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ARTIFICIAL LIGHTING

IN FACTORY AND OFFICE

CIS

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Foreword

This Information Sheet was prepared by a specialist on the technical staff of the Commonwealth Department of Labour and National Service, the CIS National Centre for Australia. It is based on a set of Data Sheets prepared by the Department as part of its effort to promote good physical working conditions in industry. The CIS hereby gratefully acknowledges its indebtedness to the Australian National Centre (ADL) for supplying the material for this study

INTRODUCTION

Good lighting is becoming increasingly recognised as an important aid to management in achieving high productivity and in providing satisfactory working conditions for employees which will enable them to work efficiently, accurately and safely, with minimum fatigue.

In almost all cases this illumination has to be partially or wholly provided by artificial means; but conditions for seeing can be just as good under artificial light as under natural daylight, provided that the artificial installation is properly designed.

It must be stressed that sound design involves much more than the provision of a certain minimum level of illumination on the work, for whilst this is certainly important, it is only one of several equally important basic requirements.

BASIC REQUIREMENTS

Make the task easy to see: Besides providing sufficient light on the work, it is important to make sure that the illumination is of suitable quality; i.e., it should contain both diffuse and directional components since this combination produces the soft shadows which reveal the shape and position of objects, and also helps to create the reflected highlights which reveal the shape and texture of shiny surfaced articles. On the other hand, troublesome reflections which may obscure details in the task must be avoided; and in some cases visibility depends not so much upon the quantity of illumination as upon the use of some special device or technique (such as the placing of a luminous background behind the work to make its outlines show up more clearly).

Provide comfortable seeing conditions: Glare and gloom must be eliminated by housing lamps inside well-designed lighting fittings which adequately screen them from view, and also distribute some light to the ceiling and upper walls of the room. Correct spacing and placing of these fittings with respect to the work is often of great importance; moreover, the main interior surfaces of the room (such as the ceiling, walls, plant, etc.) must be finished in suitable light-reflecting colours.

Keep the installation in good working order : In designing an installation the need for future maintenance must not be overlooked. It is therefore necessary to choose equipment that will be easy to service, and also provide safe and easy means of access, thus helping to ensure that the installation will be given the regular attention needed to maintain its efficiency.

Attention to these points will not only enable people to see their work properly, but will also help them to continue to perform it hour after hour, day in day out, without unnecessary fatigue. They are of less importance in non-working areas such as corridors, entrance halls, locker rooms and the like, where people spend comparatively short periods and only casual seeing is involved. In such places, decorative considerations may be more important than the purely functional ones, and the approach is consequently different. But in working interiors where visual tasks are critical and prolonged, meticulous attention should be given to all the basic requirements for comfortable and efficient seeing, even the apparently trivial ones.

It should also be noted that the practical achievement of good lighting depends more upon the care taken over the design of a scheme than upon the amount of money spent in its execution. Moreover, since poor seeing conditions cause inefficiency, spoilt work and accidents, money spent on an installation complying with all the requirements for good seeing is an investment which not only ensures better and safer working conditions but which also helps to promote maximum productivity.

When planning or assessing a factory or office artificial lighting scheme, it is important to make sure that it complies with existing standards; moreover, attention should be given to the following points :

- Are all parts of the interior adequately lit in accordance with recommendations in the recognised code?
- Are there any tasks requiring special treatment (e.g., the provision of a luminous background) to make them easy to see?
- Are the lighting fittings properly placed with respect to the work, so as to minimise risk of its obscuration by unwanted reflections? (Very important in offices.)
- Is the type of lamp (incandescent, fluorescent or mercury-vapour) the most economical and satisfactory one to employ?
- Do the lighting fittings control glare adequately, and is adequate light reaching the ceiling or roof? (If not, there is risk of both glare and gloom.)
- Are suitable finishes used on the walls, roof and other main interior surfaces? (A well-planned colour scheme is no less important than well-planned lighting.)
- Are the fittings readily accessible for routine maintenance?
- Have employees complained about the lighting in any way? (such complaints are often of great help in pinpointing defects in an existing installation.)

Choice of illumination level

The choice of an appropriate illumination level for a given task is greatly influenced by local customs and conditions. An examination of minimum illumination level standards in various countries reveals considerable variations from one to another. Guidance on this particular point should therefore be sought in nationally-recognised codes of practice or recommendations, some of which are listed in the appended bibliography (page 61).

In the absence of such information, however, the data given in Table I (which are based on the most recent Australian standards) may be used as a guide. In practice, intermediate values are also used, and the full range of illumination values is as follows : 2, 5, 7, 10, 15, 20, 30, 50, 70, 100, 150, 200, 300 (or more) lumens per square foot; further subdivision is seldom necessary.

It is essential to remember that whilst doubling the illumination on a badly underlit task will produce a substantial improvement in the efficiency with which it can be performed, further doubling and re-doubling of this illumination produces a smaller and smaller improvement each time. In other words, the curve tends to flatten out at a performance level which no further addition to the illumination can improve. Moreover, because of this flattening, achievement of the final few per cent of performance will often mean an enormous increase in the quantity (and cost) of the lighting required.

In this Information Sheet, numerical data are quoted in round numbers since a higher degree of precision is not required. More precise relationships between equivalent metric and non-metric units are given in Table II, which includes conversion factors for other commonly used luminance units.

SELECTION OF LAMPS

The first step is to choose between the three main types of lamp : incandescent filament, tubular fluorescent and colour-corrected mercury vapour lamps (sodium vapour lamps are seldom suitable for interior lighting on account of their poor colour rendering properties).

Incandescent filament lamps

The simplicity, compactness and versatility of this type of lamp make it suitable for many applications; but for ordinary general lighting purposes, its comparatively short life and low lumen-per-watt efficiency put it at a disadvantage as compared with the other two types. However, in some cases the low capital cost of an incandescent lighting scheme may offset its higher running cost (Fig. 1).

Suitable applications are as follows :

- where artificial lighting is only occasionally required (e.g., now and then on dark afternoons in winter, or in seldom visited storerooms);

Table I

Recommended minimum values of illumination for various classes of visual task

Class of visual task	Minimum illumination on task* (lumens/sq.ft., footcandles)	Typical examples
Casual seeing	2	To permit safe movement (e.g. in corridors with little traffic)
	10	Boiler house (coal and ash handling); dead storage of rough, bulky materials; locker rooms
Ordinary rough tasks	15	Rough, intermittent bench and machine work; rough inspection and counting of stock parts; assembly of heavy machinery
Moderately critical tasks	30	Medium bench and machine work, assembly and inspection. Ordinary office work such as reading, writing, filing
Critical tasks	70	Fine bench and machine work, assembly and inspection; extra-fine painting, spraying; sewing dark coloured goods
Very critical tasks	150	Assembly and inspection of delicate mechanisms; tool and die making; gauge inspection; fine grinding work
Exceptionally difficult or important tasks	300 or more	Fine watchmaking and repairing

* These figures refer to the mean value of illumination obtained during the life of the installation and averaged over the work plane or specific task area (i.e. the so-called "service value of illumination").

Table II

Metric equivalents of non-metric units of illumination and luminance

ILLUMINATION	1 lumen per square foot (lm/ft^2)* = 10.76 lux (lx)			1 lux (lm/m^2) = 0.0929 lm/ft^2	
LUMINANCE	Candelas per square inch	Stilbs	Nits	Footlamberts	Apostilbs
1 Candela per square inch (cd/in^2)	1	1.55×10^{-1}	1.55×10^{3}	4.52×10^{2}	4.87×10^{3}
1 Stilb (sb, cd/cm^2)	6.45	1	1×10^{4}	2.92×10^{3}	3.14×10^{4}
1 Nit (nt, cd/m^2)	6.45×10^{-4}	1×10^{-4}	1	2.92×10^{-1}	3.14
1 Footlambert (ft-L)	2.21×10^{-3}	3.42×10^{-4}	3.42	1	1.08×10
1 Apostilb** (asb)	2.05×10^{-4}	3.18×10^{-5}	3.18×10^{-1}	9.29×10^{-2}	1

* Also known as the "footcandle"

** Also known as the "blondel"

- where space is restricted (e.g., in small adjustable local lighting units mounted on a machine tool);
- where a powerful concentrated beam of light is required.

<u>Tubular fluorescent lamps</u>

The high efficiency and long life of these lamps makes them particularly suitable for general lighting purposes, and it is possible to obtain lamps with particularly good colour-rendering properties when this characteristic is needed. It should be noted, however, that such lamps have a lower lumen per watt efficiency than the conventional type. The main drawback of the tubular fluorescent lamp is its bulk, and the fact that it provides a narrower choice of wattage is also a disadvantage.

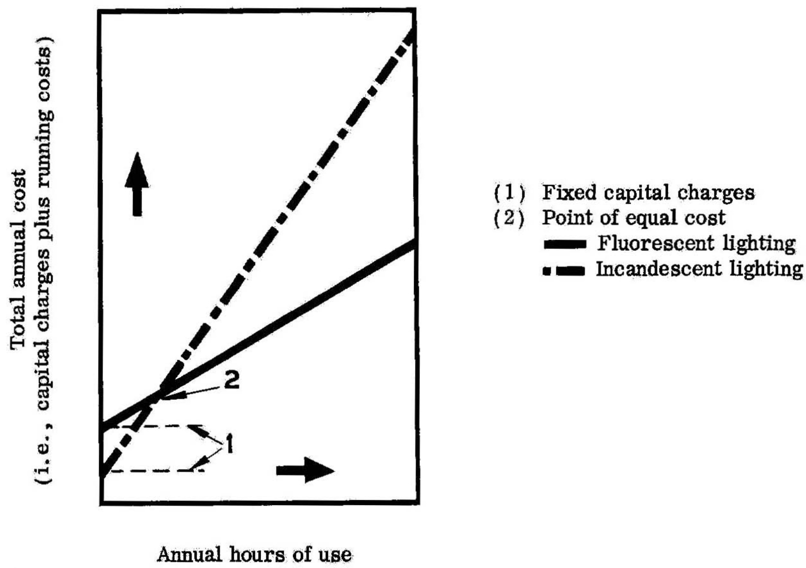


Fig. 1. - The number of hours an installation is likely to be used per year determines whether incandescent or fluorescent lighting will be the more economical alternative

Suitable applications are as follows :

- where artificial light is needed regularly every day (Fig. 1);
- where an elongated light source is needed;
- where good colour rendering is particularly important;
- to replace an incandescent lighting scheme when the illumination level must be increased, but the wiring is already fully loaded.

Mercury vapour lamps

For interior lighting purposes, the "colour-corrected" variety with a fluorescent powder on the outer jacket should be used. These have colour rendering properties which are quite good enough for most industrial lighting purposes. The main advantage of the mercury vapour lamp is that whilst its lumen per watt efficiency approaches that of the tubular fluorescent variety, it is more compact and also available in much higher wattage sizes.

In a large, lofty factory building (such as a steelworks) which would need an enormous number of tubular fluorescent units to light it, it is more economical to use a small number of high-wattage colour-corrected mercury vapour fittings suitably spaced throughout the interior. In such cases the saving in maintenance cost alone may be considerable.

Suitable applications are consequently as follows :

- in lofty industrial buildings where widely spaced high-wattage fittings can be used without making the illumination on the work-plane uneven;
- for exterior lighting of storage areas, docks, roadways, etc. If colour rendering is unimportant, ordinary uncorrected mercury lamps (and sodium lamps) may be used.

CHOICE OF LIGHTING FITTINGS

The design of a lighting fitting should be considered just as carefully as its cost. Well designed units are not necessarily more expensive than poor ones, and often provide much more comfortable and efficient seeing conditions.

Lighting fittings should be of sound mechanical and electrical construction and have a suitable, durable finish; they should comply with the requirements of the local Electricity Authority, and they should be easy to erect and service. All types of lighting fittings require cleaning at regular intervals, and it is particularly important to make sure that this task can be performed easily and safely.

In the case of handlamps, local lights on machines, and other equipment than can be actually touched by the worker, electrical safety is particularly important and low voltage gear (under 50 volts) is recommended.

When the atmosphere may contain explosive gases or vapours, suitable flameproof fittings must be used; special types of fitting are also available for use when the atmosphere contains corrosive vapours.

Airborne dirt tends to collect inside enclosed fittings, which "breathe in" air each time they cool down after switching off. In the case of downward facing shades and trough reflector units, it is better to have ventilating slots above the lamps since this allows the dirt-laden air to pass up through the fitting. It is frequently observed that such units collect dirt less quickly than do closed-top troughs and reflectors.

General lighting units

In working interiors it is most important that general lighting units should :

(a) screen the lamps, thus preventing excessive glare; and

(b) distribute light to the roof and upper walls, unless these surfaces are separately lit (e.g., by daylight entering through a sawtooth roof).

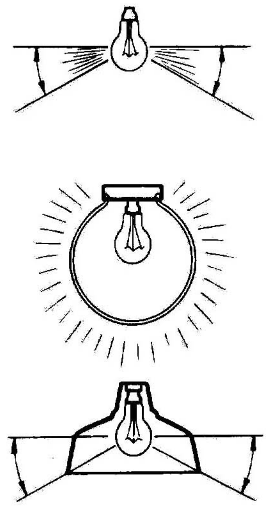


Fig. 2. - Glare is prevented by limiting the brightness visible in this zone. Overbright lamps must therefore be screened :

either with translucent diffusing

or with opaque shades or louvres

This applies to fluorescent lamps as well as to incandescent lamps

Glare control

As shown in Figure 2, glare is mainly caused by light emitted at or near the horizontal. Lamps must therefore be screened from view throughout this critical zone; in practice, this is achieved either with opaque shades and louvres, or with translucent diffusing material which cuts down the brightness of the unit to more comfortable proportions. When visual tasks are difficult and prolonged, glaring lighting units can produce much unnecessary strain and fatigue. Thus it is extremely important to observe any recommendations on the subject in the accepted lighting code.

In the absence of such information, the recommendations on pages 39 to 50 may be used as a guide, since they will ensure a degree of glare control which most people will probably find acceptable.

Upward light

Unless the ceiling or roof is separately lit, suspended units should always emit a proportion of their light upwards. As Figures 3 and 4 show, this light is diffusely reflected from the roof (which must of course have a suitable light colour). Besides eliminating the gloomy "tunnel effect" which occurs when overhead surfaces are left shrouded in darkness, this arrangement helps to produce optimum seeing conditions. The diffuse light (from the roof) and the direct light (from the fittings) combine to create the soft shadows which best reveal the shape and relative position of objects; whilst the illuminated roof and upper walls provide the large, low brightness areas which are essential when shiny-surfaced work has to be examined (Figures 5 and 6).

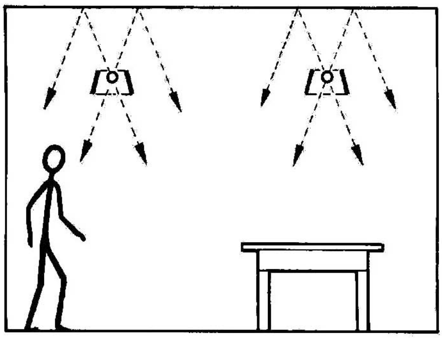


Fig. 3. - A mixture of direct light from the lamps plus diffuse light reflected from the roof generally provides the best seeing conditions

Here it may be noted in passing that one reason why people so often prefer to work under natural lighting is that daylight usually contains this mixture of diffuse and directional components. Moreover, the daylit walls and roof (and in many cases the sky outside) provide the large areas of low brightness needed for tasks involving inspection of shiny metal (tinplate marking and cutting, scraping bearings, typesetting by hand, engraving and reading metal scales, etc.).

Typical general lighting units

Typical forms of general lighting equipment are briefly described below, together with notes on some of the applications for which the various types of unit are particularly suited.

Industrial type troughs and shades

These should preferably have small slots which allow at least 10-15% of the light to escape in an upward direction. This will be sufficient to dispel overhead gloom, and also ensure adequate ventilation of the fitting, thus helping to prevent dirt from collecting inside. To ensure that neither the lamps nor the bright interior surfaces of the fitting will be visible through the slots, these apertures should be located above the lamps rather than alongside them; moreover, the slots should preferably be horizontal, as shown in the fluorescent unit in Figure 7. This is a point of considerable importance, since badly placed slots, especially those in the sides of a fitting, defeat one of the main objectives - namely that of screening the lamps throughout the whole of the critical zone in Figure 2.

