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INDUSTRIAL LIGHTING

This Bulletin replaces "Wartime Lighting," now out of print, and contains much new material.

BULLETIN NO. 1

Industrial Welfare Division

DEPARTMENT OF LABOUR AND NATIONAL SERVICE

Commonwealth of Australia

1945

INTRODUCTION

WELL-PLANNED, sufficient and comfortable light is one of the conditions of efficient production. Lack of it slows down output and increases fatigue, spoilt work, and time lost through accidents.

Although for special reasons some factories built recently operate entirely by artificial light, there is no doubt that people generally prefer daylight. It is important that new factories should be planned so as to provide sufficient natural lighting, free from glare. Experience has shown that much more effective use can be often made of daylight in existing work-rooms, by such means as frequent cleaning of windows, repainting of walls to reflect more light,* and the provision of light-coloured blinds to prevent glare from direct sunlight.

Many existing buildings have unsatisfactory natural lighting so that they are not adequately lighted throughout the day. Artificial lighting is needed during the day for fine work wherever:

(a) the sky is not visible from the working-plane;

(b) the distance from the working-place to the nearest window is greater than twice the height from the floor to the head of the window;

(c) the illumination is less than the standard for artificial light reproduced in Chapter II of this bulletin.

The need for providing adequate lighting for shift-work in wartime has greatly enriched Australian experience in the industrial lighting field. In 1942, the Standards Association of Australia published Code No. (E) CA501 for the "Interior Illumination of Buildings by Artificial Light." This has since been widely applied, and is the standard adopted by the National Security (Standards of Lighting) Regulations, which (as a measure for improving wartime industrial efficiency) apply to new or altered installations in protected establishments. Electricity supply undertakings are giving skilled technical advice to their consumers about the application of the standards, as are also consulting engineers, architects and many electrical merchants, and contractors. Experience has shown the value not only of making new installations comply with the standards, but also of improving existing installations; and it has shown that satisfactory improvements can usually be made with very little increase in electricity consumption.

In the belief that this recent experience can also contribute to the competitive efficiency of Australian industry in the post-war world, the standards of the Australian Standard Code, and the methods of their application, are illustrated in this bulletin.

*Chapter III "Colour in Industry" has the same general application with natural as with artificial light.

I. AN A.B.C. OF LIGHTING PRINCIPLES

A. Five Factors of Vision

IF eyesight is good or properly corrected by glasses, visibility depends upon the contrast of the object with its background, and upon how well the object is lighted. Lighting that is adequate for one task may be inadequate for another. The five factors involved in seeing are: eyesight, size of object, contrast, time (speed), and illumination.

1. Eyesight

Correction of eye defects is the first step towards proper seeing. Periodic eyesight examinations pay dividends to both employers and employees. Many employees engaged on fine tasks would do quicker and better work if their eye defects were corrected with glasses.

2. Size

It is harder to see a small object than a large one, and harder still to see fine detail on the small object. Sewing dark materials with fine self-coloured thread, assembling instruments or parts, and non-automatic precision machine work are examples of exacting tasks that require good eyesight and good lighting. The finer the work, the higher the level of illumination necessary for comfortable vision.

3. Contrast

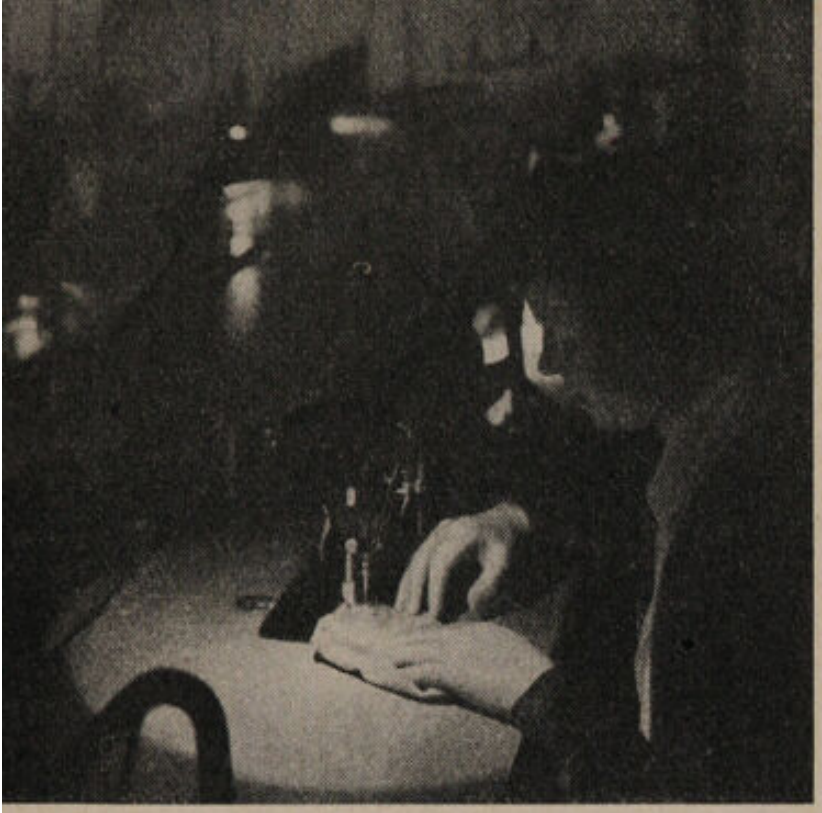
Between an object and its background. A black thread is in strong contrast with white material, but is almost lost to view against a black material.

Rough Work

Fig. 1. 200-watt lamps in glass-steel reflectors mounted at 9-ft. on 10-ft. centres provide 5 to 10 foot-candles for the rough finishing shown above.
Photo: *A. Joyce & Co., Melbourne, Vic.*

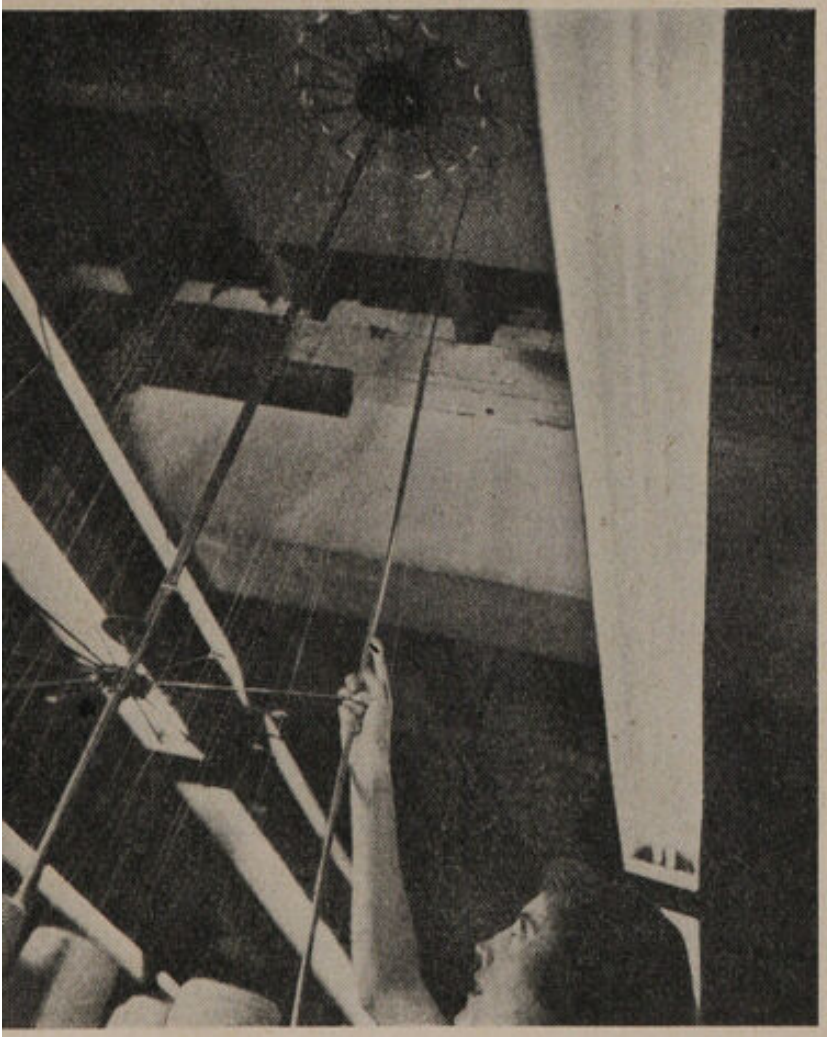
Fine Work

Fig. 2. Lack of contrast between work and background, and fineness of work, make more light necessary. Sewing with black thread on black cloth would need 25 to 50 foot-candles.



Bad Contrast Between Work Light and General Lighting

Fig. 3. Plenty of light on the work but also plenty of eye-strain due to the surrounding gloom. This causes fatigue and loss of time by requiring continual adjustment of the eyes. General lighting one-fifth as strong as that needed on the work avoids this bad contrast.



Good Contrast Between Work and Background

Fig. 4. Watching fine, moving material is fatiguing when contrasts are poor. In this thread-replacement job an orange-coloured board on the ceiling over the "overhead stop motion" plus upward light gives good contrast for replacing cream, khaki and airforce-blue threads.
Photo: *Alpha Knitwear Pty. Ltd., Sydney, N.S.W.*

The less the contrast, the more difficult the seeing task and the higher the illumination required for comfortable vision.

Between the brightness of the work task and the general surroundings. Few people are able to work at relatively near tasks for long without looking up, nor is it physiologically desirable that they should try to do so. If work is carried out in a pool of light surrounded by gloom, the iris of the eye is frequently expanding and contracting to adjust itself to the contrast. This constant movement is very tiring.

The Australian Standard Code lays down that the illumination of the surroundings should not be less than one-fifth of that of the work-task, and in no case less than five foot-candles.

Dark-coloured surroundings remain gloomy even if well lighted. (See Chapter III "Colour in Industry" for methods of improving the contrast of many work-tasks with their background.)

4. Time

Speed is a vital factor in many industrial tasks. Goods have to be inspected as they pass by; broken threads or defects must be seen at once. Higher levels of illumination make it possible to pick out faults more quickly by appearing to slow down moving objects, so that details become clearer.

5. Illumination

The nature of the work cannot usually be varied, and illumination is generally the chief factor under the control of management for

improving the visual comfort of the employees and the efficiency of production.

Enough light is not all that is necessary; the light must be of the right quality, otherwise glare or shadows may make conditions worse than if there is too little light.

B. Glare Impedes Vision

The glare from unscreened lamps causes general discomfort, and over a long period can cause eye-strain. Another form of glare, equally harmful, is the reflection of high-brightness light-sources in the shiny surfaces of machines and work-tasks.

The effects of glare are often not immediately apparent, but it not only strains eyesight but wastes light by reducing the ability to see detail. Glare in the eyes causes fatigue to the whole body, reduces production and increases the number of mistakes.

1. Direct Glare

Look for the following causes of direct glare:

Unscreened lamps in working areas;

Reflectors that do not screen the lamps properly;

Light sources close to the line of vision;

Diffusing fittings enclosing lamps greater than the rated size (see page 29).

2. Reflected Glare

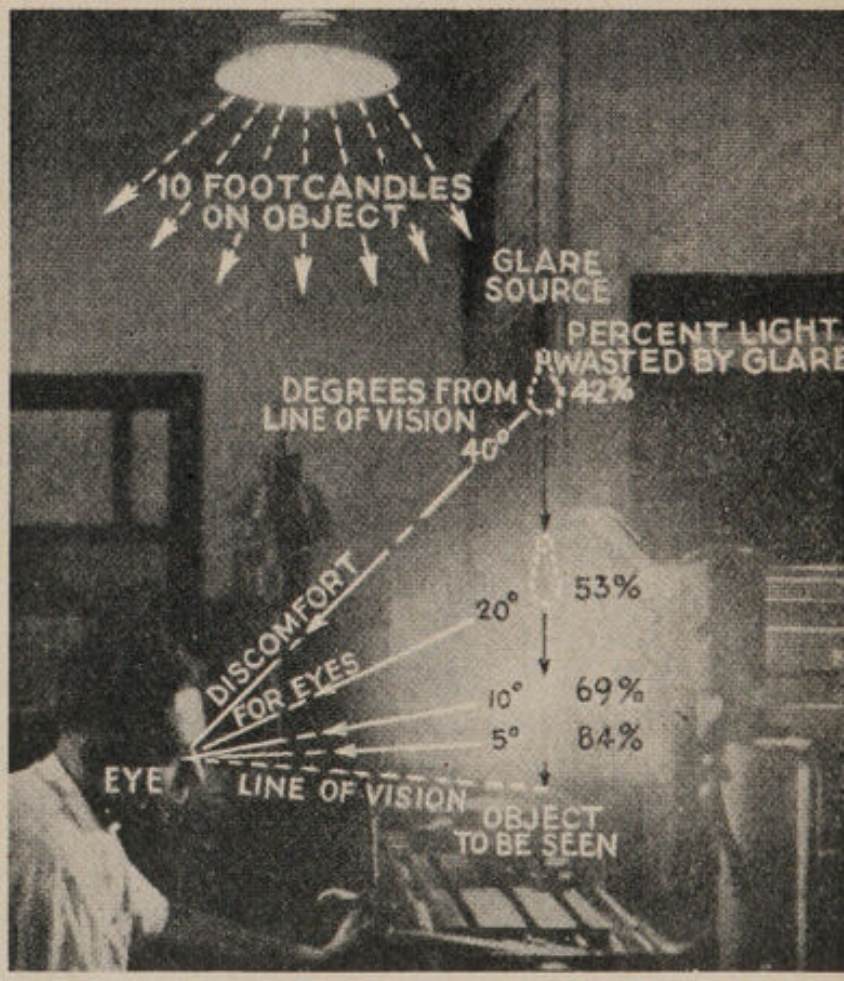
Reflected glare is often more uncomfortable than direct glare, and also more harmful because it comes generally from a direction below the horizontal, where the eye has no natural protection. Reflected glare may be caused by:

(a) Using the wrong type of lighting for tasks on polished or glossy surfaces that mirror the light-sources;

(b) Bad location of supplementary-lighting equipment, permitting bright reflections of the source to reach the eye.

