AS/NZS 1680.1:2006

AS/NZS 1680.1:2006

Australian/New Zealand Standard™

Interior and workplace lighting

Part 1: General principles and recommendations

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AS/NZS 1680.1:2006

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- Association of Consulting Engineers Australia
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- Department of Commerce (NSW)
- Energy Efficiency and Conservation Authority of New Zealand
- IES: The Lighting Society
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- Photometric testing laboratories

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Australian/New Zealand Standard™

Interior and workplace lighting

Part 1: General principles and recommendations

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee LG-001, Interior and Workplace Lighting to supersede AS 1680.1—1990, *Interior lighting.*

This Standard forms Part 1 of the AS/NZS 1680 series, which covers lighting of interiors and workplaces. The series title has recently been changed from 'Interior lighting' to reflect an expansion in the scope of the series.

The AS(/NZS) 1680 series currently consists of the following:

AS(/NZS)		
1680	Interior and workplace lighting	
1680.0	Part 0:	Safe movement
1680.1	Part 1:	General principles and recommendations (this Standard)
1680.2.1	Part 2.1:	Circulation spaces and other general areas
1680.2.2	Part 2.2:	Office and screen-based tasks
1680.2.3	Part 2.3:	Educational and training facilities
1680.2.4	Part 2.4:	Industrial tasks and processes
1680.2.5	Part 2.5:	Hospital and medical tasks
1680.3	Part 3:	Measurement, calculation and presentation of photometric data
1680.4	Part 4:	Maintenance of electric lighting systems

NOTE: Until the revision of this series is complete, some of the above Standards might have, as a main title, 'Interior lighting'.

The significant changes that have been made in this Standard in relation to the previous publication include the following:

- A substantial editorial revision, including a re-organized presentation of many of the concepts explained.
- A significant expansion of the section on Glare (Section 8), including the addition of the CIE unified glare rating (UGR) system and further details on the (existing) luminance limiting approach.
- Addition of information to Section 9, including daylight values for New Zealand.
- Major modifications to Section 12 due to the addition of AS/NZS 1680.4 to the series.

Specific information in this Standard, including various figures and tables, has been reproduced from a number of the reference documents listed in Appendix F, and from the CIBSE Code for Interior Lighting in particular. Grateful acknowledgement is made of this assistance.

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Part 1: General principles and recommendations

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out general principles and recommendations for the lighting of interiors of buildings for performance and comfort. It applies primarily to interiors in which specific visual tasks are undertaken and takes into account both electric lighting and daylight. The recommendations have the object of producing a visual environment in which essential task details are made easy to see and adverse factors which may cause visual discomfort are either excluded or appropriately controlled.

Recommendations for the lighting of particular interiors or activities are provided in the Standards which comprise AS(/NZS) 1680.2. Refer also to AS/NZS 1680.0 for basic requirements for safe movement.

The Standard does not deal with lighting for the purposes of decoration, display, entertainment or sport.

NOTE: Attention is drawn to the AS(/NZS) 2293 series of Standards which set out requirements for the lighting necessary to alleviate panic and to permit safe evacuation of the building occupants should this be required in the event of loss of the normal lighting.

1.2 OBJECTIVE

The objective of this Standard is to provide the reader with a comprehensive explanation of the factors relevant to interior lighting and with recommendations and guidance in dealing with these factors. The intent of this guidance is to facilitate the creation of visual environments that exclude or, at least, control visual fatigue and thereby promote efficiency and wellbeing in the illuminated space.

This Standard does not specify precise types and arrangements of lighting equipment necessary to meet the recommendations and it is anticipated that the technical knowledge and experience of a qualified lighting designer/engineer will normally be required to apply this Standard and create the most suitable lighting scheme for any particular interior space.

Although the principles explained in this document are applicable to all aspects of interior lighting, this Standard is specifically intended for task-oriented and general movement lighting, rather than specialized areas such as mood lighting, display lighting or theatrical lighting.

1.3 REFERENCED DOCUMENTS

The documents referred to in this Standard are listed in Appendix A.

NOTE: A number of additional documents that are considered useful sources of information are listed in Appendix B.

1.4 DEFINITIONS

For the purpose of this Standard, the definitions given in AS/NZS 2633, AS 3665 and those below apply.

NOTE: AS 3665 gives simplified definitions for some of the basic lighting terms and quantities used in this Standard. For the more precise primary definitions, see AS 1852(845).

1.4.1 Average illuminance

For a specified surface area (e.g. a particular task area, the surface on which tasks may be placed within a room, the floor of a passageway or one or more walls within a room) the arithmetic mean of the illuminance values, calculated or measured as applicable, from within the area.

(Refer also to Appendix B for details regarding the choice of the illuminance values to be averaged.)

1.4.2 Cut-off angle (of a luminaire)

The angle, in a given vertical half-plane, between the downward vertical axis and the line of sight at which all surfaces of high luminance (of lamps and of the luminaire) just cease to be visible.

NOTE: The term 'shielding angle' is sometimes used to refer to the difference between the cut–off angle and the horizontal, i.e. shielding angle = 90° – cut-off angle.

1.4.3 Initial illuminance

The value of average illuminance which is initially provided by the lighting system, i.e. with new lamps (aged to 100 h), clean luminaires and room surfaces.

1.4.4 Maintained illuminance

The defined level below which the average illuminance on any surface is not allowed to fall. It is the minimum illuminance at which maintenance operations, such as replacing lamps and cleaning the luminaires, windows, rooflights and room surfaces are to be carried out.

1.4.5 Task area

The area within which the task is located. This may be the whole of the room or a small part of it.

1.4.6 Task detail

The minute portion of the task which is under examination at any given moment.

1.4.7 Task illuminance

The value of maintained illuminance which is recommended for a specific visual task.

1.4.8 Task surroundings

Surface visible within 45° of the line of sight when looking at details anywhere on the task. The surfaces may be in the same plane as the task or at some distance from it.

NOTES:

1 Surfaces within 15° of the line of sight are referred to as the 'immediate task surroundings'.

2 The actual size and shape of the task surroundings will depend on the size and shape of the task, the distance of the task from the eye of the observer and from the surface(s) against which the task is seen.

1.4.9 (Visual) task

The whole object (large or small) which is to be examined, e.g. part of a car body under assembly, document or drawing being read, watch being repaired.

1.4.10 Uniformity of illuminance

The ratio of the minimum illuminance to the average illuminance on a given plane within the calculation or measurement area.

NOTES:

1 When determining the uniformity of illuminance for general lighting systems, the minimum illuminance considered is the lowest value of the grid of calculated/measured illuminances within the applicable calculation or measurement area.

2 This is the generally used measure of illuminance uniformity and is often designated U1. Other measures exist and are usually designated U2 etc.

1.4.11 Unwanted reflections

Reflections in the task or its surroundings which interfere with visual efficiency and comfort. Refer to Section 5 for further detail.

1.4.12 Veiling reflections

A term sometimes applied to an unwanted reflection that reduces task contrast (see also Section 5).

1.4.13 Visual system

In the human, those organs and mental processes that give rise to vision. It comprises the functions of the eyes and brain.

1.4.14 Working plane

The plane horizontal, vertical, or inclined in which the visual task lies. (See also Clause 3.6.)

SECTION 2 GENERAL REQUIREMENTS OF GOOD INTERIOR LIGHTING

2.1 THE IMPORTANCE OF QUALITY LIGHTING

The simplest interpretation of providing lighting to a visual task is to provide 'light' i.e. illuminance. This leads to a simplistic but commonly held view that the only solution to any lighting problem is to provide more illuminance.

However, while merely supplying some specified quantity of light might provide an adequate viewing environment for simple viewing tasks, such an approach will rarely provide optimum viewing conditions and for more complex or detailed tasks will not meet even basic criteria.

While the provision of sufficient illuminance on the task is a necessary element, in many instances task visibility depends heavily on the way in which the light is applied. Critical factors are the luminance contrast of the task and luminance adaptation level of the observer. Further, creation of the comfortable visual conditions which people require in order to maintain efficiency over a period of time depends on factors such as the distribution of light throughout the space; the use of suitable colours and finishes on relevant reflecting surfaces; the choice of luminaires with adequate glare control; and the elimination of unwanted reflection.

Attention to all of these factors produces 'good quality lighting'. Experience has shown that when inefficiency, eye fatigue, spoilt work or accidents are blamed on the lighting system, failure to meet one or more of the 'quality' recommendations is often a significant part of the problem and insufficient illuminance is either a contributing factor only or not an issue at all.

2.2 OBJECTIVES OF AN INTERIOR LIGHTING SYSTEM

2.2.1 Outline

The objective of a lighting system in a given space (typically a room or specific part of a room) is to contribute to the provision of the following in relation to the intended users of the space:

(a) Safety.

(b) Performance of physical tasks.

(c) An appropriate visual environment.

The variation in the emphasis on each of these aspects will vary for different spaces and even within spaces.

For example, the lighting considered suitable for a factory toolroom will place much more emphasis on lighting the relevant tasks than on the appearance of the room, but in a hotel lounge the priority will be on the visual environment of the room (although task lighting for a reception desk might be required). In both cases the adequate contribution of the lighting to a suitably safe environment for the intended uses of the space is implicit.

Consideration of the above aspects is particularly important where visual tasks are critical and prolonged or are carried out under conditions of stress.

2.2.2 Specific considerations

2.2.2.1 *Safety*

The primary contribution of lighting to the safety of the users in a space consists of facilitating the recognition of hazards (such as obstacles or moving parts) both in general and in relation to specific physical tasks, and in illuminating safety warning signs and safe pathways within the space.

Allowing users of the space to avoid conditions such as mental fatigue and eye strain, especially in potentially hazardous environments, is a secondary safety benefit of good lighting.

To provide lighting for safety purposes, the specific details to be considered are as set out in Clauses 2.2.2.2 and 2.2.2.3.

2.2.2.2 *Performance of physical tasks*

Efficient seeing of the task depends mainly on—

(a) adequate illumination of the task;

(b) freedom from unwanted reflections;

(c) use of special techniques where appropriate; and

(d) luminance of the surroundings correctly related to that of the task.

2.2.2.3 *General visual environment*

A safe and comfortable visual environment depends mainly on—

(a) avoidance of excessive illuminance variations;

(b) absence of direct glare from lamps, luminaires or windows;

(c) an appropriate luminance distribution on interior surfaces;

(d) use of suitable colours on the main interior surfaces; and

(e) use of light sources with suitable colour characteristics.

2.3 OTHER CONSIDERATIONS

The recommendations of the AS(/NZS) 1680 series presume that the occupants of the interior have normal or near normal vision. Some people have reduced vision, usually as the result of uncorrected refractive errors (myopia, hypermetropia, astigmatism) or presbyopia (loss of ability to focus on near tasks that occurs universally with increasing age). Although these defects are readily corrected by glasses some people do not seek the correction they need. Increased lighting can help people with uncorrected vision defects, however, it is more economical and efficient to ensure that the occupants have normal or near normal vision rather than to over-design the lighting system.

2.4 DAYLIGHT AND ELECTRIC LIGHT

One of the most fundamental decisions to be made when designing the lighting of an interior is the relationship between daylight and electric light.

The decision regarding the provision of daylight to a space will be influenced by many considerations in addition to the lighting effects. For example, the energy consumption and costs involved, the possible building forms available, the need for a controlled or secure environment and the uncomfortable thermal conditions (both hot and cold) that can be produced by large areas of window glass are all relevant factors.

There is little doubt that windowless interiors are generally disliked, particularly if they are small and that, given a choice, people prefer to work by daylight and to enjoy a view.

Assuming that daylight is available, or is an option, there are three possible approaches to consider, viz—

(a) to rely on daylight during daytime and to design the electric lighting only for night-time conditions;

(b) to use daylight as available but supplement it as required by electric lighting; or

(c) to ignore daylight and design the building assuming electric lighting only.

The preferred common approach is for daylight and electric light to be combined to produce sufficient and suitable lighting on the task and throughout the room, by day and night. Then the electric lighting serves to supplement daylight when and where it is insufficient and the daylight contributes an element of variation and directional flow to the appearance of the interior.

NOTE: Windows can be a source of direct disability glare and can sometimes cause a gloomy interior unless due regard is taken of the recommendations of this Standard.

SECTION 3 TASK VISIBILITY

3.1 SCOPE

This section explains the major factors affecting the appearance of a task to a visual system and recommends minimum requirements for these factors in order to achieve 'good' general visibility.

3.2 VISIBILITY AND VISUAL PERFORMANCE

3.2.1 General

For any given task the performance of a given person is essentially a function both of the ability of that person to perform that task (task performance potential) and of the person's attitude towards performance of that task (task performance attitude).

The attitude of the individual determines to what extent the task performance potential is realized and thus is the controlling factor in determining what the actual task performance will be. Attitude includes factors such as motivation, dedication and concentration, all of which are of a psychological or social nature and are beyond the scope of this Standard. Lighting, with all the other factors of the physical environment, may influence performance potential but cannot directly affect task performance attitude.

Visual performance is the rate of information processed by the visual system. One measure of the task visual performance would be the speed and accuracy with which the task (which is usually a part of another task) is accomplished.

Task visibility is the ease, speed and accuracy with which the task may be seen and can be considered as the visual task performance potential. It can be determined from measurements of visual task performance at the maximum level of task performance attitude.

3.2.2 Critical detail

For any visual task the task visibility is generally determined by the visibility of the most difficult element that must be detected or recognized in order to perform the task. This detail is referred to as the critical detail. The visibility of the critical detail is a function of the difficulty experienced in discriminating it visually from the background against which it is seen.

The visibility of a detail depends on many factors including—

(a) apparent size of the detail (the quotient of its size and the viewing distance);

(b) luminance and colour of the detail;

(c) adaptation luminance;

(d) contrast in luminance and colour between the detail and its background;

(e) available observation time;

(f) form of the detail;

(g) similarity in form and texture between the detail and the immediate surroundings;

(h) advance knowledge about the moment when the detail will appear in the visual field;

(i) position of the detail in the visual field;

(j) advance knowledge about the position of the detail in the visual field; and

(k) experience with the visual task.

3.3 LUMINANCES IN THE VISUAL FIELD

3.3.1 Adaptation luminance

Remembering that luminance is a measure of the brightness of a surface (either by reflection or emission), the most important lighting factor in achieving good task visibility is the relationship of the luminance of the task to the luminances of the surroundings.

When a person views a visual task, the particular distribution of the luminances of the task and each surface within the field of vision is referred to as the luminance pattern. Certain properties of the visual system modify or adapt themselves to each luminance pattern presented until they reach a final state. This state is referred to as the adaptation level of the combined visual system and luminance pattern and is expressed as a luminance—referred to as the adaptation luminance. Normally, the average luminance in the visual field can be taken as the adaptation luminance for that situation.

3.3.2 Adaptation level

The properties of the visual system that adapt themselves to the luminance pattern are as follows:

(a) *Visual acuity or sharpness of vision* The capability of the visual system for discrimination between details or objects which are very close together. Usually this is expressed by the apparent size of the smallest detail that can be discriminated.

(b) *Contrast sensitivity* The capability of the visual system for discrimination of small relative luminance differences. Usually this is expressed by the reciprocal value of the minimum perceptible relative luminance difference.

(c) *Oculomotor function efficiency* The efficiency of those functions controlling accommodation, convergence, pupillary contraction, eye movements, etc.

NOTE: Further definitions for these functions are beyond the scope of this Standard.

Visual acuity, contrast sensitivity, and oculomotor function efficiency each increase with increasing adaptation luminance but only up to a certain maximum level for each. Also, the positive effect on task visibility of increased adaptation luminance will be controlled and ultimately limited by which of these factors is critical to the particular visual task.

For example, for tasks where the apparent size of the detail is critical with respect to task visibility, increased visual acuity due to increased luminances is of dominant importance for improving task visibility. When, however, the apparent size of the critical detail is far above the visual acuity threshold the contribution of increased visual acuity is negligible.

3.3.3 Luminance ratios

In general the visual task should be the obvious area of visual attention within the field of vision. This suggests that the task area should be ‘brighter’ than the surrounds since people are phototropic (i.e. attracted to light) and areas of high luminance in the task surrounds would be distracting.

In working interiors the degree of luminance contrasts within the visual field is important. In display lighting or in the theatre very dramatic effects can be produced by lighting the object of regard (the task) to make it ‘dazzlingly bright’ but in interiors where sustained tasks are performed, dramatic luminance contrasts may not aid task performance but rather reduce it, mostly due to the fatigue of transient adaptation effects (see Clause 8.5).

It has been found that while the task area should have the highest luminance in the visual field it is important that attention be paid to the immediate and general surrounds. Refer to Table 3.2 for the recommended ratio of luminances of the task : immediate surrounds : general surrounds.

3.3.4 Luminance and illuminance

While the objective in illuminating a task is to produce appropriate luminances and contrasts for task visibility it is simple and usual to express the requirements for the provision of lighting in terms of illuminances (i.e. the light falling on the visual field). Provided the interior surfaces have the reflecting properties recommended in Section 6, appropriate illuminances can be stated that will give rise to the required luminances and, hence, the desired task visibility.

Similarly, if the recommendations of Section 6 are followed, especially when using local lighting systems with general/environmental lighting systems, satisfactory luminance ratios will be achieved, producing comfortable viewing conditions for the task relative to its surroundings.

3.4 THE EFFECTS OF ILLUMINANCE

3.4.1 General working planes

Despite some visual tasks being three-dimensional, in most cases the visual task or tasks in an interior are carried out more or less in one plane, for example, paper-based office tasks. It is common to specify a required illuminance on that particular plane—referred to as the ‘working plane’.

The concept of the working plane is also applicable where there may be two or more task planes, since one of the planes may be illuminated using a special lighting system. For example, in classrooms, the horizontal plane at desk height would be the major horizontal working plane to be illuminated by the main lighting system while the second task plane, e.g. blackboards and whiteboards, could be illuminated using a special system solely for that purpose. It should be noted that the achievement of illuminances on task planes facilitates task visibility but does not necessarily achieve the necessary or desired visual appearance or comfort of a space.

3.4.2 Influence of illuminance on task performance

3.4.2.1 *General*

The following two aspects of any task determine the effect of the illuminance provided on the performance of that task:

(a) The extent to which the visual component of the task affects overall task performance.

(b) The difficulties associated with the performance of the visual component of the task.

3.4.2.2 *Importance of the visual component*

Where there is only a small visual component, as in audio typing, the influence of illuminance on overall task performance is likely to be small but where the visual component is a major element of the complete task, as in copy typing, then the illuminance provided will be important.

3.4.2.3 *Difficulties associated with the visual component*

The effect of lighting on the visual component of task performance depends on the size of the critical details of the task and on their contrast with their background (see Figure 3.1). If the time allowed to perform the reading task in Figure 3.1 is not important, i.e. the task is self-paced, then good accuracy of reading may be achieved where the size of the detail is small or the contrast is low. However, it is a common requirement in many work situations that tasks be performed both quickly and accurately.

An indication of the effect of lighting on both self-paced and time-paced tasks can be achieved using a standardized task such as that shown in Figure 3.2(a). The rings, called Landolt rings, have gaps and the task is to identify those rings with gaps at a certain orientation. The difficulty of the task will vary according to the gap size and contrast between the ring and background of the chart used plus the illuminance provided. In the self-paced task, performance does not depend upon time but if time is important then the observer must trade speed off against possible accuracy.

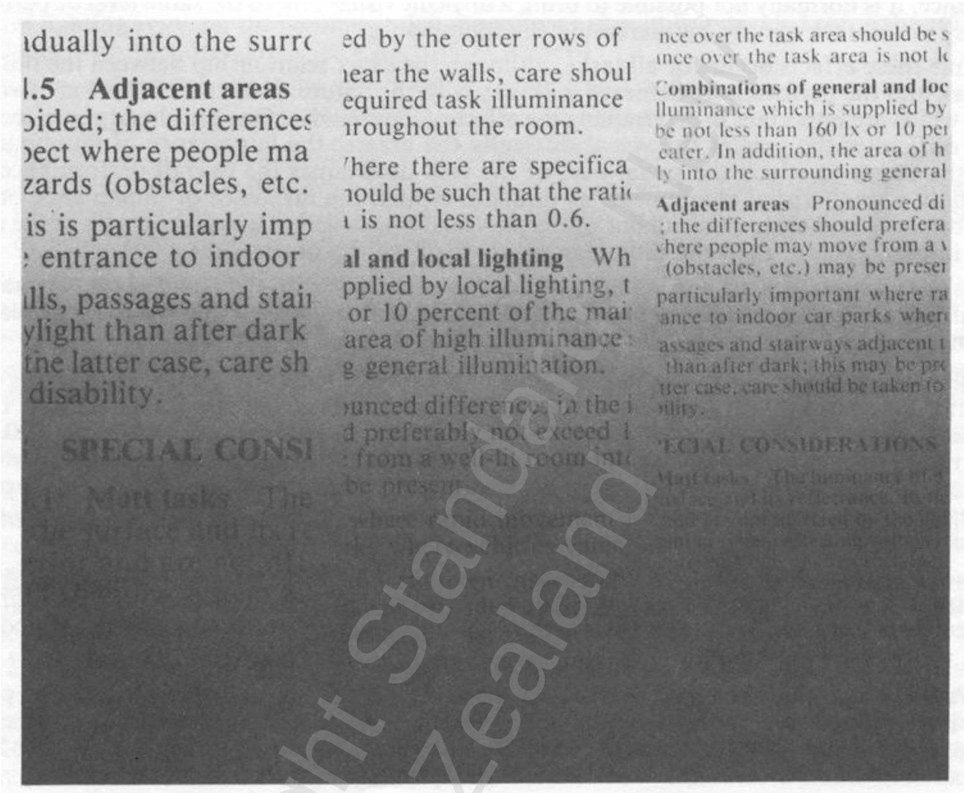
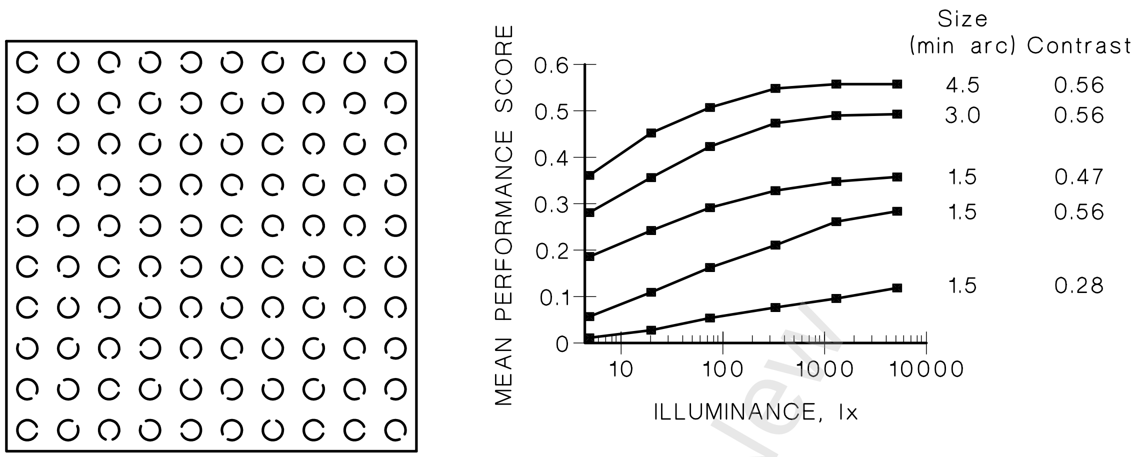


FIGURE 3.1 THE EFFECT OF VARYING SIZE AND CONTRAST OF TASK DETAILS ON EASE OF READING



(a) Typical Landolt ring chart

(b) Mean performance scores for various charts and levels of illiminance

FIGURE 3.2 THE LANDOLT RING CHART AND MEAN PERFORMANCE SCORES

Figure 3.2(b) shows the effect of illuminance on the performance of the laboratory task described. The following three important points should be noted from Figure 3.2(b):

(a) Increasing the illuminance on the task produces an increase in performance following a law of diminishing returns.

(b) The illuminance at which performance levels off is dependent on the visual difficulty of the task, i.e. the smaller the size and the less the contrast of the task, the higher the illuminance at which performance levels off (or saturates).

(c) Although increasing illuminance can increase task performance, it is normally not possible to bring a difficult visual task to the same level of performance as an easy visual task simply by increasing the illuminance.

These principles illustrate the points made in Clause 3.3.2 and apply to virtually all tasks, although the exact relationship between the illuminance on the task and the performance achieved will vary with the nature of the task.

3.4.3 Influence of illuminance on overall lighting quality

Figure 3.3 shows mean assessments of the quality of lighting obtained in an office lit uniformly by a regular array of luminaires. Increasing the illuminance on the plane of the desk increases the perceived quality of the lighting until it levels off at about 800 lx. This demonstrates the importance of the illuminance as one factor in determining people's satisfaction with an interior. This is especially so when the lighting of a space is achieved using uniform arrays of luminaires because the luminances of the bounding surfaces of the space depend greatly upon the interreflected light from a lighting system designed to mainly illuminate specific tasks.

Figure 3.3 shows the same trend of diminishing returns as does Figure 3.2. The perceived increase in lighting quality with increasing illuminance is another factor which has determined the illuminances recommended in Table 3.1, particularly since most traditional working interiors employ lighting systems comprising uniform arrays of luminaires.

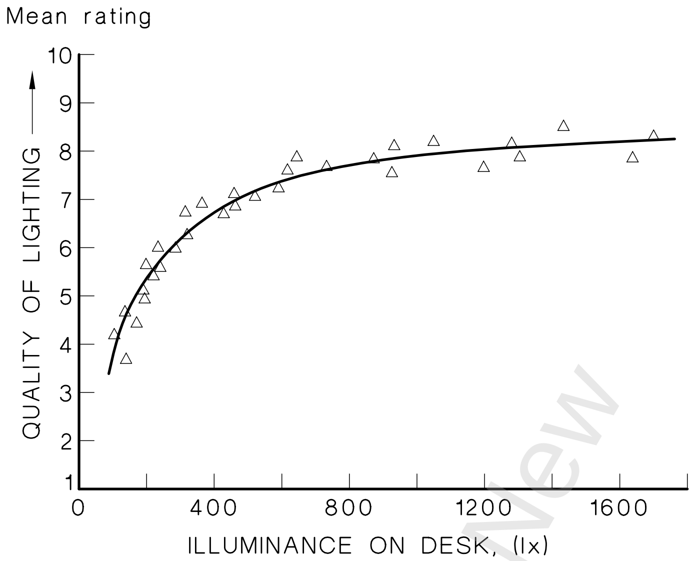


FIGURE 3.3 MEAN ASSESSMENT OF QUALITY OF LIGHTING

3.5 THE USE OF MAGNIFICATION

For visual tasks with details that are too small to be seen comfortably with the unaided eye, a small degree of magnification will markedly improve visibility and will be more effective than increasing the illuminance.

3.6 RECOMMENDED ILLUMINANCES

Recommended values of maintained illuminance for particular tasks or interiors are given in the AS(/NZS) 1680.2 series. Where tasks are not specifically covered in that series, appropriate maintained illuminance values should be selected from Table 3.1 of this Standard by comparison with the task characteristics or examples given in that Table.

NOTE: Refer to Appendix C for relevant information regarding the quantity 'maintained illuminance'.

It is recommended that the maintained illuminance in any continuously occupied working interior should be not less than that recommended in Table 3.2.

For workstations, the recommended maintained illuminance should be provided to each of one or more defined working planes (horizontal, vertical, or inclined), with the worker standing or sitting in the normal working position. Allowance for the possibility of light being obstructed by the worker's body is particularly important.

For general lighting systems, the recommended illuminance should be provided throughout the space in accordance with this Standard, on one or other of two horizontal planes, located at either 0.7m or 0.85m above the floor, as per Table 3.2, unless otherwise stated in the AS(/NZS) 1680.2 series or determined by an appraisal of the task.

3.7 MAINTENANCE OF ILLUMINANCE

The initial illuminance which should be provided by the lighting system will need to be significantly higher than the recommended or required maintained illuminance in order to allow for the progressive loss of light which will occur due to the following:

(a) *Lamps* The reduction over time in lumen output caused by ageing of the lamps and the accumulation of dust and dirt on the lamps.

(b) *Luminaires* The reduction in light output from the luminaires caused by the collection of dust and dirt on the reflecting and transmitting surfaces.

(c) *Room surfaces* The reduction in useful light reaching the working plane caused by the accumulation of dust and dirt darkening the reflecting room surfaces, mainly the upper walls and ceiling.

(d) *Windows and rooflights* The drop in useful light reaching the working plane caused by dirt on the glazing of windows and rooflights. This dirt can be deposited on both the inside and outside surfaces of the glazing.

AS/NZS 1680.4 gives information on the allowances which should be made in lighting calculations for the light losses described above. The point is made that the required value of initial illuminance will critically depend on the maintenance regime adopted, i.e. lower values of initial illuminance will be possible where the lighting system is more frequently maintained.

The maintenance cycle adopted should ensure that the average illuminance will at no time fall below the recommended or required maintained illuminance.

TABLE 3.1

RECOMMENDED MAINTAINED ILLUMINANCES FOR VARIOUS TYPES OF TASKS, ACTIVITIES OR INTERIORS

Class of task		Recommended maintained illuminance lx	Characteristics of the activity/interior	Representative activities/interiors
Movement and orientation*		40	Interiors rarely visited with visual tasks limited to movement and orientation	Corridors; cable tunnels; indoor storage tanks; walkways.
Rough intermittent*		80	Interiors requiring intermittent use with visual tasks limited to movement, orientation and coarse detail.	Staff change rooms; live storage of bulky materials; dead storage of materials needing care; locker rooms; loading bays.
Normal range of tasks and work places	Simple	160	Any continuously occupied interior where there are no tasks requiring perception of other than coarse detail. Occasional reading of clearly printed documents for short periods.	Waiting rooms; staff canteens; rough checking of stock; rough bench and machine work; entrance halls; general fabrication of structural steel; casting concrete; automated process monitoring; turbine halls.
	Ordinary or moderately easy	240	Continuously occupied interiors with moderately easy visual tasks with high contrasts or large detail (>10 min arc).	School chalkboards and charts; medium woodworking; food preparation; counters for transactions.
	Moderately difficult	320	Areas where visual tasks are moderately difficult with moderate detail (5-10 min arc or tolerances to 125µm) or with low contrasts.	Routine office tasks, e.g. reading, writing, typing, enquiry desks.
		400		Inspection of medium work; fine woodwork; car assembly.
	Difficult	600	Areas where visual tasks are difficult with small detail (3-5 min arc or tolerances to 25µm) or with low contrast.	Drawing boards; most inspection tasks; proofreading; fine machine work; fine painting and finishing; colour matching.
	Very difficult	800	Areas where visual tasks are very difficult with very small detail (2-3 min arc) or with very low contrast.	Fine inspection; paint retouching; fine manufacture; grading of dark materials; colour matching of dyes.
Extremely difficult		1200	Areas where visual tasks are extremely difficult with extremely small detail (1-2 min arc or tolerances below 25µm) or of low contrast. Visual aids may assist.	Graphic arts inspection; hand tailoring; fine die sinking; inspection of dark goods; extra-fine bench work.
Exceptionally difficult		1600	Areas where visual tasks are exceptionally difficult with exceptionally small detail (<1 min arc)or with very low contrasts. Visual aids will be of advantage.	Finished fabric inspection; assembly of minute mechanisms, jewellery and watchmaking.

* Refer also to AS/NZS 1680.0 for minimum requirements for safe movement.

NOTE: See the Standards in the AS(/NZS) 1680.2 series for the recommended maintained illuminance for specific tasks and interiors.

3.8 UNIFORMITY OF ILLUMINANCE

3.8.1 General considerations

The principles explained in Clause 3.3.3 regarding luminance ratios also apply when deciding on appropriate variations in illuminance, both between a specific task and its immediate surrounds and between various areas of a room or space. For example, large or sudden changes in illuminance across a task area are likely to cause distraction and dissatisfaction, and may affect task performance. However a greater degree of non-uniformity is acceptable, and often advantageous, between the illuminance on the task area and the parts of the room which do not contain tasks, (although a minimum uniformity is still necessary to avoid discomfort) while some lighting systems are designed with deliberate variations in illuminance either to highlight areas or to create interest by providing contrast.

The variation of illuminance across an area is expressed as the uniformity of illuminance. (Refer to Clause 1.4.10).

3.8.2 General lighting systems

Where a general lighting system is used, a fairly high degree of uniformity of illuminance on the working place is required as the aim of such systems is to allow a particular task or series of tasks to be performed anywhere within the space, without alterations to the lighting. Refer to Table 3.2 for recommended minimum illuminance uniformity.

General lighting systems utilize a regular array of luminaires often resulting in lower illuminances in areas close to the walls and in the corners, typical values being as low as 50% of the average illuminance at the sides of the room and 25% of the average in the corners. If tasks are to be performed near the walls, care should be taken in locating the outermost row of luminaires to ensure that the required task illuminance is achieved or supplementary task area lighting should be considered for these locations.

For the purpose of the above recommendation, each task area should be taken as the whole area within the space where required tasks may be performed. The physical boundaries of the task area will vary depending on the shape of the space, the nature of the task, and the layout and type of equipment required to perform the task.

3.8.3 Task area lighting

Refer to Table 3.2 for the recommended minimum uniformity of illuminance over a task area.

The illuminance on the immediate surrounds to the task area should preferably be not greater than the illuminance on the task area. Any change in illuminance should be gradual rather than sharp-edged.

3.8.4 Combinations of general and local lighting

Where the room contains one or more isolated task areas, each requiring a high illuminance which is supplied by local lighting, the average illuminance throughout the room should be not less than that recommended in Table 3.2. In addition, the transition between each area of high illuminance and the surrounding general illumination should be gradual rather than sharp-edged.

3.8.5 Adjacent spaces

Pronounced differences in the illuminance between adjacent spaces should be avoided, (refer to Table 3.2 for the recommended maximum ratio). Particular attention should be given to this aspect where people may move from a well-lit space into a less well-lit space in which hazards (obstacles, etc.) may be present.

Examples of this include a well-lit room adjoining a corridor or stairwell or, especially, the entrance to an indoor car park adjoining a day-lit street where rapid changes in visual adaptation are involved.

Spaces adjacent to entrances to buildings may need a higher illuminance during daylight than after dark; this may be provided by the electric lighting or by the admittance of daylight. In the latter case, care should be taken to ensure that the daylight source does not cause visual discomfort or disability.

3.9 FURTHER CONSIDERATIONS FOR TASK CHARACTERISTICS

3.9.1 Matt tasks

For a diffuse reflecting (i.e. matt) surface the luminance is proportional to the product of the illuminance on the surface and the reflectance of the surface. Therefore, the visibility of a given task with a matt surface can be increased (to a point) by increasing the illuminance on it.

However, remembering (Clause 3.3.3) that the visibility of task is significantly affected by the ratio between the luminances of the task, the immediate surrounds and the general surrounds, if these three elements all comprise matt surfaces and are all to be illuminated by general lighting, the means to increase the task visibility is to choose surrounds with appropriate reflectances. (Refer to Table 3.2).

3.9.2 Specular tasks

For a perfectly specular surface the luminance is proportional to the product of the environmental luminance in the direction of reflection and the reflectance of the surface.

3.9.3 Gloss tasks and the luminance factor

In practice, most surfaces are neither perfectly matt (i.e. diffuse reflecting) nor perfectly specular but have mixed reflection properties. Thus, the luminance depends both on the illuminance of the surface and on the luminances in the directions of reflection. Such surfaces are referred to as ‘glossy’.

As explained (Clause 3.9.1) for a matt surface the luminance is related to the illuminance by the reflectance. In order to create a similarly simple relationship between the illuminance and luminance of a glossy surface a ‘luminance factor’ was created. This term is defined in AS 3665 but, briefly, the luminance factor of a surface in a given direction under given lighting conditions is the ratio of the surface luminance in that direction to the luminance of a perfect white matt surface when lit identically.

Since glossy surfaces have mixed specular and diffuse reflection properties, it follows that for these surfaces the luminance factor will be constant and equal to its reflectance in all directions only in an environment of uniform luminance, for example, an indirectly lit white room. Under non-uniform conditions the luminance factor can vary between 0 (for a perfectly matt black surface) to values much greater than 1 when the surface is such that light sources can be seen reflected in it.

3.9.4 Surrounds

From Clause 3.9.3 it may be seen that the contrasts of tasks that are not perfectly matt are affected by the lighting, because they are determined by the luminance factors of detail and background which, in turn, are functions of reflectance, luminances and geometry.

It follows that for glossy tasks and surroundings not only is the illuminance of importance for good visibility but also the directionality of the lighting, which is a general term to describe the spatial distribution of the light incident at the task.