Fig. 4. - There were many complaints in this tool-grinding shop when lit with closed-top units (left-hand photo). The trouble was completely cured by substituting fittings with large apertures above the lamps (right-hand photo) : this made shiny-surfaced work much easier to handle (see also Fig. 6)

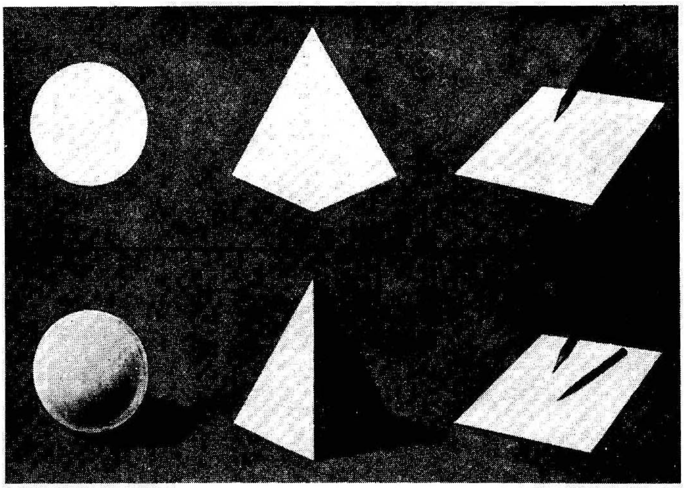
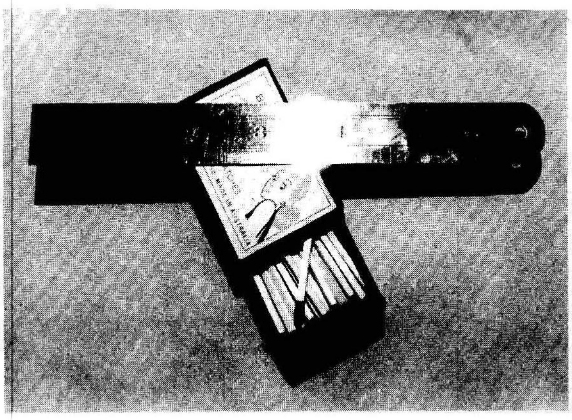
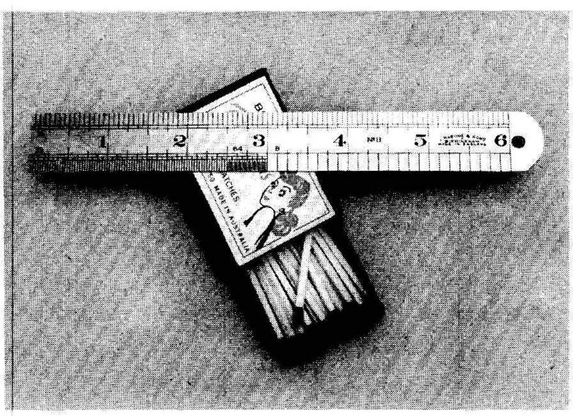


Fig. 5. - Soft shadows help to define the shape and position of objects. Note how the shadow reveals the space between the pencil point and the paper beneath it



a)



b)

Fig. 6. - Visibility of details on a shiny surfaced object depends upon what the shiny surface reflects rather than upon the level of illumination falling on it. Here the same level has been produced by :

(a) directional light from a bright lamp in a deep shade

(b) diffused light from a well-lit, light-coloured ceiling

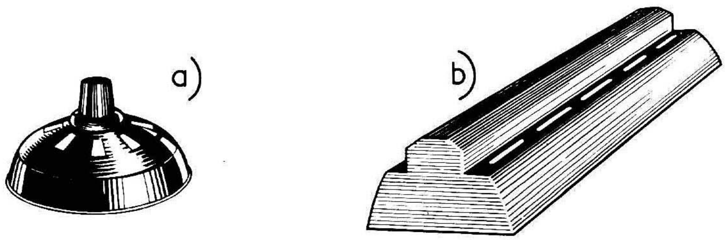


Fig. 7. - Typical ventilated industrial units
(a) Incandescent (b) Fluorescent

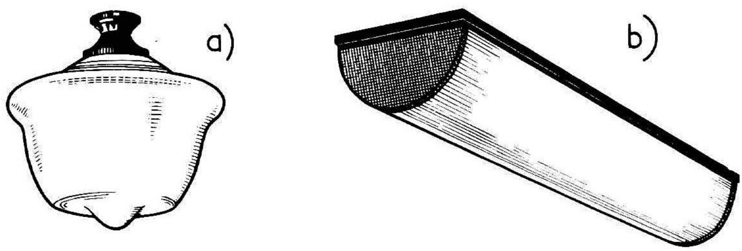


Fig. 8. - Typical enclosed diffusing units
(a) Incandescent (b) Fluorescent

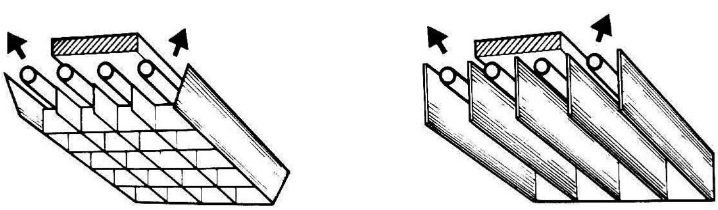


Fig. 9. - Typical louvred units
Note : The outer lamps should emit unobstructed
upward light

Totally-enclosed diffusing units

Units of the type shown in Figure 8 provide high quality lighting, and the incandescent variety are by far the best type to use when an office is to be lit with incandescent lamps. The fluorescent version gives comparatively little upward light, and for this reason should be ceiling-mounted rather than suspended. It is particularly important to make sure that such fittings employ adequate diffusing material which keeps their brightness within acceptable limits.

Louvred fluorescent units

These may have metal louvres, or translucent diffusing ones. If suspended from the ceiling, at least some of the lamps should emit unobstructed upward light as shown in Figure 9. Such units are generally less affected by airborne dirt than totally enclosed types.

"Direct-indirect" units

The essential feature of this type of unit is the pair of large apertures (some 2 or 3 inches wide) above the lamps. These large slots allow some 40% of the available light to escape to the ceiling and for this reason it is convenient to refer to them as "40/60" fittings (this being the relative proportions of upward and downward light). Being made entirely of metal, such fittings are frequently cheaper than the enclosed diffusing type; and when

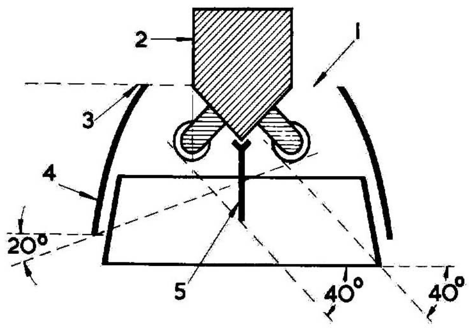


Fig. 10. - Characteristic features of well-designed "40/60" units :

(1) Wide slots allow approximately 40 per cent of the light to escape upwards to the roof
(2) Side face of ballast channel is above centre-line of lamp. This prevents it from becoming excessively bright
(3) Upper edge of the reflector conceals bright interior surfaces from view
(4) Lower edge of the reflector gives at least 20° shielding of the far lamp when the louvre assembly is removed
(5) Optional louvre assembly consisting of longitudinal fins to increase shielding to at least 40° for both lamps, plus transverse fins to provide 30° shielding lengthwise (used in office lighting installations)

carefully placed so as to prevent obscuring reflections in the work, they provide particularly good quality office lighting, even when suspended close to the ceiling with the slots only 20 or 30 cm away from it. Figure 10 summarises the main design features of this type of unit.

Bare fluorescent lamp units

In general, bare-tube units are too bright to use in working interiors where work is critical and prolonged. However, bearing in mind the point made in Figure 2, if the room is very small (so that all lamps are well up out of the field of view of the occupants) they can be safely used (Fig. 11a). They can also be sometimes employed in long, narrow rooms where everyone views the units more or less end-on (Fig. 11b); some specific advice on the subject is given on page 44. Again, it is sometimes possible to avoid glare by hiding the lamps behind roof beams or other ceiling features which provide the necessary screening. Bare-tube units are of course quite suitable for use in places where visual tasks are not critical and where people only spend brief periods at a time (non-working areas, corridors, etc.).

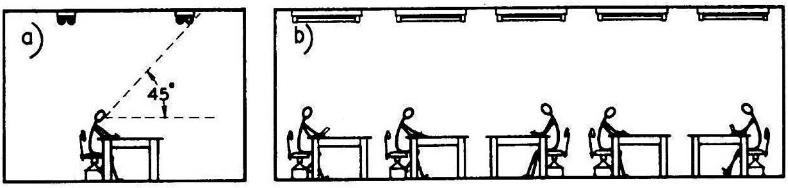


Fig. 11. - Bare fluorescent lamp units are least likely to cause serious glare :
(a) in small rooms where all lamps are well up out of the field of view
(b) in long narrow rooms where everyone views the units end-on

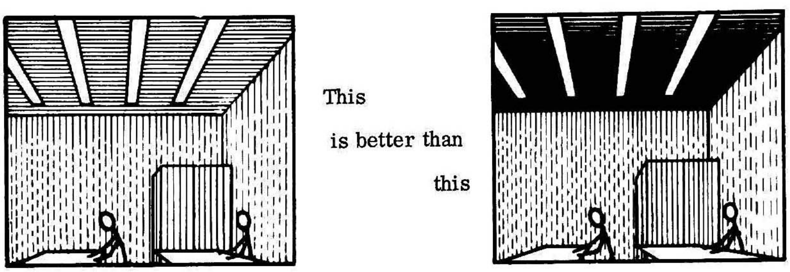


Fig. 12. - A light-coloured ceiling is essential when using flush-mounted units

Recessed units

In offices with low ceilings it is often necessary to recess the lighting fittings, leaving the mouth flush with the ceiling (Fig. 12). In such cases light from the fittings can only reach the ceiling by reflection, and the system is most likely to be satisfactory when the room is small in size, with a light decoration scheme, or when the general illumination is reasonably high (at least 50 lm/ft^2, or 500 lux). In all cases, the ceiling should be finished as near white as possible to make the most of the illumination reaching it. If the room is a large one, a more satisfactory degree of glare control is likely to be achieved if the mouths of the recessed units are screened with louvres rather than with a sheet of diffusing material.

Luminous and louvred ceilings

In general, a louvred ceiling gives better visual conditions than a luminous ceiling made of continuous sheets of diffusing material. A uniformly bright luminous ceiling tends to produce excessively diffused lighting which is apt to make the interior look dull unless the illumination level is particularly high. It also requires much more frequent cleaning than the louvred variety. The main application for luminous and louvred ceilings is when an ugly roof structure has to be hidden, or when some special architectural effect is desired. Where it is possible to slope the louvres in such a way as to give the light a directional component (preferably similar to that of daylight from the windows), obscuring reflections in office tasks can be minimised (Fig. 13).

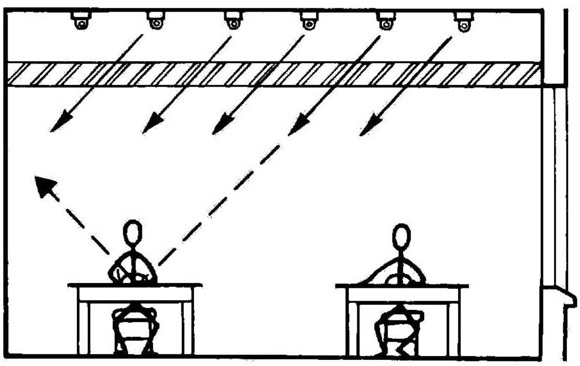


Fig. 13. - A louvred ceiling with sloped louvres gives the light a directional component which minimises the risk of obscuring reflections

Indirect lighting units

Fittings which throw all their light on to the ceiling (Fig. 14) are seldom used nowadays for general lighting installations in working interiors except where there are special reasons, such as likelihood of troublesome reflections in the work which it is impossible to avoid in any other way; this point is further discussed on page 52. Indirect units can also be sometimes usefully added to an installation of direct lighting fittings which cannot by themselves produce adequate ceiling illumination

Local lighting units

Lamps mounted low down near the work are particularly liable to cause glare unless completely screened from view by an opaque shade of some kind. Possibility of glare from the bright interior surfaces of the shade should also be considered, and the comfort of workers at neighbouring machines should not be overlooked. Electrical safety is also particularly important, especially in the case of handlamps which are often used in places where a mains voltage shock may well be fatal.

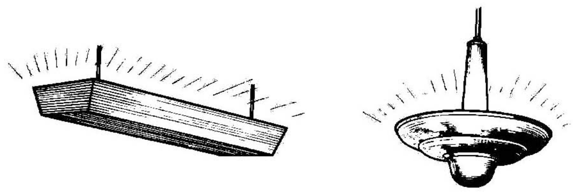


Fig. 14. - Typical totally-indirect lighting units
(a) Fluorescent (b) Incandescent

Incandescent lamp units

Deep shades should be used and a black band should preferably be painted round the inner edge of adjustable shades which may be set at an angle (Fig. 15). 'Rough service' lamps should be used if the unit is subject to vibration or shock, and preferably frosted lamps rather than clear ones when working on bright metal (thus reducing annoying glitter). Flexible leads should be protected from damage.

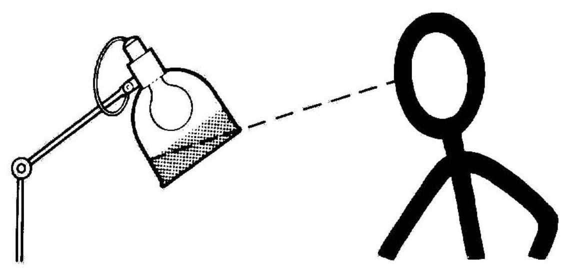


Fig. 15. - A matt black band painted inside the rim of an adjustable local lighting unit helps to prevent glare

Handlamps should be of a well-designed, strongly-constructed type. The lamp socket should be properly shrouded, and insulated from the wire guard. The latter should be strongly made, and should preferably have some form of anti-glare shield (Fig. 16); the use of frosted lamps will also help to minimise glare. The handle should be of insulating material, and the flexible cable should be strong, well protected and securely anchored.

Low-voltage incandescent lamps are more efficient and robust than equivalent mains voltage types. They are safer to use, provided that the supply transformer is properly insulated and earthed, preferably at the centre point of the secondary winding. In particularly dangerous situations (e.g., inside a metal tank or boiler shell) the lamp voltage should preferably not exceed 32 volts, with centre-point earthing to reduce the maximum potential to earth to 16 volts.

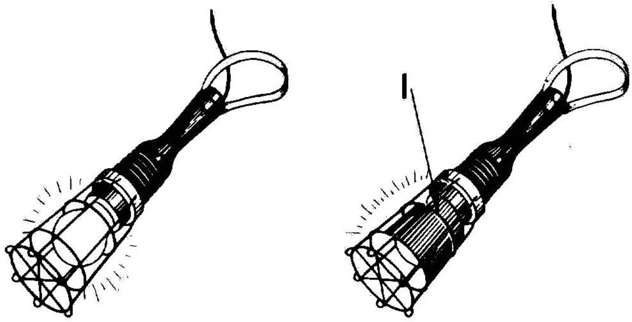


Fig. 16. - To avoid glare, use should be made of a hand-lamp fitted with a small screen (1) in preference to an unshielded one

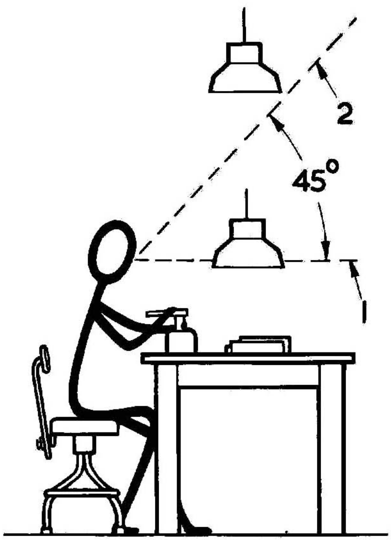


Fig. 17. - To avoid glare from local lighting units, they should be mounted with the lower edge of the trough :

either below dotted line (1)
or above dotted line (2)

Fluorescent lamp units

Troughs should be mounted either low enough to ensure that all bright surfaces are completely hidden, or high enough to ensure that they are well outside the normal field of view (Fig. 17). If this is impracticable, the brightness of visible parts of shades, louvres, etc., can be reduced by blackening them. A light-coloured finish should be used on the outside of troughs which hang low before the eyes, as in Figure 17.

INSTALLATION PLANNING

Three main types of artificial lighting installation are used in factories and offices, namely :

a) uniform general lighting;
b) general, plus local supplementary lighting;
c) localised general lighting.

The choice depends on the nature and location of the visual tasks to be performed.

Uniform general lighting

A uniform general lighting installation may be defined as one in which the fittings are evenly distributed throughout the whole interior, without any particular regard for the location of the workpoints in the room. It will be noted that this definition excludes ordinary office lighting installations where the avoidance of troublesome reflections depends very much on correct placing of light fittings with respect to desks and tables. For this reason, the special problem of office installation planning will be discussed on page 24 in the section on "Localised general lighting".