Direct Glare

Fig. 5. Direct glare from unscreened lamps placed too close to the line of vision, and bright reflections from the table top, slow down production even during daylight hours in the work-room.



Glare is Waste of Light

Fig. 6. This diagram illustrates the percentage of light that can be wasted by glare from unscreened lamps placed close to the line of vision.

Glare Impedes Efficiency

Fig. 7. Reflected glare makes this micrometer scale very difficult to read. Scales on polished surfaces require well-diffused lighting.

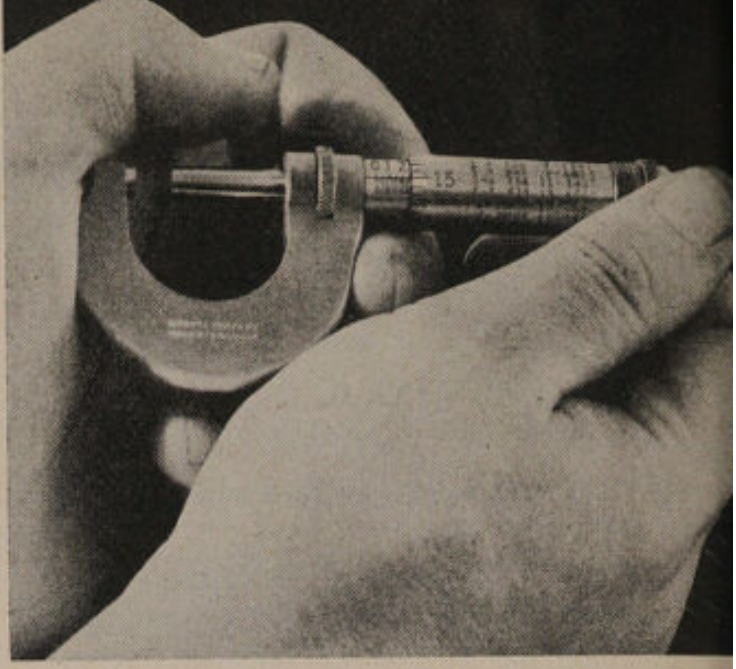


Fig. 8. The same micrometer lit by a large-area diffusing fitting. It is easy now to see the markings on the barrel.

C. Explanation of Lighting Terms

1. Reflection and Absorption

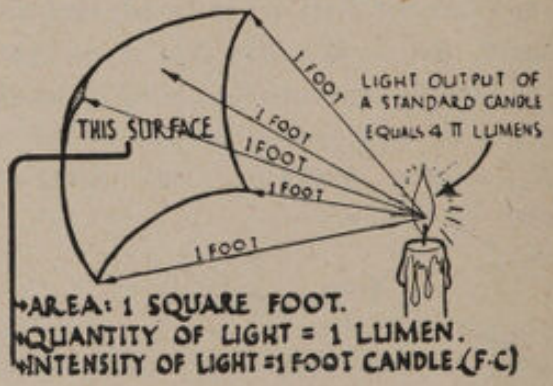
When light falls upon objects, part is *absorbed* and part *reflected*. Objects are seen by the light reflected from them, except silhouettes, which are seen against a lighted background. The nature of the surface determines how, and the colour determines what percentage of, light is reflected.

2. Quantity of Light and Illumination

The quantity of light emitted by a lamp or reaching a surface is measured in *lumens*. (The term "candle-power" should be avoided as it is confusing, and is usually incorrectly used.) The *foot-candle* is the illumination produced by one lumen of light falling uniformly upon one square foot of surface.

3. Quality of Light

High-quality lighting is free from appreciable glare—whether direct from the lamp or reflected from glossy surfaces—and harsh contrasts of light and shade. The greater the diffusion the better the quality.



QUANTITY OF LIGHT

Quantity of light is measured in lumens, not "candle-power."

4. Diffusion

Light is said to be diffused when it comes from a larger surface than the electric lamp itself. The usual method is to surround the lamp with a diffusing medium of much larger surface-area. The larger the area of the effective light-source the higher the quality of the light. For example, the most comfortable work-light is completely indirect, when the ceiling is used as the effective source of light.

5. Brightness

The brightness of a light-source or of a surface reflecting light depends on the quantity of light emitted or reflected per unit area. In the case of diffusing fittings, glare is frequently caused if the area of diffusing glass is not

large enough. If larger fittings are used with the same size of lamp, the same quantity of light is emitted, but the surface brightness of the fitting is less. The desirable size of fitting for various sizes of lamp is given on page 30.

6. Size of Lamp

The size of an electric lamp is usually stated in "watts" rather than "candle-power." "Watts" indicate the electricity consumption (e.g., 1000 watts for one hour or 500 watts for two hours consumes one unit of electricity). Size is more effectively stated, however, in terms of light-output (lumens) than electricity input (watts), particularly as fluorescent lamps are more efficient than incandescent lamps.

Lumens emitted by various sizes of incandescent lamp:

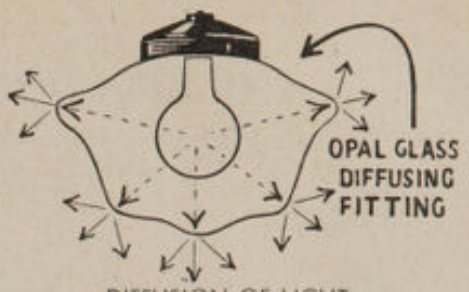
100 watts	1,200 lumens
150 watts	2,030 lumens
200 watts	2,900 lumens
300 watts	4,720 lumens
500 watts	8,470 lumens
750 watts	13,610 lumens
1000 watts	19,100 lumens

7. The Light Meter

Just as the intensity of heat (temperature) is measured with a thermometer, so the intensity of light (illumination) is measured with a light meter, operated by means of a light-sensitive cell. The amount of illumination is measured in foot-candles. Most meters also indicate on the dial the type of task for which the various values of illumination are suitable. The portion of the scale between 0 and 10 foot-candles is usually coloured red and marked "For rough work only" or "Unsuitable for most tasks."

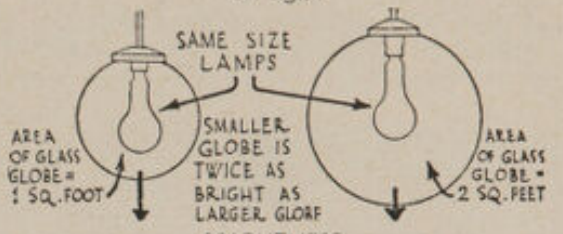
8. Angle of Cut-Off

The angle of cut-off is the extent to which lighting fittings screen the light-source from view. It is the maximum angle below the horizontal at which the light-source cannot be seen. The 20-degree cut-off shown is the minimum prescribed by the Australian Standard Code, and refers to the deep-bowl type of reflector.



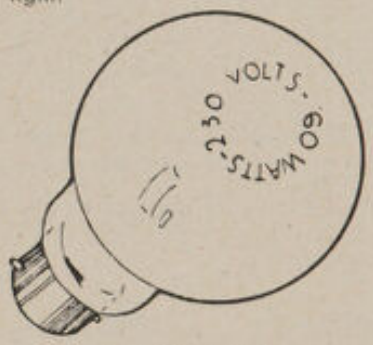
DIFFUSION OF LIGHT

Light rays passing through opal glass are scattered and the outer surface becomes, in effect, the source of light.



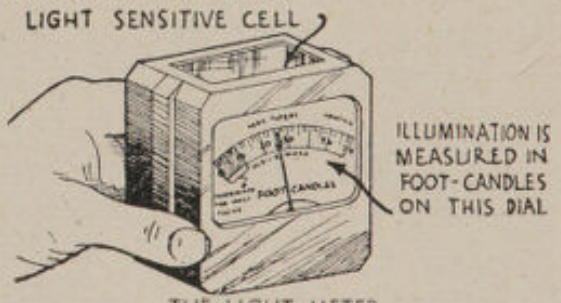
BRIGHTNESS

Bright-looking light fixtures cause eye-strain. An increased area of glass reduces brightness without reducing light.



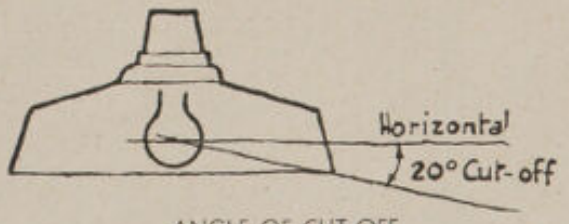
SIZE OF LAMP

The size of an electric lamp is usually stated in 'watts' rather than 'candle-power.' The best measure of size however, would be in terms of light output (lumens), because some lamps, notably the fluorescent type, are more efficient than others.



THE LIGHT METER

Illumination is measured in foot-candles on the dial of this meter. Such a meter should be available for periodic tests whenever lighting conditions are important to production or comfort.



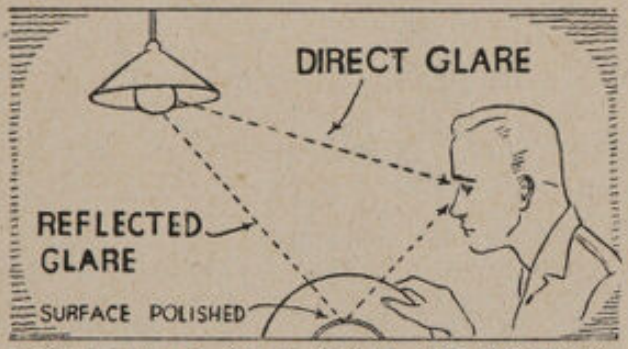
ANGLE OF CUT-OFF

The cut-off angle is the angle below the horizontal at which the light-source is screened from view by the reflector.

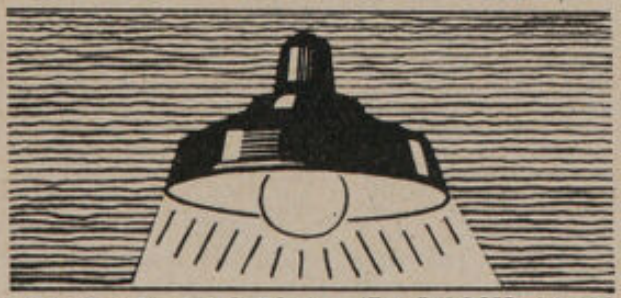
II. REQUIREMENTS OF GOOD PRACTICE

ILLUMINATION SUITABLE FOR A ROUGH TASK WOULD BE INADEQUATE FOR A FINE TASK.

WORK DONE IN POOL OF LIGHT CAUSES EYE-STRAIN.



EXPOSED LAMPS CAUSE GLARE AND EYE-STRAIN.



INADEQUATE REFLECTORS WITH EXPOSED LAMPS CAUSE GLARE.

AVOID LARGE LAMPS IN OPEN REFLECTORS NEAR WORK-TASK.

A. Summary

1. Provide sufficient light on each work-task.

Minimum standards are prescribed in foot-candles for tasks varying in degrees of difficulty. When these foot-candle values are applied with lighting of good quality, working conditions in the majority of factories will be considerably improved.

2. Prevent working in a pool of light with surrounding gloom.

General lighting should be provided throughout areas where work is done, and it should be not less than one-fifth of the light on the work-task, and in no case lower than five foot-candles.

3. Prevent glare from exposed lamps in working areas.

All visible lamps should be fitted with properly designed reflectors or diffusing fittings, or otherwise shaded from view. In passages and spaces other than working-areas, which are not visible from working-areas, inside-frosted lamps of 100 watts or smaller can be used unshaded.