TABLE 3.2

LIGHTING PARAMETER FOR GENERAL LIGHTING— RECOMMENDATIONS

Parameter	Recommended range/value		
Maintained illuminance in[1] continuously occupied interior	(a) Provided by a general lighting system	≥160 lux	
	(b) As for (a) but with task lighting	≥160 lux (excluding the task lighting contribution)	
Typical working plane height	(a) Tasks at 'desk' height	0.7 m	
	(b) Tasks at 'bench' height	0.85 m	
Uniformity of illuminance[2],[3]	(a) Circulation spaces	≥0.3 (along the route)	
	(b) General lighting systems	≥0.5 (over the space)	
	(c) Task	≥0.7 (over task area)	
Illuminance ratio between adjacent spaces	Maximum[4]	10.1	
Maximum luminance ratio	Visual task	Immediate surrounds	General surrounds
	10	3	1

(1) These values may be superseded by lower minimum values specified in the AS(/NZS) 1680.2 series.

(2) Refer also to AS/NZS 1680.0 for minimum requirements for safe movement.

(3) Uniformity over the space excludes the contribution of specific task lighting and the influence of furnishing within the space. Refer Clause 3.8.1.

Task lighting uniformity should include the effect of objects and obstructions in the local environment.

(4) Consider need for lower ratio if there are hazards in the space with the lower illuminance.

NOTE: When evaluating a lighting system for compliance with the recommended maintained illuminance, it should be noted that the average illuminance in an interior cannot normally be determined to an accuracy of better than about 10%.

3.10 EXAMPLES OF VISUAL PERFORMANCE

Previous clauses in this section have addressed various factors affecting task visibility.

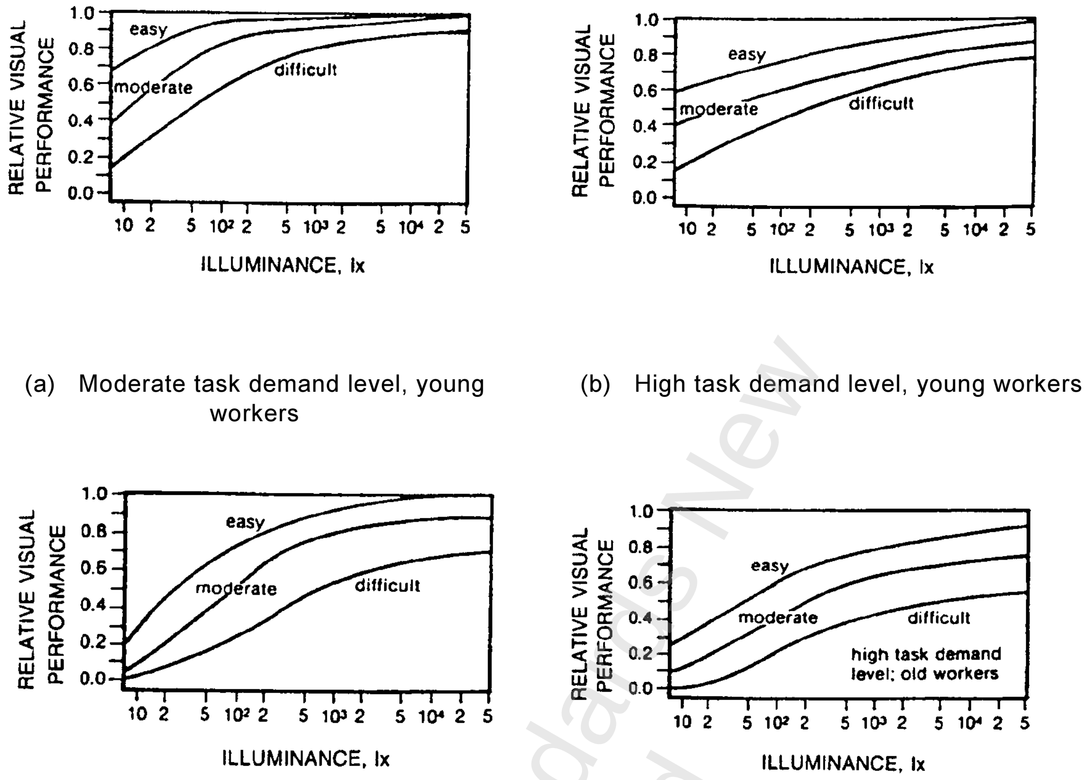
CIE 19.2 gives equations, tables and graphs describing the relationship between task illuminance and measured relative visual performance for various age groups and values of task difficulty and task demand level, these terms being defined as follows:

(a) *Task difficulty* is used to describe the intrinsic visual difficulty of the task display and includes factors such as apparent size of the critical detail, reflectance contrast between the detail and the background, form of the detail, informational requirement, etc.

(b) *Task demand level* includes the demands imposed on the oculomotor functions for ocular search and scanning and demands on speed or accuracy of performance.

(c) *Age* is used as a parameter to represent the quality of the visual system as a function of the optical qualities of the eyes, of glare sensitivity, of response of the ocular muscles, etc. In general the individual quality of the visual system of a worker, assuming proper optical correction, can be expressed as that of a certain age group so that an equivalent visual age can be assigned to a particular worker depending on the quality of his/her visual system. This visual age may be higher or lower than the actual age of the worker. However, for some kinds of deficiencies of the visual system an increase of illuminance by itself will be effective for improving visibility.

Some of these results are summarized in Figure 3.4.



(a) Moderate task demand level, young workers

(b) High task demand level, young workers

(c) Moderate task demand level, old workers

(d) High task demand level, old workers

FIGURE 3.4 RELATIVE VISUAL PERFORMANCE AS A FUNCTION OF TASK ILLUMINANCE, VISUAL TASK DIFFICULTY, TASK DEMAND LEVEL AND AGE GROUP

Comparing the figures from left to right reveals the effect of task demand level. Comparing the figures from top to bottom reveals the effect of age. For any given target value of relative visual performance it can be seen that the required values of illuminance are higher the more difficult the task, the higher the task demand level and the higher the age of the workers. It can also be seen that an increase of illuminance cannot compensate for task difficulty, task demand level and age under all circumstances. For instance a target value of 1.0 can be obtained only for easy tasks of moderate demand level.

3.11 DEPARTURES FROM THE RECOMMENDED MAINTAINED ILLUMINANCES

3.11.1 General comments

The maintained illuminances given in Table 3.1 and in the AS(/NZS) 1680.2 series have proven to be adequate for the provision of effective and economical lighting for healthy adults with any appropriate refractive correction. Further, if these recommendations regarding room surface reflectances (Refer to Section 6) are followed, the maintained illuminances should result in satisfactory surface luminances when using a general lighting system. The following clauses give advice on the use of illuminances other than those recommended.

3.11.2 Higher values of maintained illuminance

(a) The following are some circumstances where higher maintained illuminance values may be justified:

  (i) *Aged people* As the eye ages its transmittance is reduced resulting in less light reaching the retina. Further, there may be intra-ocular scatter of light which reduces contrast sensitivity. In spaces where all or the majority of occupants are aged, improved seeing may result from higher maintained illuminances (say one or two steps higher in the Table 3.1 scale), provided that glare effects are also controlled. Where possible, efforts should be made to increase task contrast rather than increasing illuminances.

  (ii) *Speed and accuracy of performance are paramount* These requirements might arise in situations where errors could have serious effect. One step higher in the Table 3.1 scale might be considered in these cases.

(b) The following are some circumstances where higher maintained illuminance values have been used:

  (i) *Low reflectances with a general lighting system* Low luminance interiors can be the result of low room surface reflectances or the use of high screens and partitions in interiors, e.g. work stations. To some extent room surfaces will appear brighter if a higher maintained illuminance is used. However, this is an inefficient way of brightening the ceiling and walls, since the floor cavity is the least reflective surface. Consideration should be given to wall washing or installing perimeter luminaires closer to the bounding walls.

  (ii) *Luminaires with low cut-off angles* These are often used in offices with screen based equipment and in reception areas, lobbies, etc. As in (i) higher maintained illuminances may improve the appearance of these spaces but, again, it is an inefficient way to brighten the room surfaces.

3.11.3 Lower values of maintained illuminance

The objectives of Clause 3.6 are the achievement of good seeing conditions for task performance and the creation of a pleasant visual environment. As noted in Clause 3.11.1 these objectives are usually achieved by using only a general lighting system. However, the objectives can be achieved by using a mix of lighting systems, e.g. task lighting and environmental lighting. Therefore a lighting designer may, with the agreement of the client, use maintained illuminance values other than those recommended in Table 3.1 and AS(/NZS) 1680.2, provided that this is the result of task analysis and documented with supporting arguments. In doing so, it is essential that the lighting designer applies the methods set out in AS/NZS 3827 and follows the recommendation in Table 3.2 regarding the minimum maintained illuminance in continuously occupied interiors.

SECTION 4 DIRECTIONAL EFFECTS OF LIGHTING

4.1 GENERAL CONSIDERATIONS

The directional distribution of light in a space is important to the appearance of objects and consequently for both task performance and the perception of the space. The effect of directional lighting on the appearance of objects depends on the form and the surface characteristics of the objects. The effect of the directional distribution of light on an object can be described in terms of—

(a) the illuminance pattern;

(b) the highlight pattern; and

(c) the shadow pattern,

but no complete description of the way in which lighting affects the appearance of objects has yet been developed.

4.2 MODELLING AND SHADOWS

4.2.1 Diffuse and directional light

The effect which a lighting system has on the subjective appearance of a room depends on the modelling and shadow conditions produced by a mixture of diffuse and directional light. The latter may be controlled by the use of different lighting systems, by appropriate positioning of luminaires and, to a lesser extent, by varying the reflectance of the room surfaces.

The recommendations of Section 6 are intended to ensure the provision of modelling and shadow conditions which will be satisfactory for most spaces. However, requirements for other interiors may vary depending on the type of activity which is to take place and on personal tastes. The effects that lighting systems produce can vary from the extremes of highly diffuse to highly directional lighting, as follows:

(a) Highly diffuse lighting, such as from a luminous ceiling, provides even overall illumination with little shadow or modelling in the task.

(b) Highly directional lighting, such as from downlights, spotlights or direct sunlight, provides uneven general illumination, sharp deep shadows and harsh modelling.

A combination of diffuse and directional light is almost always required, with some diffuse lighting (perhaps by inter-reflection) to avoid undesirable dark areas with hard dense shadows, and some directional lighting to provide recognition of three dimensional objects and to impart ‘sparkle’ and ‘life’ to the environment.

The desired proportions of directional and diffuse illumination depend on a variety of factors and proportions are at present largely a question of experience, but Clause 4.2.3 provides a means for predicting the effect on the environment in terms of the vector/scalar ratio at any point in the interior.

4.2.2 Particular effects

Account should be taken of the following points which have an effect on modelling and shadow conditions:

(a) A small light source causes hard, dense shadows and sharp modelling; multiple small sources cause multiple hard-edged shadows which become less dense as the number of sources increases. Multiple shadows also tend to destroy modelling and may be confusing.

(b) A large area source, such as a nearby window or luminous panel, tends to produce soft-edged shadows and soft but well-defined modelling.

(c) Room surfaces of high reflectance increase diffusion and soften shadows. Low reflectance surfaces, by decreasing diffusion, accentuate shadows.

(d) Local lighting can be arranged to provide desired task shadow, modelling and reflections, in a room having diffused lighting. This technique is particularly useful for inspection tasks.

(e) The 'liveliness' of coloured objects, particularly if glossy, can be enhanced by highlights produced by the reflection of a small bright light source.

4.2.3 Vector/scalar ratio

The strength of directional lighting at a point can be quantified by the ratio of the magnitude of the illumination vector to the scalar illuminance (see Paragraph B4.1, Appendix B). This quantity is known as the vector/scalar ratio. The direction of the flow of light is given by the direction of the illumination vector. Figure 4.1 displays examples of different vector/scalar ratios and different illumination vector directions and describes some typical lighting conditions in which these appearances are produced. No single value of vector/scalar ratio is right for all purposes but, for general use where the perception of faces is important, vector/scalar ratios in the range of 1.2 to 1.8 will be satisfactory.

There is some evidence that directions of the illumination vector in the range 15 degrees to 45 degrees from the horizontal are preferred. This condition can be readily achieved in rooms lit during daytime by side windows but is very difficult to achieve at night when only electric light is in use. For practical reasons, most electric lighting is ceiling mounted, so the vector direction is almost always vertically downward. If, for this situation, the vector/scalar ratio is high, harsh and unnatural shadows will be produced on the face. To overcome this situation the lighting designer has to rely on light reflected from the room surfaces to soften the shadow.

4.3 REVEALING TASK CHARACTERISTICS

Clause 4.2 gives indications as to how certain task attributes can be revealed, particularly three-dimensional ones. It follows from Clause 4.2 that the form of an object depends not only upon revealing it but lighting it in such a way that the directions of its surfaces are revealed. The texture of a surface can be revealed in a similar way, i.e. by using a combination of diffuse and directional lighting. Gloss is revealed by producing reflections of, preferably, small bright sources in the surface.

These lighting effects are important in inspection tasks where defects have to be detected in materials, where there may be no inherent luminance contrast; so shadow and highlight can be used to advantage. For example, Figure 4.2 shows how grazing directional light (i.e. light almost parallel to the surface under examination) can be used to reveal a pulled thread in a fabric by casting a shadow on one side and a brighter area on the side facing the light source.

In other cases, inspection may employ other lighting techniques, such as the reflection of a grid of lines in a gloss surface to check flatness. Transparent liquids in transparent containers can be viewed against a luminous panel in order to reveal the liquid level.

4.4 REVEALING THE ENVIRONMENT

Areas such as foyers, lift interiors, boardrooms, showrooms and the interiors of buildings such as dwellings, churches, restaurants, hotels, motels and theatres are sometimes seen as special cases where lighting for effect and atmosphere takes precedence over lighting the task. There certainly may be greater emphasis on lighting for effect but all lighting involves revealing both the task and the environment in which the task is placed.

The techniques referred to in the preceding clauses can be applied to revealing the architectural environment and the greater the need for lighting for effect and atmosphere the more the qualified lighting designer can exploit the extremes of the directional effects of lighting.

Details on the various approaches to non-task lighting are beyond the scope of this Standard.

More information on the influence of lighting systems on the appearance or atmosphere of the interior is provided in Clause 11.2.4.

<table>
<tr><th>Vector direction between 15° and 40° below horizontal</th><th>Vector direction predominantly vertically downwards</th><th>Vector/scalar ratio and directional strength</th><th>Typical assessment of directional qualities</th><th>Typical conditions</th></tr>
<tr><td></td><td></td><td>3.0
Very strong</td><td>Strong contrasts; detail in shadow not discernible</td><td>Selective spotlighting; direct sunlight</td></tr>
<tr><td></td><td></td><td>2.5
Strong</td><td>Noticeably strong directional effect; suitable for display, generally too harsh for human features</td><td>Luminaires of narrow light distribution, low flux fraction ratio, dark floor. Windows on one side, dark surfaces</td></tr>
<tr><td></td><td></td><td>2.0
Moderately strong</td><td>Pleasant appearance of human features for formal or distant communication</td><td rowspan="2">Luminaires of narrow light distribution with medium or light floor. Luminaires of medium or wide light distribution with dark floor. Side windows with light room surfaces.</td></tr>
<tr><td></td><td></td><td>1.5
Moderately weak</td><td>Pleasant appearance of human features for formal or close communication</td></tr>
<tr><td></td><td></td><td>1.0
Weak</td><td>Soft lighting effect for subdued contracts</td><td>Luminaires of medium or wide light distribution with light floor. Side windows in opposite walls</td></tr>
<tr><td></td><td></td><td>0.5
Very weak</td><td>Flat, ‘shadow-free’ lighting; directional effect not discernible</td><td>Luminous ceiling or indirect lighting with light room surfaces</td></tr>
</table>

NOTE: See Appendix B for methods of measurement for vector/scalar ratio.

FIGURE 4.1 RELATIONSHIP OF VECTOR/SCALAR RATIO TO ASSESSMENT OF DIRECTIONAL QUALITIES OF THE LIGHTING

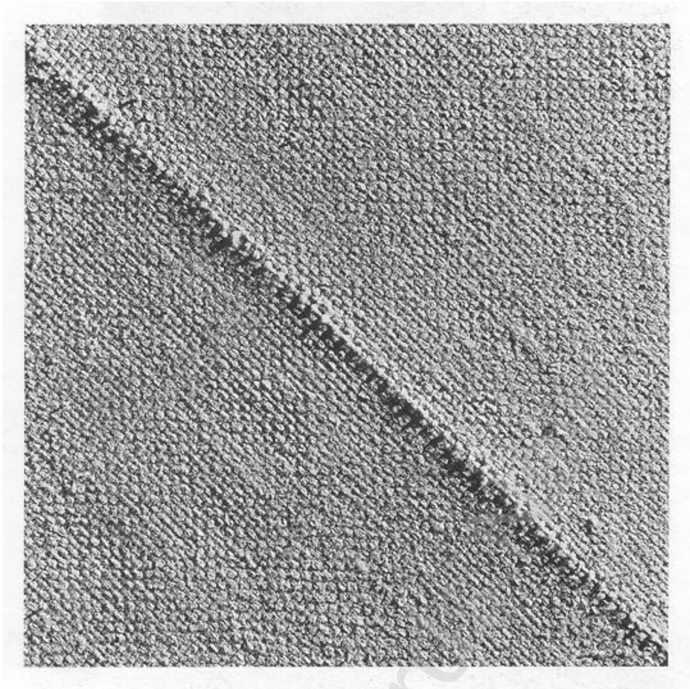
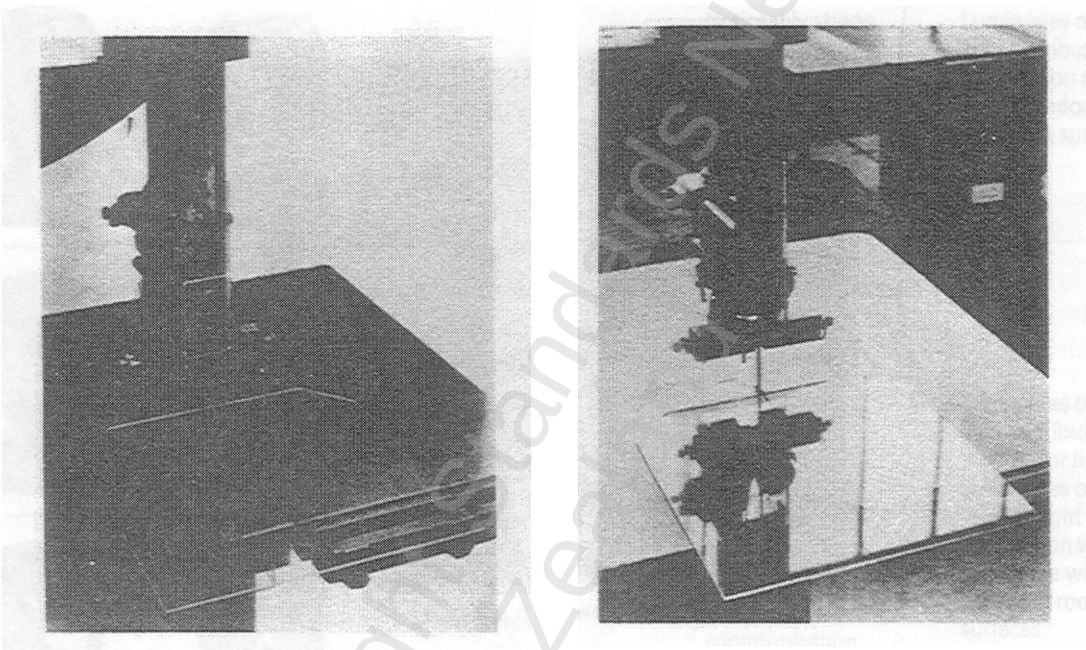


FIGURE 4.2 DIRECTIONAL LIGHT SHOWS A PULLED THREAD IN A FABRIC

SECTION 5 UNWANTED REFLECTIONS

5.1 GENERAL CONSIDERATIONS

Veiling reflections are high luminance reflections which overlay the detail of the task (see Figure 5.1). Such reflections may be sharp edged or vague in outline, but regardless of form task performance may be affected because veiling reflections usually reduce the contrast of a task, thus making task details difficult to see and causing discomfort. The use of screen-based equipment makes the consideration of unwanted reflections more important than when the majority of visual tasks were matt and on the horizontal plane.



(a) No appreciable veiling reflection

(b) Veiling reflection over large portion of visual task surroundings

FIGURE 5.1 THE EFFECTS OF VEILING REFLECTIONS

Two circumstances must exist before veiling reflections occur. The first is that part of the task (either task detail, background, or both) is glossy to some degree. The second is that the part of the interior which is specularly reflected towards the observer (called the offending zone) has a higher luminance than other parts of the interior. The most common sources of such high luminances are windows and luminaires. The most generally applicable methods of avoiding veiling reflections are to use matt materials in task areas or to arrange the geometry of the viewing situation so that the luminance of the offending zone is low.

The magnitude of the effect of the veiling reflections occurring on a two-dimensional task at a particular position can be quantified by the contrast rendering factor, as explained in Clause 5.7.

It should be noted that although veiling reflections are usually detrimental to task performance there are some circumstances in which they are useful, e.g. inspection lighting.

5.2 RELATIVE LOCATION OF TASKS, LIGHT SOURCES AND SCREENING

Whenever possible, the relative position of the task and any luminaires or windows should be so arranged that unwanted reflections are not visible in or around the task when the latter is viewed from the normal working position.

Though often difficult to achieve in practice, appropriate location or orientation of the task is by far the most effective way of preventing veiling reflections. In offices, desks should preferably be placed between the rows of luminaires rather than directly under them and the sides of the desks should preferably be parallel to the long axis of relevant elongated luminaires.

In offices intended to have a regular desk layout, the long axes of the luminaires should be parallel to the window wall, with the outermost row as close to it as possible and the desks set out as above. In offices which have an irregular desk layout, small adjustments in the final position or orientation of individual desks can effect a considerable reduction in veiling reflections.

The principles set down above apply both to horizontal and vertical tasks but, in the case of the latter, and especially for gloss tasks, such as screen-based equipment, some advantage may be obtained by the use of partition screens to limit reflections of windows and lighting equipment. Partition screens can also reduce distractions resulting from extraneous movement seen either directly or by reflection in the task. (See also Clause 5.6.)

5.3 USE OF LOCAL LIGHTING (INCREASING TASK ILLUMINANCE)

When it is not possible to eliminate veiling reflections by following Clause 5.2, their effect should be minimized by raising the task illuminance without increasing the (reflected) source luminance.

Typical examples are the use of adjustable luminaires located at drawing boards, and the use of small local lights under instrument cover-glasses. The additional illuminance provided serves to swamp veiling reflections (and their contrast-diluting effect) caused by overhead luminaires.

The illuminance required depends on the luminance of the source producing the reflections and the nature of the task itself.

Care should be taken to ensure that the luminaires used to provide this additional light—

(a) are positioned in accordance with the recommendations of Clause 5.2; and

(b) adequately screen the lamp(s) from the view of the operator and other workers in the vicinity, when the luminaire is correctly aimed.

NOTE: Luminaires which do not provide sufficient shielding, or which are incorrectly aimed in use, can cause visual discomfort or annoyance.

5.4 LIMITATION OF SOURCE LUMINANCE

When veiling reflections are likely to be a serious problem, and neither of the methods described in Clauses 5.2 and 5.3 can be applied, an attempt should be made to reduce the luminance of the source producing the reflections. Alternatively, the tasks should be screened so as to prevent light falling on it from the unsuitable direction.

Interiors lit totally by indirect lighting or luminous ceilings exhibit a high task illuminance to source luminance ratio. This fact can be used to advantage however, the results are inferior to those obtainable by the methods recommended in Clauses 5.2 and 5.3. These forms of lighting are also unsatisfactory in other ways and should only be used as a last resort unless care is taken to avoid excessive ceiling luminance uniformity.

This is because the ceiling is usually the largest visible surface and, if it is uniformly bright, can have a disturbing, overbearing effect. Further, in low luminance situations, the ceiling can make the space appear soporific and/or gloomy.

5.5 AVOIDANCE OF GLOSSY SURFACES IN VISUAL TASK SURROUNDS

Glossy surfaces in the surroundings of the visual task should be avoided as far as possible. In particular—

(a) surfaces of machines should have a non-glossy finish;

(b) plated parts (especially scales or dials) should have a satin finish; and

(c) desk, table and bench tops, and floors should not have high-gloss, dark-coloured surfaces which can reflect well-defined images of overhead light sources or bright areas seen through doors or windows. Desks and information areas should not be covered with glass or transparent plastics.

The distracting effect of these images is related to their conspicuousness rather than their brightness. Although non-glossy materials are preferable for desk tops, satin finishes are acceptable provided they are light in colour, as recommended in Clause 6.3.5.

5.6 REFLECTIONS IN SCREEN-BASED EQUIPMENT

The screen of an item of screen-based equipment can behave somewhat like a mirror and, frequently, high luminance objects are reflected from the screen towards the operator, and become a potential cause of complaints. Such reflections are seen in the screen superimposed on the text and can both reduce the contrast (and hence the visibility of the display) and be distracting if they occur outside the immediate task surrounds areas. In addition, sharply defined high luminance reflections can constitute misleading cues about the distance at which the eyes should be focussed. Screen technology has improved regarding brightness, lower specular reflectance and flat surfaces reducing reflection and contrast dilution problems.

The effects of veiling reflections in screen-based equipment can be reduced or eliminated by one or more of the following approaches:

(a) The reflections can be reduced either by selecting a screen which has been treated in some way (e.g. coating the surface of the screen) or by using a curved circularly-polarizing filter which is placed in front of the display screen.

(b) For colour displays with negative contrast (e.g. dark writing on a light background), the luminance of reflections can be lower than the background luminance of the display, in which case the high luminance reflections will be less pronounced although a reduction in contrast of the characters may still occur.

(c) The most common sources of high luminance in an interior are the sky, seen through windows, and the luminaires. The first can be screened off by means of blinds or curtains. Preferably, screen-based equipment should be placed so that the operator's line of sight is parallel to the axis of elongated luminaires and to the windows. (Refer to Clause 5.2).

(d) Remembering the basic principle of minimising the effects of veiling reflections i.e. that the luminances of those parts of the interior which the operator does see reflected in the screen should be uniform and low, the luminance of any luminaires, or any other sources of high luminance, which the operator might see reflected in the screen-based equipment, should be as low as possible.

NOTE: For further guidance, refer to AS 1680.2.2.

5.7 CONTRAST RENDERING FACTOR

Various attempts have been made to produce design aids to predict the effects of the unwanted reflections produced by bright sources in tasks. The most promising of these is the concept of the contrast rendering factor (CRF) since it can be calculated, provided that sufficient task, environmental, source and operator position details are available and it can be measured using a suitable measuring instrument.

Basically, CRF gives an indication of how well the contrasts in a task are revealed when viewed in the relevant space compared with when the task is viewed illuminated by a uniform hemispherical source. Because almost all tasks contain some gloss the complex reflection properties (luminance factor) of the task must be known before the CRF can be calculated. However, a standard task, similar to paper-based office tasks, has been developed and can be used for both calculation and, in its physical form, for measurement.

Where the lighting designer wishes to assess in numerical terms the contrast diluting effects of a chosen lighting system, the calculation of CRF should be considered. Further details are given in CIE 19.21.

SECTION 6 SURFACES

6.1 GENERAL CONSIDERATIONS

Lighting involves the creation of suitable luminances within the field of view both for task performance and for the creation of a suitable visual environment.

The effect a lighting system creates in an interior is strongly influenced by the properties of the room surfaces, the relevant properties being reflectance and colour. For this reason, if for no other, the lighting designer should always attempt to identify the relevant details of the proposed surface finishes early in the design process.

Clearly, the properties of the room surfaces affect the appearance of the space however, in conjunction with suitably distributed illumination, correctly chosen finishes on the ceiling, walls, furniture and plant can help to increase the amount of light reaching the task; improve diffusion of light and soften shadows; eliminate excessive variations in the brightness distribution; and minimize veiling and distracting reflections.

The recommendations which follow are concerned mainly with the average reflectance of large areas and leave the lighting designer ample scope to introduce variety with hue and pattern.

NOTE: Appendix D gives information on the calculation of the average reflectance of room surfaces and the effective reflectance of cavities, such as ceiling and floor cavities.

6.2 SURFACE REFLECTANCES FOR EFFICIENT LIGHT DISTRIBUTION

In order to maximize the utilization of the light available from a lighting system it is desirable to have higher surface reflectances as these will facilitate the interreflection of light, minimize the number of lamps required and promote the effective use of daylight.

However, while it is important, in general, to achieve as high a room utilization factor as possible this should not be achieved at the cost of appearance and comfort. Therefore, the recommendations of Clause 6.3 must take precedence over the need for efficiency.

6.3 SURFACE REFLECTANCES FOR GOOD SEEING CONDITIONS

6.3.1 Importance of room surface reflectances

For any space, apart from the lighting equipment (luminaires, windows, etc.) the luminances of the field of view are created by the reflection of the light by the bounding surfaces of a space and the equipment, furnishings and decorations placed within the space. In most interiors, the most important of these are the bounding surfaces—walls, ceiling and floor—due to their size. Therefore, the reflectances of these surfaces should be selected with appropriate consideration.

6.3.2 Ceilings

6.3.2.1 *Introduction*

The properties of the ceiling affect both the viewer's perception of the room and the illuminance on the working plane. (Refer to Section 10 for further information on the relationship between ceilings and lighting equipment.)

6.3.2.2 *Size*

In large rooms the ceiling significantly affects the illuminance provided to the working plane due to the high proportion of its area to the total relevant surface area. (Refer to Paragraph D5 for the formula for Room Index.) The ceiling of a large room also frequently forms a large proportion of the visual field due both to its size and the tendency for large rooms to provide few obstructions between the viewer and the ceiling.

In smaller rooms the contribution of the ceiling to the working plane illuminance is less significant and the ceiling typically forms little, if any, part of the visual field.

6.3.2.3 *Reflectance*

For interiors lit from the ceiling, the significance of the ceiling reflectance on the illuminance of the working plane increases as the room index increases. In fact it is recommended that the effective reflectance of the ceiling cavity should be at least 0.6, which usually requires a surface reflectance of at least 0.8. A white or near white ceiling is usually required to produce this value.

Where the ceiling forms a significant part of the visual field the luminance of the ceiling plays a key role in establishing the viewer's adoption level and perception of other luminances in the field of view. A dark ceiling can cause the whole space to appear under lit and, due to high contrast levels, lighting equipment such as luminaires and windows can appear glaring. A bright ceiling can be distracting. In regard to this consideration, the desirable reflectance value for large ceilings especially is 0.8.

In small rooms, where the ceiling typically forms a small part of the visual field, a ceiling of lower reflectance (i.e. darker) can produce acceptable levels of working plane illuminance but if too low a reflectance is chosen the room can appear gloomy, especially if illuminated predominately by side windows.

6.3.2.4 *Indirect lighting*

Where indirect lighting is used, including uplighting i.e. where the ceiling is illuminated from below to become the source of general lighting, a white or near-white ceiling (i.e. reflectance of 0.8) is usually the ideal. However, as high ceiling illuminances can cause distraction or act as a large-area glare source the details of the incident light should be designed in accordance with Clauses 8.3.4.7 and 10.5.2.

6.3.2.5 *Acoustic and thermal ceilings*

The effective reflectance of acoustically treated ceilings is often reduced due to the use of cavities or rough surface textures. Therefore the reflectance of the finish should be as high as possible to achieve the recommendations in Clauses 6.2, 6.3.2.3 and 6.3.2.4.

Some acoustic and thermal barriers used as ceiling treatments employ a rippled aluminium surface. These, because they are specular, can have a low surface brightness from some directions and can therefore appear dark. On the other hand they can also reflect light sources producing very high luminances in the field of view.

6.3.2.6 *Luminous ceilings*

Luminous ceilings are governed by the same principles as highly reflective, or highly lit non-luminous ceilings, therefore care is needed in their use. To minimize discomfort glare for the occupants of the interior, the luminance of the ceiling should not exceed the values recommended in Clause 8.3.4.7. (See also Clause 10.4.2.4.)

6.3.3 Walls

6.3.3.1 *Introduction*

The contribution of wall reflectances to the illuminance on the working plane in a room is relatively small, except in areas adjacent to the walls. However the wall reflectances are important to the appearance and comfort of a room.

6.3.3.2 *Basic principles*

In order to maximize the contribution of the walls to the illuminance levels in a room, it is tempting to use high wall reflectances. However there are several potential negative consequences to this.

Large areas of high reflectance can compete for attention with the visual task causing fatigue and discomfort. Also, if the high reflectance is achieved by the use of a glossy finish glare by reflection is likely to occur.

In working interiors, the average reflectance of the principal walls should be between 0.3 and 0.7.

6.3.3.3 *Windows and other surface interruptions*

In a typical room, to allow for the effects on the overall wall reflectance of objects with a low reflectance such as windows (typical reflectance 0.1), furniture, wall hangings, curtains etc, the wall finish should have a reflectance value greater than 0.5 for the overall value to be above the recommended 0.3 minimum. The recommended maximum will typically only be reached with a light coloured finish on a blank wall free of any of the above interruptions.

Further, for a wall containing one or more windows, the reflectance of the opaque surfaces including the window framing and trim, should be not less than 0.6 in order to reduce contrast with the bright, daylight scene outside.

6.3.3.4 *Specific applications*

Where the perception of people's faces is particularly important, e.g. lecture theatres and conference rooms, the reflectance of walls which form the background against which people are seen should not exceed 0.6.

Where the task is very light in colour, as in offices where much white paper is used, walls and furniture should be reasonably light in colour and adequately lit. There should not be too great a difference in reflectance between upper and lower walls and the lower portion of walls which may fall within the field of vision when viewing the task should not be of noticeably higher brightness than the task area.

6.3.3.5 *Practical considerations*

Keeping in mind the above guidelines, where it is desired to use a darker colour on the lower part of a wall in order to avoid marking etc, a finish of reflectance not less than 0.25 may be used.

6.3.4 Floors

In installations utilizing recessed luminaires it is important that the floor has a high reflectance as the illumination of the ceiling is largely dependent on light reflected from the floor. Further, dark floor cavities will tend to make ceilings and walls look underlit, especially when daylight from side windows is used. However, light coloured floors typically create a maintenance problem.

With these influences in mind, it is recommended that the floor cavity reflectance be in the range 0.2 to 0.3. This might require choosing light coloured surfaces (such as furniture) within the floor cavity to offset the reflectance of a necessarily darker floor surface.

The reflectance of the floor surface in working areas should not be greater than 0.4 and highly polished floors, especially if dark in colour, should be avoided (see also Clauses 5.5 and 6.4).

6.3.5 Furniture and equipment

Machines and equipment (including cupboards, racks and benches) which fill a substantial part of the field of view should generally be finished in light or medium colours with reflectances of between 0.2 and 0.5. Furniture, particularly the tops of desks and tables, should be similarly finished. Darker colours should only be used where the surfaces are likely to become soiled or marked very quickly, where the task itself is dark, or on the outer surface of machine guards through which the task is viewed.

6.4 NATURE OF SURFACE FINISHES

In general, matt finishes provide a more uniform brightness distribution than glossy finishes because they improve diffusion and do not give rise to reflected highlights. Polished or glossy surfaces, particularly if dark in colour, reflect highlights which may cause distraction and gloss finishes on surfaces above eye-level often show up irregularities.

Therefore, on walls (especially above eye-level), on ceilings, and on large horizontal surfaces below eye-level (e.g. floors, table and bench tops), non-glossy finishes should be used wherever practicable.

Where glossy finishes on machines or equipment are essential to withstand hard wear and soiling, they should be as light in colour as is practicable (but should not result in higher luminances than the task). Where a matt finish is likely to deteriorate rapidly (e.g. from attack by steam or oil), a semigloss or satin finish is to be preferred to full gloss.

6.5 COLOUR OF SURFACES

The colours of surfaces in a room interact with the lighting.

High value colours provide a scheme that is bright but visually interesting.

Having some areas of high chroma colours in a space adds interest, but large areas of high chroma colour can be overpowering and may also darken the space. Also, reflected light from surfaces of high chroma colour can alter the colour of the rest of the space, requiring changes to the lighting.

For further detail, refer to Appendix E.

6.6 COLOUR FOR IDENTIFICATION AND SAFETY

6.6.1 Basic principles

The simple colour scheme recommended in Paragraphs E.1.2 and E.1.3 provides an unobtrusive background to items of special importance requiring identification with eye-catching touches of bright colour. However, to be effective the technique should be used with great restraint and only when there is a genuine need for such colour treatment.

This applies particularly to colour used for safety purposes. Safety colours should only be used in those rare cases when a potential hazard can neither be eliminated nor effectively guarded.

Moreover, since the purpose of safety colour is to attract attention it is essential to employ brightness contrast as well as colour contrast.