Typical applications

Uniform general lighting is suitable in places where the workpoints are not fixed (e.g., foundries and large assembly shops, warehouses, etc.)

Mounting height

General lighting units should be mounted as high as possible. This will reduce the risk of glare and improve light distribution throughout the interior. Moreover, increasing the mounting height often permits the use of a small number of powerful, widely spaced units, thus improving the overall efficiency and reducing cleaning costs.

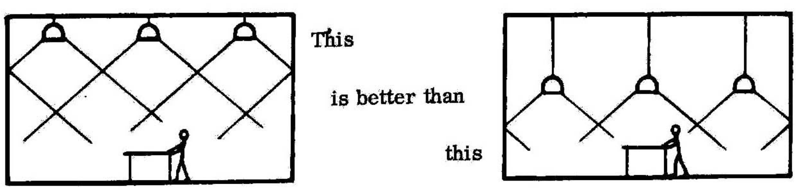


Fig. 18. - General lighting units should preferably be mounted as high as possible

Contrary to popular belief, increasing the mounting height of a large general lighting installation does not greatly reduce the illumination level on the work; for whilst the unit directly over the workpoint certainly contributes much less light, additional illumination from neighbouring units largely makes up the deficiency (Fig. 18).

Spacing

The space between the units must not exceed a certain proportion of the mounting height above the work plane. A reasonably uniform illumination level is important in installations of this kind, and the minimum value should preferably be not less than 2/3 of the average throughout the room.

For totally enclosed diffusing units and open troughs and reflectors, the spacing-to-mounting-height ratios should not exceed the values shown in Figure 19. For louvred fluorescent units, these maximum spacings should be reduced by about 15%. These spacings are measured between the centres of adjacent units in a row, and not between the ends of the units.

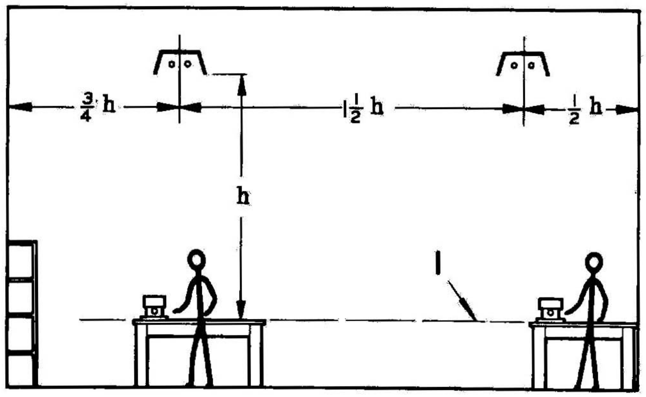


Fig. 19. - Maximum recommended spacing for industrial type units
Measurements are to the centre point of the unit in all cases, and are expressed as a multiple of the mounting height h above the work plane (1). The ¾ h figure applies when there is a gangway next to the wall, whilst the ½ h figure is used when people work close to the wall. For louvred units, maximum spacing between fittings should be reduced to 1¼ h

For this purpose the mounting height h is measured from the work plane, not the floor. In most cases, the work plane can be assumed to lie about 3 feet above floor level, but this is not always the case; as Figure 20 shows, one should always base spacing/mounting-height calculations on the highest work plane.

General, plus local supplementary lighting

In this system, additional local units (usually mounted close to the work-point) supplement the evenly distributed general lighting provided by overhead units (Fig. 21).

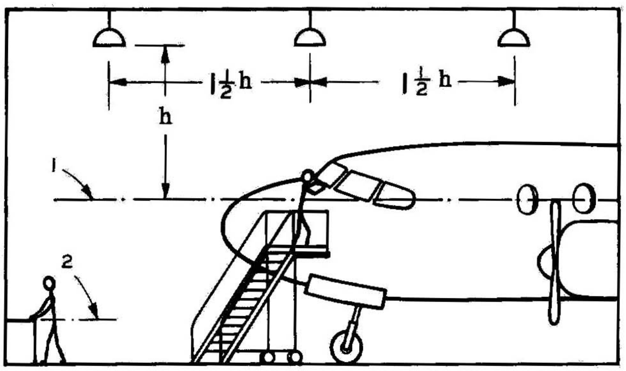


Fig. 20. - When determining the maximum allowable spacing between units, calculations should always be based on the mounting height above the highest work place in the interior. Here h should be measured from level (1) rather than level (2)

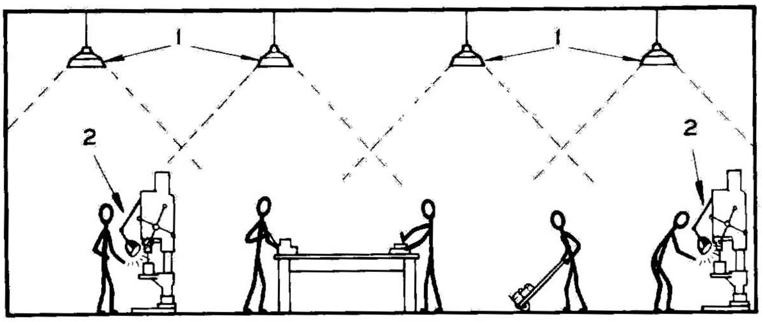


Fig. 21. - Some general lighting is always needed even when tasks are locally lit
(1) Uniform general lighting (2) Local supplementary lighting

Typical applications

This system of lighting is particularly suitable in places where a high level of illumination is needed at a few definite locations scattered about the room (e.g., when a shop mainly devoted to rough assembly work also contains one or two lathes); also, when light from the overhead installation cannot reach the workpoint (e.g., inside the throat of a heavy power press).

When a worker's visual task is concentrated within a small area (e.g., around the needle of a sewing machine), an intense illumination can be readily produced with a comparatively low-wattage lamp housed in a suitable shade close to the workpoint.

However, even if all workpoints in a factory are locally lit in this way, it is still essential to provide some general illumination throughout the whole interior to prevent excessive contrast between the worker's task and the general surroundings, and to enable him to move safely about the plant.

As a general rule, the average level of illumination throughout the interior should not be less than the square root of the illumination level on the locally lit task.

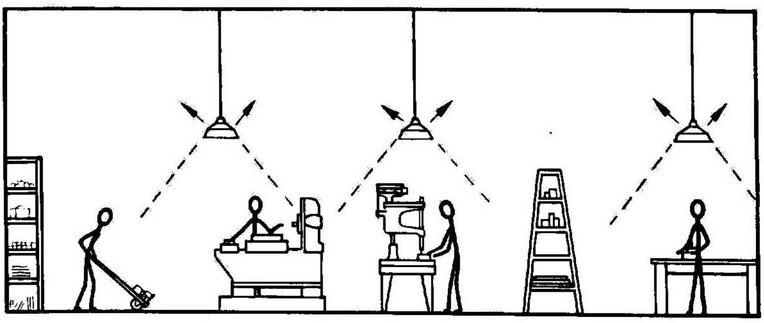


Fig. 22. - Open-top units are particularly recommended for localised general lighting installations in factories, since the units sometimes have to be widely spaced

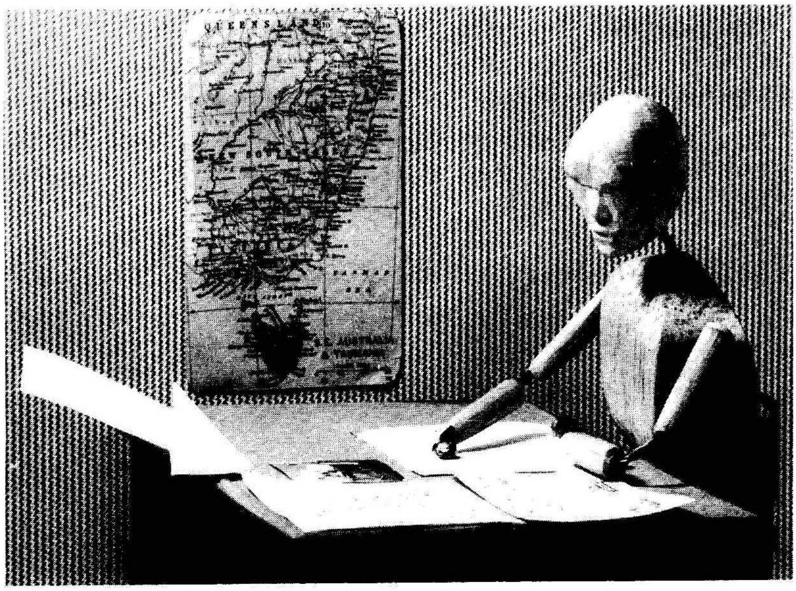
Localised general lighting

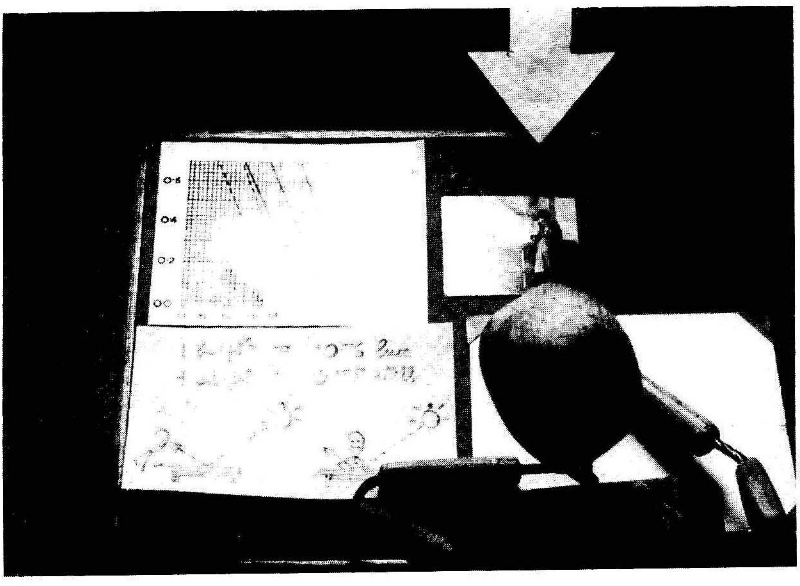
In this system, illumination is wholly provided by overhead units of conventional type, which are often (though by no means always) arranged in a regular pattern of the kind used in uniform general lighting. The essential difference is that the existing, or probable, layout of the furniture, plant and equipment is carefully considered when planning the scheme; and whilst a uniform distribution of illumination is often aimed at, greater diversity is permissible, especially in factory installations where critical workpoints are spaced further apart.

Typical applications

These are in factories where individual work benches or machines requiring strong illumination are spaced at irregular intervals throughout an interior (Fig. 22), and in offices where correct placing of lighting units with respect to desks is of considerable importance in preventing troublesome reflections in and around the work.

Factory installations of this kind need not obey the spacing-to-mounting-height limits given in Figure 19, but it is essential to make sure that no part of the interior is left in darkness. Slotted-top units are particularly recommended for such installations, since their upward light diffusely reflected downward from the ceiling or roof is of great help in counteracting the effect of the unusually wide spacing between units.

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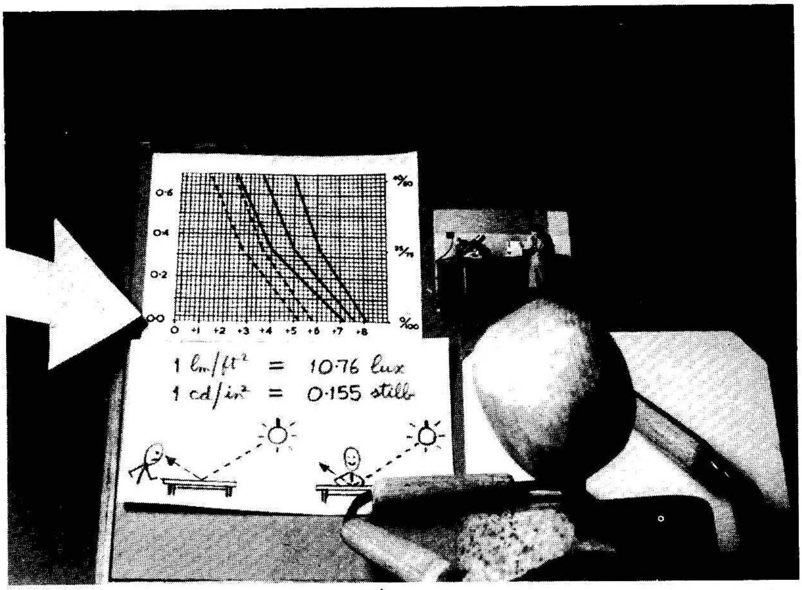


Fig. 23. - Visibility of many office tasks is greatly affected by the direction from which the light falls (here indicated by the large arrow). Light coming mainly from the front (see figures on the left) produces obscuring reflections which are very noticeable when the work has a glossy surface. In the case of pencil manuscript and drawings, the absence of an overall sheen makes the presence of reflections less obvious, but their effect on visibility is just as bad. Light coming mainly from the side (see figure below) cannot cause obscuring reflections of this kind; it therefore gives far better visibility for the same illumination. Reflections caused by badly placed lighting fittings are an extremely common cause of serious complaint in offices

<u>Office installations</u> usually have to provide reasonably even illumination throughout the room. Compliance with the maximum spacing recommendations in Figure 19 is therefore necessary. Careful positioning of the units in relation to desks, tables and drawing boards is also of considerable importance since this is much the best way of avoiding troublesome reflections which so often cause complaints in situations where pencil drawings and manuscripts have to be studied. Pencil strokes become much harder to see when they "catch the light" because the additional brightness dilutes (and may even destroy) the contrast between the dark pencil mark and the paper on which it lies (Fig. 23). Incidentally, this destruction or dilution of task contrast is often loosely referred to as "reflected glare", but should not be confused with the glare produced by excessively bright light sources in the field of view.

When planning an office lighting installation, an attempt should always be made to light desks and tables from the side rather than from directly in front. As Figure 24 shows, this means that fluorescent fittings should be placed parallel to the side of a desk (a) rather than its front edge (b); moreover, the desks should be placed between the rows of units (c) rather than directly under them.

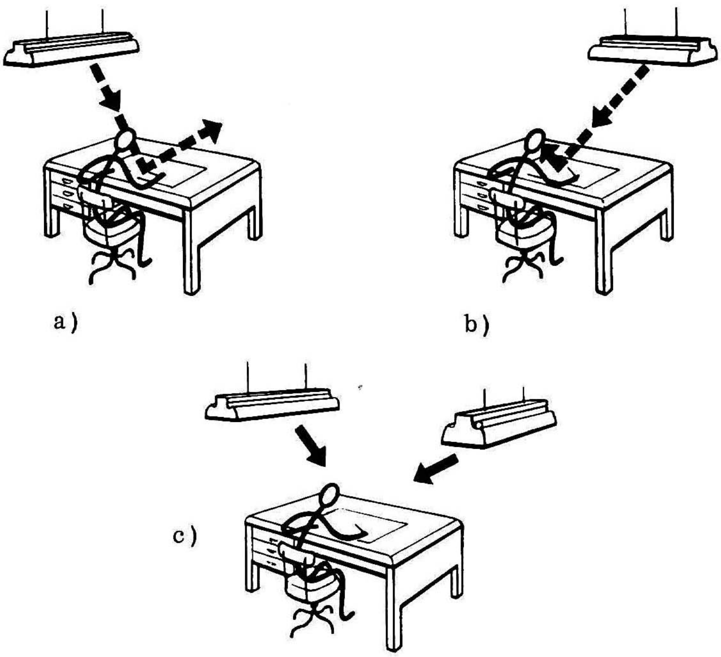


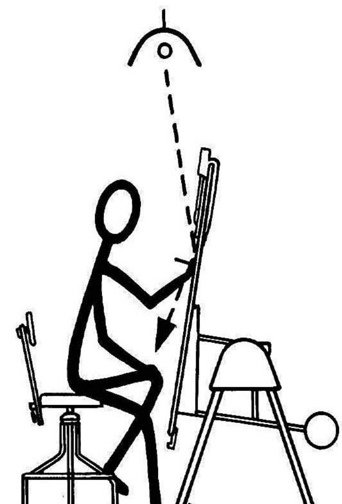
Fig. 24. - Light from the side is best for a desk, since unwanted reflections are then directed away from rather than into the worker's eyes. Where possible, desks should be placed between the rows of fittings rather than directly under them

In many cases, the exact layout of desks and tables is not known at the time the installation is planned. However, it is frequently possible to estimate where they are likely to be placed. For instance, desks are generally arranged side-on to the windows, and in a large general office it is therefore usually best to arrange the rows of units parallel to the window wall, with the outermost row as close to it as possible, thus making it easy to arrange desks between the rows rather than directly under them (Fig. 25).