4. Ensure that proper reflectors are used and avoid large glaring lamps in small inadequate reflectors.

Reflectors should be used to screen lamps from view down to an angle of at least 20 degrees below the horizontal, and lamps of 300 watts and over, mounted below 20 feet, should be screened to an angle of not less than 30 degrees.

5. Prevent the use of large glaring lamps in open reflectors in close proximity to workers.

Incandescent lamps, 500 watt or larger, or other high-brightness lamps of equivalent light-output, should not be used in open-type reflectors if mounted less than 14 feet above the floor.

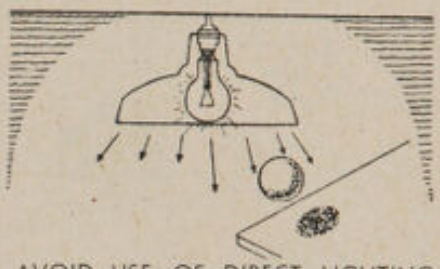
6. Prevent local lights at or near machines from creating a glare nuisance.

Deep reflectors are required for this purpose, to provide screening down to an angle of at least 40° below the bottom of the largest lamp that can be inserted. Reflectors of this type will screen the lamp even when tilted.

LOCAL LIGHTS SHOULD BE SCREENED.

7. Prevent glare in the offices of industrial premises.

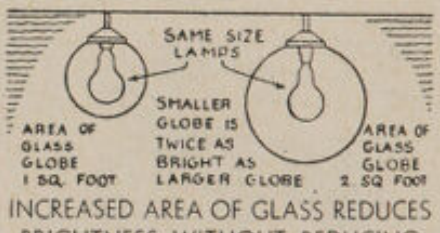
Direct lighting should not be permitted in offices where continuous clerical work is carried out. This provision is intended to prevent glare—particularly reflected glare from glossy paper—and to avoid harsh shadows. Office lighting, therefore, calls for diffused, or semi- or totally-indirect fittings.



AVOID USE OF DIRECT LIGHTING IN OFFICES.

8. Prevent glare when glass diffusing fittings are used.

Much glare trouble and accompanying eye-strain can be traced to the extreme brightness of diffusing fittings used in offices, or for the finer types of visual factory task. The same emission of light (but a much more comfortable appearance) will result from the use of an adequate size of glass fitting. (See Table 4, page 30.) For any given size of lamp the size of fitting prescribed is greater for low mounting heights, because the fittings are then nearer to the eyes.



INCREASED AREA OF GLASS REDUCES BRIGHTNESS WITHOUT REDUCING LIGHT.

9. Prevent reflected glare from smooth or polished surfaces.

Steps should be taken to prevent glare being reflected from polished surfaces to the eyes of the workers and this may be done by shielding or carefully planning the positions of lights, or by using diffusing fittings.

POLISHED SURFACES REFLECT GLARE.

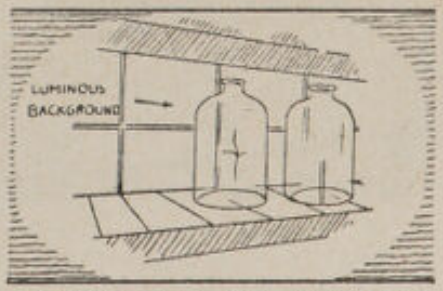
10. Avoid eye-strain with difficult tasks.

Open-type reflectors should not be used for work that is likely to cause eye-strain. The standards call for the use of an indirect or other diffusing light-source, or for a fluorescent lamp-fitting.

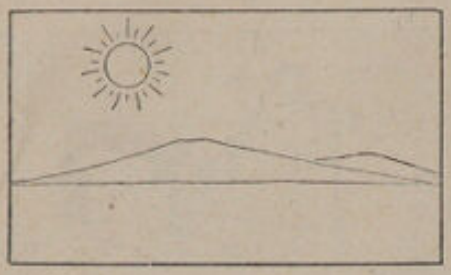
DIFFICULT TASKS NEED SPECIAL LIGHT

11. Use light contrasting colours, or special lighting methods, to improve contrast between work-tasks and backgrounds.

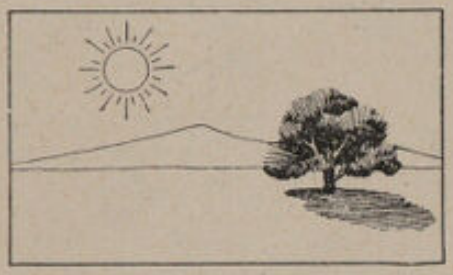
Where possible, visual tasks should be made easier by ensuring that the background shows the detail of the object being worked on to the best advantage. This can be effected by adjusting the colour of the background, or by using a special method of lighting. For example, defects or dirt in bottles, normally hard to detect, will be clearly seen against a luminous background.



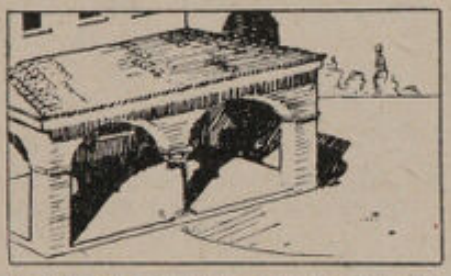
BACKGROUNDS ARE IMPORTANT.



10,000 FOOT-CANDLES IN SUMMER SUNLIGHT

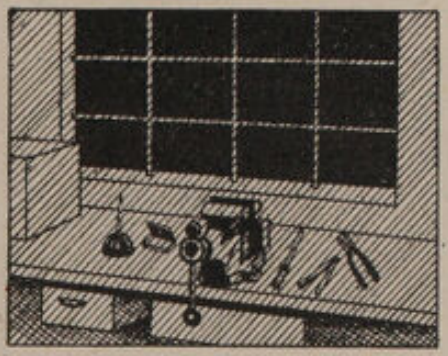


1000 FOOT-CANDLES IN THE SHADE OF A TREE



500 FOOT-CANDLES IN THE SHADE OF A PORCH

200 FOOT-CANDLES ON A BENCH BENEATH A WINDOW



2 FOOT-CANDLES AT NIGHT ON THE SAME BENCH IN THE AVERAGE BADLY-LIGHTED FACTORY

B. How Much Light is Needed?

Eyes see best at daylight levels of illumination. Naturally, it is not economic to provide so much light for work that is not visually exacting. The values shown in Tables 1 and 2 are taken from the Australian Standard Code, and represent the amount of light needed for efficient work. These quantities of light, therefore, comply with good lighting practice.

TABLE 1

Quantity of Illumination Required for Six Classes of Work

(Service Values)

Class	Class of Work	Illumination in Foot-Candles
1	Very severe and prolonged visual tasks such as precision work requiring a high degree of accuracy, e.g., fine engraving and tasks requiring rapid discrimination and response	50 or over
2	Severe and prolonged visual tasks such as drawing, sewing on dark material, or discrimination and inspection of fine details of low contrast	25–50
3	Moderately critical and prolonged tasks such as fine machine-work, fine assembling, sewing on light material; close study in class-rooms or elsewhere	15–25
4	Ordinary visual tasks such as detailed office-work, reading, ordinary bench-work	10–15
5	Less exacting visual tasks, such as intermittent office-work, large assembly work, packing	5–10
6	Seeing in passages and spaces other than working-areas	2–5

Typical examples of the above classes of work are illustrated on page 20.

TABLE 2

TYPICAL ILLUMINATION VALUES NEEDED FOR VARIOUS INDUSTRIAL INTERIORS AND TASKS

(Service Values)

Type of Industrial Premises and Task	Illumination in Foot-Candles
Assembly Shop	
Rough work	5-10
Medium work	10-15
Fine work	15-25 (B)
Extra fine work	25-50 (B)
Bakery	5-10
Canning	10-15
Chemical Works	
Hand furnaces, boiling tanks, stationary driers, stationary or gravity crystallising, mechanical furnaces, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallising, bleaching	5
Tanks for cooking, extractors, percolators, nitrators, electrolytic cells	5-10
Clay Products and Cement Works	
Grinding, filter pressing, kiln-room	5-10
Moulding, pressing, cleaning and trimming	10-15
Enamelling	10-15 (A)
Colouring and glazing	10-15
Cloth Products	
Cutting, inspecting, sewing, pressing, cloth treating (oil cloth, etc.)—	
Light goods	15-25
Dark goods	25-50
Dairy Products	10-15
Die Sinking	
General	25-50 (B)
Fine	Above 50 (B)
Drawing Office	
Rough drawing and sketching	15-25 (B)
Prolonged close work and design in detail	25-50 (B)
Electrical Manufacturing	
Battery manufacture, mica working	10-15
Electrical Manufacturing (contd.)	
Coil and armature winding, insulating processes—	
General	10-15
Fine	25-50 (B)
Engraving	Above 50 (B)
Flour Milling	
Cleaning, grinding or rolling	5-10
Baking or roasting	10-15
Flour grading	15-25 (A)
Food Preparation & Manufacture in any Industry	
Handling, inspection, preparation	10-15
Foundry	
Charging floor, tumbling, cleaning, pouring, shaking out	5-10
Rough moulding and core making	5-10
Fine moulding and core making	15-25
Glass Works	
Mix and furnace rooms, pressing, glass-blowing machines, polishing	5
Grinding, cutting glass to size, silvering	10-15
Fine grinding, bevelling, insp'tion	25-50 (C)
Hat Manufacturing	
Dyeing, stiffening, braiding, cleaning, refining, forming, sizing, pouncing, flanging, finishing, ironing	10-15
Sewing—Light	15-25
Dark	25-50
Inspecting	
Rough	5-10
Medium	15-25 (B)
Fine	25-50 (B)
Extra fine	Above 50 (B)
Instrument Manufacturing	Above 50 (B)
Leather Manufacturing	
Vats	5
Cleaning, tanning and stretching	5
Cutting, fleshing and stuffing	5-10
Finishing and scarfing	10-15

Type of Industrial Premises and Task	Illumination in Foot-Candles
Leather Working	
Pressing and winding—	
Light	10-15
Dark	15-25
Grading, matching, cutting, scarfing, sewing—	
Light	15-25 (A)
Dark	Above 50 (A)
Machine-Shops & Fitting-Shops	
Rough bench and machine work	5-10
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	10-15
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing	15-25 (B)
Extra fine bench and machine work, grinding (fine work)	25-50 (B)
Offices	
General	10-15 (B)
Business machines, etc.	25-50 (B)
Stenographic work and prolonged reading shorthand notes	15-25 (B)
Packing	
Crating, boxing, etc.	5
Paint Manufacturing	10-15 (A)
Paint Shop	
Dipping, firing	5-10
Rubbing, ordinary painting, spraying and finishing	10-15 (A)
Fine painting, spraying and finishing	15-25 (A)
Extra fine painting, spraying and finishing (automobile bodies, piano cases, etc.)	25-50 (A)
Paper Manufacture	
Beaters, grinding	5-10
Calendering	10-15 (B)
Finishing, cutting and trimming	15-25 (B)
Plating	5-10
Polishing and Burnishing	10-15 (B)
Power House	
Boilers, coal and ash handling, storage battery rooms	5
Auxiliary equipment, oil switches and transformers, engines, generators, blowers, compressors	5-10
Switchboards	15-25 (B)

Type of Industrial Premises and Task	Illumination in Foot-Candles
Printing Industry	
Matrixing and casting, miscellaneous machines, presses	10-15
Lithographing, electrotyping	15-25 (A)
Imposing	25-50 (C)
Linotype, monotype, type-setting, stone engraving	25-50 (B)
Sorting and packing	5-10
Proof reading	25-50 (B)
Rubber Manufacturing and Products	
Compounding mills, fabric preparation, stock cutting, tubing machines, solid tyre operations, mechanical goods, building, vulcanising	5-10
Calendering, bead building, finishing inner tube operation, mechanical goods, trimming, treading	10-15
Sheet Metal Work	
Miscellaneous machines, ordinary bench work, punches, presses, shears, stamps, welders, spinning	10-15 (B)
Fine bench work, tinplate inspection	15-25 (C)
Shoe Manufacturing	
Hand turning, miscellaneous bench and machine work	10-15
Cutting, lasting and welting	15-25
Stitching	25-50
Inspecting and sorting	15-25 (A)
Smith Shop	
Forging	5-10
Soap Manufacturing	
Kettle houses, cutting, soap chip and powder	5
Stamping, wrapping and packing, filling and packing soap powders	5-10
Steel and Iron Mills, Bar, Plate and Wire Products	
Soaking pits and re-heating furnaces	2-5
Charging and casting floors	5-10
Muck and heavy rolling, shearing rough by gauge, pickling and cleaning	5
Plate inspection	10-15
Automatic machines, rod, light and cold rolling, wire drawing, shearing fine by line	10-15

Type of Industrial Premises and Task	Illumination in Foot-Candles
Stone Crushing and Screening	
Belt conveyor tubes, main line shafting spaces, spacing chute-rooms inside of bins	2-5
Primary breaker-room, auxiliary breakers under bins	2-5
Screen-rooms	5
Structural Steel Works	5-10
Sugar Grading	15-25 (A)
Sweet Making	10-15
Testing	
Rough	5-10
Fine	10-15
Extra fine instruments, scales, etc.	25-50 (B)
Textile Mills	
Cotton	
Spinning—	
Opening, scrutching, lapping and carding	5
Drawing and twisting	5-10
Ring Spinning	5-10
Warping—	
Light goods	5-10
Dark goods	10-15
Drawing frames	15-25
Weaving—	
Looms	10-15
Burling and mending	25-50 (A)
Perching	Above 50 (A)
Cloth-rooms, warehouse, etc.	2-5
Silk	
Winding, throwing, dyeing	10-15

Type of Industrial Premises and Task	Illumination in Foot-Candles
Textile Mills (continued)	
Quilling, warping, weaving and finishing—	
Light goods	5-10
Dark goods	10-15
Woollen	
Spinning—	
Scouring, washing, etc.	5
Grading and sorting	10-15
Combing, carding, twisting	5-10
Warping—	
Light goods	5-10
Dark goods	10-15
Weaving—	
Looms	10-15
Burling and mending	25-50 (A)
Perching	Above 50 (A)
Cloth-rooms, warehouses, etc.	2-5
Tobacco Products	
Drying, general	2-5
Grading and sorting	15-25 (A)
Stripping	5-10
Upholstering	
Automobile, coach and furniture	10-15
Welding	
Rough	5-10
Fine	10-15
Wood Working	
Rough sawing and bench-work	5-10
Sizing, planing, rough sanding, medium machine and bench-work, gluing, veneering, cooperage	10-15
Fine bench and machine working, fine sanding and finishing	15-25

"A" denotes tasks for which lighting having a colour quality similar to ordinary daylight should be used.