One reason for the effectiveness of the yellow and black diagonal stripe pattern often used to identify hazards is that it combines vivid colour and a high brightness contrast. However, to be really eye-catching, the stripes should be bold enough to be readily perceived out of the corner of the eye.

6.6.2 Standard safety colours

Colours used to identify hazards and safety equipment (such as fire appliances, first-aid facilities, etc.) should comply with AS 1318. These particular colours should be strictly reserved for the purposes specified in that Standard.

Where lines of sight to safety equipment or facilities might be blocked the location may be effectively indicated by placing an appropriately coloured patch on the wall above the equipment (or coloured band if on a column), at least 2 m above the floor.

6.6.3 Colour for identification

Identification colour should not be more prominent than functional needs require and should not be used for decoration.

The identification needs of some pipelines and ducts might require their entire surface to be an appropriate identifying colour. However, where this is not the case, pipelines and ducts should be made an inconspicuous part of the whole scheme and merely colour-banded at a few strategic points in accordance with AS 1345.

Stop controls (or other safety tripping devices) on machines should be colour-identified to enable anyone to find them in an emergency and non-emergency controls should not be coloured unless there is some special reason for doing so.

However, inconspicuous patches of particular colour and shape may be used to assist maintenance procedures. An example is the indication of lubrication points, the correct lubricant, and how often each point should be given attention.

The edge of each step in a stairway can be highlighted by a single, bold, contrasting stripe set back about 35 mm from the front edge of the tread, making the stairway quicker and safer to descend in an emergency, especially in dim illumination caused by the failure of one or more luminaires. This treatment is more effective than multiple striping.

6.7 AVOIDING DISTRACTING PATTERNS

The provision of large areas of wall with conspicuous closely-spaced lines or unbroken regular dot patterns such as can occur with some acoustic or decorative treatments, cause visual discomfort and should be first considered in conjunction with the following:

(a) Dot patterns (e.g. wall linings of perforated material) only cause trouble when they are closely spaced and completely uniform over a large area. Any random pattern (even the grain in natural timber) which provides something for the eyes to fix on will prevent this particular ill-effect.

(b) Line patterns (e.g. light-coloured battens alternating with dark cavities) produce disturbance of a different kind, but it has been found that this only occurs when the space between adjacent lines subtends less than 1 degree at the observer's eye (i.e. when the spacing of the lines is less than about one-sixtieth of the viewing distance).

    NOTE: Further information on this can be found in Ref.3.

SECTION 7 LIGHT SOURCE COLOUR

7.1 GENERAL CONSIDERATIONS

Light sources have two colour properties related to the spectral composition of their emission. One is the apparent colour of the light that the source emits and the other is the effect that the light has on the colours of surfaces. The former effect is called colour appearance and the latter, colour rendering.

When a light source is being chosen, the colour properties of the source should be considered in addition to economic considerations such as its efficacy and life.

Whilst individual coloured light sources can be used for decorative effects, considerable restraint should be exercised in the use of monochromatic or strongly coloured light sources, particularly for the general lighting of interiors, as the effects of carefully chosen surface colours are diluted or distorted when the whole of the visual field is subjected to a single strong colour.

This Section refers to the attributes of electric light sources but it should be noted that daylight exhibits wide variations in colour appearance, from the extremes of 'warmness' at sunset to 'coolness' in areas of shadow illuminated by the light of the clear blue sky. However, during most of the day and irrespective of the sky conditions, daylight provides a continuous spectrum and hence good colour rendering properties.

7.2 COLOUR APPEARANCE OF SOURCES

The colour appearance of near white light sources is normally defined in terms of their correlated colour temperature (CCT), expressed in kelvin (K). The higher the correlated colour temperature the cooler the appearance of the source; the reddish-yellow flame of a candle is about 1900 K; the ordinary incandescent lamp, about 2800 K; and cool bluish-white south sky daylight, over 6500 K.

Each lamp type has a specific correlated colour temperature but for practical use, the correlated colour temperatures have been grouped into three classes by the International Commission on Illumination (CIE), as set out in Table 7.1.

TABLE 7.1

CIE LAMP COLOUR APPEARANCE GROUPS

Colour appearance group	Colour appearance	Correlated colour temperature, K
1	warm	<3300
2	intermediate	$3300 \leq 5300$
3	cool	>5300

NOTE: The term 'cool' used throughout this document equates to the colour appearance range designated 'cold' in ISO 8995/CIE S008/E.

The choice of an appropriate apparent colour of light source for a room is largely determined by the function of the room. This may involve such psychological aspects of colour as the impression given of warmth, relation, clarity, etc., and other considerations such as the need to have a colour appearance compatible with daylight and yet to provide a white colour at night. The following are some general rules to help with the selection of apparent colour:

(a) For rooms lit to a maintained illuminance of 240 lx or less, a warm or intermediate colour is preferred (see Clause 7.5.2); cool apparent colour lamps tend to give rooms a gloomy appearance at such illuminances.

(b) Lamps of different correlated colour temperature should not be used in the same room unless a specific effect is desired.

7.3 COLOUR RENDERING OF SOURCES

The colour rendering properties of a light source are dependent upon its spectral energy distribution. The desired colour appearance of an illuminated object will only be obtained if the light source contains all necessary spectral components in suitable proportion. The colour rendering properties of a light source can be measured and described according to the CIE Colour Rendering Index system.

The CIE Colour Rendering Index special system expresses for any one of fourteen specific colours when illuminated by the light source in question, the degree on a scale of 1 to 100 to which the appearance conforms to that of the same colour illuminated by a reference light source of similar colour temperature. The general symbol for the Special Colour Rendering Index is R_i and any light source can have up to 14 R_i values determined (i.e. R_1 R_{14}) where each value of i refers to the specific colour for which the colour rendering quality of the source has been determined.

The R_i index system refers to single colours only, but the average of values R_1 to R_8 constitutes the CIE General Colour Rendering Index, designated R_a. This average figure gives a general indication of the overall colour rendering properties of a lamp. The colour temperature of the source should also be taken into account when assessing the suitability of the lamp. If the colour temperature is below 3000 K, a high R_a value means that the source will give results similar to that of an incandescent lamp (R_a = 99), which is ideal for some purposes. On the other hand, if colour rendering similar to that in daylight is necessary, the lamp should have an appropriate correlated colour temperature in addition to a high R_a value. The high-efficacy tubular fluorescent lamps normally used in factory and office installations have R_a values in the range 80-90. Special lamps with R_a values greater than 90 are also available in a selection of correlated colour temperatures.

The CIE general colour rendering index (R_a) is the most widely accepted measure of the colour rendering properties of light sources and further information on the practical significance of R_i and R_a is given in CIE 13.3.

Table 7.2 gives recommendations on appropriate light source colour properties for various purposes.

7.4 NATURE OF THE TASK

Where visual tasks involving good colour judgement are to be performed, electric light sources with high CIE general colour rendering indices (i.e. from Groups IA or IB) are necessary. Where colour matching is to be done, lamps of colour rendering group IA of appropriate correlated colour temperature should be used. The surfaces of surrounding areas where accurate colour judgements are being made should be of weak chroma (not greater than /1) and medium reflectance (not less than 0.4). A maintained illuminance of at least 600 lx should be provided on the task. For further detail on accurate colour matching, refer to AS 4004.

Where the task is one that requires giving special consideration to colour rendering, further advice will be given in the appropriate Standard in the AS(/NZS) 1680.2 series. These cases are comparatively rare because few industrial and office tasks need a colour rendering better than that provided by conventional tubular fluorescent lamps, and many tasks are even less demanding. However, the exceptions can present special problems because requirements vary from task to task. In some cases, the full range of hues may have to be accurately rendered, whereas in others specific colours or colour contrasts may have to be brought out or even exaggerated. In such cases, selection should be based on experience or experiment and, in absence of expert knowledge, advice should be sought from the lamp manufacturer or other suitable source of information.

When the colour sensitive task is confined to a specific area in the room, it may be possible to employ special local lighting and use conventional lamps for the rest of the interior.

TABLE 7.2

LIGHT SOURCE COLOUR PROPERTIES RECOMMENDATIONS

Colour rendering group	General Colour Rendering Index range	Colour appearance (see Table 7.1)	Examples for use	
			Preferred	Acceptable
1A	$R_a \geq 90$	Warm Intermediate Cool	Colour matching, clinical examinations*, art galleries and museums	
1B	$80 \leq R_a < 90$	Warm Intermediate Cool	Homes, hotels, restaurants, shops, offices, schools, hospitals, industrial buildings	
2	$60 \leq R_a < 80$	Warm Intermediate Cool		Industrial buildings
3	$40 \leq R_a < 60$			Industrial buildings
4	$20 \leq R_a < 40$			Rough industries

* See AS/NZS 1680.2.5 for specific recommendations.

7.5 NATURE OF THE INTERIOR

7.5.1 General considerations

Where the main consideration is the appearance of the space and objects within it, light sources with a high CIE general colour rendering index may be desirable. In general, light sources with good colour rendering properties (Groups 1A and 1B) make surfaces of objects appear more colourful than do light sources with moderate or poor colour rendering properties (Groups 2, 3 and 4). In addition, light sources with poor colour rendering properties may distort some colours to a marked extent. Thus, where a colourful appearance is desirable, lamps with good colour rendering properties are appropriate. However, the particular level of colour rendering acceptable in any particular circumstance remains a matter of individual judgement. Ultimately the CIE general colour rendering index is no substitute for actually seeing the effect of different light sources when it comes to assessing their contribution to the appearance of an interior.

In addition to satisfying the needs of the task, the colour appearance and colour rendering properties of the lamps should suit the type of interior; in particular, the type of activity, the illuminance, and the colour scheme employed.

The main concern is not so much with accuracy of colour rendition as with the production of a pleasing and satisfying effect. Naturally, the importance of this depends on circumstances. In semi-decorative interiors such as shops, schools, hotels, homes, and special offices where appearance of the room and its occupants is an important consideration, the use of lamps with good colour rendering properties (Group 1B or better) may be economically justified.

7.5.2 Interior colour schemes

Because the appearance of a colour scheme and hence whether it meets the required criteria for aesthetics, function, etc are dependent on colour rendering, and because the colour appearance of the luminaires form part of the colour scheme, the interior colour scheme should be decided in conjunction with the choice of lamp. When the result is of paramount importance, it is recommended that the proposed coloured materials be viewed under the proposed source before a final choice is made.

The principles regarding choice of lamp colour appearance indicated in Clauses 7.2 and 7.3 also apply to some extent to interior colour schemes; i.e. if the illuminance is very low, schemes based on warm colours are usually preferable to those in which cool colours predominate.

7.6 COMPATIBILITY WITH DAYLIGHT

If part of the interior is illuminated by daylight, the electric sources should blend satisfactorily with the natural light.

As lamps with correlated colour temperatures of greater than 4000 K will generally be acceptable, for most industrial and office lighting applications this requirement does not greatly limit the choice of light source. However, where there is significant night-time use of the building, lamps with correlated colour temperatures less than 4000 K may be desirable for reasons of appearance.

7.7 COMPATIBILITY WITH OTHER LAMPS

Where it is proposed to mix light sources in a compatible manner in an interior it will be necessary to match the correlated colour temperatures. If the sources are to illuminate areas of identical colour, their colour rendering properties should also match.

In other installations where special coloured lighting effects are to be incorporated, the compatibility between the selected light sources will typically be of less significance.

7.8 MAINTENANCE

Careful selection of light sources at the initial installation stage can be negated by uninformed maintenance procedures. Moreover, because the general colour rendering index is an average of eight R_i values, two different brands of lamp with an identical R_a value will not necessarily have identical colour rendering properties.

For this reason, when colour rendering is critical, replacement lamps should be identical with those originally selected; hence maintenance procedure manuals should include full details of relevant lamps.

In addition, it might be necessary to replace all lamps of the same type in a room or area at the same time if the colour properties change with age.

SECTION 8 GLARE AND RELATED EFFECTS

8.1 GENERAL CONSIDERATION

8.1.1 Introduction

Glare is the collective term for a number of effects produced in the visual system when one or more sources of luminance in the visual field are significantly greater than the luminance to which the visual system is adapted.

The two major effects dealt with in this section are disability glare, which impairs vision, and discomfort glare, which causes discomfort to the observer but does not necessarily impair vision. The former is a physiological effect while the latter is psychophysical.

Disability glare and discomfort glare can thus occur simultaneously or separately.

This Section will also briefly mention two adaptation effects which can affect seeing conditions (see Clauses 8.4 and 8.5).

8.1.2 Reduction of glare from windows

Although the most severe glare from windows arises when they provide a direct view of the sun, views of a bright, overcast sky or of highly reflective buildings also cause windows to be sources of discomfort glare in particular. Windows can, therefore, produce discomfort, disability and reduced contrast sensitivity (an effect similar to disability glare) resulting from high adaptation luminances. The discomfort produced by windows cannot be calculated using the method given in Clause 8.3.3.

Specific techniques to reduce the glare effects from windows include the following:

(a) Reducing the size of windows.

(b) Arranging working positions so that windows are not close to lines of sight. In particular, not having working positions facing windows.

(c) Installing adjustable curtains, blinds or opaque louvres to windows for use as required.

(d) The use of tinted low transmission glazing.

(e) Provision of light coloured (i.e. high reflectance) surfaces on the window wall, e.g. frame and glazing bars, if any (see Clause 6.3.3).

(f) Arranging for light to fall on the wall area adjacent to the windows either from other windows, roof lights or from specially located luminaires.

8.1.3 Reduction of glare from luminaires

Because a luminaire is both a potential glare source and usually a primary source of illuminance, several of the approaches applicable to windows are not applicable or have mixed consequences regarding glare.

For example, choosing a luminaire with a low source luminance will reduce the luminance of the potential glare source but might also reduce the level of background illuminance in the line of sight.

Despite this and similar considerations, the following techniques are recommended for reducing glare, especially discomfort glare, from luminaires:

(a) Choosing luminaires with low illuminance, especially with the lamp and specular reflecting surfaces shielded from view. (Refer to Clause 8.2.2.)

(b) Locating luminaires and working positions so that luminaires are not close to lines of sight.

(c) Use of high reflectance surfaces on ceilings and upper walls.

8.2 DISABILITY GLARE

8.2.1 General principles

Disability glare occurs when a luminance in the field of view with a significantly higher luminance than the object of regard causes scattering of light in the eye resulting in a reduction in the contrast between the object and its background sufficient to make important details invisible. (The term disability glare only correctly applies to the situation of light scattering in the eye, however it is commonly taken to include some local adaptation effects with similar consequences, such as when a source of high luminance is viewed directly, and noticeable after-images are be created, also obscuring details.) The scattered light produces a veiling luminance which is superimposed over the scene. For each glare source, the veiling luminance, L_v, can be calculated and, for, young adults

$$L_v = \frac{10E}{\theta^2}$$

Where E is the illuminance in the plane of the eye produced by the glare source and θ is the angle, in degrees, from the line of sight to the glare source. The relationships are shown in Figure 8.1

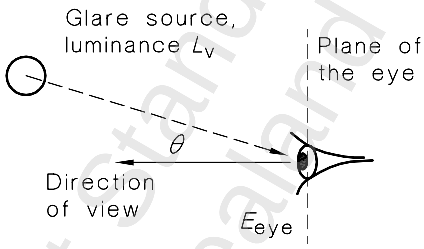


FIGURE 8.1 THE GEOMETRY FOR CALCULATING VEILING LUMINANCE

Because disability glare is caused by the glare source's high luminance and position relative to the line of sight, the three approaches to reducing disability glare are to reduce the luminance of the glare source, move it further from the line of sight, or to increase the luminance of the object of regard. The first is the most effective, especially by shielding the glare source from view (see Clause 8.2.2). In most cases, in interior lighting, if discomfort glare is minimized, disability glare is unlikely to be a problem.

8.2.2 Cut-off angles

8.2.2.1 *Required cut-off*

Partly enclosed luminaires (e.g. luminaires with open reflectors or louvres) should screen lamps from view throughout the complete range of angles, from the horizontal down to at least the appropriate cut-off angle recommended in Table 8.1. For the purpose of this Clause cut-off angles should be measured in accordance with AS 1680.3.

The principle of screening the lamps to provide an appropriate cut-off is illustrated in the examples of Figures 8.2 and 8.3.

Holes incorporated in luminaires for ventilation or other purposes should be so located or baffled as to prevent direct view of the lamps. This applies especially to luminaires which may be mounted at or below eye-level to provide localized lighting for the task.

As well as the lamp being adequately screened, the luminance of the image of the lamp in the side of the reflector directed towards the observer should not exceed the appropriate luminance limit recommended in Table 8.3 or Table 8.4.

8.2.2.2 *Basis for recommended cut-off angles*

The cut-off angles recommended in Table 8.1 are based on the assumption that—

(a) the visual tasks are predominantly below eye-level; and

(b) the light emitting aperture of the luminaires lies in the horizontal plane.

If the visual tasks are predominantly above eye level or if the luminaires are suspended or mounted at an angle (e.g. on an inclined ceiling), special precautions may be necessary such as—

(i) special positioning of luminaires; or

(ii) provision of additional shields, louvres or baffles.

TABLE 8.1

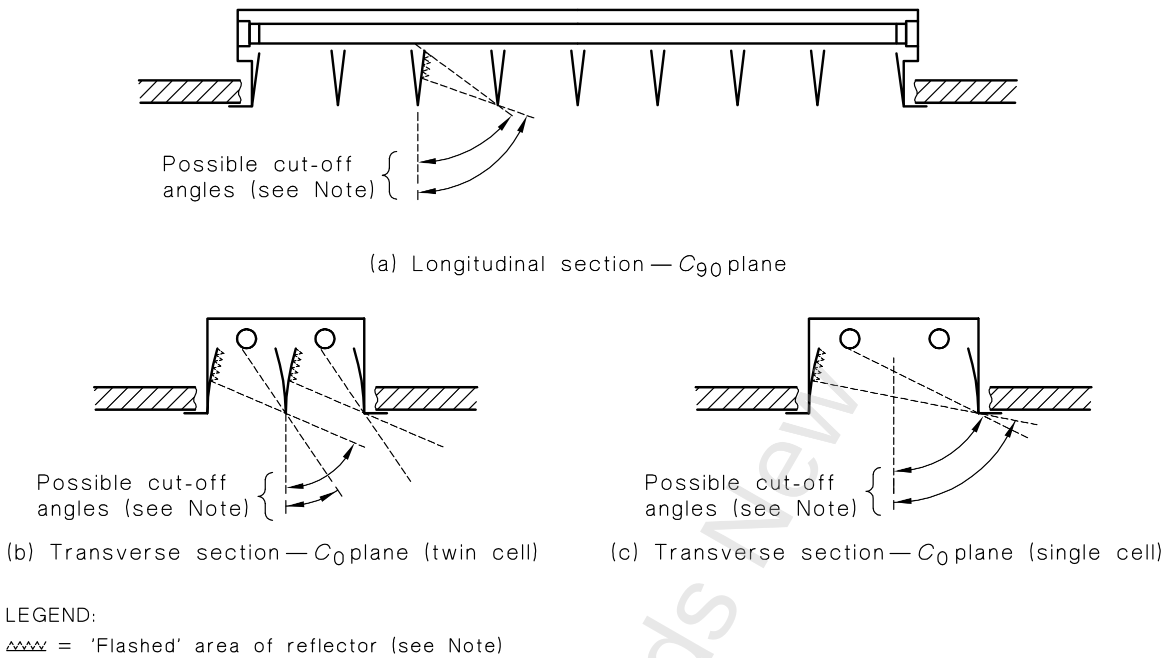
RECOMMENDED CUT-OFF ANGLES FOR PARTIALLY ENCLOSED LUMINAIRES

Type of installation	**Cut-off angle not to exceed:**		
	Lamps having a luminance not exceeding 25 kcd/m^2 (i.e. tubular fluorescent lamps)	**Lamps having a luminance exceeding 25 kcd/m^2 but not exceeding 500 kcd/m^2 (lamps with diffusing envelope, e.g. inside frosting or fluorescent coating, to reduce the brightness of the luminous filament or arc)**	**Lamps having a luminance exceeding 500 kcd/m^2 (lamps which permit direct view of luminous filament or arc)**
Offices, school classrooms, industrial interiors with difficult visual tasks	60°	60°	50°
General industrial interiors	70° (in the vertical plane at right angles to the axis of the lamp)	70°	60°
Storerooms (dead storage), passages, etc (casual seeing only)	No screening of lamp(s) required	70°	70°
Local lighting (luminaires mounted above eye level)	70°	50°	50°

NOTES:

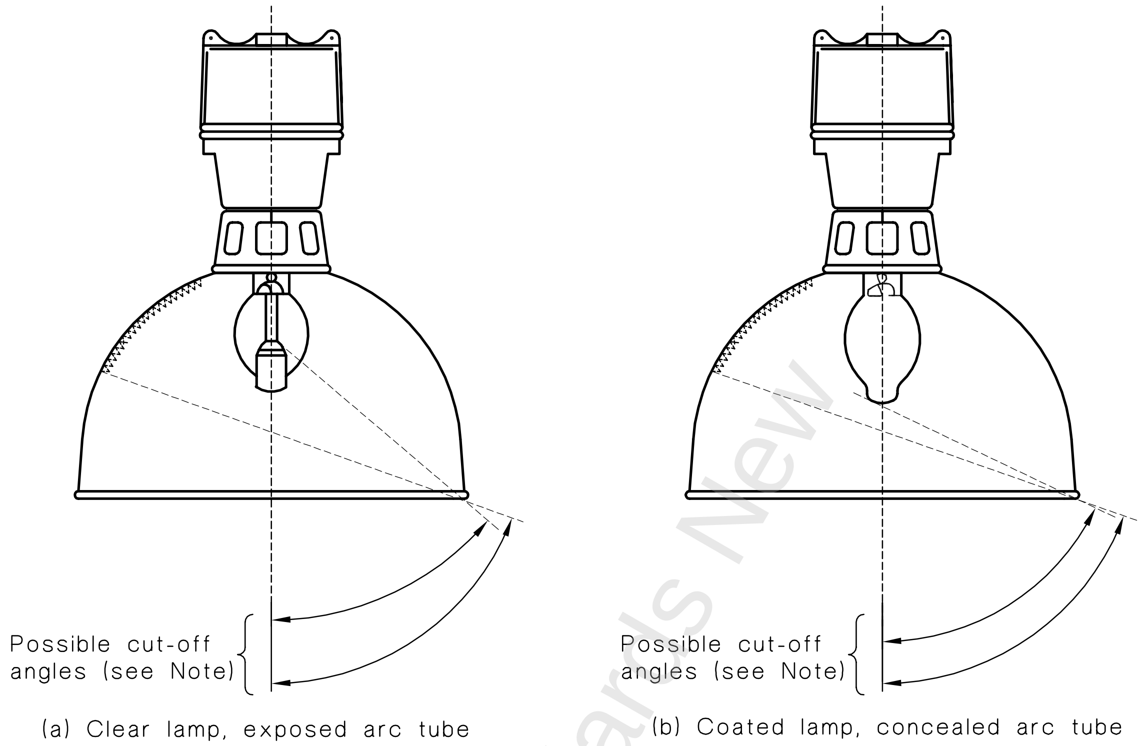
1 Cut-off angles should be measured as specified in AS 1680.3. See also Figures 8.2 and 8.3 for an illustration of cut-off angle for various luminaires.

2 Where a luminaire in a passage can be seen by occupants of adjacent rooms because of the use of transparent glass partitioning or for other reasons, the cut-off angle appropriate to those rooms should apply.



NOTE: For non-specular reflectors or baffles, the cut-off angle will be that at which the light source becomes directly visible. For specular and semi-specular reflectors, the cut-off angle will be that at which the high-luminance reflection of the light source (i.e. the 'flashed' area of the reflector) becomes directly visible.

FIGURE 8.2 EXAMPLE OF LOW-BRIGHTNESS FLUORESCENT LUMINAIRE SHOWING CUT-OFF ANGLES



LEGEND:
= 'Flashed' area of reflector (see Note)

NOTE: For non-specular reflectors or baffles, the cut-off angle will be that at which the light source becomes directly visible. For specular and semi-specular reflectors, the cut-off angle will be that at which the high-luminance reflection of the light source (i.e. the 'flashed' area of the reflector) becomes directly visible.

FIGURE 8.3 EXAMPLES OF LUMINAIRES WITH DISCHARGE LAMPS SHOWING CUT-OFF ANGLES

8.2.2.3 *Built-in lighting*

The required degree of cut-off can sometimes be achieved by integrating the lamps into the permanent structure of the building (e.g. by locating bare lamp luminaires behind roof beams).

8.3 DISCOMFORT GLARE

8.3.1 General principles

Discomfort glare occurs whenever light entering the eye causes discomfort. This discomfort can be immediate but sometimes may only become evident after prolonged exposure. The current understanding of discomfort glare is that the glare effect, G, is a function of—

- the luminance of the source, L;
- the luminance of the background, L_b;
- the angular size of the source, ω; and
- the source's displacement from the line of sight, p,

of the form—

$$G = \frac{L^{a}\omega^{c}}{L_{b}^{b}\, p^{d}}$$

where a, b, c, and d are constants determined experimentally.

Figure 8.4 shows the geometrical relationships.

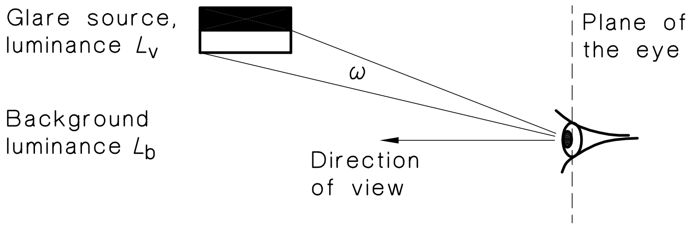


FIGURE 8.4 FACTORS AFFECTING THE DISCOMFORT GLARE SENSATION

There are other factors that influence discomfort glare but their effects cannot be expressed in quantitative terms. These include exposure time, the adaptation state of the visual system, the effects of fatigue, age, alcohol and other drugs and, possibly, the aesthetic appearance of the source (luminaire).

The latter point may indicate that some luminaires are not as likely to cause glare as others with similar luminances. The fundamental research on discomfort glare used diffusing luminaires, employing opal glass diffusers. Some modern luminaires use diffusely reflecting painted surfaces and anecdotal evidence suggests that these may not be perceived as glaring, although they may fail the luminance or glare index criteria given in the following clauses. At this stage, due to the lack of research evidence, the lighting designer may need to use experience is deciding on the use of these luminaires.

From the relationship discussed above, the approaches to reducing discomfort glare are to reduce the luminance of the glare source, reduce the apparent size of the glare source (or any potential source), increase the background luminance in the line of sight, and locate potential glare sources away from anticipated lines of sight. Note that the luminance of the glare source is the most significant variable (see the formula for the *UGR* in Clause 8.3.3).

8.3.2 Systems for the limitation of discomfort glare

This Standard provides two alternative systems for the control of discomfort glare from electric lighting as follows:

(a) The CIE unified glare rating (*UGR*) system (see Clause 8.3.3).

(b) A luminaire selection or luminance limiting system (see Clause 8.3.4).

Each system has distinctly different characteristics and applications, as described in the respective clauses. However, the luminaire selection system is a 'go/no go' system, which gives no indication of the likely discomfort effect of a luminaire which 'just misses' the luminance criteria (see Table 8.2 and the specific recommendations of the AS(/NZS) 1680.2 series). The *UGR* is the procedure for assessing the level of discomfort glare, but for a limited set of situations, the more simple luminare selection procedure is sufficient for ensuring compliance.

Clause 8.2.1 also applies, since screening lamps and/or their images in reflectors minimizes discomfort as well as reducing disability effects.

8.3.3 The CIE *UGR* system

Some types of task or interior environment require more critical attention to the control of discomfort glare. This applies particularly where one or more of the following conditions exist:

(a) The dominant task in the space is screen based.

(b) The room is large, i.e. having a room index of 2 or more, resulting in a significant number of luminaires within the field of view of the occupants.

(c) The visual tasks are difficult (e.g. small detail, poor contrast, rapid perception) and require sustained visual attention.

(d) The direction of view of the workers is at or above the horizontal for significant periods, e.g. control rooms, lecture theatres, some VDU areas.

(e) The room surfaces and equipment are abnormally dark coloured or poorly lit, i.e. not complying with the recommendations of Section 6 and Clause 10.5.

For these situations the degree of discomfort glare to the occupants of the interior may be predicted by the determination of the *UGR*, commonly called the glare index, using the formula-based method in CIE 117. Note that this is a glare rating of the lighting system (room plus luminaires) not a luminaire rating.

The *UGR* is calculated for each source and summed using the following formula—

$$UGR = 8\log\frac{0.25}{L_{\mathrm{b}}}\sum\frac{L^2\omega}{p^2}$$

where

L_{b} is the background luminance (candelas per square metre),

L is the luminance of the luminous parts of each luminaire in the direction of the observer's eye (candelas per square metre),

ω is the solid angle of the luminous parts of each luminaire at the observer’s eye (sr), and

p is the Guth position index for each luminaire (displacement from the line of sight).

It is usual for *UGR* calculation procedures to determine the luminance of each glare source by dividing the luminous intensity in the direction of the ‘worst point’ by the projected area of the source in that direction. This assumes that the source luminance is uniform, but in reality, it may be distinctly non-uniform. Likely causes of this are a direct view of part of the lamp or of its reflected image. The result is that users will be exposed to small areas of significantly higher luminance than are assumed in the calculation, and designers should be aware that the effect will be for the calculated *UGR* to underrate the level of discomfort glare that will be experienced.

The *UGR* of the lighting system should be determined for the ‘worst case’, in the direction of the furniture layout for the room. This is usually the longest view, i.e. from a workplace near a wall looking along the room. The *UGR* can be calculated at individual workplaces, as a design guide, but there has been no experimental confirmation of the discomfort probability determined at particular locations.

The use of this method will result in the calculation of a value of *UGR* for the space, with higher values indicating a greater probability of discomfort glare and vice versa. The least perceptible difference of *UGR* which can be appreciated visually is one unit. The least difference in *UGR* which makes a significant change in the degree of discomfort glare is three units.

Recommended maximum values of glare index for particular interiors/activities are given in the AS(/NZS) 1680.2 series. The values of *UGR* are taken from the following scale; each step in the scale represents one significant change in glare effect:

13, 16, 19, 22, 25, 28.

For the purpose of determining compliance with the recommended maximum *UGR*, the calculated value should be rounded (up or down) to the nearest whole number corresponding to the above scale; differences of less than 1.5 being rounded down and differences of 1.5 and greater being rounded up. For example, a calculated *UGR* of 20.4 would be rounded down to 19.

Where the interior or activity is not specifically covered in the AS(/NZS) 1680.2 series, an appropriate maximum *UGR* value should be selected from Table 8.2 of this Standard by comparison with the examples given.

TABLE 8.2

TYPICAL MAXIMUM *UGR* (GLARE INDEX) VALUES FOR VARIOUS SUSTAINED TASKS OR ASSOCIATED INTERIORS

Nature of task or interior and required glare control	Maximum *UGR* (glare index)	Examples of sustained tasks or associated interiors
Rough tasks—limited degree of glare control necessary	25*	Warehouses (packing and despatch); cold stores; boiler and turbine houses; machine and tool shops (rough bench and machine work); plant rooms.
Normal range of tasks or interiors glare control important	22	Food preparation and cooking; inspection and testing (coarse work, go/no go); assembly shops; sheet metal works; machine and tool shops (fine and medium machine work); glass finishing (bevelling, etching, decorative cutting).
	19†	Lecture theatres, schools (classrooms and assembly halls); libraries (general); inspection and testing; offices; control rooms; printing industry (proofreading); drawing offices (general and CAD/CAM); fabric production.

* For those applications for which a maximum *UGR* of 25 or more is recommended, the calculation of a glare index is not normally justified. The use of the luminaire selection system (see Clause 8.3.4) will be sufficient.

† A greater degree of glare control, i.e. a *UGR* of less than 19, may be required for exceptionally difficult visual tasks or where there is prolonged viewing of a task at, or above a horizontal line of sight.

The light output distribution of a luminaire and the projected area of its light emitting or reflecting parts are important factors in determining the *UGR* of a lighting system. Clause 9.5.1(e) and Table 9.3 give information on the influence of different characteristic types of luminaires on the resulting *UGR* for rooms of different size. This information is indicative only and cannot be used for lighting design.

8.3.4 Luminaire selection system

8.3.4.1 *General*

The lighting designer sometimes has to select a lighting system based on incomplete task or environmental information. For example, the nature of the task may not be known or the surface finishes or partitioning details may not have been decided by the stage at which lighting design decisions are needed. In these cases the lighting designer will make assumptions, based on the brief and good practice. If the lighting system comprises a uniform array of one type of luminaire (i.e. either a general lighting system (see Clause 10.3.2) or an environmental lighting system (see Clause 10.3.5) then a luminaire selection system can be used.

The luminaire selection system is based on the premise that the probability of discomfort will be reduced by controlling the luminances of a luminaire in particular directions, depending upon the size of the space and the illuminance to be used. Luminaire luminances are limited by either—

(a) modifying lamp luminance by optical control methods to maintain luminances at the specified critical angles within the limits recommended (see Clause 8.3.4.6); or

(b) cutting off direct view of the lamp(s) with the use of opaque reflectors, louvres or permanent parts of the building (see Clause 8.2.1).

It is likely that local task lighting will be used in the same space as environmental lighting systems (see Clause 10.3.5). For the premise on which the luminaire selection system is based to be true in such a case, it must be assumed by the designer that, as well as the assumptions listed in Clause 8.3.4.2, any task lighting subsequently provided will not appreciably increase the probability of discomfort.

8.3.4.2 *Application of system*

The primary advantage of the luminare selection system is that it allows lighting designers (and manufacturers) to assess a particular luminaire for a task type or interior before the final design details are known. As noted in Clause 8.3.2 it is a 'go/no go' gauge. It simply suggests that at least 50% of a population in the work place will not judge the lighting system to be uncomfortable.

It is also based on the assumptions that—

- the maintained illuminance is not greater than 600 lux;
- the maximum luminous opening of the luminaire does not exceed 1200 mm × 600 mm;
- the intensity distribution of the luminaire is 'general dispersive', i.e. it is not an extreme 'bat-wing' distribution;
- the room cavity reflectances are close to 0.7 for the ceiling, 0.5 for the walls and 0.2 for the floor;
- the 'worst case' glare positions are as shown in Figure 8.5 and that they occur only in the C_0 and C_{90} planes;

  NOTE: In the case of some open cell luminaires, the worst case is likely to be the C-plane containing the diagonal of the cell/s (typically around C45). If viewing directions are in or close to this plane any discomfort effect could be assessed using the *UGR* system.
- the task is located horizontally and the direction of view to the task is below the horizontal; and
- the visual effort is similar to that for normal reading and writing tasks.

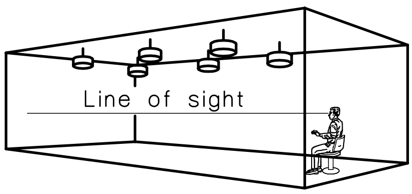


FIGURE 8.5 THE ASSUMED 'WORST CASE' VIEWING POSITION.

The recommendations of Clauses 8.3.4.3 to 8.3.4.7 apply to general lighting systems which utilize a uniform or near uniform array of the one type of luminaire.

The recommendations of Clause 8.3.4.8 apply to luminous ceilings and to indirect lighting systems.

Assessment of compliance with the luminance limits recommended should be carried out by measurements in accordance with the appropriate procedure in AS 1680.3.

8.3.4.3 *Maximum luminances of luminaires in general lighting systems*

The luminance of luminaires in general lighting systems should not exceed the maximum values recommended in Tables 8.3 or 8.4, as appropriate, having regard to—

(a) the type of luminaire used (see Clause 8.3.4.4);

(b) the particular angles at which luminance limitation is necessary (see Clause 8.3.4.5); and

(c) the maintained illuminance which is appropriate for the interior (see Clause 8.3.4.7).

Tables 8.2 and 8.3 automatically take account of viewing directions both along and across the room. The luminance limits in Tables 8.3 and 8.4 are based on the following scale of values, in kilocandelas per square metre:

1, 1.5, 2, 3, 4, 6, 8, 12 and 16.

Refer to Clause 8.3.4.6 for further information on the procedure involved in the application of the luminance limiting system.

In addition to the limiting values in Tables 8.3 and 8.4, the luminances at intermediate γ angles shall not exceed those shown in Figure 8.6.

