given direction, related to the apparent area of the surface. The unit is candela per square metre.

LUMINANCE FACTOR means the ratio of the luminance of a reflecting surface, viewed in a given direction, to that of a perfectly uniform white diffusing surface identically illuminated.

LUMINOSITY (brightness) means the visual perception of the amount of light emitted from a given area.

LUMINOUS EFFICACY means the ratio of the luminous flux emitted by a lamp to the power consumed by it.

LUMINOUS FLUX means the light emitted by a source or received by a surface, irrespective of the directions in which it is distributed. The unit is the lumen.

LUMINOUS INTENSITY means the luminous flux per unit solid angle in a specified direction.

MOUNTING HEIGHT means the vertical distance between a luminaire and either the working plane or the floor.

MUNSELL SYSTEM means the Munsell system of classification of surface colour using uniform colour scales of hue, value and chroma.

MUNSELL VALUE means an index of the lightness of a surface, ranging from 0 (black) to 10 (white).

REFLECTANCE means the ratio of the flux reflected from a surface to the flux incident on it.

REFLECTANCE, SPECTRAL means the characteristic of reflectance at wavelengths through the visible spectrum.

REFLECTION, DIFFUSE means a reflection whereby the light is reflected from the surface in many directions.

REFLECTION, SPECULAR means reflection in accordance with the laws of optical reflection, as in a mirror.

REFLECTION, VEILING means the reflection of a bright element, often a light source, occurring in a visual task, which has the effect of reducing task visibility.

UNIFORMITY RATIO means the ratio of the minimum illuminance to the average illuminance.

WORKING PLANE means the plane in which the visual task lies. Unless otherwise indicated it is assumed to be horizontal and 0.85 m above the floor.

4 GENERAL DESIGN CONSIDERATIONS

4.1 Introduction

4.1.1
Lighting design should be integrated intimately with the area to be illuminated; the designer should seek to create an interior that has a lively and stimulating appearance by providing variety in the visual scene, with due attention being given to colour rendering. Such factors as the shape and size of the space, the colouring and reflectances of the surfaces of the room and its contents, the activity to be carried on there, the availability of natural light and whatever aesthetic goals the owner may impose will — or should — affect lighting design to an important extent. It follows that they should be determined while lighting design is being undertaken, and hence collaboration between the lighting designer and the architect is essential.

4.2 Checklist for the designer

4.2.1
The most important items the designer needs to know are as follows:

(a) Details of all the activities associated with the functions of each space

(b) The visual tasks concerned and their locations

(c) Reflection properties of surfaces

(d) Needs for emphasis, modelling and colour rendering

(e) Availability of natural light

(f) Colour appearance of light source and its blend with natural light

(g) Control of glare due to both direct and indirect light

(h) Locations for luminaires, and access to them

(i) Special requirements for luminaire performance, such as in hazardous locations, or to meet difficult access or maintenance requirements.

4.3 Distribution of luminance

4.3.1
The visual environment to be achieved is one which will enable the occupants to see with ease and accuracy the essential details of a specific task or activity, to move about easily and safely, to work most efficiently and to enjoy a comfortable and pleasant environment. Luminaires should be positioned to suit the tasks that are expected to be performed within the area. An appropriate distribution of luminance can help to concentrate attention on specific parts of the interior or task. However illuminances should not vary to the extent that dark or dim areas are created.

4.4 Steadiness of light output

4.4.1
Installation should be designed to provide apparently steady light. The light sources used, and the methods of operating them, should be such that any light modulation will be insufficient to cause discomfort or inconvenience and will normally be unnoticeable. Cyclic variations of light output of frequency not less than 100 Hz (as with lamps operated by a 50 Hz a.c. supply) are generally unnoticeable. Where necessary, suitable precautions should be taken to prevent light modulation of any frequency which would be likely to occasion undesirable stroboscopic effects.

5 NATURAL LIGHT IN LIGHTING DESIGN

5.1 Introduction

5.1.1
Lighting design should be directed toward the use of daylight, on the grounds of both colour rendering and economy. Its use together with artificial lighting is the subject of this section. Further information on energy conservation is given in Section 14.

5.2 Daylight factor

5.2.1
The amount of daylight that is available for use in a room is expressed as a ratio between it and the illuminance that is simultaneously present out of doors. A procedure for determining this ratio, called *daylight factor*, is given in Appendix A.

5.2.2
Except when daylight is evenly distributed throughout a room, which would occur only with rooflights, an average daylight factor for the area would not be adequate for assessing lighting. Instead the minimum daylight factor, that occurs in the worst-lit working position, should be taken into account.

5.3 Outdoor illuminance in New Zealand

5.3.1
For design purposes, outdoor illuminance, E_O, expresses the diffuse daylight illuminance due to the sky (that is, excluding direct sunlight) on an unobstructed horizontal plane. The percentage of time within a standard year for which a given value of E_O is exceeded is shown in fig. 1 and table 1, where a standard year comprises the hours between 8am and 5pm each day with allowance being made for 1 hour of daylight saving from November to February inclusive.

5.3.2
These data have been derived from measured values of global irradiance at Auckland, Wellington, Christchurch and Invercargill by Leslie and Trethowan. While differences between the centres are not great, interpolations for other locations must

Fig. 1 AVAILABILITY OF DAYLIGHT IN NEW ZEALAND

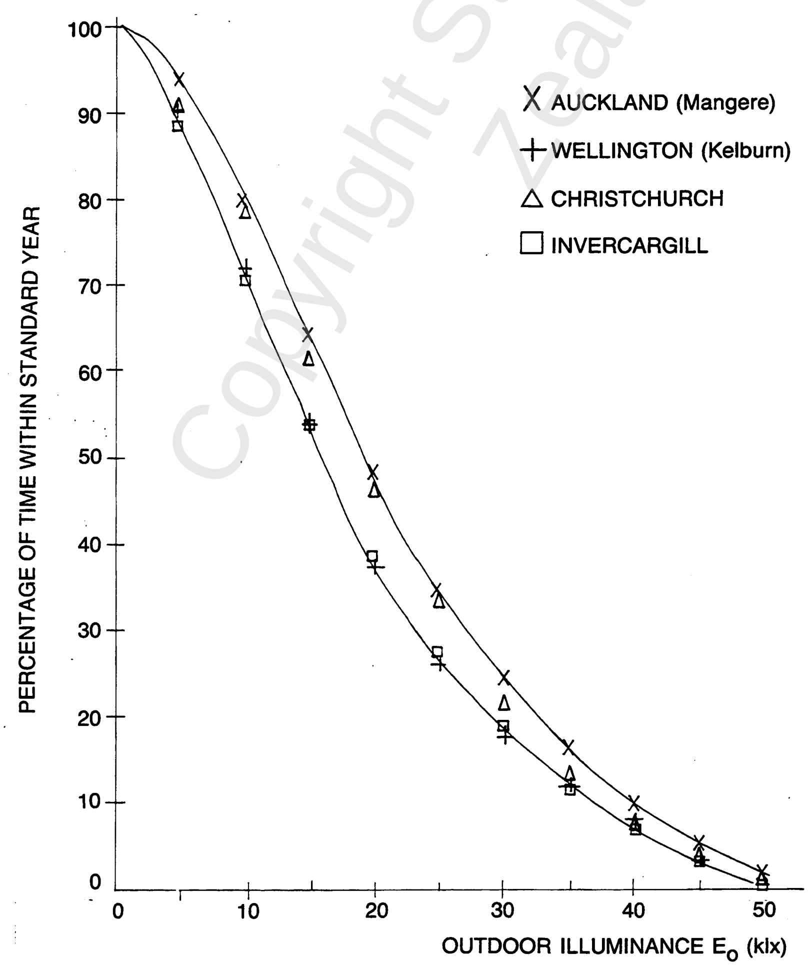


Table 1 VALUES OF OUTDOOR ILLUMINANCE E_o EXCEEDED FOR VARIOUS PERCENTAGES OF STANDARD YEAR

Percentage of standard year	*Outdoor illuminance, E_o*			
	Auckland (Mangere)	*Wellington (Kelburn)*	*Christchurch*	*Invercargill*
	klx	klx	klx	klx
90	6.4	5.1	5.1	4.1
80	9.9	7.8	9.3	7.1
75	*11.5*	*9.2*	*11.0*	*8.6*
70	13.1	10.6	12.6	10.1
60	16.3	13.2	15.6	13.0
50	19.3	16.0	18.8	16.0

be made with some care as it can be seen that daylight availability is influenced by both the latitude of the location and the dryness of its climate.

5.3.3
These data enable estimates to be made of the extent to which daylight will provide a given illuminance indoors. For example, in Christchurch the value of E_O exceeds 11.0 klx for 75 % of the standard year, so for a daylight factor of 3 percent, indoor illuminance will exceed 330 1x for that period of time.

5.3.4
For situations where it is intended that lighting will be switched off when daylight is adequate, it is recommended that the minimum daylight factor should be sufficient to provide the design service illuminance for not less than 75 % of the standard year. In this way, the 75 % values of E_O from table 1 are recommended for use in design for these applications.

5.3.5
The design target of 75 % of the standard year equates to 6.75 hours per day average throughout the year between 8am and 5pm. For buildings that are continuously occupied, the number of hours per day is rather greater than this to an extent that varies slightly with latitude. It is recommended that the 75 % values of E_O are used for design, but that performance is stated in terms of average hours per day throughout the year as follows.

	average hours per day throughout the year
Auckland	7.2
Wellington	7.4
Christchurch	7.5
Invercargill	7.6

NOTE — Although design using the 75 % values of E_O gives a greater average duration of daylight in more southerly locations, the daily duration is less during winter, but is more than compensated for by increased duration during summer.

6 CLASSIFICATION OF LIGHTING INSTALLATIONS

6.1 Types of installations

6.1.1
Lighting installations covered by this code are classified as follows:

(a) *Daylight installation.* In this type of installation, daylight is normally sufficient to meet all lighting needs during the day, with artificial lighting required primarily for night-time use

(b) *Task lighting installation*. In this type of installation, work stations are provided with local lighting which is related to the visual demands of the work. General lighting is provided separately, and this may be partly or completely by daylight during the day

(c) *Combined lighting installation.* In this type of installation, lighting during the day is by a combination of daylight and artificial lighting. The distribution of artifical lighting complements that of daylight, to achieve an overall distribution that not only ensures adequate task lighting throughout the space, but which also avoids the appearance of relatively poor lighting remote from the windows. During night time a different distribution of artificial lighting provides adequate lighting throughout the space

(d) *Permanent artificial lighting installation.* In this type of installation, artificial lighting operates whenever the space is occupied. Daylight is not sufficient to warrant partial operation of the artifical lighting, although in other ways windows may fulfil important visual functions. Illuminance is sufficient to satisfy both visual task requirements and the appearance of adequacy of lighting.

6.2 Selection of type of installation

6.2.1

The selection of an installation type requires careful consideration as many factors can influence the choice of an appropriate installation. The following procedure, which is shown diagrammatically in fig. 2, enables several of these to be taken into account. It is recommended as a design guide rather than as a rigid procedure.

(a) Follow the procedure given in 7.1.1 to determine the design illuminance for the installation. These recommended service illuminances consist of a number of steps on the scale given in CIE Publication 29, that is 20, 30, 50, 75, 100, 150, 200, 300, 500, 750, 1000, 1500, 2000, 3000 and 5000 lx. Call the design illuminance E

(b) Calculate the average daylight factor, DF_{av}, and the minimum value, DF_{min}. (see Appendix A)

(c) Obtain the 75 % value of E_o, in klx, from table 1 and calculate the minimum daylight illuminance, $E_{d(min.)}$, in lux, this being the daylight illuminance in the worst-lit part of the room that is maintained from 75 % of the standard

$$E_{d(min.)} = 10\ E_o \times DF_{min.}$$

(d) If $E_{d(min.)}$ is greater than the design illuminance, this indicates that daylight will provide the design illuminance throughout the space for 75 % of the standard year, and a *daylight installation* is recommended.

(e) If daylight illuminance is not sufficient to achieve the design illuminance for more than 75 % of the standard year, and the design il-

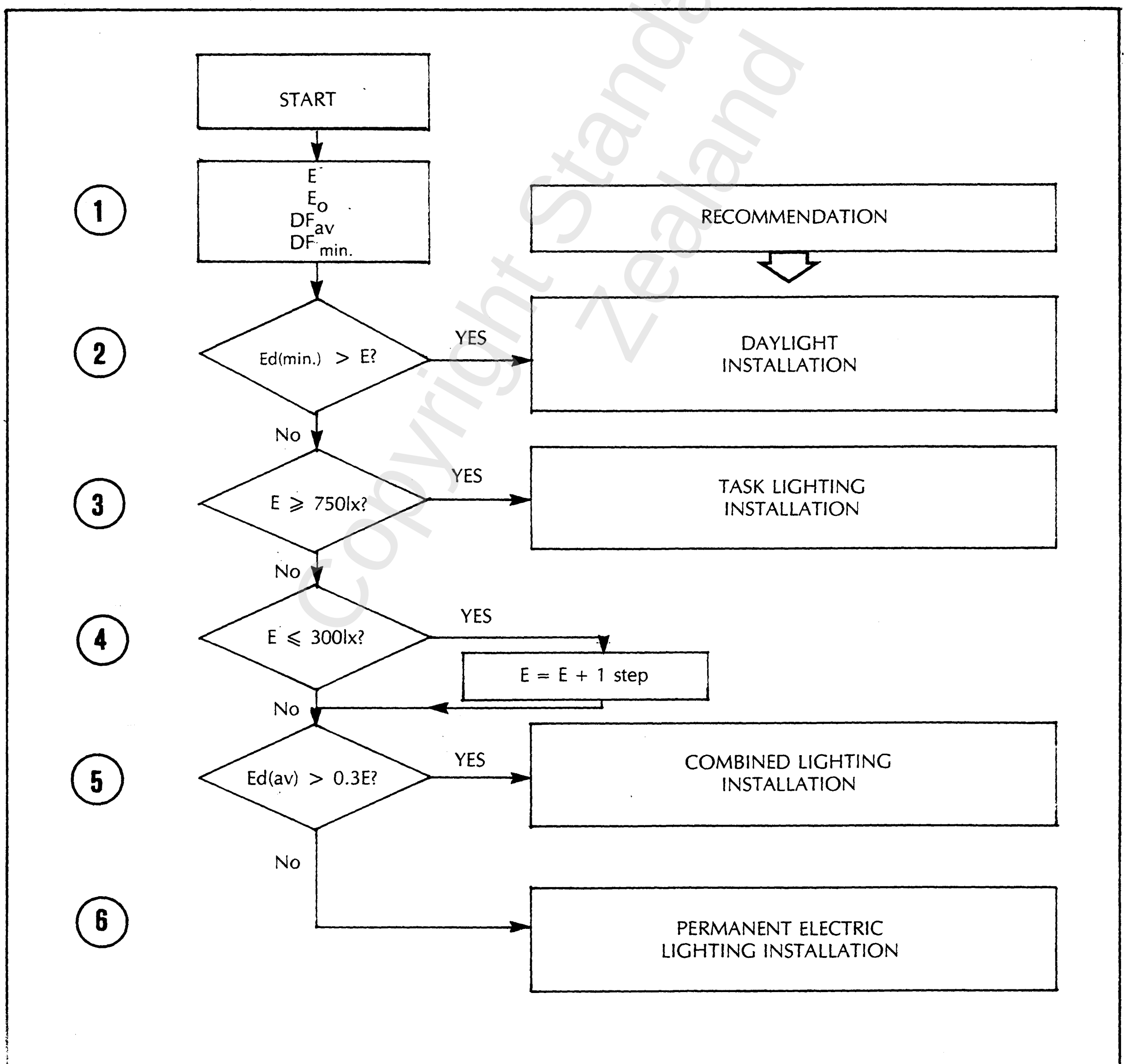


Fig. 2 SELECTION OF TYPE OF INSTALLATION

luminance exceeds 750 lx it is recommended that this be achieved by a *task lighting installation*. The illuminance for the building as a whole may be 2 service-illuminance steps below the task illuminance, and the daylight illuminance may be sufficient to meet this requirement.

NOTE — According to circumstances, task lighting may be advisable for lower design illuminances.

(f) If daylight illuminance is not sufficient to achieve the design illuminance for more than 75 % of the standard year and the design illuminance is less than 750 lx, the remaining alternatives require careful consideration of the daytime appearance of the workplace. If the design illuminance is less than 300 lx it is recommended that this be increased by one service-illuminance step (see figs. 2 and 3).

(g) Calculate the average daylight illuminance, $E_{d(av)}$, in lux, from the expression:

$$E_{d(av)} = 10\ E_o \times DF_{av}$$

If this value exceeds 30 % of the design illuminance, this indicates that daylight is sufficient to provide for 30 % of the average lighting requirement for 75 % of the standard year, and a *combined lighting installation* is recommended.

(h) If $E_{d(av)}$ is less than 30 % of the design illuminance, the contribution of daylight is not significant and a *permanent artificial lighting installation* is recommended.

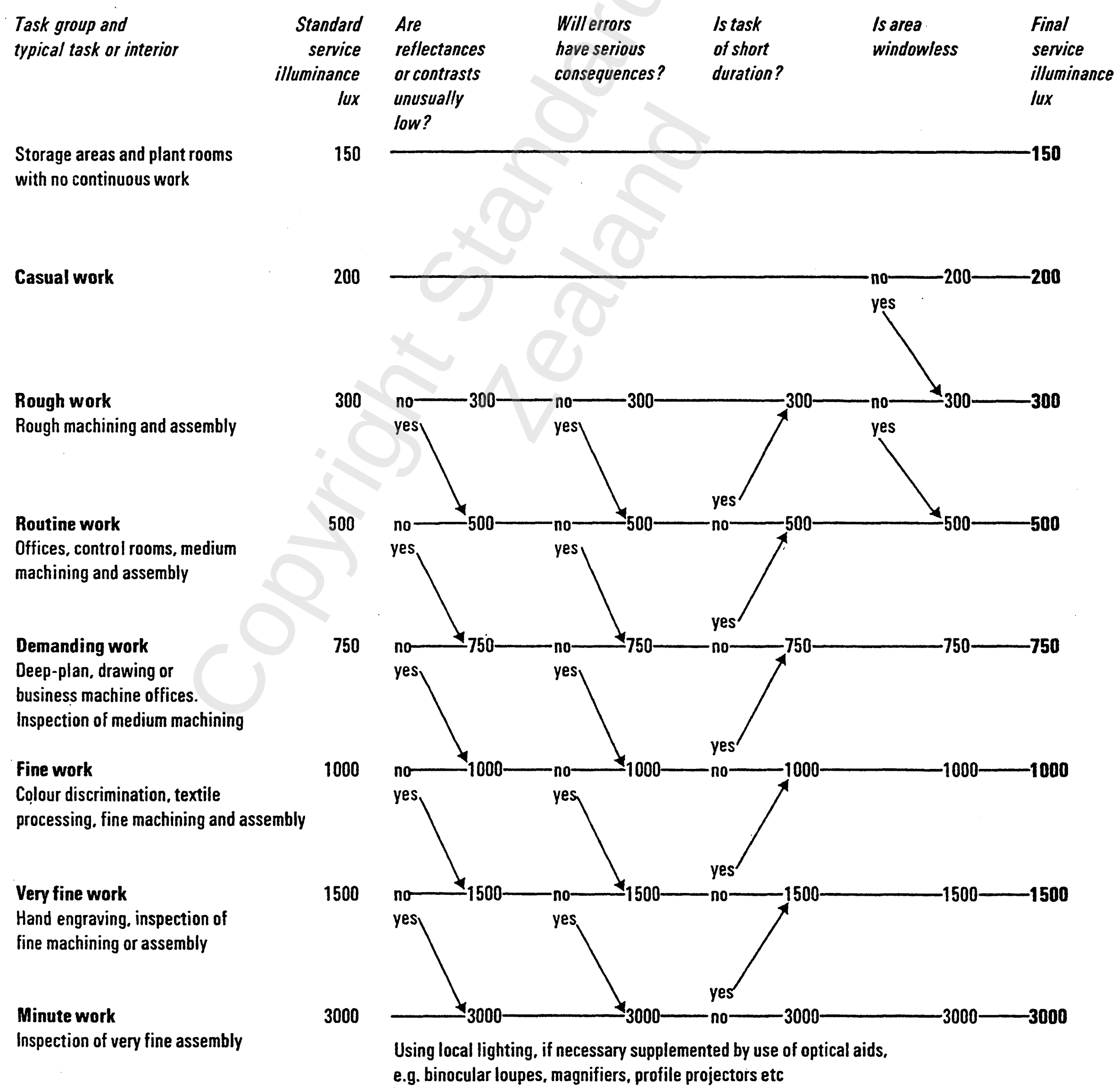


Fig. 3 ADJUSTMENT OF ILLUMINANCE FOR CERTAIN FACTORS

7 DESIGN OF LIGHTING INSTALLATIONS

7.1 Procedure for general lighting design

7.1.1
The following is a straightforward procedure for general lighting design. However, it should be noted that often there will be special considerations that will require the designer to depart from this procedure.

(a) Determine the visual tasks associated with each activity to be performed in the space, and the locations at which they occur

(b) Select the standard service illuminance from table B1 in Appendix B. Take note of all the other factors listed for each task

(c) Using fig. 3, decide whether there are circumstances which require an adjustment to be made to the standard service illuminance, and determine the design service illuminance

(d) Refer to Section 6 and decide which of the four types of lighting installation is appropriate. Design guidance for each of these types of installation is given in clauses 7.2 to 7.5.

7.2 Daylight installation

7.2.1
Night lighting in a daylight installation
When it has been determined that a daylight installation is suitable, the designer has only to design artifical lighting for use when daylight fails. Clause 7.5 deals with the design of permanent artificial lighting installations, but in this instance the lighting should take account of the directional nature of the daylight: linear luminaires should be arranged in rows parallel to windows or roof lights, and whenever appropriate, preference should be given to locating the rows between workstations so that lighting is received from both sides rather than from directly overhead. Such an arrangement will, at least for the more common types of luminaires, minimize both veiling reflections and discomfort glare. Separate switching of rows in larger installations can ease the transition from daytime to night-time lighting, but other factors such as variation in working hours in different sections may affect switching arrangements.

As in this case artificial lighting is used as a substitute for, rather than in combination with daylight, consideration should be given to the use of lamps of moderately warm colour, especially in areas of low illuminance (200 lx or less) or those adjacent to filament lighting. Of the high-efficacy fluorescent tubes the White (Code 35), which has a correlated temperature of 3500K, is often preferred to the Cool White (Code 33) for this application.

7.2.2
Factors affecting daylight distribution
Some room features can affect the distribution and the efficient use of daylight. In particular, consideration of the following factors can contribute to a successful design:

(a) The colour of ceilings — preferably this should be white or near-white

(b) The reflectivity of walls — walls opposite windows should have good reflective properties. A light-coloured outside wall serves to minimize the contrast between wall and window.

NOTE — Appendix C gives additional information on surface reflectance.

(c) The positioning of work stations — where the outside light comes from windows rather than skylights, workstations should be situated so that personnel normally face one of the side walls (at right angles to the window wall) so the light comes from the side, and so that they may face a wall which, not needing to be a reflecting surface, may be treated with colour and thus be more pleasing

(d) Curtains, blinds and shading — curtains or blinds can introduce colour and can be used to control sun glare. However a preferred means of controlling sun glare is appropriately-designed external shading.

7.3 Task lighting

7.3.1
Task lighting is provided by luminaires placed near the visual task to illuminate only a limited area. It is recommended for the following situations:

(a) When the work involves critical visual tasks

(b) Where increased illuminance is required only in restricted areas

(c) When perception of forms and textures requires strongly directional light

(d) When the general lighting is locally obstructed

(e) When higher illuminances are needed by a person with reduced vision

(f) When stroboscopic problems arise in workshops due to discharge lighting not being phase-balanced. Local filament lighting can help in such cases

(g) When it is necessary to overcome veiling reflections in or adjacent to the task.

7.3.2
Because of the specialized nature of task lighting, it is not possible to give detailed guidance in this code. However, the following points should be noted:

(a) The avoidance of glare, both direct and reflected, requires that the light distribution of the luminaire is appropriate, and that the luminaire is positioned suitably for the operative's line of sight

(b) If the luminaire is adjustable, it is necessary for operatives to be made aware of how to make adjustments to suit them

(c) It is advisable for the range of adjustment of a luminaire to be such that glare cannot be caused to an adjacent operative

(d) Apart from glare, the close proximity of a luminaire to an operative may result in complaints about such factors as flicker, noise or heat output.

(e) General lighting may be two steps lower than the task lighting. For example, if the task illuminance is 750 lx, the general illuminance may be 300 lx. This can substantially reduce the electrical lighting load.

7.4 Combined lighting installation

7.4.1
Principle
The task is to design artificial lighting so that it supplements natural light during the day and replaces it at night. This type of lighting is appropriate to most areas in which daylight provides more than 30 % of the calculated daytime lighting requirement. This percentage can be calculated from the expression

$$\frac{E_{d(av)}}{E} \times 100$$

where: $E_{d(av)}$ is the average daylight illuminance (see clause 6.2.1)

E is the design service illuminance

NOTE — A calculated value in excess of 100 % means that the *average* required illuminance is provided by daylight for more than 75 % of the standard year; however as the requirements for a daylight installation have not been met (see clause 6.2), daytime artificial lighting will be required in the worst-lit parts of the room.

7.4.2
Design procedure
An ideal way to provide a combined lighting installation would be for luminaires to be equipped with dimming control operated by a photoelectric device to maintain constant illuminance. However, if this is not feasible, the following procedure is recommended:

(a) Select the lamp and luminaire to be used for the installation. The use of multi-lamp luminaires with suitable control gear and internal wiring to allow individual lamp operation is recommended, since this offers more flexibility to adjust the artificial illumination according to the distribution of daylight within the area

(b) Examine the distribution of daylight within the room, dividing the area into a number of zones of daylight-lighting level according to the number of different illuminance levels available from the luminaires. Thus, for a single-lamp luminaire, there will be only two zones — that where the lamps are "off" and that where the lamps are "on". For a twin-lamp luminaire with suitable control gear there will be 3 zones, off, one lamp on, and both lamps on.
For example, consider a situation where the required illuminance, E, is 500 lx and the E_o value is 11.0 klx. Twin-lamp luminaires have been selected for the installation. Therefore, there will be 3 daytime lighting zones, as follows:

(i) *The "off" zone* where the daylight illuminance for 75 % of the standard year is greater than 500 lx, and the lamps are off at times when that daylight illuminance is exceeded

(ii) *The "single-lamp" zone* where the daylight illuminance is less than 500 lx but more than 250 lx

(iii) *The "twin-lamp" zone* where the daylight illuminance is less than 250 lx.

The daylight factors defining these zones are calculated using the following expression:

$$\text{Daylight factor (\%)} = \frac{E}{E_o} \times 100$$

and the values can be summarized as follows:

Daylight illuminance lx	*Lighting zone*	*Daylight factor* %
⩾ 500	Off	⩾ 4.6
< 500, ⩾ 250	Single-lamp	< 4.6, ⩾ 2.3
< 250	Twin-lamp	< 2.3

The lighting designer needs to plot just 2 daylight-factor contours — those for 4.6 % and 2.3 % — on a plan of the room, — since these divide the room into its 3 daytime lighting zones.

(c) Compare the plot of the daytime lighting zones with the proposed lighting layout. If necessary, adjust the layout to achieve a convenient pattern of control

(d) Arrange for the installation of a manual control consisting of a rotary 3-position switch marked Off-Night-Day, provided that its function will be understood by the users. Alternatively, it is recommended that a conventional on/off switch be installed for user-control and that day/night mode of operation be set automatically by a photoelectric control.

7.4.3
Colour of light source
A successful combined lighting installation requires the use of an artificial lighting source that combines well with daylight. Of the NZ-manufactured fluorescent tubes, both the Cool White (Code 33) and the White (Code 35) have the advantage of high luminous efficacy and are satisfactory for locations where accurate colour discrimination is not important. However, the colour appearance of the Cool White source makes it more suitable for locations where it will be used in conjunction with daylight. Where more natural colour appearances are required, the De Luxe White (Code 34) is to be preferred, even though its blend with daylight is rather less satisfactory. If the objective is to achieve colour appearances that will match those experienced under daylight, then the Daylight (Code 55) is the best choice. These two latter tubes have lower luminous efficacies, and the 55 tube has a distinctly "cool" colour appearance unless used at illuminances of at least 500 lx.

7.5
Permanent artificial lighting installation

7.5.1
Aims
Apart from any special consideration listed in table B1 of Appendix B, the principal aims are to achieve lighting for which:

(a) the design service illuminance is provided with acceptable uniformity throughout the space;

(b) the limiting Glare Index is not exceeded;

(c) the color characteristics are appropriate;

(d) the installation is economical to install and to maintain, and achieves efficient utilization of electrical energy;

(e) the luminaires integrate with the materials and dimensions of the room and contribute to its overall appearance.

7.5.2
Design procedure

7.5.2.1
Illuminance
The lumen method, given in Appendix E1, provides a basic framework for proceeding with design. However, although it allows the planning of an installation that will satisfy the first of the aims listed in 7.5.1, the calculation cannot be completed until decisions have been made which affect the attainment of all of the other aims. In particular, it requires the designer to select the lamp type and luminaire. Usually the circumstances of the situation will restrict the choice to a limited number of lamp and luminaire combinations, but it is important that the designer should examine the full range of practical alternatives that is available. They should be considered with regard to the points listed in 7.5.2.2 to 7.5.2.5. Table 2 lists characteristics of various light sources, and table 3 provides more detailed information on colour appearance and colour rendering of fluorescent lamps manufactured in New Zealand.

NOTE — Information on fluorescent lamps that are manufactured overseas and imported for use in New Zealand may be obtained from New Zealand manufacturers.

7.5.2.2
Glare
The procedure for Glare Index calculation is given in Appendix D. It must be noted that this procedure relates only to the control of direct discomfort glare due to the luminaires: the designer must be wary of reflected glare or glare from windows.

7.5.2.3
Energy Use
The procedure for calculating the Lighting Energy Design Target is given in Section 13, and this sets the limit for installed electrical loading. The importance of lamp luminous efficacy and luminaire utilisation factor are obvious, but often overlooked is the need to consider carefully the light loss factor. As explained in Section 9 and Appendix F, this is affected by the lumen depreciation characteristics of the lamp and by the design of the luminaire.