"B" denotes tasks requiring freedom from direct and reflected glare and very good diffusion.

"C" denotes tasks requiring discrimination of fine detail by using (a) the reflected image of a luminous area, or (b) the transmitted light from a luminous area. In respect of such tasks it is necessary that the luminous area should be large enough to cover the surface being inspected, and that the brightness should be within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and very low brightness, in which the source brightness is the principal factor rather than the foot-candles produced at a given point.

Important: The illumination values shown are the values prescribed by the Australian Standards Code for the actual tasks. General lighting throughout the entire working-area need not reach the prescribed illumination values, but this illumination should be at least 1/5th of that on the work-task and in no case less than five foot-candles.

III. COLOUR IN INDUSTRY

THE colour of walls, ceilings, machines, furniture and work surfaces is of great importance to the comfort, efficiency and eyesight of industrial workers. Here are some guiding principles.

Light colours reflect far more light than dark ones and help considerably in lighting the interior by reflecting the light falling upon them.

Dark-coloured surroundings are depressing and gloomy. They remain so even when well lit, and they absorb, instead of reflect, much of the light paid for in the electricity account.

Dark-coloured surroundings are bad for eyesight because they create too great a contrast with brightly-lighted work-tasks. (See "Contrast," page 5.)

Warm places seem cooler when painted grey-blue or light-green, and cool places warmer if they are buff or sunshine cream.

Many visual tasks can be made easier by attention to the colour or brightness of the background to the work.

Pleasant, colourful surroundings tend to make work more cheerful.

Glossy finishes should be avoided unless service conditions are severe. Matt and egg-shell gloss do not reflect strong highlights.

A. The Building Interior

Ceilings are above the line of normal vision, and all light reflected from them helps to illuminate the task. White is usually the most suitable colour for ceilings in work-places, but they may be slightly tinted when the interior is well lighted both by day and by night.

White walls, however, cause glare, because they are often brighter than the work-task, and the eye has more difficulty in seeing the work. Therefore, walls should not be white or off-white, but painted in some light colour (reflection factor 60 to 75 per cent—see typical recommended colours illustrated). Deep colours should be avoided, most satisfactory shades being light green or blue and pale sunshine cream or buff. All-over colours are more attractive than walls with dadoes. If a darker colour at the base of walls is considered essential for maintenance, it should be as low as possible (4 ft. 6 in. is ample) and in as light a colour as practicable. A dado of medium colour (reflection factor 25-40 per cent) is both serviceable and a fair reflector of light.

Employees become less fatigued if the walls they sit facing all day are painted a colour that is suitable and not too bright.

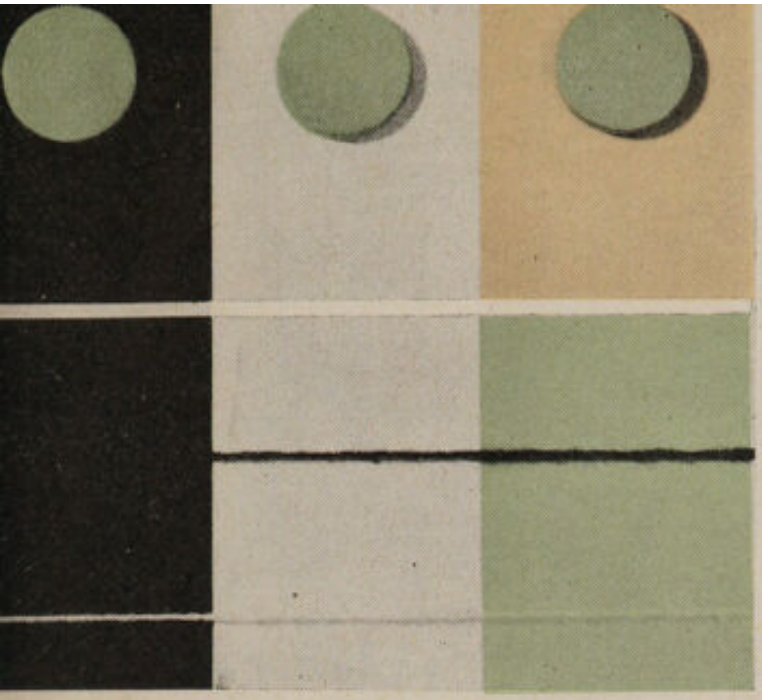
Floors are important reflectors of light when work is done on vertical or under surfaces. Special white sand and cement is used extensively overseas, especially in aircraft factories to provide a light-coloured concrete floor, which can be usually maintained at a reflection factor of about 30 per cent. However, near-white floors are not recommended for most tasks.

B. The Best Colours to Use

Avoid large areas of strong colour, such as bright red, yellow or green. They are likely to cause eye-fatigue and after-images. Keep strong colours for identifying pipe lines, handles of controls, etc.

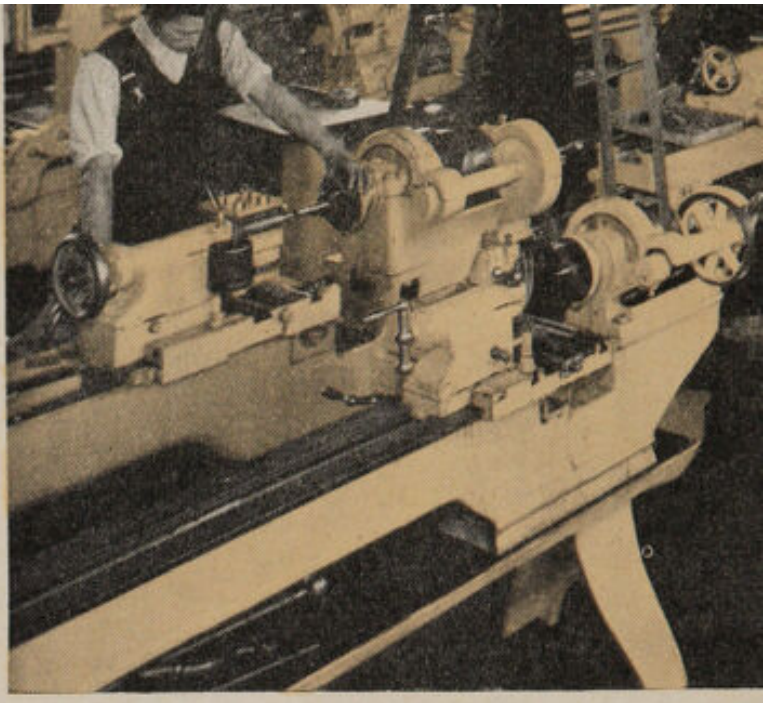
Very light colours are best for general use, especially if applied in a plain, all-over fashion and not picked out in another shade. Some contrast between the main colour and that of columns, machines, or furniture is desirable to avoid monotony.

After wide-scale investigation of Australian and overseas colour practice in industry, and consultation with manufacturers, architects, consulting engineers and paint manufacturers, the Department is issuing recommendations for colour practice in industrial interiors. A series of six light and four medium typical recommended colours has been developed by the



Colour Contrasts Make for Easy Seeing

Fig. 9. Contrast between a task and its background is necessary for vision, but this is best effected by contrast in both colour and brightness rather than by extreme brightness contrast, which causes eye-fatigue.



Colour is Useful in a Machine Shop

Fig. 10. Working parts of this machine are painted in buff, giving a pleasant light-coloured environment for the work-task. The lack of guarding of belts cannot be recommended.

COMMONWEALTH INDUSTRIAL TYPICAL RECOMMENDED COLOURS

(Known to the paint trade as C.I. colours)

SIX LIGHT COLOURS FOR WALLS AND INTERIOR SURFACES GENERALLY—EXCEPT CEILINGS (60-75% Reflection Factor)

*C.I. LIGHT GREEN (Cool Colour)

C.I. WARM BUFF (Warm Colour)

*C.I. LIGHT BLUE (Cool Colour)

*C.I. BUFF (Warm Colour)

*C.I. SUNSHINE CREAM (Warm)

C.I. LIGHT GREY

*Suitable for light-duty machines

FOUR MEDIUM COLOURS FOR DADOES AND SURFACES LIKELY TO GET DIRTY (25-40% Reflection Factor)

C.I. MEDIUM TAN (Warm Colour)

C.I. MEDIUM BLUE (Cool Colour)

†C.I. MEDIUM GREEN (Cool)

†C.I. MEDIUM GREY

†Particularly suitable for large machines

Colour Makes an Efficient and Attractive Work-Room

Fig. 11. Light buff walls and light buff lino on the bench tops make good use of colour. Rows of 40-watt hot-cathode lamps 10 ft. apart give general lighting of 40 foot-candles and supplementary 20-watt hot-cathode lamps over the benches raise the light on the work to 200 foot-candles, suitable for the very delicate work done. A similar use of colour has wide applicability also to less specialized work.

Department and adopted by the principal paint manufacturers. The colours will be referred to as "Commonwealth Industrial," abbreviated by the paint trade to "C.I." colours. Actual samples, in semi-gloss finish, are shown on page 17, and any of these colours should be readily available in industry in the particular type and make of paint required, subject to the limitations imposed by Paint Control Orders.

C. Colour on Machines

Machines in industry, whether sewing machines or lathes, knitting machines or giant presses, are usually painted black or dark grey and often have chrome or nickel handles and parts. Custom alone dictates this practice, as soft colours like those illustrated are much more pleasant to work with, and the chrome or nickel parts reflect uncomfortable high-lights that can easily be avoided if satin finishes are used.

Dark-coloured machines absorb light and often form unsuitable backgrounds to fine seeing tasks, also they are unnecessarily sombre and unattractive. At the same time, the use of bright colours, such as orange, bright green or blue should be avoided because they are tiring and difficult to live with.

Do not paint any machine that uses a cutting compound without first checking to make sure that the paint will not be stripped off by the compound.

Where Keen Sight Means an Airman's Safety

Fig. 12. Inspecting aircraft instrument components for flaws. Workers face light green walls, in a general light of ten foot-candles plus 40 foot-candles of cold-cathode fluorescent lighting on the task.

D. Backgrounds to Work-Tasks

A good deal of industrial work is made unnecessarily difficult because of the nature and colour of the background. Broken threads are looked for against a background of dark space; articles are assembled or inspected against a confused background of space and moving objects, or against backgrounds of the same colour; fine work is done on bench or table tops that are shiny and reflect annoying high-lights or in some other way are an unsuitable background to the task.

The use of artificial backgrounds (screens, partitions, etc.), the selection of suitably coloured materials for work surfaces, or the judicious use of paint on backgrounds and surroundings, will make easier many difficult seeing tasks in industry.

E. Identifying Colours

It is desirable to use strong colours, such as yellow and orange, for identifying dangerous moving parts of machines, safety-grips, control-buttons and the like; provided that they are not so close to the seeing-task as to be distracting.

Another valuable use of colour in industry is for identifying various types of pipe-line, such as gas, air, electric conduits, etc., and for traffic lanes in large factories where small power-driven trolleys are used.

The effective use of colour for safety in identification is, however, dependent upon the development of a national Standards Code.