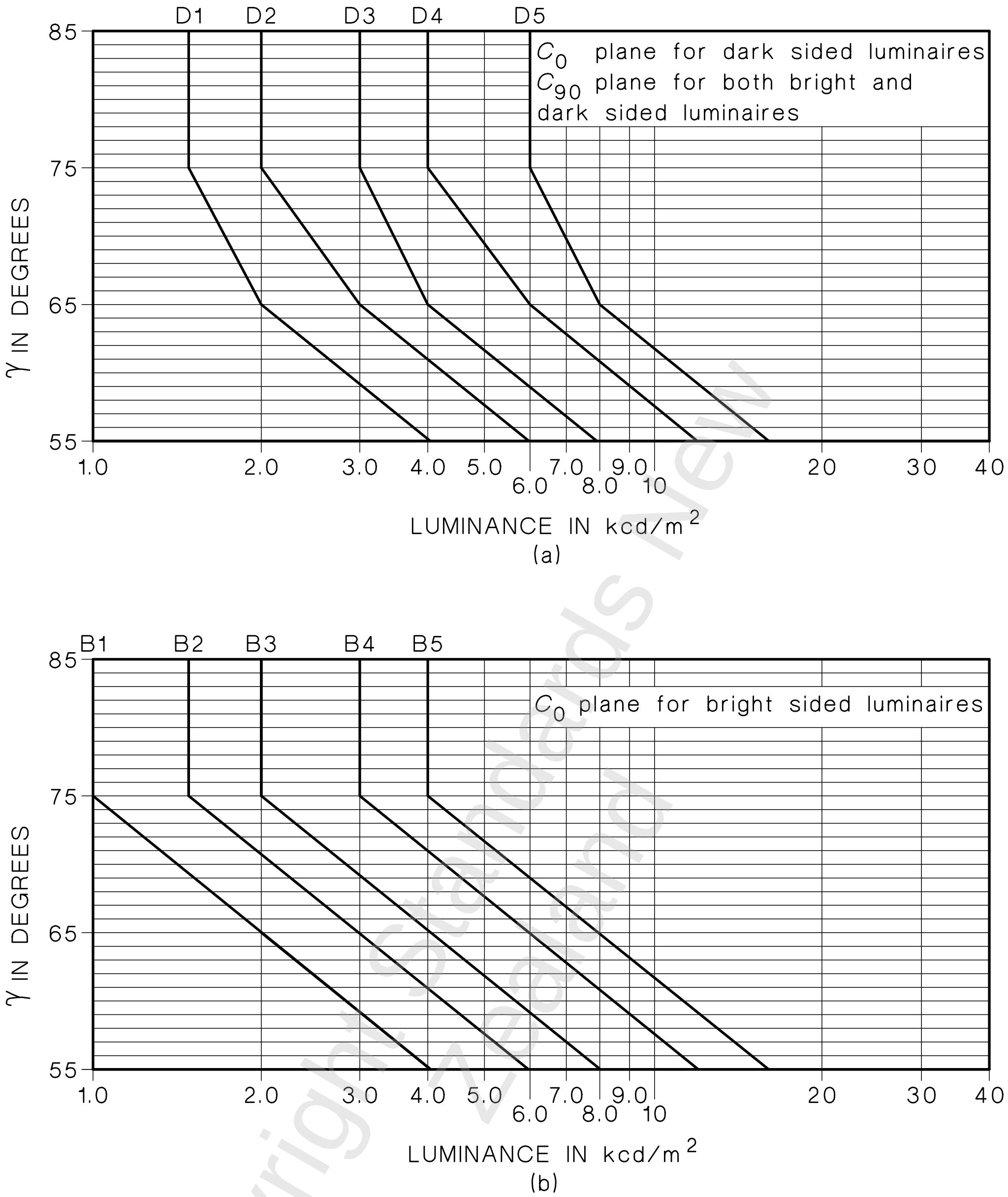


FIGURE 8.6 THE LIMITING LUMINANCE VALUES FOR LUMINAIRES

8.3.4.4 *Types of luminaire*

For the purpose of Tables 8.3 and 8.4 and Figure 8.6 the following distinction in the types of luminaire applies:

(a) *Non-elongated luminaires* Luminaires for which the ratio of the length to the width of the light emitting base is equal to or less than 3:1, e.g. luminaires that utilize tungsten filament lamps or compact forms of tubular fluorescent lamp.

(b) *Elongated luminaires* Luminaires for which the ratio of the length to the width of the light emitting base is greater than 3:1, e.g. luminaires that utilize horizontally mounted tubular fluorescent lamps of the linear form.

(c) *Dark-sided luminaires* Recessed luminaires, luminaires in which the luminous portion of the base projects less than 30 mm vertically (refer to Figure 8.7), and luminaires having side panels that are opaque.

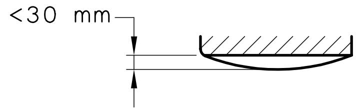


FIGURE 8.7 DARK-SIDED LUMINAIRE

(d) *Bright-sided luminaires* All luminaires other than those described in (c) above.

8.3.4.5 *Angles requiring luminance limitation*

Tables 8.3 and 8.4 provide maximum luminance values at four γ angles (i.e. 55°, 65°, 75° and 85°) for both the C_0 and C_{90} vertical planes through the luminaire. For elongated luminaires (see Clause 8.3.4.4) different luminance limits apply for the C_0 and C_{90} vertical planes but for non-elongated luminaires the same luminance limits apply in both the C_0 and C_{90} vertical planes.

The particular γ angles at which it is necessary to comply with the recommended limits will depend on the—

(a) size of the space; and

(b) height of the luminaires relative to the predominant eye height of the occupants.

Clause 8.3.4.6 sets out the procedure by which the relevant angles are determined.

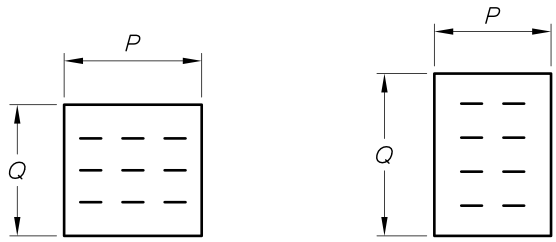
8.3.4.6 *Points regarding the use of Tables 8.5 and 8.6*

(a) Elongated luminaires

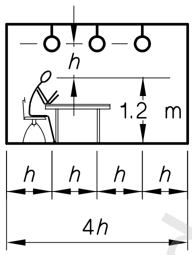
The following procedure applies to horizontally mounted luminaires with a base length to width ratio of more than 3:1.

(i) Determine room dimension *P* parallel to the long axes of the horizontally mounted luminaires, and the transverse dimension *Q* (see Figure 8.8(a)).

(ii) Convert these two dimensions into multiples of the mounting height (*h*) above eye-level (see Figure 8.8(b)).

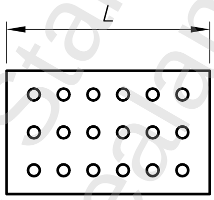


(a) Room dimensions for *P* and *Q* for elongated luminaires



NOTE: Eye level normally assumed to be 1.2 m for seated persons (as indicated) and 1.7 m for standing persons.

(b) Mounting height *h* relevant to eye level



(c) Room dimensions *L* for non-elongated luminaires

FIGURE 8.8 ILLUSTRATIONS OF P,Q, L AND h

(iii) Determine the γ angles in the C_0 and C_{90} planes at which luminance limitation is necessary, with the aid of Table 8.4.

TABLE 8.3

LUMINANCE LIMITATION VALUES FOR ELONGATED LUMINAIRES

Relevant room dimension categories	Angles at which luminance limitation is necessary (degrees)	
	In C_0 plane	In C_{90} plane
$Q > 5h$	55, 65, 75, 85	–
$2h \leq Q \leq 5h$	55, 65, 75	–
$Q < 2h$	55, 65	–
$P > 5h$	–	55, 65, 75, 85
$2h \leq P \leq 5h$	–	55, 65, 75
$P < 2h$	–	55, 65

(iv) Identify the appropriate set of luminance limits in Tables 8.5 or 8.6, taking into account the maintained illuminance, the applicable γ angles as determined from (iii), and the type of luminaire (see Clause 8.3.4.4).

(b) Non-elongated luminaires

The following procedure applies to luminaires with a base length to width ratio of 3:1 or less; for these luminaires the same limits apply in both the C_0 and C_{90} vertical planes.

(i) Determine L the longest dimension of the room. (Refer to Figure 8.8 (c).)

(ii) Convert L into a multiple of mounting height (h) above eye-level (see Figure 8.8(b)).

(iii) Determine the γ angles in the C_0 and C_{90} planes at which luminance limitation is necessary, with the aid of the Table 8.4.

TABLE 8.4

LUMINANCE LIMITATION VALUES FOR NON-ELONGATED LUMINAIRES

Room dimension category	Angles in both C_0 and C_{90} planes at which luminance limitation is necessary (degrees)
$L > 5h$	55, 65, 75, 85
$2h \leq L \leq 5h$	55, 65, 75
$L < 2h$	55, 65

(iv) Identify the appropriate set of luminance limits in Tables 8.5 or 8.6, taking into account the maintained illuminance, the applicable γ angles as determined from (iii), and the type of luminaire (see Cause 8.3.4.4).

8.3.4.7 *Influence of illuminance*

While a higher illuminance will, in general, result in higher surface luminances and an increase in the adaptation luminance for the occupants of the space, that increase in adaptation luminance (and the expectation of a lower probability of discomfort) does not fully compensate for the increased number of luminaires (and, hence, increased total projected area of sources) required to achieve the higher illuminance.

Therefore, Tables 8.5 and 8.6 recommend different luminance limits for various maintained illuminance ranges.

8.3.4.8 *Maximum luminances for luminous ceilings and indirect lighting systems*

Where luminous ceilings are used, the average luminance of the ceiling should not exceed 0.5 kcd/m^2 when viewed within the range of angles which are appropriate in terms of Clause 8.3.4.5.

Where indirect lighting systems are used, the average ceiling luminance should not exceed 0.5 kcd/m^2 and the maximum luminance at any point on the ceiling should not exceed 1.5 kcd/m^2. (See also Clause 10.5.2.)

TABLE 8.5

LUMINANCE LIMITS FOR LUMINAIRES FOR USE IN OFFICES, SCHOOLS AND INDUSTRIAL INTERIORS WITH DIFFICULT VISUAL TASKS

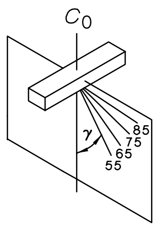
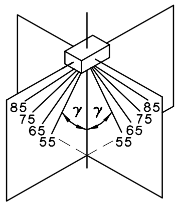
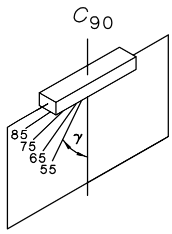
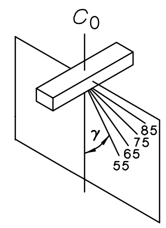
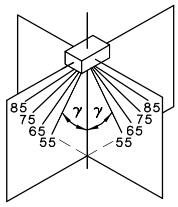
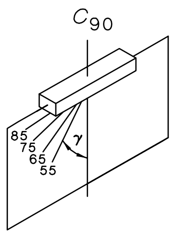
<table>
<tr><th rowspan="2">Applicable plane of measurement</th><th rowspan="2">γ-angles for which luminance limits apply</th><th colspan="4">Maximum luminances, kcd/m²</th></tr>
<tr><th colspan="2">For maintained illuminances ≤400 lx</th><th colspan="2">For maintained illuminances >400 lx</th></tr>
<tr><td rowspan="7"></td><td>Curve in Figure 8.6</td><td colspan="2">Luminaires having</td><td colspan="2">Luminaires having</td></tr>
<tr><td></td><td>BRIGHT sides</td><td>DARK sides</td><td>BRIGHT sides</td><td>DARK sides</td></tr>
<tr><td>See Note</td><td>B2</td><td>D2</td><td>B1</td><td>D1</td></tr>
<tr><td>85°</td><td>1.5</td><td>2</td><td>1</td><td>1.5</td></tr>
<tr><td>75°</td><td>1.5</td><td>2</td><td>1</td><td>1.5</td></tr>
<tr><td>65°</td><td>3</td><td>3</td><td>2</td><td>2</td></tr>
<tr><td>55°</td><td>6</td><td>6</td><td>4</td><td>4</td></tr>
<tr><td rowspan="6"></td><td>Curve in Figure 8.6</td><td colspan="2">Luminaires having BRIGHT OR DARK sides</td><td colspan="2">Luminaires having BRIGHT OR DARK sides</td></tr>
<tr><td>See Note</td><td colspan="2">D2</td><td colspan="2">D1</td></tr>
<tr><td>85°</td><td colspan="2">2</td><td colspan="2">1.5</td></tr>
<tr><td>75°</td><td colspan="2">2</td><td colspan="2">1.5</td></tr>
<tr><td>65°</td><td colspan="2">3</td><td colspan="2">2</td></tr>
<tr><td>55°</td><td colspan="2">6</td><td colspan="2">4</td></tr>
<tr><td colspan="6">NOTE: The procedure described in Clause 8.3.4.6 should be followed to determine the γ angles for which the luminance limits apply.</td></tr>
</table>

TABLE 8.6

LUMINANCE LIMITS FOR LUMINAIRES FOR USE IN GENERAL INDUSTRIAL INTERIORS

<table>
<tr><th rowspan="2">Applicable plane of measurement</th><th rowspan="2">γ-angles for which luminance limits apply</th><th colspan="6">Maximum luminances, kcd/m²</th></tr>
<tr><th colspan="2">For maintained illuminances ≤240 lx</th><th colspan="2">For maintained illuminances ≥240 lx ≤400 lx</th><th colspan="2">For maintained illuminances >400 lx</th></tr>
<tr><td rowspan="6"></td><td>Curve in Figure 8.6</td><td colspan="2">Luminaires having</td><td colspan="2">Luminaires having</td><td colspan="2">Luminaires having</td></tr>
<tr><td></td><td>BRIGHT sides
B5</td><td>DARK sides
D5</td><td>BRIGHT sides
B4</td><td>DARK sides
D4</td><td>BRIGHT sides
B3</td><td>DARK sides
D3</td></tr>
<tr><td>85°</td><td>4</td><td>6</td><td>3</td><td>4</td><td>2</td><td>3</td></tr>
<tr><td>75°</td><td>4</td><td>6</td><td>3</td><td>4</td><td>2</td><td>3</td></tr>
<tr><td>See Note 65°</td><td>8</td><td>8</td><td>6</td><td>6</td><td>4</td><td>4</td></tr>
<tr><td>55°</td><td>16</td><td>16</td><td>12</td><td>12</td><td>8</td><td>8</td></tr>
<tr><td rowspan="6"></td><td>Curve in Figure 8.6</td><td colspan="2">Luminaires having</td><td colspan="2">Luminaires having</td><td colspan="2">Luminaires having</td></tr>
<tr><td></td><td colspan="2">BRIGHT OR DARK sides
D5</td><td colspan="2">BRIGHT OR DARK sides
D4</td><td colspan="2">BRIGHT OR DARK sides
D3</td></tr>
<tr><td>85°</td><td colspan="2">6</td><td colspan="2">4</td><td colspan="2">3</td></tr>
<tr><td>75°</td><td colspan="2">6</td><td colspan="2">4</td><td colspan="2">3</td></tr>
<tr><td>See Note 65°</td><td colspan="2">8</td><td colspan="2">6</td><td colspan="2">4</td></tr>
<tr><td>55°</td><td colspan="2">16</td><td colspan="2">12</td><td colspan="2">8</td></tr>
<tr><td colspan="8">NOTE: The procedure described in Clause 8.3.4.6 should be followed to determine the γ angles for which the luminance limits apply.</td></tr>
</table>

8.4 GLOOM IN INTERIORS

Gloom can be defined as the lighting condition which results in a space being described as underlit, while, in fact, it may satisfy the criteria set down in this Standard for task illuminances. It is likely that gloom is an adaptation effect due to either excessive or inadequate vertical luminances in the environment. Windows (due to their allowing views of high external luminances) can increase the adaptation luminance sufficiently so that interior (surface) luminances result in very low apparent brightnesses. The interior vertical illuminances may be inadequate due to insufficient daylight reaching them or because sufficient electric lighting onto those surfaces is not used to compensate for the high adaptation luminance from the window. This is a particular problem in single-side daylit rooms that are deep in plan or use low surface reflectances.

The gloom effect also occurs when daylight is excluded and the electric lighting system produces light mainly downwards. Here the luminances of vertical surfaces can be very low; horizontal illuminances can be high but the space is perceived as underlit. This can occur when direct type luminaires, such as downlights, are used in rooms with a low reflectance floor cavity.

The effect of different types of luminaires on the brightness of interior surfaces is indicated in Clause 9.5.2(f) and Figure 9.3.

8.5 TRANSIENT ADAPTATION EFFECTS

A disability effect can result from the short-term change in adaptation that can arise from the brief view of a bright light source, either directly or by reflection. Care is needed to avoid this, especially in situations where safety or security are important. Longer adaptation effects occur when moving from brightly lit to dimly lit spaces, such as entering a covered car park from the sunlit outdoors or leaving a building by night. Care should be taken to allow adaptation to change, without visually disabling the observer, by providing a threshold zone where the lighting changes between the two extremes over sufficient spatial distance that the observer can sufficiently adapt at the speed at which he or she is moving (see also Clause 3.8.5).

SECTION 9 LIGHT SOURCES, LUMINAIRES AND CONTROL SYSTEMS

9.1 SCOPE

This Section provides basic information on light sources (both daylight and electric light), luminaires and control systems for electric lighting. Maintenance of lighting equipment is discussed in AS/NZS 1680.4 as one of the considerations of lighting systems. The intention here, in the case of electric lighting, is to give sufficient information to demonstrate the differences between broad classes of equipment. It is not sufficiently precise for design purposes; manufacturers' data should always be consulted.

9.2 DAYLIGHT

The sun is the primary source of daylight. However its light is diffused and scattered by the earth's atmosphere, so that the whole sky becomes a secondary source. Daylight therefore is the sum of light which is produced directly by the sun (sunlight) and indirectly by the scattering effect of the atmosphere (skylight). These two components of daylight are referred to separately although the term daylight is often used when referring to skylight which is normally the main source of daylight in buildings. Both sunlight and skylight can be used to illuminate interiors directly through openings (windows, rooflights, etc.) or indirectly by being reflected from external surfaces or devices (ground, building facades, shading controls, etc.).

The illuminance produced on the earth's surface by daylight varies with atmospheric conditions and the changing position of the sun throughout the day. The illuminance produced by the sun is predictable within fairly close limits depending on the sun's altitude and also upon the clarity of the atmosphere. Under a clear (cloudless) sky the level of skylight depends upon the same factors but is more variable than direct sunlight. When the sky is partly or wholly cloud covered, the level of available light varies widely. In general, scattered white clouds or thin cloud layers produce higher levels than the clear sky or a heavy dense overcast sky.

Both the clear sky and overcast sky have been standardized and therefore the resulting illuminances can be calculated. However, with the exception of clear sky conditions which commonly apply in the hot arid (north west and central) regions in Australia, the partly cloudy (intermediate) sky is the predominant sky condition. Some theoretical models have been produced to include intermediate sky conditions which allow the calculation of illuminances based on the probabilities of certain atmospheric and cloudiness conditions. However, these models are still being validated.

With the exception of the clear sky which is relatively stable in Australia, partly and fully cloudy skies produce dynamic lighting conditions and therefore it is impossible to use the concept of constant illuminances as used in electric lighting design. Daylight availability can be defined in terms of—

(a) the average amount of skylight and sunlight available during typical periods (day, month, season or year) taking into account average turbidity and cloudiness; or

(b) the external skylight illuminance available on an unobstructed horizontal plane for a certain percentage of daytime working hours.

The concept described in (a) can be used for energy tradeoff computer programs when the probability of occurrence of sky types can be obtained from meteorological data. However the adequacy of the illuminances produced by daylight can be more accurately defined and predicted by the concept described in (b) related to the frequency of occurrence of external horizontal illuminance levels. Table 9.1 shows skylight availability (i.e. the external horizontal illuminance available from an unobstructed sky) for some Australian and New Zealand locations for which this data is available.

TABLE 9.1

SKYLIGHT AVAILABILITY FOR CERTAIN AUSTRALIAN AND NEW ZEALAND LOCATIONS

Location	External skylight illuminance in klux for percentage of working hours*.						
Australia†	**90%**	**85%**	**80%**	**75%**	**70%**	**65%**	**60%**
Northern tropical	12.7	13.3	14.8	16.1	17.8	19.0	19.8
North west and Central	7.5	7.9	8.4	8.6	8.8	9.1	9.4
Brisbane	7.9	8.8	9.4	10.1	11.0	12.8	15.8
Perth	8.8	9.7	10.5	11.1	11.9	12.6	14.2
Sydney	8.8	10.6	11.3	13.3	14.5	16.1	18.4
New Zealand‡							
Auckland	6.4	7.9	9.9	11.5	13.1	14.5	16.3
Christchurch	5.1	7.0	9.3	11.0	12.6	13.9	15.6
Wellington	5.1	6.3	7.8	9.2	10.6	11.9	13.2
Invercargill	4.1	5.4	7.1	8.6	10.1	11.5	13.0

* For the purpose of this table, working hours are defined as follows: In Australia – from 9 a.m. to 5 p.m; In New Zealand – from 8 a.m. to 5 p.m.

† Data obtained from Ref.5 in Appendix F.

‡ Based on data obtained from NZS 6703.

NOTE: Data on skylight availability for Australian locations other than those indicated in Table 9.1 may be obtained from Ref. 2.

9.3 WINDOWS AND ROOFLIGHTS

The majority of windows and rooflights employ transparent media (typically glass) which admit light. In most cases they are designed to admit direct skylight and reflected skylight and sunlight but to stop as much as possible the entry of direct sunlight. The minimization of direct sunlight not only reduces thermal transfer, but also eliminates the areas of high luminance contrast which can result from patches of sunlight in working interiors.

The transparent window or rooflight allows surfaces in a room to 'see' large area sources of light (the sky, ground, neighbouring buildings, etc). These area sources illuminate the interior surfaces which in some cases may be the task areas and in others the bounding surfaces. Interreflection aids in the redistribution of light. Geometric relationships exist between the interior illuminances produced and the luminances of the sources (sky, ground, neighbouring buildings, etc) visible from the point indoors. The luminance of a patch of sky seen from a point indoors can vary considerably (especially if 'white' clouds are present). It can be seen that the calculation of illuminances is complicated by the dynamic nature of the sky, the constantly changing sun position and the geometry of the point with respect to the window.

In general, it is wrong to think of the window or rooflight simply as a wall-(or ceiling-) mounted luminaire, since the part of the external, extended source which is visible (hence the characteristics of the 'luminaire') will vary with position in the space.

A number of design aids exist to calculate average and point-by-point illuminances produced by windows and rooflights based on various models of sky luminance distribution. The more detailed methods need the assistance of a computer in order to accommodate the wide range of opening and room geometries.

9.4 ELECTRIC LAMPS

9.4.1 Types

The main types of light sources used for interior lighting are shown in Table 9.2.

Within each type there is a range of lamps available which differ in construction, wattage, luminous efficacy, colour properties, cost, etc. The common incandescent lamp is referred to as a general lighting service (GLS) lamp. Various systems of letter codes are used to designate particular types of discharge lamp, however, no internationally agreed set of letter designations exists.

9.4.2 Lamp characteristics

A summary of the important characteristics of various lamp types is provided in Table 9.2. The table only gives an overview of the range of lamp types available. For information on a specific lamp the manufacturer's data should always be consulted.

Each basic lamp type described in Table 9.2 can have a number of variations in construction. These variations can involve its shape, the number and type of caps it has, the presence of a fluorescent or diffusing coating on an outer envelope, the chemical composition of any fluorescent coating and the provision of a reflector inside the lamp. Manufacturer's data should be consulted for details of the options available.

The operating details are concerned with such matters as run-up time, re-ignition time, operating positions, and susceptibility to environmental conditions. Run-up times and re-ignition times are important because most of the discharge lamps do not produce their maximum light output immediately after switch on. Usually several minutes are required before the maximum light output is achieved. Further, unless special circuits are used, high pressure discharge lamps will not immediately re-ignite after an interruption of supply. Usually a period of several minutes is necessary for the lamp to cool before it will re-ignite. These factors limit the suitability of some lamp types for rapid switching and dimming. It is also worth noting that not all lamp types can operate in all positions and that some lamp types are sensitive to such external environmental factors as air temperature and vibration.

The luminous efficacies given in Table 9.2 are expressed in lumens/lamp watt. The lumen output of each lamp type used in the calculation of luminous efficacy is the lighting design lumen value.

The term 'life' when applied to an electric lamp can have two distinct meanings. These are—

(a) the time after which the lamp ceases to operate; and

(b) the time after which the light output is so reduced that it is more economic to replace the lamp even though it is still functioning electrically.

Typically, lamps with filaments fall into the first category but discharge lamps fall into the second. Whilst defining the average life of lamps with filaments presents little problem, defining the life of a discharge lamp does, because it depends so strongly on the economic factors involved. Table 9.2 gives ranges of lamp life for each lamp type. For lamps with filaments the life is expressed as the time after which 50 percent of a large sample of lamps will have failed. For discharge lamps, with the exception of the low pressure sodium type, life is expressed as the time after which the light output of the lamp will have fallen 30 percent below the initial light output. For the low pressure sodium discharge lamp, the life is related to a 30 percent reduction in luminous efficacy, rather than a 30 percent reduction in light output because for this lamp type the luminous efficacy, rather than the light output, tends to change with time. A range of times is given for each lamp type because the time for a specific installation will vary with the construction and rating of the lamp used, even for lamps of the same type, and with such operating conditions as the voltage applied and the switching cycle.

TABLE 9.2

SOME SELECTED LAMP CHARACTERISTICS (NOTE 1)

Lamp type	Luminous efficacy (Note 2) lm/W	Lamp life (Notes 3 and 5) h	Colour appearance (see Table 7.1)	Colour rendering group (see Table 7.2)
Tungsten filament	5-20	1000-2000	Warm	1A
Tungsten halogen	15-25	2000-4000	Warm	1A
High pressure mercury vapour	35-60	5000-10 000	Intermediate	3
Metal halide	66-105	5000-10 000	Warm, intermediate or cool (Note 4)	1B or 2 (Note 4)
Tubular fluorescent (including compact fluorescent)	35-105	5000-18 000	Warm, intermediate or cool	1A, 1B or 2 (Note 4)
High pressure sodium	66-105	6000-24 000	Warm	2 or 4
Low pressure sodium vapour	100-185	6000-12 000	Monochromatic yellow	—
Light emitting diode (LED) (Note 6)	10-20 (white)	Up to 50 000	Warm, intermediate or cool	1B or 2

NOTES:

1. The data given in the table is indicative only. Manufacturer's data for the particular lamp selected should always be consulted.
2. These are lamp efficacies. Control gear losses must be considered for discharge lamps when calculating installed efficacy. The range of efficacies listed are indicative only and do not necessarily include every lamp produced by all manufacturers.
3. For discharge lamps, these lives indicate time to 30 percent reduction in light output. Note that switching cycles, wattage, etc can have a marked impact on life.
4. For some lamp types the colour rendering group will depend on the particular lamp selected.
5. See information on lamp lumen depreciation and replacement in AS/NZS 1680.4.
6. Light emitting diodes (LEDs) are assumed to be 'white'. These are still new and characteristics depend upon many factors.

Different lamp types have different colour properties. Further, for some lamp types it is possible to change these colour properties by using fluorescent coatings of different chemical composition. This approach is widely used in the low pressure mercury discharge lamp (tubular fluorescent). A general indication of the colour properties of selected lamp types is provided in Table 9.2 in terms of their colour appearance (see Table 7.1) and colour rendering group (see Table 7.2).

9.4.3 Control gear

The control gear which is associated with discharge lamps should fulfil three functions. It should—

(a) start the lamp;

(b) control the lamp current after ignition; and

(c) correct the power factor.

Control gear consumes energy and, for a given type, some circuits consume more than others. The efficacy of a lamp circuit as a whole depends on the total power taken by the lamp and the control gear. It is also necessary to consider the power factor of the circuit in order to minimize the capital costs of the installation and to ensure correct cable ratings.

The current and wattage ratings of cables, fuses and switchgear used in the control gear must be related to the total current in the circuit, although allowance may be necessary for increased currents and voltages during switching. Harmonic currents may be present and will increase the neutral current in a three-phase system. Current ratings of neutral conductors should be the same as that of phase conductors. Manufacturers can supply information about the power factor and harmonic currents of their control gear. All electrical installations should comply with AS/NZS 3000.

9.4.4 Flicker

All electric lamps operating from an a.c. supply have an inherent oscillation in light output. The source of the oscillation is different for different lamp types, depending on the physical mechanisms by which the light is produced. For incandescent lamps, the oscillation is usually small because of the thermal inertia of the filament. For discharge lamps the oscillation can be more marked and depends on asymmetry and instability in the arc. For most light sources in most situations, the oscillation is not visible but when it does become visible the effect is called flicker. Flicker is a source of distraction and discomfort to people, particularly as it is easily detected by peripheral vision and thus cannot be readily avoided. Although sensitivity to flicker varies widely between individuals, the main factors which influence its perception are the frequency and the amplitude of the modulation and the area over which it occurs. Large amplitude modulations occurring over large areas at low frequencies are the most uncomfortable conditions. Small amplitude oscillations over small areas may pass unnoticed.

9.4.5 Stroboscopic effects

The oscillation in light output from a lamp can produce a stroboscopic effect even when the oscillation is not visible. The stroboscopic effect is an illusion which makes a moving object appear as stationary or as moving in a different manner from its real movement. The strength of any stroboscopic effect depends on the frequency, regularity and amplitude of the oscillation in luminous flux relative to the frequency and regularity of the movement of the object. The most dramatic effects will occur when the frequencies are matched or are multiples or sub-multiples of each other and the amplitude of modulation is large. Wherever a significant stroboscopic effect is possible the lighting should always be designed to minimize such effects for reasons of safety. Measures which can be taken to eliminate or reduce stroboscopic effects are described in Clause 11.4.5.2.

9.4.6 Electronic control gear

The lighting industry is moving towards electronic control of lighting equipment. Previously, control was dominated by passive components (resistors, inductors and capacitors) but now more active devices (transistors, etc) are being used. Some lamps, such as the T5 tubular fluorescent lamps, are designed to be operated only on electronic ballasts. Electronic transformers are used to supply extra low voltage tungsten halogen lamps.

There are many advantages from electronic control including soft-starting lamps (with better quality versions to prevent electrode damage thus increasing lamp life); power factor control; increased lamp and system efficacies; elimination of flicker (due to the use of frequencies well above the human flicker fusion frequency); dimming (of fluorescent lamps to 2-5% output); elimination of or reduced stroboscopic effects; switching faulty lamps out of circuit and integration with building (energy) management systems.

Electronic ballasts and transformers often use switch-mode power supplies, meaning that they can radiate or conduct frequencies that may affect other equipment, such as computers and control equipment. Therefore, lighting equipment must now comply with requirements for electromagnetic compatibility (EMC).

9.4.7 Innovations and trends

The information given concerning light sources and control gear is correct at the date of publication of this Standard. Because of ongoing developments and because of the need to use accurate information in lighting design, the information on light sources and control gear should be sought from the manufacturers.

9.5 LUMINAIRES

9.5.1 Luminaire Standards

Luminaires can take many different forms, but all have to provide support, protection and electrical connection to the lamp(s). In addition luminaires have to be safe during installation and operation and be able to withstand the surrounding ambient conditions.

There are a number of Australian Standards which apply to particular types of luminaires or which set out requirements for certain characteristics or components of luminaires, including the following:

(a) Essential safety requirements for luminaires and their components (e.g. lampholders, starterholders, ballasts, capacitors, starters)—see AS 3117, AS/NZS 60598.2.8, AS/NZS 60598.1, AS 3140, AS/NZS 60922, AS/NZS 61050, AS 3158, AS/NZS 61347.2.8, and other Approval and Test Specifications in the AS/NZS 3100 series, as applicable.

(b) Performance and other general requirements for lamps and auxiliary equipment (e.g. ballasts, capacitors, starters)—see AS 2325, AS 2643, AS/NZS 4782.1, AS/NZS 60923, AS/NZS 61048.

(c) Requirements for luminaires used for emergency lighting purposes—see AS 2293.1.

(d) Interface requirements for physical compatibility of recessed luminaires with suspended ceilings, and with air diffusers associated with air-handling luminaires—see AS 2946.

(e) Procedures for photometric measurements for luminaires for interior lighting and the presentation of photometric data—see AS 1680.3.

(f) Requirements for luminaires for use in hazardous locations—see the AS/NZS 60079 series for applicable Standards.

(g) Requirements for electromagnetic compatibility—see AS/NZS 4251, AS/NZS CISPR 14.1 and AS/NZS CISPR 15.

In addition, AS 60529 describes a classification system for the degree of protection provided by the enclosures of the electrical equipment, including luminaires. This classification, essentially expressed in the form of a code involving the letters IP followed by two numerals (e.g. IP54), designates a variety of protection ratings for the enclosure. The two numerals have the following significance:

(i) *First numeral* Denotes the protection of persons against access to hazardous parts and protection of internal equipment against the ingress of solid foreign objects.

(ii) *Second numeral* Indicates the protection of internal equipment against harmful ingress of water.

9.5.2 Luminaire characteristics

Although meeting the requirements of various Australian Standards is a common factor in luminaire design, it does little to limit the diversity of luminaires that are available. Luminaires vary in their construction, mounting position, distribution of light, the efficiency with which they provide light on the working plane, the extent to which they are likely to cause discomfort glare and the manner in which they light an interior. The most commonly occurring types of luminaire and their typical performance characteristics are given in Table 9.3. The luminaire characteristics referred to in that Table are described in Items (a) to (f) below:

It must be emphasized that Table 9.3 is intended only as an overview; it is not suitable for lighting design. However, it can guide the user as to the choice and type of luminaire needed for a particular set of lighting criteria. There are many forms of luminaire other than those displayed and the same type of luminaire can show considerable variation in its characteristics. For accurate information, the manufacturer's data should always be consulted. Photometric data supplied by manufacturers should be obtained from photometric measurements according to AS 1680.3 and calculated according to that Standard.

(a) *Mounting position* Luminaires are usually either recessed into the ceiling (recessed), fixed on the ceiling (surface mounted), or suspended from the ceiling (pendant mounted). Some luminaires can be mounted in all three positions but most are only suitable for surface or pendant mounting. The mounting position is indicated by the letters R (recessed), S (surface), or P (pendant) as appropriate in Column 2 of Table 9.3.

(b) *Polar curve (intensity distribution) shape* The polar curve shape is a schematic illustration of the luminous intensity distribution of the luminaire. The luminous intensity distribution of the luminaire characterizes the way in which the luminaire controls the light from the lamp. For linear luminaires, two curves, representing axial (A, the C_{90} plane) and transverse (T, the C_0 plane) luminous intensity distributions are shown. For symmetrical luminaires a curve representing the average luminous intensity distribution is given. The polar curve shape for each luminaire type is given in Column 3 of Table 9.3.

(c) *Nominal spacing/mounting height ratio (SHR NOM)* When designing a uniform lighting system using the lumen method conformance with the uniformity criterion is ensured by limiting the spacing between the luminaire centres (see Section 11 and Appendix D). The maximum spacing that is allowable is determined by the luminous intensity distribution of the luminaire and its mounting height. Therefore the spacing allowable for each luminaire type is expressed as a ratio of the spacing to the mounting height. Typical nominal values of spacing/mounting height ratio are given for each luminaire type in Column 4 of Table 9.3. (See AS 1680.3 for the determination of spacing/mounting height ratios.)

(d) *Utilization factor* The efficiency of a lamp/luminaire combination when used to provide uniform lighting in a particular room can be expressed by the utilization factor. The utilization factor is the luminous flux which reaches the working plane expressed as a ratio of the luminous flux emitted by the lamp. For each luminaire type, the utilization factor will vary with the efficiency, distribution and spacing of the luminaires as well as with the room proportions and the reflectance of the room surfaces. Thus for any single luminaire type, a range of utilization factors will be obtained. An indication of the range of utilization factors likely to occur in rooms of different room index, with low and high surface reflectances, is given for a regular array at the nominal spacing of a typical luminaire of each type, in the form shown in Figure 9.1.

This information is given in Column 5 of Table 9.3. (See AS 1680.3 for the determination of utilization factors and Appendix D of this Standard for notes on the assumptions and limitations which apply to their use.)

(e) *Glare index* The luminous intensity distribution of a luminaire and its projected area are important factors in determining the glare index of the installation. The glare index produced by a regular array of luminaires of any particular type will also vary with the room proportions, the room surface reflectances and the room and luminaire orientation relative to the line of sight. Column 6 of Table 9.3 gives an indication of the range of glare indices likely to occur in square rooms of different areas with low and high surface reflectances, for a regular array of each luminaire type, in the form shown in Figure 9.2. For linear luminaires solid lines indicate limits of endwise viewing; broken lines indicate limits for crosswise viewing.