7.5.2.4
Colour appearance of lamps
Appropriate colour appearances of lamps are described in Appendix B as being warm, intermediate or cool. This characteristic of a lamp is indicated by its correlated colour temperature, as follows:

Correlated colour temperature	*Colour appearance*
$\geqslant$ 5000 K	Cool (bluish white)
< 5000 K, $\geqslant$ 3300 K	Intermediate (white)
< 3300 K	Warm (yellowish white)

Table 2

CHARACTERISTICS OF LIGHT SOURCES USED FOR GENERAL LIGHTING

Lamp	*Tungsten filament*	*Tungsten halogen*	*Low-pressure sodium*	*High-pressure sodium*	*High pressure mercury fluorescent*	*Hot cathode tubular fluorescent*	*Cold cathode tubular fluorescent*	*Mercury halide*
Luminous efficacies*† (lm/W)	8–18	17–22	120–175	75–95	35–55	30–80	40–60	65–85
Wattage range	25–1 500	300–1 500	35–200	250–1 000	50–2 000	4–125	20–30 W/m	Up to 10 000
Nominal life† (h)	1 000	2 000	6 000	6 000	7 500	5 000–7 500	20 000	6 000
Need for control gear	No	No	Yes	Yes	Yes	Yes	Yes	Yes
CIE colour rendering group	1	1	3	3	3	See table 2	See table 2	2
Available with internal reflector coating	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Operating position	Any	Horizontal	Horizontal‡	Any	Any	Any	Any	Some restrictions
Correlated colour temperature (K)	2 800–3 000	2 800–3 100	. . .	2 200	4 000	2 700–6 500	2 700–6 500	3 600–4 400

*Efficacies vary considerably within a given range and are based on lighting design and lumen output, and exclude control gear losses.
†For up-to-date information on this characteristic reference should be made to manufacturers' catalogues.
‡Certain of the low wattage lamps can be used vertically.

Table 3

COLOUR CHARACTERISTICS OF TUBULAR FLUORESCENT LAMPS MANUFACTURED IN NEW ZEALAND

Phosphor	*Correlated colour temperature (K)*	*Colour appearance*	*CIE colour rendering index*	*Colour rendering*	*Applications*
Cool white Code 33	4200	Blends well with daylight but at low illuminances gives slightly cold night-time appearance.	67	Emphasizes yellows and to a lesser extent greens; subdues reds and distorts browns.	The most widely used tube for commercial and industrial general lighting.
White Code 35	3500	Not compatible with daylight. Distinctly warmer and more cheerful night-time appearance than '33' particularly at low illuminances. Blends fairly well with incandescent lighting.	66	Emphasizes yellows and to lesser extent greens; subdues reds and to lesser extent blues, which tend towards violet.	Use for windowless areas or for work areas where electric lighting is not used during daytime; also low-illuminance areas and outdoor lighting.
Deluxe white Code 34	3800	Neutral (neither warm nor cool) appearance over wide range of illuminances. Blends fairly well with either daylight or concealed incandescent lighting.	85	Equal emphasis given to blues, greens and yellows, but more to reds.	Shop and display areas and any situation where more natural and attractive appearances of colours justify the lower efficacy.
Daylight Code 55	6500	Cold appearance at low illuminances.	93	Emphasizes blues and to some extent greens. For good colour discrimination, illuminance to be not less than 500 lx.	A colour-matching lamp to be used where colours are to appear as they do by daylight. Also may be used combined with incandescent spotlights to give excellent display lighting.

7.5.2.5
Colour rendering
The colour rendering properties of lamps can be classified into 3 groups according to CIE Colour Rendering Index, Ra, which relate to the importance of coloured surfaces displaying their natural appearance. These groups are as follows:

CIE Colour natural rendering group	Ra	*Importance of appearance*
1	⩾ 85	Very important
2	< 85, ⩾ 70	Moderately important
3	< 70	Unimportant

8 GLARE

8.1 Introduction

8.1.1
The eye is able to adapt itself to luminances which extend over a range of a million or more to one, but at any particular adaptation level there is a restricted range which contributes to useful seeing. This is illustrated in fig. 4. At low levels a luminance one-tenth of the average to which the eye is adapted may be too low for any detail to be made out, and a surface 100 times that level may not be too bright for comfort. At a higher level the corresponding range might be from one hundredth to only 10 times the adaptation level. Thus, though higher levels of illuminance give better visibility they also are accompanied by greater danger of glare. Moreover, glare is also affected by the size of the source.

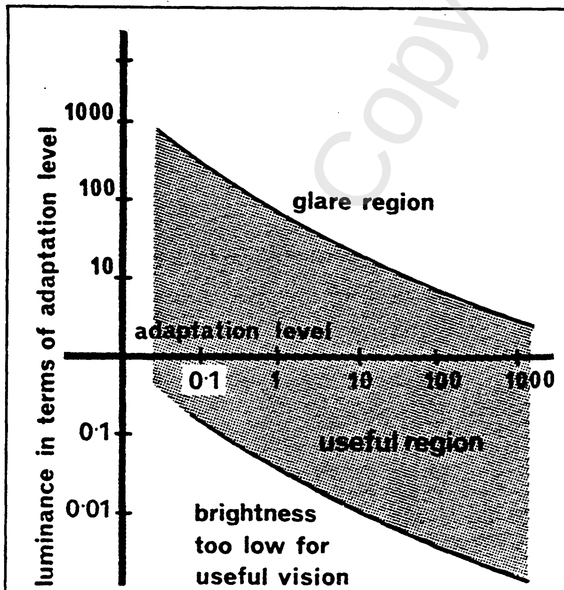


Fig. 4 USEFUL REGION OF VIEWING FOR A PARTICULAR ADAPTATION LEVEL

8.2 Types of glare

8.2.1
Glare effects may be separated broadly into two categories; *disability glare* as it affects vision and *discomfort glare* as it affects well-being.

8.2.2
A practical distinction is between *direct glare* and *indirect glare*, the latter being due to light being reflected off a glossy surface and the former being due to direct light from a light source. Fig. 5 illlustrates how luminaires fitted with louvres prevent glare but not indirect glare.

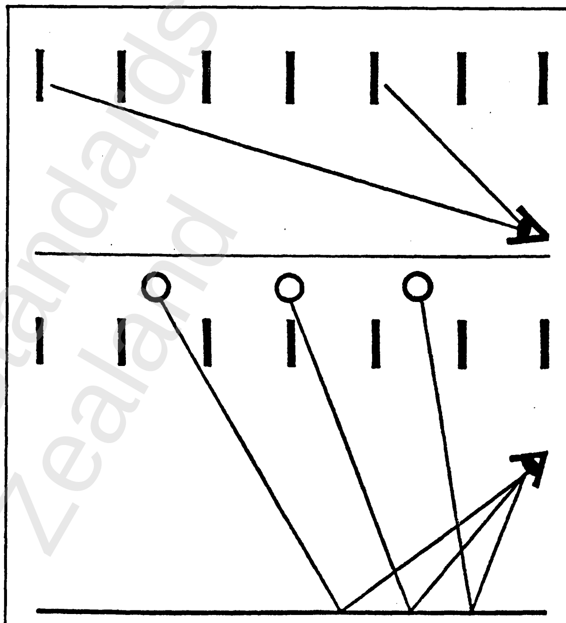


Fig. 5 LOUVRES PREVENT DIRECT GLARE, BUT INDIRECT GLARE CAN STILL OCCUR BY REFLECTION FROM GLOSSY SURFACES

8.2.3
One type of indirect glare is veiling reflection, which is produced by the reflection of a primary source on a glossy surface. A situation which produces veiling reflections is shown in fig. 6.

8.3 Measurement of glare

8.3.1
Contrast-rendering factor (CRF)
This is intended to specify how well a particular lighting system renders contrast in a particular task seen from a particular direction. The concept is based upon a comparison of the visibility of the task in the real situation and that of the same task seen within an integrating sphere, where light comes equally from all directions. The CRF for the latter situation has been given an arbitrary value of 1. Pen-

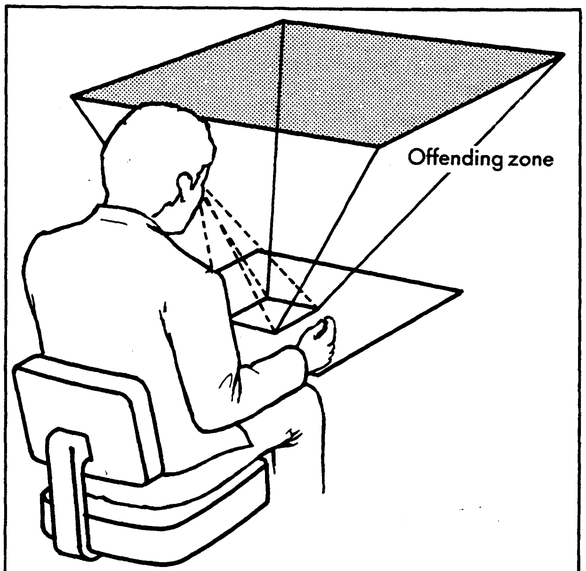


Fig. 6 LUMINAIRES IN THE OFFENDING ZONE CAN CAUSE VEILING REFLECTIONS

cil handwriting under conventional lighting has been found to have CRF values between 0.8 and 0.9, while under some indirect or unconventional systems, such as polarizers, bat-wing or trouser-leg distribution the value can be between 0.9 and 1.1. Although contrast-rendering is an important element in visibility, this approach is not yet well enough developed to be of use in lighting design. The designer should employ commonsense methods to minimize veiling reflections.

8.3.2
Numerical evaluation of direct glare
The most successful of many attempts to produce a practical system for this is the IES Glare Index System, which has been adopted by Great Britain and many other countries. IES Technical Report No. 10 sets out a procedure for the determination of the glare index from the extensive collection of tables it contains. These tables give the "initial glare index" for regular arrays of luminaires of each BZ class for a wide range of room proportions and decorations, and further data permit the initial index to be modified to account for differences in mounting height, downward flux and luminous area.

However, where an initial glare index table for the selected luminaire is available, this should be used in preference to the tables in IES Technical Report No. 10, since it will be more precise. A scale of glare indices for the whole range of interiors in which work is carried out is given. For example, the "limiting glare index" of an ordinary office is given as 19, meaning that if the glare index of an office lighting installation is 19 or less, glare has been kept within reasonable limits. These limiting glare indices are based on practical observation by a panel. A shortened version of the IES method, and examples of its application, is given in Appendix D.

8.3.3
Procedure
After a provisional arrangement of luminaires has been established by means of the lumen method as given in Appendix E the glare index is determined, and if it is unsatisfactory the arrangement must be modified. If a specification demands that the scheme be strictly consistent with the recommendations of the IES Code, the full calculation described in that document should be followed. This is rarely necessary, but when a glare index is stated the method used for its calculation should be stated also. For comparison the results of the full computation are given after each example in Appendix D. In looking at these discrepancies it should be remembered that a one unit difference in glare index is just detectable, and a difference of 3 units is required, in practice, to be significant.

9
ALLOWANCE FOR LIGHT LOSS WITH TIME

9.1
Light-loss factor

9.1.1
The light-loss factor is the ratio between the design service illuminance and the initial illuminance.

9.1.2
It is necessary to assess the light-loss factor for an installation to ensure that the specified light levels are achieved in practice and also to provide a basis for comparing alternative luminaire systems. The light-loss factor should be applied to the calculation when determining the number of lamps which will be required to provide the required luminance.

9.1.3
The value of the light loss factor, LLF, is given by the expression:

$$LLF = LD \times LRD$$

where LD is lamp lumen depreciation, being the ratio of the average lumen output for a stated lamp life to the initial (100h) output.

LRD is luminaire and room depreciation, being an allowance which takes account of the loss in light due to the accumulation of dirt on lamps, luminaires and room surfaces.

9.2
Lamp lumen depreciation

9.2.1
The luminous output of all lamps decreases with time, but the rate of decrease varies widely between lamp types. Technical information on lamp lumen depreciation may be obtained from manufacturers' data. An idea of the sort of decrease to be expected is given in fig. 7, which shows the range of depreciation for fluorescent and other discharge lamps.

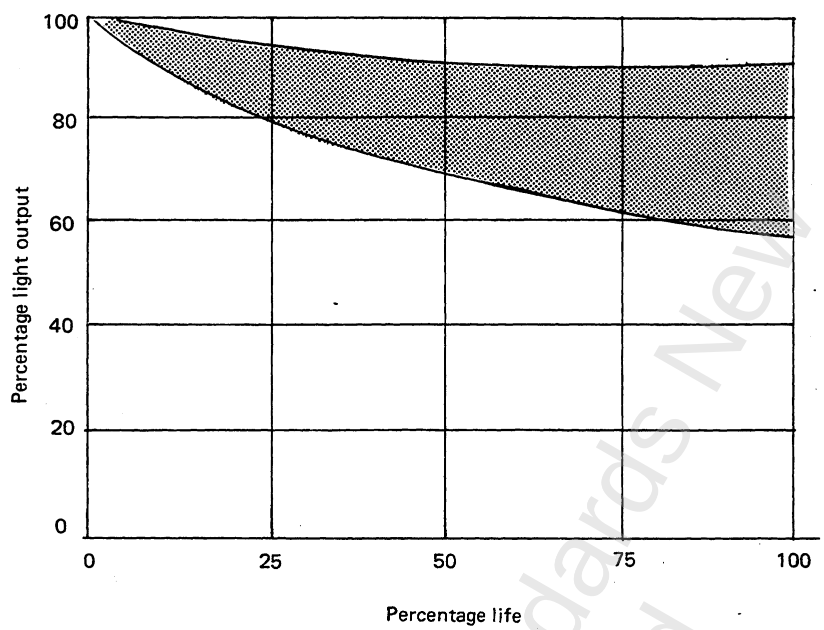


Fig. 7 RANGE OF LAMP LUMEN DEPRECIATION FOR FLUORESCENT AND OTHER DISCHARGE LAMPS

9.2.2
Apart from the intrinsic qualities of the lamp itself depreciation can be influenced by external factors such as heat and voltage fluctuations in the electricity supply.

9.3 Luminaire and room depreciation

9.3.1
The degree to which dirt can cause light loss is influenced by luminaire design, ventilated luminaires faring better than those with closed tops and open bases, and sealed luminaires being least affected of all. Fig. 8 illustrates the relative performance of various types, and table 4 gives suggested depreciation factors for four types of luminaire in five grades of ambient conditions.

NOTE — Further information on the effect of dirt accumulation on lamps and luminaires is given in the British CIBS/IES Technical Report No. 9 and the American IES Lighting Handbook, Application Volume, Section 4-21.

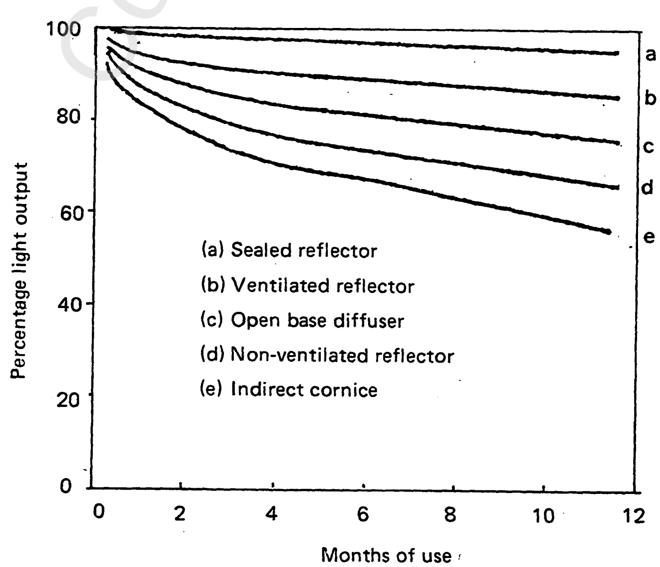


Fig. 8 LIGHT LOSS DUE TO DIRT ACCUMULATION FOR VARIOUS LUMINAIRE TYPES

Table 4

SUGGESTED LUMINAIRE AND ROOM DEPRECIATION (LRD) FACTORS FOR LUMINAIRES IN VARIOUS AMBIENT CONDITIONS

Luminaire type	*Ambient conditions*				
	Very clean	*Clean*	*Medium*	*Dirty*	*Very dirty*
Open, non-ventilated	0.90	0.80	0.71	0.64	0.56
Open, ventilated	0.95	0.89	0.83	0.78	0.72
Enclosed	0.97	0.93	0.88	0.83	0.78
Glass refractor or Enclosed and filtered	0.98	0.95	0.93	0.89	0.86

9.3.2
The lighting designer should bear in mind that, in addition to light loss due to the accumulation of dirt, materials used in luminaires can deteriorate to varying degrees with age and cause a gradual reduction in light output. For example, a vitreous enamelled reflecting surface has a lower rate of depreciation than an anodized aluminium reflector, but it has lower initial reflectance. Polystyrene refracting and diffusing materials tend to yellow more rapidly than acrylic materials.

NOTE — Further information on luminaire materials is given in Appendix F.

9.3.3
The accumulation of dirt on room surfaces reduces the amount of luminous flux reflected onto the working plane. This will vary from one installation to another, but will be most important in small rooms and those with a large component of indirect lighting. The appropriate luminaire and room depreciation factor should be established using table 4 and be included in the light loss factor calculation.

9.4 Cleaning and lamp replacement intervals

9.4.1
These should be specified as part of lighting design in order to ensure continued satisfactory illuminances. The actual interval chosen in each case would depend upon rapidity of accumulation, but cleaning and lamp replacement schedules should be co-ordinated. Fig. 9 shows typical depreciation curves for an installation of fluorescent lamps in a clean environment using various cleaning and lamp replacement schedules.

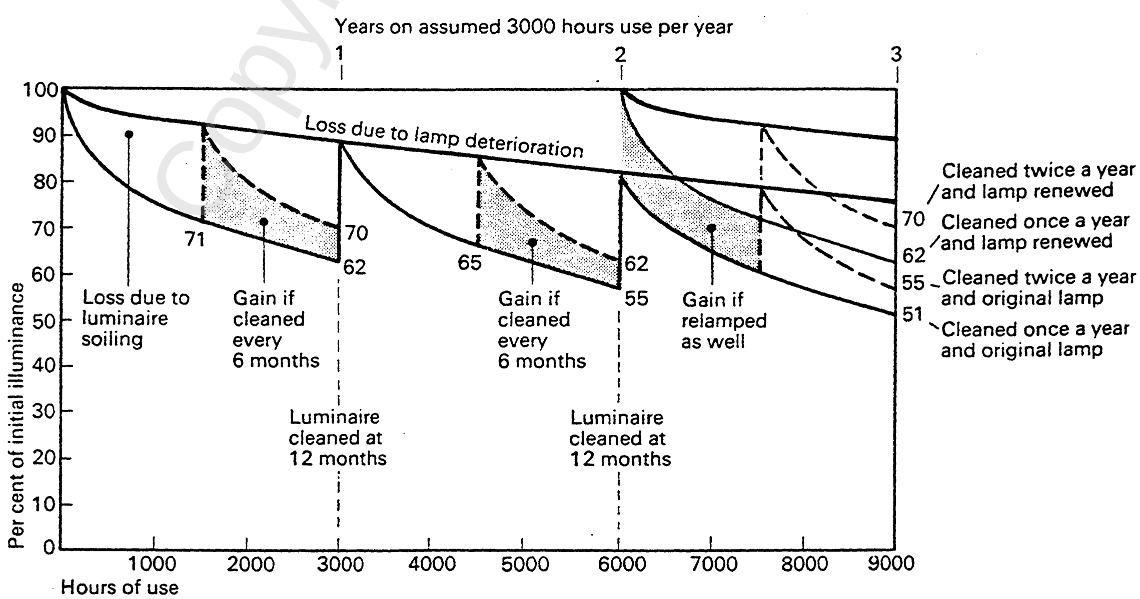


Fig. 9 COMBINED DEPRECIATION CURVES SHOWING THE EFFECT OF CLEANING AND LAMP REPLACEMENT SCHEDULES FOR AN INSTALLATION USING FLUORESCENT LAMPS

10 LUMINAIRES

10.1 Classification

10.1.1
Luminaires used in installations which are designed in compliance with this code are classified as follows:

(a) By light distribution

(b) By mounting position

(c) By electrical and mechanical design.

10.1.2
Light distribution
Luminaire light distributions are classified in accordance with the BZ system (see IES (GB) Technical Report No. 2) by which:

(a) A BZ classification number in the range 1 to 10 classifies the distribution of light emitted below the horizontal by an installation of luminaires.

(b) The Flux Fraction Ratio (FFR) expresses the ratio of upward to downward emitted light.

10.1.3
Mounting position
Mounting positions are classified as follows:

(a) Recessed — The luminaire is housed in a ceiling, wall or floor so that any visible projection is insignificant. If the dimensions of a luminaire are related to the building module the luminaire is described as "modular". The method of fixing recessed luminaires must be related to the ceiling or wall structure and to the weight of the luminaire: standard fixing arrangements are provided by the manufacturers. The trimming of openings made for the accomodation of luminaires should be designed to minimize the leakage of light and dust

NOTE — The temperature of air in a recessed luminaire is certain to be higher than the free-air temperature.

(b) Semi-recessed — The luminaire is partly housed in a ceiling, wall or floor. The comments in the previous paragraph on the installation of recessed luminaires also apply to semi-recessed luminaires

(c) Surface mounted — The thermal insulating effect of the ceiling and where heated ceilings exist, may require the fitting of heat- resistant cable. Where a sprinkler system is fitted care should be taken that luminaires do not interfere with its operation. In stock rooms and other high-risk areas particular care should be taken to site or shield luminaires to prevent stock being placed too close to them

(d) Wall-bracket — Provisions governing surface mounted luminaires, given in paragraph (c) above, apply also to wall-bracket luminaires

(e) Pendant

(f) Portable.

10.2 Luminaires associated with air-conditioning

10.2.1
The heat generated by lighting equipment can be considerable, and luminaires are available which are designed to transfer this heat to the apparatus that heats or cools the building.

10.2.2
Care should be taken to ensure that building heating does not directly affect tubular fluorescent lamps as these are temperature sensitive with regard to light output, colour appearance and colour rendering.

10.2.3
If integrated lighting and air-distribution systems are installed in suspended ceilings attention must be paid to ceiling design, including method of suspension and, where the space above the ceiling is to be used as an air-duct, a low leak-rate in the ceiling itself and around the luminaires.

10.3 Luminous ceilings (transmitted light)

10.3.1
General
A luminous ceiling consists of diffusing, prismatic or louvre panels with lamps mounted above. The diffusing panels can be sheet, either flat or corrugated, or can be shaped to give a sculptural effect. Prismatic panels are used to reduce the brightness of the ceiling at normal angles of view.

10.3.2
Lighting systems
Tubular fluorescent lamps (hot cathode) are the sources most often associated with luminous ceilings, although cold cathode fluorescent lamps or other types of discharge lamp of acceptable colour rendering may be used. Spacing-to-height ratios should not as a general rule exceed 1.5:1, but with high reflectance above the lamps and a high degree of diffusion in the panels this could be increased to 2:1. Where the ceiling above the lamps has a low reflectance provision of lamps with internal reflector coatings, or luminaires with reflectors is recommended.

10.3.3
Temperatures
Luminous ceilings often provide high illuminance (1000 lux or more) and the resultant ambient temperature above the ceiling may reach temperatures at which the light output of lamps is affected or control-gear overheats. Special design or even mechanical ventilation may be required in such cases.

10.3.4
Fire rating of luminous ceilings
These installations give no protection to structural elements against fire. For fire rating purposes these ceilings fall into two classes:

(a) *Closed type.* With this type the ceiling forms a continuous imperforate translucent membrane supported by a suspension system. It could have an adverse effect on the operating time and water distribution of any sprinklers that are fitted above the membrane. Design recommendations to meet this type of contingency are given in BS CP 290.

(b) *Open type.* This has panels composed of cells or louvres which will allow water from the sprinklers to pass through and will not prevent hot gases from a fire from setting off the sprinkler system, in installations where sprinklers are installed above the ceiling.

10.4
Luminous ceilings (indirect light)

10.4.1
In this case the ceiling and walls are part of the lighting design as all or most of the light will be reflected from them. The following points should be taken into account by the designer:

(a) A degree of variation in ceiling luminance is acceptable, but extreme variation is not. Thus lamps should not be too close to the ceiling

(b) Tubular fluorescent lamps should be of uniform colour and luminance

(c) Smudges above lamps due to convection will occur

(d) Reflective surfaces on ceiling and upper walls should be white or very pale, and of a matt finish

(e) Where continuous lines of light are required, cold cathode tubular fluorescent lamps can be specially made to suit the dimensions of the room.

11
MEASUREMENT OF ILLUMINANCE

11.1
Average illuminance

11.1.1
The measurement of the average illuminance may be necessary for any of the following reasons:

(a) to check the calculated value of a new installation;

(b) to determine compliance with a specification or recommended practice;

(c) to reveal the need for maintenance, modification or replacement;

(d) for comparison in order to achieve a solution which is expedient from the viewpoints of both lighting quality and economy.

11.2
Measurement of planar illuminance

11.2.1
Any photometer used for measuring planar illuminance should have ranges which cover the illuminances to be measured without it being necessary to take readings at pointer indications less than about one-fifth of the full-scale value of the range. For accurate work the photometer should have a photocell which is corrected to take account of the effects of light falling on it at oblique angles (a cosine-corrected photocell). If the photometer is to be used to measure illuminances in systems with different types of lamp or with daylight, a colour-corrected photocell should preferably be used; if the photocell is not colour-corrected, the appropriate correction factor (usually supplied by the manufacturers) must be applied. The calibration of photometers should be checked at least every 12 months.

NOTE — Requirements for two types of portable photoelectric photometers, Type P1 and Type P2, are specified in BS 667; errors of ±10 % and ±15 % of indication respectively are permitted.

11.2.2
Unless otherwise specified, measurements on the horizontal plane should be made at a height of 0.85 m above the floor. A portable stand to support the cell at the correct height and in a horizontal position is useful.

11.3
Measurement of mean spherical illuminance

11.3.1
A device used for measuring mean spherical illuminance must respond equally to light coming from all directions. An ordinary photocell can be adapted to satisfy this requirement by placing over it a small diffusing sphere and, by trial and error,

masking the sphere until the response is the same to light coming from any direction. This is best checked using a collimated beam of light.

11.3.2
If a suitable photometer is not available, a good approximation of the mean spherical illuminance can be obtained by measuring with an ordinary photocell the planar illuminance on each face of a regular tetrahedron and taking the mean of the four readings.

11.3.3
Mean spherical illuminance can be measured by other methods, and where the illumination vector is also to be measured there are certain advantages in using a photometer which has a diffusing hemisphere over the photocell. If two readings are taken at the point in question, the first with the photocell facing in a given direction and the second at 180° to that direction, the average of the two readings will be the mean spherical illuminance. Alternatively, two cells, each covered by a diffusing hemisphere, can be mounted back to back and the average of their readings taken; this average value is the mean spherical illuminance.

NOTE — Instruments are available commercially for measuring mean spherical illuminance.

11.4
Measuring conditions

11.4.1
Field measurements apply only to the conditions that exist during the survey. Recognising this, it is very important to record a complete detailed description of the surveyed area together with all other factors that might affect results, such as:

(a) lamp type and age;

(b) luminaire and ballast type;

(c) voltage;

(d) interior surface reflectances;

(e) state of maintenance, last cleaning date;

(f) measuring instrument used in the survey.

11.4.2
Before taking readings, photocells should be exposed to the approximate illuminance to be measured until the reading becomes stabilized — which usually requires 5 to 15 minutes. Care should be taken so that a shadow is not cast on the photocell when taking a reading.

11.4.3
Measurement of the illuminance obtained with an artificial lighting system should either be made after dark, or with daylight excluded from the interior. Before making measurements, the lamps should be switched on and their light output allowed to stabilize. If discharge lamps (including fluorescent lamps) are used, at least 20 minutes should be allowed to elapse before taking readings. When fluorescent lamps are mounted inside totally enclosed luminaires stablilization may take longer.

11.4.4
In installations with new discharge or fluorescent lamps at least 100 hours of operation should elapse before measurements are taken. Ventilation systems should be operating normally.

11.5
Measurements in empty or non-working interiors

11.5.1
For accurate measurement the area should be divided into squares with sides of approximately one metre and the illuminance measured in the centre of each square at the height of the working plane. The average illuminance of the whole area can be obtained by averaging all these measurements.

11.5.2
For general overhead lighting systems the number of measuring points can be reduced if an accuracy of ±10 % is considered sufficient. Table 5 lists the minimum number of measuring points to be taken for various values of the room index, which is defined as follows:

$$\text{Room index} = \frac{L \times W}{H_m (L + W)}$$

where: L = length of room
W = width of room
H_m = height of luminaires above the working plane

11.5.3
A limitation on the use of the table occurs when the grid for measuring points coincides with the grid of the lighting points. In this case errors are possible and more points than the number given should be used. It may also be necessary to increase the number of measuring points to obtain a symmetrical grid to suit a particular room shape.

Table 5
RELATIONSHIP BETWEEN ROOM INDEX AND THE NUMBER OF MEASUREMENT POINTS

Room index	*Minimum number of measurement points*
Below 1	4
1 and below 2	9
2 and below 3	16
3 and above	25

11.5.4
The following examples illustrate the use of the method:

(a) For an interior measuring 20 m × 20 m and with luminaires mounted 4 m above the working plane

$$\text{Room index} = \frac{20 \times 20}{4\ (20 + 20)} = 2.5$$

Sixteen points of measurement are therefore required, that is, a 4 x 4 grid

(b) If the room measures 20 m x 40 m and the luminaires are mounted at the same height, it should be treated as two 20 m x 20 m areas and thirty-two points of measurement should be used

(c) If the room measures 20 m x 33 m, the number of measurement points required should be derived by first considering a 20 m x 20 m area within the larger rectangle. From example (a) and treating this area by itself, sixteen points would be required. The number for the room is then obtained proportionately, that is,

$$\text{No. of points} = 16 \times \frac{20 \times 33}{20 \times 20} = 26$$

The points are placed at the centres of rectangles which should be as "square"as possible, taking twenty-six as the minimum number of points; twenty-eight points on a 4 x 7 grid could be used.

11.6
Measurements in furnished working interiors

11.6.1
In working interiors the illuminance should be measured at each working place (for example, desk, bench) and then averaged.

11.6.2
If the area contains tall machinery or high racks a statement of the average illuminance will often make little sense. Therefore the illuminance should be measured only in those zones or at those places where they are necessary for the activity required to be carried out.