IV. BEST METHODS OF LIGHTING

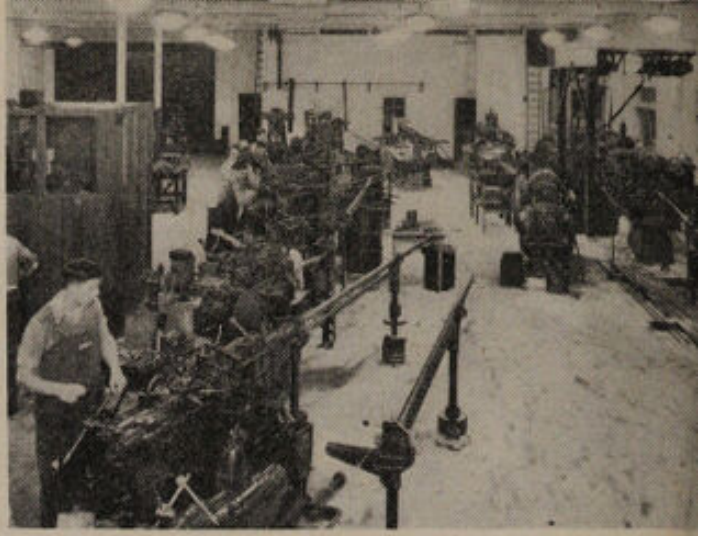
Class 1

Very severe and prolonged visual tasks—50 foot-candles and above.

It is often uneconomic to light the whole of the interior to the requirements of the work-task in this class. Localized general or general plus supplementary lighting is recommended in such cases.

The very fine precision assembly work illustrated in Fig. 13 has 70 foot-candles on the assembly bench and 30 foot-candles between the benches plus subsidiary general lighting.

The installation is localized general lighting using two 18 m.m. 80 m.a. cold-cathode tubes to each reflector, with a mounting height of 6 ft. 6 in. The length and low brightness of the tubes results in shadowless, cool lighting and absence of glare.



Class 3—15-25 Foot-Candles

Fig. 15. Fine machine work with general lighting by 500-watt lamps giving 20 foot-candles on the task. Light-coloured painting is used throughout the work-room. Photo: *Keefer Bros. Pty. Ltd., Melbourne, Vic.*

Class 2

Severe and prolonged visual tasks—25-50 foot-candles.

In factories where good lighting is needed throughout the interior, the required foot-candles are obtained by general lighting. Where assembly benches or machines are in permanent

Class 1—50 Foot-Candles and Above

Fig. 13. Very fine precision work with 70 foot-candles on the work-task and 30 foot-candles between benches. Reflectors screen the tubes from the eyes of the workers opposite.

Photo: *J. W. Handley Pty. Ltd., Melbourne, Vic.*

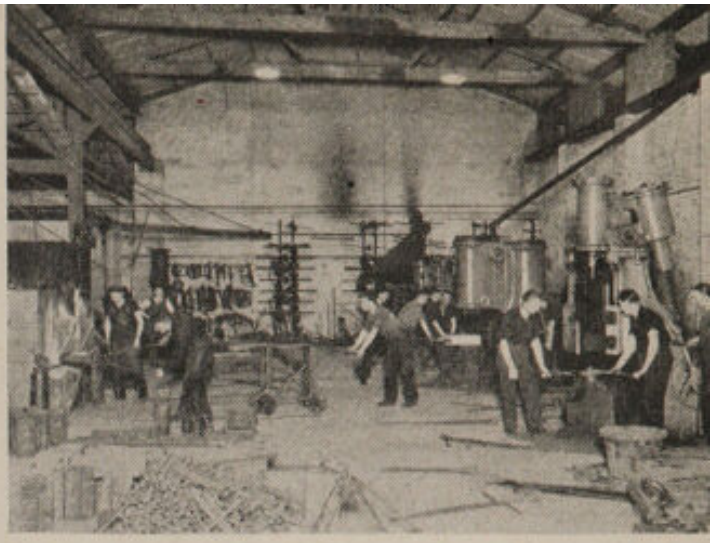
Class 2—25-50 Foot-Candles

Fig. 14. Sewing on dark materials with 25 foot-candles of light on the work-task and 15-20 foot-candles of general lighting. The work-room is painted throughout in light colours.

Photo: *Jantzen (Aust.) Ltd., Sydney, N.S.W.*

Class 4—10-15 Foot-Candles

Fig. 16. For tending food-processing machinery 12 foot-candles of light is provided on the task and throughout the interior. Good diffusion prevents reflected glare from tinplate.
Photo: *Kraft Walker Cheese Co. Pty. Ltd., Melbourne*



Class 5—5-10 Foot-Candles

Fig. 17. Rough work on heavy billets of iron is not an exacting visual task and the 8 foot-candles of general light throughout the interior is sufficient.
Photo: *E. J. Hadaway, Melbourne, Vic.*

positions, localized general lighting, or general plus supplementary lighting can be used.

In Fig. 14, two rows of reflectors are shown to each double-sided bench, with the rows placed slightly behind the operatives. This gives 25 foot-candles of practically shadowless, glare-free lighting at the needles. Quantity of light through the interior is 15-20 foot-candles.

Class 3

Moderately critical and prolonged visual tasks —15-25 foot-candles.

The quantity of light required for tasks falling into this category is usually insufficient to justify local lighting. Localized general lighting may often be effectively employed, but the general illumination throughout the working-area must not be less than 5 foot-candles.

General lighting, by means of 500-watt glass-steel reflectors spaced 15 ft. by 11 ft. 6 in. and mounted 11 ft. 6 in. high, gives 20 foot-candles on the fine machine work illustrated in Fig. 15.

The comparatively low brightness of glass-steel fittings softens shadows and reduces direct and reflected glare to acceptable levels.

Class 4

Ordinary visual tasks—10-15 foot-candles.

General lighting will usually be most satisfactory for this class of work-task. Foot-candles must not fall below 5 throughout the working-area.

In Fig. 16 the quantity of light on the task and generally is 12 foot-candles, obtained from 200-watt lamps in 24-in. reflectors with 18-in. glassware, spaced on 10-ft. centres, and mounted 9 ft. 6 in. high.

The glass-steel fittings are rated for a size larger lamp than is used, which keeps down the surface brightness of the glass, and avoids reflected glare from stainless steel surfaces.

Class 5

Less exacting visual tasks—5-10 foot-candles.

General lighting is usually the most satisfactory for the less exacting visual tasks. In the smith shop illustrated in Fig. 17 general lighting, by 1000-watt lamps in 20-in. R.L.M. reflectors spaced 32 ft. by 20 ft., gives 8 foot-candles of light throughout the interior.

High mounting of the reflectors reduces glare to a permissible level while the rough work on heavy billets of iron is such that reflected glare is not appreciable.

General Plus Supplementary Lighting

Fig. 19. For the precision work in the assembly of aircraft instruments, it was economical to provide 40 foot-candles needed on the work by 65-watt fluorescent lamps near the benches, with 10 foot-candles of general incandescent diffused lighting. Photo: *H. A. Chivers, Melbourne, Vic.*

Localised General Lighting

Fig. 20. When work is in a set position at assembly benches or on machines, the "localized general" arrangement of fittings, to follow the bench or machine layout, is often adopted. Photo: *A. Mushin Pty. Ltd., Fitzroy, Vic.*

General Lighting

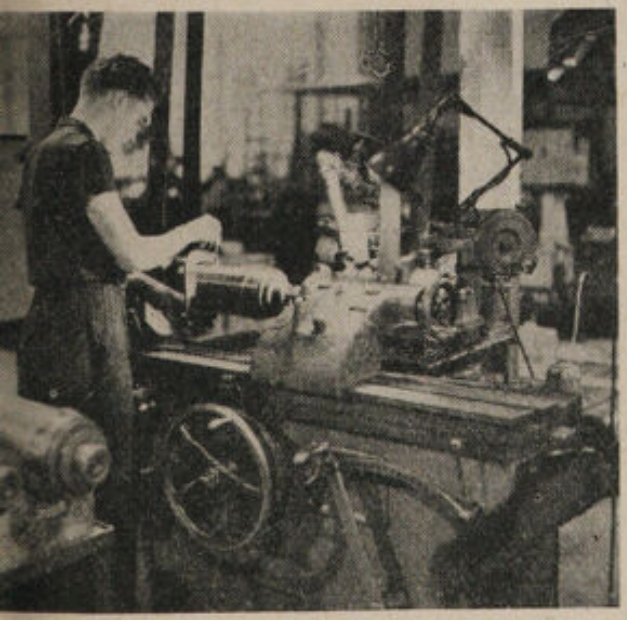
Fig. 18. An example of general lighting in a machine-shop that provides 12 foot-candles, sufficient for medium machine work. 200-watt inside-frosted lamps in 16-in. R.L.M. reflectors are mounted at 12-ft. on 14-ft. centres. Glare is reduced by the inside frosting and close spacing. Light-coloured walls and ceiling are a feature of the plant.

Following the installation of the present system production rose sharply, eye-strain was reduced, and accidents fell from a fairly high rate to nil over a period of three months.

Average Production of Rolls-Royce Merlin Cylinders in 24 Working-Hours

	Production Old Lighting	Production New Lighting	% Increase in Production
Rough Turning	15	18	20
Boring	16	18	12½
Finish Turning	15	18	20
Camming	14	18	28½
Milling C/C Flats	15	18	20
Facing to Length	15	18	20
Grinding	16	20	25
Debur, Polish and Stamp	10	20	100

Photo at left: *Litchfield Engineering Co. Ltd., Adelaide, S.A.*



Supplementary Lighting

Fig. 21. Lighting designed to light the immediate work-task only, is called supplementary lighting. The type adopted will depend upon the nature of the task. Photo: *Litchfield Engineering Co., Adelaide, S.A.*

Fig. 22. An example of a luminous panel used for the inspection of mica washers by transmitted light. Photo: *Leggett Products Pty. Ltd., Melbourne, Vic.*

A. Types of General Lighting Fitting

1. Direct Lighting

Direct light is that which comes straight from the lamp without passing through any diffusing medium. Open-type reflectors produce direct lighting. It is the cheapest form of illumination, but it has the disadvantage of causing direct glare and also reflected glare from glossy surfaces. Although suitable for many industrial applications, direct lighting is unsuitable for precision work, where the detail of the work-task is small. It is also unsuitable for assembly, machine-tool and other work on shiny surfaces, or for operations where shadows are likely to prove troublesome.

Typical efficiency (using incandescent lamps): one watt per square foot of floor-area equals six foot-candles.

2. Diffused Lighting

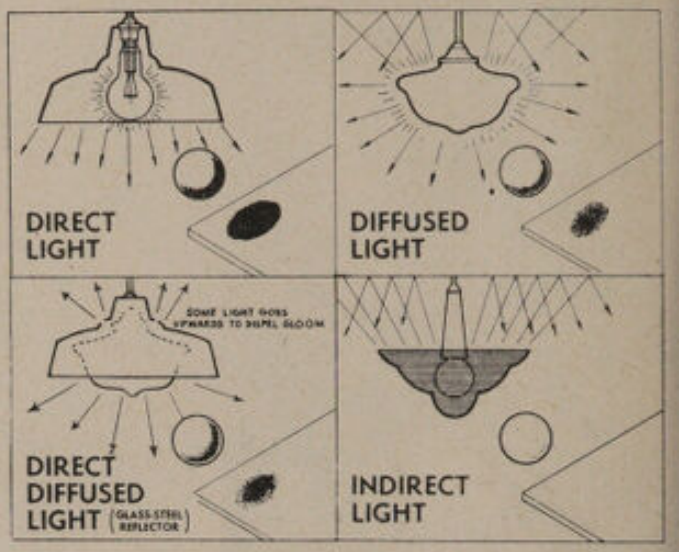
One way of diffusing electric light is to enclose the lamp in a large opal-glass globe. The light spreads all over the globe, which is, of course, of much greater area than the filament of the electric lamp. There is less glare, and shadows are much softer.

Diffused lighting is suitable for high-quality industrial and office lighting where ceilings are lined and are of a light colour.

Typical efficiency (using incandescent lamps): one watt per square foot of floor-area equals four foot-candles.

3. Direct Diffused Lighting

The demand for high-quality diffused lighting in factories with unlined ceilings results in the use of a combined reflecting and diffusing unit. This type of unit is an ideal incandescent lamp-fitting for high-quality general lighting in industry. It is suitable for general lighting or localized general lighting of fine assembly, fine machine-work, or work on shiny surfaces.



FOUR TYPES OF LIGHTING FITTING.

Typical efficiency (using incandescent lamps): one watt per square foot of floor-area equals four and a half foot-candles.