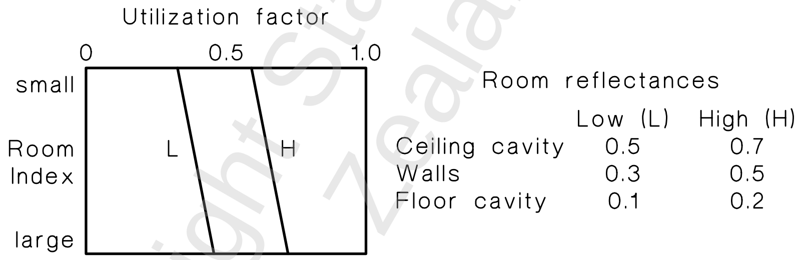


FIGURE 9.1 EXAMPLE OF UTILIZATION FACTOR DATA GIVEN IN TABLE 9.3

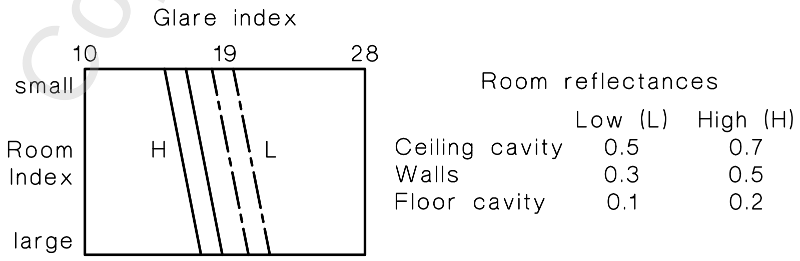


FIGURE 9.2 EXAMPLE OF GLARE INDEX DATA GIVEN IN TABLE 9.3

(f) *Room surface brightness* The luminous flux distribution of a luminaire determines to some extent the relative brightness of walls and ceilings. For a regular array of luminaires of each type, the pattern of brightness of walls and ceilings for rooms with average surface reflectances is indicated in Column 7 of Table 9.3, in the form shown in Figure 9.3.

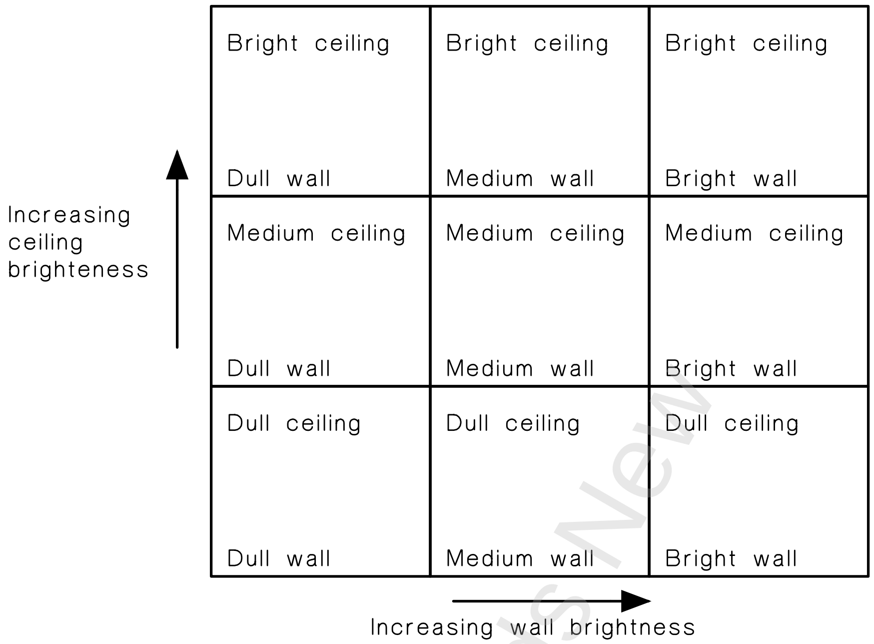


FIGURE 9.3 KEY TO ROOM SURFACE BRIGHTNESS DATA GIVEN IN TABLE 9.3

TABLE 9.3
LUMINAIRE CLASSIFICATION CHARTS

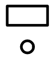
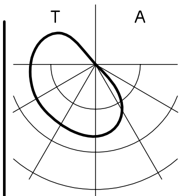
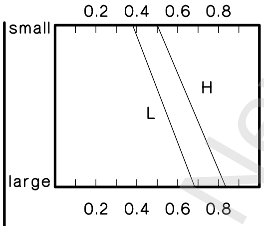
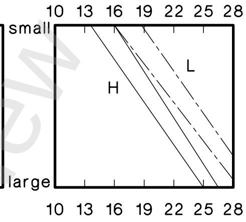
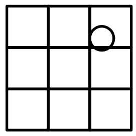
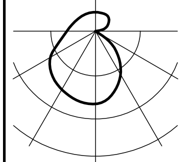
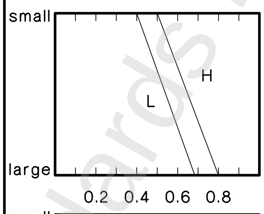
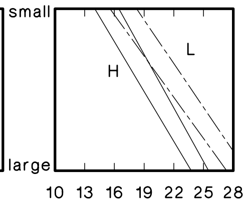
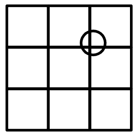
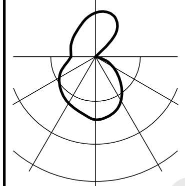
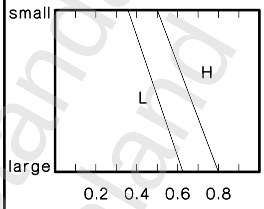
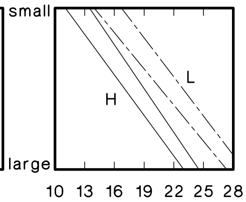
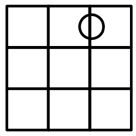
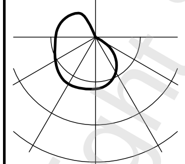
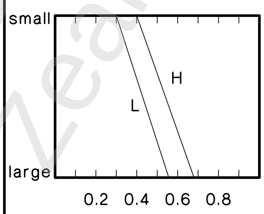
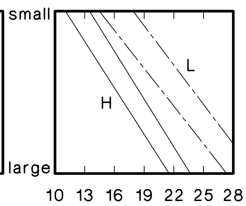
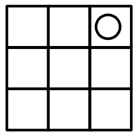
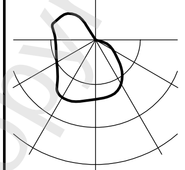
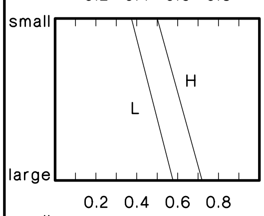
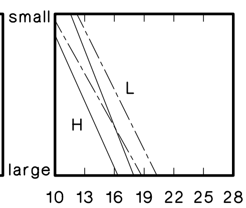
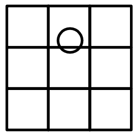
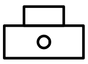
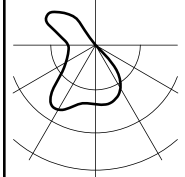
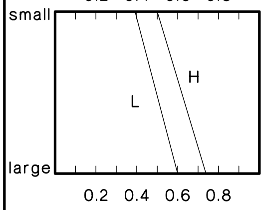
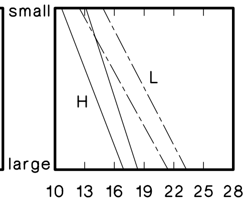
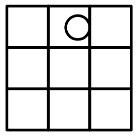
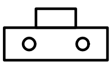
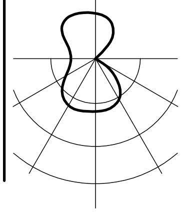
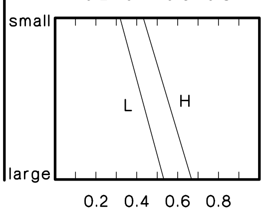
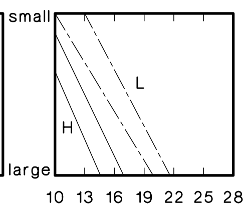
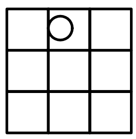
1		2	3	4	5	6	7
Luminaire		Mounting	Polar curve	SHR NOM	Utilization factor	Glare index	Surface brightness
Batten		SP		1.75			
Batten		SP		1.75			
Batten		SP		1.75			
Slim opal diffuser		SP		1.75			
Slim prismatic		SP		1.50			
Medium single prismatic		SP		1.75			
Wide twin prismatic		SP		1.75			

TABLE 9.3 (*continued*)

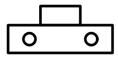
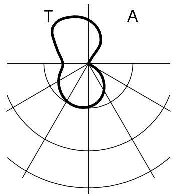
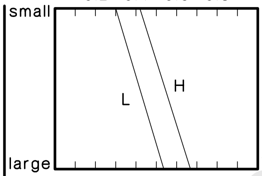
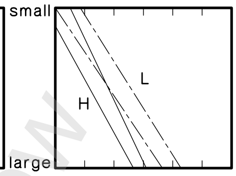
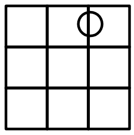
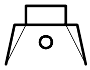
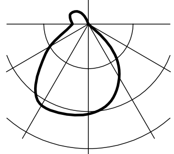
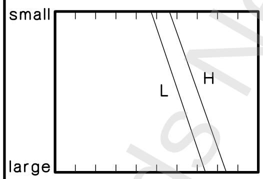
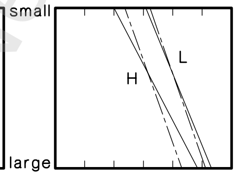
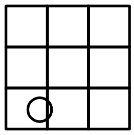
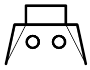
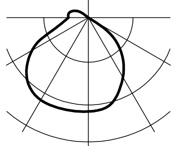
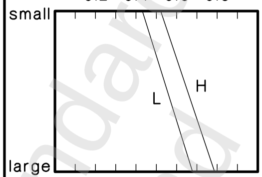
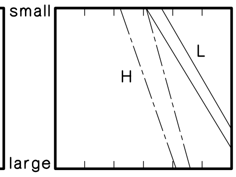
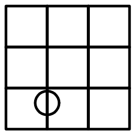
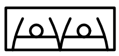
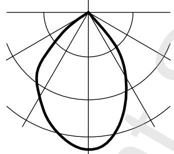
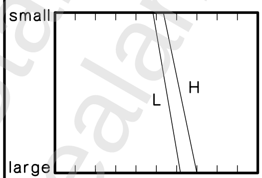
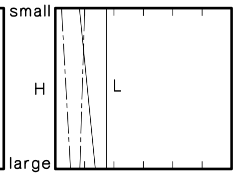
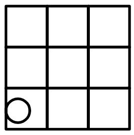
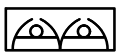
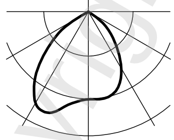
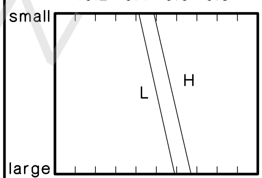
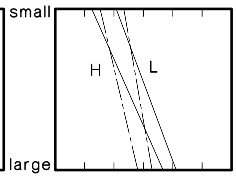
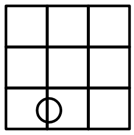
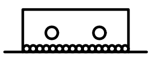
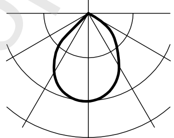
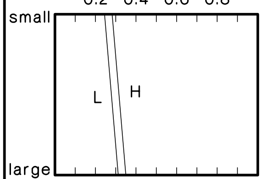
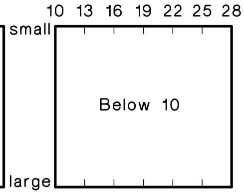
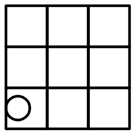
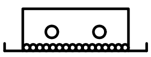
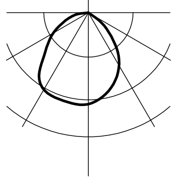
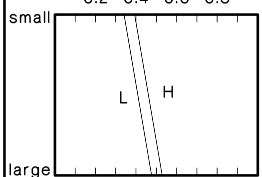
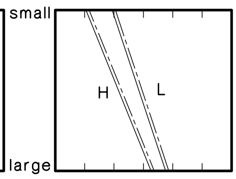
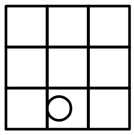
1 Luminaire	2 Mount-ing	3 Polar curve	4 SHR NOM	5 Utilization factor	6 Glare index	7 Surface brightness
 Wide twin opal diffuser	SP		1.75			
 Slotted white trough reflector	SP		1.75			
 Slotted white trough reflector	SP		1.5			
 Elliptical aluminium reflector with transverse blades	RSP		1.0			
 Faceted aluminium batwing reflector with transverse blades	RSP		1.75			
 Metalized parabolic cell louvre	RSP		1.0			
 Recessed modular with flat sheet prismatic lens	RSP		1.5			

TABLE 9.3 (*continued*)

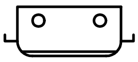
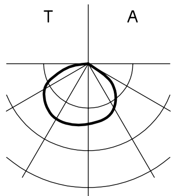
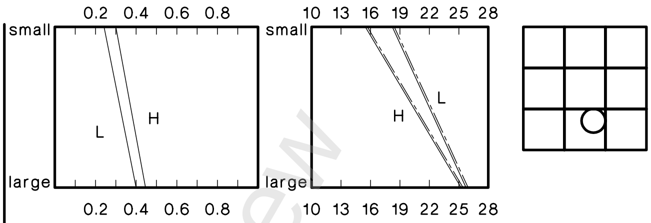
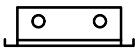
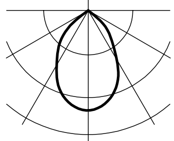
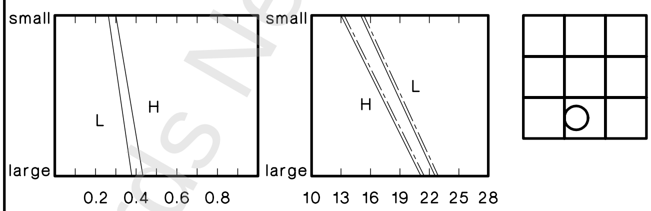
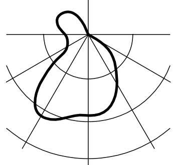
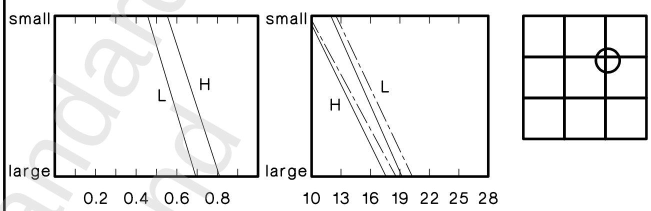
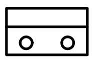
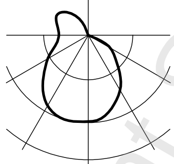
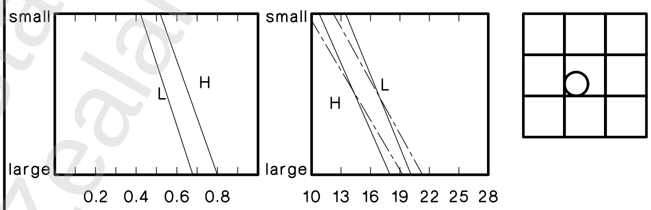
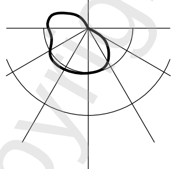
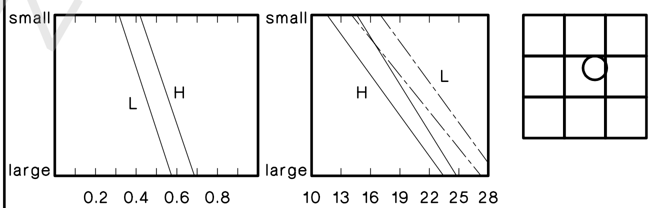
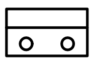
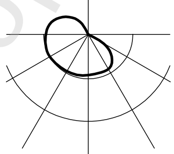
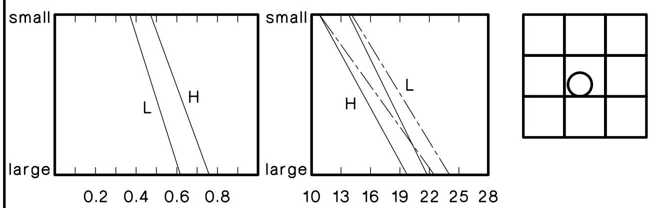
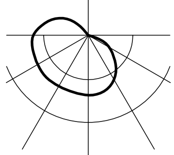
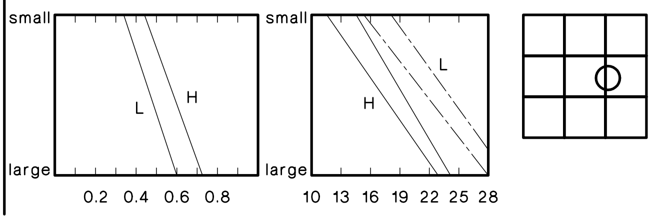
1 Luminaire	2 Mounting	3 Polar curve	4 SHR NOM	5 Utilization factor	6 Glare index	7 Surface brightness
 Recessed modular with opal dished diffuser	R		1.50			
 Recessed modular with 45° cut off white cell louvre	R		1.25			
 Opal sides prismatic base	SP		1.50			
 Opal sides prismatic base	SP		1.50			
 Opal sides and base	SP		1.50			
 Opal sides and base	SP		1.50			
 Industrial clear patterned	SP		1.75			

TABLE 9.3 (*continued*)

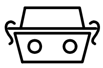
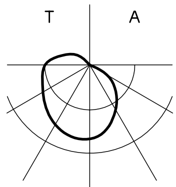
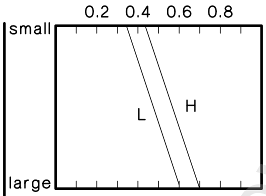
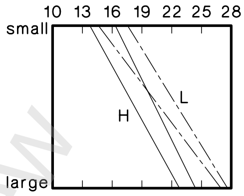
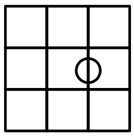
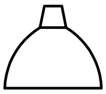
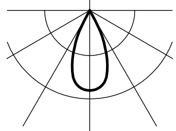
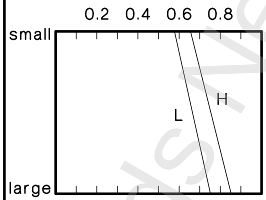
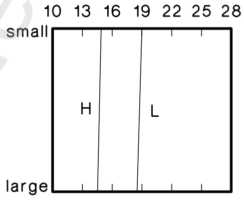
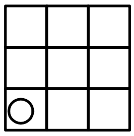
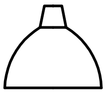
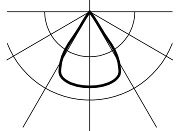
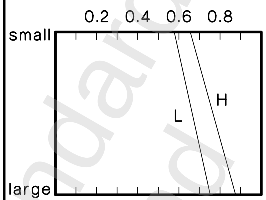
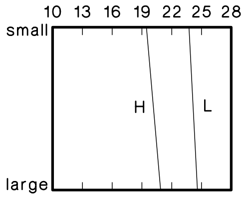
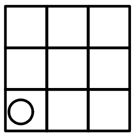
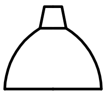
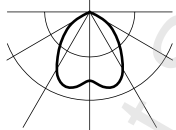
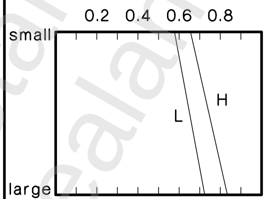
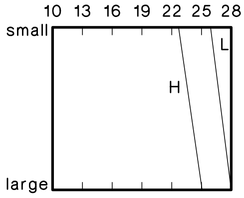
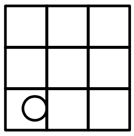
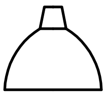
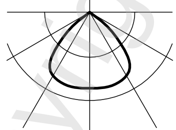
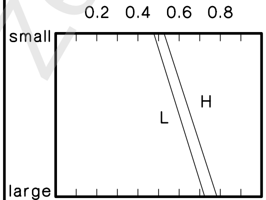
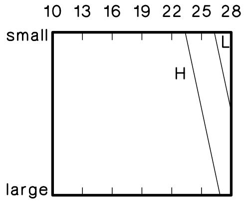
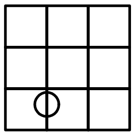
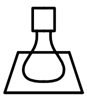
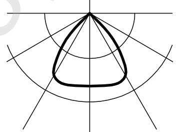
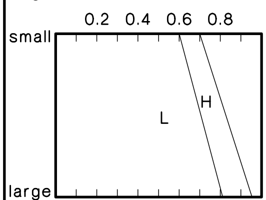
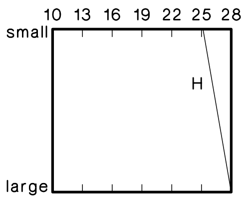
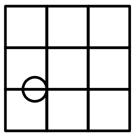
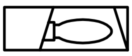
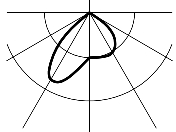
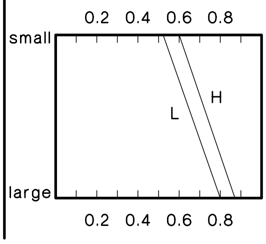
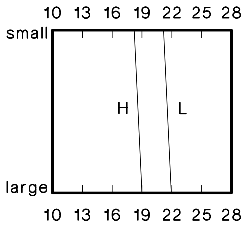
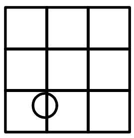
1 Luminaire	2 Mounting	3 Polar curve	4 SHR NOM	5 Utilization factor	6 Glare index	7 Surface brightness
 Industrial clear patterned	SP		1.50			
 High bay concentrating reflector	P		0.75			
 High bay medium spread reflector	P		1.25			
 High bay batwing reflector	P		1.75			
 High bay diffuser reflector	P		1.50			
 Reflector lamp with skirt reflector/shield	P		1.25			
 Box with batwing facetted reflector	RSP		1.75			

TABLE 9.3 (*continued*)

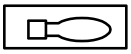
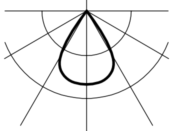
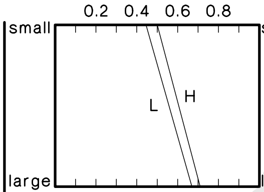
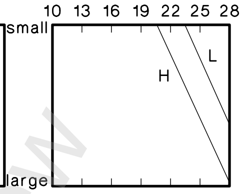
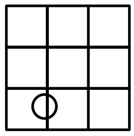
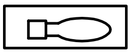
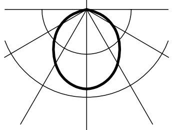
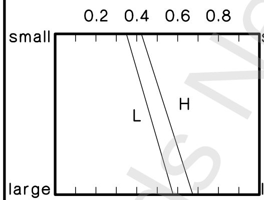
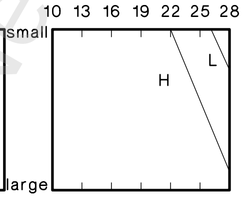
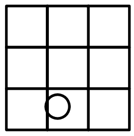
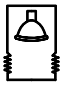
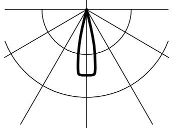
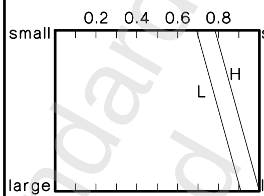
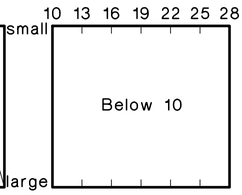
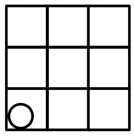
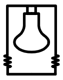
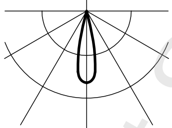
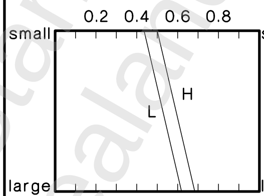
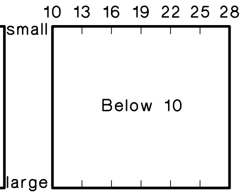
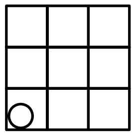
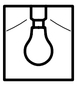
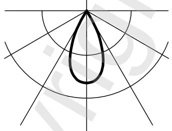
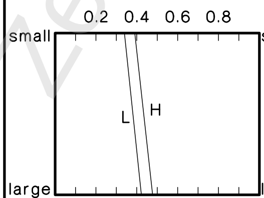
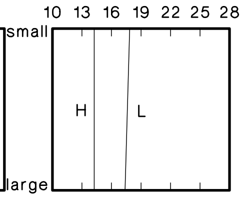
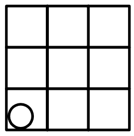
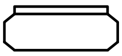
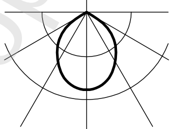
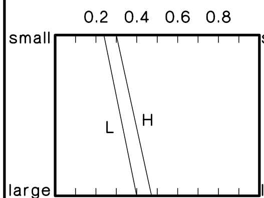
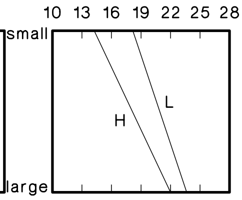
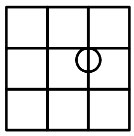
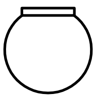
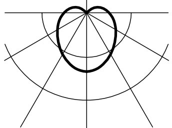
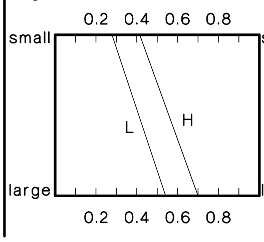
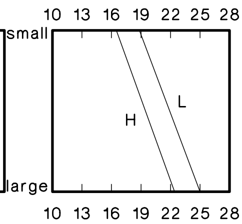
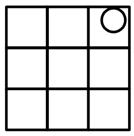
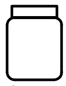
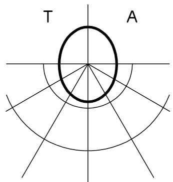
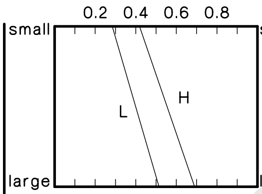
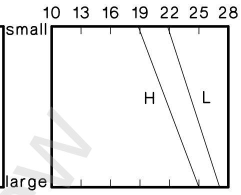
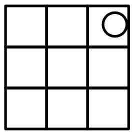
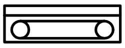
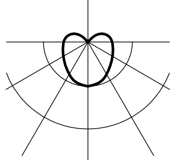
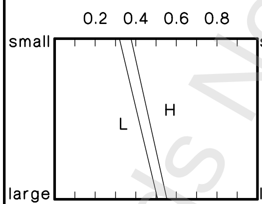
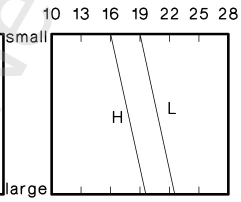
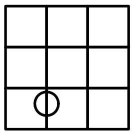
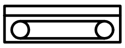
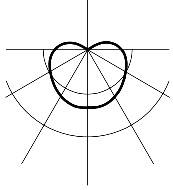
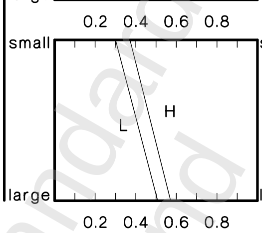
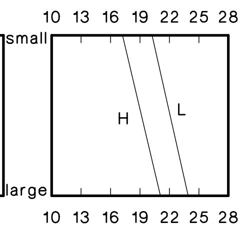
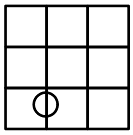
1 Luminaire	2 Mounting	3 Polar curve	4 SHR NOM	5 Utilization factor	6 Glare index	7 Surface brightness
 Box with prismatic base	RSP		1.25			
 Box with opal base	RSP		1.50			
 Downlight, narrow beam with Par 38 lamp	RSP		0.25			
 Downlight, narrow beam reflector lamp	RSP		0.50			
 Downlight, GLS lamp plus reflector	RSP		1.25			
 Opal bowl	S		1.50			
 Opal sphere	SP		1.75			

TABLE 9.3 (*continued*)

1	2	3	4	5	6	7
Luminaire	Mounting	Polar curve	SHR NOM	Utilization factor	Glare index	Surface brightness
 Opal cylinder	SP		1.75			
 Circular fluorescent, prismatic bowl	SP		1.25			
 Circular fluorescent, opal bowl	SP		1.50			

9.6 CONTROL SYSTEMS (FOR ELECTRIC LIGHTING)

9.6.1 The function of control systems

Control systems are an inherent part of any lighting system. They can take many forms, varying from a simple wall switch to being a part of a sophisticated computer based building management system. Whatever the method used, the aim of a control system is always to ensure that the lighting system is only operating when it is required, and that when it is, it is operating in the required state. The aim of most control systems is to vary the light output of the installation, either by switching or by dimming the lamps (see Section 10).

It should be noted that switching systems which are imposed on the occupants may generate user resistance. The system adopted should therefore provide the occupants with some degree of choice for the control of the lighting.

9.6.2 Switching

In principle, all light sources can be switched but the light output that is immediately available on switch on and the interval necessary between switch off and switch on varies with lamp type. Switching can be achieved by a number of different methods. The simplest is the manual switch. Remote switches which use an infrared transmitter and a receiver on the luminaire are also available. Both these forms of switching require human initiative. Alternative forms of switching operate without human intervention. Lamps can be switched by time switches or in response to the availability of daylight or the occupation of the interior. Photocells are used to sense the level of daylight available in an interior, whilst sensors of noise level movement and reflected radiation have also been used to detect people's presence in an interior. PIR type movement detectors are now the most common form of motion sensor.

One particular aspect of switching that has limited its use in the past has been the difficulty of switching individual or small groups of luminaires without excessive investment in wiring. Recent developments in electronics have made it possible to send switching signals by low voltage wiring or by high frequency transmission pulses (power line carrier technology) over the existing supply wiring. Further, logic circuitry now exists which allows individual luminaires to respond in one of several different ways. Such systems provide great flexibility in the way the lighting can be used.

9.6.3 Dimming

Whenever the ability to steadily diminish the illuminance in a room is desirable, dimming is required. Tungsten filament lamps can be readily dimmed. Not all discharge lamps can be dimmed and those that can be, such as tubular fluorescent lamps, need special control gear. Dimming lamps reduces the energy consumed by the lamp, but not necessarily in proportion to the light output, and usually changes its colour properties. Dimmers can be controlled manually or automatically in response to time or daylight availability. Many of the electronic developments mentioned in relation to switching can also be associated with dimming.

It should be noted that additional control wiring may be necessary when digital dimming systems are used.

SECTION 10 LIGHTING SYSTEMS

10.1 INTRODUCTION

This Section discusses the various lighting systems that can be used in interior lighting. The maintenance of lighting systems is discussed in AS/NZS 1680.4. While each system will be discussed separately it must be realized that most lighting installations will contain more than one system, often in combination. The various ways of introducing daylight into interiors will be treated as lighting systems.

10.2 DAYLIGHTING SYSTEMS

10.2.1 General considerations

Windows and rooflights allow the entry of sunlight and skylight into buildings and should be suitably located and sized to exploit available daylight as a light source in appropriate interiors. The location of the openings influences the pattern of daylight penetration, the direction of light, and the interior design. Furthermore the psychological aspects of view and contact with the outside should not be ignored or underestimated. Successful utilization of daylight depends upon careful attention being paid to window and rooflight design, as well as to interior finishes, if discomfort and disability from glare are to be avoided.

10.2.2 Windows

Windows should be positioned to provide as much daylight as possible into rooms while satisfying other environmental design criteria such as sun-control, heat gain, heat loss, sound isolation, privacy and views. Other factors that need to be considered include orientation, security and cost. Daylight on the work plane in a window-lit room is a mixture of two main components, viz—

(a) an external component received directly from the sky or by reflection from exterior surfaces visible through the window; and

(b) an internal component received indirectly by reflection from the interior surfaces of the room (see Figure 10.1).

Near the window wall, the direct component is dominant, but drops off much more rapidly than the internal reflected component, which becomes dominant deeper inside the room (see Figure 10.2).

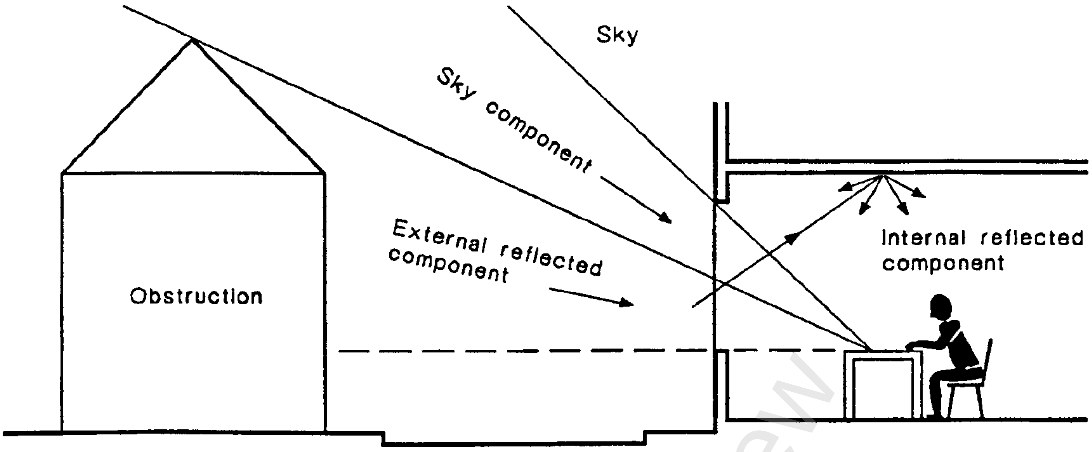
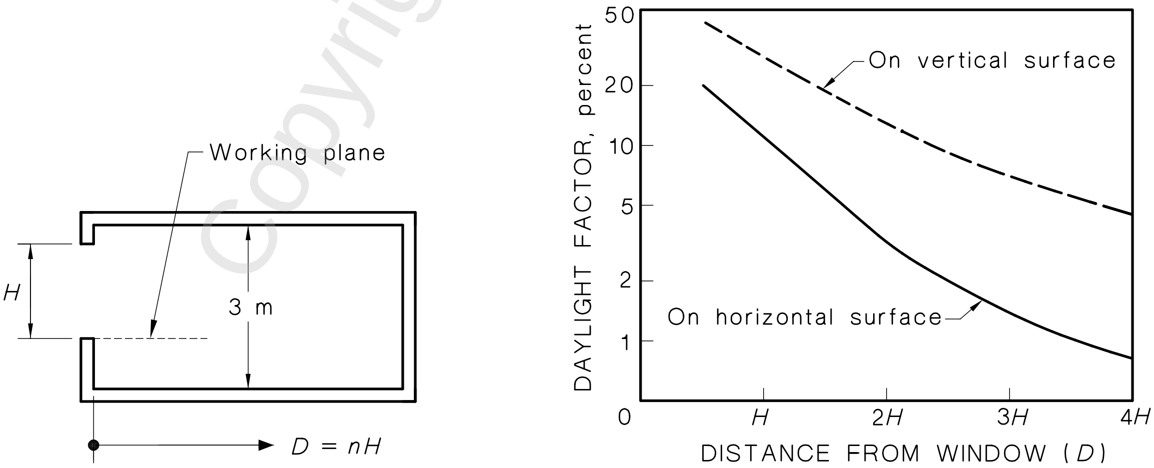


FIGURE 10.1 THE COMPONENTS OF DAYLIGHT WHICH CONTRIBUTE TO THE ILLUMINANCE AT A POINT IN A ROOM

In addition, the reflected component (internal or external) is relatively glare-free depending on the luminance of the reflecting surfaces. Consequently, by screening the window with suitable external louvres (or internal blinds) angled so as to reduce the direct component but increase the reflected component, the variation in illuminance across the work plane can be reduced, and the general quality of the lighting considerably increased.

The main part of the reflected component on the work plane originates at the ceiling above it. This is itself largely illuminated by light reflected from surfaces below sill level, such as opposite building facades or ground surfaces below, which can attain high luminances especially when sunlit. For example, under full sunlight even a bitumen paved car parking area has a luminance similar to, or even greater than that of the overcast sky (often used for daylight factor calculation); and with light-coloured external paving, the luminance, and consequently the light available, will be at least two or three times greater.



NOTE: The daylight illuminance is shown as daylight factor, which is the percent of available outdoor horizontal illuminance available at the point indoors.