In drawing offices with horizontal boards, it is particularly important to observe the principles outlined above. When the boards are vertical, however, units are often best arranged at right-angles to the window wall and parallel with the top edge of the board. As shown in Figure 26, this arrangement will ensure that reflections are kept out of the draftsman's eyes.

Fig. 25. - Since office workers normally sit side-on to the windows, fluorescent fittings should be placed parallel to the window wall, with the outermost row as close to it as possible

Fig. 26. - Vertical drawing boards are best lit by a fitting placed above and parallel to the top edge of the board as shown. This will ensure that reflections are thrown downwards



In power-station switchrooms and other places where there are glass-faced wall-mounted instruments, obscuring reflections can be prevented by mounting the units at sufficient height from the floor to ensure that reflections are thrown below eye-level (Fig. 27).

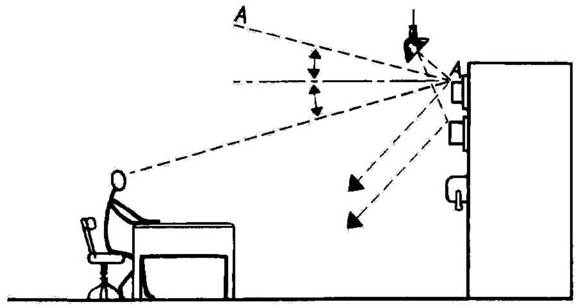


Fig. 27. - Lighting a power station switchboard. Lighting fittings mounted above line "A-A" cannot produce obscuring reflections on the glass covers of the meters

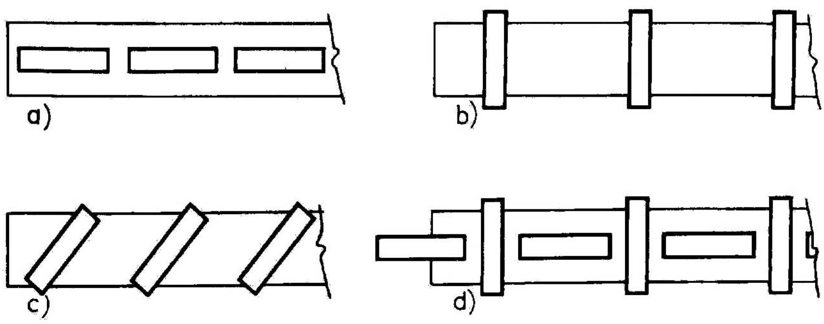


Fig. 28. - Alternative methods of lighting a long, narrow workbench

Work benches can be lit in a number of ways, a few of which are shown in Figure 28. Here, arrangement (a) is generally the best one to use when the work lies flat on the bench and the lighting fittings hang low down with the edge of the shade below eye level (as was shown in Figure 17). If vertical surfaces have to be seen, arrangement (b) is generally more suitable; here the units are placed just above head level, and when the work is held in a vice near the front edge of the bench, the front ends of the fittings should project well out beyond this point. Arrangement (c) is a variation of (b) which increases the proportion of light falling from the worker's left front, while arrangement (d) provides a particularly strong and shadow-free form of lighting.

Artificial lighting in daylit offices

The trend towards lower ceilings and deeper rooms in the modern multi-storey office building makes it increasingly difficult to rely solely on daylight, except in a comparatively small area close to the windows. Throughout the greater part of the room, supplementary artificial lighting has to be used all the time during working hours; this of course does not mean that windows should be dispensed with altogether. Even though office workers have long accepted the need to use permanent supplementary artificial lighting in such buildings, there is generally considerable objection to the idea of working in a completely windowless office, and it is evident that the ability to "see outside" does appear to contribute to their sense of well-being, even though the windows in question may be so far away that the task lighting is mostly artificial.

It is important to recognise that this psychological benefit is not the only reason why natural lighting is preferred. Daylight from near-by windows has a number of inherent technical advantages as well. For instance, glare is well controlled (provided that the workers sit side-on to the windows); again, there is plenty of light not only on the work but also on the ceiling and upper walls of the room. More important still, the light falls on office desks and tables from the side, thus minimising the risk of task obscuration by troublesome reflections. Daylight from near-by windows thus satisfies the requirements for good seeing more or less automatically; if a supplementary artificial lighting installation is to give equal satisfaction, it must be carefully designed in accordance with the principles explained in this Information Sheet.

The only real difference between the design of an ordinary artificial lighting installation and a "permanent supplementary" one, lies in the quantity of illumination required. Paradoxically, the presence of a window often makes it necessary to provide more artificial light, not less. This is because the eye adjusts its sensitivity to suit the prevailing brightness distribution within the field of view, hence the bright sky or brightly lit outdoor scene visible through a window tends to reduce the sensitivity of the eyes. This does not worry people working near the window, for the strong natural light on their task will more than make up for any reduction in eye sensitivity; but in remoter areas there is no such compensation, Moreover, to make matters worse, as the distance from the window increases, the useful daylight on the horizontal workplane falls off much more rapidly than does the glare-producing component on the vertical plane (i.e., the plane of the worker's eyes). In fact, at a distance from the window equal to only about three times the ceiling height, the daylight cast in a worker's eyes may be five or six times greater than that reaching his desk; and for this reason it may be necessary to provide considerably more artificial light than would satisfy his needs at night.

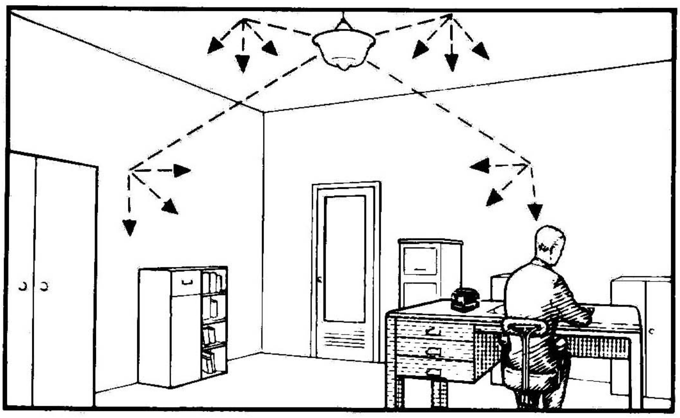
As mentioned on page 3 , it is not easy to lay down rules regarding quantity of illumination; also in this case the problem is complicated by the fact that sky brightness varies considerably from place to place and from day to day. However, the following rule is suggested as a rough practical guide:

Suggested minimum level of illumination : When artificial lighting has to be used in large "daylit" offices where it is possible for people at the back of the room to see the distant windows, workers in these remoter areas should have at least 50 lumens per square foot (i.e., approximately 500 lux) on their work.

This suggestion is based on practical experience in Melbourne (latitude 38°) and may not meet the case in places where the external illumination is exceptionally high (e.g., tropical areas). In these circumstances, control of the visible brightness by shading devices, or grey glass in the windows, may be a better solution than increasing the amount of artificial light.

INTERIOR COLOUR TREATMENT

No lighting scheme can be fully effective unless well-chosen (and well-maintained) finishes are provided on main interior surfaces such as ceilings, walls, plant and equipment. Here, the main object is to use colours which will reflect rather than absorb light. Diffused light thrown back in this way can contribute substantially to the total illumination on the work (Fig. 29). It also greatly improves the quality of the lighting by softening shadows and minimising harsh contrasts in the field of view, thus contributing to visual comfort and efficiency.



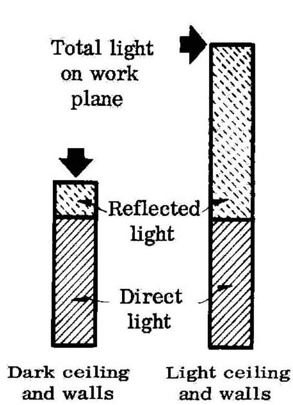


Fig. 29. - Use of light-toned interior surface finishes greatly improves the efficiency of an installation. Work plane illumination normally contains a large proportion of light coming by diffuse reflection from the ceiling and upper walls. If the latter surfaces are dark in colour, much of this useful light will be absorbed and lost

A white ceiling is particularly beneficial in a working interior; but for other surfaces a compromise must be made. White walls, for instance, can be glaring when brightly lit and the same is true of excessively light coloured floors and equipment, which may also show dirt too easily.

Recommended reflection factors

The ability of colours to reflect light is denoted by their " reflection factor". Pure white and pure black surfaces respectively reflect 100% and 0% of the light falling on them. It is important to realise that the brightness (or " lightness ") of intermediate colours does not change in proportion to their reflection factors. For instance, a "middle grey" with a tone value half way between black and white reflects 20% of the incident light - not 50% as one might perhaps expect. Figure 30 illustrates this point. Here the reflection factor values are spaced out in roughly equal steps of apparent brightness. This chart shows the ranges of reflection factor recommended for main interior surfaces in working areas.

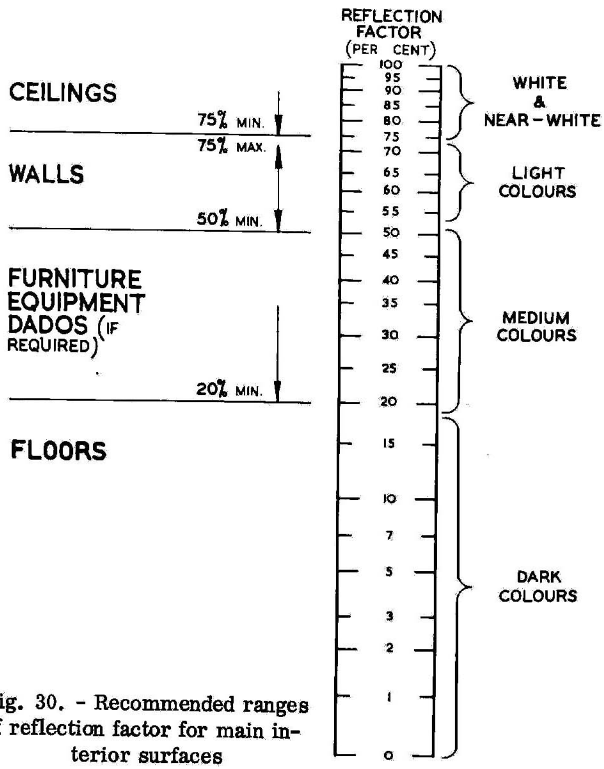


Fig. 30. - Recommended ranges of reflection factor for main interior surfaces

For <u>ceilings</u>, the reflection factor should be at least 75%, which means white or near-white. A matt finish is preferable (aluminium paint is <u>not</u> recommended).

<u>Walls</u> are best finished in light pastel colours in the 50-75% range, except in the case of very brightly lit walls (e.g. those adjacent to a large win-

dow) which may need toning down to 40% or less to prevent them from becoming too glaring. Conversely, walls containing windows (but which receive no direct light themselves) can often be painted white with advantage.

Furniture should preferably have a reflection factor of at least 20%, and the modern blond wood finishes and light grey paints for steel cabinets are greatly to be preferred to the old-fashioned dark stained wood and dull olive green finishes which used to be so frequently used. On desk and table tops which form a background to the work, it is particularly important to guard against distracting reflections. As Figure 31 suggests, light-coloured

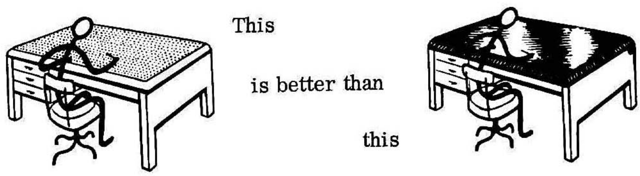


Fig. 31. - Seeing conditions are far better with a light-coloured matt finished desk top, than with a dark-coloured glossy one which produces irritating and distracting reflections in the surroundings of the work

matt finished materials such as linoleum or plastic cloth are much to be preferred to the old-fashioned dark glossy finishes. If a desk is covered with a sheet of plate glass, the underlying surface should always be as light as possible. If a desk has a glossy finish which cannot be changed, use a large blotting pad, as shown in Figure 40.

Floors should be reasonably light in colour. Practical considerations usually govern the nature of a floor finish, but 20-25% or so is generally a satisfactory figure. Floor finishes which are very much lighter than this should be treated with caution since they can sometimes cause glare (e.g. in particularly well-lit office interiors).

Colours and colour schemes

As already mentioned, the main thing is to use colours with suitable light-reflecting properties, but it is also important to employ colours and colour schemes which will be easy to "live with". Large expanses of vivid colour may seem cheerful and effective at a casual glance, but often lose their appeal for people who have to work alongside them day after day.

Similarly, it is desirable to keep the colour scheme simple. In working areas one should use only a few main colours, and in particular, avoid elaborate "picking out" of inessential details such as pipe lines, conduit, and other things which need no such special identification.

Identification colours on machines should be reserved for things which really matter, such as stop buttons and other safety tripping devices which must be found quickly in an emergency. " Safety colours" must also be used with great restraint. Dangerous moving parts should be guarded, not coloured, and when guarding is impossible, colour should be used to highlight the actual hazard and not merely as a general warning. For example, in the case of an overhead travelling crane, warning colour should be confined to the pulley block and the hook, and the crane as a whole should not be treated.

Colour in non-working areas

The above suggestions apply to working areas. In non-working areas such as corridors, lunch rooms, locker rooms, etc., stronger colours can be safely used. Indeed, in such places an adventurous colour scheme often provides a welcome change from the more functional type of treatment used in working interiors.

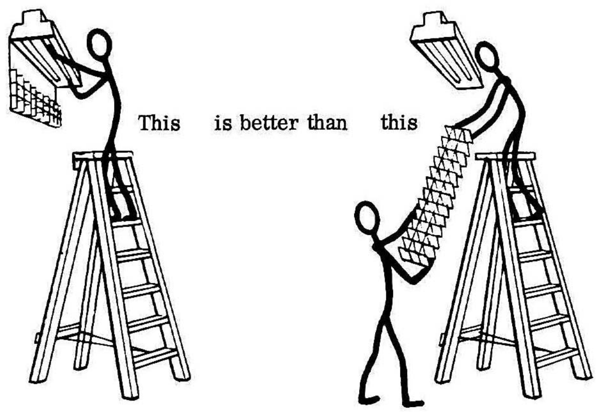


Fig. 32. - Louvres anchored with short chains (which can be unhooked when necessary) make servicing easier

MAINTENANCE

Unless a lighting installation is properly maintained, lamp depreciation and dirt accumulation on the fittings will cause an increasing loss of light; in some circumstances this can cut the illumination level by half in the space of only a few months.

To counteract this, and prevent waste of light, it is therefore necessary to make provision for maintenance when planning the installation, and to establish a regular cleaning schedule.

When choosing equipment, make sure that it will be easy to clean and re-lamp (Fig. 32), and also provide safe and ready means of access to the units. For a large installation of high-mounted units, devices such as mobile towers, elevated platforms or catwalks should be considered. Alternatively, units which can be lowered to the floor for servicing may be more suitable. It is also sometimes possible to service units from ground level using a long-handled brush or vacuum cleaner. Pole lamp-changers with special jaws to grip and remove screw-based incandescent lamps in open reflectors are also used.

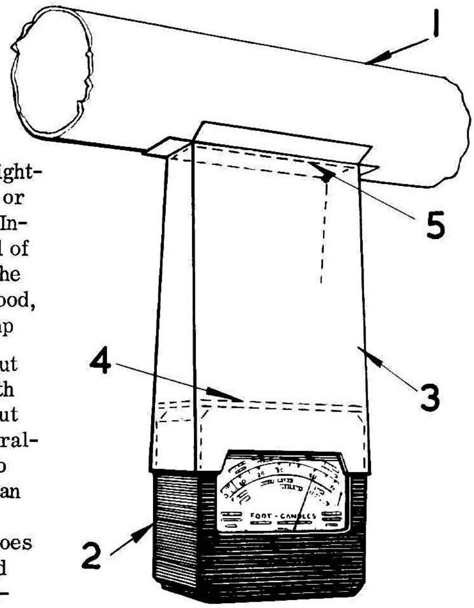


Fig. 33. - Use of a light-meter to compare the brightness of tubular fluorescent lamps, and thus compare the light output of lamps of the same physical size

(1) Tubular fluorescent lamp (2) Light-meter (3) Hood made of sheet metal or card, finished matt black inside (4) Internal flange to hold the sensitive cell of light-meter at a fixed distance from the mouth of the hood (5) Mouth of the hood, pressed up against the wall of the lamp

For light-meters calibrated up to about 100 lm/ft^2 (or 1000 lux), a hood mouth about 1.5 by 5 cm in size, held at about 7 cm from the sensitive cell will generally be suitable. If the instrument is too sensitive, cover part of the cell with an opaque mask attached to the internal flange (4). Note : This instrument does not give readings in absolute units and thus can only be used for making comparisons

Cleaning schedules should be carefully planned. Fittings should be cleaned at regular intervals and not just when a lamp fails. The need for this is often overlooked because dirt collects so slowly and evenly that a deposit which may be absorbing a large proportion of the light is often difficult to detect until it is disturbed. Under average conditions, lighting fittings (including the lamps) should be dusted and wiped over with a damp rag at least once every 6 months or so, and more often still if there is a good deal of airborne dirt. In the latter case, it may be necessary to take down the units occasionally and actually wash them, though care must be taken not to immerse lamp sockets and other electrical components in water. Naturally, fittings should never be cleaned whilst they are switched on.