4. Indirect Lighting

Lighting is called indirect when lighting fixtures direct light to the ceiling, which thus becomes the effective source of light. There is no glare and there are practically no shadows. Indirect or semi-direct lighting is better in quality than direct lighting, but larger lamp sizes are required for the same illumination. The elimination of glare and the reduction of harsh shadows make indirect lighting ideal for drawing-offices and difficult visual tasks.

Indirect lighting should not be used where the heating effect of the larger lamps required is likely to be objectionable.

Typical efficiency (using incandescent lamps): one watt per square foot of floor-area equals two foot-candles.

B. How to Use Open-Type Reflectors

1. Quick Reference Table

The following table shows the minimum screening required for all open-type reflectors, with the exception of adjustable supplementary local lighting fittings and fluorescent reflectors.

TABLE 3

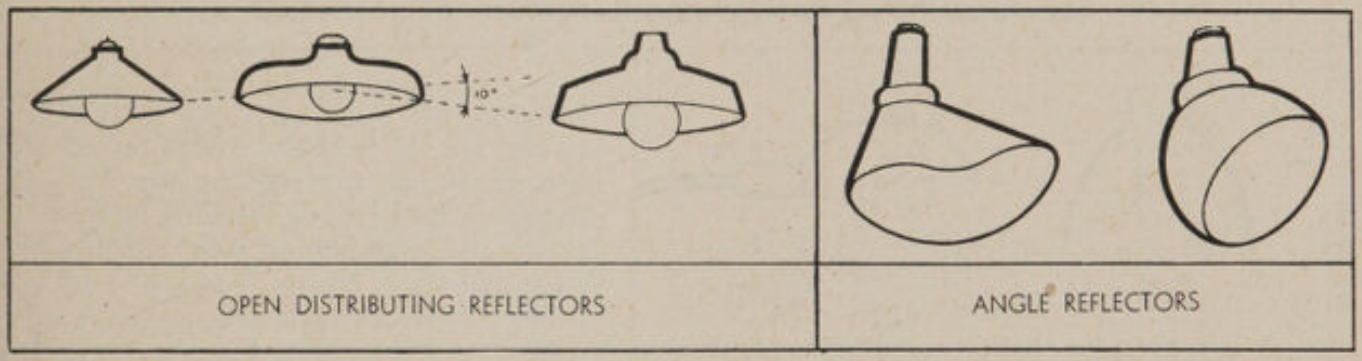
MINIMUM CONCEALMENT OF LAMPS AT VARIOUS MOUNTING HEIGHTS IN WORKING-AREAS

Mounting Height	0-14 ft.	14 ft.-20 ft.	Over 20 ft.
500-watt lamp and over	Open - type reflector should not be used	Not less than 30° cut-off	Not less than 20° cut-off
300-watt lamp	Not less than 30° cut-off	Not less than 30° cut-off	Not less than 20° cut-off
200-watt lamp and under	Not less than 20° cut-off	Not less than 20° cut-off	Not less than 20° cut-off

2. Standard and Sub-Standard Reflectors

CUT-OFF LESS THAN 20°

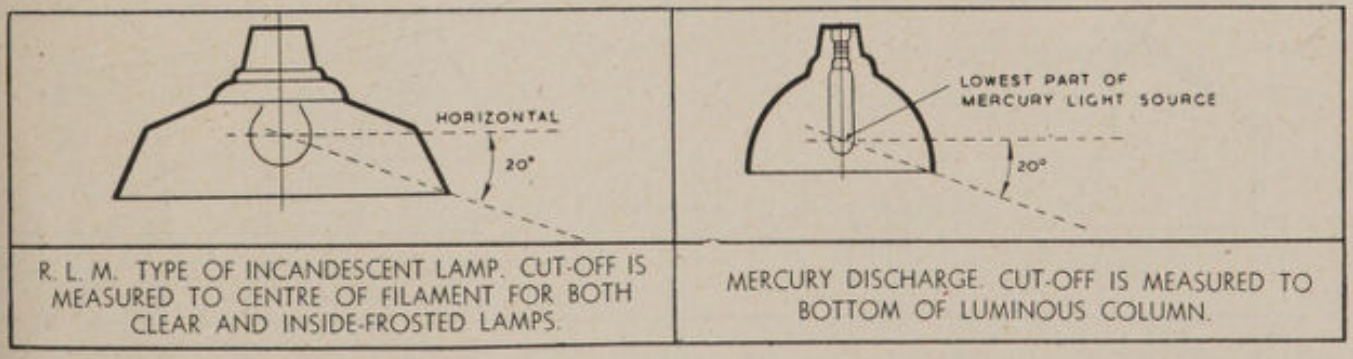
Should not be used for General Lighting



OPEN DISTRIBUTING REFLECTORS | ANGLE REFLECTORS

STANDARD 20° OPEN-TYPE REFLECTORS

(Except Fluorescent Tubes)



R. L. M. TYPE OF INCANDESCENT LAMP. CUT-OFF IS MEASURED TO CENTRE OF FILAMENT FOR BOTH CLEAR AND INSIDE-FROSTED LAMPS.

MERCURY DISCHARGE. CUT-OFF IS MEASURED TO BOTTOM OF LUMINOUS COLUMN.

For incandescent lamps, cut-off is measured to the centre of the filament for both clear and inside-frosted lamps.

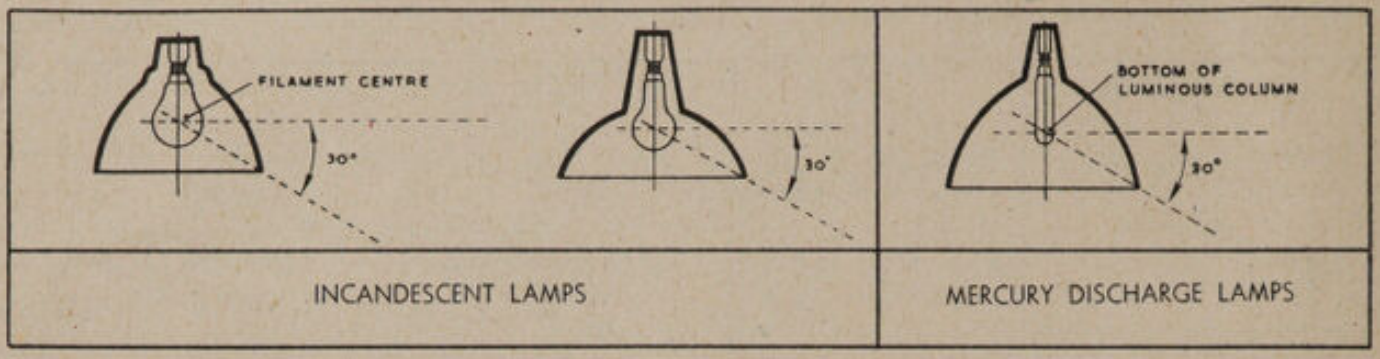
For mercury discharge lamps, cut-off is measured to the bottom of the luminous column.

20° is the minimum screening required of any reflector. 20° cut-off reflectors may be used as follows:

With 200-watt or smaller incandescent (equivalent in mercury discharge 80 watt) at any mounting height except near eye level.

With 300-watt and larger incandescent (equivalent in mercury discharge 125 watt and over) above 20 ft. mounting height.

STANDARD 30° OPEN-TYPE REFLECTORS



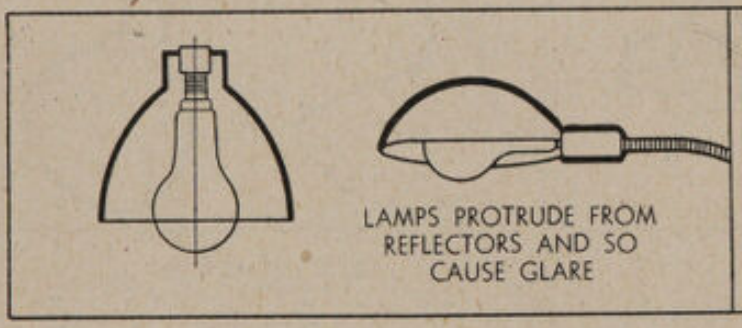
30° cut-off reflectors may be used as follows:

With 300-watt or smaller incandescent (equivalent in mercury discharge 125 watt and under) at any mounting height except near eye level.

With 500-watt or larger incandescent (equivalent in mercury discharge 250 watt and over) above 14 ft. Such lamps must not be used in any open-type reflector below 14 ft.

CUT-OFF LESS THAN 40°

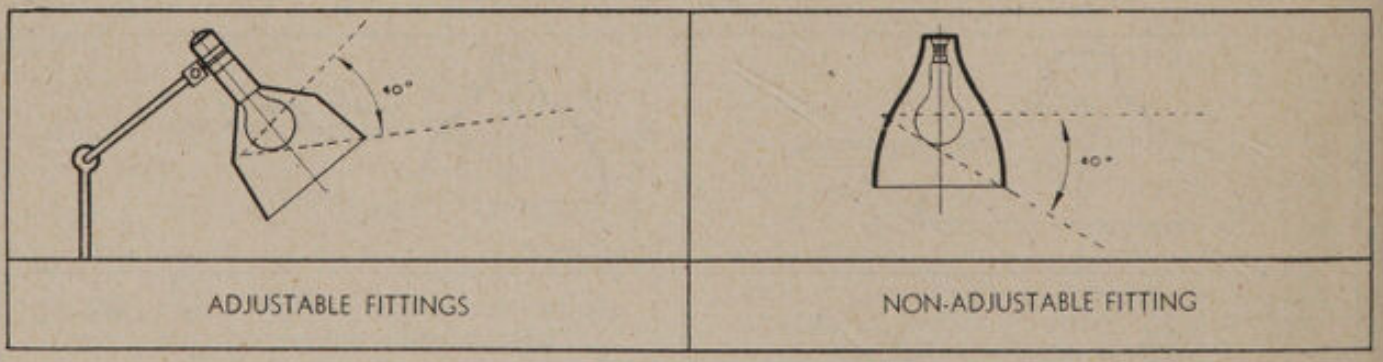
Supplementary Local-Lighting Reflectors– Sub-Standard



Scoop or half-shade types of reflectors, or the use of over-size lamps in reflectors, is not approved by the Australian Standard Code, as such fittings expose the lamp bulb to view and thus cause glare.

STANDARD 40° OPEN-TYPE REFLECTORS

Recommended for Local Lighting



Not-Adjustable: Supplementary local-lighting reflectors mounted in vicinity of eye level should have a 40° cut-off irrespective of lamp size.

Adjustable Fittings: Supplementary local-lighting fittings for use on machines, etc., should comply with the following:

(a) 40° cut-off measured to the lower surface of the rated lamp.

(b) The design of the fitting should prevent lamps larger than the rated lamps from being inserted.

For low-voltage lamp bulbs smaller than standard, and for unsuitable fittings already in use in industry, adaptation may be possible, and further information is contained in "Technical Information" issued by this Department.

3. Standard Fluorescent Open-Type Reflectors

The cut-off angle of any open-type fluorescent fitting is taken tangential to the lower surface of the lamp. If there are two or more lamps side by side, the cut-off angle is taken tangential to the furthest lamp.

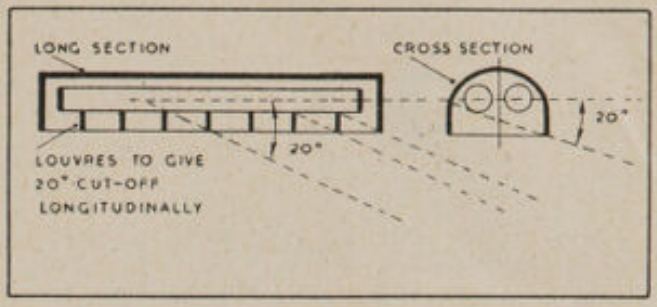
When open-type fluorescent reflectors are used in industry, screening is needed as follows:

(a) Reflectors with less than four lamps side by side need to have a cut-off of 20° at right angles to the axis of the lamp. Screening is not required end-on to the lamps.

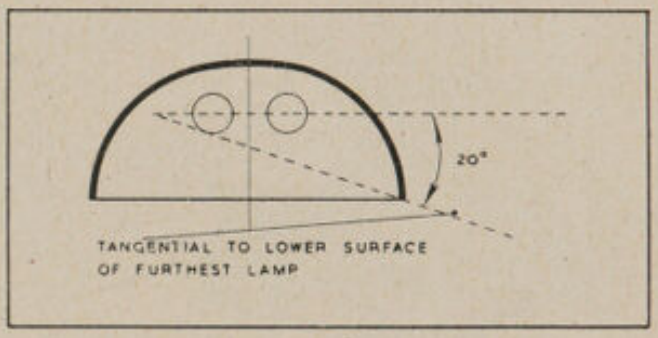
(b) Multi-lamp fittings with four or more lamps side by side need a cut-off of no less than 13° at right angles to the long axis of the lamps and irrespective of mounting height. Screening end-on to the lamps is not required.

