

Australian/New Zealand Standard™

Interior and workplace lighting

Part 1: General principles and recommendations



AS/NZS 1680.1:2006

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee LG-001, Interior and Workplace Lighting. It was approved on behalf of the Council of Standards Australia on 22 December 2005 and on behalf of the Council of Standards New Zealand on 13 January 2006.
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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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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Interior and workplace lighting

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. $\text{shielding angle} = 90^\circ - \text{cut-off angle}$.

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.

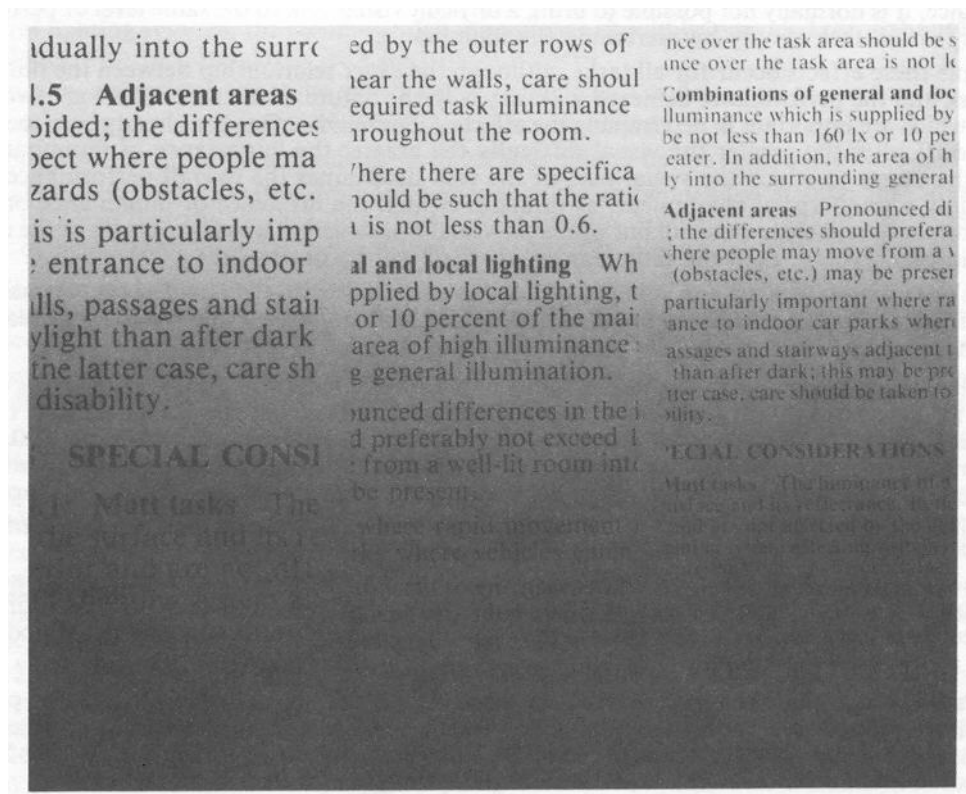
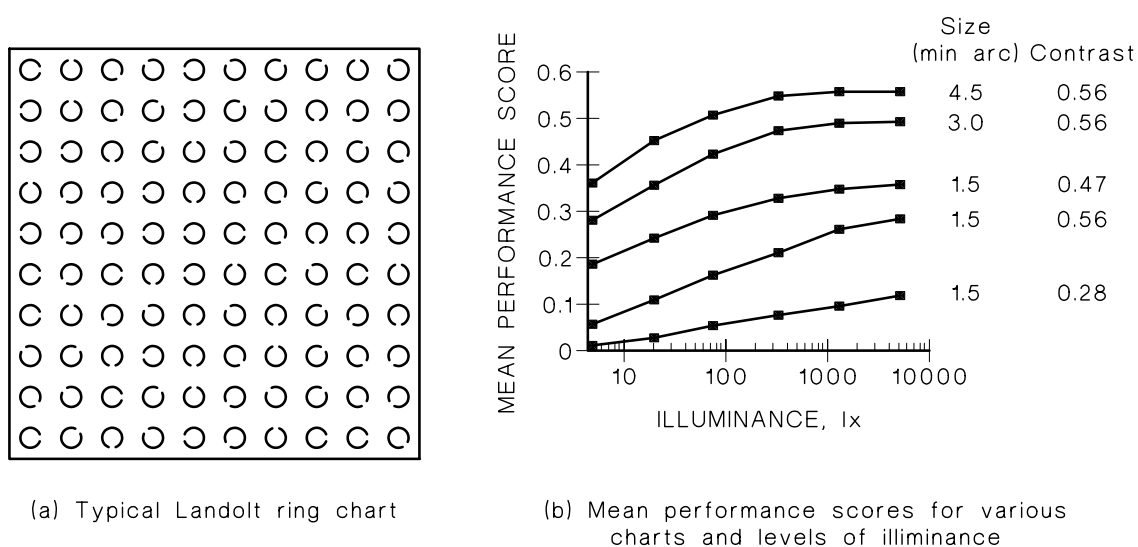