Cleaning should be done often enough to prevent the illumination level from dropping more than about 20-30% during the interval. A systematic check with a light-meter at several fixed points in an installation is one way of deciding how often to service it.

Lamp replacement should also be done systematically, and it is not always advisable to wait until they actually fail to light. The output of an incandescent lamp does not drop a great deal before it finally burns out; but this is not necessarily true of the fluorescent type, which may continue to strike long after the light output has dropped to a very low figure. Generally speaking, when the output of such a lamp has dropped to less than about ¾ of the initial (100 hour) value, it is usually more economical to replace it than to let it continue to burn on with ever diminishing efficiency.

To estimate the depreciation in light output of fluorescent lamps, their brightness may be compared with that of new (100 hour) lamps of the same type. Figure 33 shows how a simple light-meter can be adapted for this purpose with the aid of a small hood, the mouth of which is pressed against the lamp at a point about half way along it. This device does not give readings in absolute units, but enables the luminance of the lamp under test to be compared with a representative sample of new lamps of the same type. When taking readings, make sure that the lamps have burnt for at least 15 minutes beforehand, and that the mains voltage is correct.

Group replacement of all the lamps together at some predetermined time is often favoured for large installations in which many units are in use for approximately the same number of hours each day. This group replacement takes place after the installation has burned for a fixed number of hours, or after some fixed proportion (say 20%) of the lamps have failed.

Lamps removed at the end of the fixed period need not be scrapped; they may be used up in places of lesser importance, such as corridors, and some of them will be needed to replace lamps which fail before the whole installation is due for replacement.

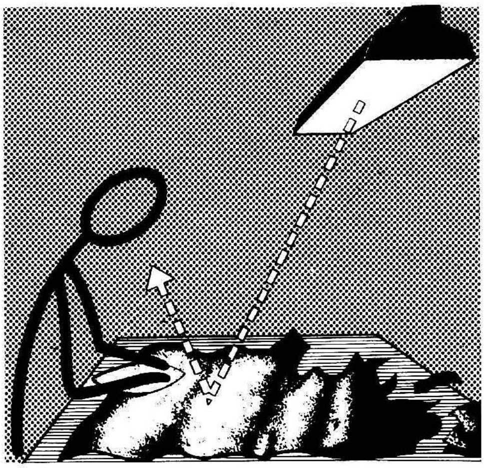
SPECIAL TECHNIQUES

The majority of factory and office tasks can be performed efficiently and safely under lighting provided by conventional means. In certain cases, however, special lighting techniques or equipment are required. Some typical instances are described below.

Examining shiny surfaces. - As explained earlier on page 11, the visibility of polished metal surfaces depends upon what they reflect rather than the mere level of illumination falling on them. The same principle applies to other kinds of shiny surfaced work, even when it has only a slight gloss (e.g., black leather), and details can often best be revealed by arranging the work so that it "catches the light" (Fig. 34). In practice, it is often necessary to provide a reasonably uniform light source of fairly large size, such as a diffusing glass or plastic panel lit from behind, a plain light-coloured wall or screen suitably illuminated, or the open sky seen through a window.

Detecting surface irregularities. - A beam of light skimming a surface will make small surface irregularities cast shadows which clearly reveal their presence. This usually calls for a directional beam of light such as that provided by an internal reflector lamp, or a row of such lamps arranged to give a broad beam (Fig. 35). Alternatively, a strategically placed tubular fluorescent lamp or luminaire may be used to serve a similar purpose.

Using ultraviolet light. - Ultraviolet light causes certain substances to fluoresce brilliantly in a darkened room. Typical uses are for the detection of fine surface cracks and the revelation of otherwise invisible marks.



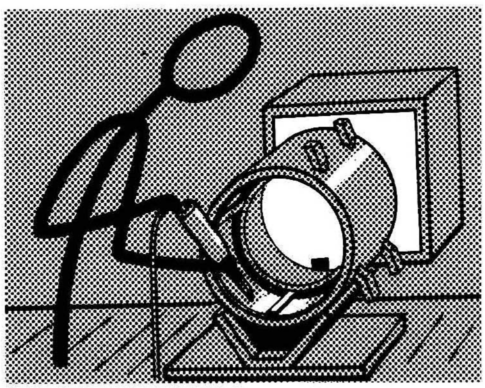


Fig. 34. - Two typical cases where reflections of the light source help to reveal detail in shiny-surfaced work

(a) Flaws in glossy leather are easy to see when the whole surface reflects light to the eye

(b) A properly protected luminous panel set at the end of a hollow casting clearly reveals the surplus metal to be removed

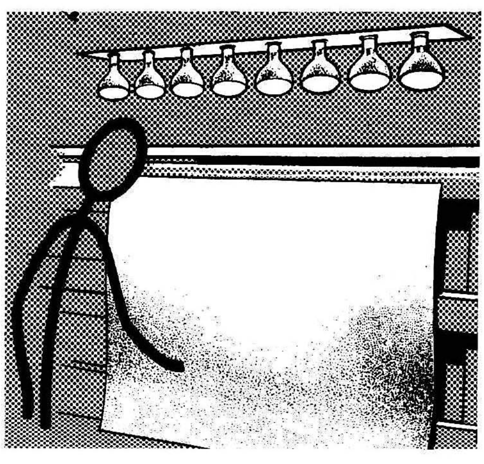


Fig. 35. - A beam of light skimming a smooth surface immediately reveals any tiny irregularities. Here a row of reflector lamps is used to show up defects in a lithographic plate

Magnifying minute detail. - Details just too small to be seen comfortably with the naked eye can be made much more readily visible by using a low-power magnifier. Proper lighting is also important, but with minute visual tasks of this kind, size of detail is the dominating factor and a mere 1.5 times magnification may be more beneficial than a hundred-fold increase in illumination. Magnifiers in more or less continuous use should preferably be large enough to permit the comfortable use of both eyes at once (Fig. 36). Fixed magnifiers are best suited to stationary or very slowly moving objects; they are not recommended when the work moves past rapidly on a conveyor belt.

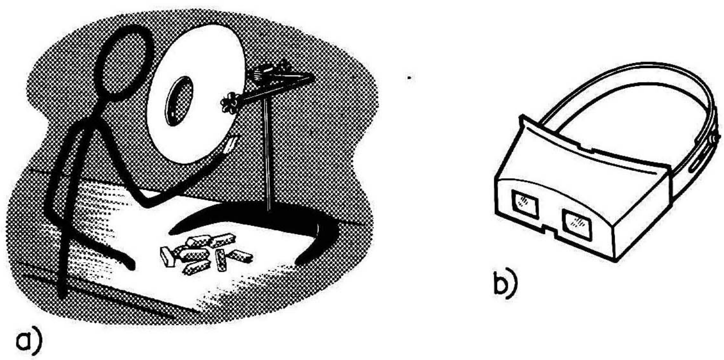


Fig. 36. - Typical industrial magnifying devices

(a) Bench-mounted magnifier with a lamp built into the housing

(b) Binocular loupe, worn by the operator

Background treatment

One important form of "special technique" is the provision of a suitable background for the task. This requires particular attention in two cases :

(a) when a strongly contrasting background helps to make significant details stand out more clearly;

(b) when there are eye-catching distractions which need to be eliminated or hidden from view.

(a) When small objects have to be seen, backgrounds which contrast in brightness are much more effective than those which merely contrast in colour, since the eye cannot readily distinguish the hue of very small objects. The main classes of task requiring a contrasting background (or illumination from behind) are those in which the outlines of the object are important, and those involving examination of transparent or translucent objects. In some cases, a simple painted surface will do all that is required; whereas in others, self-luminous devices of the type shown in Figure 37 may be needed. Figure 38 shows a pair of typical applications for luminous backgrounds of this kind.

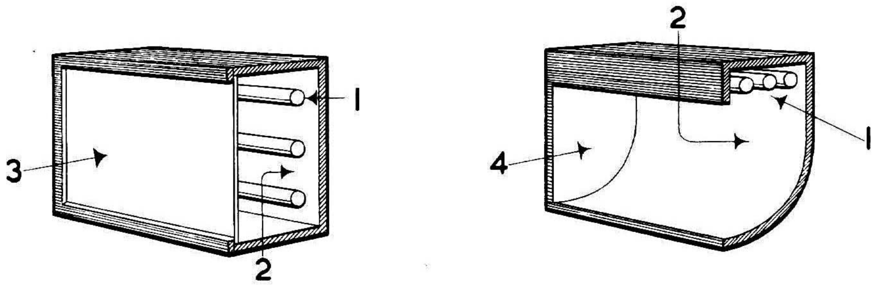


Fig. 37. - Alternative methods of constructing luminous background devices

(1) Lamps (2) Matt white finish on all interior surfaces
(3) Diffusing glass or plastic panel (4) Face open, or covered with clear glass to exclude dust

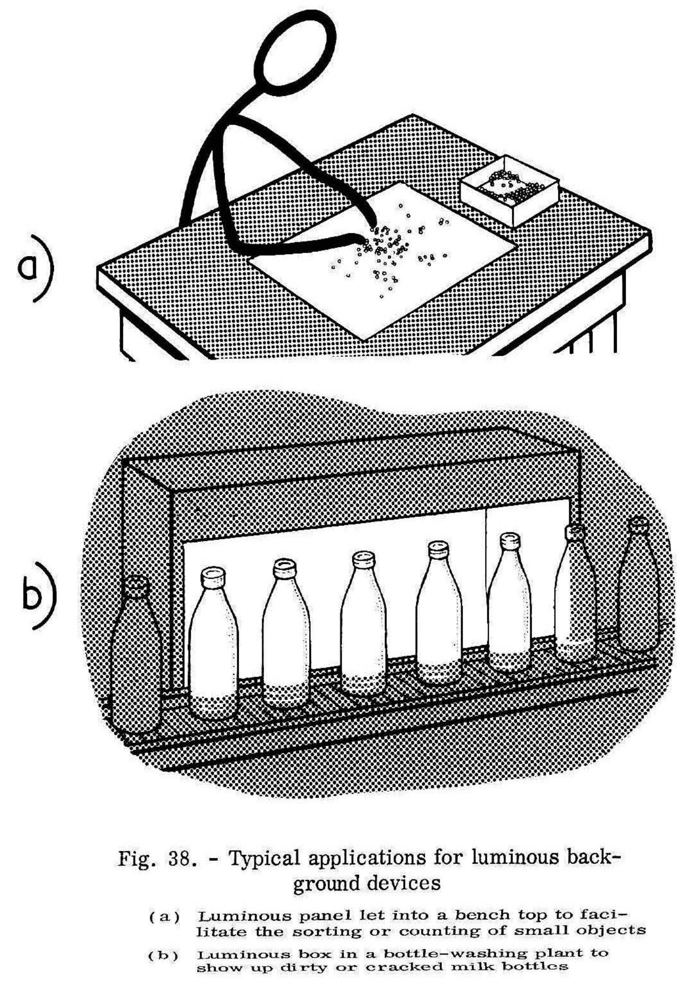


Fig. 38. - Typical applications for luminous background devices

(a) Luminous panel let into a bench top to facilitate the sorting or counting of small objects

(b) Luminous box in a bottle-washing plant to show up dirty or cracked milk bottles

It should be noted particularly that bright backgrounds are only suitable for translucent objects, or work in which the outline shape is all-important. They make details within the boundary of the task harder to see, and if these are important (as is usually the case) a plain, unobtrusive background slightly darker in tone than the work itself is much the best choice.

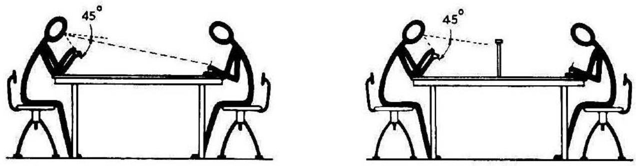


Fig. 39. - A person engaged on critical assembly work may be seriously distracted by the hand movements of a second worker sitting opposite, when these are visible in the immediate surroundings of the task. A low partition up the centre of the bench will put matters right

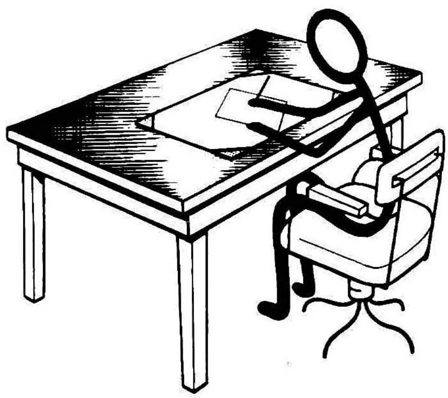


Fig. 40. - Reflections in a dark, glossy desk or table top can be made much less irritating if a large, light-coloured blotting pad is placed under the work

(b) Potential distractions which can cause considerable unnecessary fatigue when they appear in the background of tasks requiring close, continuous attention are of two main kinds :

- Objects moving irregularly or unexpectedly in the worker's general field of view (e.g., machinery which starts or stops at irregular intervals, the moving hands of a worker seated opposite, flashing or flickering lights, etc.). These can cause severe distraction, and should not be permitted within 45° of the line of sight when the gaze is fixed on the task (Fig. 39).

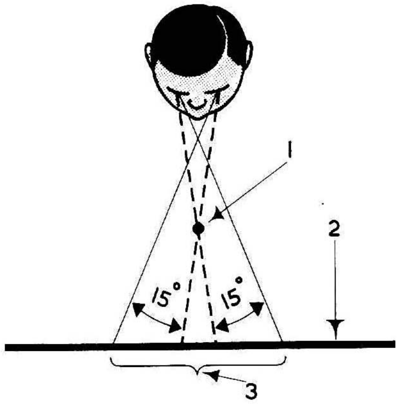


Fig. 41. - Close work on a small object (1) held well away from the background (2) is less fatiguing if the latter is plain over area (3) at least. The reason is that each eye will see the work against a different part of the background, and any eye-catching details within area (3) will be " seen double ". This condition imposes considerable extra strain on the eyes

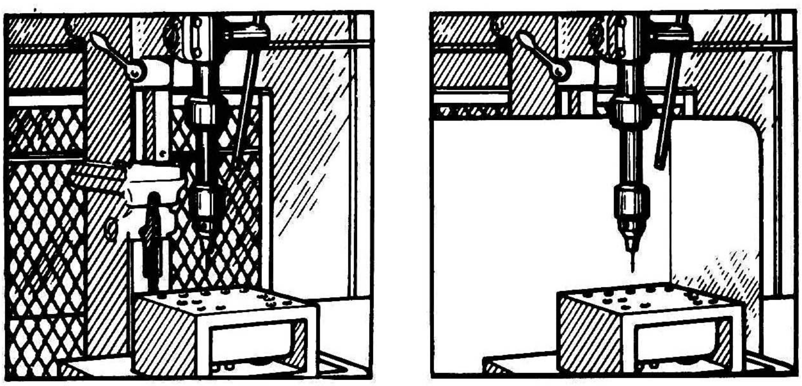


Fig. 42. - Elimination of distracting detail with the help of a screen behind the workpoint

- Strong contrasts in brightness or colour in the immediate surroundings of the task, especially when the latter is close to the eyes (Fig. 40). Though less distracting than moving objects, such contrasts can cause unnecessary fatigue if permitted to appear within 15° of tasks requiring close, continuous attention (Fig. 41).

Figures 39 to 42 show a few simple ways of eliminating potential distractions.

GLARE ASSESSMENT AND CONTROL

As already mentioned on page 8 , glare is mainly caused by light emitted at or near the horizontal by inadequately screened lamps. Screening can be done either with opaque shades and louvres which hide the lamp altogether throughout the critical range of angles, or with translucent diffusing materials which reduce the brightness to more comfortable proportions.