When these reflectors are used in offices, screening requirements are identical to those set out in (a) above, except that the cut-off is needed both end-on and side-on. An alternative to end-on screening, is the use of diffusing glass underneath lamps.

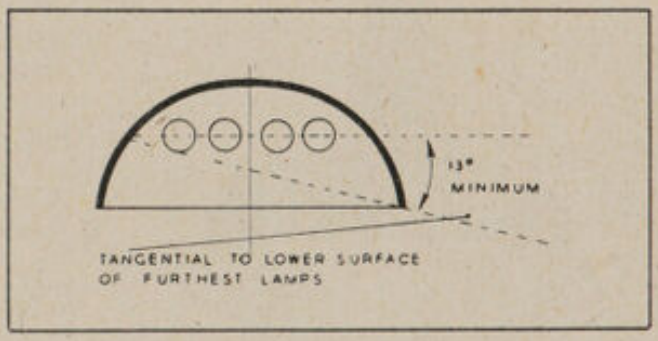
Experience since the last revision of the Code has shown that diffusing fluorescent fittings are far more satisfying than any form of adapted open-type reflector, for the lighting of offices.



CUT-OFF ANGLE FOR FLUORESCENT FITTINGS IN OFFICES

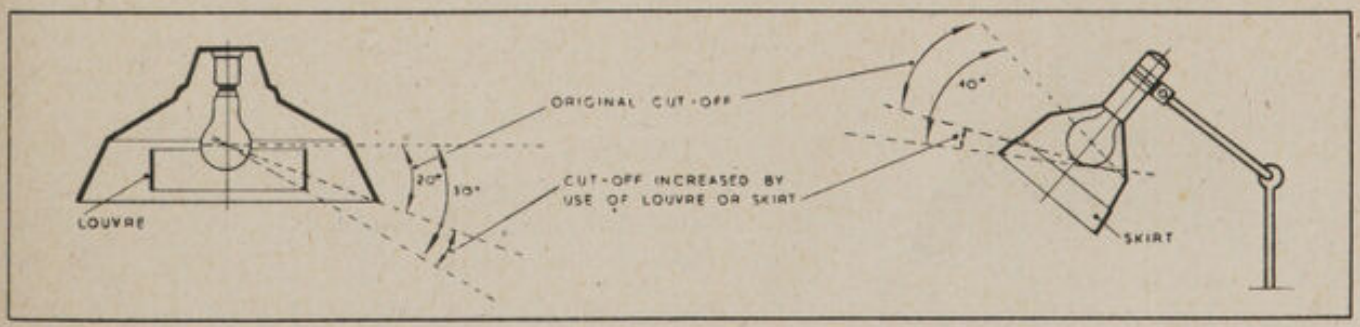


CUT-OFF ANGLE FOR LESS THAN FOUR FLUORESCENT LAMPS

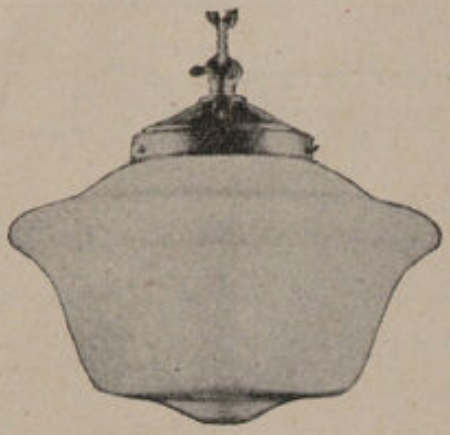


CUT-OFF ANGLE FOR 4 OR MORE FLUORESCENT LAMPS

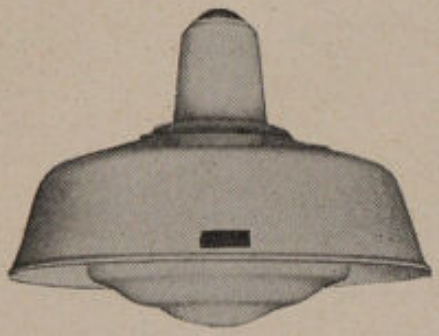
4. Adaptation Fittings for Existing Reflectors



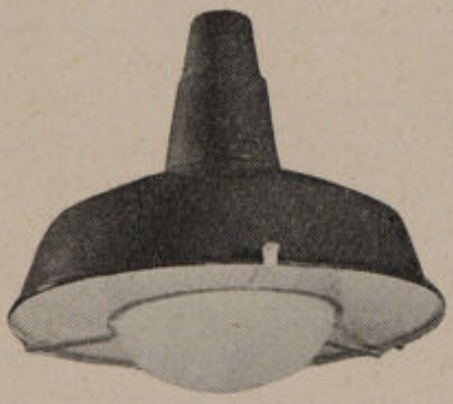
Where existing reflectors are unsuitable, it may not be necessary to scrap them. They may be equipped with louvres or skirts, designed to provide the cut-off required. Care should be taken in selecting adaptation fittings that the distribution of the light is not unduly restricted.



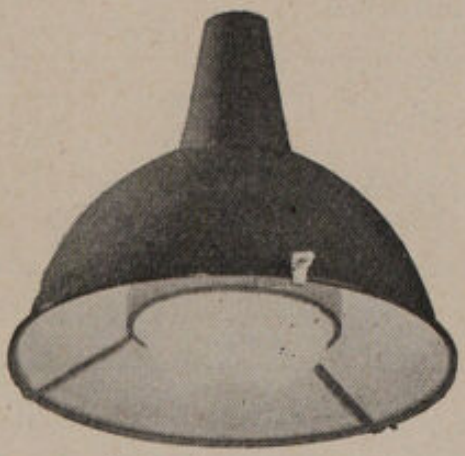
OPAL-GLASS ENCLOSING FITTING



GLASS-STEEL FITTING LARGELY CONCEALS BRIGHT GLASS



R. L. M. REFLECTOR FITTED WITH DIFFUSING DISH



DEEP-BOWL DISPERSIVE REFLECTOR FITTED WITH DIFFUSING DISH

C. How to Use Diffusing Fittings to Prevent Glare

Good lighting practice requires the use of diffusing fittings:

(a) In offices in which continuous clerical work is performed.

(b) In industry for work of a difficult nature; work requiring concentrated attention over long periods, such as work on shiny surfaces coming within the categories of fine or extra fine, and for which the minimum quantity of illumination prescribed is 15 foot-candles; for medium or rough work on polished materials where reflected glare is likely to result from the use of high-brightness light-sources in open reflectors.

Diffusing fittings are used in offices and industrial premises for higher-quality lighting than can be produced by open reflectors. Such fittings include glass-steel reflectors for high-quality industrial lighting, and opal-glass enclosing fittings, which are used in most offices and in some factories having lined, light-coloured ceilings and walls.

Most existing office installations have small, low-hung diffusing fittings spaced at from 10-feet to 16-feet centres. The 100- or 200-watt lamps frequently used usually provide inadequate lighting, and attempts are made to obtain more illumination by increasing the lamp size. This results in direct glare from the fitting because the area of diffusing glass is insufficient.

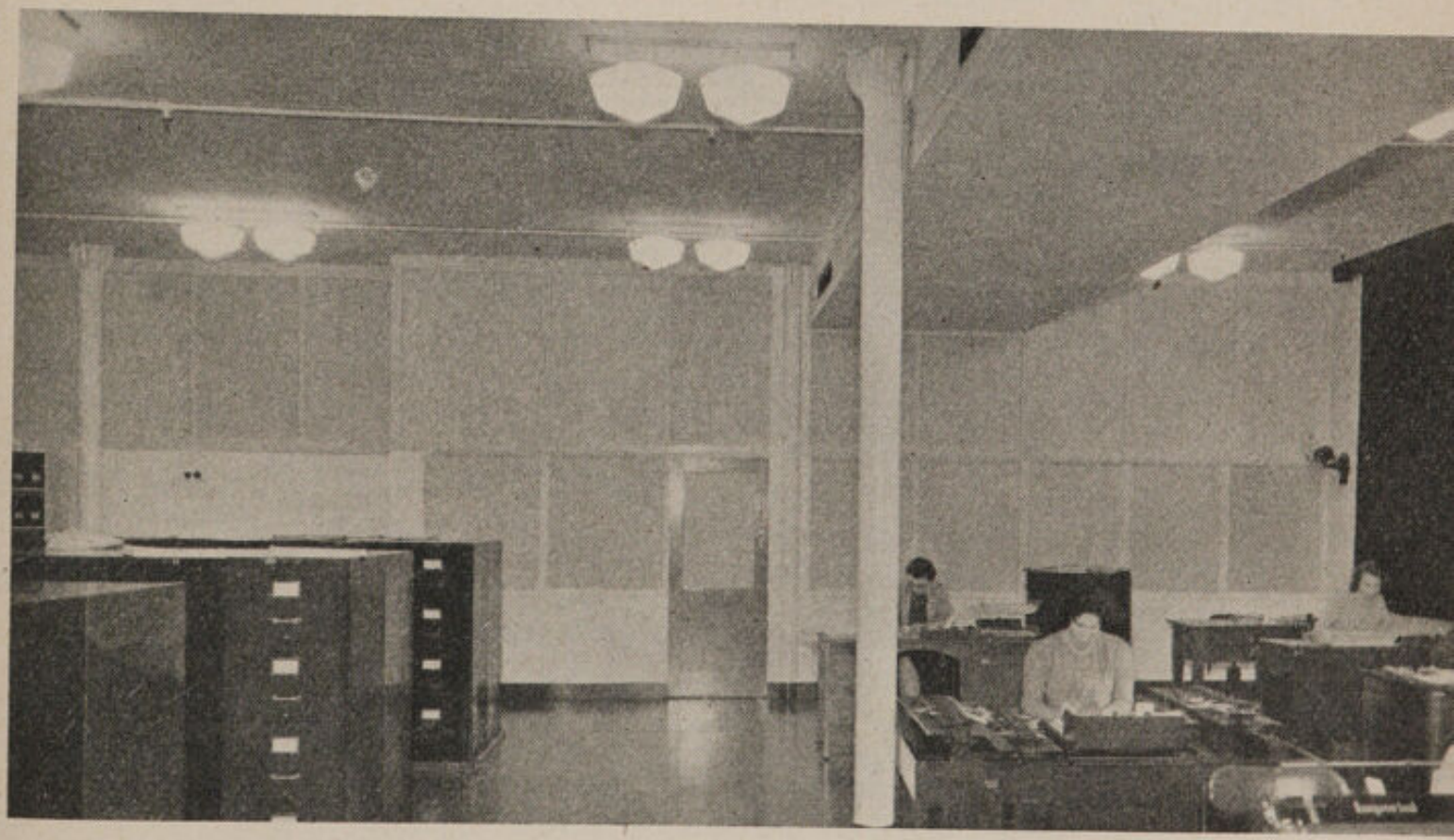
To prevent glare, an adequate area of diffusing surface must be used, thus keeping the brightness of the fittings within comfortable limits.

Table 4 shows, for various mounting heights, (a) comfortable limits of brightness that will avoid eye-strain where the difficulty of the work requires the use of diffusing fittings, and (b) the size of fitting needed to reduce brightness to within the limits shown. The brightness value given is the average number of lumens per square foot over the surface of the fitting when a new lamp is inserted. Not all parts of the fitting will be equally bright, but no part should be more than one-fifth brighter than the average. The limits given for initial brightness take account of the fact that brightness decreases during the service life of the lamp, and it is assumed that service brightness will average 70 per cent of the initial brightness.

Brightness values are shown for diffusing fittings and for glass-steel fittings. Because 80 per cent. of the side elevation of the diffusing portion of glass-steel fittings is screened by the reflector, brightness can be 75 per cent greater.

Glass-Steel Diffusion

Fig. 23. Sewing without eye-strain and without mistakes under 18 foot-candles of diffused lighting. The higher glass brightness of these 200-watt glass-steel fittings is acceptable, because the glass is screened by the reflector. Photo: *Forward Fashions, Melbourne, Vic.*



Office Lighting

Fig. 24. A 200-watt lamp in each 16-in. diffusing fitting gives 15 foot-candles of glareless lighting with brightness at a comfortable level. Photo: *State Electricity Commission, Melbourne, Vic.*

Adaptation Fittings for Diffused Lighting

To avoid scrapping unsuitable equipment, existing open-type reflectors should, wherever possible, be fitted with diffuser dishes designed to comply with the required brightness values.

D. Maintenance

The installation of a proper artificial lighting system in a factory will not result in satisfactory lighting conditions unless the installation is properly maintained. The principal causes of depreciation of lighting installations are (a) dirty reflectors; (b) darkened walls and ceilings; (c) unreplaced burnt-out lamps and over-aged lamps; (d) replacement of burnt-out lamps with others of inadequate size and (e) under-voltage burning of lamps.