FIGURE 3.1 THE EFFECT OF VARYING SIZE AND CONTRAST OF TASK DETAILS ON EASE OF READING



(a) Typical Landolt ring chart

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

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):

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

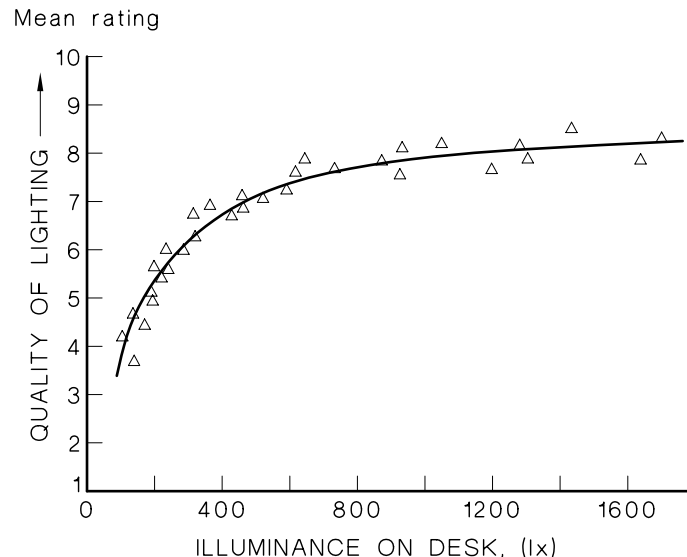


FIGURE 3.3 MEAN ASSESSMENT OF QUALITY OF LIGHTING

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	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	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	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. Inspection of medium work; fine woodwork; car assembly.
	Difficult	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	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.

OTE: 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%.

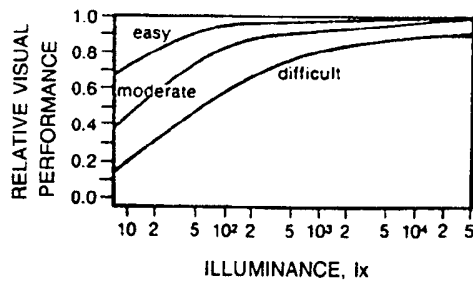
3.10 EXAMPLES OF VISUAL PERFORMANCE

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

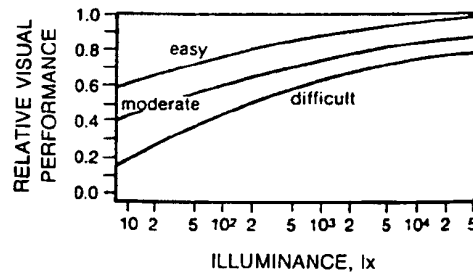
CIE 19.2 gives equations, tables and graphs describing the relationship between task illuminance and measured relative visual performance for various age groups and values of task difficulty and task demand level, these terms being defined as follows:

- (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.

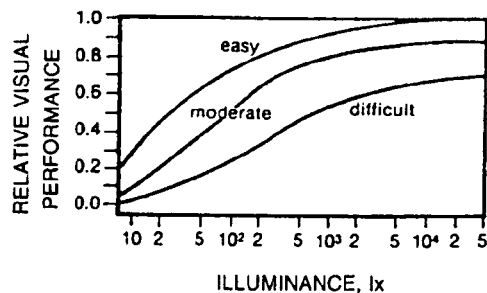
Some of these results are summarized in Figure 3.4.