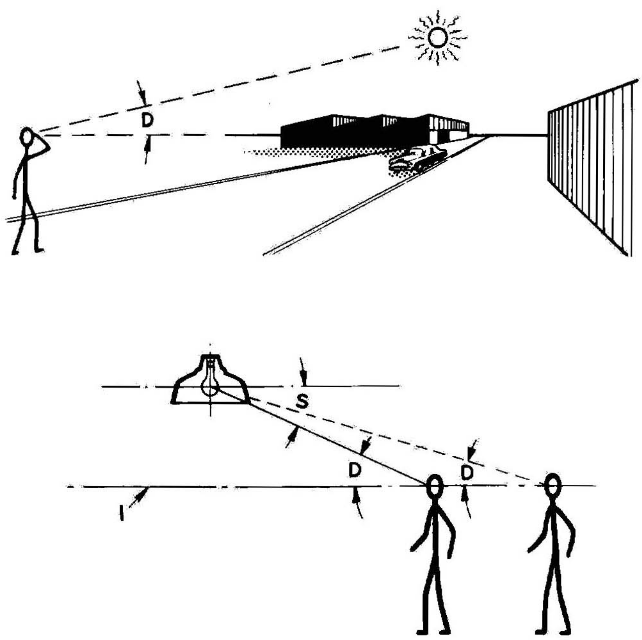


Fig. 43. - Glare becomes rapidly greater when angle D becomes smaller. Lighting fittings are designed to hide the naked lamp from view when the displacement angle D above the horizontal line of sight (1) is equal to or less than some predetermined shielding angle S

Glare control by shielding

The principles underlying shielding are illustrated in Figure 43. The key point is that the closer a glaring light source approaches the observer's line of sight, the more troublesome it becomes. The late afternoon sun provides a striking illustration of the enormous increase in glare which occurs when displacement angle D becomes very small.

Exactly the same principle applies in the case of artificial light sources and as Figure 43 shows, the primary object of using a shade or louvre is to ensure that lamps in " open " units are concealed from view when they approach too close to the horizontal line of sight. In other words, the fitting screens the lamp from view whenever the displacement angle D becomes less than some predetermined value, known as the " shielding angle ".

It should be noted that the " shielding angle " concept assumes a horizontal line of sight, but in the majority of factory and office situations workers do not have to raise their eyes above the horizontal, and this assumption works quite well in practice.

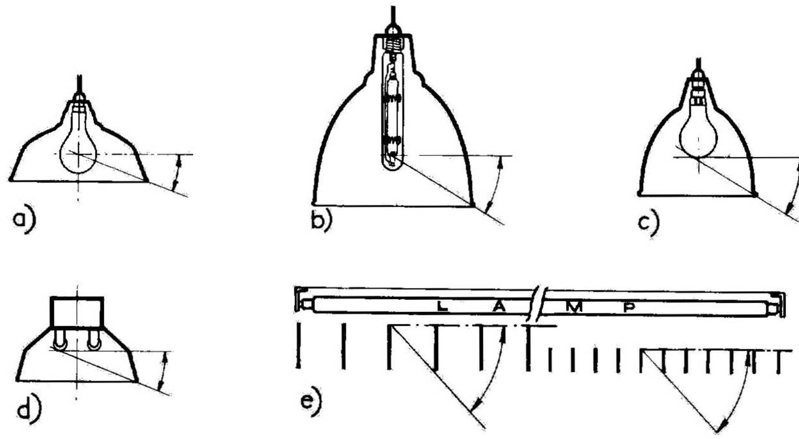


Fig. 44. - Methods of measuring the shielding angle of various types of fitting

Measurement of shielding angle

When determining the shielding angle of an " open " type lighting fitting, the unit is assumed to be mounted level (i.e., with its base horizontal). In the case of simple reflectors and troughs, the angle is measured to the lamp, the exact point depending upon the type used. With clear and inside-frosted incandescent lamps, this point is assumed to be the centre of the filament (Fig. 44a). In the case of ordinary mercury-vapour discharge lamps, the lower end of the arc is used (Fig. 44b). For lamps with a roughly uniform surface brightness, such as tubular fluorescent lamps, colour-corrected mercury lamps, and silica coated (" opal ") incandescent lamps, it is logical to measure shielding angles tangential to the surface of the bulb (Fig. 44c); moreover, in the case of multilamp units it is obviously necessary to choose the most distant lamp as illustrated in Figure 44d. In the case of louvred units, the position of the lamp is less important; here the shielding angle is controlled by the ratio between the depth and spacing of the louvre blades, as shown in Figure 44e.

It is important that the lamp remain screened throughout the whole of the required shielding angle; cutting slots in the sides of a reflector, or leaving lamps unscreened altogether at the horizontal as shown in Figure 45, defeats the whole purpose of shielding.

The actual shielding angle depends upon the type of lamp and the degree of glare control required. For tubular fluorescent lamps of moderate brightness used in ordinary industrial interiors, 20° shielding in the plane at right angles to the lamp axis is generally reckoned enough. Where a higher degree of glare control is needed (e.g., in offices), this transverse shielding should be increased to at least 40°, with 30° endwise shielding as well.

With high brightness (e.g., incandescent) lamps, the risk of glare is obviously greater, and there is also increased likelihood of trouble from unwanted reflections. Consequently their use in overhead "open" type units is usually confined to factory-type installations. Moreover, high-wattage units of this kind must not be allowed to hang too low overhead.

Fig. 45. - Lamps must remain screened throughout the whole of the shielding angle. Troughs with slots cut in the sides, or units with a louvred base but completely open sides are thus unsatisfactory

These points are further amplified in Table III which is based upon recommendations contained in the Australian Artificial Lighting Standard Code[1]. This empirical system of shielding angle data has been in use for a number of years, and has proved satisfactory in practice. In the absence of national or local recommendations, it may be safely used as a general guide when selecting cut-off fittings for general lighting installations in working interiors.

Diffusing fittings

In the case of diffusing fittings, glare is controlled by limiting the brightness visible within the critical range of angles at and below the horizontal. The maximum luminance (i.e., measured brightness[2]) that can be tolerated in lighting fittings used for general lighting installations depends upon the combined effect of a number of factors, the most important being

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[1] Australian Standard Code for the Artificial Lighting of Buildings. A.S. CA 30-1965. Standards Association of Australia, 157 Gloucester Street, Sydney. 34 pp. Price 12s. 6d.

[2] When referring to measured brightness, it is customary to use the term "luminance" to avoid confusion with "apparent brightness" which may vary a great deal depending on the state of adaptation of the observer's eyes. An automobile headlamp, for instance, appears far brighter by night by day, but its luminance in candelas per unit projected area is constant.

the mounting height of the units, the shape and size of the room, and the orientation of certain types of elongated unit with respect to the line of sight. The influence of these various factors is briefly explained in Table IV.

Whilst it has long been recognised that the control of glare is no less important than the provision of suitable levels of illumination, it is only comparatively recently that research has made it possible to formulate design principles which take all these complex factors into account whilst at the same time keeping calculations simple enough for the designer to tackle them in the course of his everyday work.

In the absence of locally recognised standards, the following procedure is suggested as a guide. This is based upon recommendations in the Australian Artificial Lighting Standard Code designed to produce a degree of glare control appropriate to factory and office interiors lit by diffusing units, and there is evidence to suggest that these particular recommendations in the Australian Standard Code produce results which should be reasonably acceptable in other parts of the world as well.

Whilst the method may appear a trifle complicated at first sight, it is actually quite simple to apply in practice once the general principles have been mastered; and it then provides a most useful guide to the selection of the right kind of fittings to use in various situations. This is a matter of considerable importance, since units which may be quite suitable for use in a particular size of room may cause severe glare when used in a bigger one; and once an installation of excessively bright fittings has been installed, there is seldom any cheap or simple method of correcting the situation.

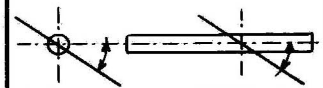
<u>Luminance limits for diffusing fittings</u>

A practical system of luminance limits embodying the general principles outlined in Table IV is explained hereafter. It applies to well-designed general lighting installations, and is intended to ensure the degree of glare control normally found acceptable in offices and other working areas where diffusing fittings are employed.

In Figure 46 the combined effects of factors (1) and (2) in Table IV are taken into account by expressing the length and width of the room in terms of <u>h</u>, the mounting height of the units above eye-level. Where the work is normally carried out seated, eye-level is assumed to be 4 ft (120 cm) above the floor; if it is normally carried out standing, eye-level is usually assumed to be 5½ ft (165 cm) above the floor. The data in Figures 46 and 47 also take into account the orientation of elongated units with a high side-brightness, which produce appreciably different amounts of glare when viewed endwise and crosswise as explained in Table IV(3).

In accordance with standard practice, the system of luminance limits is designed to cover the "worst case", namely that of an observer with his back to the wall and looking either along or across the room, depending on which view is the more glaring. Moreover, these limits apply to fitting luminance measured broadside-on, since it is this viewpoint which causes the most glare in the case of fluorescent fittings with bright sides (see Table IV (3)). The data in Figure 46 are based on the assumption that some or all of the people in the room will view such fittings broadside-on when they raise their eyes from their work.

Table III - Recommended shielding angles for cut-off fittings used in various types of installation with various types of lamp

<table>
<tr><td rowspan="2">Type of installation</td><td colspan="8">Shielding angle required</td></tr>
<tr><td>Tubular fluorescent lamps (luminance ≤ 10 cd/in^2 or 1,5 stilb)
</td><td colspan="7">Incandescent filament, mercury vapour discharge, and "colour-corrected" mercury lamps (lamps with luminance > 10 cd/in^2, or 1.5 stilb)</td></tr>
<tr><td>Offices, and industrial interiors where visual tasks are very difficult</td><td>At least 40° crosswise and 30° endwise</td><td colspan="7">Use of open units in which lamps can be seen from below is not recommended in this case</td></tr>
<tr><td rowspan="7">General industrial interiors</td><td rowspan="7">At least 20° crosswise (endwise shielding not required)</td><td colspan="2">Wattage of lamp</td><td colspan="5">Mounting height above the floor in feet and meters</td></tr>
<tr><td>Filament</td><td>Mercury</td><td>> 25
7,5</td><td>20–25
6–7,5</td><td>15–20
4,5–6</td><td>10–15
3–4,5</td><td>< 10 ft.
3 m</td></tr>
<tr><td>≤ 200</td><td>80</td><td>20°</td><td>20°</td><td>20°</td><td>20°</td><td>30°</td></tr>
<tr><td>300</td><td>125</td><td>20°</td><td>20°</td><td>30°</td><td>30°</td><td rowspan="4">Use of these lamps in open units at lower mounting heights may cause excessive glare near the units</td></tr>
<tr><td>500 and 750</td><td>250</td><td>20°</td><td>20°</td><td>30°</td><td></td></tr>
<tr><td>1000</td><td>400</td><td>20°</td><td>20°</td><td></td><td></td></tr>
<tr><td>≥1500</td><td>1000</td><td>20°</td><td></td><td></td><td></td></tr>
<tr><td>Storerooms, corridors and other non-working areas where only casual seeing is required</td><td>No shielding required (provided unit not visible from adjacent work-areas)</td><td colspan="7">20° shielding sufficient (provided unit not visible from adjacent work areas)</td></tr>
</table>

Procedure for determining luminance limits for diffusing fittings

Room dimensions P and Q are chosen as follows :

(a) for installations of horizontally-mounted fluorescent units which emit a substantial part of the light from the sides of the fitting (e.g., bare-lamp units, and totally enclosed diffusers of the type shown in Table IV(3))

P will be the room dimension parallel to the long axes of the units (regardless of whether this is the longer or shorter dimension of the room)

Q will be the transverse dimension (see Figure 46)

(b) for all other installations (e.g., incandescent diffusing globes, and horizontally-mounted fluorescent units which emit most of their light through a flat diffusing panel or translucent louvre grid in their base) :

P will be the shorter and

Q will be the longer dimension of the room (see Figure 46).

The appropriate luminance limit is found at the intersection of the nearest P column and Q row in Figure 46. Here P and Q are the dimensions of the room expressed as multiples of h, the mounting height of the lighting fittings above eye-level. The luminance limit values themselves are derived from Table V .

The special case of endwise viewing

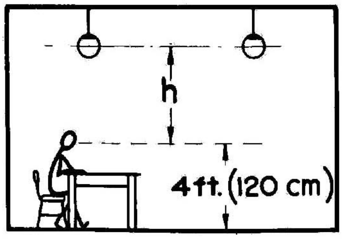
Normally, the seating arrangements in an office are not known at the time the lighting scheme is being planned, or they may vary, and it is therefore necessary to cater for the "worst case" as explained above. But persons who view the units more or less end-on when they raise their eyes from their work will be subjected to much less glare, as explained in Table IV(3). Consequently if it is possible to make sure that everyone in the room will always work facing this particular way, fittings with a given side-brightness can be safely used in much larger rooms, and at lower mounting heights than would otherwise be possible.

This important special case is catered for by the auxiliary table in Figure 47; these data apply only to horizontally-mounted fluorescent units viewed endwise (i.e., all persons facing in the direction indicated by the arrows on the sketches in Figure 47); but they do not apply to recessed troughs with a flat base, or to any other type of unit which has unlit sides.

Varying the degree of glare control

As already mentioned, the tables of Figures 46 and 47 are designed to ensure a degree of glare control appropriate in most general offices and other interiors where diffusing fittings are normally used. If desired, still better glare control can be achieved by observing a luminance limit lower than that specified in Table V , the improvement in any given case being roughly proportional to the number of steps down the luminance scale in Table V . For instance, if it is felt that a draftsman has a difficult visual task and should therefore be given even less glaring conditions than an or-

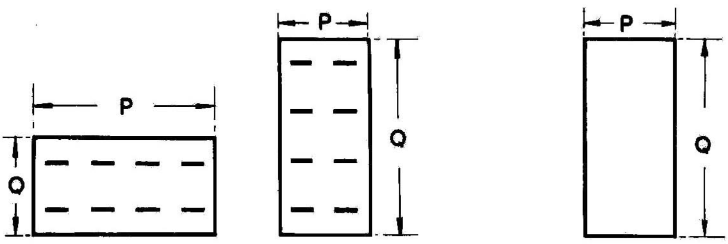
h is height above eye-level.
Room dimensions P and Q
are in multiples of h



Determination of P and Q

(a) When using fluorescent units with bright sides:

(b) When using any other type of unit:

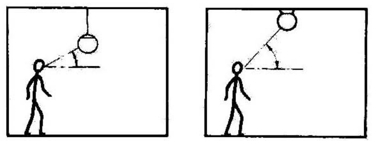
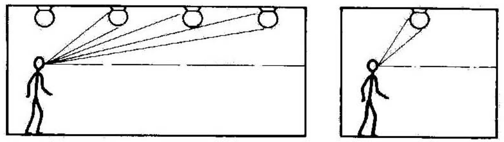
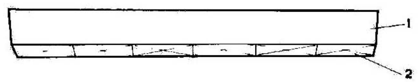
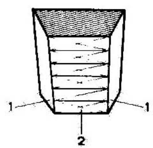


		Room dimension P									
		2 h	3 h	4 h	5 h	6 h	7 h	8 h	10 h	12 h	14 h
Room dimension Q	2 h	H	H	H	H	G	G	G	G	G	G
	3 h	G	F	F	F	F	F	F	E	E	E
	4 h	F	E	E	E	E	D	D	D	D	D
	5 h	E	D	D	D	D	D	D	C	C	C
	6 h	D	D	C	C	C	C	C	C	C	C
	7 h	D	C	C	C	C	C	C	C	C	C
	8 h	D	C	C	C	B	B	B	B	B	B
	10 h	C	C	B	B	B	B	B	B	B	B
	12 h	C	B	B	B	A	A	A	A	A	A
	14 h	C	B	B	B	A	A	A	A	A	A

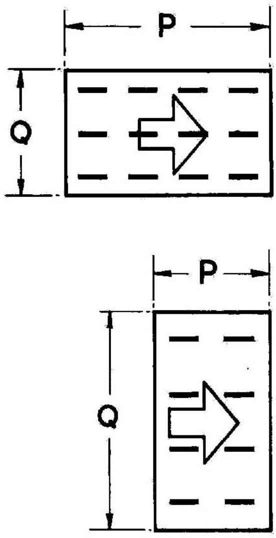
Fig. 46. - Luminance limits for evenly distributed general lighting by means of diffusing fittings (occupants facing in different directions)

Table IV

Factors influencing the degree of glare produced by a given diffusing fitting (or bare fluorescent lamp unit)

(1) <u>Mounting height</u>  This is more glaring than this	Glare is worse when the mounting height of the installation is lowered, since the lighting units then approach closer to the horizontal line of sight
(2) <u>Size of room</u>  This is more glaring than this	Glare is worse in large rooms than in small ones, because of the additional glare produced by the many distant units which are seen close to the horizontal line of sight
(3) <u>Orientation of lighting unit</u>  This is more glaring than this 	When a substantial amount of light is emitted from the sides of a fluorescent fitting, the unit will be much more glaring when viewed broadside-on than when viewed end-on; since in the latter case the apparent area of the bright side panels (1) will be greatly diminished. This does not apply to the horizontal base panel (2), for though this panel looks a different shape, its apparent area remains the same; hence the glare produced by recessed units (and units with unlit sides) is much the same regardless of whether they are viewed endwise or crosswise

dinary office worker, it may be desirable to adopt a luminance limit one or even two steps below that specified in Figure 46. A similar tightening of the luminance limit may be appropriate in conference rooms, school rooms and other places where people have to spend a fair amount of their time looking in a horizontal direction, and are thus exposed to more glare than the office worker who only occasionally raises his eyes from the desk.