11.7
Illuminance measurements

11.7.1
When local lighting supplements the general lighting the illuminance at the point of work should be measured with the worker in his normal working position. The measuring instrument should be so located that when readings are taken, the surface of the light-sensitive cell is in the plane of the work or of that portion of the work on which the critical visual task is performed (horizontal, vertical or inclined).

12
MEASUREMENT OF LUMINANCE

12.1
Luminance surveys

12.1.1
Luminance surveys, unlike illuminance surveys, should always be made under actual working conditions and from a specified work point location, using a combination of the daylight and artificial lighting facilities available.

12.1.2
All lighting in the area, both general and supplementary, should be in normal use. Work areas used during both day time and night time should preferably have two sets of readings, as the luminance distribution and thus the degree of visual comfort experienced, may differ markedly between these times.

12.1.3
The luminances can be recorded graphically by marking the measured luminances on a photograph or perspective drawing of the room concerned.

12.2
Surfaces to be considered

12.2.1
In most cases the luminance pattern of the room is mainly determined by the luminances of the following surfaces:

(a) visual task

(b) immediate surroundings of the task

(c) general background of the task

(d) vertical planes opposite the observer, for example, walls at eye level

(e) windows at noon and during night time

(f) floor from different viewing angles

(g) ceiling from different viewing angles

(h) luminaires from different viewing angles.

13
LIGHTING AND ENERGY

13.1
Introduction

13.1.1
Apart from building factors which influence the energy demands of a lighting installation, energy conservation requires consideration of the following 3 key factors:

(a) avoidance of over-lighting

(b) avoidance of excessive electrical load

(c) avoidance of non-essential usage.

13.2
Avoidance of over-lighting

13.2.1
The lighting designer should ensure that the correct design service illuminance has been selected. Section 7 provides detailed methods for this.

13.2.2
Approximations are necessarily made when calculating illuminance for general lighting schemes. To allow for the approximations, schemes are frequently designed to a somewhat higher value than specified to avoid the risk of the achieved illuminance being below specification. This practice of over-lighting wastes energy. If more precise data are used in the calculations it is often possible to design closer to specification and to reduce energy requirements by several percent. To achieve this, accurate information is needed about the nature and position of the tasks, the room surface reflectances, the light loss factor and the photometric characteristics of the luminaire. Lighter finishes on walls, ceilings and floor use light more efficiently.

13.2.3
Where work locations have been established before luminaires are selected or installed there are frequent opportunities to apply localised and general lighting, using recommended illuminances over work locations but a lower illuminance in circulation spaces. The task lighting may be incorporated into the work station or may be separate from it.

13.2.4
Section 9 gives details on light loss factors. Minimizing these can show substantial savings on energy requirements of an installation. Installation owners should be advised of the lamp replacement and luminaire cleaning intervals allowed for in calculations and the energy savings which should result. However, the light loss factors incorporated into the calculation should be realistic and reflect the owner's actual intentions.

13.3
Avoidance of excessive electrical load

13.3.1
Introduction
NZS 4220 discusses lighting energy design targets and approves the procedure in Part 1 of the CIBS Building Energy Code. This latter document lists recommended minimum lamp efficacies and utilisation factors, and gives a lighting design procedure which incorporates reference to these listings. As this procedure can be rather restricting on the scope of lighting design, similar listings are given below but with a procedure which enables the lighting designer to calculate lighting energy design targets for each part of a building. Some changes have been made to the listed values to account for technical developments since the CIBS guide was published in 1977, but the overall intention is to offer designers a more flexible alternative approach rather than to supersede these two documents.

13.3.2
Circuit efficacy ($e_{min.}$)

Recommended minimum circuit efficacies are listed in table 6. The circuit efficacy is the initial (100 hour) lumen output of the lamps divided by circuit watts including losses due to ballast and any other ancillary gear.

Table 6
RECOMMENDED MINIMUM CIRCUIT EFFICACIES

Application	*Minimum circuit efficacy* ($e_{min.}$)	*Suitable lamp type*
	lm/w	
Where moderate colour rendering is acceptable	60	MCF, MBF SON, MBI
Where good colour rendering is required	40	MCF, MBI
Where very good colour rendering is required	35	MCF

NOTE —
(1) The following abbreviations are used in the table:

MBF : Mercury fluorescent — high pressure

MBI : Mercury halide — high pressure

MCF : Tubular fluorescent

SON : High pressure sodium

(2) Tungsten lamps may be suitable, where by careful light control a high utilisation factor is achieved.

13.3.3
Utilisation factor (UF)
Table 7 gives recommended minimum utilisation factors for two values of room index; interpolation is permissible. Surface reflectances of 0.7, 0.5 and 0.2 apply for ceiling, walls and work plane respectively, but where lower reflectances occur, the designer should seek to have the reflectances increased rather than accept a lower lighting efficiency.

Table 7

RECOMMENDED MINIMUM UTILISATION FACTORS

Importance of aesthetic quality of lighting system	*Minimum utilisation factor, $UF_{min.}$ at quoted room indices* 5.0	2.0
Very important	0.55	0.46
Important	0.60	0.53
Not important	0.80	0.65

13.3.4

Light loss factor (LLF)

As discussed in section 9, the light loss factor has two components. The lumen depreciation (LD) relates to the type of lamp and the anticipated lamp life: this must be determined by the lighting designer. The luminaire and room depreciation (LRD) relates to the effects of dirt accumulation, and recommended minimum values, $LRD_{min.}$, are as follows:

Commercial spaces	0.9
Industrial spaces	0.8

Thus, the recommended miniumum light loss factor, $LLF_{min.}$, is given by:

$$LLF_{min.} = LD \times LRD_{min.}$$

13.3.5

Lighting energy design target (LEDT)

A lighting energy design target is required for each area that has a separately defined lighting requirement.

Then:

$$LEDT = \frac{E}{e_{min.} \times UF_{min.} \times LLF_{min.}} \text{ W/m}_2$$

where:

E = the design service illuminance in lux

$e_{min.}$ = the recommended minimum circuit efficacy in lm/W, from table 6

$UF_{min.}$ = the recommended minimum luminaire utilisation factor from table 7.

$LLF_{min.}$ = the recommended light loss factor derived from clause 13.3.4.

13.3.6

Application of the lighting energy design target

The lighting designer may opt for general, localised or local task lighting as judged to be appropriate, but whatever type of installation, the lighting loading (W/m²) is obtained by dividing the total installed wattage by the area of zone under consideration. This is not to exceed the lighting energy design target.

13.4
Avoidance of non-essential use

13.4.1

The designer should arrange lighting controls so that proper energy management of the lighting is possible.

13.4.2

Manual switching should be arranged to control small sections of the lighting installation. The switches should be placed so that they are convenient to use and closely associated with the area the switch controls, so that staff are encouraged to operate the lighting in the most economical way.

13.4.3

Automatic switching can be introduced whereby artificial lighting in the areas of the building which benefit from adequate daylight is either block switched by contactor or progressively dimmed electronically, all under the control of photo-electric cells.

13.4.4

In most cases the lighting installation which meets the users' requirements will be more than adequate for the building cleaners, and reductions in running costs will be achieved by automatically reducing the illuminance available for cleaning staff. Further savings may be made by limiting the duration that lights may be left on after normal business hours.

NOTE — The life of fluorescent lamps is reduced by switching. However, the value of the energy saved by turning them off normally exceeds the consequential small increase in lamp-change costs incurred. The life of other types of discharge lamps and of incandescent lamps is not materially affected by normal switching.

13.5
Energy management

13.5.1

Energy management in buildings involves the control of internal and external heat gains and losses plus transportation of heat for use or disposal. Both the heating and cooling cycles can be utilized. From a lighting standpoint the use of return-air luminaires, as described in clause 10.2, can be of primary importance. In terms of energy costs, the effectiveness of any lighting design cannot be considered in isolation and some comparison should be made between the lighting energy costs and the other building energy costs. The selected lighting system will have an effect on many other elements of the building and ultimately its usage.

13.5.2

Where the designer prepares alternative proposals to determine the best illumination/energy fit there will be cost implications which the owner is required to resolve. If the alternatives are related to capital cost of similar items it will be sufficient to advise the owner of the illumination efficacy and the capital cost of each scheme.

13.5.3
The availability of daylight, automatic control systems and the hours of use are not responsive to simple calculation methods. Where the designer intends to use these and similar methods to reduce energy consumption the capital cost of the equipment and its maintenance and running costs are factors to be considered, along with flow-on cost into other items of building.

13.5.4
The designer should advise the owner of the capital cost of any additional equipment, the anticipated running costs and the flow on costs arising from the proposal, for example variations to building and air-conditioning plant costs due to increased glazing.

NOTE — It is not necessary for the designer to calculate the payback period for additional plant required for energy conservation as most building owners will have the expertise to judge the validity of the additional investment.

13.6 Precautions to be taken when seeking to minimize energy consumption

13.6.1
Table 8 lists the precautions that need to be taken when measures to minimize energy consumption are being considered.

14 LIGHTING SPECIFICATION

14.1
It is recommended that lighting designers use the pro-forma shown in fig. 10 to state their proposals. The adoption of this standard form of presentation of information will assist users to compare alternative proposals. In most cases all of the information will be relevant and is to be provided, but where some information is omitted the reason for omission is to be stated.

14.2
The designer should advise the user to give careful attention to the maintenance section as this states the conditions taken into account by the lighting designer for calculating lighting performance. It is important for the user to appreciate that the stated service illuminance depends upon the operation of an appropriate maintenance schedule.

Table 8
PRECAUTIONS TO BE TAKEN WHEN SEEKING TO MINIMIZE ENERGY CONSUMPTION

Action taken to minimize energy consumption	*Precautions*
Increase daylight contribution	Avoid excessive areas of glazing to reduce heat losses in winter and to reduce noise penetration. Use screening (preferably external) to avoid glare problems, external shielding to reduce solar gain, and double glazing to reduce noise.
Use local or localized rather than general lighting	Flexibility in lighting layout may be necessary to permit rearrangements in work organisation. Choose only those sources which satisfy colour rendering requirements.
Use a more efficient light source	Ensure satisfactory colour rendering is maintained.
Use a more efficient luminaire	Use only luminaires which will satisfy discomfort glare requirements.
Increase reflectances of room surfaces	Avoid reflectances above recommended range, as these could introduce visual discomfort and distraction.
Improve light loss factor	Allow for possibility of increased labour costs for more frequent servicing of equipment.
Control hours of use of electtric light by planned switching	Ensure careful design of systems to minimize risk of staff dissatisfaction. Observe safety requirements for staff entering interior or circulation space.

LIGHTING SPECIFICATION FOR . . . .

(Details of Building, Area, etc to be inserted here)

OBJECTIVES

Design service illuminance	lux
Uniformity ratio	
Limiting glare index	
Other factors:	

DAYLIGHT

Average daylight factor	percent
Minimum daylight factor	percent
Other factors:	

INSTALLATION TYPE

Daylight installation
Task lighting installation
Combined lighting installation
Permanent artificial lighting installation
Other:

ARTIFICIAL LIGHTING

Layout
Number of luminaires
Working plane area, length, width
Rows lengthwise, crosswise
(layout diagram attached)
Working plane height above floor level
Mounting height above working plane
Suspension height

(continued overleaf)

Fig. 10 PRO-FORMA LIGHTING SPECIFICATION

Lamp	Manufacturer, reference	
	Lamp type	
	Lamp watts	W
	Initial (100 hour) lumens	lm
	Lamp replacement period	hours
	Lamp lumen depreciation factor (LD)	
Luminaire	Manufacturer, reference	
	Lamps per luminaire	
	Total watts per luminaire, including control gear losses	
	Light output ratio	
	BZ classification	
	Flux fraction ratio	
Controls	Switching arrangement is shown on layout diagram	
Performance	Calculated initial illuminance	lux
	Esimated light loss factor	
	Calculated service illuminance	lux
	Calculated* glare index	
	Lighting electrical load	kW
	Lighting power factor	
	Illumination efficacy	lm/W

*State method if not as Appendix D

MAINTENANCE

Window glazing cleaning period	months
Maintained glazing transmittance	
Luminaire cleaning period	months
Lamp replacement period	months
Assumed hours of use per year	

Maintained surface reflectances:

ceiling
walls
floor

. . . . Lighting Designer

. . . . Date

(continued)

Fig. 10 PRO-FORMA LIGHTING SPECIFICATION

APPENDIX A

METHODS OF DAYLIGHT FACTOR CALCULATION

A1
Introduction

A1.1
A CIE document (Publication 16: E-3.2 1970) on daylight calculations lists 58 methods and more have been proposed since. The choice of a particular method will depend on its appropriateness to the situation, the range of methods with which the designer is familiar, and the availability of data.

A1.2
This appendix describes the methods of the Building Research Establishment (BRE) in Britain, as they are the most widely used in New Zealand. The simplified tables are given in full, but the most exacting procedures are described in outline only, for in order to apply them it would be necessary to obtain the protractors and reference material mentioned in the text.

A1.3
Increased use of computer methods will lead to designers making less use of tabular and graphic methods of this sort. Engineers whose work involves them frequently in daylight design would be well advised to make themselves familiar with other methods so that they can choose the most appropriate method for a given situation.

A2
The three components of daylight factor

A2.1
In order to arrive at a figure for daylight factor the following three components must be determined:

(a) The sky component (SC)

(b) The externally-reflected component (ERC)

(c) The internally-reflected component (IRC)

The daylight factor is obtained by summing the three components and making an allowance for factors which reduce the level of daylight available in practice.

A3
Determination of the sky component

A3.1
BRE daylight factor protractors

A3.1.1
The complete set of BRE daylight protractors (second series) comprises two sets of five transparent circular protractors: one set is used when a uniform sky is assumed for design purposes, and the other when the CIE standard overcast sky is assumed. Fig. A1 shows the BRE sky component protractor for vertical glazing and CIE overcast sky, this sky being the recommended design condition for use in New Zealand. Other protractors in the set can be used to estimate sky components for inclined and horizontal arrangements of glazing, but for straightforward applications of vertical glazing it often is more convenient to use the tabular data. (See clause A3.2).

A3.1.2
The protractors are produced by Her Majesty's Stationery office, London, and their use is described in detail in BRE Digest No. 41. In brief, the appropriate scale of the protractor is placed on scale plans and elevations showing the glazing, and the intersections of sight-lines from the point of interest to the edges of the area of sky visible through the glazing (that is, above or to the side of any obstruction) are read off, as shown in fig. A2. The resulting SC is automatically corrected for the light transmittance of clear glass. This method can be used only if the glazing is rectangular, or can be related to the equivalent rectangle.

A3.2
BRS simplified sky component tables

A3.2.1
Fig. A3 shows part of a room which has a window on one side. The working plane is 0.85 m above the floor, and H is the effective height of the window head above the working plane after allowing for any obstructions. D is the distance from the reference point to the plane of the window. W_1 and W_2 are the effective widths of the window on each side of a line drawn normal to the plane of the window from the reference point. The ratios H/D, W_1/D and W_2/D can be worked out, and by using table A1 the sky components can be obtained. W_1 and W_2 must be treated separately. In general, the sky components at any other reference point can be obtained by addition or subtraction.

A3.2.2
The correction for an obstruction is obtained as follows:

(a) Measure the average angle to the top of the obstruction as seen from the reference point

(b) Using the left scale of table A1 for W/D and the bottom scale for the angle read off the value of the sky component.

NOTE — W_1 and W_2 must be treated separately

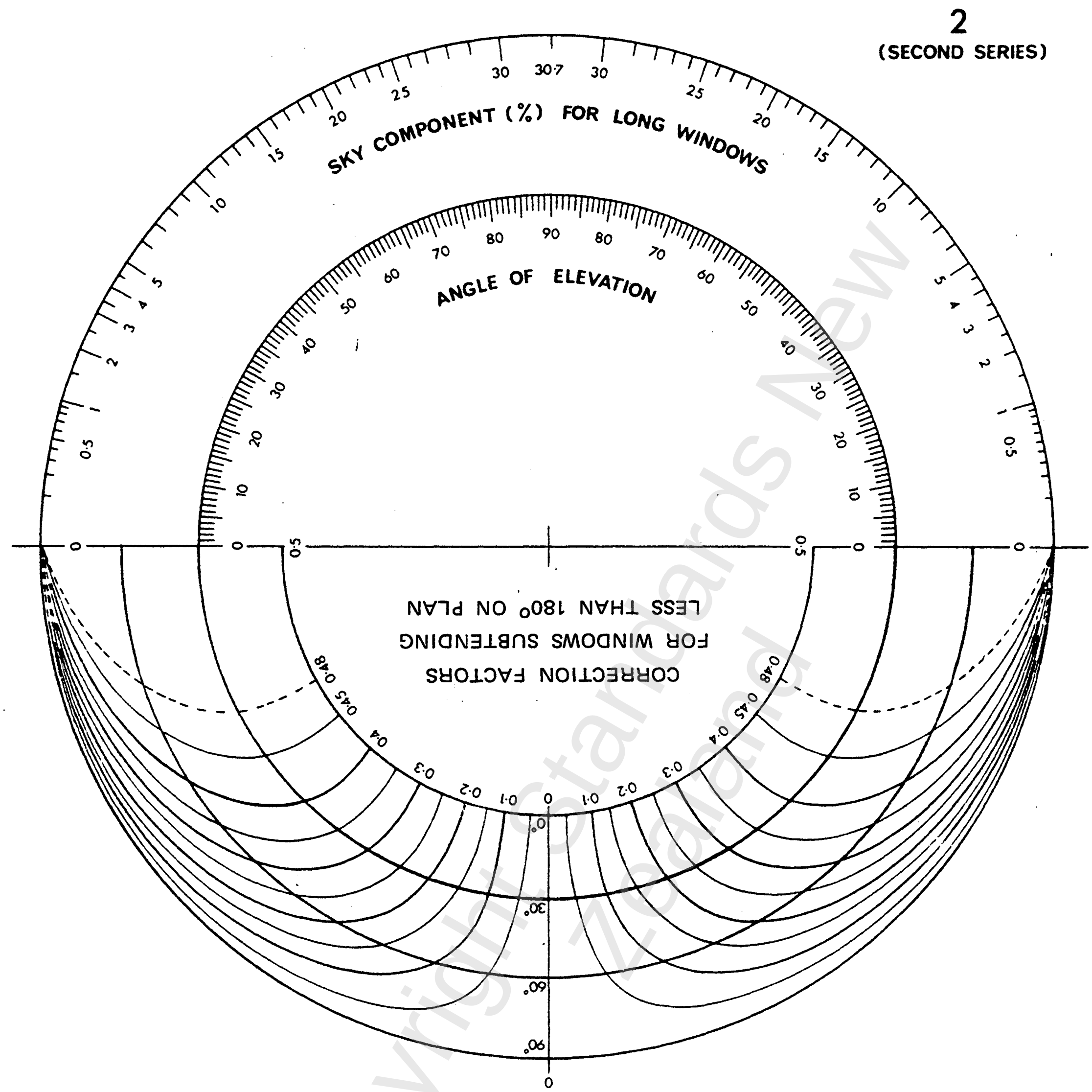


Fig. A1 BRE SKY COMPONENT PROTRACTOR FOR VERTICAL GLAZING (CIE OVERCAST SKY) (Reproduced by courtesy of the Director, Building Research Establishment, UK, and by permission of the Controller, HMSO. Crown copyright.)

(c) Multiply the value of the sky component by 0.8 and subtract this figure from the sky component for the full window.

NOTE — This procedure gives the corrected sky component plus the externally reflected component.

A4
Determination of the externally-reflected component

A4.1

The scale drawings of the design area and the BRE protractors, as used for the determination of the sky component, are used also for the determination of the externally-reflected component. The sight lines of the obstructions visible through the glazing (to the obstructed edges of the window and the horizontal and vertical limits of the obstruction) are used to define the points on the protractor scale. The obstruction is then treated like a patch of sky with a luminance one-fifth that of the equivalent patch of CIE standard sky. The method can be applied to a complex obstruction only if this can be reduced to the equivalent rectangle.

A5
Determination of the internally reflected component

A5.1
BRE split-flux formula

A5.1.1
BRE Digest No. 42 gives details of the split-flux method for determining IRC. Application of the formula enables average IRC to be determined, but for design purposes it is more convenient to refer to nomograms which give either average or minimum IRC. These nomograms are shown in fig. A4 and fig. A5.

A5.2
BRE simplified IRC table

A5.2.1
The BRE simplified IRC table can be used for reasonably unobstructed vertical glazing. This is shown as table A2.

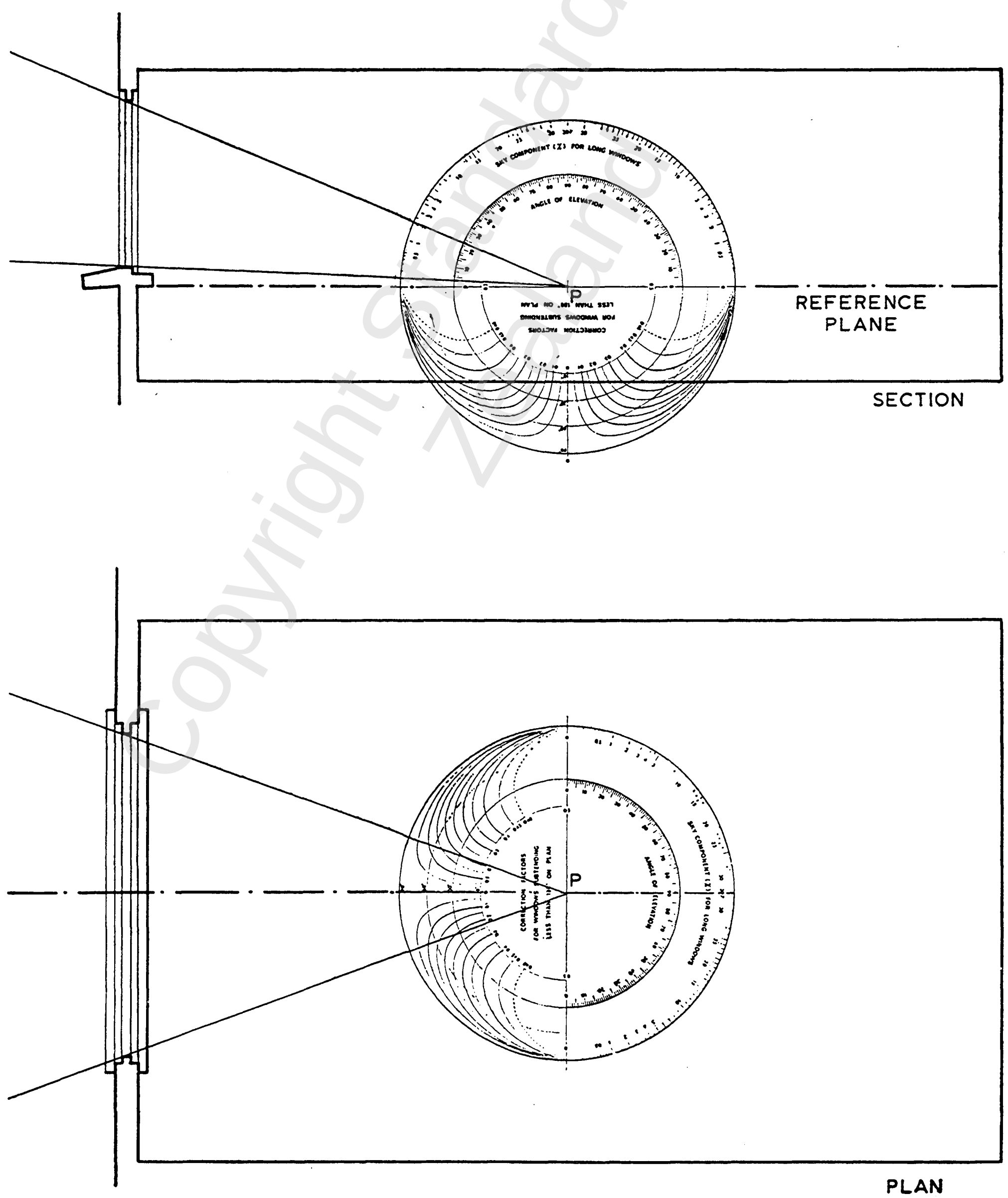


Fig. A2 **USE OF BRE PROTRACTOR NO. 2 TO DETERMINE THE SKY COMPONENT FROM A VERTICALLY GLAZED WINDOW**

Table A1

DAYLIGHT FACTOR ESTIMATION

Sky components (CIE Standard overcast sky) for vertical rectangular windows with clean clear glass

Ratio W/D \ Ratio H/D																													
0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	5.0	∞
0.1	0	0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3
0.2	0	0.1	0.1	0.2	0.4	0.5	0.7	0.8	1.0	1.1	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.4	2.5
0.3	0	0.1	0.2	0.3	0.5	0.7	1.0	1.2	1.5	1.7	1.9	2.1	2.3	2.4	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.4	3.5	3.6	3.6	3.7	3.7
0.4	0	0.1	0.3	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.7	2.9	3.2	3.3	3.5	3.6	3.8	3.9	4.0	4.1	4.3	4.4	4.5	4.5	4.6	4.7	4.8	4.9
0.5	0	0.1	0.3	0.5	0.8	1.2	1.5	1.9	2.2	2.6	3.0	3.3	3.6	3.8	4.0	4.2	4.4	4.6	4.7	4.8	5.0	5.2	5.3	5.4	5.5	5.7	5.8	5.9	5.9
0.6	0	0.1	0.3	0.6	1.0	1.3	1.7	2.2	2.6	3.0	3.4	3.8	4.1	4.4	4.6	4.9	5.1	5.3	5.4	5.6	5.8	6.0	6.2	6.3	6.4	6.6	6.7	6.8	6.9
0.7	0	0.2	0.4	0.7	1.0	1.5	1.9	2.4	2.8	3.3	3.8	4.2	4.5	4.8	5.1	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.1	7.3	7.4	7.6	7.7
0.8	0.1	0.2	0.4	0.7	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.5	4.9	5.2	5.6	5.8	6.1	6.3	6.5	6.7	7.0	7.3	7.5	7.6	7.8	8.0	8.2	8.3	8.4
1.0	0.1	0.2	0.4	0.8	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8	5.2	5.6	5.9	6.2	6.5	6.7	6.9	7.1	7.4	7.7	7.9	8.1	8.2	8.5	8.7	8.8	9.0
1.2	0.1	0.2	0.4	0.8	1.3	1.8	2.3	2.9	3.4	4.0	4.6	5.0	5.5	5.9	6.2	6.5	6.8	7.1	7.3	7.5	7.9	8.1	8.4	8.6	8.7	9.0	9.2	9.4	9.6
1.4	0.1	0.2	0.5	0.9	1.4	1.9	2.5	3.1	3.7	4.3	4.9	5.4	5.9	6.4	6.8	7.2	7.5	7.8	8.1	8.3	8.7	9.1	9.3	9.6	9.8	10.1	10.3	10.5	10.7
1.6	0.1	0.2	0.5	0.9	1.4	1.9	2.5	3.2	3.8	4.5	5.1	5.7	6.2	6.7	7.1	7.5	7.8	8.2	8.5	8.7	9.1	9.5	9.8	10.0	10.2	10.6	10.9	11.1	11.6
1.8	0.1	0.2	0.5	0.9	1.4	2.0	2.6	3.3	3.9	4.0	5.3	5.9	6.4	7.0	7.4	7.8	8.2	8.5	8.8	9.1	9.6	10.0	10.2	10.5	10.7	11.1	11.4	11.7	12.2
1.9	0.1	0.2	0.5	1.0	1.4	2.0	2.6	3.3	4.0	4.7	5.4	6.0	6.6	7.2	7.6	8.1	8.5	8.8	9.2	9.5	10.0	10.4	10.8	11.1	11.3	11.8	12.0	12.3	12.6
2.0	0.1	0.2	0.5	1.0	1.5	2.0	2.6	3.3	4.0	4.7	5.4	6.1	6.7	7.3	7.8	8.2	8.6	9.0	9.4	9.7	10.2	10.7	11.1	11.4	11.7	12.2	12.4	12.7	13.0
2.5	0.1	0.2	0.5	1.0	1.5	2.1	2.6	3.3	4.0	4.8	5.5	6.2	6.8	7.4	7.9	8.4	8.8	9.2	9.6	9.9	10.5	11.0	11.4	11.7	12.0	12.6	12.9	13.3	13.7
3.0	0.1	0.2	0.5	1.0	1.5	2.1	2.7	3.4	4.1	4.8	5.6	6.2	6.9	7.5	8.0	8.5	8.9	9.3	9.7	10.0	10.7	11.2	11.7	12.0	12.4	12.9	13.3	13.7	14.2
4.0	0.1	0.2	0.5	1.0	1.5	2.1	2.7	3.4	4.1	4.9	5.6	6.3	6.9	7.5	8.0	8.6	9.0	9.4	9.8	10.1	10.8	11.3	11.8	12.2	12.5	13.2	13.5	14.0	14.6
6.0	0.1	0.2	0.5	1.0	1.5	2.1	2.8	3.4	4.2	5.0	5.7	6.3	6.9	7.6	8.1	8.6	9.1	9.5	9.9	10.2	10.9	11.4	11.9	12.3	12.6	13.2	13.6	14.1	14.9
∞	0.1	0.2	0.5	1.0	1.5	2.1	2.8	3.4	4.2	5.0	5.7	6.3	7.0	7.6	8.1	8.6	9.1	9.5	9.9	10.3	10.9	11.5	11.9	12.3	12.7	13.3	13.7	14.2	15.0
0°	6°	11°	17°	22°	27°	31°	35°	39°	42°	45°	48°	50°	52°	54°	56°	58°	60°	61°	62°	63°	66°	67°	69°	70°	72°	74°	76°	79°	90°
	Average angle to top of obstruction as seen from reference point.																												

NOTE — (1) Ratio H/D = Height of windowhead above working plane/distance from window.

(2) Ratio W/D = Effective width of window to one side of normal/distance from window.

A6
Calculation of the daylight factor

A6.1
The daylight factor (%) is calculated using the following formula:

$$DF = (SC + ERC + IRC) \times M \times G \times B$$

where:

M is a factor which makes allowance for the effect of accumulated dirt on the glazing. Recommended values are given in table A3.

G is a glazing transmittance factor. The BRS methods assume that the glazing has a diffuse light transmittance of 0.85. For an actual glazing transmittance, t, G = t/0.85.

B is a glazing bars factor. It is often convenient to base calculations on the size of the window aperture rather than on individual panes, and to allow for the overall obstruction of light due to glazing bars. Typical values of B are 0.8 for metal window frames and 0.7 for wooden frames.