FIGURE 10.2 TYPICAL VARIATION OF DAYLIGHT FACTOR IN A ROOM AS A FUNCTION OF *H*

In areas where strong sunlight is the rule rather than the exception and in tropical latitudes where external illuminance values are very high even under overcast conditions, this method can be used to create high quality daylighting of many interiors.

It is not possible to achieve the uniformity of illuminance sought in electric lighting systems from daylight, except in buildings using uniform arrays of rooflights. It is not necessary to try to achieve high uniformity since the gradient or change (and expectation) is sufficient to make the lack of uniformity unnoticed, provided that the areas remote from the windows are adequately lit by electric lighting.

10.2.3 The use of windows

In all types of interior, windows should be designed to provide a view of the world outside including landscape or townscape as well as the sky. When this is to be their primary function, relatively small windows located at eye height may be sufficient; but in all cases windows should occupy at least 30 percent of the window wall width, with the windows being located within a viewing angle of 60° measured from the centre of the room.

Where possible, windows should be provided in more than one wall. (They should also preferably be placed adjacent to walls abutting the window wall.)

It is also useful to splay window reveals, both internal and external, to introduce a measure of contrast grading, widen the external view and increase the light admitted.

When none of these measures can be used, the window wall should have a reflectance of at least 0.6 (see Clause 6.3.3) or electric lighting should be provided close to the window wall.

One main object of the above recommendations is to increase the luminance of the window wall and to prevent it from appearing as a dark frame around the bright window.

In addition, the glare control recommendations in Clause 8.1.2 should be carefully observed.

10.2.4 Rooflights

Rooflights fall into two main categories, viz —

(a) those with vertical glazing or close to vertical (e.g., saw-tooth and monitor roofs); and

(b) skylights let into horizontal flat roofs or pitched roofs.

Rooflights are particularly useful in single-storey buildings where they can supplement the light from windows, particularly in very deep rooms. The quality of light from a rooflighting system is similar to that provided by electric lighting systems, i.e., the flow of light is mainly from above. The design of rooflights requires the same attention to detail as the design of windows. A regular array of rooflights can provide satisfactory working plane illuminances for large portions of daylight hours.

Rooflights allow the utilization of daylight and reflected sunlight. Direct sunlight can be utilized, provided that it is suitably diffused and the heating effect is considered. Diffusing skylights recessed into a flat roof can admit much more light when sunlit than under overcast sky conditions. In areas where sunlight is prevalent, it may be more economical to design for sunlight conditions, employing electric light only on occasional dull days or at night.

10.2.5 Use of rooflights

In working interiors where it is possible to provide daylight throughout the whole interior for a substantial proportion of working hours, design should be based on a daylight factor capable of providing 200 lx or more throughout 90 percent of normal working hours between 9 a.m. and 5 p.m.; and with a diversity similar to that specified for general electric lighting systems in Clause 3.8.2.

Provision of a diffusely reflecting surface on the underside of a saw-tooth roof is particularly recommended. If aluminium foil is employed, it should have an embossed or corrugated surface to aid diffusion.

The objective is to improve the quality and quantity of light inside the building by increasing the penetration of diffuse, reflected light, originating from the sky and from adjacent sunlit and skylit sections of the outer surface of the roof.

10.2.6 Glazing recommendations

Glass and plastics such as acrylics, fibreglass and polycarbonate are used for daylight admission into buildings. Plastic materials are sensitive to UV radiation which affects their chemical composition and makes them more brittle and less transparent. It is important that UV-resistant plastic glazing materials are used, particularly in applications where exposure to direct sunlight is high.

Diffusing glasses or plastics may have high transmission in the visible range but they can reduce contact with the outside and degrade views out; therefore they should be avoided for windows capable of providing a view. It is common practice to use tinted glazing, e.g. ‘anti-glare’ or ‘heat resistant’ and mirrored glasses, over large areas to avoid excessive heat gain and glare. However because of their low transmission of light, these glazings cannot properly respond to the varying external conditions and electric lights need to be used during daylight hours. Therefore tinted and reflective mirrored glazing should not be considered as a general strategy in the design of daylighted interiors. Low emissivity glazings reflect a larger fraction of incident solar infrared radiation than untreated glass.

On the other hand special circumstances may require reduced light transmittance. Museums often require reduced lighting levels for conservation reasons and low transmission glazings can satisfy these requirements while allowing daylight into the space and the exploitation of views through windows.

When using heat reflecting glazing, thought must be given to possible ill-effects that external reflections (particularly reflected sunlight) may have outside the building. Also such glazing should not exhibit disturbing reflections of objects inside the room. Reflected images of luminaires and brightly lit surfaces near the window wall can seriously interfere with the view of the outside scene when deep, open-plan offices have glazing with an internal reflecting surface.

10.2.7 Control of sunlight penetration

In working interiors, sunlit glazing should be externally screened with overhangs or louvres; or internally shaded with blinds or other suitable devices.

Unwanted sunlight penetration usually causes excessive contrast rather than excessive luminance. Lowering the light transmission of the window is therefore of little help. The use of diffusing glass or translucent plastic in windows (or vertical rooflights) is not satisfactory either, and should never be used in windows at or near eye-level. When sunlit, the diffuse glazing will become excessively bright and become a severe source of glare. For the same reason, clear glass windows should never be given a thin coat of paint in an attempt to exclude unwanted sunlight.

When external horizontal louvres are used, they should preferably admit light reflected from below outside the building. This upward light when re-reflected from a white or near-white ceiling penetrates deep into the interior and is inherently glare-free. Similarly, a suitably angled internal venetian blind can reflect the sun’s rays upwards to the ceiling surface.

Control of sunlight penetration with the aid of overhangs and louvres is an exact science and various aids exist for the design of these. External architectural features known as light shelves can be an effective means of window shading while using a large surface to reflect sunlight onto the ceiling through a highlight window.

As in the case of windows, the sky, sun or sunlit surfaces visible inside or outside the building should not be allowed to interfere with the visual comfort or efficiency of persons working in the area. Patches of sunlight on the work area are often the worst offenders and sunlit glazing should be screened or shaded with suitably designed overhangs or louvres.

In general, clear glazing should be used except in the case of skylights.

Skylights are difficult to shade, yet must be glazed with material sufficiently diffusing to ensure even illuminance over the area below. As they become exceedingly bright when sunlit, they should not be visible within 40 degrees of the horizontal line of sight.

Suitable internal screening is easily arranged in the case of flat roofs, but is much more difficult when the roof surfaces slope. In either case, skylights tend to admit a great deal of heat. The cost of interior cooling in such a building should therefore always be taken into account in determining the most economical balance between daylight and electric lighting.

In predominantly sunny, clear sky areas where rooflights designed for the conventional overcast sky condition may admit too much heat most of the time, it may be more economical to employ smaller diffusing skylights, treating these like electric lighting luminaires with a luminance, in candelas per square metre, equal to the illuminance, in lux, on the outside of the skylight multiplied by the latter's diffuse transmittance and, finally, divided by pi (π). Electric lighting would then only be needed on occasional dull days or at night.

10.3 ELECTRIC LIGHTING SYSTEMS

10.3.1 General comments

Electric lighting systems can be classified by—

(a) function;

(b) layout and location;

(c) light distribution; or

(d) position.

This Standard will use function as the criteria for lighting systems. The techniques which can be used within these systems are discussed in Clause 10.4.

10.3.2 General lighting systems

These are lighting systems that provide a uniform, horizontal illuminance over the whole of a space. This is usually achieved using a uniform or near uniform array of luminaires. Such a lighting system may also provide environmental lighting (see Clause 10.3.5). A general lighting system is often designed to provide the required task illuminance in those spaces in which only one task type is involved and where the task can be located in any position within the space. On the other hand, a general lighting system may provide the required maintained illuminance for the space, with localized general lighting (Clause 10.3.3) or local lighting (Clause 10.3.4) providing higher illuminances (together with other lighting criteria) in the task areas. General lighting systems are usually designed to provide the required illuminance using the lumen method although it is now becoming common for calculations to be carried out using computer aided design tools.

10.3.3 Localized general lighting systems

These are used where part of a larger space requires lighting over an area larger than a single workstation which has requirements in addition to those provided by, say, the general lighting system or, perhaps, the environmental lighting system. An example is a drawing office area within a general office or a specialized area in a general factory space. In some cases localized general lighting systems can be designed using the lumen method, with due consideration to the possibility of the 'room' not having any 'walls', while in other cases a combination of methods may be needed in order to ensure compliance, for example, for tasks on other than horizontal planes. Computer aided design tools are suitable for designing these systems.

10.3.4 Local lighting systems

These are lighting systems which are specially designed for particular task locations. The locations can be as small as a watchmaker's field of view through a magnifier or as large as an industrial inspection station. The important point is that the lighting is designed specifically for the task in the location. It is likely that the lighting will not be designed using the lumen method. It is unusual to use a local lighting system in isolation, since its function is oriented towards the particular task requirements, but is used in conjunction with some form of general or environmental lighting system.

10.3.5 Environmental lighting systems

The distinguishing feature of an environmental lighting system is that its primary function is to illuminate the environment in order to provide comfortable and pleasant viewing conditions. It will be sometimes necessary to use a separate environmental lighting system, even when using a general lighting system, especially if the requirements for the general lighting system mean that, say, wall luminances are inadequate due to reduced vertical illuminances in areas using screen-based equipment. Another case may be where dimming is used in a daylighting/electric lighting system which would otherwise result in excessive contrasts due to reduced wall luminances. It is likely that the environmental lighting system will be designed to produce required vertical surface luminances. Such a system can be also used to provide lighting for effect and atmosphere (see Clause 10.3.8).

10.3.6 Emergency evacuation lighting systems

These are described in detail in AS 2293.1 and may be part of another lighting system provided that they comply with AS 2293.1. However, it should be noted that the sole function of such a system is the safe evacuation of people from buildings in the event of the failure of the normal lighting system.

10.3.7 Safety lighting systems

These are any lighting systems, other than emergency evacuation lighting, which are used in the event of the failure of the normal lighting system. They may be used to allow the safe shutting-down of a process in the event of an emergency or to allow the completion of a process (for example, a surgical procedure). The individual requirements will dictate whether such a safety lighting system can be incorporated into any other lighting system.

10.3.8 Effect and atmosphere lighting systems

These could be thought of as a subset of environmental lighting systems but it must be emphasized that environmental lighting systems are primarily concerned with providing good seeing conditions within a space. The creation of special effects or atmosphere is in addition to the primary requirement of good seeing conditions. Display lighting is an example of lighting for effect (although it obviously has task demands). Illuminated advertising signs are another example of effect lighting while the use of real or electric candles in chandeliers or on tables could be considered primarily lighting for atmosphere (although in the former case, large chandeliers may provide general lighting).

10.4 METHODS WHICH CAN BE APPLIED IN LIGHTING SYSTEMS

10.4.1 General comments

Clauses 10.4.2 to 10.4.4 are primarily concerned with the characteristics of lighting systems that influence the brightness distribution in the interior. In general, this can be achieved using the following:

(a) *Direct lighting* Lighting where at least 90% of the emitted luminous flux is directed downwards, e.g. downlighting and luminous ceilings.

(b) *Indirect lighting* Lighting where at least 90% of the emitted luminous flux is directed onto ceilings and upper walls, e.g. uplighters.

(c) *Direct-indirect lighting* Lighting where the proportions of emitted luminous flux in the downward and upward directions lie between those specified in (a) and (b). This classification includes lighting systems which utilize luminaires described in some classification systems as 'semi-direct', 'general diffused' and 'semi-indirect'.

Local lighting (see Clause 10.3.4) is not deemed to be a lighting system in terms of this Section since such lighting makes little contribution to the brightness of the main interior surfaces. Local lighting should therefore be used only in conjunction with one of the classes of lighting system described above.

See AS/NZS 1680.4 for advice relating to the selection of lighting systems based on maintenance considerations.

10.4.2 Direct lighting

10.4.2.1 *Relationship between luminaires and ceiling*

Direct lighting can be best described in terms of the relationship between the luminaires of the system and the ceiling. Three major categories exist:

(a) Individual luminaires with flashed horizontal diffuser or refractor panels.

(b) Individual luminaires with dark apertures produced by matt or specular reflectors or matt black internal obstructions.

(c) Luminous ceilings.

Recommendations on the use of each category are made in Clauses 10.4.2.2 to 10.4.2.4.

NOTES:

1 Flashed surfaces are those that are filled with light from the source and, from normal viewing directions, would be described as 'bright'. The luminance of the surface is usually a significant fraction of the source luminance.

2 Dark apertures, reflectors, etc., are those that are not described as being bright from normal viewing directions. In some cases the low luminances may be due to absorption by low reflectance finishes while in others, and more typically, it is through the use of specular reflectors which carefully control lamp flux so that very little is reflected towards viewers' eyes. The luminance of such an aperture or reflector is usually an insignificant fraction of the source luminance.

10.4.2.2 *Flashed luminaires*

Where flashed luminaires are used care should be taken to avoid excessive brightness contrasts between the luminaires and the adjacent ceiling. This is especially important in large interiors with many luminaires in the field of view and in interiors where the visual tasks lie predominantly in or near the vertical.

The recommendations in this Clause are designed to obviate such distracting contrasts. However, where circumstances dictate the use of ceilings having a reflectance of less than that recommended in Clause 6.4, the luminaires may need to be of a type having a lower luminance than that required for compliance with Clause 8.3.

It has been found from observation that, for tasks which lie in or near the horizontal, the brightness contrast between luminaires and the ceiling appears distracting if the ratio of the average luminances, measured at 70 degrees to the downward vertical, exceeds about 50:1.

10.4.2.3 *Dark luminaires*

It is not uncommon for some downlight installations to be described as gloomy, that the ceiling appears heavy and low, that people feel spot-lit when directly beneath the downlight and that features cannot be seen when between downlights. The first two comments refer to the contrasts between the luminaires and the ceiling: dark luminaires are often perceived as not producing sufficient, if any, light since the ceiling is illuminated by light reflected mainly from the floor (cavity). The latter two comments are related to the distribution of light from the luminaires (often narrow to eliminate direct glare effects) and the location of luminaires (see Clause 10.5). It is important that the ceiling and walls are sufficiently bright to avoid a gloomy appearance.

10.4.2.4 *Luminous ceilings*

The term luminous ceiling refers to situations where most of the ceiling is occupied by either diffusing panels or louvre systems which may comprise either matt or specular reflectors.

Diffusing luminous ceilings tend to produce excessively diffused illumination and require frequent cleaning to prevent dirt and dust from impairing both their efficiency and appearance. They should be made of fully diffusing materials and the lamps should be so spaced that the underside of the ceiling appears uniformly bright. The average luminance of the ceiling should comply with Clause 8.3.4.8.

Louvred ceilings provide better modelling than diffusing luminous ceilings because of the greater vertical light component. To ensure that the ceiling has an evenly bright appearance, the lamps should be appropriately spaced and the ceiling cavity finished white.

10.4.3 Indirect lighting

Totally indirect lighting can produce an excessively diffused illumination resulting in a bland visual environment, but such lighting may be useful for special applications, e.g. interiors devoted exclusively to the use of screen-based tasks (see AS 1680.2.2) and other tasks where veiling or distracting reflections are liable to be particularly troublesome.

Indirect lighting can also be used in conjunction with local (task) lighting to illuminate the ceiling and walls so as to achieve a suitable brightness distribution.

Luminaires used for indirect lighting should be located above eye-level for standing persons (typically 1.7 m above the floor) so as to avoid glare and annoyance.

In large areas illuminated by discharge lamps, the luminaires should be connected across more than one phase of the supply in order to minimize the possibility of distraction resulting from flicker (see Clause 9.4.4).

10.4.4 Direct-indirect lighting

Where luminaires are either suspended or surface mounted, opportunity should be taken to direct some light upwards onto the ceiling in order to—

(a) reduce the brightness contrast between the luminaires and the adjacent ceiling; and

(b) minimize the tendency for the interior to appear 'gloomy' as a consequence of the ceiling being inadequately lit.

10.5 LOCATION OF LUMINAIRES

10.5.1 General

The recommendations of this Clause are additional to the need to locate luminaires to provide the necessary task illuminances specified in Clause 3.6.

Section 6 makes recommendations on surface reflectances and the previous clauses of this Section discuss characteristics of various lighting systems that influence the brightness distribution of interiors. This Clause concerns the choices made regarding locating luminaires to achieve the desired brightness distributions. Comments on the location of windows and the integration of electric light and daylight are made in Clauses 10.2 and 10.6.

In general, luminaires should be located to achieve the dual objectives of a satisfactory brightness distribution in the general environment and, where necessary, satisfactory brightness contrasts between light sources and finishes and between tasks and their backgrounds.

10.5.2 Illumination of ceilings

Some lighting techniques are more effective than others in providing light onto the ceiling and Clause 10.4.2.3 should be noted for direct lighting systems which utilize dark luminaires. For lighting systems that have a high proportion of luminous flux directed downwards, the reflection of the floor cavity substantially affects ceiling illuminance. High floor cavity reflectance is essential wherever fully recessed luminaires are to be used.

The ceiling should be illuminated so that the average brightness is sufficient to achieve the desired lightness and spaciousness for the interior and to reduce the contrast between the ceiling and the lighting system (if ceiling mounted). The ceiling luminance pattern does not need to be uniform and some variation can add interest provided that the changes in luminance are gradual, i.e. that the patterns do not have sharp or ‘hard’ edges.

Indirect lighting, such as installations which utilize uplighters, can employ non-uniform ceiling luminance distributions provided that, to minimize distracting brightness contrasts, the ratio of the maximum luminance to the minimum luminance of the illuminated surfaces should not exceed 20:1. Ceilings should also comply with the luminance limits specified in Clause 8.3.4.8. Bright areas should not have ‘hard edges’, i.e. there should not be rapid changes in the luminance of the illuminated surfaces.

Direct-indirect lighting should be installed to ensure that the upward light from luminaires is distributed on the ceiling in such a way that excessively bright patches on the ceiling are avoided. Similarly ‘hard-edged’ patterns should be avoided.

Some surface mounted and suspended luminaires can produce high ceiling luminances adjacent to the luminaire. Care should be taken that the resulting ceiling luminances comply with Clause 8.3.4.8. Manufacturers’ data should be consulted on recommended suspension heights for suspended luminaires. Some luminaires emit a portion of upward flux through slots in their reflector systems. In general, these should not be suspended closer than 150 mm from the ceiling.

10.5.3 Illumination of walls

Where a regular arrangement of ceiling mounted luminaires is used, the row of luminaires adjacent to the walls should be installed at a distance that will ensure that the wall surfaces are adequately illuminated. Alternatively, the walls should be illuminated independently of the general lighting, e.g. by ‘wall washer’ luminaires or pelmet lighting (see also Clause 10.6).

The distance from the walls at which the luminaires need to be installed will depend on the nature of the light distribution. However, most direct lighting luminaires, e.g. downlights, luminaires with low-brightness louvres and certain types of luminaires with prismatic lens panels, will need to be installed closer to the walls than the conventional half-spacing distance.

Some direct type luminaires have a sharp cut-off which can produce hard-edged patterns; these can sometimes leave the upper part of a wall parallel to the luminaires darker than the lower part. Scalloping can occur on transverse walls adjacent to luminaires. Care should be taken to avoid these distracting light and shadows patterns on the walls of rooms in which the occupants look horizontally for most of the time, e.g. in lecture theatres.

10.6 DAYLIGHT-ELECTRIC LIGHT INTEGRATION

Increasing use is being made of systems that integrate daylight and electric light, with the object of reducing the energy demands of buildings. These systems can be relatively simple switching systems where the electric lighting is switched off and on in response to available daylight illuminances (see Figure 10.3) or they can be more sophisticated, employing delayed dimming in place of on-off switching.

From the recommendations of Clause 10.2, it can be seen that the success of these schemes, in terms of visual comfort rather than horizontal illuminance, are dependent upon the brightness distributions of the spaces. Many existing buildings provide adequate visual conditions during daylight hours only if the electric lighting is in full operation, since the electric lighting illuminates the room surfaces.

The successful integration of daylight and electric light in other than the smallest of window-lit rooms and some systems employing rooflights will depend not on the balance of daylight and electric light illuminances, but on the achievement of a satisfactory brightness distribution, including the effects of sky glare.

Not only should the recommendations of Clause 10.2 be followed, but it may be necessary to reduce glass transmittances in order to provide comfortable seeing conditions at the cost of reduced daylight illuminances.

In some cases of integration it may be desirable to provide separate electric lighting for the working plane and the room surfaces, particularly the walls, in order to maintain a satisfactory brightness distribution when the working plane electric lighting is dimmed or switched. The window wall may need special attention, e.g. it may be necessary to provide permanent wall-washers for the window wall in order not to increase the window contrast when dimming or switching takes place.

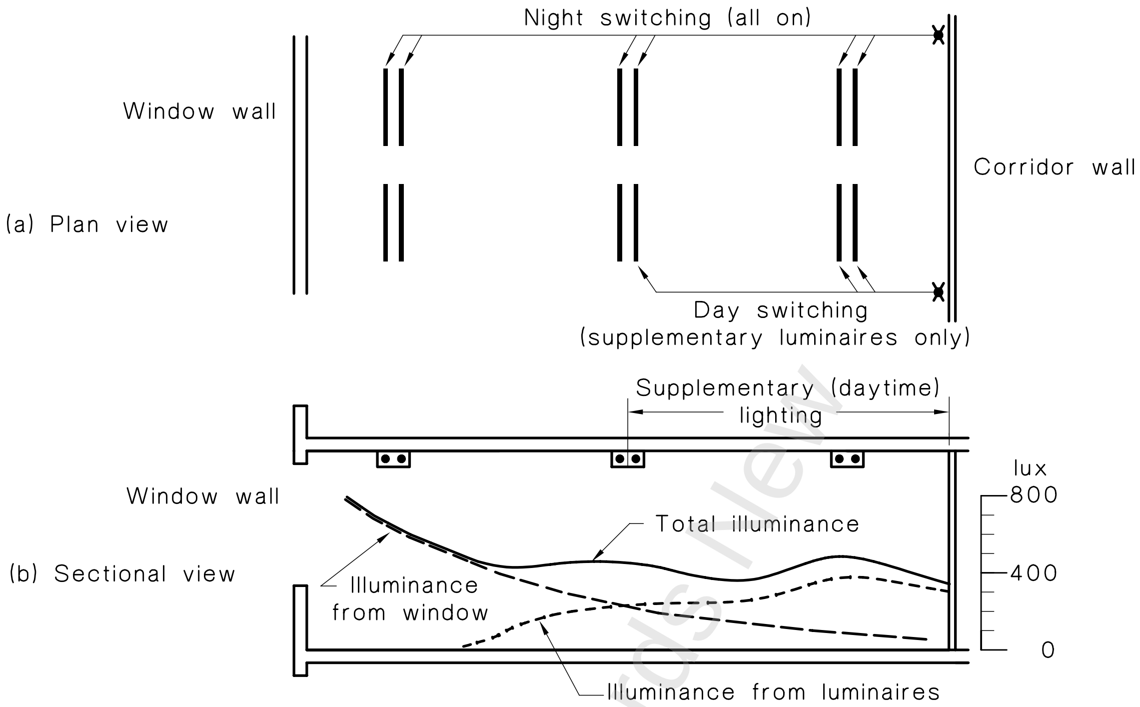


FIGURE 10.3 THE INTEGRATION OF DAYLIGHT AND ELECTRIC LIGHT IN A SIDE-LIT ROOM USING SWITCHING

10.7 ENERGY-EFFECTIVE LIGHTING

10.7.1 General comments

Significant savings in energy consumption, and therefore in cost, without reducing performance and visual satisfaction can be achieved by applying an energy-effective design and operating approach to lighting systems. Savings in energy consumption follow from measures which reduce the electrical loading and from measures which reduce the time of use.

10.7.2 General measures for energy saving

10.7.2.1 *Daylight and energy conservation*

Windows and rooflights can have a significant impact on the net annual energy consumption of buildings. Energy savings can result from direct reduction in electricity consumption with consequent additional savings from reduced cooling loads. However, although proper design and effective management of windows can provide substantial energy savings, increasing the window areas or transmittance can reach a point, depending on climate and orientation, beyond which total energy consumption increases due to greater cooling loads. Energy requirements for the air conditioning will, in most cases, increase as daylight is increased.

There is an optimum window area for minimizing nett annual energy consumption depending on climate and orientation. However, control of solar gain is vital if daylighting strategies are to provide net energy benefits. New and more efficient fenestration systems are being developed for greater energy efficiency and visual comfort and it may be expected that windows with variable transmittance will become commonly available in the future.

10.7.2.2 *Integration of lighting and air conditioning*

Energy management in buildings involves control of internal and external heat gains and losses, and transportation of heat for use and disposal. Depending on the circumstances heating or ventilation or cooling systems or a combination thereof are used for this purpose. Since the heat produced by the lighting forms part of the total heat load of the building the three forms of heat dissipation of the lighting (convection, conduction and radiation) should be accounted for in the design of the air conditioning installation. It may prove effective to use return air luminaires which in general will make it easier to meet the comfort criteria for the indoor climate and which for most types of tubular fluorescent lamps may improve their luminous efficacy due to the controlled ambient temperature for the lamps.

10.7.2.3 *Maintenance*

Proper maintenance procedures including cleaning and group relamping at the most economic lamp life can save costs and energy and can prolong the life of the system. Room surfaces should also be cleaned in order that their reflectances are maintained. Glazing and any reflectors in daylighting systems should also be cleaned regularly.

10.7.3 Energy savings from reduction in electrical load

10.7.3.1 *Lamps and control gear*

Lamps and control gear of highest efficacy should be used in so far as their other characteristics are consistent with the required quality criteria for the lighting system. In this respect attention should be given to the following lamp properties: colour appearance; colour rendering; luminance; luminous flux; lamp lumen depreciation; life; size; available luminaire types; starting and running up characteristics; and dimming possibilities. In most cases, electronic control gear will give superior performance with discharge lamps.

10.7.3.2 *Luminaires*

Luminaires should be selected which, in a given application, give the highest utilization factor in so far as their other characteristics are consistent with the required quality criteria for the lighting system. In this respect attention should be given to the following luminaire properties: suitability of the light distribution for that application; glare limitation; luminaire lumen depreciation due to dust and dirt collection or to discolouration of its materials; ease of cleaning and lamp exchange; mounting possibilities; IP designation (where appropriate); and appearance (where appropriate).

10.7.3.3 *Arrangement of luminaires*

Luminaires should preferably be arranged so that emphasis is given to the lighting of work areas. In interiors where the workstations are known, fixed localized general lighting may be energy-effective. This technique, which provides the recommended illuminance at the work locations and less light in the circulation zones, may actually improve the appearance of the interior if compared with the provision of overall uniform lighting throughout the area. Illuminance ratios between the working and the circulation zones within the same space should not exceed 3:1. If the location of the workstations is not known beforehand or is likely to change occasionally, a flexible mounting system may be provided that enables adaptation of the arrangement of the luminaires to the layout of the workstations.

10.7.3.4 *Room surface reflectances*

High reflectance finishes on walls, ceiling, floor and furniture use light more efficiently. However, guidelines as to reflectances should be observed (see Section 6).

10.7.4 Energy savings from reduction in time of use

Control of the electric lighting according to the required level at a given time and at a given place can be effective in energy saving. The level required depends on the available daylight, on the occupancy of the workstation, on the tasks to be performed (requirements for paper or screen-based visual tasks may be different from those for cleaning or the requirements at a given workstation may vary in time depending on the tasks to be performed at that moment) and on the individual worker (see Clause 9.6).

It should be noted that frequent switching of most of the modern tubular fluorescent lamp types does not influence lamp life to such an extent that this would form an objection to using lighting control for the purpose of energy saving with these lamp types, However, the trade-offs should be considered in the preliminary design stage.

Details of various switching/dimming strategies are beyond the scope of this Standard.

10.7.5 Energy calculations

All lighting designers should ensure that their designs do not waste energy. However, the most important considerations about energy consumption are usually financial ones. Few users are willing to invest extra money to achieve energy savings unless the savings offer a reasonable rate of return on that investment. Functional lighting tends to be more efficient than decorative lighting. This is not to say that decorative lighting is wasteful. If the design objectives call for particular conditions to be created, then they should be provided. If they are not provided, then, although the design may use less energy, it will not be effective and cannot, therefore, be regarded as satisfactory.

It is easy to assume that the efficiency of a lighting system should be the most important yardstick in any design, and to give it undue bias. If this happens, not only will important design objectives be suppressed, but the resultant scheme is unlikely to be the best financial proposition. Scheme efficiency should therefore be considered in parallel with other design details.

It should be remembered that the losses in productivity which may result from a poor lighting scheme will far outweigh any savings which may be achieved in the installation cost.

For many lighting systems time of use will be determined by the ability of the lighting control system to switch the lighting in response to daylight availability or the needs of the users. To compare the effectiveness of alternative control systems the lighting designer will need to estimate the probable annual use of electric lighting under each system.

In New Zealand, for specific lighting power values, refer to NZS 4243.

SECTION 11 LIGHTING DESIGN PROCEDURE

11.1 INTRODUCTION

Lighting design is a complex process and no hard and fast rules can be devised which will suit all design problems or every lighting designer. Nevertheless, the following design approach represents reasonable practice and will give guidance to less experienced lighting designers.

A flowchart of the overall process is given in Figure 11.1, and each stage is detailed in the following Clauses.

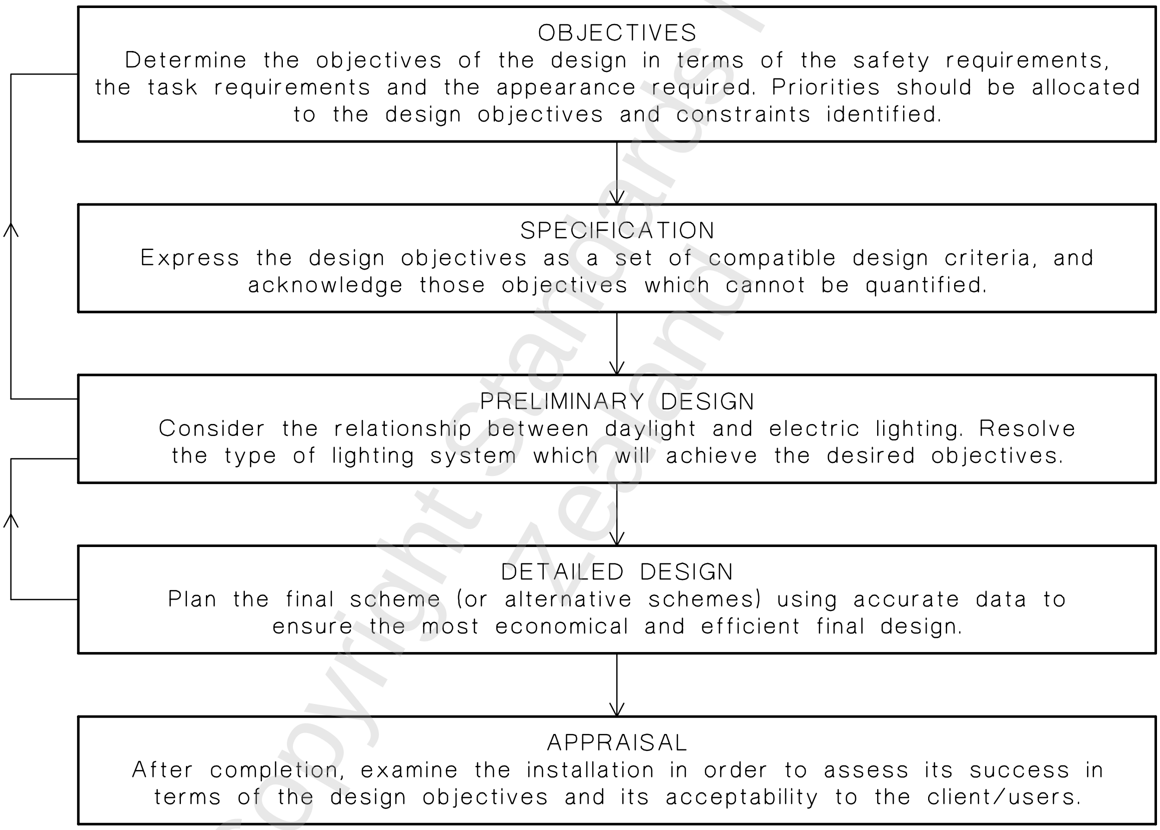


FIGURE 11.1 LIGHTING DESIGN FLOWCHART

11.2 OBJECTIVES

11.2.1 Introduction

The first stage in planning any lighting system is to establish the lighting design objectives. It is important that time and care are expended on this stage because it is the objectives that guide the decisions in all the other stages of the design process. Establishing the objectives for a design is not the same as reading the detailed recommendations set down in the AS(/NZS) 1680 series, in particular the illuminance requirements. The lighting objectives can be considered in three parts as described in Clauses 11.2.2, 11.2.3 and 11.2.4 respectively.

11.2.2 Safety

The lighting should be safe in itself and should allow the occupants to work and move about safely. These are not only primary objectives but also statutory obligations. It is, therefore, necessary to identify any hazards present and to consider whether emergency lighting might be required.

In some cases it may be necessary to consider the use of standby lighting systems in the event of the failure of supply to the main lighting system in order that a process may continue.

It should be noted that for some classes of buildings there exists a statutory requirement to provide emergency evacuation lighting. This has the sole purpose of allowing the safe evacuation of people from buildings in the event of certain emergencies. Reference should be made to the regulations of the relevant Building Control Authority, and to the requirements of AS 2293.1.

11.2.3 Identifying visual tasks

The type of work that takes place in the interior will define the nature and variety of the visual tasks. An analysis of the visual tasks (there is rarely just one) in terms of size, contrast, duration, need for colour discrimination and so on, is essential to establish the quantity and quality of the lighting required to achieve satisfactory visual conditions.

The lighting designer should be wary of general descriptions. A general office, for example, can, at one extreme, have occupants whose job it is to answer the telephone and, as a result, the visual tasks may be quite simple. At the other extreme the occupants may have to transcribe text, handwritten in pencil, onto terminals equipped with display screens, and this presents a complex set of visual tasks. In addition to establishing the nature of the tasks done in an interior, it is also necessary to identify the positions where the tasks occur and the planes on which the tasks lie. This information is essential if lighting matched to the tasks is to be provided.

11.2.4 Creating appearance and atmosphere

The lighting of a space will affect its character, and the character of objects within it. It is, therefore, necessary to establish what mood or atmosphere is to be created. This is not a luxury to be reserved only for prestige offices, places of entertainment, and the like, but should be considered in all designs, even for those areas where it will be given less importance than other factors.

The sense of space and of form can be influenced by appropriate lighting design. Since the eye is involuntarily drawn towards light, the apparent proportions of a room can be influenced by the direction of lighting and the differences in luminance of the defining surfaces. Thus, a long room can appear to be shortened by transverse lines of light or by lightening the end walls and darkening the side walls. Similar treatment will give a square room more interesting proportions.

Unity of design can be achieved where one element is more strongly defined by lighting than the surroundings. Unity is also achieved by a ‘family likeness’ in lighting equipment used in different spaces in the one occupancy. This does not imply use of the same luminaire type regardless of the different needs, but the use of luminaires having a related shape, or by a harmony of layout.

11.2.5 Priorities and constraints

When establishing the objectives, it is important to differentiate between those which are essential and those which are desirable. It is also important at this stage to establish both the design objectives and the design constraints.

Often the most obvious and the most important constraint is financial. Obviously everyone wants to spend the minimum possible, but different owners will spend differing amounts, for otherwise similar areas, according to their own valuation of the final result. For this reason, it is important to establish the financial constraints. These will affect the importance of the various design objectives, but should be opposed if they suppress any of the essential objectives.

Ideally, it should be possible to consider both capital expenditure and running costs to achieve the most economical scheme. In some circumstances this does not happen, and only the capital cost is considered, because a second system of budget control applies to the running cost. Although this is a highly unsatisfactory approach and should be resisted, it may be forced upon the lighting designer. More usually it is possible to relate capital and running costs to establish the lowest overall investment. The normal method of doing this is to calculate fixed and variable costs, allowing for depreciation, interest and inflation, over a fixed term.

There are many other constraints which may affect the design objectives, such as energy consumption, environmental considerations (which may limit the range of acceptable luminaires), physical problems of access, and so on. These constraints should be recognized at the objectives stage of the design.

11.3 SPECIFICATION

Once the lighting objectives have been defined, they should be expressed in a suitable form. Not all design objectives can be expressed as measurable quantities. For example, the need to make the environment appear ‘prestigious’, ‘efficient’ or ‘vibrant’ cannot be quantified. Furthermore, although many objectives can be expressed in physical terms, suitable design techniques may not exist or may be too cumbersome. For example, it is difficult to accurately determine the losses caused by furnishings when determining the floor cavity equivalent reflectance. Similarly, it is difficult to calculate and predict accurately the contrast rendering factor at a point. This does not mean that the objectives represented by these should be ignored, but that experience and judgement may have to replace calculation.