Room dimension Q	Room dimension P: 2 h	3 h	4 h	5 h	6 h or more
3 h	J	J	H	H	H
4 h	J	H	H	G	G
5 h	H	H	G	G	G
6 h	H	G	G	F	F
7 h	H	G	F	F	F
8 h	G	F	F	F	F
10 h	F	F	F	E	E

Fig. 47. - Luminance limits for endwise viewing of fluorescent fittings with high side-brightness (all occupants facing in a direction parallel to the long axes of the units, i.e. in the direction indicated by the arrows on the sketches)

Table V

Luminance limits for diffusing fittings used for evenly distributed general lighting of workplaces

Luminance limit	A	B	C	D	E	F	G	H	J
Candela/in^2	1/2	3/4	1	1½	2	3	4	6	8
Candela/cm^2	0.08	0.1	0.15	0.2	0.3	0.4	0.6	0.8	1.2

This refers to average luminance measured at 70° in the vertical plane at right angles to the axis of fluorescent units, as explained in the text. Note that these two luminance limit ranges are expressed in round figures; corresponding cd/in^2 and cd/cm^2 values are not necessarily exact equivalents

On the other hand, in many factory interiors devoted to rough work it is possible to tolerate a considerable amount of glare. In such cases the luminance limits set out in Figure 46 will be too restrictive, and capable of being increased by two or three steps without causing undue hardship. But it should be noted that such interiors are generally lit by cut-off fittings rather than diffusing ones, and the graded shielding angle recommendations of Table III become of more practical importance than the luminance limits given in Figure 46. Incidentally, fittings which rely on both shielding and diffusion (e.g., office-type units with diffusing sides and an egg-crate louvre in the base) should comply with the recommendations of both Table III and Figures 46 and 47.

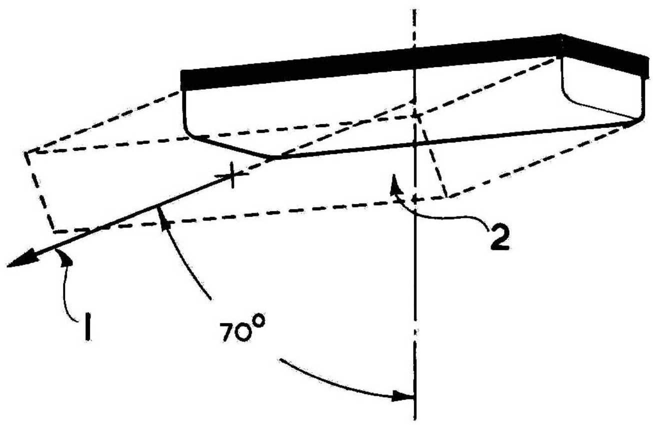


Fig. 48. - When a fitting has a reasonably uniform brightness when viewed at 70° to the downward vertical, the required luminance (in cd/in^2 or cd/cm^2) can be found by dividing the candela value (1) by the projected area (2)

Determining the luminance of fittings

For the purposes of the tables in Figures 46 and 47, fittings are classified according to their luminance measured at an angle of 70° to the downward vertical and broadside-on to the unit in the case of horizontally-mounted fluorescent fittings. Theoretically, luminances at all angles of view between the horizontal and about 45° below it are significant; but in practice a luminance measurement in the specified direction is sufficiently accurate.

In the case of units which have a reasonably uniform brightness when viewed in the specified direction, the luminance (in cd/in^2 or cd/cm^2) can be found by dividing the candela figure (determined from the unit's polar curve) by the projected area of the fitting, as shown in Figure 48.

If the unit does not have a reasonably uniform brightness, the above-mentioned method may not give a meaningful result. In the case of a fitting with a metal egg-crate louvre in the base and translucent sides (Fig. 49a), the candelas emitted at 70° to the downward vertical should be divided by the projected area of the translucent luminous side panel rather than that of the whole fitting.

Similarly, in the case of bare-lamp units (Fig. 49b), the projected area of the lamps themselves should be measured, and the projected area of the supporting channel ignored. It should be noted that the easiest and most satisfactory way of determining the luminance of a bare fluorescent lamp unit is to divide the rated lumen output of one of the lamps by 9.25 (thus obtaining the candelas emitted normal to the lamp axis) and then divide again by the projected area of the lamp in square inches or square centimeters as the case may be. This projected area is of course obtained by multiplying the diameter of the lamp by its lit length.

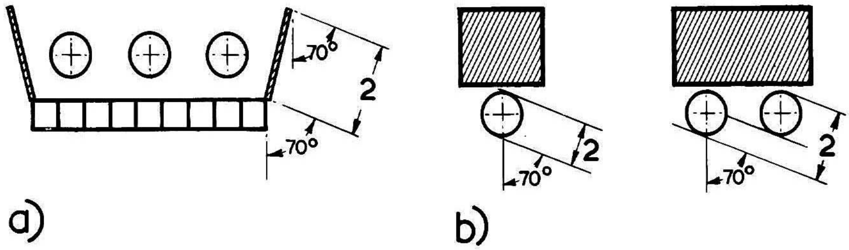


Fig. 49. - When a fitting does not have a reasonably uniform luminance, the candela figure should be divided by the projected area (2) of the translucent luminous parts of the fitting, or of the lamps themselves in the case of bare-lamp units

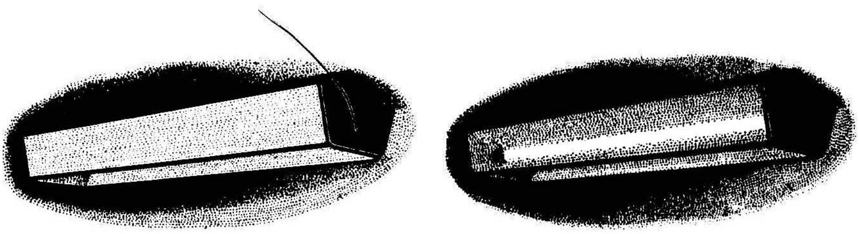


Fig. 50. - Good diffusers have a reasonably uniform brightness, but poor ones clearly reveal the position of the lamp. When this happens, the fitting should be treated as a bare-lamp unit

Occasionally, units incorporate translucent materials which have such poor diffusing properties that the luminance of the lamps inside is not appreciably reduced (Fig. 50). Such units should be treated as bare-lamp units.

Choosing suitable types of lighting fitting

Table VI gives a general idea of the luminance classification of some typical office-type units and bare fluorescent lamps. This table is only intended as a rough guide, but when studied in conjunction with Table V and Figure 46 it can be of considerable help when trying to decide the kind of fittings to use in a proposed installation.

For instance, it becomes obvious that in very large interiors over about 10 h by 10 h in size, totally enclosed diffusing fittings (either recessed or ceiling-mounted) are likely to be too glaring, and some form of louvred unit should therefore be considered instead. Again, it can be seen that bare fluorescent lamp units are unsuitable for general use in any but the smallest office interiors. Incidentally, Table VI also clearly demonstrates the danger of regarding the bare fluorescent tube as a "low-brightness, glare-free" source, since such lamps actually have a considerably higher luminance than the totally-enclosed, opal-glass incandescent lamp units normally used for office lighting in the pre-fluorescent lamp era.

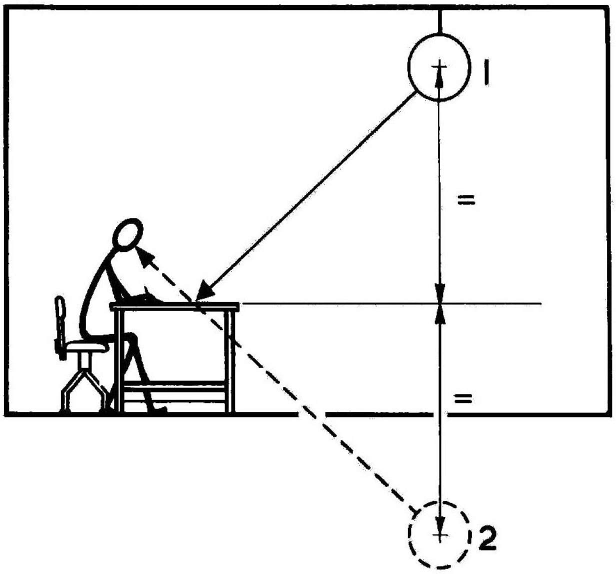


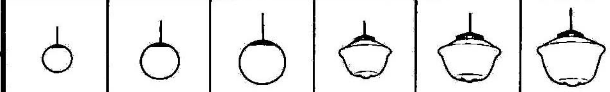
Fig. 51. - Reflections of a light-source (1) seen mirrored in a highly-polished desk top, appear to be coming through it from a source located some distance away at point (2)

Reflected glare

The term "reflected glare" is commonly used to describe the variety of ill-effects produced by unwanted reflections appearing in and around the work. The term is somewhat misleading, since such reflections are rarely bright enough to produce discomfort glare of the kind discussed in the previous section, and they generally interfere with visual comfort and efficiency in quite a different way.

For instance, reflections in a highly-polished dark-coloured desk top can sometimes cause severe distraction and annoyance when seen in close proximity to the task, not so much because of their brightness (which may be comparatively small) as because of the fact that the clearly defined image does not appear to lie in the plane of the table top, but at a considerable distance beneath it (Fig. 51), thus producing a situation not unlike that described in Figure 41.

Table VI - Approximate luminance classification of typical general lighting units

Typical fluorescent equipment Lamps are the normal high-efficiency type, with an 'average throughout life' lumen output. Any translucent material used is presumed to be sufficiently diffusing to hide lamps completely	Luminance[1] not exceeding	Typical incandescent equipment Shape, overall diameter, and lamp wattage of totally enclosed, general diffusing type units made of good quality opal glass					
5 ft (152 cm) 65 and 80 watt 1½ in. (38 mm) dia. bare-lamp units	H						
4 ft (122 cm) 40 watt 1½ in. (38 mm) dia. bare-lamp units 2 ft (61 cm) 20 watt 1½ in. (38 mm) dia. bare-lamp units	G	8 in. (20 cm)	10 in. (25 cm)	12 in. (30 cm)	14 in. (35 cm)	16 in. (40 cm)	18 in. (45 cm)
	F	—	200 W	—	—	300 W	500 W
	E	100 W	150 W	200 W	200 W	—	300 W
Twin-lamp totally enclosed diffusing units	D	75 W	100 W	150 W	150 W	200 W	—
	C	60 W	75 W	100 W	—	150 W	—
"Direct-indirect" units, and other forms of cut-off unit[2]- with white painted metal reflectors and louvres	B						
Cut-off units[2] with polished metal reflectors. Louvred ceilings made of metal or diffusing plastic	A						

[1] See Table V.

[2] The term "cut-off units" refers here to those which control glare with the aid of opaque shades or louvres.

However, by far the commonest and most serious ill-effect produced by troublesome reflections is the dilution or destruction of contrast within the task. The most obvious example of this is the overall sheen which veils glossy surfaces such as tracing cloth, shiny printed matter, glass-fronted instruments, and the like. But it is important to realise that an overall gloss is not the only possible source of troublesome reflections; for instance, pencil marks become much harder to see when they "catch the light", for the visibility of a pencil mark depends on the contrast in brightness between it and the paper on which it lies. If this contrast is diminished, visibility is correspondingly reduced; this point is illustrated in Figure 23. It is this fact which makes so-called "reflected glare" such an extremely common cause of trouble in offices.

Prevention of task obscuration by troublesome reflections

The best and most effective way of eliminating reflected glare is to locate the lighting units and work with respect to one another, so that the unwanted reflections are directed away from rather than into the worker's eyes. Practical methods of achieving this are discussed in the section on Localised General Lighting (pages 21 to 26).

Whilst correct placing is the only way of getting rid of the reflections entirely, the dilution of task contrast can be reduced to negligible proportions by increasing the task illumination with the aid of a local lighting unit suitably placed near the workpoint. Practical application of this principle is briefly discussed on page 57 and in Figure 57.

Alternatively, it may be possible to reduce the brightness of the light source responsible for the troublesome reflections. The most effective way of doing this is to employ a matt-surfaced ceiling evenly illuminated with indirect lighting units (or an evenly bright translucent luminous ceiling). However, whilst this expedient may sometimes have to be used as a last resort, it is less effective than either of the other two methods (proper placing of the lights, or increase of the illumination on the workpoint with a properly positioned local lighting unit).

DIAGNOSIS AND REMEDY OF COMPLAINTS

Employees will often work without complaint in very badly lit factories and offices, and it is a curious fact that even when people finally realise that there is something seriously wrong with their visual environment, they can seldom recognise exactly where the fault lies, and therefore give vague or irrational answers when asked what is troubling them.

For this reason, whilst complaints about a lighting installation should be regarded as a fairly sure sign that something is amiss, the sufferer's explanations can seldom be taken at their face value; and the only sure way of diagnosing lighting complaints is to check the installation systematically to discover where it falls short of the basic requirements discussed earlier in these pages.

A few of the faults which most often produce complaints are briefly discussed below and some simple ways of dealing with the situation are suggested in each case.

Glare

In factories, glare often results from the use of high-brightness lamps in unsuitable fittings which do not screen the sources from direct view (Fig. 52). In offices, the fault sometimes lies in the use of inadequate diffusing materials, such as clear figured glass, which does not appreciably reduce the brightness of the lamp behind it (Fig. 50).

Complaints traceable to glare mostly occur in places where visual tasks are critical and prolonged, for in these circumstances even moderately excessive brightness (such as that of bare fluorescent lamps) can build up serious discomfort over a period of time.

Fig. 52. - Simple conical shades, and reflectors too small for the lamp they carry, give no protection against glare

The cumulative effect associated with lighting faults of this kind is somewhat analogous to the cumulative discomfort produced by a hard or badly designed seat which may be quite satisfactory to sit upon for a few minutes, but which becomes progressively more uncomfortable as time goes by.

Because of this cumulative effect, it is not always easy for inexperienced persons to tell at a glance whether an installation is or is not "excessively bright". However, Figure 53 shows a useful rough and ready test to apply in interiors where visual tasks are critical and prolonged. The procedure is as follows : from the working position, sight a distant object at eye level and then momentarily screen the fitting from view as shown. If this action enables details in the object to be seen a little more clearly, or makes seeing even slightly more comfortable, the installation is probably creating enough glare to cause serious discomfort to people forced to work under it for long periods.

The above-mentioned test should always be applied when the occupants of an office complain that there is "too much light", since this phrase is one frequently used by those working under excessively bright lighting units.

Inadequate upward light

When factories are lit by fittings which throw all their light down on to the work, leaving the roof or ceiling and upper walls in comparative darkness, it becomes difficult or impossible to examine shiny metal surfaces, since the isolated light sources merely produce a dazzling glitter on the work (as shown in Figure 6). This is sometimes responsible for a mistaken belief that such tasks "cannot be done by artificial light". Even when the task does not involve examination of shiny surfaces, inadequate ceiling illumination has the disadvantage of making an interior appear rather gloomy and may even increase eye fatigue.

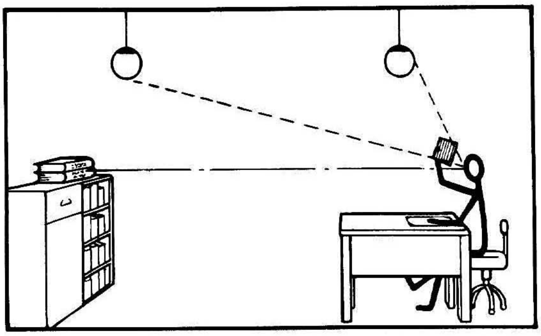


Fig. 53. - If momentary shading of the eyes produces any perceptible improvement in visibility of objects on the far side of an office, the lighting units are probably just a little too bright

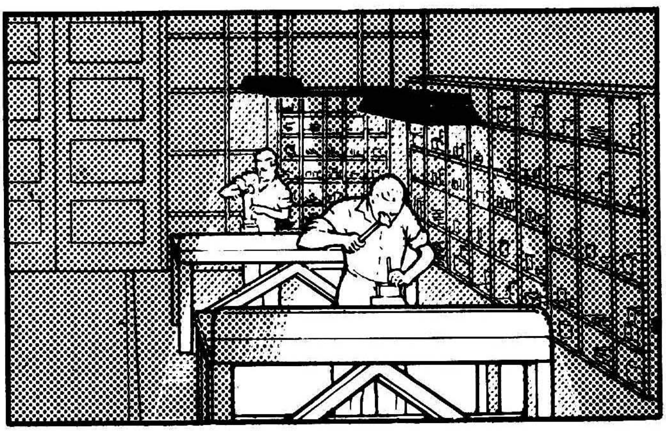


Fig. 54. - Prolonged work in a pool of light in an otherwise badly lit room can cause eye fatigue

People who work in an isolated pool of light in the middle of a darkened interior (Fig. 54) have to readjust their eyes every time their gaze shifts from the brightly lit workpoint. This can cause considerable fatigue and dissatisfaction when the visual task is a prolonged and exacting one.