Table A2

MINIMUM INTERNALLY REFLECTED COMPONENT OF DAYLIGHT FACTOR : BRS SIMPLIFIED IRC TABLE

Window area as percentage of floor area	*Minimum IRC*											
	Reflectance of floor											
	0.1				*0.2*				*0.4*			
	*Average reflectance of walls**											
	0.2	*0.4*	*0.6*	*0.8*	*0.2*	*0.4*	*0.6*	*0.8*	*0.2*	*0.4*	*0.6*	*0.8*
2	—	—	0.1	0.2	—	0.1	0.1	0.2	—	0.1	0.2	0.2
5	0.1	0.1	0.2	0.4	0.1	0.2	0.3	0.5	0.1	0.2	0.4	0.6
7	0.1	0.2	0.3	0.5	0.1	0.2	0.4	0.6	0.2	0.3	0.6	0.8
10	0.1	0.2	0.4	0.7	0.2	0.3	0.6	0.9	0.3	0.5	0.8	1.2
15	0.2	0.4	0.6	1.0	0.2	0.5	0.8	1.3	0.4	0.7	1.1	1.7
20	0.2	0.5	0.8	1.4	0.3	0.6	1.1	1.7	0.5	0.9	1.5	2.3
25	0.3	0.6	1.0	1.7	0.4	0.8	1.3	2.0	0.6	1.1	1.8	2.8
30	0.3	0.7	1.2	2.0	0.5	0.9	1.5	2.4	0.6	1.3	2.1	3.3
35	0.4	0.8	1.4	2.3	0.5	1.0	1.8	2.8	0.9	1.5	2.4	3.8
40	0.5	0.9	1.6	2.6	0.6	1.2	2.0	3.1	1.0	1.7	2.7	4.2
45	0.5	1.0	1.8	2.9	0.7	1.3	2.2	3.4	1.2	1.9	3.0	4.6
50	0.6	1.1	1.9	3.1	0.8	1.4	2.3	3.7	1.3	2.1	3.2	4.9

* Excluding windows.

NOTE — These values assume a ceiling reflectance of 0.7 and an angle of external obstruction of 20°.

Table A3

FACTORS TO ALLOW FOR DIRT ACCUMULATION ON GLAZING

Locality	*Class of industry*	*Angle of slope of glazing (measured to the horizontal)*		
		90°–75°	*60°–45°*	*30°–0°*
Country or outer suburban area	Clean Dirty	0.9 0.7	0.85 0.6	0.8 0.55
Built-up residential area	Clean Dirty	0.8 0.6	0.75 0.5	0.7 0.4
Built-up industrial area	Clean Dirty	0.7 0.5	0.6 0.35	0.55 0.25

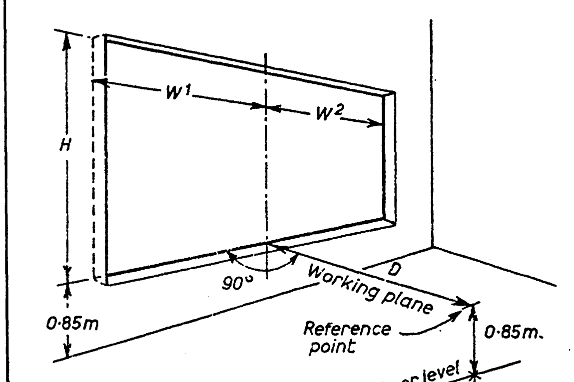
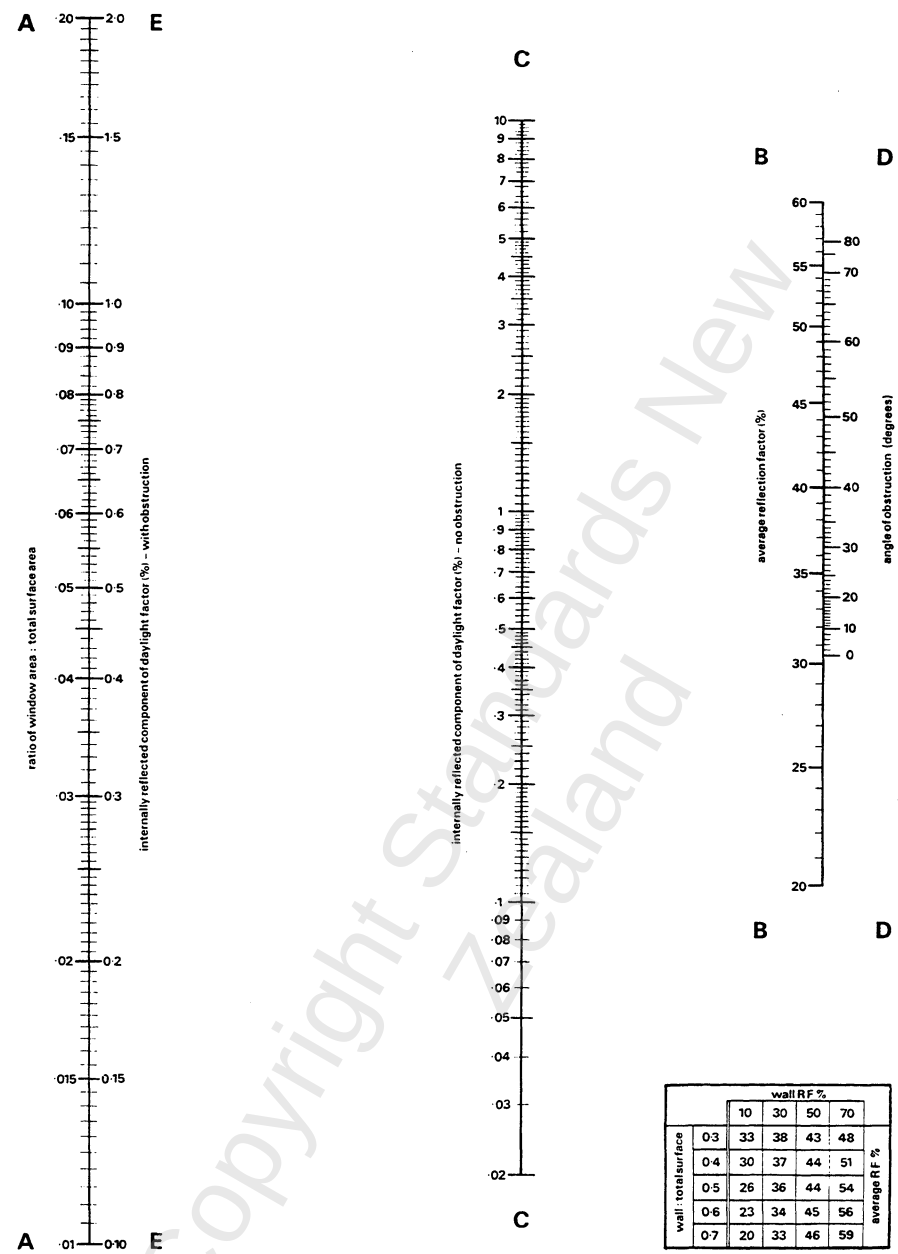


Fig. A3 DERIVATION OF SKY COMPONENT OF DAYLIGHT FACTOR FOR A VERTICAL RECTANGULAR WINDOW

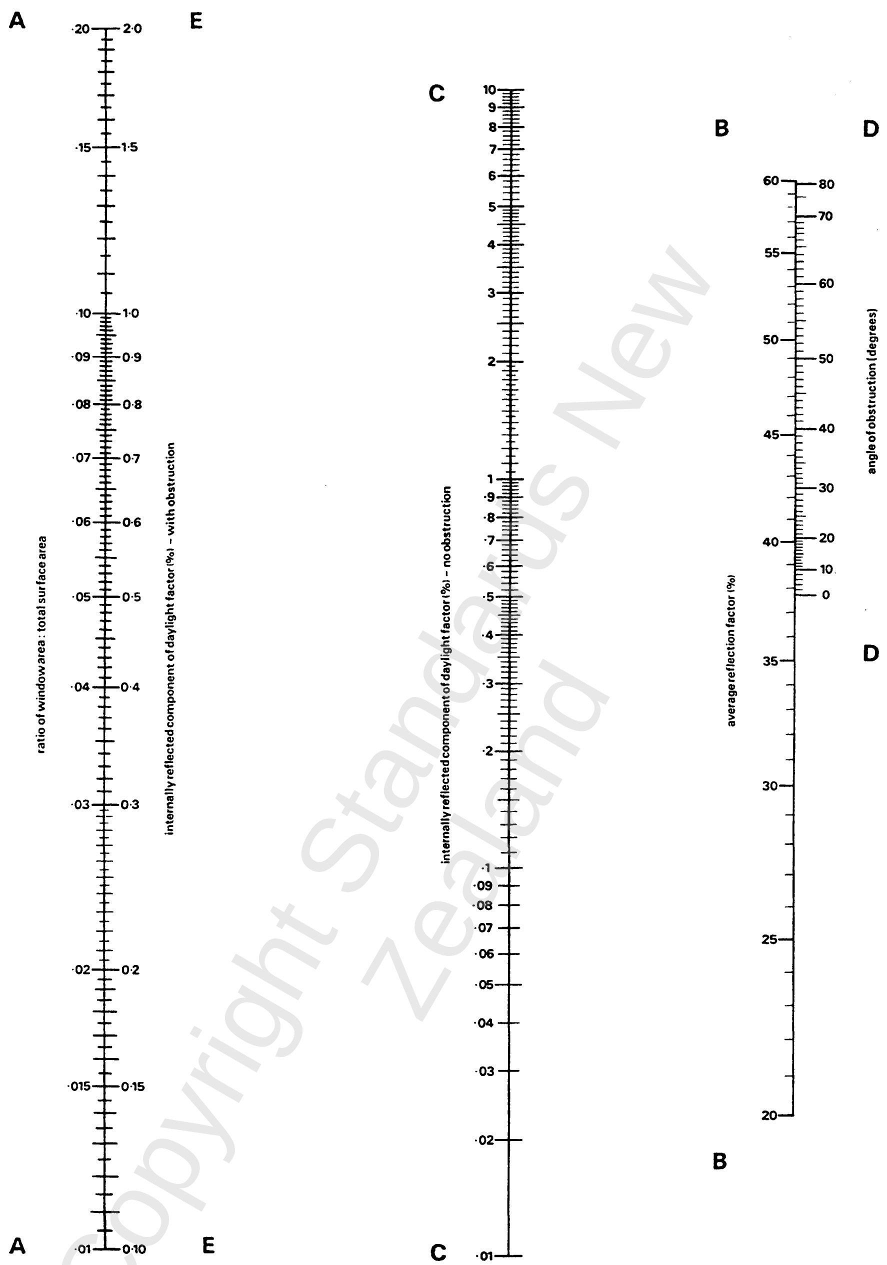


wall : total surface	wall RF % 10	30	50	70
0·3	33	38	43	48
0·4	30	37	44	51
0·5	26	36	44	54
0·6	23	34	45	56
0·7	20	33	46	59

(Values in table: average RF %)

Nomogram I. Average internally reflected component of daylight factor

Fig. A4 NOMOGRAM FOR THE CALCULATION OF THE *AVERAGE* INTERNALLY REFLECTED COMPONENT OF DAYLIGHT FACTOR IN SIDE-LIT ROOMS



Nomogram II. Minimum internally reflected component of daylight factor

Fig. A5 NOMOGRAM FOR THE CALCULATION OF THE *MINIMUM* INTERNALLY REFLECTED COMPONENT OF DAYLIGHT FACTOR IN SIDE-LIT ROOMS

APPENDIX B

RECOMMENDED STANDARD SERVICE ILLUMINANCES

B1
Table of illuminances

B1.1
Table B1 lists recommended standard service illuminances for a large number of interiors and the various tasks performed in them. The table gives the corresponding limiting glare index for each of the tasks, and gives recommendations for the colour of the lighting source. The recommendations agree, in general, with those given in CIE Publication 29 and with the guidance document on codes issued by a committee of European lighting societies.

Table B1

RECOMMENDED STANDARD SERVICE ILLUMINANCES

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
GENERAL BUILDING AREAS					
Circulation areas					
Corridors, passageways	100 (Mean spherical)	1.2 m above floor	22	Intermediate or warm	Scalar illuminance to be not less than 1/8 horizontal planar illuminance in adjacent areas and not less than 120 lux if there is no daylight.
Lifts (passengers)	150	Floor	––	"	
Stairs	150	Treads	––	"	
Escalators	150	Treads	––	"	Avoid specular reflections on treads.
External covered ways	30	Ground	––	"	Illuminance should be compatible with adjacent lit areas.
Entrances					
Entrance halls, lobbies waiting rooms	150 (Mean spherical)	1.2 m above floor	––	Intermediate or warm	
Enquiry desk	500	Desk	19	"	
Gatehouses	200	Desk	16	"	
Kitchens					
Food stores	150	Floor	––	Intermediate or warm	
Working areas	500	Working surface	22	"	Position luminaires relative to working areas. Proof luminaires may be required.
Medical and first aid centres					
Consulting rooms treatment areas	500	Desk or bed	––	Intermediate or warm	Colour rendering is important. Examination lighting should be provided.
Medical stores	100	Vertical on shelves	––	"	
Rest rooms	150	Bed	––	"	Restrict luminance seen by recumbent patient.

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Staff rooms					
Changing, locker and cleaners' rooms, cloakrooms, lavatories.	150	Floor	—	Intermediate or warm	
Rest rooms	150	Table height	19	Intermediate or warm	Change in character from general lighting desirable.
Stores and stock rooms					
General	150	Vertical plane	—	Intermediate or warm	
INDUSTRIAL BUILDINGS AND PROCESSES					
Aircraft factories and maintenance hangers					
Stock parts production	750	Machines	22	Intermediate or warm	
Fabrication and inspection	500	Working plane	22	"	Portable luminaires required, consider luminaires in floor.
Aircraft engine testing	750	Engine	22	"	Portable luminaires required;
Inspection and repairs (hangars)	500	Aircraft horizontal and vertical	22	"	proof luminaires may be required.
Assembly shops					
Casual work	200	Working plane	25	Intermediate or warm	
Rough work eg frame and heavy machinery assembly	300	"	25	"	
Medium work eg engine assembly, vehicle body assembly	500	"	22	"	
Fine work eg electronic and office machinery	1000	Bench	19	Cool intermediate or warm	Colour rendering may be critical. Avoid specular reflections.
Very fine work eg instrument and small precision mechanism assembly	1500	Bench	16	"	Colour rendering may be critical. Optical aids may be required.
Bakeries	Proof luminaires may be required				
General	300	Working plane	22	Intermediate or warm	
Decorating, icing	500	"	22	Cool, intermediate or warm	
Boiler houses					
General	150	Working plane	25	Intermediate or warm	Position luminaires relative to major tasks, including those on vertical planes, instrument panels etc. Proof luminaires may be required.

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Book binderies					
Folding, pasting punching, stitching	500	Working plane	22	Intermediate or warm	
Cutting, assembling, embossing	750	"	22	"	
Boot and shoe factories					
Sorting, grading	1500	Working plane	16	Cool or intermediate	Colour rendering is important.
Sticking	1000	"	22	"	
Closing: preparatory operations	1000	"	22	Intermediate or warm	
Cutting tables and presses	1500	"	16	"	
Bottom stock preparation lasting, bottoming, finishing, shoerooms	1000	"	19	"	
Breweries and distilleries					
Process areas	300	Working plane	22	Intermediate or warm	Proof luminaires may be required.
Bottle inspection	Special lighting				
Building					
Industrialized building plants	500	Working plane	22	Intermediate or warm	Vertical surfaces often important.
Concrete shops	300	"	25	"	
Canning and preserving factories	Enclosed proof luminaires may be required				
Preparation	500	Working plane	25	Intermediate or warm	
Canned and bottle goods retorts	300	"	25	"	
Automatic processes	200	"	25	"	
Car parks					
Underground	30	Floor	22	Intermediate or warm	Vertical obstructions should be illuminated to higher value than floor, possibly by appropriate positioning of luminaires. Proof luminaires may be required.
Multi-storey:					
parking floors	30	Floor	22	"	
ramps	50	Vertical sides	19	"	
Carpet factories					
Winding, beaming	300	Working plane	25	Intermediate or warm	
Designing, Jacquard card cutting, setting pattern, tufting, cropping, cutting, hemming, fringing, latexing and latex drying	500	"	22	"	
Weaving, mending	750	"	22	Cool or intermediate	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Inspection:					
general	1000	Inspection surface	19	"	
piece dyeing	750	On carpet	—	"	Directional local lighting may be required.
Chemical works					
Pump and compressor houses	150	Floor	—	Intermediate	Local lighting on instrumentation, controls and sight glasses required; proof luminaires may be required in all areas.
Interior plant areas	300	Working plane	25	"	
Control rooms:					
desks	300	Desk	16	Intermediate or warm	Avoid specular reflections in instrument glasses and panels; limit illuminance on internally lit controls.
vertical panels	300	On panel	16		
rear of panels	150	Vertical plane at floor level	—	"	
Chocolate and confectionery factories					
General	300	Working plane	25	Intermediate or warm	Proof luminaires may be required.
Automatic processes	200	"	25	"	"
Hand decorating, inspection, wrapping, packing	500	"	22	"	"
Clothing factories (see also Glove factories, hat factories, hosiery and knitwear factories)					
Matching up	750	Working plane	19	Cool	Colour rendering is **very** important.
Cutting	750	"	19	Intermediate or warm	
Sewing	1000	"	19	"	Additional local lighting should be provided at sewing machines.
Pressing	500	"	22	"	
Inspection	1500	"	16	Cool	Colour rendering is **very** important.
Hand tailoring	1500	"	19	Cool, intermediate or warm	Local lighting may be used.
Cold stores					
General:					
constant operation	300	Floor of aisles	25	Intermediate or warm	Proof luminaires may be required depending on temperature. Sources of warm colour appearance may be preferred.
infrequent access	150	"	25	"	
Breakdown, make-up and despatch	300	Floor	25	"	
Air-locks	300	Floor	—	"	Illuminance should be compatible with daylight and electric light in adjacent areas.

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	Standard service illuminance lux	Position of measurement	Limiting glare index	Colour appearance of lamps	Notes
Collieries (Surface buildings)	Possible low maintenance factors				
Coal preparation plants:					
working areas	300	Working plane	28	Intermediate or warm	Proof luminaires may be required.
picking belts	500	"	22	"	"
other areas	150	Working plane	28	Intermediate or warm	Proof luminaires may be required.
Winding houses	150	"	25	"	
Lamp rooms:					
main areas	150	"	28	"	
repair sections	300	"	25	"	
Weigh cabins	150	"	28	"	
Fan houses	150	"	28	"	
Die sinking shops					
General	500	Working plane	22	Intermediate or warm	
Fine	1500	"	19	"	
Dye works	Proof luminaires may be required. Atmospheric absorption may be high				
General areas	300	Working plane	25	Cool or intermediate	
'Grey' fabric examination (perching)	1000	Inspection surface	19	Cool or warm	Local lighting may be used.
Dyehouse laboratories, dyers' offices	1000	Benches	19	Cool	Accurate colour matching facilities identical to final examination required in addition to general lighting.
Final examination (perching)	1500	Inspection surface	16	Cool or warm	Local lighting may be used. Accurate colour matching facilities identical to above required in addition to general lighting.
Electrical machine shops					
Manufacture, winding assembly, testing of large machines	750	Working plane, horizontal or vertical	25	Intermediate or warm	In large plant assembly both down lighting and sidelighting may be required.
Electricity generating stations					
Turbine and boiler houses:					
boiler houses, platforms etc	150	Working plane	—	Intermediate or warm	Position luminaires relative to major tasks including those on vertical planes. Additional local lighting for gauge glasses and instrument panels may be required.
boiler and turbine house basements (including feed pump bay)	100	"	—	"	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
turbine and gas turbine houses (operating floor level)	200	Floor	25	"	
Plant areas:					
ash handling plants, settling pits	100	Ground	—	"	
battery rooms, chargers and rectifiers	100	Floor	—	"	Proof luminaires required.
cable tunnels, cable basement	50	"	—	"	
circulating water culverts, screen chambers	50	Working plane	—	"	
Coal plant:					
conveyors over bunkers	100	Working plane	—	Intermediate or warm	
conveyor houses, gantries	100	"	—	"	
other areas where operators are in attendance	150	"	—	"	
Control rooms:					
desks	300	Desk	16	"	Avoid specular reflections in instrument glasses and panels. Limit illuminance on internally lit controls.
vertical panels	300	On panel	16	"	
rear of panels	150	Vertical plane at floor level	—	"	
Precipitator chambers, platforms etc	100	Working plane	—	"	
Precipitator dust hopper outlets	50	"	—	"	
Pump houses	150	Floor	—	"	
Relay and telecommunications rooms	150	Vertical plane at floor level	25	"	
Storage tanks (indoor)	50	Operating point	—	"	
Substations and switchrooms:					
diesel generator rooms	150	Floor	25	"	Local lighting over instruments and controls.
high-voltage substations (indoor)	100	Vertical on panels	—	Intermediate or warm	
switch-rooms (metal clad and cubicle switchgear)	200	Vertical on switchgear	25	"	
high-voltage substations (indoor)	100	Vertical on panels	—	Intermediate or warm	
switch rooms (metal clad and cubicle switchgear)	200	Vertical on switchgear	25	"	
Engraving shops					
Hand	1500	Working plane	16	Intermediate or warm	Optical aids normally required.
Machine	See Die sinking				

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Farm buildings	Proof luminaires may be required				
General purpose buildings	30	Floor	––	Intermediate or warm	
General purpose buildings (windowless)	50	"	––	"	
Farm workings:					
general	100	Floor	25	"	
workbench or machine	300	Working plane	25	"	Local lighting may be used.
Production inspection	500	Task	22	"	
Milk premises (handling and storing)	100	Floor	25	"	
Sick animal pens, calf nurseries	50	Floor	28	"	
Yards	20	Ground	––	"	
Fire stations					
Appliance rooms	300	Floor	22	Intermediate or warm	
External aprons	30	Ground	––	"	
Flour mills					
Roller, purifier, silks and packing floors	300	Working plane	25	Intermediate or warm	Proof luminaires may be required.
Wetting tables	500	"	25	"	"
Forges					
General	300	Working plane	25	Intermediate or warm	Possible low maintenance factors.
Foundries					
Charging floors, tumbling, cleaning, pouring, shaking out, rough moulding, rough core making	300	Working plane	28	Intermediate or warm	Possible low maintenance factors.
Fine moulding, core making, inspection	500	"	25	"	
Furniture factories					
Raw materials stores	100	Floor	28	Intermediate or warm	
Finished goods store	150	"	25	"	
Wood machining and assembly:					
rough sawing and cutting	300	Working plane	22	"	
machining, sanding and assembly of components	500	"	22	"	
Cabinet making:					
veneer sorting and preparation	1000	"	19	Cool or intermediate	
veneer pressing	500	"	22	intermediate or warm	
components stores	150	Floor	25	"	
fitting, final inspection	750	Working plane	22	"	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Upholstery:					
cloth inspection	1500	"	16	Cool or intermediate	Local lighting may be required. Colour rendering is important.
filing, covering	500	"	22	Intermediate or warm	
slipping	750	"	22	"	
cutting, sewing	750	"	22	"	
Mattress making:					
assembly	500	"	22	"	
tape edging	1000	"	22	"	Local lighting may be required.
Gauge and tool rooms					
General	1000	Working plane	19	Intermediate or warm	Optical aids may be required.
Garages					
Parking areas (interior)	30	Ground	22	Intermediate or warm	Proof luminaires are essential in pits where petrol engines are serviced and may be necessary elsewhere. Portable extra-low-voltage luminaires required.
General repair, servicing, greasing pits, washing, polishing	300	Working plane	22		
Workbench	500	Bench	19	"	
Glass works and processes					
Furnace rooms, bending, annealing lehrs	150	Working plane	28	Intermediate or warm	Specular reflections likely at surface of glass. Possible low maintenance factors.
Mixing room, forming (blowing, drawing, pressing, rolling) cutting to size, grinding, polishing, toughening	300	"	25	"	
Finishing (bevelling, decorating, etching, silvering)	500	"	22	"	
Brilliant cutting	Special lighting required				
Inspection:					
general	500	Working plane	19	Intermediate or warm	
fine	Special lighting required				
Glove factories					
Pressing, knitting, sorting, cutting	500	Working plane	22	Intermediate or warm	
Sewing	750	"	22	"	Additional local lighting should be provided on sewing machines.
Inspection	1500	"	16	Cool or intermediate	Local lighting may be used. Colour rendering important.
Hat factories					
Stiffening, braiding, refining, forming, sizing, pouncing, ironing	300	Working plane	22	Intermediate or warm	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Cleaning, flanging, finishing	500	"	22	"	Additional local lighting should be provided at sewing machines.
Sewing	750	"	22	"	
Inspection	1500	"	16	Cool or intermediate	Local lighting may be used. Colour rendering is important.
Hosiery and knitwear factories					
Flat bed knitting machines	500	Needles	22	Intermediate or warm	
Circular knitting machines	750	"	22	"	Additional local lighting may be required.
Lock stitch and over-locking machines	1000	Working plane	19	"	"
Linking or running on	1000	"	19	"	"
Mending	1500	"	16	"	Local lighting may be used.
Examinations, hand finishing	1500	"	16	Cool or intermediate	Colour rendering is important.
Inspection and testing shops (engineering)					
Medium work eg 'Go' and 'No-Go' gauges, sub assemblies	500	Working plane	22	Intermediate or warm	
Fine work, eg telecommunications equipment, calibrated scales, precision mechanisms, instruments	1000	"	19	Cool, intermediate	Colour rendering may be important.
Very fine work, eg gauging and inspection of small intricate parts	1500	"	16	"	Colour rendering may be important. Local lighting and optical aids may be required.
Minute work, eg very small instruments	3000	"	19	"	Special lighting and optical aids required.
Iron and steel works	Possible low maintenance factors				
Stairs, gangways, basements quarries, loading docks	150	Floor	—	Intermediate or warm	
Slabyards, melting shops, ingot stripping, soaking pits, blast furnace working areas, pickling and cleaning lines	150	Working plane	28	"	Proof luminaires may be required.
Mechanical plant, pump houses, mill motor rooms, power and blower houses	150	"	28	"	
Mould preparation, rolling and wire mills, slab inspection and conditioning, cold strip mills, sheet and plate finishing, tinning, galvanizing, machine and roll shops	300	Working plane	28	Intermediate or warm	Proof luminaires may be required.
Plate inspection	500	Inspection surface	25	"	
Tinplate inspection	Special lighting				

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Jewellery and watchmaking factories					
General	500	Working plane	22	Intermediate or warm	Most processes require directional local lighting.
Fine processes	1000	"	16	"	Optical aids normally required.
Minute processes	3000	"	19	"	Optial aids and local lighting required.
Gem cutting, polishing, setting	1500	"	19	Cool, intermediate or warm	Optical aids normally required.
Laboratories (general)					
General	750	Bench	19	Cool, intermediate or warm	Position luminaires over benches. Proof luminaires may be required. For requirements of specialised laboratories see relevant building or process.
Laundries and dry cleaning works					
Receiving, sorting, washing, drying, ironing (calendering), despatch, dry cleaning, bulk machine work	300	Working plane	25	Intermediate or warm	Proof luminaires may be required.
Hand ironing, pressing, inspection, mending, spotting	500	"	25	"	
Leather working factories					
General	300	Working plane	25	Intermediate or warm	
Pressing, glazing	750	"	22	"	
Cutting, scarfing, sewing	1000	Working plane	22	Intermediate or warm	
Grading, matching	1500	"	16	Cool	
Machine and fitting shops					
Casual work	200	Working plane	25	Intermediate or warm	Local lighting on machines may be required. In large shops, both down lighting and side lighting may be required.
Rough bench and machine work	300	"	25	"	
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing, polishing	500	"	22	"	
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing	1000	"	22	"	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Milk bottling plants					
General working areas	300	Working plane	25	Intermediate or warm	Local lighting required for instruments and glasses. Proof luminaires may be required.
Bottle filling	750	"	25	"	Proof luminaires may be required.
Bottle inspection	Special lighting				
Motor vehicle plants					
General sub-assemblies chassis assembly, car assembly, body sub-assemblies, body assembly	500	Working plane	22	Intermediate or warm	Additional lighting should be provided when necessary beneath assembly lines.
Upholstery	See Furniture factories				
Final inspection	750	Working place	19	Cool or intermediate	Special lighting required. Colour rendering is important.
Spray booths	See Paint shops and spray booths				
Paint shops and spray booths					
Dipping, firing, rough spraying	300	Working plane (may be vertical)	28	Intermediate or warm	Proof luminaires may be required in all areas
Rubbing, ordinary painting, spraying and finishing	500	"	22	Cool or intermediate	Refer to local authority regulations.
Fine finishing, spraying and finishing	750	"	22	Cool	Colour rendering is very important.
Retouching and matching	1000	"	22	Cool or intermediate	
Paint works					
Automatic processes	200	Working plane	25	Intermediate or warm	Proof luminaires may be required.
General	300	"	25	"	"
Special batch mixing	750	"	22	"	"
Colour matching	1000	"	19	Cool	Local lighting may be used. Colour rendering very important.
Paper mills					
Paper and board making:					
general	300	Working plane	25	Intermediate or warm	
automatic processes	200	Working plane	25	Intermediate or warm	
Pulpmills, preparation plants	300	Working plane	25	Intermediate or warm	Proof luminaires may be required.
Inspection, sorting (overhauling)	500	Working plane	19	Intermediate or warm	
Paper converting processes — general	300	Working plane	25	Intermediate or warm	
Associated printing	500	Working plane	22	Intermediate or warm	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Plastics works					
Plastics processing calendering, extrusion injection, compression and blow moulding, sheet fabrication, shaping, machining, trimming, polishing, cementing	500	Working plane	25	Intermediate or warm	
Plating shops					
Vats and baths	300	Working plane	25	Intermediate or warm	Proof luminaires may be required.
Buffing, polishing, burnishing	500	Working plane	22	Intermediate or warm	
Final buffing and polishing	750	Working plane	22	Intermediate	Directional lighting may be required.
Potteries					
Grinding, filter pressing kiln room, moulding, pressing, cleaning, trimming, glazing, firing	300	Working plane	28	Intermediate or warm	
Enamelling, colouring, decorating	750	"	16	Cool or intermediate	Colour rendering is important.
Printing works					
Type foundries:					
matrix making, dressing type, hand and machine casting	300	Working plane	25	Intermediate or warm	
font assembly, sorting	750	"	22	"	
Composing rooms:					
hand composing, imposition and distribution	750	"	19	"	Attention should be paid to direction of light.
machine composition — keyboard	750	Copy	19	"	
Machine composition — casting	300	Working plane	22	Intermediate or warm	
Proof presses	500	Bedplate	22	Cool, intermediate or warm	Colour rendering is important.
Proof reading	750	Desk	16	"	Dimming may be required.
Illuminated tables — general	300	Table top	22	"	
Printing machine room:					
presses	500	Rollers	22	Intermediate or warm	
pre make-ready	500	Working plane	22	"	
printed sheet inspection	1000	Inspection surface	19	Cool or intermediate	Colour rendering is important.
Graphic reproduction:					
general	500	Working plane	22	Cool, intermediate or warm	
precision proofing, retouching, etching	1000	"	16	"	Local lighting may be used. Colour rendering important.