In the future design tools may be developed to allow the determination of some of the qualitative factors mentioned above.

It is essential that lighting designers produce safe and healthy environments. Bad lighting can contribute towards accidents or result in inadequate working conditions. The lighting designer should take note of any statutory requirements that affect lighting conditions. These demand (or will demand) that the lighting be both sufficient and suitable with the former term usually referring to the illuminance on tasks or for safe movement, etc, while the latter is concerned with quality aspects, such as, glare limitation, colour, etc.

Legislation is concerned with what is essential. This is less onerous than what is considered good practice. This Standard is generally concerned with good practice although there are some recommendations that can be considered absolute minima (or ‘essential’).

The preceding sections of this Standard have identified those factors which should be considered in developing the specification for a lighting system. To those can be added the financial constraints and any energy budget considerations. It is essential that the specification not be limited to only those factors which can be quantified.

11.4 PRELIMINARY DESIGN

11.4.1 Introduction

When the design specification has been established the purpose of the remaining stages of design is to translate these physical requirements into the best possible solutions, with the intention of meeting the original objectives. The lighting designer should never lose sight of the fact that the aim is to meet the original objectives, and that the specification is only a stepping stone in this process, and not an end in itself. Indeed, if it proves difficult to plan a lighting system that meets the design specification it may be necessary to reassess the original objectives. There are no hard and fast rules about how to plan a lighting system, and experience and judgement will usually dominate the planning process. Nevertheless, the planning stages can be divided into preliminary design and detailed design (see Clause 11.5).

At the preliminary design stage, the lighting designer aims to establish whether the original objectives are viable, and resolve what type of design can be employed to satisfy these objectives. The first stage in the general planning of a lighting system is to consider the interior to be lit, its proportions, its contents, and most importantly the daylight available.

11.4.2 Room surfaces

It is usual that the architect or interior designer selects the finishes for room surfaces. However, as noted in Section 6, the decisions made regarding surface finishes affect not only the efficiency of a lighting system but, more importantly, the resultant visual appearance. The visual appearance is not just the aesthetic appearance—it also establishes the room surface luminances and, therefore, the adaptation luminance against which the other luminances in the environment are judged. Thus, qualities such as glare and gloom will be affected.

The lighting designer needs to know the choices of surface finishes at the earliest stage of design. The lighting designer should be involved in the selection of finishes to ensure that choices are not made which compromise the quality of the luminous environment in working interiors. Choices made on surface finishes may also influence later choices on light source colour and also on the locations of luminaires.

11.4.3 Daylight

In the past windows and rooflights were essential to the lighting and ventilation of buildings. Inexpensive electric lighting and air-conditioning have resulted in very deep plan buildings in which the window has not been considered as a light source. However, it is important to exploit the light provided by windows, wherever possible, to reduce the demands made on electric lighting (energy).

The use of windows and rooflights for lighting cannot be considered in isolation from their impact on other environmental factors—solar heat gain, fabric heat loss, ventilation, noise, dirt, view, architectural considerations, security, waterproofing, etc.

At the time of publication no reliable and accurate method of daylighting design exists for the main population centres of Australia. This is because of the lack of suitable long term meteorological data for sky parameter determination and the lack of correlation studies between predicted performance based on existing models and prototype performance. In the absence of more sophisticated models, existing CIE models for clear and overcast skies can be used and, if cloud cover data are available, attempts can be made at intermediate sky calculations based on cloud cover data and the two CIE sky models.

However, this does not mean that daylight design should not be attempted. What it does mean is that most models and data will give indicative performance based on averages over long periods and not instantaneous, daily performance. Since energy budgets are based on long-term performance this means that present models can be used to indicate the major impact of a daylighting design strategy rather than short term effects.

It is important not to neglect the quality aspects of the visual environment when undertaking daylight design or integrated daylight/electric lighting systems.

From the above it can be appreciated that it is usual to design the electric lighting as if daylight did not exist. However, daylight (or, more particularly, the location and size of windows and rooflights) may suggest the form of, and especially the control system for, the electric lighting. In some cases decisions made regarding fenestration may require additional electric lighting to reduce contrasts between windows and their surrounds.

For these reasons it is essential that every lighting designer be aware of daylight prediction methods and understand how windows contribute to the quality of the visual environment. If a daylighting analysis is undertaken, the lighting designer should note any data or model limitations. At this stage no particular sky model or design method can be recommended as being ideal for Australian conditions. However, a number of systems developed for temperate (cloudy) and hot dry (clear) regions exist and more general systems are under development.

In some cases the lighting designer may have to make recommendations on sun control devices. This is because windows and rooflights can become sources of glare since they allow a direct view of the sun or a bright sky. In practice the strongest complaints are associated with direct sunlight. Therefore, the best strategy for reducing discomfort from windows and rooflights it to concentrate on controlling solar penetration: this will also reduce sky glare.

The appropriate form of solar protection will depend on whether the discomfort is mainly thermal or visual: if both, some combination of screening measures may be needed. Protection may be fixed or moveable. Although fixed baffles can simplify maintenance and ensure a tidier facade, moveable protection is generally preferable because daylight and views can be maximized. In most cases it is preferable that the siting and orientation of the building and the design of the facade be used rather than add-on devices.

11.4.4 Choice of electric lighting systems

Lighting systems which provide an approximately uniform illuminance over the whole working plane are called general lighting systems. The luminaires are normally arranged in a regular layout. The appearance of the installation is usually tidy but may be rather bland. General lighting is simple to plan using the lumen method and requires no co-ordination with task locations. The greatest advantage of such systems is that they permit complete flexibility of task location.

The major disadvantage of general lighting systems is that energy may be wasted illuminating the whole area to the level needed for the most critical tasks. Energy could be saved by providing the necessary illuminance over only the task areas and using a lower ambient level for circulation and other non-critical tasks.

Localized general lighting (see Clause 10.3.3) systems employ an arrangement of luminaires designed to provide the required illuminance on work areas together with a lower illuminance for the other areas.

Considerable care should be taken to coordinate the lighting layout to task positions and orientation. The system can be inflexible and correct information is essential at the design stage. Changes in the work layout can seriously impair a localized system, although uplighters and other easily relocatable or switchable systems can overcome these problems.

Localized systems normally consume less energy than general lighting systems unless a high proportion of the area is occupied by workstations. This should be confirmed by specific calculations. Localized systems may require more maintenance than general lighting systems.

Local lighting (see Clause 10.3.4) provides illumination only over the small area occupied by the task and its immediate surroundings. A general lighting system must be installed to provide sufficient ambient illumination for circulation and non-critical tasks. This is then supplemented by the local lighting system to achieve the necessary illuminance on tasks. The general surround illuminance should not be less than one-third of the task illuminance.

Local lighting can be a very efficient method for providing adequate task illumination, particularly where high illuminances are necessary or flexible directional lighting is required. Local lighting can be provided by luminaires mounted on the workstation (e.g. desk lights).

Local lighting must be positioned to minimize shadows, veiling reflections and glare. Although local luminaires allow efficient utilization of emitted light, the luminaires themselves may be inefficient and can be expensive. Most local lighting systems are accessible and often adjustable. This increases wear and tear and hence maintenance costs but provides some individual control.

Both local and localized general lighting offer scope for switch control of individual luminaires which can be off when not required, but care should be taken with localized luminaires to ensure that sufficient ambient illumination is provided.

11.4.5 Choice of lamp and luminaire

11.4.5.1 *General considerations*

The choice of lamp will affect the range of luminaires available, and vice-versa. Therefore, one cannot be considered without reference to the other. When planning an electric lighting scheme, lighting designers try to select a single optimum lamp and luminaire combination which will meet their objectives. In experienced hands, or where there is a limited range of equipment available, this approach can be effective, but many lighting designers remain uncertain as to the value of their solution and whether or not there is a better choice. One method of design which avoids this dilemma and draws attention to areas of difficulty, is to follow a procedure which does not try to identify a single lamp and luminaire combination but rather rejects those combinations which are unsatisfactory. In this manner, whatever remains will be acceptable and a final choice can be made by comparison. With such an approach unrealistic requirements will manifest themselves by causing those choices to be eliminated. The need to juggle with different requirements in order to achieve a satisfactory compromise is avoided, since this will occur automatically. Finally, because all of the unrejected luminaire and lamp combinations are acceptable, the most efficient and economically acceptable scheme can be selected. This approach lends itself to computer aided design.

11.4.5.2 *Choice of lamp*

The lighting designer should compile a list of suitable lamps, by rejecting those which do not satisfy the design objectives. The availability of suitable luminaires can then be checked and the economics of each assessed. General guidance can be obtained from Clause 9.4 of this Standard.

The run-up time of most discharge lamps (excluding fluorescent lamps) is unsatisfactory for applications requiring rapid provision of illumination or switching unless hot restrike versions are used or auxiliary tungsten lamps are provided.

Lamps should have colour rendering properties suited to their intended use. Good colour rendering i.e. R_a>80 may be required in order to achieve better discrimination between colours where that is part of the visual task. Alternatively, good colour rendering may be required to achieve a particular appearance or degree of comfort (e.g. merchandizing, offices, etc.).

A warm apparent colour (e.g. ≤3300 K) tends to be preferred for informal situations, at lower illuminances and in cold environments, whilst a cool apparent colour (e.g. ≥5300 K) tends to be preferred for formal situations, at higher illuminances, and in hot environments. Adjacent areas should not be lit with sources of significantly different apparent colour unless a special effect is required.

The life and lumen maintenance characteristics of the lamps should be considered to arrive at a practicable and economic maintenance schedule.

Where moving machinery is used care should be taken to avoid stroboscopic effects. All lamps operating on an alternating current exhibit some degree of cyclic variation of light output. It is most significant with discharge lamps which do not employ a phosphor coating. The problem can normally be reduced or eliminated by having alternate rows of luminaires on different phases of the supply and ensuring that critical areas receive illumination in roughly equal proportion from each phase. Alternatively the lamps may be operated from high frequency supplies, or illumination from local luminaires (with acceptable lamps that do not cause stroboscopic problems) can be used to swamp the general illumination.

When selecting a range of suitable lamps, the lighting designer should consider the types of luminaires which are available and the degree of light control and light output required. Accurate light control is more difficult with large sources than with compact sources, however the latter will have a higher luminance (for the same output) and are potentially more glaring.

Standardization of lamp types and sizes within a particular site or company can simplify maintenance and stocking and should be one of the aims of a good design.

11.4.5.3 *Choice of luminaire*

In the choice of luminaire, the lighting designer can exercise a combination of professional judgement, personal preference and economic analysis. Luminaires may have to withstand a variety of physical conditions, such as vibration, moisture, dust, ambient temperature, vandalism and so on. In addition, the onus is on the lighting designer to specify safe equipment. General guidance on the characteristics of luminaires can be obtained from Clause 9.5 of this Standard.

The lighting equipment selected should comply with appropriate Australian or New Zealand Standards. Essential safety requirements are set out in the series of approval and test specifications which accompany the general requirements of AS/NZS 3100. It is important to ensure that equipment is selected which can withstand and operate safely in the environmental conditions that will be encountered. The IP ratings for the enclosures of electrical equipment, which is discussed in Clause 9.5, gives guidance regarding the ability of the luminaire to withstand the ingress of solid foreign bodies and moisture. The lighting designer should make sure that the manufacturer's claims apply for the location and throughout the intended life of the luminaire i.e. deterioration may occur during the life of the luminaire. This is particularly true of a claimed IP rating, which, without further qualification, applies to a new luminaire.

Not only should the luminaire withstand the ambient conditions, it may have to operate in a hazardous area, such as a refinery, mine or similar environment. In this event, special equipment is required to satisfy safety regulations. Such equipment is beyond the scope of this Standard.

The light distribution of the luminaire should be carefully considered as it influences the distribution of illuminance and the directional effects that will be achieved. To establish the nature of the distribution of illuminance and directional effect that will be achieved for a regular array of a given luminaire, see Clause 9.5.2.

The utilization factor (UF) for a luminaire is a measure of the efficiency with which light from the lamp is used for illuminating the working plane. The product of utilization factor and lamp circuit luminous efficacy is the installed efficacy of the lighting system. In other words, it is a measure of how much luminous flux reaches the working plane for each watt of power applied. Luminaires can be ranked in order of the installed efficacy they provide, so that the most efficient luminaire, capable of meeting the other requirements, is selected. However, the luminaire with the highest installed efficacy may not offer the highest operating efficacy (see Clause 10.7.5). If a greater degree of switching control can be achieved with one type of lamp than another (e.g. tubular fluorescent versus high pressure sodium discharge), then the order may be reversed. This is because the hours of use may be sufficiently reduced in one case to offset its slightly lower installed hours of use which must be achieved for the schemes to have equal operating efficacies. Thus, if one scheme has twice the installed efficacy of a second scheme, then for the second scheme to have a better operating efficacy its hours of use must be 50 percent of that for the first scheme.

Luminaire reliability and life will have a direct impact on the economics of the scheme, and must be realistically considered. The ease with which luminaires can be installed and maintained will also affect the overall economics and convenience of the scheme. Luminaires with good maintenance characteristics and which can be easily maintained will not only save on maintenance costs, but will also be more efficient throughout their life.

Luminaires which can be unplugged and detached, or which have removable gear, can simplify maintenance by allowing remote servicing.

11.4.6 Lighting system management

A good lighting system should not only be well designed, but should also be managed and operated effectively and efficiently. System management should—

(a) control the use of the system to ensure efficiency; and

(b) maintain the system in good order.

The lighting system should be designed and managed to permit good control of energy use. This is important during the working day and outside working hours.

Methods of control fall into three broad categories:

(i) *Manual methods* Manual control relies upon individuals and appointed members of staff controlling the lighting system. These methods tend to be inexpensive in capital costs but may be less effective than automatic methods. To be effective the lighting system should be well planned to permit flexible switching of individual luminaires or banks of luminaires. The switch panels should be sensibly located and clearly marked (a mimic diagram can be very helpful) An education program to ensure staff awareness is essential and this can be reinforced with posters, and with labels on or adjacent to the switch panels.

    One of the main problems with manual methods is that, whilst occupants may be aware that daylight is insufficient and will turn on lights, it is rare for them to respond to sufficient daylight by turning lights off.

(ii) *Automatic control* Automatic control in the form of an imposed switch-off (say, at lunchtime) can be effective, since, if daylight is adequate, the luminaires may not be turned back on.

    A considerable amount of energy is often wasted after working hours when the lights are left on to no useful purpose. The full lighting system may be on when cleaners are in the building. The provision of automatic cleaners' circuits controlling only some of the lighting to provide reduced illuminances can save money.

Automatic control systems, such as time switches or photocells, can be inexpensive and can switch (or dim) banks of lights. Photocells can monitor the level of useful daylight and turn off luminaires or individual lamps in rows adjacent to the windows. Whether or not this is economic will depend upon the daylight and the proportion of the working year for which the required illuminance is exceeded.

Time switches provide a convenient method of ensuring that unwanted lighting is not provided outside working hours.

Occupancy detectors can be used to detect the presence of occupants and to control the lights accordingly. These normally rely on passive infrared motion detectors to determine occupancy. A time-lag should normally be built into the system to prevent premature switch-offs particularly in small areas where working occupants may not generate enough movement to activate the detector.

Automatic systems should normally have some degree of manual override (on and off) to cater for unexpected circumstances. Systems which automatically cancel lighting but are manually reset can offer greater savings than those which switch on again automatically. Occupants can always be relied upon to turn on lighting if they need it.

(iii) *Computer-based control* The use of these systems is increasing. They rely upon dedicated computers or distributed logic to control the lighting. The most important advantages of such an approach are that complex decisions can be taken from moment to moment, based upon the precise state of the building's operation or the requirements of the occupants, and that the system is controlled by software. This feature means that the control programs can be refined and tailored to suit the building and can be easily amended to suit changed circumstances and preselectable scenes can be programmed for individual areas or integrated with access control systems to provide a system based on real time demand.

Such systems can be interfaced with a building management system which can continuously monitor the building to operate it at maximum efficiency and economy. For example, lighting load can be shed in non-critical areas if the electricity maximum demand is reached during winter months, or shed in summer if cooling demands become excessive.

With any control system considerable care must be taken to ensure that acceptable lighting conditions are always provided to meet the occupants physical or personal needs. Safety should always be of paramount importance.

Control systems which are obtrusive or disruptive or not user friendly are counter-productive and may even be sabotaged by the staff. For this reason, dimmer systems are often preferred. Photocells and other sensing circuitry should incorporate a delay to prevent sporadic and disruptive switch-offs. Any lighting control system should respond immediately when a switch-on or any other manual function is called for.

It should be noted that the response time in most building management systems is too great to allow integration of the two systems, however features such as common backbone cabling or alarm monitoring can be shared.

11.5 DETAILED DESIGN

When the overall design has been resolved in general terms, detailed calculations are required to determine such things as the number of luminaires, the glare index, the final cost and so on. Design calculations can be complex and the use of computers is widespread. It is easy in these circumstances to lose sight of the original objectives and purpose of the design. When the lighting designer feels that the design is completed an analysis of how well the original objectives have been met should then be undertaken.

It may be found that the resultant design is unsatisfactory in some regard. This is by no means uncommon and reflects the inadequacy of the methods of design that are currently available. The only course of action is to revise the design until a suitable solution is found. This iterative procedure is a normal part of the design process.

The main light-technical calculations involved in lighting design are the determination of illuminances, surface luminances and glare index. Optionally, contrast rendering factor may be calculated as a measure of freedom from unwanted reflections. Energy and economic calculations are needed to evaluate the energy demands of the lighting system and to determine the capital and operating costs.

Average illuminances and surface luminances can be calculated using the lumen method or using a computer program of known performance. The advantage of this latter method is that illuminance and luminance can usually be calculated for individual horizontal or vertical planes. The definitions of terms and quantities required for the calculations are given in Appendix D.

The glare index should be determined by the method recommended in Clause 8.3.3.

Energy calculations should take due regard of installed and operating efficacies (see Clause 10.7.5).

Economic analysis should use whichever method is most appropriate to the client's financial operations and should include capital and operating costs but in most cases the economic analysis will also include the cost of money, depreciation, taxation, inflation and other considerations. Further details are beyond the scope of this Standard.

11.6 APPRAISAL

After a lighting system has been completed it is often instructive for the lighting designer to undertake an appraisal. In addition to the obvious subjective assessment made by the lighting designer, a completed appraisal should involve—

(a) a photometric survey of the lighting conditions achieved;

(b) a discussion with the clients centred on their assessment of the lighting system; and

(c) a discussion with the users of the lighting system to discover their reactions to the system.

The results of the photometric survey can be compared with the quantitative elements of the specification. Hence the extent to which the lighting system meets the specification can be established (Appendix B describes the important aspects of field measurements of lighting). The discussion with the clients and the users of the lighting system should reveal the extent to which the system meets their expectations and requirements, although it may tell the lighting designer more about the limitations of the original design objectives and specification than the design itself. The justification for undertaking an appraisal is reassurance and education.

SECTION 12 MAINTENANCE OF LIGHTING SYSTEMS AND EQUIPMENT

12.1 NEED FOR MAINTENANCE

Maintenance of lighting systems keeps the performance of the system within the design limits, promotes safety, and, if considered at the design stage, can help to minimize the electrical load and capital costs. Maintenance includes replacement of failed or deteriorated lamps and control gear, and the cleaning of luminaires and room surfaces at suitable intervals. Windows and rooflights also need regular maintenance.

Lighting systems need maintaining because without it they deteriorate. The light output from lamps decreases with time of operating until the lamp fails. Different lamp types deteriorate at different rates. Further, dirt deposition will occur on lamps, luminaires and room surfaces. Different lamp types in different luminaires in different locations will produce a different pattern but the underlying processes are the same. Similarly different daylighting systems will have particular maintenance characteristics, depending upon the location, glazing system and orientation.

12.2 MAINTENANCE OF ELECTRIC LIGHTING SYSTEMS

Advice on the maintenance of electric lighting systems is given in AS/NZS 1680.4.

12.3 DEPRECIATION AND MAINTENANCE OF WINDOWS AND ROOFLIGHTS

12.3.1 Causes of light loss

The glazing in windows and rooflights also becomes dirty with time, reducing the transmittance of the system and the light admitted. The glazing can be soiled on the inside from the nature of the activity undertaken in the room and on the outside from the condition of the atmosphere and the degree to which the glazing is self-cleaning when it rains.

12.3.2 Depreciation due to dirt

Clause 12.3.1 indicates that the transmittance of glazing materials can be reduced by soiling from inside and outside. Table 12.1 shows depreciation factors which can be applied in daylighting calculations to allow for dirt due to the nature of the external environment, the type of activity being undertaken inside the room and the slope of the glazing.

12.3.3 Maintenance of windows and rooflights

The maintenance policy determined for the lighting system should include recommendations on cleaning glazing, especially if daylight is intended to contribute to the lighting of the space. Often window cleaning is intended to remove dirt so that views are unspoilt, however, from Table 12.1 it can be seen that regular cleaning, especially in dirty areas or where internal soiling occurs rapidly, can reduce the energy demands on electric lighting where daylight and electric lighting are integrated.

TABLE 12.1

GLAZING DEPRECIATION FACTORS

Location	Glass angle	Clean work (non-industrial)	Dirty work (industrial)
Country or outer suburban	Vertical	0.9	0.8
	Sloping	0.8	0.7
	Horizontal	0.7	0.6
Built-up residential	Vertical	0.8	0.7
	Sloping	0.7	0.6
	Horizontal	0.6	0.5
Built-up industrial	Vertical	0.7	0.6
	Sloping	0.6	0.5
	Horizontal	0.5	0.4

12.4 MAINTENANCE OF ROOM SURFACES

12.4.1 Deterioration of room surfaces

The films of dust and dirt that deposit on all room surfaces and glazing, with consequent depreciation in the transmission and reflection factors, affect the illuminance within a room.

The rate and extent of the reduction caused by these factors vary according to the following:

(a) The texture of the surface—glossy and semi-gloss surfaces generally depreciate less rapidly than matt surfaces and are easier to clean. However, consideration should be given to the possibility of unwanted reflections where very high gloss surfaces are used.

(b) Inclination of the surface—vertical surfaces collect dirt less rapidly than horizontal surfaces.

(c) The location of the building in relation to industrial areas and activities within the premises.

(d) Atmospheric effects, e.g. condensation and rain on glazing, darkening of cold uninsulated white ceilings during the heating of the premises, especially by circulation from hot air convectors (pattern staining effect).

(e) Cleaning and renovation schedules.

12.4.2 Room surface cleaning interval

Some building use legislation stipulates that room surfaces in factories should be cleaned and redecorated regularly, but regular cleaning is important in all buildings if a dirty appearance is to be avoided. Regular cleaning is particularly important where light reflected from the room surfaces makes an important contribution to the lighting of the interior, e.g. where daylight from the side windows is used or where an indirect lighting system is present.

APPENDIX A

LIST OF REFERENCED DOCUMENTS

(Normative)

STANDARDS

AS	
1318	Use of colour for the marking of physical hazards and the identification of certain equipment in industry (known as the SAA Industrial Safety Colour Code)
1345	Identification of the contents of piping, conduits and ducts
1680	Interior lighting
1680.2.2	Part 2.2: Office and screen-based tasks
1680.3	Part 3: Measurement, calculation and presentation of photometric data
1852	International electrotechnical vocabulary
1852(845)	Chapter 845: Lighting
2293	Emergency escape lighting and exit signs for buildings
2293.1	Part 1: System design, installation and operation
2325	Tungsten filament lamps for general service—Performance requirements
2643	Fluorescent lamp ballasts of reactive type—Performance requirements
2700	Colour standards for general purposes
2700S	Colour standards for general purposes—Swatches
2946	Suspended ceilings, recessed luminaires and air diffusers—Interface requirements for physical compatibility
3117	Approval and test specification—Bayonet lampholders
3140	Approval and test specification—Edison-type screw lampholders
3158	Electric cables—Glass fibre insulated—For working voltages up to and including 0.6/1 (1.2)kV
3665	Simplified definitions of lighting terms and quantities
4004	Lighting booths for visual assessment of colour and colour matching
60529	Degrees or protection provided by enclosures (IP Code)
AS/NZS	
1680	Interior lighting
1680.2.5	Part 2.5: Hospital and medical tasks
1680.4	Maintenance of electric lighting systems
2293	Emergency evacuation lighting for buildings
2293.2	Part 2: Inspection and maintenance
2633	Guide to the specification of colours
3000	Electrical installations (known as the Australian/New Zealand Wiring Rules)

AS/NZS	
3100	Approval and test specification—General requirements for electrical equipment
3128	Approval and test specification—Portable lamp standards and brackets
3827	Lighting system performance—Accuracies and tolerances
4251	Electromagnetic compatibility (EMC)—Generic emission standard
4782	Double-capped fluorescent lamps—Performance specifications
4782.1	Part 1: General
60079	Electrical apparatus for explosive gas atmospheres
60598	Luminaires
60598.1	Part 1: General requirements and tests
60598.2.8	Part 2.8: Particular requirements—Handlamps
60922	Auxiliaries for lamps—Ballasts for discharge lamps (excluding tubular fluorescent lamps)—General and safety requirements
60923	Auxiliaries for lamps—Ballasts for discharge lamps (excluding tubular fluorescent lamps)—Performance requirements
61048	Auxiliaries for lamps—Capacitors for use in tubular fluorescent and other discharge lamp circuits—General safety requirements
61050	Transformers for tubular discharge lamps having a no-load output voltage exceeding 1000 V (generally called neon-transformers)—General and safety requirements
AS/NZS CISPR	
14.1	Electromagnetic compatibility—Requirements for household appliances, electric tools and similar apparatus—Emission
15	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
NZS	
4243	Energy efficiency—Large buildings
6703	Code of practice for interior lighting design
CIBSE* TM5	Calculation and use of utilization factors (Technical Memorandum TM5, London: 1980)
CIE†	
13.3	Method of measuring and specifying colour rendering properties of light sources
19	An analytical model for describing the influence of lighting parameters upon visual performance
19.21	Vol 1: Technical foundations
19.22	Vol 2: Summary and application guidelines
117	Discomfort glare in interior lighting
ISO/CIE	
ISO 8995:2002/ CIE S008/E:2001	Lighting of indoor work places

* Chartered Institution of Building Services Engineers

† International Commission on Illumination, Vienna

APPENDIX B
CALCULATION AND MEASUREMENT OF ILLUMINANCE
(Informative)

B1 INTRODUCTION

With the widespread use of computer calculation programs to model interior lighting designs, variations in the spacing of the calculation points chosen, or their relationship to the walls and luminaires, can cause significant variations to the calculated (i.e. predicted) average illuminance and uniformity even though the lighting in the space does not change. The larger the spacing of the points the greater the effect of moving their location. Further, if the number and, in particular, the location of the points at which measurements are taken differ significantly from those chosen for design calculations there can be a significant difference between the calculated and the measured results.

This was not a problem when the primary methods of design were holistic, such as the lumen method, as the uniformity was assumed as part of the design method and the cut-off of the distributions of many luminaires was not as defined, however there is now a need to co-ordinate the points at which the lighting is calculated with those at which the lighting is measured.

The purpose of this appendix is to provide an approach to design calculations and a simplified measurement approach that can be consistent with each other.

B2 CALCULATION GRIDS

When performing lighting calculations using computer programs, if the grid spacing is too large there will be unacceptable variation in the average illuminance and uniformity with variations in the location of the grid relative to the luminaires. Reducing the grid size will reduce the errors in the uniformity and average illuminance but if a small grid is applied over a whole room the effects of the walls produce unduly pessimistic predictions of these parameters.

Reducing the grid spacing will also increase the calculation time.

When calculating horizontal illuminance in a room using a program that calculates at each of a grid of points the following minimum criteria should be applied:

(a) The maximum spacing of the points should be 200 mm (In very large areas or areas with high ceilings the spacing may be extended to 500 mm).

(b) No calculation point should be closer than 1000 to a wall, partition or vertical obstruction that is included in the calculation.

(c) Uniformity calculations should only be applied to areas of less than 50m^2. Larger spaces can be subdivided for the purpose of calculation of uniformity.

B3 MEASUREMENT

B3.1 Basic considerations

Measurement of the average illuminance may be necessary for one or more of the following purposes:

(a) For a new lighting system, to check the accuracy of the calculated (i.e. predicted) values against those actually produced.

(b) To determine compliance of the installation (as opposed to the design) with the recommendations of the AS(/NZS) 1680 series, or with a design specification.

(c) To reveal the need for maintenance, modification or replacement.

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

The following factors should be taken into consideration when interpreting the results of measurement surveys.

(i) The accuracy and calibration of the light meter used for the measurement and the errors inherent in the measurement process.

(ii) The overall tolerances and accuracy inherent in the delivery of a lighting installation. (Refer to AS/NZS 3827.)

(iii) The inability of the eye to differentiate even relatively large differences in average illuminance.

B3.2 Measurement conditions

Field measurements apply only to the conditions that exist during the survey. Recognizing this, it is important to record a detailed description of the surveyed area and all 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; and

(f) measuring instrument used in the survey.

The photoreceptor should be corrected to take account of the effects of light falling on it at oblique angles (cosine-correction) and should also be colour corrected. If the receptor is not colour corrected, the appropriate correction factor (usually supplied by the manufacturer) should be applied.

The intervals for calibration of photometers depend on the type of device used as photoreceptor in the instrument and should be observed strictly. Before taking readings, photocells should be exposed to the approximate illuminance to be measured until the reading becomes stabilized. Care should be taken not to cast a shadow on the photocell when taking a reading.

Measurement of the illuminance obtained with an electric lighting system should either be made after dark, or with daylight excluded from the interior. For new lighting systems and existing systems where group lamp replacement has been made, the lamps should be aged by operation for at least 100 h for discharge lamps (including fluorescent lamps) and 20 h for incandescent lamps.

Prior to the measurements being taken the lighting system should be operated for sufficient time to allow the light output of the lamps to stabilize, usually 1 h for discharge lamps. Air conditioning or ventilation systems in the interior should be operating normally.

B3.3 Average illuminance at a workstation

When the illuminance at a particular workstation is to be measured to check for compliance with recommended values for the task, a sufficient number of illuminance measurements should be made over the task area to provide a representative average illuminance value. The measurements should be made on the plane (horizontal, vertical or inclined) in which the visual task is performed with the worker in his or her normal position, even if this results in a shadow on the photocell.

B3.4 Average illuminance and uniformity in an interior

The measurement of the average illuminance in a space can only be accurately determined by measuring the illuminance at each of a series of points, set out in a regular pattern, then calculating the arithmetic mean of those values. This value can be used to estimate the uniformity, with the accuracy of the estimate being dependent on the number and spacing of measurement points, the relative location of the points with respect to the luminaires and the actual uniformity of the illuminance provided.

Measurement of random points may give some indication but cannot be related to the recommendations of the Standard as any given point selected may not represent equal areas or a representative distribution of high and low points. In determining the uniformity it is important to remember that the minimum measurement used in the formula is the lowest illuminance measured at any of the regularly spaced measurement points and not necessarily the absolute minimum illuminance in the space, which might exist at a location that does not correspond to a measurement point.

As a relatively close spacing of measurement points is required to prevent the localized effect of individual luminaires, and as there is typically a repeating pattern of luminaires in a large area, measurements over a single large area typically yield enormous quantities of repetitive data that will not give accurate results if too large a spacing between the measurement points has been chosen to minimize the amount of data. It is typically more accurate and also easier to concentrate on one or more smaller, representative measurement areas, and apply a closer spacing between measurement points than might be used if covering the whole space.

Where possible a typical space or measurement area should be selected for the initial measurement that will be able to be used as a quick check at future times throughout the life of the installation.

In measuring the horizontal illuminance in an area the following criteria should be applied:

General

- The measurement areas chosen do not need to cover the whole space to be measured, but should collectively represent all areas of both the lighting layout and the physical environment.
- Where there is a regular array of lighting the measurement area should cover an entire pattern.
- The measurement area should be divided into a number of identical rectangles that should be as near to square as possible.
- The illuminance should be measured at the centre of each rectangle, at the height of the working plane (see Clause 3.6) A portable stand to support the photocell at the correct height and in the horizontal position is useful for this purpose.
- Maximum spacing of measurement points along x or y axis – to be 1000 mm.
- The variation in spacing between points in the x and y axis should not exceed 10%.
- No measurement point should be closer than 1000 mm to a wall.
- When $BW < \mathrm{Tan}^{-1}(MH/1.5)$ the measurement point spacing shall be reduced to 500 mm

  where

  BW is the smallest angle in the intensity distribution between the $I_{\max}$ and 50% $I_{\max}$

  MH is the vertical height from the calculation grid to the luminaire

Additional requirements for spaces with a floor area >25m2

- Minimum area of measurement – $9m^2$.
- Minimum number of luminaires included in the area – 4.
- For spaces with non-regular lighting layouts or different room conditions, several measurement areas to be selected to give a representative set of measurements.

Additional requirements for spaces with a floor area <25m2

- The entire area shall be measured.
- Minimum number of points – 9.

NOTE: Unless the measurements are taken at the exact locations of the calculation points there can be poor correlation with the average illuminance and uniformity, between the calculated and the measured results. The extent of the variation will depend on the spacing and disposition of the grids within the room and the relationship of the grids to the luminaire locations. It will also vary with different types of luminaires. With the guidelines above a difference of up to ±15% can still be attributed to the differences between grids.

This is additional to the measurement error and the accuracy and tolerance in the lighting design.

Measuring at the calculation points is generally not practical as they are rarely known and if available would result in an impractical number of points being measured.

B4 OTHER ILLUMINANCE MEASUREMENTS

B4.1 Scalar illuminance

Scalar illuminance is a useful measure of the lighting conditions when there are no obvious working planes in the interior. For precise measurements of scalar illuminance, instruments based on a photocell with a diffusing sphere attached are available. However, a good approximation to the scalar illuminance at a point can be obtained using a conventional illuminance meter by averaging the illuminances measured on the six faces of a cube centred at the point. An even better approximation, particularly where there is little inter-reflected light, is given by the average of the illuminances on four faces of a regular tetrahedron centred at the point.

B4.2 Illumination vector

The illumination vector is a measure of the 'flow of light' in a room. It can be combined with the scalar illuminance to give the vector/scalar ratio which is a measure of the modelling effect of the lighting (see Clause 4.2.3). Precise measurements of the magnitude and direction of the illumination vector can be made using commercially available equipment based on a matched pair of cosine corrected photovoltaic cells mounted back-to-back. Alternatively, measurements of magnitude and direction can be obtained by the vector addition of the differences in illuminance between the three pairs of opposing faces of a cube centred at the point. Yet another approach is to measure the two components of the illumination vector separately. Once the direction of the illumination vector at a point has been established, the magnitude of the illumination vector can be obtained from the difference in illuminances on the opposing faces of the plane through which the vector direction passes normally.

APPENDIX C

NOTES ON CHANGES TO ILLUMINANCE RECOMMENDATIONS

(Informative)

In editions of this Standard prior to 1990, recommended illuminance values were expressed in terms of the 'service illuminance' which is essentially an average value throughout the space and over the period between maintenance of the lighting system. However, difficulties were experienced with this approach in determining whether or not a particular lighting system complied with the recommendation at any given time.

The recommendations in Table 3.1 have therefore been expressed in terms of the 'maintained illuminance' which corresponds to the average illuminance for the task or interior below which it is necessary to take remedial action in terms of maintaining the lighting system. The maintained illuminance thus represents a minimum allowable average illuminance which applies at all times through the life of the lighting system, making the task of assessing the system for compliance much simpler.

An illustration of the relationship between maintained illuminance and service illuminance is given in Figure C1.