As explained in Figure 4, the ideal cure for such complaints is to exchange the closed-top lighting fittings for more suitable ones which allow a proportion of the light to escape upwards. When this is impossible, an alternative solution is to turn a few of the existing units upside down.

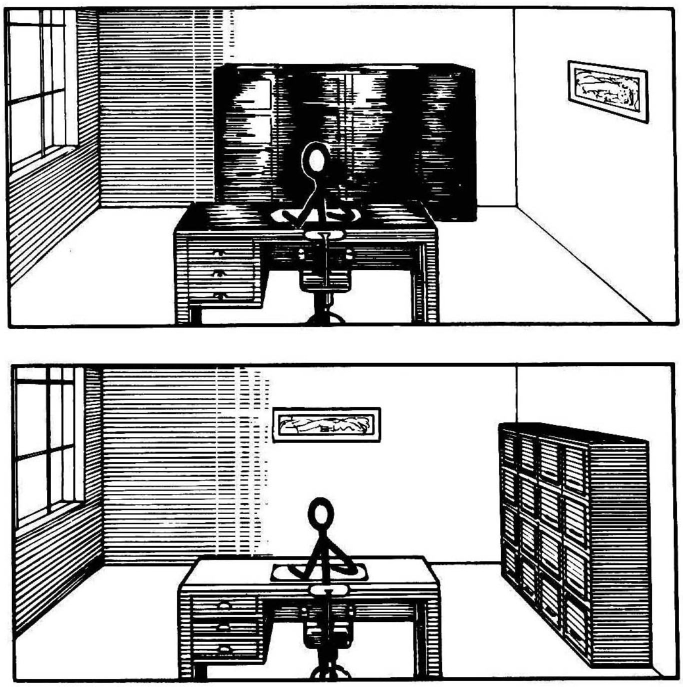
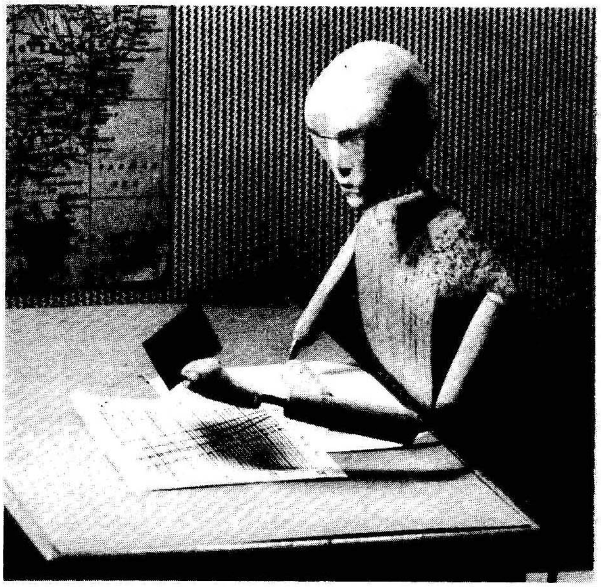


Fig. 55. - If a large piece of dark-coloured furniture fills a substantial part of the field of view of a person engaged upon a prolonged and difficult visual task, his complaint of eye fatigue can sometimes be cured by moving the dark object to one side, or better still, refinishing it in a lighter colour

Unsuitable colour treatment

For obvious reasons, excessively dark finishes on ceilings and other main interior surfaces can produce much the same ill-effects as inadequate upward light. In factories, poor colour treatment is generally the result of neglect; but in offices excessively dark colours are sometimes deliberately used for decorative purposes.

When a person engaged on a task demanding close, continuous attention makes an apparently inexplicable complaint of visual discomfort, it is well worthwhile investigating whether there is a big difference between the brightness of his task, and that of his general field of view. If, for instance, there is a large piece of dark-coloured furniture immediately in front of him, it is sometimes possible to cure the complaint by repainting the offending object, or by moving it to one side as indicated in Figure 55.



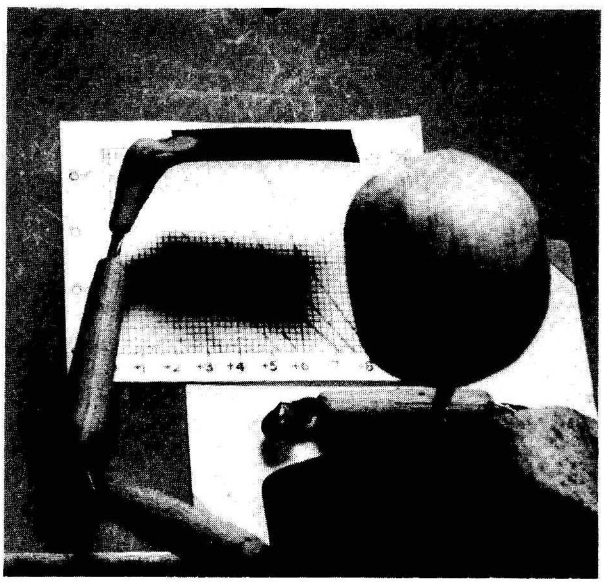


Fig. 56. - The presence of obscuring reflections can be detected by shading the task as shown. If detail is noticeably easier to see in the shaded area despite the reduced illumination reaching it, an attempt should be made to increase the proportion of light reaching the task from the side. If the units themselves cannot be moved, it may be possible to turn the desk, or place a suitable table lamp beside the task

It must be emphasised that the improvement in visual comfort will not be immediately apparent and will take time to make itself felt. However, experience has shown that changes of this kind do produce results. This is, in fact, an excellent example of the fact that when visual tasks are critical and prolonged it is of importance to comply with all the basic requirements for good seeing - even the apparently trivial ones.

Troublesome reflections

When office workers complain, one of the first things to look out for is the presence of unwanted reflections which dilute or destroy contrasts within the task as explained on page 50.

A good practical method of testing for the presence of these unwanted reflections is illustrated in Figure 56. The procedure is to look at the task from the normal working position and then block the light falling on it from the front. If, in spite of the reduced illumination, pencil strokes and other details become easier to see, the visibility of the task is obviously being reduced by unwanted reflections. Laying a small mirror face up on the work will often help to show which light source is mainly responsible for the trouble; and once this has been identified, common sense will usually suggest a solution.

When repositioning is not practical, it is sometimes possible to improve matters by increasing the illumination on the workpoint, thus making it more difficult for the unwanted reflections to dilute or destroy contrasts within the task. Figure 57 shows an application of the principle : here, obscuring reflections appearing on the upper surface of a glass guard over a grinding wheel are rendered harmless by providing strong local illumination on the workpoint. Similarly, obscuring reflections on a drawing board can be nullified with the help of a small, suitably placed adjustable local lighting unit.

When neither repositioning nor extra illumination of the workpoint is practical, totally indirect lighting can sometimes be used as a last resort. This will minimise, but not eliminate, the unwanted reflections.

Complaints of eye fatigue are sometimes traceable to reflections in desks and table tops, for when such reflections appear in close proximity to tasks requiring close, continuous attention, they can cause considerable distraction and annoyance. These particular reflected images are most troublesome when they are clearly defined, hence complaints are most likely to arise when desks and tables have a dark, high-gloss finish or, worst of all, a dark surface covered with a sheet of plate glass. However, provision of a large blotting pad (as shown in Figure 40) will do much to alleviate the trouble.

Poor illumination

In practice, an excessively low illumination level is often the result of bad maintenance rather than bad design. Sometimes a spectacular improvement can be produced merely by cleaning the fittings and replacing worn-out lamps. When investigating a complaint of poor lighting, at least one of the units should be thoroughly wiped with a damp cloth, since an even film of dirt which has slowly collected over a long period is often difficult to detect if it remains undisturbed.

When employees claim that their work is insufficiently lit, and a check with a light-meter shows that the illumination is actually quite adequate, it is possible that the presence of glare or troublesome reflections may be making the work hard to see and thus creating the illusion that it is underlit. The techniques illustrated in Figures 53 and 56 can be of great help in such cases.

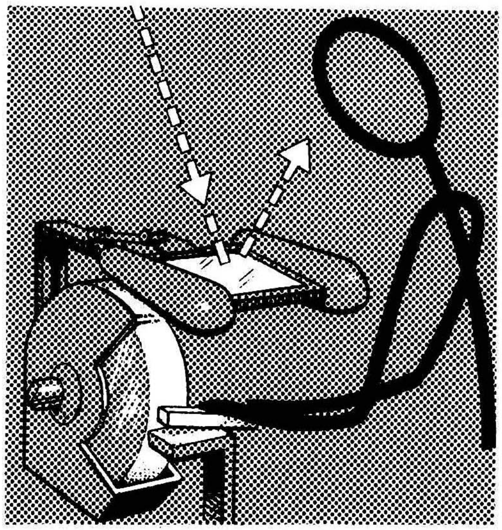


Fig. 57. - Obscuring reflections on a glass guard can be overcome by strongly lighting the work beneath it

Excessively difficult visual tasks

When employees complain that a particular task is too difficult or fatiguing, the possibility of using one of the special techniques referred to on pages 33 to 38 should be considered. Since the choice and application of such techniques is not always easy, the help of a competent industrial lighting engineer should be sought whenever possible. In the absence of skilled advice of this kind, a careful first-hand examination of the task should be made with the object of finding out exactly what details within the task have to be seen, so that the best way of making them clearly visible can be chosen.

The first-hand examination of the visual task is exceedingly important, for even experienced workers who are thoroughly familiar with their job often find it difficult or impossible to explain the visual clues that enable them to perform it. The prick-marks made in paper by a draftsman's needle-point dividers provide an illustration of this fact. The feature which distinguishes a prick-mark from adjacent pencil dots, dirt specks, etc., is the minute highlight on the side of the hole furthest from the principal source of light. This fact is of no direct interest to the draftsman who has learned by experience to recognise a prick-mark when he sees one, and may indeed be quite unaware of the visual clue (i.e., the minute highlight) which enables him to do it. But the fact is of importance to the lighting engineer faced with the problem of making the task easier to see, since it indicates that lighting with a directional component designed to accentuate the highlight may be more effective than extremely diffused illumination which will tend to suppress it altogether.

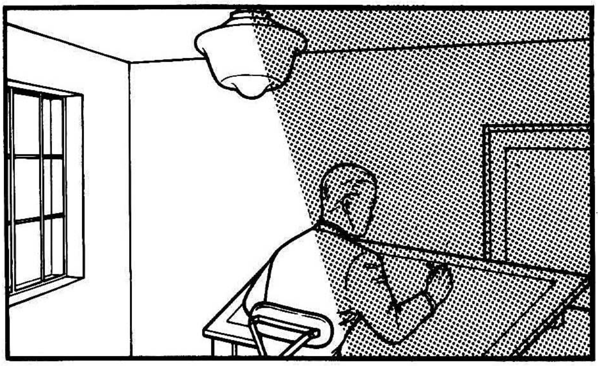


Fig. 58. - Unnoticed dirt may be stealing half the light

Flicker and stroboscopic effect

Whilst these phenomena are seldom the root cause of complaints, they have attracted a great deal of public attention and it may therefore be worthwhile stating one or two facts about them.

All lamps operating on alternating current produce light which pulsates at twice the supply frequency. Whilst this presents no problem in the vast majority of cases, a few isolated individuals who are particularly sensitive to this "flicker" may be seriously disturbed by a pulsation in the task brightness which is too slight and too rapid to be detected at all by most people.

These hypersensitive individuals are most likely to be troubled when a very bright surface occupies a large portion of their field of view. A strongly lit drawing board fulfills this condition ideally, which may possibly help to explain why these apparently inexplicable complaints seem to arise more often in drawing offices than anywhere else.

Complaints of this kind only arise when all the light comes from lamps on a single phase of the electricity supply and can be cured by running adjacent rows of lamps off different phases.

The flicker referred to above should not be confused with the localised "end flicker" sometimes visible near the ends of fluorescent tubes. This has a negligible effect upon the task illumination; if it causes irritation, screening the ends of the lamp will eliminate the trouble.

The pulsation in the light from lamps running off alternating current also sometimes causes a stroboscopic effect, i.e. the appearance of a stationary or slowly moving blurred pattern on rapidly moving objects. This is only troublesome when the pattern appears on details in the task which have to be closely examined. In these circumstances the pattern can be very distracting and must be eliminated by using multiphase lighting or slightly altering the speed at which the task is moving.

Complaints against fluorescent lighting

As we have seen, people suffering from the ill-effects of poorly designed lighting can seldom put their finger on what is wrong, and will thus advance quite irrational reasons for their distress. Quite frequently, blame is put on some fancied inherent defect in the light produced by fluorescent lamps.

Most of this prejudice against fluorescent lighting probably springs from the fact that fluorescent lighting installations are more likely to be badly designed than are incandescent ones. There is also a wide-spread but erroneous belief that the ordinary fluorescent tube is a "low-brightness, glare-free" source, a mistake which could never be made in the case of the incandescent lamp, which has such an extremely high brightness that shielding of some kind is obviously necessary.

Again, the design of fluorescent lighting equipment presents considerably greater mechanical difficulties. The need for a bulky backbone to house the control gear and support the large reflector or diffuser makes it far harder to arrange for adequate ceiling illumination than in the case of incandescent lighting, where the conventional totally enclosed opal-glass diffusing unit readily supplies ample upward light.

Properly designed fluorescent lighting installations provide seeing conditions equal to, if not better than, those obtainable with any other form of light source, including natural daylight; but this is only possible if careful attention is given to all the basic requirements discussed in this Information Sheet.

J. C. Lowson

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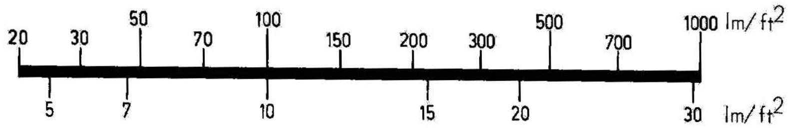
CORRIGENDUM

CIS Information Sheet No. 11 "Artificial Lighting in Factory and Office"

The second paragraph on page 21 is to be replaced by the following text and figure:

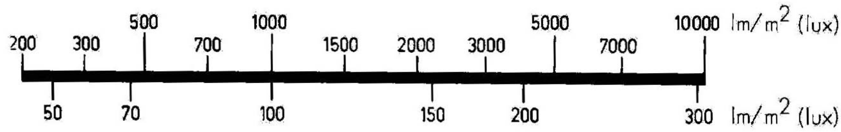
As a general rule when using non-metric light unit measurements, the average level of illumination throughout the interior (E_g) should not be less than the square root of the illumination level on the locally lit task (E_l) ($E_g = \sqrt{E_l}$; E in lm/ft^2) or when using metric units, not less than three times the square root of the local illumination ($E_g = 3\sqrt{E_l}$; E en lux) (s. Fig. 21a).

Local illumination



Minimum general illumination

Local illumination



Minimum general illumination

Fig. 21a - Relationship between local illumination and minimum general illumination in the non-metric and metric system

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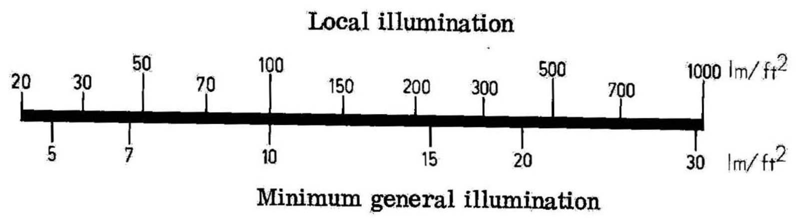

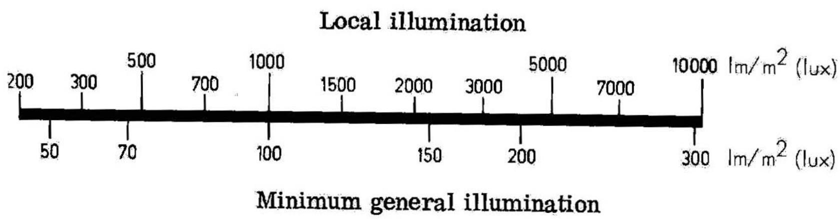

Fig. 21a - Relationship between local illumination and minimum general illumination in the non-metric and metric system

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