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	Standard service illuminance lux	Position of measurement	Limiting glare index	Colour appearance of lamps	Notes
Colour reproduction and printing:					
inspection — colour and registration	1500	"	16	Cool	Colour rendering is critical.
Rubber processing factories					
Fabric preparation creels, dipping, moulding, compounding, calendering	300	Working plane	23	Intermediate or warm	
Tyre and tube making	500	"	22	"	
Sheetmetal works					
Benchwork, scribing, inspection	750	Working plane	22	Intermediate or warm	
Pressing, punching, shearing, stamping, spinning, folding	500	"	22	"	
Slaughterhouses	Reference should be made to the Ministry of Agriculture & Fisheries Hygiene Requirements				
General	500	Working plane	25	Intermediate or warm	Proof luminaires may be required.
Inspection	750	Working plane	19	Cool or intermediate	Colour rendering is important.
Soap factories					
General areas	300	Working plane	25	Intermediate or warm	Proof luminaires may be required.
Automatic process	200	"	25	"	
Control panels	300	Panels (may be vertical)	25	"	Avoid specular reflection in panels.
Machines	300	Machines	25	"	
Edible product processing and packing	300	Working plane	25	"	Reference should be made to the Ministry of Agriculture & Fisheries Hygiene Requirements.
Structural steel fabrication plants					
General	300	Working plane	28	Intermediate or warm	
Marking off	500	"	28	"	
Textile mills (except jute)					
Bale breaking, blowing, carding, roving, slubbing, spinning (ordinary counts), winding, beaming, combing (coloured), twisting	300	Working plane (may be vertical)	25	Intermediate or warm	Proof luminaires may be required in some areas.
Healding (drawing in)	1000	Vertical plane	22	Intermediate or warm	Local lighting required.
Weaving:					
heavy woollens	500	Working plane	19	Cool, intermediate or warm	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
medium worsteds, fine woollens	750	"	19	"	
fine worsteds	1000	"	19	"	
Burling	1000	Inspection surface	19	"	Directional local lighting may be used.
Mending	1500	"	16	"	
Inspection (perching):					
'grey'	1000	"	19	Cool or intermediate	Directional local lighting may be required.
final	3000	"	19	Cool	Local lighting required. Colour rendering is critical.
Textile mills (jute)					
Weaving, spinning flat, Jacquard carpet looms, cop winding, yarn calendar	300	Working plane	25	Cool, intermediate or warm	
Tobacco factories					
Machine processes	500	Working plane	22	Cool or intermediate	Colour rendering is important.
Hand processes	750	"	22	"	
Upholstery factories — See Furniture factories					
Warehouses and bulk stores					
Large material, loading bays	150	Identification labels	25	Cool, intermediate or warm	Identification labels may be vertical, and/or at floor level. Colour code may be used. Minimise glare to fork lift truck drivers to high luminance sources.
Small material, racks	200	"	25	"	
Packing, despatch	300	Bench	25	"	
Issue counters	500	"	22	"	Local lighting may be used.
Welding and soldering shops					
Gas and arc welding, rough spot welding	300	Working plane	28	Intermediate or warm	
Medium soldering, brazing, spot welding, eg domestic hardware	500	"	25	"	
Fine soldering, spot welding eg instruments	1000	"	19	"	Local lighting may be used.
Very fine soldering, spot welding, eg electronics	1500	"	16	"	Local lighting may be used.
Woodworking shops	Possible low maintenance factors				
Rough sawing, bench work	300	Bench	22	Intermediate or warm	Unguarded rotating machinery may be in use. Local tungsten lighting lead/lag fluorescent luminaires or other measures required to avoid stroboscopic effect.
Sizing, planing, rough sanding, medium machine and bench work, glueing, cooperage	500	Working plane	22	"	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Fine bench and machine work, fine sanding, finishing	750	"	22	"	Lighting on vertical planes important at bench.
OFFICES AND SHOPS					
Offices					
General offices with mainly clerical tasks and occasional typing	500	Desk	19	Intermediate or warm	Minimise veiling reflections by suitable luminaire location.
Deep-plan general offices	750	"	19	"	"
Business machine and typing offices	750	Copy	19	"	"
Filing rooms	300	File tables	19	"	File tables may be vertitical and at floor level.
Conference rooms	750	Tables	16	"	Consider variation of illuminance to suit different functions, eg conferences and lectures. Dimming may be required.
Executive offices	500	Desk	16	"	Possible need to vary lighting using dimmers.
Banking halls:					
working spaces	500	"	19	"	
public spaces	300	Floor	19	"	
Computer rooms	500	Working plane	19	"	Avoid specular reflections in consoles. See also "Visual display units" below.
Punch card rooms	See Business machine and typing offices				
Drawing offices:					
drawing boards	750	Board	16	Cool, intermediate or warm	Colour rendering may be important. Boards may be vertical or inclined. Consider local lights.
reference tables and general	500	Table	16	Cool, intermediate or warm	Colour rendering may be important.
Visual display units*	200 500	Keyboard Hard copy	16 16	Intermediate or warm	Position VDU to avoid reflection of window in screen; locate luminaires to avoid screen reflections. Cut-off local lighting for hard copy.
Print rooms	300	Table	19	Cool, intermediate or warm	
Shops					
Conventional with counters	500	Counters — horizontal	19	Cool, intermediate or warm	Type of merchandise dictates required colour rendering. Local or

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Conventional with wall displays	500	Display — vertical	19		localised lighting needed to emphasize particular displays.
Self-service	500	Vertical on displayed merchandise	19	Intermediate or warm	"
Supermarkets	500	"	22	"	"
Hypermarkets	500	"	22	"	In these very large areas definition of perimeter walls by higher luminance is desirable.
	1000	Horizontal on working plane	22	"	
Showrooms:					
cars	500	Vertical on cars	19	Cool, intermediate or warm	
general	500	Merchandise	19	Cool, intermediate or warm	Vertical surfaces may be important. Colour rendering may be important.
Covered shopping precincts and arcades main circulation spaces	100–200 or 100 scalar	Floor	22	Intermediate or warm	
PUBLIC AND EDUCATIONAL BUILDINGS					
Further education establishments					
Lecture theatres:					
general	300	Desk	16	Intermediate or warm	Dimming facilities may be required. Suitable lighting required for lecturer's face and notes. Low noise level required.
chalkboards	500	Vertical plane	—	"	Ensure correct offset to give reasonable uniformity and avoid reflection at chalkboard surface.
demonstration bench	500	Bench	16	"	
Examination halls, seminar rooms, teaching spaces	500	Desk	19	"	Where main view is across eg to chalkboard, LGI should be 16 in that direction.
Art rooms	500	Easel	19	Cool or intermediate	"
Laboratories	500	Bench	19	Cool, intermediate or warm	Type of laboratory may dictate colour rendering requirements. Local lighting may be used.
Workshops	See appropriate industrial process				
Staff rooms, student common rooms, student hostels etc		See General building areas			

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Schools					
Assembly halls:					
general	300	Working plane	19	Intermediate or warm	Provision for reduced illumination may be included for stage and film use.
platform and stage	Special lighting				
Teaching spaces:					
general	300	Working plane	19	"	Illuminance may be reduced to 150 lux in spaces lit by tungsten lamps, eg nursery and infant schools. Where main view is across eg to chalkboard, LGI should be 16 in this direction.
general, where also used for further education	500	"	19	"	
chalkboard	500	Vertical plane	—	"	Ensure correct offset to give reasonable uniformity and avoid reflections at chalkboard surface.
Lecture theatres:					
general	300	Desk	16	"	See also Lecture theatres Further education establishments.
chalkboard	500	Vertical plane	—	Intermediate or warm	Ensure correct offset to give reasonable uniformity and avoid reflection at chalkboard surface.
demonstration benches	500	Bench	16	"	
Needlework rooms	500	Working plane	19	Intermediate or warm	Local lighting may be used.
Art rooms	500	Easel	19	Cool or intermediate	Colour rendering is important.
Laboratories	500	Bench	19	Cool, intermediate or warm	Type of laboratory may dictate colour rendering requirements. Task lighting may be used.
Workshops	300	Working plane	19	Intermediate or warm	Additional local lighting may be required.
Staff rooms and kitchens	See General building areas				
Dining spaces	150	Table	22	"	For multi-purpose use, refer to appropriate recommendations.
Gymnasia	300	Floor	—	"	Impact resistant luminaires required. Wall illuminance important.
Music practice rooms	300	Music	19	"	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
Transport terminal buildings — Airports, coach and railway stations					
Reception areas (desks), customs and immigration halls	500	Desk or table	22	Intermediate or warm	
Railway stations:					
booking offices	500	Counter	19	"	Avoid specular reflections in ticket-issuing machines.
Parcels and left luggage offices:					
general	150	Floor	22	"	
counters	300	Counter	22	"	
Concourses	100–200, 100 (Mean spherical)	1.2 m above floor	22	"	
Waiting areas	200	Seat level	22	"	
Restaurants, bars, kitchens	See hotels				
HOMES AND HOTELS					
Homes					
Living rooms:					
general	50	Working plane		Intermediate or warm	In all home areas, attention should be given to the lighting of room surfaces. Luminaires should be selected and positioned to give occupants a compromise between attractive "sparkle" and unwanted glare. Dimming is useful for changing atmosphere.
casual reading	150	Task		"	
sewing and darning	300	Task		"	
Studies:					
desk and prolonged reading	300	Task		"	
Bedrooms:					
general	50	Floor		"	
bedhead	150	Bed		"	
Kitchens:					
working areas	300	Working surface		"	Additional mirror lighting required in bedrooms.
Bathrooms	100	Floor		"	Additional mirror lighting required. Enclosed luminaires should be used.
Halls and landings	150	Floor		"	High luminance areas should be screened from view when ascending or descending stairs.
Stairs	100	Treads		"	
Workshops	300	Bench		"	
Garages	50	Floor		"	
Old people's homes	Illuminances should be increased 50—100% above recommendations for homes. Particular attention must be paid to avoiding glare and to revealing steps and obstructions. Two-way switches should be installed in throughways, stairs, and similar areas.				
Hotels					
Entrance halls:					
general	75 (Mean spherical)	1.2 m above floor	19	Intermediate or warm	

Table B1 RECOMMENDED STANDARD SERVICE ILLUMINANCES (continued)

Area	*Standard service illuminance lux*	*Position of measurement*	*Limiting glare index*	*Colour appearance of lamps*	*Notes*
reception, cashier	300	Desk	19	"	
Bars, coffee bars	150	Table		"	Flexibility of control required to achieve variety in lighting.
Dining rooms, grill rooms, restaurants, general	100	Table		"	Additional table lighting may be required.
Cash desks	300	Desk	"		
Lounges	100 (Mean 1.2 m above floor spherical)		16	"	Additional table lighting may be required.
Writing rooms	150	Table	19	"	
Cloakrooms	150	Floor		"	Additional mirror lighting required.
Bedrooms and bathrooms	See Homes				
Service areas kitchens	See General building areas				
Baggage rooms	100	Floor		Warm	
Laundries	300	Working place		Intermediate or warm	Roof luminaires may be required.
Cellars	150	Floor			

APPENDIX C

SURFACE COLOURS AND REFLECTANCES

C1
The Munsell System

C1.1
The colours of walls, floors, ceilings and other interior surfaces are commonly specified in terms of three variables of appearance defined by the Munsell System, namely hue, value and chroma. For lighting purposes the Munsell reference can be used to derive an approximate estimate of the reflectance of each colour by substituting the Munsell value V in the formula:

$$\text{Reflectance} = \frac{V\ (V-1)}{100}$$

For example, the value figures in the Munsell references 5Y6/2 and N7 are 6 and 7 respectively: when substituted for V in the formula, approximate reflectances of 0.3 and 0.42 are obtained.

C1.2
BS 5252 offers a range of 237 colours based on the Munsell criteria of hue, value and chroma, together with two more recently identified colour attributes, greyness and weight, two important additions. Approximate Munsell references for all 237 colours are given in Appendix A to BS 5252 and reflectances can be derived from the formula given in C1.1 above. Small samples of the 237 colours are included in BS 5252 and samples of larger area are published in the form of a fan in BS 5252 F.

C2
New Zealand building finishes

C2.1
Table C1 gives approximate reflectances of building finishes commonly used in New Zealand. Most other finishes have colour ranges described in BS 5252 or BS 4800.

Table C1
APPROXIMATE REFLECTANCES OF TYPICAL NEW ZEALAND BUILDING FINISHES

Building finish	*Approximate reflectance*
White emulsion paint on plain plaster surface White glazed tiles	0.8
White emulsion paint on acoustic tile	0.7
White emulsion paint on no-fines concrete	0.6
Natural pine plywood	0.55
White emulsion paint on wood-wool slab	0.5
Varnished pine plywood* Natural *Pinus radiata*	0.45
White asbestos cement sheet Portland cement (smooth) Natural particle board	0.4
Natural rimu (dressed) Varnished *Pinus radiata**	0.3
Concrete (light grey) Portland cement (rough) Natural mahogany (dressed) Varnished particle board*	0.25
Varnished rimu (dressed)* Varnished mahogany (dressed)*	0.15
Quarry tiles: Red, heather brown	0.1

* Typical varnishing would be two coats of clear gloss polyurethane varnish.

APPENDIX D

CALCULATION OF GLARE INDEX

D1
Basic tables and the conditions to which they apply

D1.1
Tables D1 and D2 give glare indices which apply for the following standard set of conditions:

(a) The luminaire gives equal amounts of light upwards and downwards; that is, its flux fractions are both 50 %, and its flux fraction ratio is 1

(b) The height, H, of the fitting above eye-level is 3.05 m.

NOTE — Eye-level is taken as 1.2m above the floor.

(c) The fitting has a luminous area of 645 cm^2 and a downward flux of 1000 lm

(d) The reflectances of the ceiling, walls and floor are respectively 70 %, 50 % and 14 %.

D1.2
Tables D3 and D4 apply for a floor having a reflectance of 30 %, and with other conditions as given in clause D1.1 above.

D2
Example of use of the basic tables for standard conditions

D2.1
For this example consider a room which is 12.2 m x 6.1 m in which the fittings are classified BZ7, and for which the conditions given in D1.1 apply. As the tables require the length and breadth of the room to be expressed in terms of H, in this case the length is 4H and the breadth is 2H. These dimensions are known as X and Y, depending on the direction of view of the occupants of the room. In this example, if that direction is along the length of the room X is 2H and Y is 4H. These would be reversed if the occupants were facing across the room. Assume first that they look along the greater length, for example, X—2H, Y=4H. Turning to table D1 for a symmetrical distribution, when X is 2H and Y is 4H the index for the BZ7 classification is 15.7.

D2.2
No correction is necessary as the circumstances were artificially selected here to conform with those for which the table was produced, so the ''final glare index'' is also 15.7.

D2.3
If we now assume that the direction of view is across the room, X= 4H and Y = 2H. For these values table D1 gives 12.2 for the index, and in this case also the final glare index is 12.2. (Use of the more extended tables in IES Technical Report No. 10 yields the same values in each case.)

D2.4
The low values of the glare index in this example are partly the result of a considerable mounting height in a relatively small room.

D3
Suspended luminaires; equivalent ceiling reflectance

D3.1
The basic glare tables presented here and in IES Technical Report No. 10 refer to luminaires which are at ceiling level or very close to it, in which case virtually all the upward light from the luminaire reaches the ceiling. If the luminaires are suspended some way below the ceiling, however, some of the upward light from them will strike the parts of the wall above the level of the luminaires and its effectiveness in producing illumination on the working plane will be altered. This difficulty is met by considering the real ceiling to be replaced by an imaginary one at luminaire level. This imaginary ceiling must have the same influence on illuminance as do the real ceiling and upper walls, and this will occur if it is assigned a suitable ''equivalent reflectance''.

D3.2
The reflectance of the equivalent ceiling is determined as follows:

(a) Calculate the average reflectance within the ceiling cavity, R_a, using the following formula:

$$R_a = \frac{R_1 A_1 + R_2 A_2 + \ldots . R_n A_n}{A_1 + A_2 \ldots . A_n}$$

where R_1 is the reflectance of the area A_1 within the ceiling cavity
R_2 is the reflectance of the area A_2 within the ceiling cavity
R_n is the reflectance of the area A_n within the ceiling cavity

(b) Substitute this value of R_a in the following formula to determine the reflectance of the equivalent ceiling, R_e, situated at the suspension height, h_s:

$$R_e = \frac{A_c R_a \times 100}{A_c R_a + A_t (100 - R_a)} \%$$

where A_c = the plan area of the equivalent ceiling
A_t = the total area within the ceiling cavity = $A_1 + A_2 + \ldots A_n$

Table D1

GLARE INDICATES FOR SYMMETRICAL DISTRIBUTIONS — FLOOR REFLECTANCE 14 %

Room dimensions X	Room dimensions Y	BZ1	BZ2	BZ3	BZ4	BZ5	BZ6	BZ7	BZ8	BZ9	BZ10
2H	2H	7	9.5	11.9	12.4	13.2	12	11.1	10.1	10.6	15.3
	3H	7.1	10.1	13.3	14.3	15.7	14.8	14	13.3	13.8	19.8
	4H	7.1	10.2	13.7	15.1	16.9	16.2	15.7	14.9	15.6	22.1
	6H	7	10.3	13.8	15.4	17.7	17.4	17.1	16.6	17.2	24.8
	8H	6.9	10.3	13.9	15.6	18.2	18.3	18.1	17.5	18.2	26.2
	12H	6.8	10.4	13.9	15.6	18.6	19.1	18.8	18.4	19.1	28.1
3H	2H	7	9.6	12.1	12.7	13.7	12.5	11.6	10.6	11.2	15.5
	3H	7.1	10.2	13.6	14.8	16.3	15.5	14.7	14	14.5	20.1
	4H	7.1	10.4	14.2	15.7	17.7	17.1	16.6	15.9	16.4	22.5
	6H	7.1	10.6	14.3	16	18.5	18.3	17.9	17.5	18.1	25.1
	8H	7	10.7	14.4	16.3	19	19.2	19	18.5	19.2	26.7
	12H	6.9	10.8	14.4	16.3	19.5	20	19.8	19.5	20.2	28.6
4H	2H	7	9.8	12.4	13.1	14.2	13	12.2	11.2	11.8	15.8
	3H	7.1	10.4	14	15.3	16.9	16.2	15.4	14.7	15.3	20.4
	4H	7.1	10.7	14.7	16.4	18.5	18	17.5	16.8	17.3	23
	6H	7.1	10.9	14.9	16.7	19.3	19.2	18.8	18.4	19	25.5
	8H	7.1	11.1	15	17	19.9	20.2	20	19.6	20.3	27.2
	12H	7	11.2	15	17	20.5	21	20.9	20.6	21.3	29.1
6H	4H	7.1	10.7	14.8	16.5	18.7	18.3	17.8	17.2	17.8	23.1
	6H	7.1	10.9	15	16.9	19.8	19.8	19.5	19.1	19.8	25.8
	8H	7	11.2	15.1	17.2	20.5	20.8	20.6	20.3	21	27.5
	12H	6.9	11.4	15.1	17.2	21.1	21.7	21.7	21.3	22.1	29.4
8H	4H	7.1	10.8	14.9	16.7	18.9	18.6	18.2	17.6	18.3	23.2
	6H	7.1	11	15.2	17.2	20.4	20.5	20.2	19.8	20.6	26.1
	8H	7	11.3	15.3	17.5	21	21.5	21.3	21	21.7	27.8
	12H	6.9	11.6	15.3	17.5	21.7	22.5	22.5	22.1	22.9	29.7
12H	4H	7	10.8	14.9	16.7	19.1	18.7	18.4	17.9	18.5	23.3
	6H	7	11.1	15.2	17.4	20.6	20.8	20.6	20.2	21	26.3
	8H	6.9	11.4	15.3	17.6	21.3	21.9	21.8	21.5	22.2	28
	12H	6.9	11.7	15.3	17.6	22	23.1	23.2	22.8	23.5	30

Classification of fittings: BZ1–BZ10

NOTE
Flux fraction ration : 1
Ceiling reflectance : 70 %
Wall reflectance : 50 %
Floor reflectance : 14 %

Table D2

GLARE INDICES FOR ASYMMETRICAL DISTRIBUTIONS — FLOOR REFLECTANCE 14 %

Room dimensions		BZ2						BZ3													
		ACG3 viewed		ACG7 viewed		ACG8 viewed		ACG1 viewed		ACG2 viewed		ACG4 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed		ACG8 viewed	
X	Y	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways
2H	2H	11.8	6.5	12.2	6.1	11	7.8	12.9	14.4	12.4	8.1	8.1	12.4	12.9	9.9	10.7	11.7	14.5	9.5	9.6	9.3
	3H	13.4	6.9	13.9	6.2	12.4	7.4	14.8	14.4	14.7	8.9	8.9	14.7	14.6	10.7	11.1	13.7	15.9	10.3	10.1	11.4
	4H	14	10.5	14.5	6.1	12.8	7.5	15.7	14.3	15.7	9	9	15.7	15.1	10.8	12.5	14.6	16.3	10.6	11.7	12.2
	6H	14.4	6.9	15.1	5.9	13.2	7.6	16.6	13.6	16.5	8.9	8.9	16.5	15.8	10.7	13.8	15.6	16.7	10.7	11.8	13
	8H	14.5	6.7	15.3	5.8	13.3	8.3	17.1	13.5	17	9	9	17	16.2	10.8	13	16.3	17	10.9	12	13.5
	12H	14.5	6.7	15.6	5.7	13.4	8.4	17.6	13.4	17.3	9	9	17.3	16.4	10.7	13.2	17	17.1	11	12.1	13.9
3H	2H							13	14.6												
	3H							15	14.7												
	4H							16	14.8												
	6H							16.8	14.3												
	8H							17.3	14.1												
	12H							17.7	14												
4H	2H	11.8	7.5	12	6.5	11.3	8.8	13.2	14.9	12.4	8.9	8.9	12.4	13.3	10.9	11.6	12.3	14.4	10.2	10.2	10
	3H	13.6	8.1	13.7	6.6	12.8	9.7	15.3	15.1	14.9	9.8	9.8	14.9	15.3	12.3	13.3	14.5	16	11.1	12	12.3
	4H	14.4	8.3	14.5	6.6	13.6	10.1	16.3	15.3	16.3	10.2	10.2	16.3	16.3	12.8	14.1	15.9	16.7	11.7	12.9	13.5
	6H	14.9	8.3	15.5	6.4	14.1	10.2	17.1	15	17.3	10.2	10.2	17.3	17	12.9	14.6	17.1	17.2	11.9	13.4	14.5
	8H	15.1	8.3	15.9	6.4	14.4	10.3	17.6	14.8	17.8	10.3	10.3	17.8	17.4	13	14.8	18	17.6	12.1	13.6	15
	12H	15.2	8.2	16.2	6.3	14.5	10.2	17.8	14.6	18.3	10.2	10.2	18.3	17.7	12.9	14.9	18.8	17.8	12.2	13.8	15.6
6H	4H							16.4	15.1												
	6H							17.3	14.8												
	8H							17.9	14.7												
	12H							18.2	14.4												
8H	4H	14.4	9.1	14.5	7.2	13.8	11.8	16.6	14.9	16.2	10.9	10.9	16.2	16.5	13.7	14.9	16.3	16.7	12.1	13.5	14
	6H	14.9	9.1	15.5	6.9	14.4	11	17.6	14.7	17.4	11.1	11.1	17.4	17.5	14.1	15.7	17.9	17.3	12.4	14.2	15.2
	8H	15.2	9.2	16.1	6.9	14.8	11.2	18.2	14.6	18	11.1	11.1	18	17.9	14.2	16.2	18.9	17.7	12.6	14.7	15.9
	12H	15.4	9.2	16.5	6.9	15.1	11.2	18.6	14.3	18.5	11.1	11.1	18.5	18.3	14.3	16.5	20	18	12.9	15	16.6
12H	4H	14.4	9.2	14.4	7.8	13.8	11	16.5	14.9	16.2	11.1	11.1	16.2	16.6	13.8	15.1	16.4	16.8	12.2	13.6	14.1
	6H	14.9	9.3	15.5	7.6	14.9	11.3	17.5	14.7	17.4	11.3	11.3	17.4	17.5	14.3	16.1	18.1	17.3	12.5	14.5	15.4
	8H	15.2	9.4	16.1	7.6	14.9	11.4	18	14.6	18	11.4	11.4	18	18	14.6	16.7	19.2	17.7	12.8	15	16.2
	12H	15.3	9.3	16.5	7.5	15.1	11.4	18.5	14.3	18.2	11.3	11.3	18.2	18.5	14.6	17.2	20.4	18	13.1	15.4	16.9

NOTE —
(1) An explanation of ACG is provided in clause D6.1.
(2) Glare indicates are given on bases of: Flux fraction ratio: 1, ceiling reflectance: 70 %, wall reflectance: 50 %, floor reflectance: 14 %.

Table D2 (continued)

GLARE INDICES FOR ASYMMETRICAL DISTRIBUTIONS – FLOOR REFLECTANCE 14 %

BZ4														BZ5									
ACG1 viewed		ACG3 viewed		ACG4 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed		ACG8 viewed		ACG2 viewed		ACG3 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed	
end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways
12.9	13	10.9	12.5	8.3	13.3	11.5	10.3	11.1	13.6	12.2	12.5	11.5	12.7	12.4	14.6	11.2	14.9	10.5	12	8.6	12.3	9.1	14
14.9	14.4	12.3	14.6	8.9	16.1	13	12.9	12.3	15.7	14.1	14.5	13	14.7	14.3	16.6	12.6	18.4	12.3	15.2	10.2	15.3	10.9	16.7
16	14.9	12.8	15.7	9.1	17.4	13.8	14.4	12.9	16.9	14.8	15.6	13.7	15.6	15.2	17.6	13.1	20.2	13.1	17.1	11	17.3	11.7	18
16.7	14.9	13	16.4	9	18.6	14.3	16.2	13.1	18	15.3	16.6	14	16.3	15.7	18.3	13.1	22	13.6	19.2	11.4	19.5	12.2	19
17.1	15	13.1	16.8	9.1	19.4	14.6	17.4	13.4	18.9	15.6	17.1	14.3	16.8	16	18.9	13.2	22.9	14	20.6	11.7	21	12.5	19.7
17.3	14.9	13.1	17.2	9.1	20	14.8	18.8	13.5	20	15.8	17.8	14.5	17.2	16.3	19.7	13.2	23.9	14.2	22.2	11.9	22.7	12.8	20.5
13.2	13.3																						
15.4	14.9																						
16.6	15.6																						
17.3	15.6																						
17.7	15.7																						
18	15.6																						
13.6	13.7	11.8	13	9.7	13.5	12.1	11.1	12.1	14.1	12.9	13.1	12.7	13.2	13.4	15.1	12.7	15.5	11.7	12.7	10.5	13.1	10.9	14.4
16	15.4	13.5	15.4	10.8	16.6	14	14.1	13.8	16.5	15.1	15.5	14.6	15.5	15.5	17.3	14.4	19.1	13.9	16.3	12.4	16.4	12.7	17.3
17.3	16.3	14.4	16.8	11.4	18.3	15.1	16.1	14.8	18	16.3	17	15.6	16.7	16.8	18.8	15.3	21.5	15.3	18.8	13.8	18.9	13.9	19
18	16.3	14.5	17.6	11.3	19.6	15.7	17.9	15.3	19.3	16.8	18	16	17.5	17.4	19.6	15.2	23.2	15.8	20.9	14.3	21.1	14.3	20.1
18.4	16.4	14.8	18.2	11.4	20.6	16.2	19.4	15.8	20.5	17.3	18.8	16.4	18.2	17.9	20.4	15.4	24.3	16.3	22.5	14.8	22.8	14.7	21
18.7	16.3	14.8	18.6	11.4	21.3	16.5	20.9	16	21.7	17.5	19.6	16.7	18.7	18.4	21.4	15.5	25.6	16.7	24.4	15.4	24.8	15.2	22.1
17.4	16.4																						
18.2	16.5																						
18.6	16.6																						
18.9	16.5																						
17.5	16.6	14.9	17	12.7	18.3	15.8	16.6	15.7	18.3	16.8	17.4	16.5	16.9	17.3	18.9	16.6	21.4	16.6	19.2	15.5	19.2	14.9	19
18.4	16.7	15.5	18	13	20	16.7	18.9	16.7	20	17.7	18.7	17.2	18	18.6	20.5	17.1	23.9	18.1	22.1	17	22.3	16	20.8
18.9	16.8	16.2	18.7	13.2	21	17.4	20.5	17.4	21.4	18.3	19.7	17.8	18.8	19.1	21.3	17.3	25	18.7	23.8	17.7	24.1	16.5	21.8
19.1	16.7	16.5	19.2	13.2	22	17.8	22.3	18	22.9	18.7	20.6	18.2	19.5	19.8	22.6	17.3	26.5	19.3	26	18.5	26.4	17.1	23.1
17.5	16.6	15	17	13.1	18.3	16	16.6	16	18.4	16.9	17.4	16.7	16.9	17.6	19	17.1	21.5	17.3	19.3	16.3	19.3	15.3	19.1
18.5	16.9	15.8	18.2	13.7	20.1	17.3	19.2	17.4	20.3	18.1	19.1	17.8	18.2	18.9	20.6	17.7	23.9	19	22.4	18.1	22.5	16.5	20.9
18.9	16.8	16.9	18.8	14	21.2	18	20.8	18.2	21.7	18.7	20	18.3	19	19.6	21.6	17.9	25.1	19.8	24.2	19	24.4	17.2	22
19.1	16.8	18.4	19.4	14.1	22.2	18.6	22.8	19	23.4	19.2	21	18.9	19.8	20.3	22.9	18	26.5	20.6	26.5	20	26.9	17.9	23.3

NOTE –
(1) An explanation of ACG is provided in clause D6.1.
(2) Glare indicates are given on bases of: Flux fraction ratio: 1, ceiling reflectance: 70 %, wall reflectance: 50 %, floor reflectance: 14 %.