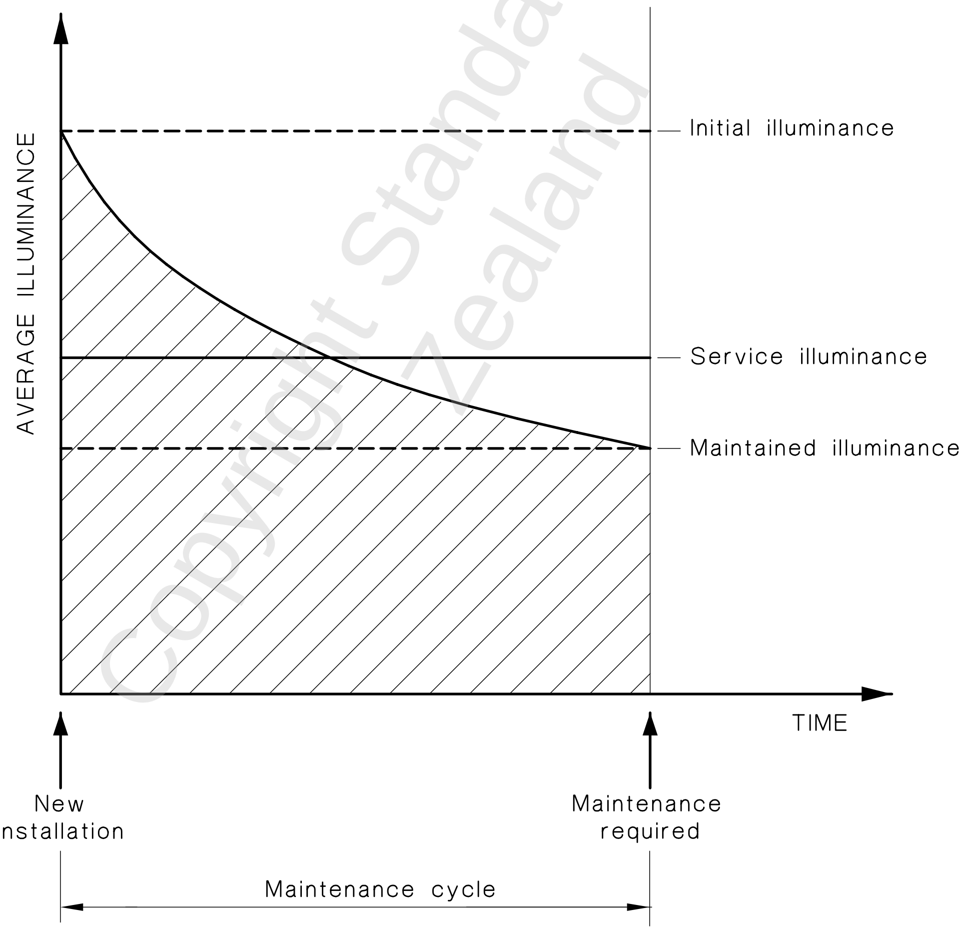


FIGURE C1 ILLUSTRATION OF THE RELATIONSHIP BETWEEN MAINTAINED ILLUMINANCE AND SERVICE ILLUMINANCE

Table C1 indicates the relationship of the recommended maintained illuminance values in this Standard to the illuminance recommendations in AS 1680—1976*.

TABLE C1

RELATIONSHIP OF RECOMMENDED ILLUMINANCES IN THIS STANDARD TO THOSE IN AS 1680—1976

Values of maintained illuminance in this Standard lx	Corresponding values of service illuminance in AS 1680—1976 lx
40	50
80	100
160	200
240	300
320	400
400	500
600	800
800	1200
1200	1600
1600	2400

To satisfy the recommendations of this Standard it will be necessary, for design purposes, to select an initial illuminance significantly greater than the recommended maintained illuminance to ensure that, for the maintenance cycle adopted, the average illuminance over the task area or throughout the room will not fall below the maintained illuminance at any time (see Clause 3.7 and AS/NZS 1680.4).

* AS 1680(1976), *Code of practice for interior lighting and the visual environment* (Superseded)

APPENDIX D

NOTES ON THE USE OF UTILIZATION FACTOR TABLES BY THE LIGHTING DESIGNER

(Informative)

D1 SCOPE OF APPENDIX

This Appendix gives guidance to lighting designers on the correct use of utilization factor (*UF*) tables when applied to practical rooms and practical layouts of luminaires. It does not deal with lighting design techniques; only with the calculations involved. Note that AS 1680.3 specifies the use of CIBSE TM5 for the calculation of utilization factors. The terminology and symbols used in this Appendix are those adopted in CIBSE TM5.

D2 APPLICATION OF UTILIZATION FACTORS

The utilization factor of a lighting system *UF*(*S*) is the ratio of the total flux received by the reference surface *S* to the total lamp flux of the system. The average illuminance *E*(*S*) over the reference surface *S* can therefore be found from the following equation:

$$E(S) = \frac{UF(S) \times N \times MF \times CF}{\text{Area of surface } S} \qquad \text{. . . D2(1)}$$

where

$UF(S)$ = the utilization factor for the reference surface S

N = the total number of lamps in the lighting system

F = the initial bare lamp flux of each lamp (e.g. 100 h values for discharge lamps)

MF = the light loss factor of the lighting system (see AS/NZS 1680.4)

CF = the product of any additional correction factors which must be applied (see AS 1680.3).

This equation can be rearranged to determine the number of luminaires required to achieve a given illuminance.

D3 ASSUMPTIONS USED IN *UF* TABLES

The calculation procedure for the production of *UF* tables is based upon a number of simplifying assumptions. A lighting designer should bear these in mind when applying *UF* tables to practical rooms. It is the lighting designer's task to translate the characteristics of a practical lighting system into the simplified parameters of the *UF* table.

The assumptions upon which standard *UF* tables are based, and their relationship to practical lighting systems are as follows:

(a) *The luminaires are point sources, with intensity distributions symmetrical about the vertical axis* Practical luminaires are frequently large or non-symmetrical. Such departures from the theoretical condition are acceptable for *UF* calculations, although there will be a slight loss of accuracy.

(b) *The rooms are square* *UFs* based upon square rooms can be used for rectangular rooms of the same room index, providing that the ratio of length to width does not exceed 4:1.

(c) *The array of luminaires is contained in the ceiling plane, and the floor is assumed to be the horizontal reference plane* The concepts of floor cavity and ceiling cavity (see Paragraph D4) enable the room index and effective reflectances of a practical room to be determined for use with *UF* tables.

(d) *The room surfaces are planes of uniform reflectance, and uniformly diffuse* Paragraph D7 gives methods for finding the effective reflectances of practical rooms.

(e) *The luminaires are arranged in a regular square array, with half spacing at the perimeter* The *UF* values based upon a square array apply to rectangular arrays with different spacings in the two main directions, providing that the mean *SHR* is the same, and the ratio of the two spacings does not exceed 2.5:1. Paragraph D9 deals with non-standard spacings at the perimeter.

D4 DEFINING THE MAIN ROOM SURFACES

For the application of *UF* tables it is necessary to consider that a room consists of only three basic surfaces, the ceiling cavity, the walls and the floor cavity. These are illustrated in Figure D1.

The position of the horizontal reference plane over which the mean illuminance is to be calculated must be defined. Unless otherwise stated (see Clause 3.6) it is normally assumed to be—

(a) 0.7 m above the floor for tasks which are at desk height; and

(b) 0.85 m above the floor for tasks which are at bench height.

This plane forms the mouth of the floor cavity, and is denoted by the reference letter *F* (for floor cavity) in calculations.

The horizontal plane containing the photometric centres of the luminaires is known as the luminaire plane. This plane forms the mouth of the ceiling cavity, and is denoted by the letter C (for ceiling cavity) in calculations.

In utilization factor calculations the horizontal reference plane and luminaire plane are treated as opaque surfaces having the same effective reflectance as their respective cavities. By this means the practical room is reduced to a simple structure consisting of only floor, ceiling and walls as shown in Figure D1.

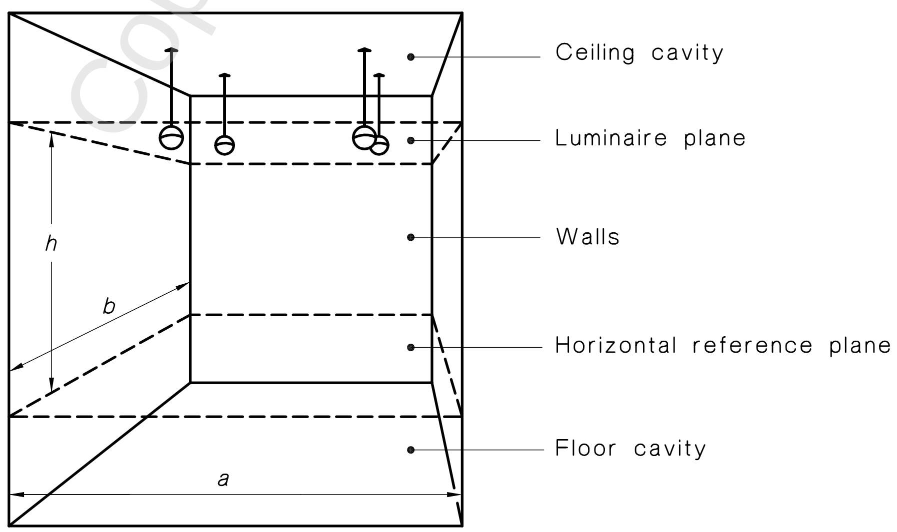


FIGURE D1 FLOOR CAVITY, WALLS AND CEILING CAVITY

D5 ROOM INDEX

The room index (K) of a room is twice the plan area of the room divided by the area of its walls between the horizontal reference plane and the luminaire plane.

For rectangular rooms the room index is given by the equation:

$$K = \frac{a \times b}{h\,(a + b)} \qquad \text{. . . D5(1)}$$

where

a, b = the dimensions of the sides of the room

h = the vertical distance between the horizontal reference plane and the luminaire plane.

Results may be rounded to the nearest value in the series 0.75, 1.00, 1.25, 1.50, 2.00, 2.50, 3.00, 4.00, 5.00.

If the plane of a room is re-entrant in shape (e.g. an 'L' shaped room), then it should be divided into two or more non re-entrant parts which can be treated separately (see Figure D2).

D6 THE AVERAGE REFLECTANCE OF A SURFACE

The average reflectance $RA(S)$ of a surface S is given by:

$$RA(S) = \frac{R(1) \times A(1) + R(2) \times A(2) + \ldots R(\mathrm{N}) \times A(\mathrm{N})}{A(1) + A(2) + \ldots A(\mathrm{N})} \qquad \text{. . . D6(1)}$$

Where $R(1)$, $R(2)$, etc., are the reflectances of the individual parts of the surface, and $A(1)$, $A(2)$, etc., are their respective areas.

D7 REFLECTANCES OF PRACTICAL ROOMS

In order to use *UF* tables, the effective reflectances of the three main room surfaces must be correctly estimated for the practical room. These effective reflectances correspond with the entries in the *UF* tables under the headings *C, W* and *F,* and are respectively:

C—The effective reflectance of the ceiling cavity.

W—The effective reflectance of the walls (the average reflectance of those portions of the walls between the luminaire plane and the horizontal reference plane).

F—The effective reflectance of the floor cavity.

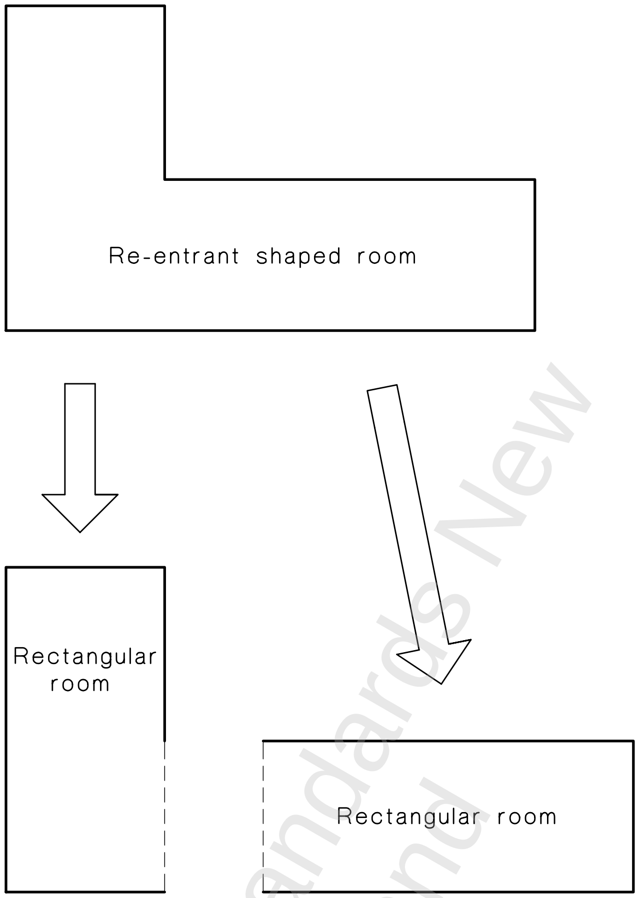


FIGURE D2 A RE-ENTRANT 'L' SHAPED ROOM IS DIVIDED INTO TWO PARTS TO ENABLE THE UTILIZATION FACTOR TO BE DETERMINED

The effective reflectance *RE(C)* of a cavity can be calculated by using the following simplified equation, which will be sufficiently accurate for most purposes:

$$RE(C) = \frac{C1 \times RA(C)}{C1 + 2[1 - RA(C)]} \qquad \ldots \text{D7(1)}$$

Where $C1$ is the cavity index of the cavity (twice mouth area/wall area) and *RA(C)* is the average reflectance of all the surfaces within the cavity (excluding the mouth) weighted according to their respective areas.

D8 MAXIMUM SPACING LIMITS FOR ACCEPTABLE UNIFORMITY

SHR MAX and *SHR MAX TR* give information about the spacing between luminaires for acceptable uniformity. With the exception of the cases listed below which apply to linear luminaires, the maximum spacing to mounting height ratio between the centres of the luminaires is *SHR MAX* and should not be exceeded.

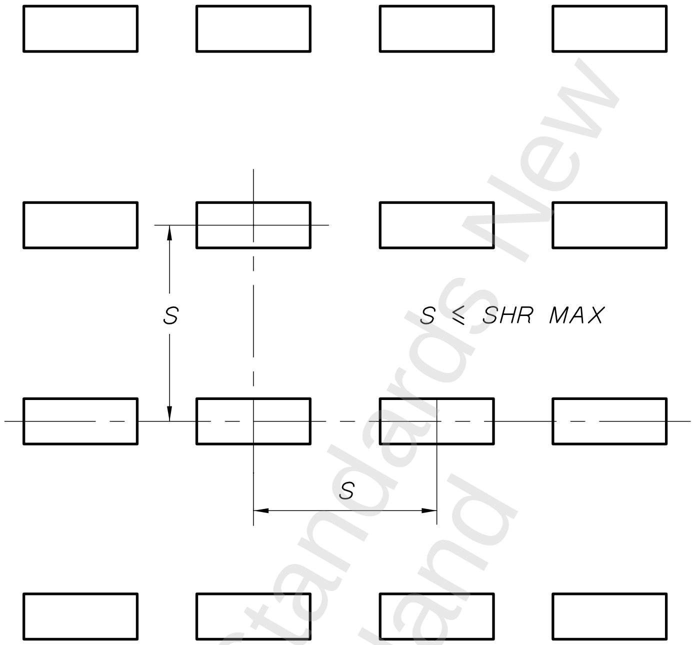
(a) *Case 1 (Figure D3)* Equal spacing S in the axial and transverse direction. The spacing in each direction must not exceed *SHR MAX.*

(b) *Case 2 (Figure D4)* Spacing in axial direction (S_a) greater than spacing in transverse direction (S_t). The spacing in the axial direction must not exceed *SHR MAX.*

(c) *Case 3 (Figure D5)* Spacing in transverse direction greater than spacing in axial direction. The axial spacing must not exceed *SHR MAX*, in addition the transverse spacing must not exceed *SHR MAX TR* and also it must not exceed $(SHR\ MAX)^2 \div (SHR\ AXIAL)$ where *SHR AXIAL* is the actual spacing to height ratio in the axial direction.

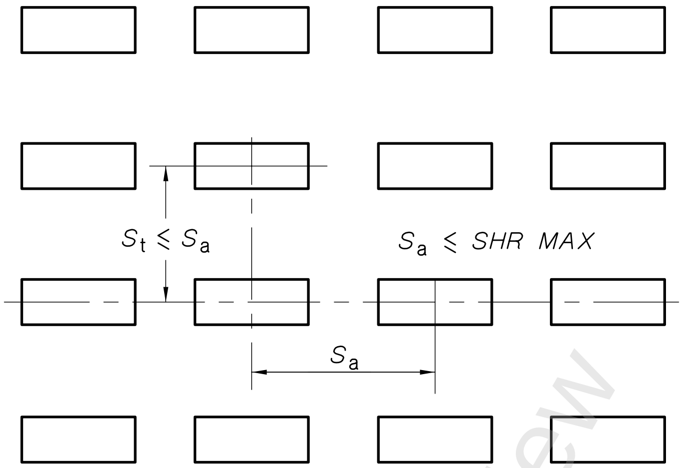
SHR MAX and *SHR MAX TR* only provide information about the maximum spacing to height ratio that will result in acceptable uniformity on the unobstructed horizontal reference plane. In practical lighting systems, obstructions or other factors frequently make closer spacing essential.

If *SHR MAX* is not published, it cannot be assumed to be greater than *SHR NOM* (the value for which the *UF* table is calculated).



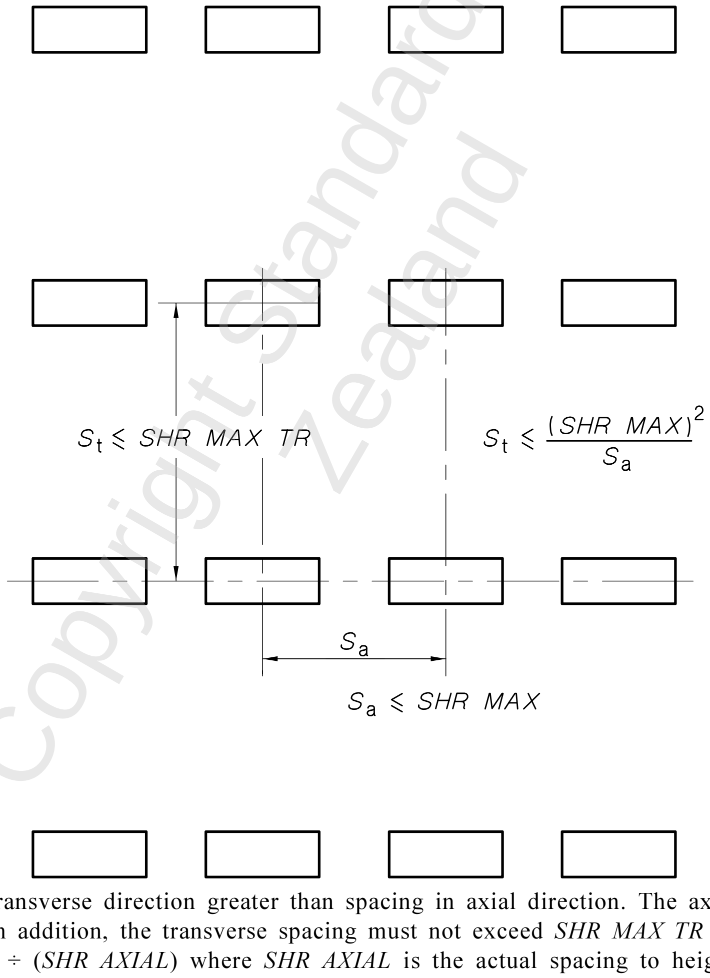
NOTE: Equal spacing in the axial and transverse direction. The spacing in each direction must not exceed *SHR MAX.*

FIGURE D3 MAXIMUM SPACING LIMITS FOR ACCEPTABLE UNIFORMITY—CASE 1



NOTE: Spacing in axial direction greater than spacing in transverse direction. The spacing in the axial direction must not exceed *SHR MAX*.

FIGURE D4 MAXIMUM SPACING LIMITS FOR ACCEPTABLE UNIFORMITY—CASE 2



NOTE: Spacing in transverse direction greater than spacing in axial direction. The axial spacing must not exceed *SHR MAX*. In addition, the transverse spacing must not exceed *SHR MAX TR* and it must also not exceed $(SHR\ MAX)^2 \div (SHR\ AXIAL)$ where *SHR AXIAL* is the actual spacing to height ratio in the axial direction.

FIGURE D5 MAXIMUM SPACING LIMITS FOR ACCEPTABLE UNIFORMITY—CASE 3

D9 PRACTICAL LAYOUTS OF LUMINAIRES

The lighting designer should check that the *SHR* of a practical layout is within the range of the *UF* table consulted; that is, within 0.5 above and below *SHR NOM* of the table. If the practical layout is not spaced equally in the two principal directions, take the arithmetic mean of the two spacings. If the *SHR* of the layout is outside the range of a *UF* table, it will be necessary to calculate *UF* (see CIBSE TM5).

It is common practice to adopt a provisional layout, so that a *UF* and hence the number of luminaires can be determined. It should be checked that the final layout is within the specified range of the *UF* table consulted (and that the *SHR MAX* is not exceeded).

If the spacing between the outer luminaires and the perimeter of the room differs from half the spacing between luminaires (upon which the *UF* tables are based), the distribution of direct light will be altered. The effect of this change can be allowed for as follows:

(a) Find the number of luminaires from the proposed layout.

(b) Calculate the ratio of the perimeter spacing to the spacing between adjacent luminaires. If this ratio is different in the two principal directions, take the mean value.

(c) Find the appropriate correction factor *C* from Table D1. Before proceeding, an approximate indication of the effect of this correction factor can be obtained from the following equation:

$$UF(F)^* = UF(F) + DF(F) \times (C-1) \quad \text{. . . D9(1)}$$

where

$UF(F)^*$ = the new utilization factor (corrected)

$UF(F)$ = the utilization factor from the *UF* table

$DF(F)$ = the distribution factor from the *UF* table, which is equivalent to $UF(F)$ for 0% reflectance of the room surfaces

C = the correction factor from Table D1.

If it is decided that this change in utilization factor is not significant, then it can be ignored. Otherwise reference should be made to CIBSE TM5 for guidance on the calculation of utilization factors by lighting designers.

D10 USING A UTILIZATION FACTOR TABLE

Use a *UF* table by following these steps:

(a) Calculate the room index and effective reflectances for the practical lighting system in accordance with Paragraphs D5, D6 and D7.

(b) Check that the *SHR* of the lighting layout falls within the range of the *UF* table (see Paragraph D9), and make any allowance for non-standard spacing to the walls. Also check that *SHR MAX* or *SHR MAX TR* (as appropriate) is not exceeded (see Paragraph D8).

(c) Read the appropriate value of *UF* from the table. Precise interpolation between values of *K* or between values of reflectance is not normally necessary. If the room index is greater than 5.0, the value of *UF* for *RI* = 5.0 may be used.

(d) If appropriate, multiply by a published factor for condition of mounting-on surface or suspended.

The sequence of the above steps may have to be altered to suit the nature of the particular problem in hand; for example, when planning a lighting system, Step (b) will normally be left until last.

For many luminaires, it will be necessary to multiply the tabled *UF* value by each applicable service correction factor. The published data for the luminaire should be studied for instructions. Examples of the correction factors which may need to be applied are given in AS 1680.3.

TABLE D1

CORRECTION FACTORS FOR NON-STANDARD SPACING OF LUMINAIRES FROM THE ROOM PERIMETER

Perimeter spacing ÷ luminaire spacing	Number of luminaires							
	2	4	10	20	40	100	200	400
0.2	0.87	0.76	0.81	0.85	0.88	0.92	0.94	0.96
0.3	0.93	0.87	0.90	0.92	0.94	0.96	0.97	0.98
0.4	0.97	0.94	0.95	0.96	0.97	0.98	0.99	0.99
0.5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.6	1.02	1.04	1.03	1.03	1.02	1.02	1.01	1.01
0.7	1.03	1.07	1.06	1.05	1.04	1.03	1.02	1.01
0.8	1.04	1.09	1.08	1.07	1.05	1.04	1.03	1.02

APPENDIX E

FURTHER DETAILS REGARDING SURFACE COLOUR

(Informative)

E1 COLOUR SURFACES

E1.1 Basic considerations

Surface colour can be classified by the use of the Munsell system. (Refer to AS/NZS 2633 for a brief description). In the Munsell system each colour is specified by three quantities; its hue, its value, and its chroma. Hue describes whether a colour is basically red, yellow, green, blue or purple, etc. Value describes the lightness of the colour and is related to its reflectance. Chroma describes the strength of the colour. This classification forms a convenient basis on which to discuss the effects of room surface colour on the appearance of space. By choosing different values for different components of the interior it is possible to dramatize or to buffer the pattern of light and shade created by the lighting. An example of this is the use of a high reflectance (high value) colour on a wall opposite a window wall.

By choosing colours of different chroma it is possible to create a pattern of emphasis. Strong emphasis requires strong chroma but their use calls for caution. An area of awkward shape which might pass unnoticed at weak chroma can look unsightly at strong chroma. Also a small area of strong chroma might be stimulating but the same chroma over a large area could be overpowering.

The strength of a colour can be heightened by the proximity of an area of white which acts as a reference base, or by a juxtaposition of an area of a complementary colour.

The selection of hue is partly a matter of fashion and partly a matter of emotion. By choosing a predominant hue for a space it is possible to create a cool or a warm, a restful or an active atmosphere.

All rooms will have a mixture of colours. This fact raises the question of colour harmony. There are a number of so-called rules of colour harmony which have little basis in fact. However, it is widely believed that the main variable influencing pleasant colour harmonies is the difference in value for the two colours compared; the greater the difference in value the greater the chances of achieving a pleasant colour combination. The effect of chroma differences is thought to be similar, combinations of colours with large difference in chroma tending to be pleasant. As for hue difference there is not believed to be any consistent effect, all the same hues, closely related hues, or complementary hues, being capable of creating either pleasant or unpleasant colour combinations.

These observations suggest that when selecting colours for an interior the first aspect to consider is the value of the colours, then the chroma and finally the hue. However, once the pattern of light, shade and emphasis has been established by the choice of the value and chroma for different surfaces, the range of hues that is available may be limited. For example, if a given surface is to have both strong chroma and high value, then it must inevitably have a yellow hue. Conversely, when a surface is required to have low value and strong chroma, inevitably a colour from the red to blue part of the hue circle will need to be used. Once the level of chroma is reduced from a high level the whole range of colours is available.

One thought that should always be borne in mind is the effect of inter-reflected light. The light reflected from a surface of strong chroma will be coloured and may influence the colour of other surfaces. The most common situation where this is seen is when a floor covering of strong chroma is lit by a lighting system which does not light the ceiling directly. In this situation, the ceiling will mainly be lit by light reflected from the floor and may appear to be a similar colour to the floor.

AS 2700 defines 206 reference colours to assist in the specification and matching of surface colours. The colours are arranged on a fold-out chart and information is given separately on the approximate Munsell notations for each of the colours. A set of larger colour reference cards is also available (AS 2700S) to facilitate colour matching.

E1.2 Suitable types of colour

Figure E1 displays the identification numbers for a selection of colours drawn from AS 2700, each colour being positioned according to its basic hue and reflectance. Note that the colours are arranged vertically in a linear scale of reflectance, which assists in comparing colours in terms of the inter-reflection of light. There is another, non-linear scale which indicates the approximate Munsell Value of the colour. If colours are to be compared in terms of their lightnesses then equal steps of Munsell value correspond to equal steps in the lightness of the colour. Figure E1 also displays ranges of reflectance desirable for each class of typical room surface and Table E1 displays some typical room surface reflectances.

Colours for use on surfaces that will fill a substantial part of the occupants' field of view in working areas should have a reflectance and surface finish in accordance with this Appendix.

The above limitations on chroma do not apply to small areas of colour; nor to colours used in non-working areas and other interiors not occupied for prolonged periods. However, the colours reserved for the identification of safety equipment and certain hazards should not be used for any other purpose (see Paragraph E1.4).

Large expanses of vivid colour can seem cheerful and attractive for brief periods but may irritate those who have to view them throughout the working day. However, the use of strong colours in large areas (and more elaborate decoration generally) is satisfactory in non-working areas such as entrance halls, lunchrooms and locker-rooms.

The assessment of chroma is difficult when viewing small colour chips or samples because the chips (or samples) appear paler than when the colour is seen over an expanse of wall or other large surface. When large samples (about 300 mm × 300 mm) are not obtainable, the chip should be viewed against a neutral background of a darker tone.

E1.3 Suitable colour schemes

E1.3.1 *General*

In working areas, the colours on main interior surfaces should comply with the recommendations in Paragraph E1.2 and should be combined into simple colour schemes in accordance with principles outlined in Paragraph E1.3. There are principles outlined in E1.3.1.

A person's mood can be affected by the surroundings, and colour monotony is just as much to be avoided as colour fatigue. Whilst the colour scheme on the main interior surfaces should be simple and unobtrusive, attractive visual rest centres in the form of colourful wall hangings, or even travel posters, are desirable in both offices and workshops to help produce a visually satisfying environment. Plants and individually coloured screens used in some landscaped offices fulfil the same function, and the view through a window can also serve as a visual rest centre.

These decorative touches should be used with discrimination, especially in places where colour is used for identification and safety purposes as indicated in Clause 6.6.

E1.3.2 *Unity and balance*

Too much of any one colour can be monotonous; hence to increase interest but maintain unity and balance there should be one key (dominant) colour balanced by lesser areas of one or two other hues, or the same hue but of different reflectance or chroma.

In small and medium-sized rooms the colour of the walls usually dominates the scheme and the balancing colours can be applied to the equipment, doors and other furniture.

In large interiors, distant walls occupy a small part of the field of view, hence the equipment will need to carry both the dominant and balancing colours. It is important that the scheme not be made over-elaborate by picking out non-essential details; the principles set out in Paragraph E1.3.5 should also be carefully observed.

E1.3.3 *Warm and cool colours*

Warm colours are those derived from red and yellow, such as cream, orange, tan, and golden brown. Cool colours are mainly derived from blue and green.

Where appropriate, colour schemes should be based either on predominantly warm or on predominantly cool hues to help create a specific impression in an interior of one or the other.

A pleasing result can be obtained by relieving a predominantly warm scheme with cool secondary colours (or vice versa). Greys can be used effectively in both cool and warm schemes, but where used as a key colour tend to produce a cool effect.

It has been found that a warm task is more comfortably seen where it has a background (i.e. the wall behind) of a cooler colour. However, a cool task seen against a warm background tends to give a less satisfactory result.

E1.3.4 *Minimizing distracting detail*

Select relieving colours of about the same reflectance as the dominant colour to minimize non-essential detail in the task area and in the general surroundings. The object is to make distracting or unsightly details less conspicuous. This is especially important in spaces where colour is used for identification or safety purposes (see Paragraph E1.3.5).

The recommendation is based on the fact that brightness contrasts catch the eye more readily than do colour contrasts which, in the absence of a brightness contrast, are not noticeable except when looked at directly. Structural details such as roof beams and trusses, overhead ducts, tanks and pipes can be rendered inconspicuous with colours of about the same reflectance as the background, whilst avoiding the monotonous effect caused by finishing everything in the same colour.

E1.3.5 *Object colours*

When large items of plant have to carry both dominant and secondary colours, it is particularly important to observe Paragraph E1.3.4.

Generally the component parts of a machine should not be distinguished with individual colour as a simple colour scheme will enable objects of special importance such as stop buttons to stand out clearly. (See Clause 6.6.)

Object colours should not conflict with those used for safety purposes (see AS 1318).

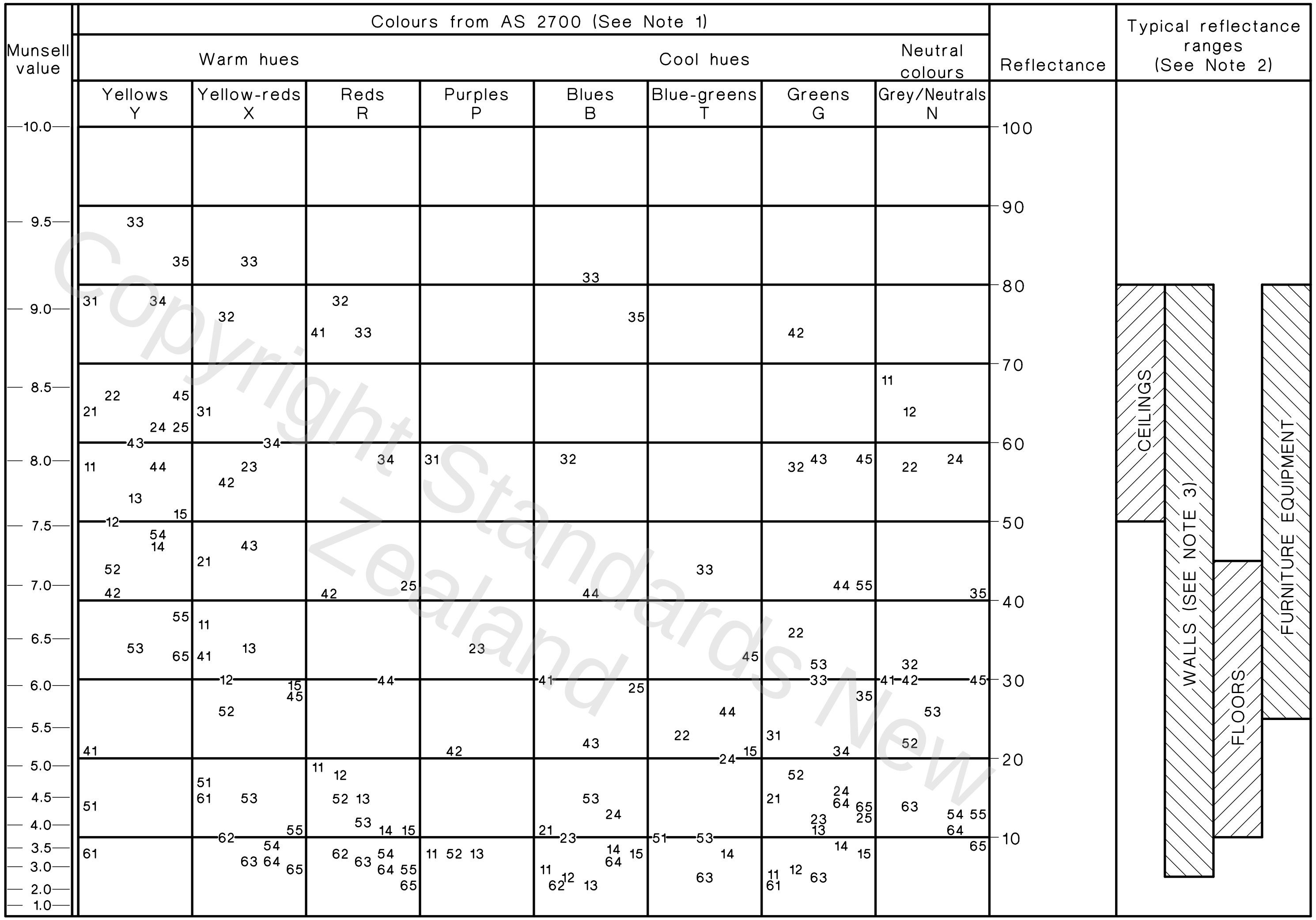
E1.3.6 *Task colour*

When planning colour schemes, the nature of the task should be taken into account.

When a wide range of particularly colourful materials is handled (as in clothing factories), a subdued colour scheme with greys predominating is useful for contrast.

Tasks of intense colour viewed in quantity for prolonged periods can produce negative after-images of complementary hue. This effect is minimized if the task surroundings are finished in a pale colour complementary to that of the intensely coloured task. In operating theatres, for example, green (the complement of red) is often used for draperies and clothing.

When both the materials handled and the clothing of employees are drab in colour (as in a heavy machine shop), a relatively colourful scheme on walls and equipment may be desirable but the recommendations of Paragraph E1.2 should be observed.



NOTES:

1. To uniquely identify each colour requires the hue group plus the value e.g. Y33, G42.
2. Refer to Table E1.
3. Refer to Paragraph E1.2 regarding the use of colours of strong chroma.

FIGURE E1 COLOURS FOR INTERIOR SURFACES IN WORKPLACES

TABLE E1

APPROXIMATE REFLECTANCES OF TYPICAL BUILDING FINISHES

Building surface	Reflectance	Material or finish
Ceilings	0.8	White water-based paint on plain plasterboard
	0.7	White water-based paint on acoustic tile
	0.6	White water-based paint on no-fines concrete
	0.5	White water-based paint on wood-wool slab
Walls	0.8	White water-based paint on plain plasterboard; Tiles: white glazed
	0.4	White fibre cement; Brick: concrete, light grey; Portland cement, smooth
	0.35	Stainless steel
	0.3	Brick: common
	0.25	Concrete, light grey; Portland cement, rough (as board marked); Brick: red; Timber panelling: light oak, mahogany, gaboon
	0.2	Timber panelling: teak, medium oak; Brick: concrete, dark grey
	0.15	Brick: dark hard-fired
	0.05	Chalkboard, painted black (new)
Floors and furniture	0.8	Paper, white
	0.45	Cement screed; PVC tiles: cream; Carpet: light grey, middle buff
	0.35	Timber: light
	0.25	Timber: medium; PVC tiles: brown and cream marbled; Carpet: turquoise, sage green
	0.2	Timber: dark; Tiles: cork, polished
	0.1	Quarry tiles: red, heather brown; Carpet: 'low maintenance'; PVC tiles: dark brown; Timber: very dark

APPENDIX F

BIBLIOGRAPHICAL REFERENCES

(Informative)

The reader's attention is drawn to the following related documents.

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NOTES

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