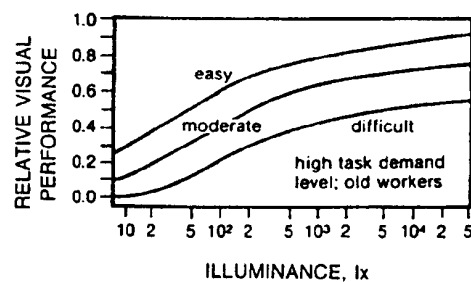
(a) Moderate task demand level, young workers



(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.

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

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

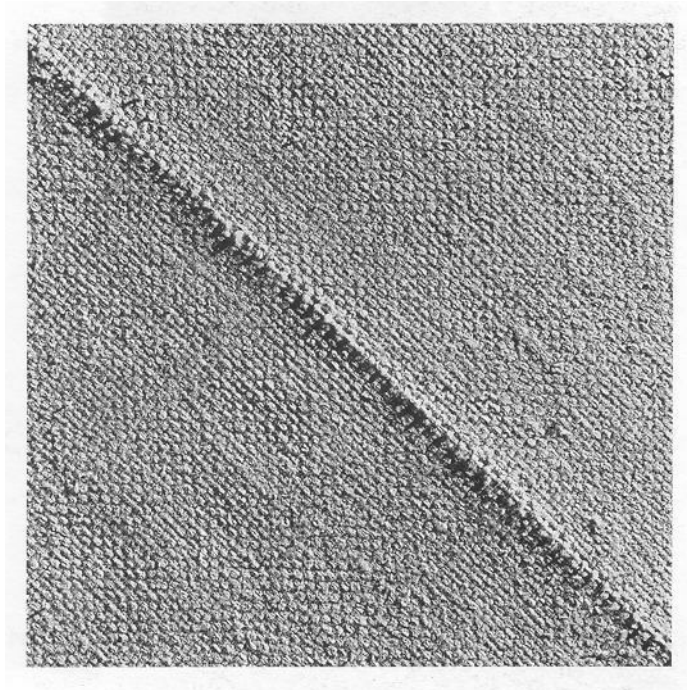
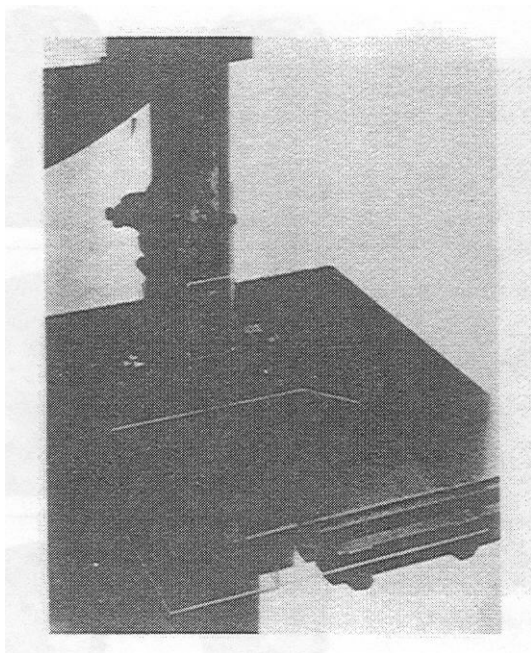


FIGURE 4.2 DIRECTIONAL LIGHT SHOWS A PULLED THREAD IN A FABRIC

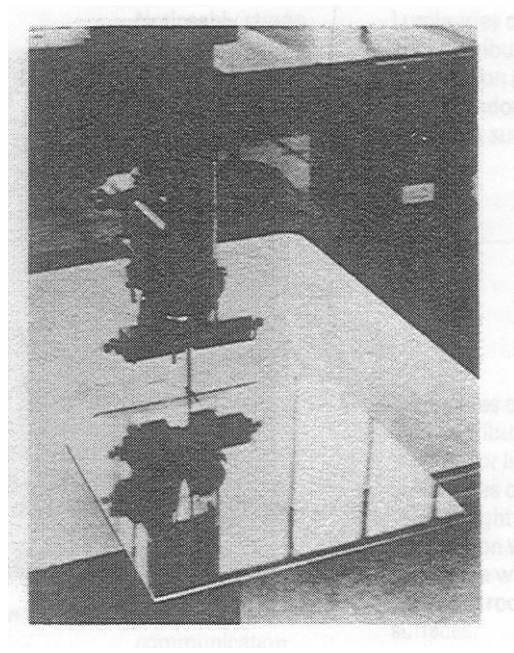
SECTION 5 UNWANTED REFLECTIONS

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.