Table D2 (continued)

GLARE INDICATES FOR SYMMETRICAL DISTRIBUTIONS – FLOOR REFLECTANCE 14 %

BZ6 ACG1 viewed end ways	cross ways	ACG2 viewed end ways	cross ways	ACG3 viewed end ways	cross ways	ACG5 viewed end ways	cross ways	ACG6 viewed end ways	cross ways	ACG7 viewed end ways	cross ways	*BZ7* ACG1 viewed end ways	cross ways	*BZ8* ACG1 viewed end ways	cross ways
11.4	12.4	10.5	12.2	9.3	12.8	9.7	12	6	10.9	9.7	13.1	10	12.5	10.7	13.9
14	15.5	12.8	15.8	11.1	16.7	11.6	15.7	8	14.8	11.7	16.8	12.5	16.4	13.2	17.9
15.2	17.2	13.8	18	11.9	18.8	12.5	17.8	8.8	17	12.5	18.9	13.8	18.8	14.3	20.1
16.2	18.9	14.5	20.6	12.2	21.1	13	20.1	9.3	19.3	13	21.2	14.7	21.1	15.3	22.7
17	20.1	15.1	21.8	12.6	22.8	13.5	21.7	9.7	20.9	13.5	22.9	15.4	22.8	15.8	24.1
17.6	21.1	15.6	23.6	12.8	24.6	13.9	23.5	10.1	22.6	13.8	24.6	15.7	24.3	16.3	25.8
11.9	12.8											10.7	12.8	11.3	14.1
14.7	16.1											13.4	16.8	14.1	18.2
16.1	18											14.9	19.4	15.5	20.7
17.1	19.7											15.8	21.7	16.5	23.2
17.8	20.9											16.6	23.4	17.2	24.8
18.4	22											17	25.1	17.8	26.5
12.5	13.3	12	13.1	11.3	13.6	11.6	12.7	8.8	11.6	11.5	13.8	11.4	13.2	12	14.3
15.5	16.8	14.9	17.2	13.8	18	13.9	16.9	11.2	16	14.2	18	14.3	17.3	15.1	18.6
17.1	18.9	16.2	19.8	15.2	20.5	15.3	19.5	12.6	18.7	15.5	20.6	16	20	16.8	21.3
18	20.5	17.3	22.1	15.7	22.9	16	21.9	13.2	12.1	16.3	23	16.9	22.3	17.8	23.7
18.7	21.7	18.1	23.8	16.3	24.7	16.7	23.7	13.8	22.9	16.9	24.8	17.8	24.1	18.7	25.5
19.3	22.9	18.5	25.6	16.6	26.5	17.2	25.5	14.2	24.6	17.3	26.6	18.3	25.9	19.3	27.2
17.4	19.1											16.5	20.1	17.3	21.4
18.7	21											17.7	22.7	18.7	24
19.5	22.3											18.6	24.4	19.6	25.8
20.2	23.5											19.3	26.4	20.3	27.6
17.8	19.4	18	20.4	17.3	21	17.1	20	15.1	19.2	17.5	21	17.0	20.2	17.9	21.5
19.5	21.6	19.8	23.4	18.9	24.1	18.8	23.2	16.8	22.4	19.2	24.1	18.6	23.1	19.7	24.4
20.4	22.9	20.7	25.2	19.7	26	19.7	25	17.6	24.2	20	26	19.5	24.8	20.6	26.1
21.2	24.2	21.4	27.3	20.4	28.1	20.5	27.2	18.2	26.3	20.7	28.2	20.3	26.9	21.4	28
18	19.4	18.6	20.4	18	21	17.6	20.1	15.9	19.2	18.1	21	17.3	20.2	18.3	21.6
19.9	21.9	20.7	23.7	20.1	24.4	19.8	23.4	18.1	22.6	20.2	24.4	19.2	23.3	20.2	24.6
20.8	23.3	21.8	25.6	21.1	26.4	20.9	25.4	19.2	24.6	21.3	26.4	20.2	25	21.3	26.3
21.9	24.8	22.9	28	22.2	28.8	22.1	27.9	20.2	27	22.3	28.8	21.3	27.2	22.4	28.3

NOTE –

(1) An explanation of ACG is provided in clause D6.1.

(2) Glare indices are given on bases of: FLux fraction ration: 1, ceiling reflectance: 70 % wall reflectance: 50 %, floor reflectance: 14 %.

Table D3

GLARE INDICES FOR SYMMETRICAL DISTRIBUTIONS – FLOOR REFLECTANCE 30 %

Room dimensions X	Y	*Classification of fittings* BZ1	BZ2	BZ3	BZ4	BZ5	BZ6	BZ7	BZ8	BZ9	BZ10
2H	2H	6	8.6	11	11.6	12.5	11.3	10.5	9.5	10.2	15.3
	3H	6.1	9.1	12.3	13.4	14.8	14	13.3	12.7	13.3	19.5
	4H	6	9.1	12.7	14.2	16	15.4	15	14.3	15.1	21.7
	6H	5.8	9.1	12.7	14.4	16.8	16.6	16.3	15.9	16.6	24.3
	8H	5.6	9.1	12.8	14.6	17.2	17.4	17.3	16.8	17.5	25.6
	12H	5.5	9.1	12.8	14.5	17.6	18.2	17.9	17.6	18.4	27.5
3H	2H	5.9	8.7	11.2	11.9	12.9	11.8	11	10	10.7	15.3
	3H	5.9	9.1	12.6	13.8	15.3	14.6	13.9	13.3	13.9	19.6
	4H	5.8	9.2	13.1	14.7	16.7	16.2	15.7	15.1	15.8	22
	6H	5.8	9.3	13.2	14.9	17.4	17.3	17	16.6	17.3	24.4
	8H	5.7	9.4	13.2	15.1	17.9	18.2	18.1	17.7	18.4	26
	12H	5.5	9.4	13.2	15	18.3	18.9	18.8	18.6	19.4	27.8
4H	2H	5.9	8.8	11.4	12.2	13.3	12.2	11.5	10.6	11.3	15.4
	3H	5.8	9.2	12.9	14.3	15.9	15.3	14.5	13.9	14.6	19.8
	4H	5.7	9.4	13.5	15.2	17.4	17	16.5	15.9	16.5	22.2
	6H	5.7	9.5	13.6	15.5	18.1	18.1	17.8	17.4	18.1	24.6
	8H	5.6	9.7	13.6	15.7	18.6	19	18.9	18.6	19.4	26.3
	12H	5.5	9.7	13.6	15.6	19.1	19.7	19.7	19.5	20.3	28.2
6H	4H	5.7	9.4	13.5	15.3	17.5	17.2	16.8	16.2	17	22.2
	6H	5.6	9.5	13.6	15.6	18.5	18.6	18.3	18	18.8	24.8
	8H	5.5	9.7	13.6	15.8	19.1	19.5	19.4	19.1	19.9	26.5
	12H	5.4	9.8	13.6	15.8	19.6	20.3	20.3	20	20.9	28.3
8H	4H	5.7	9.4	13.5	15.4	17.6	17.4	17.1	16.6	17.4	22.3
	6H	5.5	9.5	13.7	15.8	19	19.2	18.9	18.6	19.5	25.1
	8H	5.4	9.7	13.7	15.9	19.5	20	19.9	19.7	20.5	26.7
	12H	5.2	9.9	13.6	15.9	20.1	20.9	21	20.6	21.5	28.4
12H	4H	5.5	9.3	13.4	15.3	17.7	17.4	17.2	16.8	17.5	22.4
	6H	5.4	9.5	13.6	16	19.1	19.3	19.2	18.9	19.8	25.2
	8H	5.2	9.7	13.6	16	19.7	20.3	20.3	20	20.8	26.7
	12H	5.2	10	13.5	15.9	20.3	21.4	21.6	21.2	22.1	28.7

NOTE – **Flux fraction ration : 1**
Ceiling reflectance : 70 %
Wall reflectance : 50 %
Floor reflectance : 14 %

Table D4

GLARE INDICES FOR ASYMMETRICAL DISTRIBUTIONS – FLOOR REFLECTANCE 30 %

Room dimensions		BZ2						BZ3													
		ACG3 viewed		AGC7 viewed		ACG8 viewed		ACG1 viewed		ACG2 viewed		ACG4 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed		ACG8 viewed	
X	Y	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways
2H	2H	10.9	5.6	11.3	5.2	10.1	6.9	12	13.5	11.5	7.2	7.2	11.5	12	9	9.8	10.8	13.6	8.6	8.7	8.4
	3H	12.4	5.9	12.9	5.2	11.4	7.4	13.8	13.4	13.7	7.9	7.9	13.7	13.6	9.7	11.1	12.7	14.9	9.3	10.1	10.4
	4H	12.9	5.9	13.4	5	11.7	7.4	14.7	13.3	14.7	8	8	14.7	14.3	9.8	11.5	13.6	15.3	9.6	10.7	11.2
	6H	13.2	5.7	13.9	4.7	12	7.2	15.5	12.5	15.4	7.8	7.8	15.4	14.7	9.6	11.7	14.5	15.6	9.6	10.7	11.9
	8H	13.3	5.5	14.1	4.6	12.1	7.1	16	12.4	15.9	7.9	7.9	15.9	15.1	9.7	11.9	15.2	15.9	9.8	10.9	12.4
	12H	13.2	5.4	14.3	4.4	12.1	7.1	16.5	12.3	16.2	7.9	7.9	16.2	15.3	9.6	12.1	15.9	16	9.9	11	12.8
3H	2H							12.1	13.7												
	3H							14	13.7												
	4H							14.9	13.7												
	6H							15.7	13.2												
	8H							16.1	12.9												
	12H							16.4	12.7												
4H	2H	10.8	6.5	11	5.5	10.3	7.8	12.2	13.9	11.4	7.9	7.9	11.4	12.3	9.9	10.6	11.3	13.4	9.2	9.2	9
	3H	12.4	6.9	12.5	5.4	11.6	8.5	14.2	14	13.8	8.7	8.7	13.8	14.2	11.2	12.2	13.4	14.9	10	10.9	11.2
	4H	13.1	7	13.2	5.3	12.3	8.8	15.1	14.1	15.1	9	9	15.1	15.1	11.6	12.9	14.7	15.5	10.5	11.7	12.3
	6H	13.5	6.9	14.1	5	12.7	8.8	15.8	13.7	16	8.9	8.9	16	15.7	11.6	13.3	15.8	15.9	10.6	12.1	13.2
	8H	13.7	6.9	14.5	5	13	8.9	16.2	13.4	16.4	8.9	8.9	16.4	16	11.6	13.4	16.6	16.2	11.7	12.2	13.6
	12H	13.7	6.7	14.7	4.8	13	8.7	16.4	13.2	16.9	8.8	8.8	16.9	16.3	11.5	13.5	17.4	16.4	11.8	12.4	14.2
6H	4H							15.1	13.8												
	6H							15.9	13.4												
	8H							16.3	13.2												
	12H							16.6	12.9												
8H	4H	13	7.7	13.1	5.8	12.4	9.5	15.2	13.5	14.8	9.5	9.5	14.8	15.1	12.3	13.5	14.9	15.3	10.7	12.1	12.6
	6H	13.4	7.6	14	5.4	12.9	9.5	16.1	13.2	15.9	9.6	9.6	15.9	16	12.6	14.2	16.4	15.8	10.9	12.7	13.7
	8H	13.6	7.6	14.5	5.3	13.2	9.6	16.6	13	16.4	9.5	9.5	16.4	16.3	12.6	14.6	17.3	16.1	11	13.1	14.3
	12H	13.7	7.5	14.9	5.2	13.4	9.5	16.9	12.6	16.8	9.4	9.4	16.8	16.6	12.6	14.8	18.3	16.3	11.2	13.3	14.9
12H	4H	12.9	7.7	12.9	6.3	12.3	9.5	15	13.4	14.7	9.6	9.6	14.7	15.1	12.3	13.6	14.9	15.1	10.7	12.1	12.6
	6H	13.3	7.7	13.9	6	12.9	9.7	15.9	13.1	15.8	9.7	9.7	15.8	15.9	12.7	14.5	16.5	15.7	10.9	12.9	13.8
	8H	13.5	7.7	14.4	5.9	13.2	9.7	16.3	12.9	16.3	9.7	9.7	16.3	16.3	12.9	15	17.5	16	11.1	13.3	14.5
	12H	13.6	7.6	14.8	5.8	13.4	9.7	16.7	12.5	16.7	9.5	9.5	16.7	16.7	12.8	15.4	18.6	16.2	11.3	13.6	15.1

NOTE –

(1) An explanation of ACG is provided in clause D6.1.

(2) Glare indicates are given on bases of: Flux fraction ratio: 1, ceiling reflectance: 70 %, wall reflectance: 50 %, floor reflectance: 30 %.

Table D4 (continued)

GLARE INDICATES FOR SYMMETRICAL DISTRIBUTIONS — FLOOR REFLECTANCE 30 %

BZ4														BZ5									
ACG1 viewed		ACG3 viewed		ACG4 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed		ACG8 viewed		ACG2 viewed		ACG3 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed	
end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways
12.1	12.2	10.1	11.7	7.5	12.5	10.7	9.5	10.3	12.8	11.4	11.7	10.7	11.9	11.7	13.9	10.5	14.2	9.8	11.3	7.9	11.6	8.4	13.3
14	13.5	11.4	13.7	8	15.2	12.1	12	13.4	14.8	13.2	13.6	12.1	13.8	11.4	15.7	11.7	17.5	11.4	14.3	9.3	14.4	10	15.8
15.1	14	11.9	14.8	8.2	16.5	12.9	13.5	12	16	13.9	14	12.8	14.7	14.3	16.7	12.2	19.4	12.2	16.2	10.1	16.4	10.8	17.1
15.7	13.9	12	15.4	8	17.6	13.3	15.2	12.1	17	14.3	15.6	13	15.3	14.8	17.4	12.2	21.1	12.7	18.3	10.5	18.6	11.3	18.1
16.1	13.9	12.1	15.8	8.1	18.4	13.6	16.4	12.4	17.9	14.6	16.1	13.3	15.8	15	17.9	12.2	21.9	13	19.6	10.7	20	11.5	18.7
16.2	13.8	12	16.1	8	18.9	13.7	17.7	12.4	18.9	14.7	16.7	13.4	16.1	15.3	18.7	12.2	22.9	13.2	21.2	10.9	21.7	11.8	19.5
12.4	12.5																						
14.4	13.9																						
15.6	14.6																						
16.2	14.4																						
16.5	14.4																						
16.7	14.3																						
12.7	12.8	10.9	12.1	8.8	12.6	11.2	10.2	11.2	13.2	12	12.2	11.8	12.3	12.5	14.2	11.8	14.6	10.8	11.8	9.6	12.2	10	13.5
15	14.4	12.5	14.4	9.8	15.6	13	13.1	12.8	15.5	14.1	14.5	13.6	14.5	14.5	16.3	13.4	18.1	12.9	15.3	11.4	15.4	11.7	16.3
16.1	15.1	13.2	15.6	10.2	17.1	13.9	14.9	13.6	16.8	15.1	15.8	14.4	15.5	15.7	17.7	14.2	20.4	14.2	17.7	12.7	17.8	12.8	17.9
16.8	15.1	13.3	16.4	10.1	18.4	14.5	16.7	14.1	18.1	15.6	16.8	14.8	16.3	16.2	18.4	14	22	14.6	19.7	13.1	19.9	13.1	18.9
17.1	15.1	13.5	16.9	10.1	19.3	14.9	18.1	14.5	19.2	16	17.5	15.1	16.9	16.6	19.1	14.1	23	15	21.2	13.5	21.5	13.4	19.7
17.3	14.9	13.4	17.2	10	19.9	15.1	19.5	14.6	20.3	16.1	18.2	15.3	17.3	17	20	14.1	24.2	15.3	23	14	23.4	13.8	20.7
16.2	15.2																						
16.8	15.1																						
17.2	15.1																						
17.5	15.1																						
16.2	15.3	13.6	15.7	11.4	17	14.5	15.5	14.4	17	15.5	16.1	15.2	15.6	16	17.6	15.3	20.1	15.3	17.9	14.2	17.9	13.6	17.7
17	15.3	14.1	16.4	11.6	18.6	15.3	17.5	15.3	18.6	16.3	17.3	15.8	16.6	17.2	19.1	15.7	22.5	16.7	20.7	15.6	20.9	14.6	19.4
17.3	15.2	14.6	17.1	11.6	19.4	15.8	18.9	15.8	19.8	16.7	18.1	16.2	17.2	17.6	19.8	15.8	23.5	17.2	22.3	16.2	22.6	15	20.3
17.5	15.1	14.9	17.6	11.6	20.4	16.2	20.7	16.4	21.3	17.1	19	16.6	17.9	18.2	21	15.7	24.9	17.7	24.4	16.9	24.8	15.5	21.5
16.1	15.2	13.6	15.6	11.7	16.9	14.6	15.2	14.6	17	15.5	16	15.3	15.5	16.2	17.6	15.7	20.1	15.9	17.9	14.9	17.9	14.9	17.9
17.1	15.3	14.4	16.8	12.3	18.7	15.9	17.8	16	18.9	16.7	17.7	16.4	16.8	17.4	19.1	16.2	22.4	17.5	20.9	16.6	21	15	19.4
17.3	15.2	15.3	17.2	12.4	19.6	16.4	19.2	16.6	20.1	17.1	18.4	16.7	17.4	18	20	16.3	23.5	18.2	22.6	17.4	22.8	15.6	20.4
17.4	15.1	16.7	17.7	12.4	20.5	16.9	21.1	17.3	21.7	17.5	19.3	17.2	18.1	18.6	21.2	16.3	24.8	18.9	24.8	18.3	25.2	16.2	21.6

NOTE —
(1) An explanation of ACG is provided in clause D6.1.
(2) Glare indicates are given on bases of: Flux fraction ratio: 1, ceiling reflectance: 70 %, wall reflectance: 50 %, floor reflectance: 30 %.

Table D4 (continued)

GLARE INDICATES FOR SYMMETRICAL DISTRIBUTIONS – FLOOR REFLECTANCE 30 %

BZ4										BZ6												BZ7		BZ8	
ACG2 viewed		ACG3 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed		ACG1 viewed		ACG2 viewed		ACG3 viewed		ACG5 viewed		ACG6 viewed		ACG7 viewed		ACG1 viewed		ACG1 viewed	
end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways	end ways	cross ways
11.7	13.9	10.5	14.2	9.8	11.3	7.3	11.6	8.4	13.3	10.7	11.7	9.8	11.5	8.6	12.1	9	11.3	5.3	10.2	9	12.4	9.4	11.9	10.1	13.3
11.4	15.7	11.7	17.5	11.4	14.3	9.3	14.4	10	15.8	13.2	14.7	12	15	10.3	15.9	10.8	14.9	7.2	14	10.9	16	11.8	15.7	12.6	17.3
14.3	16.7	12.2	19.4	12.2	15.2	10.1	16.4	10.8	17.1	14.4	16.4	13	17.2	11.1	18	11.7	17	8	16.2	11.7	18.1	13.1	18.1	13.7	19.5
14.8	17.4	12.2	21.1	12.7	18.3	10.5	18.6	11.3	18.1	15.4	18.1	13.6	19.8	11.4	20.3	12.2	19.3	8.5	18.5	12.2	20.4	13.9	20.3	14.6	22
15	17.9	12.2	21.9	13	19.6	10.7	20	11.5	18.7	16.1	19.2	14.2	20.9	11.7	21.9	12.6	20.8	8.8	20	12.6	22	14.6	22	15.1	23.4
15.3	18.7	12.2	22.0	13.2	21.2	10.8	21.7	11.8	19.5	16.7	20.2	14.7	22.7	11.9	23.7	13	22.6	9.2	21.7	12.9	23.7	14.8	23.4	15.5	25
										11.2	12.2											10	12.2	10.7	13.4
										13.9	15.2											12.6	16.1	13.4	17.5
										15.3	17.1											14	18.5	14.8	20
										16.1	18.7											14.8	20.7	15.6	22.3
										16.8	19.8											15.7	22.5	16.4	23.9
										17.3	20.8											15.9	24	16.9	25.6
12.5	14.2	11.8	14.6	10.8	11.8	9.6	12.2	10	13.5	11.7	12.5	11.2	12.3	10.5	12.8	10.8	11.9	8	10.8	10.7	13	10.7	12.5	11.4	13.7
14.5	16.3	13.4	18.1	12.9	15.3	11.4	15.4	11.7	16.3	14.6	15.9	14	16.3	12.9	17.1	13	16	10.3	15.1	13.3	17.1	13.4	16.4	14.3	17.8
15.7	17.7	14.2	20.4	14.2	17.7	12.7	17.8	12.8	17.9	16.1	17.9	15.2	18.8	14.2	19.5	14.3	18.5	11.6	17.7	14.5	19.6	15	19	15.9	20.4
16.2	18.4	14	22	14.6	19.7	13.1	19.9	13.1	18.9	16.9	19.4	16.2	21	14.6	21.8	14.9	20.8	21.1	20	15.2	21.9	15.9	21.3	16.8	22.7
16.6	19.1	14.1	23	15	21.2	13.5	21.5	13.4	19.7	17.5	20.5	16.9	22.6	15.1	23.5	15.5	22.5	12.6	21.7	15.7	23.6	16.7	23	17.7	24.5
17	20	14.1	24.2	15.3	23	14	23.4	13.8	20.7	18.0	21.6	17.2	24.3	15.3	25.2	15.9	24.2	12.9	23.3	16	25.3	17.1	24.7	18.2	26.1
										16.4	18											15.4	19	16.3	20.4
										17.5	19.8											16.5	21.5	17.6	23
										18.2	20.9											17.4	23.2	18.4	24.6
										18.8	22.1											17.9	25	19	26.2
16	17.6	15.3	20.1	15.3	17.9	14.2	17.9	13.6	17.7	16.6	18.2	16.8	19.2	16.1	19.8	15.9	18.8	13.9	18	16.3	19.8	15.9	19.1	16.9	20.5
17.2	19.1	15.7	22.5	16.7	20.7	15.6	20.9	14.6	19.4	18.2	20.2	18.5	22.1	17.6	22.8	17.5	21.9	15.5	21.1	17.9	22.8	17.3	21.8	18.5	23.2
17.6	19.8	15.8	23.5	17.2	22.3	16.2	22.6	15	20.3	18.9	21.4	19.2	23.7	18.2	24.5	18.2	23.5	16.1	22.7	18.5	24.5	18.1	23.4	19.3	24.8
18.1	21	15.7	24.9	17.7	24.4	16.9	24.8	15.5	21.5	19.6	22.6	19.8	25.7	18.8	26.5	18.9	25.6	16.6	24.7	19.1	26.6	18.8	25.4	19.9	26.5
16.2	17.6	15.7	20.1	15.9	17.9	14.9	17.9	14.9	17.9	16.7	18.1	17.3	19.1	16.7	19.7	16.3	18.8	14.6	17.9	16.8	19.7	16.1	19	17.2	20.5
17.4	19.1	16.2	22.4	17.5	20.9	16.6	21	15	19.4	18.4	20.4	19.2	22.2	18.6	22.9	18.3	21.9	16.6	21.1	18.7	22.9	17.8	21.9	18.9	23.3
18	20	16.3	23.5	18.2	22.6	17.4	22.8	15.6	20.4	19.2	21.7	20.2	24	19.5	24.8	19.3	23.8	17.6	23	19.7	24.8	18.7	23.5	19.8	24.8
18.6	21.1	16.3	24.8	18.9	24.8	18.3	25.2	16.2	21.6	20.2	23.1	21.2	26.3	20.5	27.1	20.4	26.2	18.5	25.3	20.6	27.1	19.7	25.6	20.8	26.7

NOTE –
(1) An explanation of ACG is provided in clause D6.1.
(2) Glare indicates are given on bases of: Flux fraction ratio: 1, ceiling reflectance: 70 %, wall reflectance: 50 %, floor reflectance: 30 %.

D3.3
An alternative method for the particular case of a rectangular room, as illustrated in fig. D1, is to employ the ceiling cavity index, k_C, using the formula:

$$k_C = \frac{H_m}{H_s} \times k_r$$

where H_m is the mounting height of the luminaires, that is the height of the equivalent ceiling above the working plane

H_s is the suspension height of the luminaires, that is the height of the ceiling proper above the equivalent ceiling,

k_r is the room index; for a room of length L and width W

$$k_r = \frac{L \times W}{H_m (L + W)}$$

In this case

$$R_a = \frac{k_C R_C + 2R_W}{k_C + 2}$$

and $$R_e = \frac{R_a k_C \times 100}{(k_C \times 100) + 2(100 - R_a)}$$

where R_C = reflectance of the ceiling proper,
R_W = reflectance of the walls within the ceiling cavity

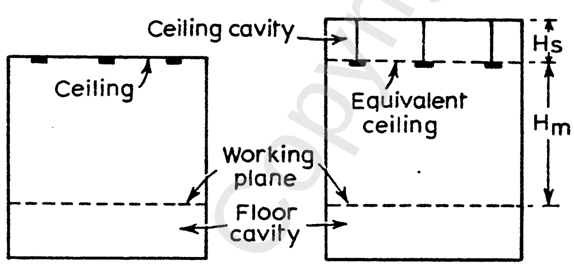


Fig. D1 EQUIVALENT CEILING FOR A RECTANGULAR ROOM

D3.4
In the glare calculation the equivalent ceiling reflectance is used instead of the real reflectance. In practice it will be found that if ceilings and upper walls are light coloured and suspension length does not exceed, say, 0.75 m, the difference in calculated glare index will be small. It is reasonable, therefore, to work directly from the glare tables, and only if the final glare index comes within a few decimal points of the limiting glare index for the particular location should it be necessary to make a re-check, using equivalent ceiling reflectances.

D4
Example of use of basic tables for non-standard conditions

D4.1
An example was given in clause D2 above of the application of the glare index tables to the standard conditions, that is, those detailed in clause D1. The tables can also be used in conjunction with conversion graphs, shown as figures D2 to D6, for conditions which differ from those detailed in clause D1, and the following is an example of their application.

D4.2
Consider a room 13 m x 6.5 m and having a height of 2.5 m. The lighting installation consists of metal cylinders for 150 W incandescent lamps fitted close to the ceiling. The luminaire is classed as BZ4 and the light output ratios are: ULOR = 25 % and DLOR = 25 %. The luminous area is 350 cm². Ceiling and walls have reflectances of 70 % and 50 % and the floor is fairly dark. Find the glare index for the worse of the two directions of view parallel to the walls. Here H = 1.3 m so X = 5H, and Y = 10H (since the view along the length of the room will give the higher index).

D4.3
From table D1, for BZ4 luminaires, the following data is obtained:

X = 4H, Y = 8H } 17.0 X = 6H, Y = 8H } 17.2

X = 4H, Y = 12H } 17.0 X = 6H, Y = 12H } 17.2

Since there is no difference between the respective values as Y changes from 8H to 12H we may write—

X = 4H, Y = 10H } 17.0 X = 6H, Y = 10H 17.2

Interpolation then gives the required figure for the index—

X = 5H, Y = 10H } 17.1

D4.4
Three corrections have now to be applied for the downward flux, luminous area, and height H.

Downward flux = DLOR x lamp output

$$= \frac{25}{100} \times 1960 \text{ lm}$$
$$= 490 \text{ lm}$$

Fig. D4 gives the correction, which may be read off as −1.8

Luminous area = 350 cm²
Fig. D5 gives the correction, namely +2.1

Height H = 1.3 m; fig. D5 gives the correction of −0.9

The total correction here is thus —

$$-1.8 + 2.1 - 0.9 = -0.6$$

Thus the final glare index, the index together with the correction, is 16.5.

NOTE — The full calculation also gives 16.5.

D5
Shortened method applied to a typical problem: systematic interpolation

D5.1
The example given in clause D4, though taking values of downward flux, luminous area and height that were all different from the standard conditions given in clause D1, retained the standard flux fraction of 1 and the 70 % — 50 % — 14 % series of reflectances. If these are different from the standard conditions also, conversion graphs as shown in figures D2 and D3 are used as well. The following example shows the application of this technique.

D5.2
A room 10 m × 7.5 m is to be lit by ceiling-mounted glass diffusing luminaires for 200 W incandescent lamps at a height of 3 m above the floor. The reflectances are: ceiling 50 %, walls 30 %, floor 14 %. The fittings are classified BZ6 and the light output ratios are: ULOR = 20 %, DLOR = 55 %. The luminous area is 875 cm². Find the glare index for people looking across the room.

Thus, H = 3 m − 1.2 m = 1.8 m

$$X = \frac{10}{1.8} H = 5.6 H$$

$$Y = \frac{7.5}{1.8} H = 4.2 H$$

D5.3
The necessary interpolation is best done systematically and in the form, shown in the table of clause D5.4. The nearest values of X given in table D1 on each side of 5.6 are those for 4 and 6. For each of these we need the value corresponding to Y being 4 and 6. Therefore, write the actual values of X and Y at the top of the first two columns, (a) and (b), and the nearest tabulated values of X and Y underneath, in the same columns, as shown in the table.

In the table D1 the column corresponding to BZ6 we see that where X is 4 and Y is 4, the index is 18.0. This value is written, together with those for the other values of X and Y, in column (c) of the table in clause D5.4.

D5.4
The first interpolation is between X = 4, Y = 4 and X = 4, Y = 6 to obtain the value for X = 4, Y = 4.2. But 4.2 is one-tenth of the way from 4 to 6. Therefore we want a value one-tenth of the way from 18.0 to 19.2. The difference between these is 1.2. Thus, one-tenth of that difference is 0.1. The required value is thus 18.0 + 0.1 = 18.1. In a similar way we interpolate between the values X = 6, Y = 4 and X = 6, Y = 6. The figures obtained from the first interpolation are inserted in column (d) of the table.

So, when X = 4, Y = 4.2, the index is 18.1 and when X = 6, Y = 4.2 it is 18.5. The second stage of the interpolation is to split the difference between 18.1 and 18.5 to account for the actual value of X, namely 5.6. This is four-fifths of the way from 4 to 6, so we need a value four-fifths of the way from 18.1 to 18.5. This is 0.3. The required value is therefore 18.1 + 0.3 = 18.4; this figure is inserted in column (e) of the table, and the interpolation has now been completed. The full account of the mental processes behind the completion of this table, which has been set out here, naturally takes some space, but in practice it can usually be accomplished quickly enough.

Table D5
TABULAR PRESENTATION OF INTERPOLATION FOR GLARE INDEX

(a)	*(b)*	*(c)*	*(d)*	*(e)*
X	*Y*	*Glare index*		
5.6	4.2	*From table D1*	*First interpolation*	*Second interpolation*
	4	18.0		
4			18.1	
	6	19.2		
				18.4
	4	18.3		
6			18.5	
	6	19.8		

D5.5
The figure of 18.4 represents the index for a flux fraction of 1 and reflectances of 70, 50, 14 %. The conversion term to account for the different values of the particular case is read off from fig. D2. The flux fraction ratio is the same as that of the upward and downward light output ratios, that is, here 20/55 or 0.36. The line for the 50/30 reflectance combination gives, for a flux fraction ratio of 0.36, a conversion term of +4.8. The initial glare index therefore, becomes 18.4 + 4.8. = 23.2. Corrections have now to be applied for downward flux, luminous area, and height, and these are calculated using the correc-

tion graphs given in figures D4, D5, and D6 as follows:

(a) Downward flux = DLOR × lamp output

$$= \frac{55}{100} \times 2720 \text{ lm}$$

$$= 1496 \text{ lm}$$

Fig. D4 gives a correction of +1.0

(b) Luminous area = 875 cm²

Fig. D5 gives a correction of − 1.1

(c) H = 1.8, and the corresponding correction (Fig. D6) is −0.6

The total correction is thus —

$$+ 1.0 - 1.1 - 0.6 = - 0.7$$

Final glare index = initial glare index + correction
= 23.2 − 0.7
= 22.5

NOTE — The full calculation also gives 22.5.

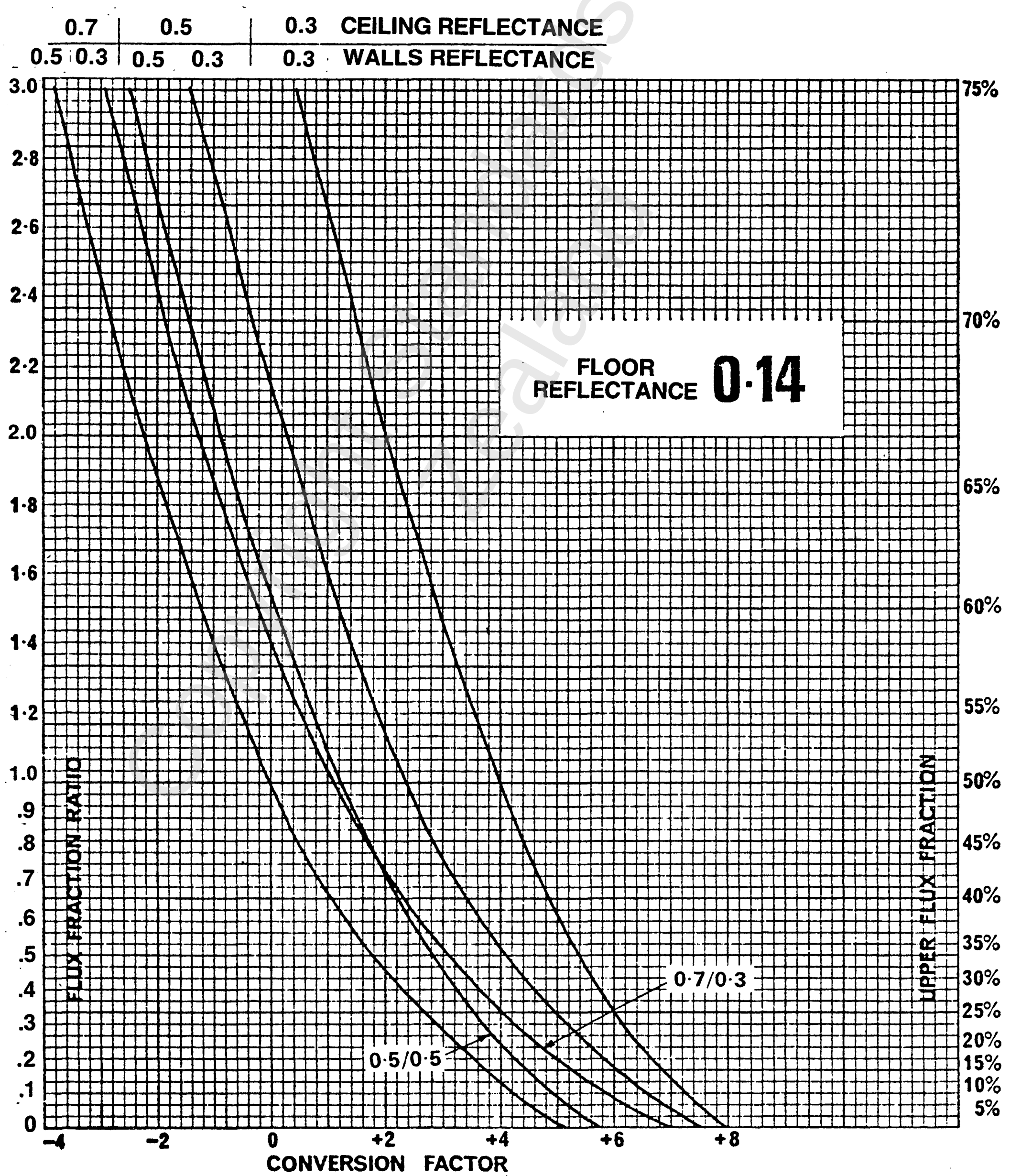


Fig. D2 CONVERSION GRAPH FOR REFLECTANCES AND FLUX FRACTION RATIOS: FLOOR REFLECTANCE FACTOR OF 14 %

D6
Method for luminaires with asymmetrical distribution

D6.1
So far, only symmetrical distributions have been considered. A luminaire which is physically symmetrical about its vertical axis (for example, most types of incandescent and high pressure discharge lamps) will have a symmetrical distribution. Tables D1 and D3 list glare indices for all classifications of symmetrical-distribution luminaires. The effect of asymmetry is to make it necessary to quote two values, one for when the luminaire is seen endwise, the other for the crosswise view. Tables D2 and D4, under each BZ class, include up to eight varieties of asymmetric distribution. These are identified by a number indicating its Asymmetry Control Distribution for Glare, that is, ACG 1 - 8. ACG 1 is for an axial distribution which is cosine, ACG 5 and 6 are

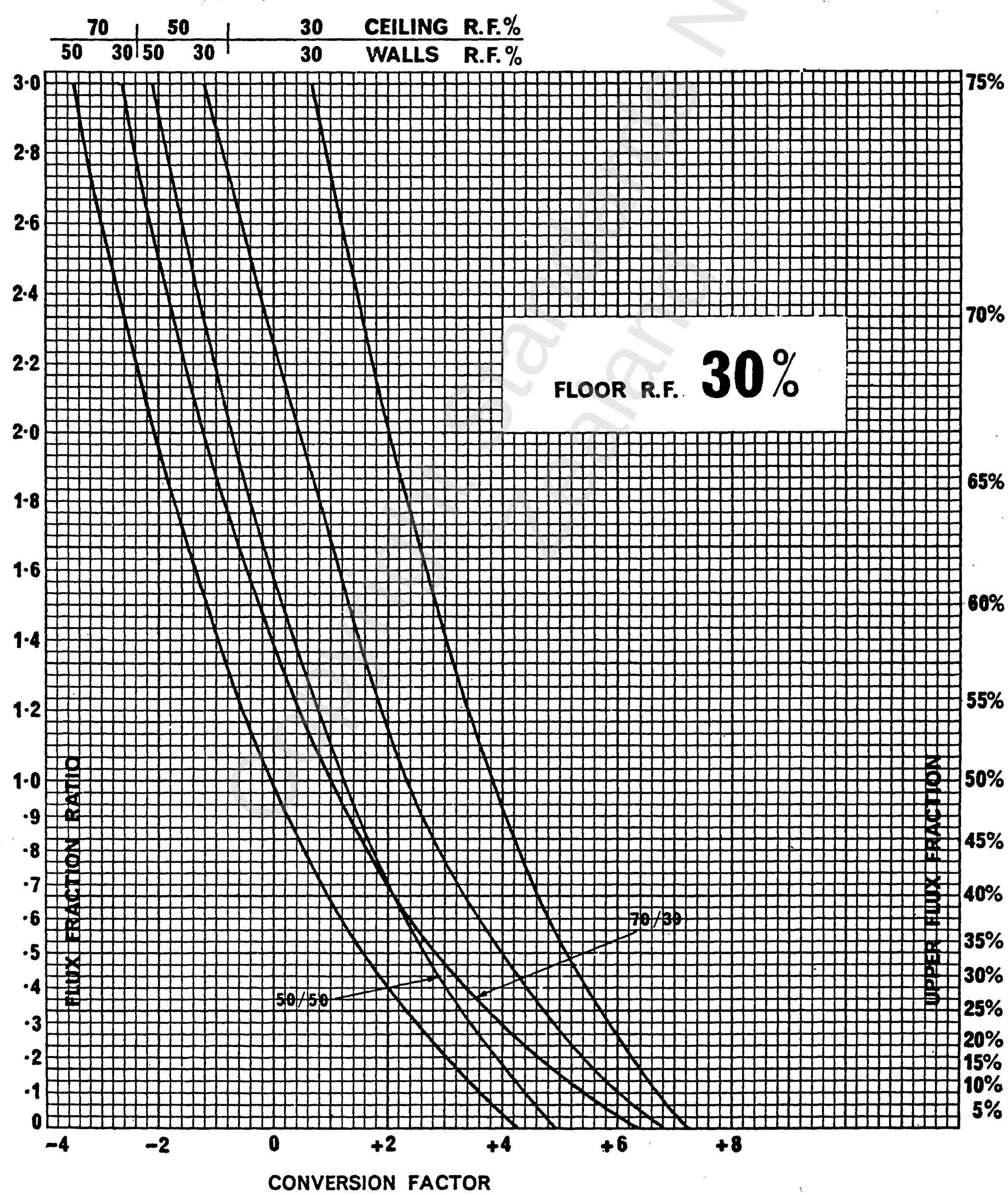


Fig. D3 CONVERSION GRAPH FOR REFLECTANCES AND FLUX FRACTION RATIOS: FLOOR REFLECTANCE FACTOR OF 30 %

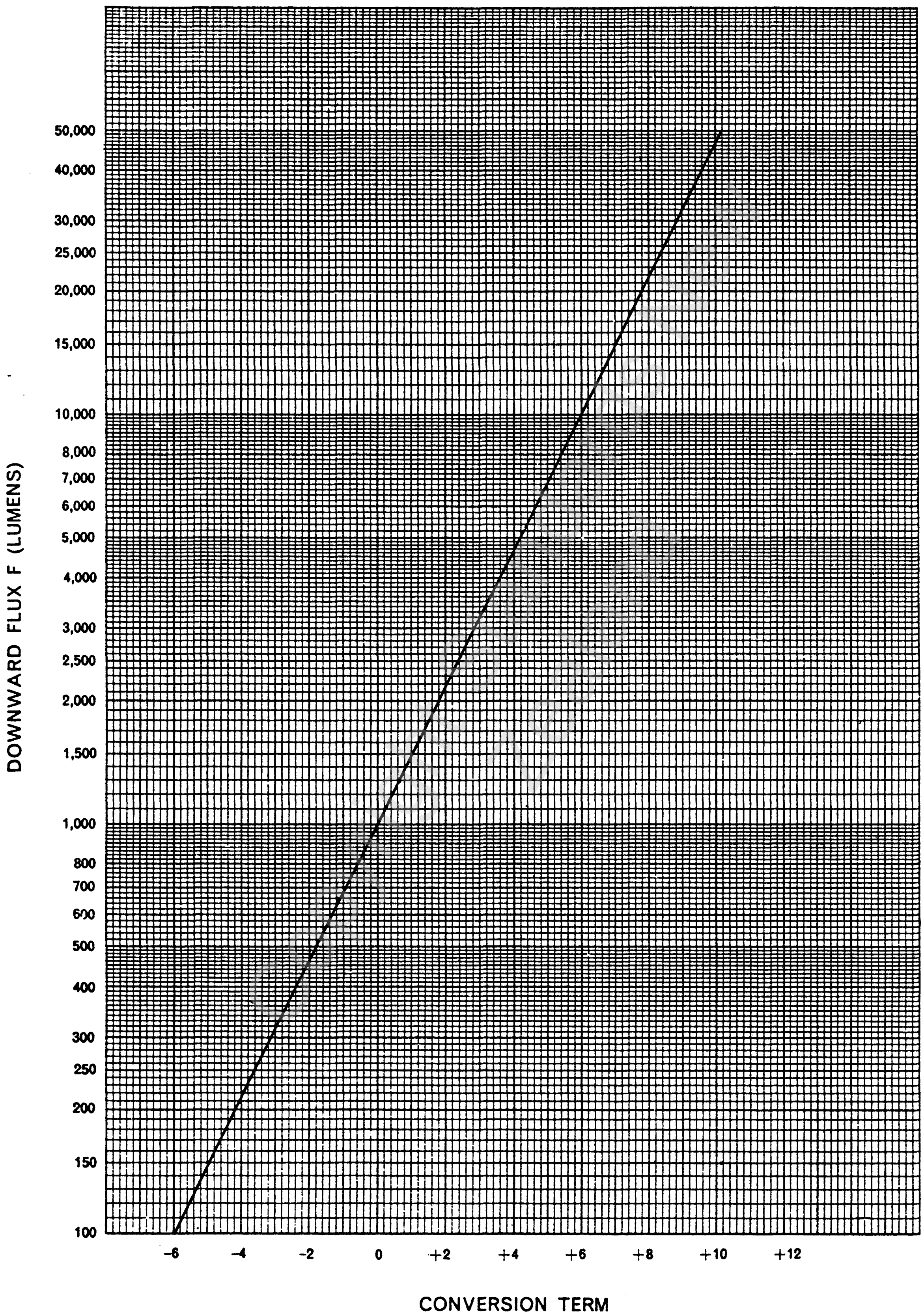


Fig. D4 CONVERSION GRAPH FOR DOWNWARD FLUX

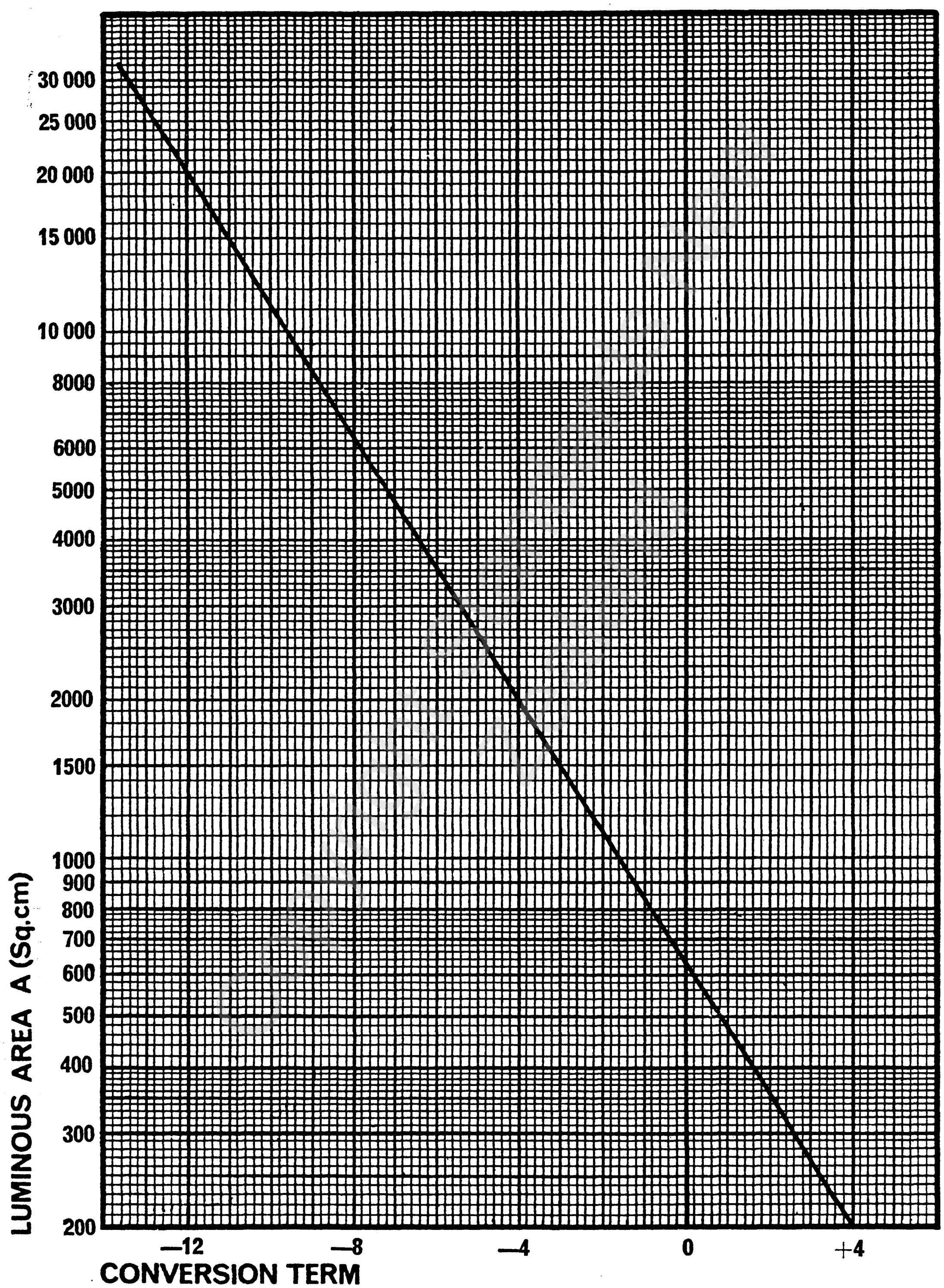


Fig. D5 CONVERSION GRAPH FOR LUMINOUS AREA representative of prismatic enclosures, and ACG 7 and 8 are representative of louvered luminaires. (These classifications have no significance other than for glare calculations.) If a particular ACG classification is not shown under a BZ classification, it is because this type of luminaire is not likely to be made.

D6.2
Manufacturers should state the ACG number in their catalogues or provide it on request, but it is possible to ascertain the classification of an asymetric luminaire if the axial and transverse polar curves are available. The following method is taken from the Supplement to the I.E.S. (U.K.) Technical Report No. 10.

D6.3
Consider the transverse and axial polar curves of an asymmetrical luminaire shown in fig. D7. Firstly it is necessary to establish if sufficient asymmetry is present to warrant consideration. To this end, values

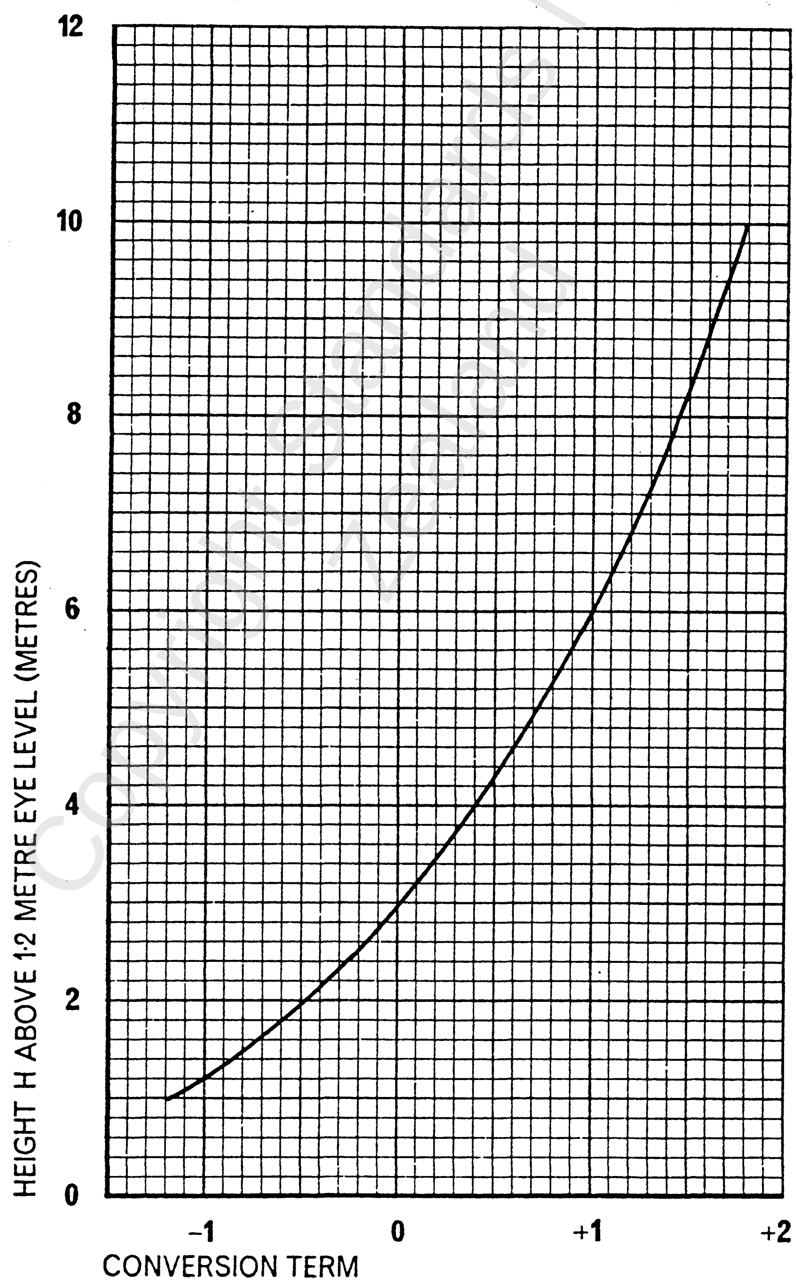


Fig. D6 CONVERSION GRAPH FOR HEIGHT

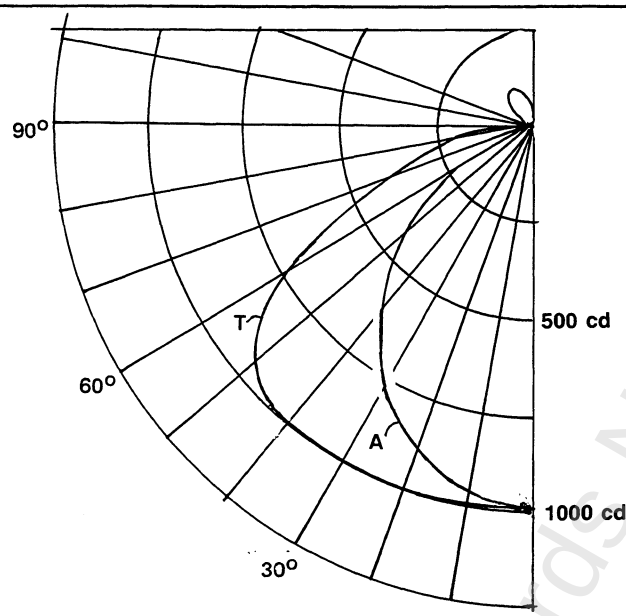


Fig. D7 TRANSVERSE AND AXIAL POLAR CURVES OF AN ASYMMETRICAL LUMINAIRE

of luminous intensity are taken at angles of 45°, 55°, 65°, 75°, and 85° to the downward vertical from both the axial and the transverse polar curves. The ratios of the smaller to larger values are taken, summated and averaged. This figure is the asymmetry criterion; if it is less than 0.75, the luminaire is considered to be asymmetric. From fig. D7 the following data is obtained:

Angle to downward vertical, θ	*Luminous intensity* I_{axial}	$I_{transverse}$	*Intensity ratio* $I_{axial}/I_{transverse}$
degrees	cd	cd	
45	550	960	0.57
55	300	860	0.35
65	100	600	0.17
75	35	300	0.12
85	2	70	0.03
		sum:	1.23

$$\text{Asymmetry criterion} = \frac{1.23}{5} = 0.25$$

As this is less than 0.75 the luminaire is considered to be asymmetric.

D6.4
To obtain the asymmetric control distribution for glare (ACG) for the luminaire, the intensity ratio $I_\theta I_o$ is calculated at 10° intervals from the downward vertical, the intensities being taken from the axial polar curve. These ratios are plotted against the angle to the downward vertical on a graph of the form shown in figures D8—D10. The ACG number of the luminaire is that of the ACG curve which is closest to the curve obtained for the luminaire. Thus, for the particular luminaire under consideration, and using the axial polar curve from fig. D6, the following table is obtained:

Angle to downward vertical θ	*Luminous intensity* I_θ	*Intensity ratio* $I_\theta I_o$
degrees	cd	
0	990	1.0
10	960	0.97
20	880	0.89
30	760	0.77
40	620	0.63
50	410	0.41
60	240	0.24
70	50	0.05
80	12	0.01
90	0	0

In this case the curve which most closely approximates to the curve of this data is ACG 3, and this, therefore, is the ACG number of the luminaire.

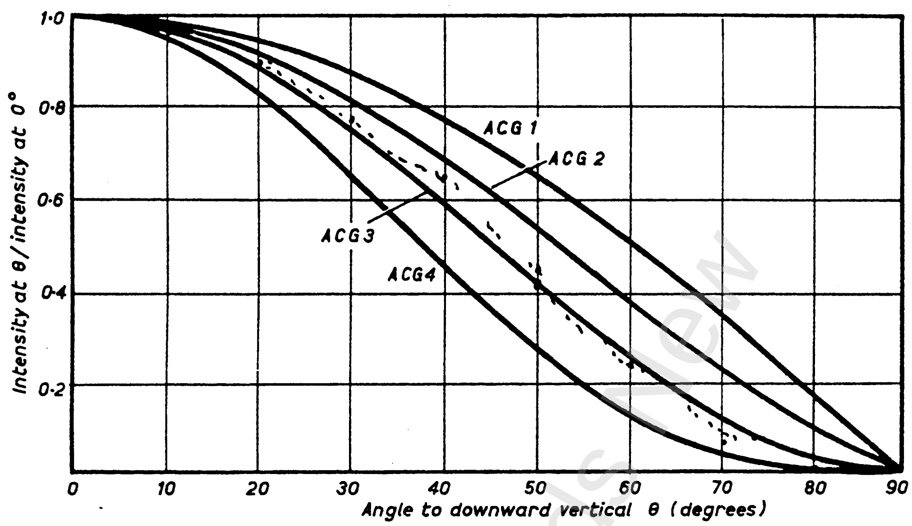


Fig. D8 ASYMMETRY CONTROL DISTRIBUTIONS ACG 1-4

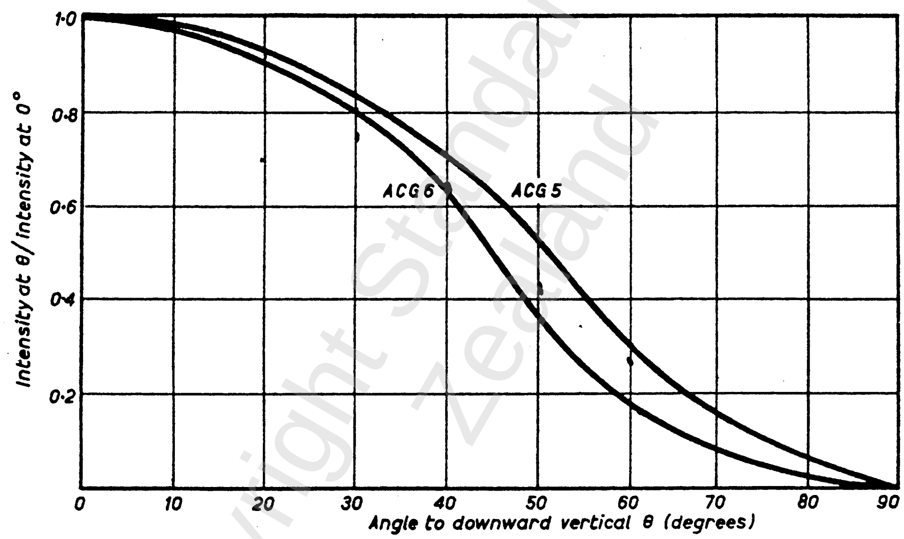


Fig. D9 ASYMMETRY CONTROL DISTRIBUTIONS ACG 5 AND 6: REPRESENTATIVE PRISMATIC LUMINAIRES

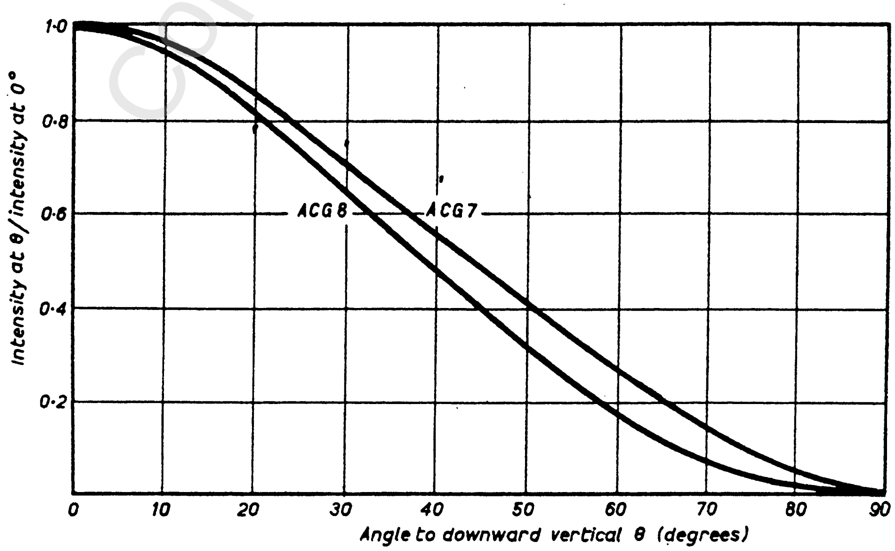


Fig. D10 ASYMMETRY CONTROL DISTRIBUTIONS ACG 7 AND 8: REPRESENTATIVE LOUVERED LUMINAIRES

D7
Example of calculation of glare index for luminaires with asymmetrical distribution

D7.1
The following example shows how the glare index for an installation of luminaires with asymmetrical distribution is calculated.

D7.2
A workshop 18 m × 12 m has a ceiling height of 4 m. Trunking is fixed in lines parallel to the shorter walls and slotted trough reflectors, each for two 65W fluorescent lamps, are attached to it at a height of 3.7 m. The White colour of tube is used. The luminaire is classified BZ 4—ACG 1, it has a luminous area of 3500 cm², and the light output ratios are ULOR 6 %, DLOR 74 %. Reflectances of ceiling and walls are both 0.3. Find the glare index for the directin of view parallel to the longer walls. In the absence of any information on the floor reflectance, this is assumed to be 14 %, and thus table D2 is used.

D7.3
Taking direction of view of the luminaires as crosswise:

$$H = 3.7\ \text{m} - 1.2\ \text{m} = 2.5\ \text{m}$$

$$X = \frac{12}{2.5} H \qquad = 4.8\ H$$

$$Y = \frac{18}{2.5} H \qquad = 7.2\ H$$

X	Y	Glare index		
4.8	7.2	*From table D2*	*First interpolation*	*Second interpolation*
4	6	16.3	16.4	16.5
	8	16.4		
6	6	16.5	16.6	
	8	16.6		

$$\text{Flux fraction ratio} = \frac{\text{ULOR}}{\text{DLOR}} = \frac{6\ \%}{74\ \%} = 0.08$$

From fig. D1, conversion term = + 7.4

Thus, initial glare index = 16.5 + 7.4 = 23.9

Downward flux = DLOR × No. of lamps × lamp output

$$= \frac{74}{100} \times 2 \times 4400$$

$$= 6500\ \text{lm}$$

X	Y	Glare index		
7.2	4.8	*From table D2*	*First interpolation*	*Second interpolation*
6	4	17.4	17.7	17.8
	6	18.2		
8	4	17.5	17.9	
	6	18.4		

Corrections, from figures D4, D5 and D6:

Downward flux (6500 lm): + 4.8
Luminous area (3500 cm): − 5.9
Height (H = 2.5 m): − 0.3

Thus, total correction = 4.8 − 5.9 − 0.3 = − 1.4,
and final glare index = 23.9 − 1.4 = 22.5

Making similar corrections as above,

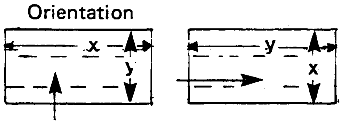
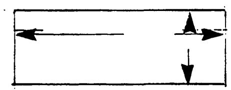
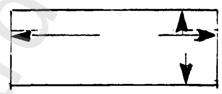
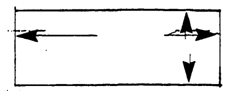
Final glare index = 17.8 + 7.4 − 1.4 = 23.8

D8
Glare worksheet

D8.1
An example of a worksheet for use in calculations for glare index is given in fig. D11.

Fig. D11

GLARE WORKSHEET

LOCATION			
LIMITING GLARE INDEX			
ROOM DATA Mounting height			
"H" (M.H. – 1.2 m)			
Room dimensions	X = Y =	X = Y =	X = Y =
Room dimensions "H"	X = Y =	X = Y =	X = Y =
Reflection factors	C = W = F =	C = W = F =	C = W = F =
Orientation 			
LUMINAIRE DATA BZ classification			
A C G No.			
Luminous area (cm²)			
Flux fraction (ULOR)/DLOR			
DLOR			
Total lamp flux (lm) per luminaire (Θ_L)			
Downward flux (DLOR x Θ_L)			
CALCULATION a) Initial unconverted glare index (from tables D1, D2, D3 or D4)			
b) Conversion term (Figs. D2 or D3)			
c) Initial glare index (a + b)			
d) Downward flux conversion term (from fig. D4)			
e) Luminous area conversion term (from fig. D5)			
f) "H" conversion term (from fig. D6)			
g) Total conversions (d + e + f)			
Final glare index (c + g)			

APPENDIX E

LIGHTING CALCULATIONS

E1
Lumen method for general lighting installations

E1.1
This method allows the calculation to be made of the number of luminaires and lamps required to produce a given illuminance in a given area. The method is as follows:

(a) Determine the design service illuminance required. (See 7.1.1)

(b) Select the type of luminaire

(c) Select the type of lamp, bearing in mind the efficacy and colour rendering required

(d) Note the length and the width of the area and the mounting height of the luminaires above the working plane, then calculate the Room Index (RI) according to the following formula:

$$RI = \frac{L \times W}{H_m (L + W)}$$

where:

L = Length of room in metres
W = Width of room in metres
H_m = Height of luminaires above the task in metres

(e) Note the reflectances of the room surfaces (See Appendix C)

(f) Obtain the space/mounting height ratio from the photometric data for the luminaire and then determine the minimum number of luminaires that can be installed in the given area

(g) Read off the Utilization Factor from the photometric data for the luminaire using the appropriate room reflectances, room ratio and mounting height

(h) Calculate the size of lamp or lamps required from the following formula:

$$F = \frac{E \times A}{N \times K \times LLF \times UF} \text{ lumens}$$

where:

F = the initial (100 hour) lumen output of the lamp
E = the design service illuminance
A = the area in square metres
K = the number of lamps per luminaire
N = the number of luminaires
UF = the Utilization Factor
LLF = the light loss factor. (See Section 10)

NOTE — This is an iterative method as modifications may need to be made as to the number and size of lamps per luminaire with consequent changes to the Utilization Factor.

E2
Calculation of illuminance

E2.1
Introduction

E2.1.1
Calculation of the illuminance at a point P on a given plane in an interior provided with light coming directly from a luminaire requires knowledge of the detailed light distribution of the luminaire. The data may be presented either as a polar curve of luminous intensity in the plane containing the light centre of the luminaire and the point in question, or as isolux contours on a plane containing the point.

E2.2
Point source

E2.2.1
The calculation of direct illuminance from a single luminaire, that for practical purposes may be regarded as a point, is done by means of formulae which assume that none of the luminaire dimensions is greater than one-fifth of the distance from the luminaire to P. The luminance at P on any plane, the normal to which makes an angle γ with the direction of incidence of the light, is:

$$E_{(\gamma)} = \frac{I_{(\theta)} \cos^2 \Theta \cos \Upsilon}{h^2} \text{ lux}$$

Illuminance on a plane normal to the direction of incidence of the light at P is

$$E_{(n)} = \frac{I_{(\theta)} \cos^2 \Theta}{h^2} \text{ lux}$$

Illuminance on the horizontal plane at P is

$$E_{(h)} = \frac{I_{(\theta)} \cos^3 \Theta}{h^2} \text{ lux}$$

Illuminance on the vertical plane at P is

$$E_{(v)} = \frac{I_{(\theta)} \cos^2 \Theta \sin \Theta}{h^2} \text{ lux}$$

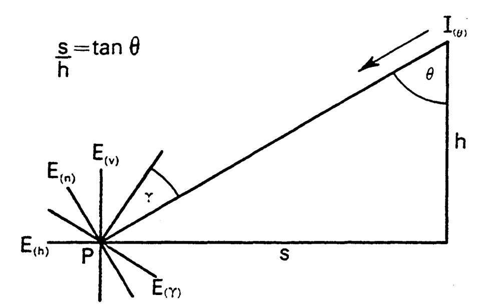


Fig. E1 ILLUMINANCE DUE TO A SINGLE POINT SOURCE

E2.3
Linear source

E2.3.1
A linear source, in this context, means a source whose width is small compared to its length. Sources may be classified as one of two types, tubular sources which have relatively small diameters (such as fluorescent tubes), and strip sources.

E2.3.2
Vertical tubular source
Fig. E2 shows a point P illuminated by a vertical tubular source of uniform brightness. The illuminance E, in lux, on the horizontal plane at P from the source is given by:

$$E = \frac{I_O}{2D} \sin^2 \alpha$$

where I_O is the luminous intensity in candelas per metre length of the source measured at right angles to its major axis, α is the angle subtended by the source at P, and D is the horizontal distance from P to the source. I_O may be calculated using the following table, which gives the approximate intensity per metre per lumen of lamp output. For example, for a lamp having a length of 1500 mm and an output of 4400 lm, $I_O = 4400 \times 0.065 = 286$ cd/m.

Lamp length	*Intensity*
mm	cd/(m.lm)
2500	0.04
1850	0.055
1500	0.065
1250	0.08
900	0.11
600	0.16

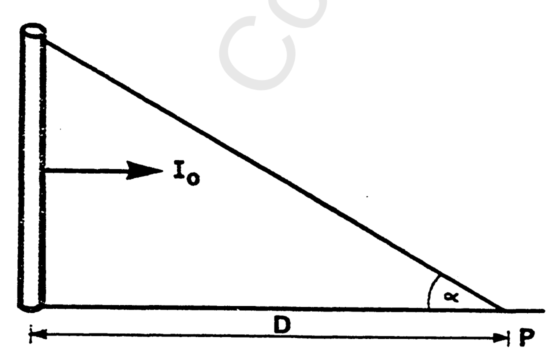


Fig. E2 VERTICAL TUBULAR SOURCE

E2.3.3
Horizontal tubular source
The illuminance E, in lux, on the horizontal plane at a point opposite one end of the lamp is given by:

$$E = \frac{I_O}{2D} (\alpha + \sin \alpha \cos \alpha) \sin \beta$$

α, β and D are defined as shown in fig. E3. α and β are measured in radians.

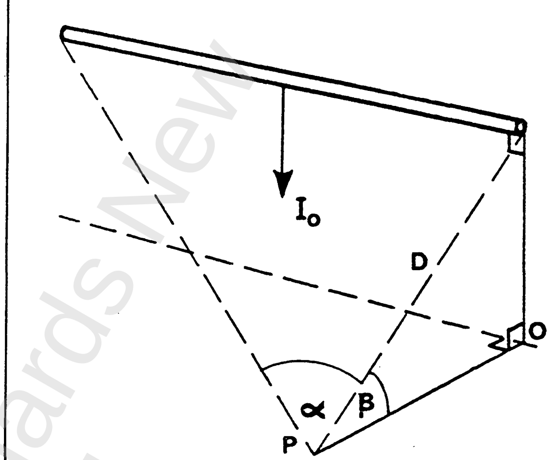


Fig. E3 HORIZONTAL TUBULAR SOURCE

E2.3.4
Narrow strip source: aspect factor method
E2.3.4.1
This method can be used when a substantially linear source is positioned at less than five times its length from the reference point. It requires manufacturer's data in the form of published aspect factors, or the axial polar curve from which these may be calculated by the method described in clause E2.4.
E2.3.4.2
The reference point, P, may lie within the length of the source or beyond it, the latter being catered for by a modification of the formula. In either case the direct illuminance given by a known source or the source required to give a specified illuminance can be determined. If the point lies within the length of the luminaire as shown in fig. E4, then

$$E = \frac{I_O (AF_\alpha + AF_\beta) \cos \theta}{(l'_1 + l'_2)\, d} \text{ and } I_O = \frac{E\, (l'_1 + l'_2) d}{(AF_\alpha + AF_\beta) \cos \theta}$$

If the point lies outside the length of the luminaire, as shown in fig. E5, then

$$E = \frac{I_O (AF_\alpha - AF_\beta) \cos \theta}{(l'_1 - l'_2) d} \text{ and } I_O = \frac{E\, (l'_1 - l'_2) d}{(AF_\alpha - AF_\beta) \cos \theta}$$

(take in figs E4 and E5)

E2.3.4.3
A continuous line of luminaires separated by small gaps may be regarded as a single luminaire which makes $l'_1 + l'_2$ the total length of the row, and the intensity is the sum of the intensity of each luminaire at angle θ.

intensity is the sum of the intensity of each luminaire at angle θ.

E2.4
Calculation of aspect factors

E2.4.1
The aspect factors may be calculated as follows:

(a) From the axial polar curve of the luminaire, read off the downward intensities at 10° intervals, and divide each by the intensity at 0° elevation (vertically downward).

(b) Plot these on a transparent grid to the same scale as the diagram shown in fig. E6 and superimpose the grid on the diagram

(c) If the match is reasonable to any of the lines A — E the relative aspect factors can be read off from the corresponding line of the graph shown in fig. E7.

(d) If the match is poor, then working in tabulated form as shown in table E1 is convenient, and the following method should be used

NOTE — In order to make the method clear, typical figures have been used in the example.

(1) Insert in column 2 the axial intensity for the corresponding angles given in column 1.

(2) Divide these by the intensity at 0° elevation and insert these figures in column 3.

(3) Multiply the figures in column 3 by the constant given in column 4 and insert the results in column 5.

(4) Make a cumulative total of column 5 in column 6. This is the aspect factor for the angle shown in column 7, and intermediate values can be obtained by interpolation.

$$E_{(h)} = \frac{I_{(\theta)} (AF_{(\alpha)} + AF_{(\beta)}) \cos\theta}{(l'_1 + l'_2)\, d}$$

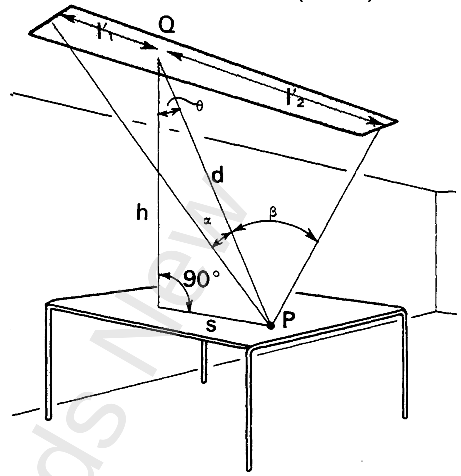
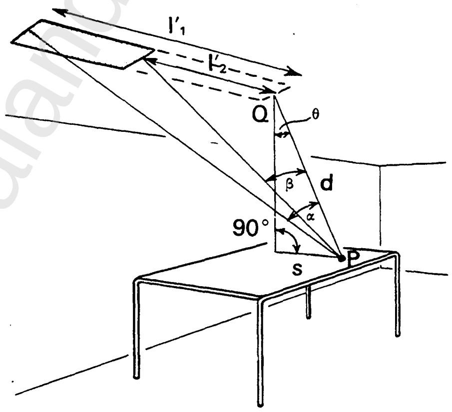


Fig. E4 NARROW STRIP SOURCE: POINT WITHIN THE LUMINAIRE LENGTH



$$E_{(h)} = \frac{I_{(\theta)} (AF_{(\alpha)} - AF_{(\beta)}) \cos\theta}{(l'_1 - l'_2)\, d}$$

Fig. E5 NARROW STRIP SOURCE: POINT OUTSIDE THE LUMINAIRE LENGTH

Table E1

TABLE FOR CALCULATION OF ASPECT FACTORS

(1) Axial angle, ϕ (deg)	*(2)* $I(\theta)$ (cd or arbitrary units)	*(3)* $I(\theta)/I(o)$	*(4)* Constant	*(5)* Column 3 x column 4	*(6)* Cumulative sum of column 5 = AF	*(7)* Aspect angle (deg)
5	176	0.9887	0.1736	0.1716	0.172	10
15	170	0.9550	0.1684	0.1608	0.333	20
25	156	0.8764	0.1580	0.1385	0.471	30
35	132	0.7416	0.1428	0.1059	0.577	40
45	88	0.4944	0.1232	0.0609	0.646	50
55	40	0.2247	0.1000	0.0225	0.668	60
65	20	0.1124	0.0737	0.0083	0.677	70
75	11	0.0618	0.0451	0.0028	0.680	80
85	1	0.0056	0.0152	0.0001	0.680	90

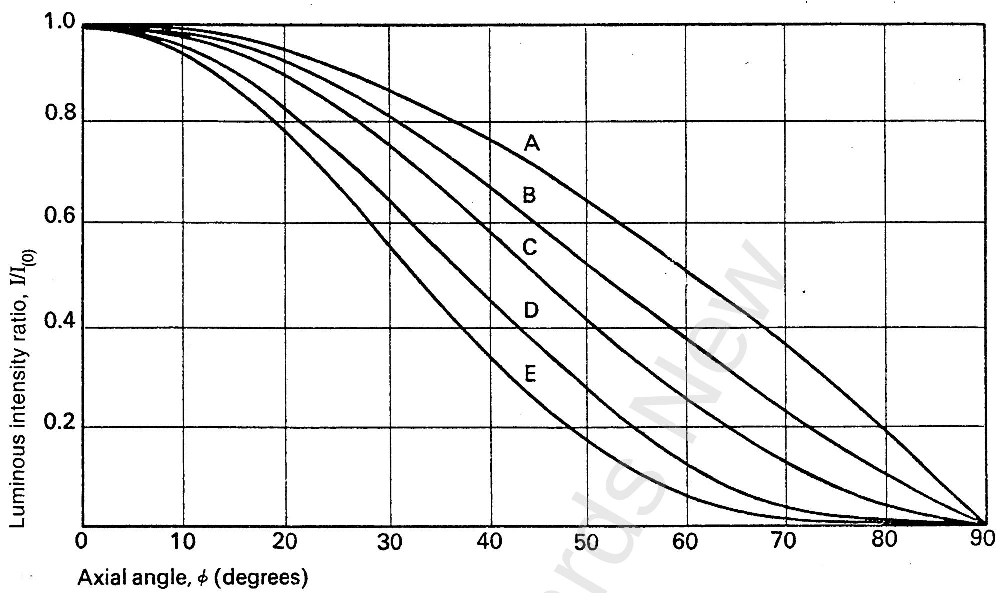


Fig. E6 LUMINOUS INTENSITY RATIOS

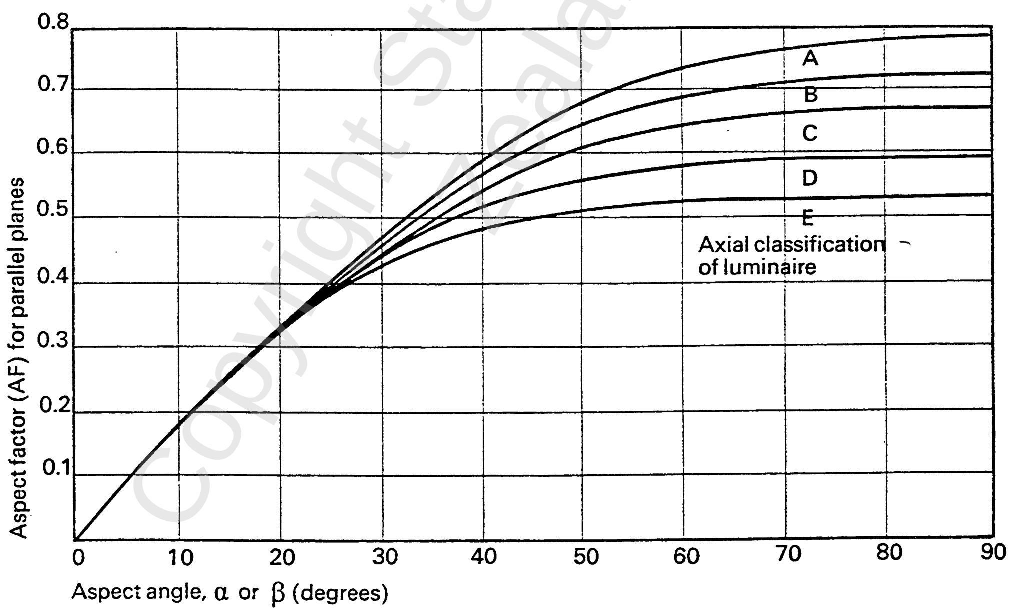


Fig. E7 ASPECT FACTORS FOR PARALLEL PLANES

E2.5
Area sources

E2.5.1
Various methods exist, most of them involving approximation since results to a limited accuracy are usually adequate. The source may, for instance, be regarded as broken down into small squares or rectangles with sides not greater than one-third of their distance from the point in question; it is assumed that the light output of each section is concentrated at its centre and the point-by-point method depending on the inverse square law is used. For many purposes the E/L method described below is appropriate.

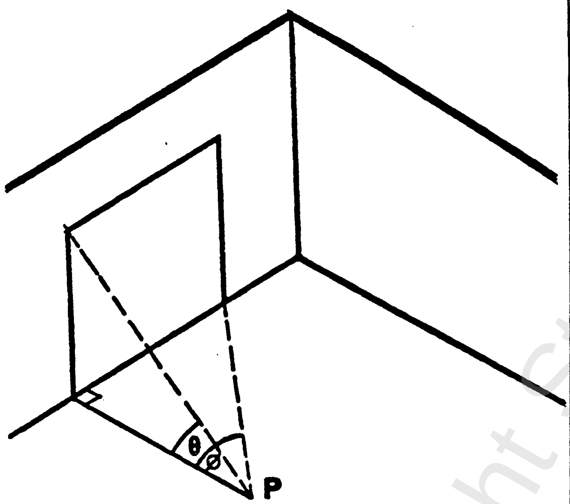


Fig. E8 AREA SOURCE WITH THE REFERENCE PLANE PERPENDICULAR TO THE PLANE OF THE LIGHT SOURCE

E2.5.2
For the case where the reference plane is perpendicular to the plane of the light source, as shown in fig. E8, the values of E/L given in table E2 are used. The illuminance in lux on the horizontal plane at point P opposite the corner of a rectangular perfect diffuser of luminance L apostilbs is given by multiplying the value of E/L from table E2 by that luminance.

E2.5.3
For the case where the reference plane is parallel to the plane of the light source, as shown in fig. E9, the method is the same as that given in E2.5.2 except that table E3 is used.

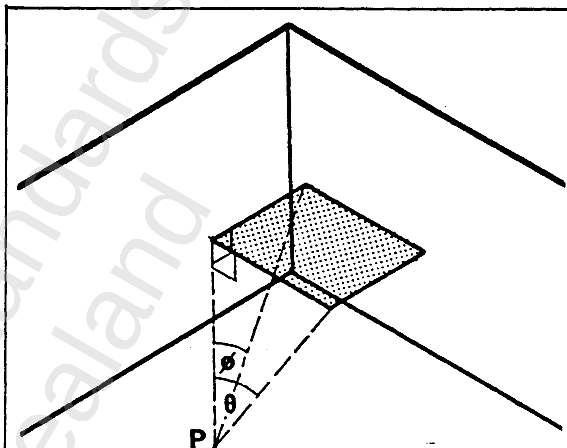


Fig. E9 AREA SOURCE WITH THE REFERENCE PLANE PARALLEL TO THE PLANE OF THE LIGHT SOURCE

Table E2

E/L VALUES — REFERENCE PLANE PERPENDICULAR TO THE PLANE OF THE LIGHT SOURCE

Angle θ	*Angle φ*								
	10°	*20°*	*30°*	*40°*	*50°*	*60°*	*70°*	*80°*	*90°*
10°	0.00083	0.0016	0.0023	0.0029	0.0033	0.0036	0.0037	0.0038	0.0038
20°	0.0032	0.0063	0.009	0.011	0.013	0.014	0.015	0.015	0.015
30°	0.0069	0.013	0.019	0.024	0.028	0.031	0.033	0.033	0.033
40°	0.011	0.022	0.033	0.041	0.049	0.054	0.057	0.058	0.058
50°	0.016	0.032	0.047	0.061	0.072	0.081	0.086	0.089	0.089
60°	0.021	0.041	0.061	0.08	0.096	0.11	0.12	0.12	0.13
70°	0.025	0.049	0.073	0.096	0.12	0.14	0.15	0.16	0.16
80°	0.027	0.054	0.081	0.11	0.13	0.16	0.18	0.2	0.21
90°	0.028	0.056	0.083	0.11	0.14	0.17	0.19	0.22	0.25

Table E3

E/L VALUES – REFERENCE PLANE PARALLEL TO THE PLANE OF THE LIGHT SOURCE

Angle θ	Angle ϕ								
	10°	20°	30°	40°	50°	60°	70°	80°	90°
10°	0.0095	0.018	0.026	0.032	0.038	0.041	0.043	0.043	0.043
20°	0.018	0.036	0.051	0.064	0.074	0.08	0.084	0.085	0.086
30°	0.026	0.051	0.074	0.093	0.11	0.12	0.12	0.12	0.13
40°	0.033	0.064	0.093	0.12	0.14	0.15	0.16	0.16	0.16
50°	0.038	0.074	0.11	0.14	0.16	0.18	0.19	0.19	0.19
60°	0.041	0.08	0.12	0.15	0.18	0.2	0.21	0.22	0.22
70°	0.043	0.084	0.12	0.16	0.19	0.21	0.23	0.23	0.23
80°	0.043	0.085	0.12	0.16	0.19	0.22	0.23	0.24	0.25
90°	0.043	0.086	0.13	0.16	0.19	0.22	0.23	0.25	0.25

APPENDIX F

MAINTENANCE OF LIGHTING INSTALLATIONS

F1
General

F1.1
For the purposes of this Standard, maintenance means cleaning of lamps and luminaires and replacing lamps. An effective maintenance program will help maintain illuminance and prevent waste of energy. This involves not only lumen depreciation factors but also lamp mortality.

F2
Lamp life

F2.1
Lamp lives are generally defined as the period during which 50 % of a given type of lamp fails. Fig. F1 provides a typical mortality curve.

F3
Lamp replacement

F3.1
Lamps may be replaced individually when they fail (spot replacement) or the entire installation may be replaced at one time (group replacement). In general, group replacement is likely to be the more economic alternative where useful lamp life is determined more by lumen depreciation than by lamp mortality, and where the costs of effecting lamp replacements are high.

F4
Cleaning methods

F4.1
The following cleaning methods for materials used in luminaires are recommended.

(a) *Aluminium*. Here very mild soaps and cleaners thoroughly and immediately rinsed will not affect the surface. Strong alkaline cleaners are not recommended.

(b) *Porcelain enamel*. Non-abrasive cleaners may be used. Detergents and most auto and glass cleaners are generally effective.

(c) *Synthetic enamel*. Strong cleaners may injur this finish, especially if left for a time. Detergents are harmless, but alcohol or abrasive cleaners should not be used.

(d) *Glass*. Most non-abrasive cleaners can be used. Dry cleaners are usually preferred on clear glass panels but not on etched or sand-blasted surfaces. Detergents are harmless and effective under most circumstances.

(e) *Plastics*. Plastics should be cleaned by detergent only. This will provide a temporary anti-static effect, much needed as dust is attracted by a static charge. Destaticizers are available which have greater permanence than common detergents. In most cases, however, cleaning at least twice a year with ordinary detergent will provide a satisfactory antistatic result. Plastics should not be wiped dry after the application of a rinse solution.

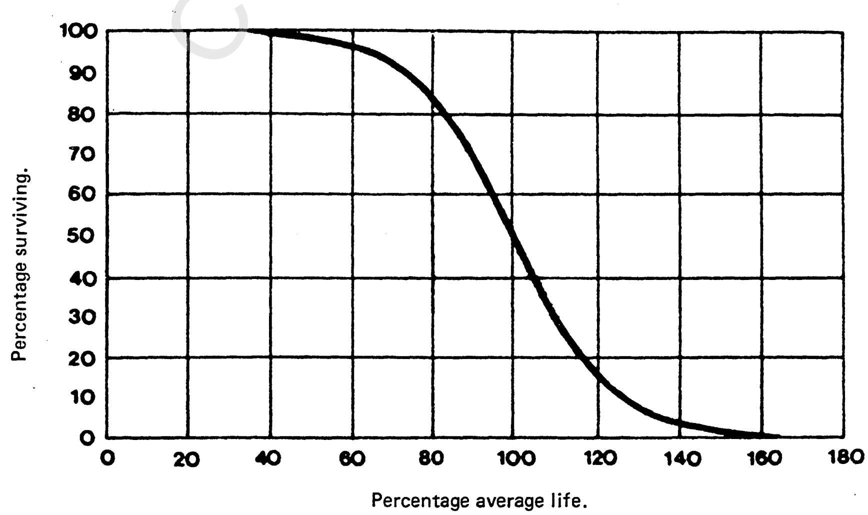


Fig. F1 TYPICAL MORTALITY CURVE FOR FLUORESCENT LAMPS

NZS 6703:1984

Code of practice for
INTERIOR LIGHTING DESIGN

CORRIGENDUM

November 1985

13.3.5

Delete the units at the end of the formula and **substitute** "W/m^2"

Fig. 10, page 28

The word "(continued)" should follow the title.

Table B1, page 53

Delete the last line and **substitute** the following:

general	75(Mean spherical)	1.2 m above floor	19	Intermediate or warm

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Table B1, page 54

Delete the sixth line and **substitute** the following:

Lounges	100(Mean spherical)	1.2 m above floor	16	"	Additional table lighting may be required

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Table D1, page 57

Delete the title and **substitute** the following:

GLARE INDICES FOR SYMMETRICAL DISTRIBUTIONS - FLOOR REFLECTANCE 14 %

Table D2, page 60

Delete the title and **substitute** the following:

GLARE INDICES FOR ASYMMETRICAL DISTRIBUTIONS - FLOOR REFLECTANCE 14 %

CORRIGENDUM (continued)

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Table D4, page 62

Delete the heading "AGC7" in the middle column under BZ 2 and

substitute: "ACG7".

Table D4, pages 63 and 64

Delete the titles and **substitute** the following:

GLARE INDICES FOR ASYMMETRICAL DISTRIBUTIONS - FLOOR REFLECTANCE 30 %

D6.4, page 72

Delete the formula at the beginning of the third line and **substitute** "I_θ/I_O"

D6.4, page 72

In the informal table **delete** the heading in the third column under the line and **substitute:**

"I_θ/I_O"

E1.1 (h), page 76

Delete the reference at the end of the last line before the note and **substitute:**

"(See Section 9)"

E2.3.4.2, page 77

Delete "(take in figs. E4 and E5)" at the end of the clause.

APPROVED TO NEW ZEALAND STANDARD

THE NEW ZEALAND STANDARD CERTIFICATION MARK SCHEME

The 'S' Mark appearing on a product, container or label is an assurance that the goods are manufactured under a system of supervision, control, and testing (including periodical inspection at the manufacturer's works by SANZ Certification Officers) designed to ensure compliance of the commodity, process, or practice with the relevant New Zealand Standard. The New Zealand Standard Certification Mark, registered as a certification trade mark under the Trade Marks Act 1953, may be used only in terms of a licence issued by SANZ, and must be accompanied by the licence number and the NZS number.

Used correctly in conjunction with advertising the 'S' Mark can provide a strong assurance of product quality for a manufactuer when selling his goods and thus becomes a powerful marketing tool.

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Declared on 14 December 1984 by the Standards Council to be a Standard specification pursuant to the provisions of section 23 of the Standards Act 1965.

First published March 1985

The following SANZ references relate to this Standard:

Project No. P6703
Draft for comment No. DZ 6703
CPT ref: CEH 1
Printing code: 1000-1984/7034/20296
Typeset by: Comset