Dirt is, however, the principal enemy of continued effective lighting. A recent example of the effects of poor maintenance was seen in a technical school in an industrial area where an excellent 18 foot-candle indirect lighting system was neglected. A survey resulted in the installation being listed as inadequate. Enquiries followed and one hour's work with dampened cloths restored the lighting from its depreciated level of 2 foot-candles. Dirt was wasting over 90 per cent of the lighting paid for.

TABLE 4

Requirements for Surface Brightness of Diffusing Fittings

Initial Values (New Lamps and Equipment)

Height above Floor to Centre of Fitting	Diffusing Fittings			Glass-Steel Fittings		
	Limit of Surface Brightness Lumens per sq. ft.	Opal-Glass Fittings within Brightness Limit		Limit of Surface Brightness Lumens per sq. ft.	Glass-Steel Fittings within Brightness Limit	
		Diameter	Lamp		Diameter	Lamp
Less than 9 ft.	714	14 in.	150 w.	1250	14 in.	200 w.
		16 in.	200 w.		16 in.	300 w.
9 ft. to 14 ft.	1143	14 in.	200 w.	2000	14 in.	300 w.
		16 in.	300 w.		16 in.	500 w.
		18 in.	500 w.		18 in.	750 w.
More than 14 ft.	1714	14 in.	300 w.	3000		
		16 in.	500 w.			
		18 in.	750 w.		18 in.	1000 w.

Note: 1. The limit of surface brightness shown is the average initial value obtained by taking an average of the maximum and minimum values on the fitting when observed from any point below a horizontal plane through the light centre.

2. In passages and spaces outside working-areas, unscreened inside-frosted lamps not exceeding 100 watts may be employed, provided they are not visible from working-areas.

3. The above limits of surface brightness apply equally to fluorescent lighting.

VI. FLUORESCENT LIGHTING

A. Development

ELECTRIC discharge lamps have an important future because they produce cool light for about one-third of the electricity consumption of incandescent lamps having the same light-output. The mains-voltage fluorescent lamp, which is the most modern source of electric discharge lighting, is still relatively new to industry, so that a brief review of its development may not be out of place.

Remarkable as have been the advances in lamp-efficiency during the past few decades (from a light-efficiency of 1.4 lumens per watt for Edison's first lamp, to 20 lumens per watt for the larger incandescent lamps of to-day), scientists have been well aware that their achievements fell far short of the theoretical efficiencies, which are 200 lumens per watt for white light and 620 lumens for the yellow-green light, to which the eye is most sensitive. These theoretical objectives are still impossible of achievement, but their existence shows the inefficiency of incandescent lamps despite manifold increases in light-output.

The basis of operation of the incandescent lamp (the emission of light because something is made white-hot), limits possible efficiency. The hotter the filament, the more light is emitted for the same wattage, but though the highest practical temperature has been attained by the use of tungsten, the best everyday lamps are still only 9 to 12 per cent efficient. The reason is that tungsten at melting point has a theoretical efficiency of only 40 lumens per watt, which is high by comparison with Edison's first lamp, but only 20 per cent of the possible efficiency.

B. Method of Operation

Scientists turned, therefore, to electric discharge lamps, which produce light not because something is made white-hot, but rather because a gas is excited electrically. They found, however, that although different gases emit different coloured light, colour is not effectively controlled by blending gases. The lamps used for street lighting (yellow light—sodium gas; blue-green light—mercury gas) are electric discharge lamps, producing three to five times the light-output of incandescent lamps of equal electricity consumption. These lamps are used in industry, but colour and flicker (stroboscopic) troubles limit their use.

Mercury discharge lamps, however, produce invisible ultra-violet light, normally absorbed by the glass, and, if required, most of the light-output can be emitted in this fashion. Fluorescent pigments used as an inside coating to the glass proved to be an effective means of changing this invisible emission into visible light. Thus was developed a modern discharge lamp which glows vividly with fluorescent light.

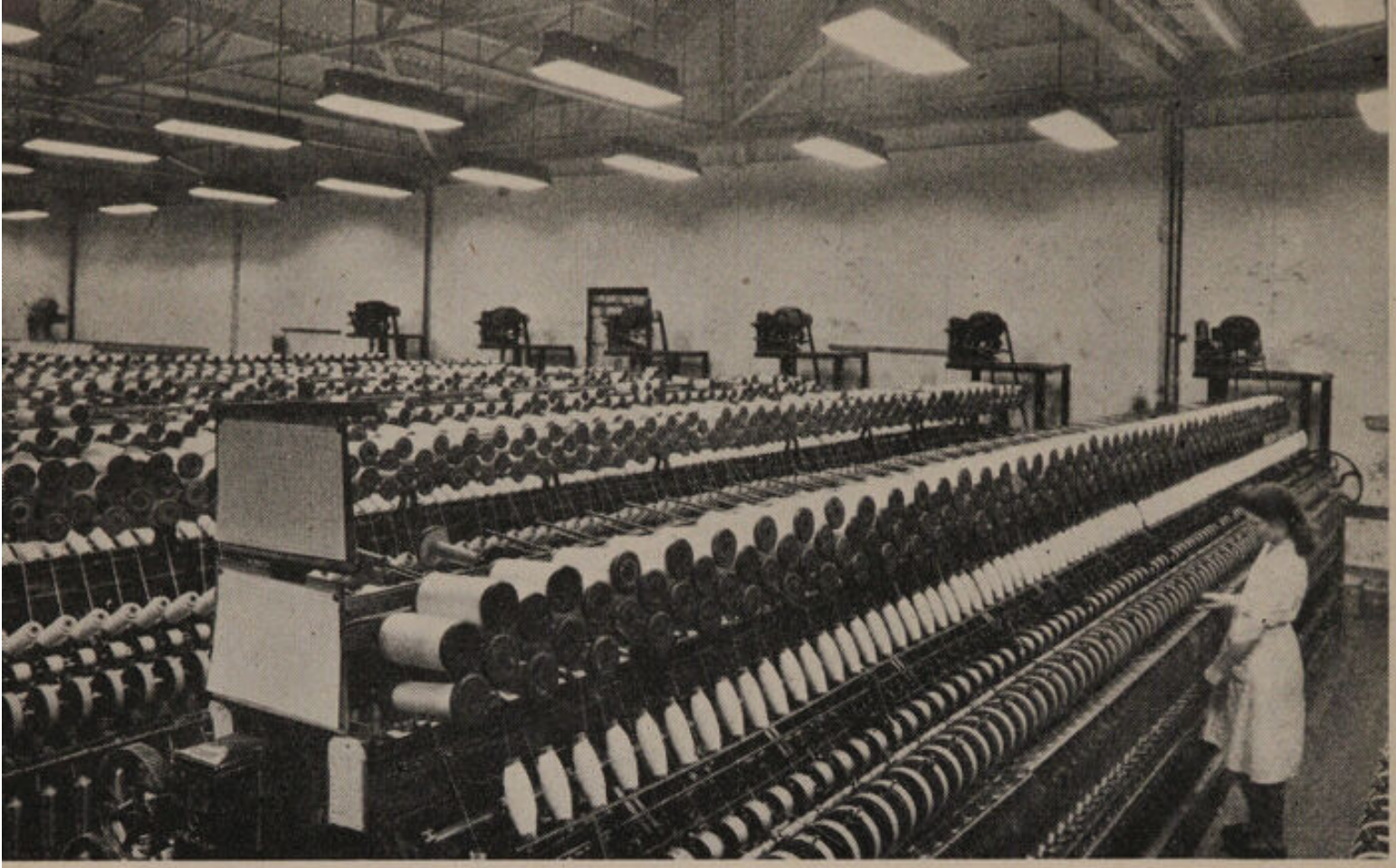
Two types of fluorescent lamps are available; namely, the cold-cathode tube, which requires a high voltage for operation, and the hot-cathode tube, which operates on a low voltage. Both types are connected to the mains supply through auxiliary equipment.

1. Hot-Cathode Lamps

Hot-cathode lamps are made as standard lamps in tubular form and have been used in millions in U.S.A. for the lighting of all types of industrial premises. Australian lamps are designed to conform to the latest American standards of performance as follows:

Wattage of Lamp	Overall Length	Lumens Output
20 watt	24 ins.	900
40 watt	48 ins.	2100
100 watt	80 ins.	4200

(Watts quoted are for lamps only: for total watts add losses in auxiliaries.)



Hot-Cathode Fluorescent Lighting in Textiles

Fig. 25. For these worsted spinning frames three two-lamp 40-watt fittings per bay mounted 10 ft. 10 in. high give 25 foot-candles of shadow-free lighting. Necessary adjustments can be seen at once. Photo: *Bentex Weaving Mills Pty. Ltd., Sydney, N.S.W.*

Hot-Cathode for Food Processing

Fig. 26. Inspecting and preparing parsnips can be done more rapidly in 20 foot-candles of glareless shadow-free lighting. The operatives are not subjected to radiant heat, as they would be if incandescent lighting were used. Photo: *W. C. Douglass Ltd., Sydney, N.S.W.*

2. Cold-Cathode Lighting

Considerable improvement has recently been made in the performance of cold-cathode tubes, which are now made to Commonwealth specification covering minimum performance and standardisation of equipment.

Individual Fittings (U-Tubes 4 ft. and 6 ft.)

Overall Length	Total Watts	Lumens (3500°K White)
4 ft.	65	1950
6 ft.	90	2700

Continuous Runs (Tube lengths 7 ft. 9 in. and 3ft. 9 in.)

	Total Watts	Lumens (3500°K White)
4 2-tube fittings each 8 ft. ...	450	13,500
3 2-tube fittings each 8 ft. ...	350	10,500
2 2-tube fittings each 8 ft. ...	235	7,050
1 2-tube fitting of 8 ft. ... and 1 2-tube fitting of 4 ft. ...	195	5,850
1 2-tube fitting of 8 ft. ...	125	3,750

All tubes are now rated at 80 milliamps.

(Watts quoted are for over-all consumption including auxiliaries. Lumens represent minimum initial specification values.)

3. Fluorescent Lighting is Cool Lighting

Fluorescent lamps produce cool lighting, which is a factor of particular importance in air-conditioned interiors and in factories that suffer from ventilation and heating problems.

The light-output of fluorescent lamps is produced by about one-third of the electrical energy required by incandescent lamps of the same light-output, and thus there is only one-third of the total heat emitted. Of this heat, about 50 per cent. is dissipated by convection currents in the air around the tubes, compared with only 10 per cent. dissipated in this way from incandescent lamps. Such heated air usually passes out of the ventilators and has little effect on the room temperature; the net result is that fluorescent lamps radiate slightly more than one-sixth of the heat of incandescent lamps of the same light-output.

4. Auxiliary Equipment

All fluorescent lamps are accompanied by auxiliary devices, usually built into the top of the fittings. These devices facilitate starting; they also limit the flow of current and thus bring the equipment within the requirements of electricity supply undertakings regarding power-factor. In the case of hot-cathode lamps, they are small in size and are gradually being simplified. The transformers used for cold-cathode tubes are somewhat more bulky. Simplified auxiliary devices for both types are in small-scale use overseas.

5. How Flicker is Overcome

One disadvantage of some fluorescent lamp installations is stroboscopic effect (flicker), which is not noticeable unless a book or other object is moved rapidly to and fro in the light. This difficulty has now been overcome in hot-cathode lamps by using two- or four-lamp fittings and twin-lamp auxiliary equipment to each pair of lamps. In electrical terms, this throws the light cycles of each pair of lamps out of phase and so almost eliminates the flicker.

C. High Quality of Fluorescent Lighting

Australian-made fluorescent lamps produce light that is a close approach to daylight. The standard wartime colour of light is 3500°K. A wide range of other colours is standard in U.S.A., but is not available in Australia at present. Some distortion of colours occurs, but it is so slight as to be unimportant except as it affects the appearance of certain perishable foodstuffs.

Tubular fluorescent lamps produce high-quality illumination because the comparatively low brightness per square inch of tube reduces direct and reflected glare to a minimum, while the long, tubular source directs light towards any object at many angles, thus softening shadows, penetrating crevices, and illuminating around curved surfaces and beneath obstructions.

D. Hot- and Cold-Cathode Compared

Although it is a matter of choice as to which of the two types of fluorescent lamps should be used in each of the numerous industrial applications, the following general summary of the principal advantages and disadvantages of each type should aid in selection. Buyers should carefully sort out the contentious matter of relative costs.

1. Hot-Cathode

Advantages

Higher lumens output per watt.

Standard lamp replacements available from many merchants.

Higher lumens output per foot.

Flicker (stroboscopic) effects almost eliminated by twin-lamp ballasts.

Disadvantages

Shorter lamp life (less than half of that of cold-cathode).

Lamp life further reduced by frequent switching on and off.

More components in auxiliary equipment, and usually heavier maintenance.

2. Cold-Cathode

Advantages

Long life (about twice that of hot-cathode).

Tube life not reduced by frequent starting.

Simple auxiliary equipment.

Disadvantages

Lower lumens output per watt and per foot.

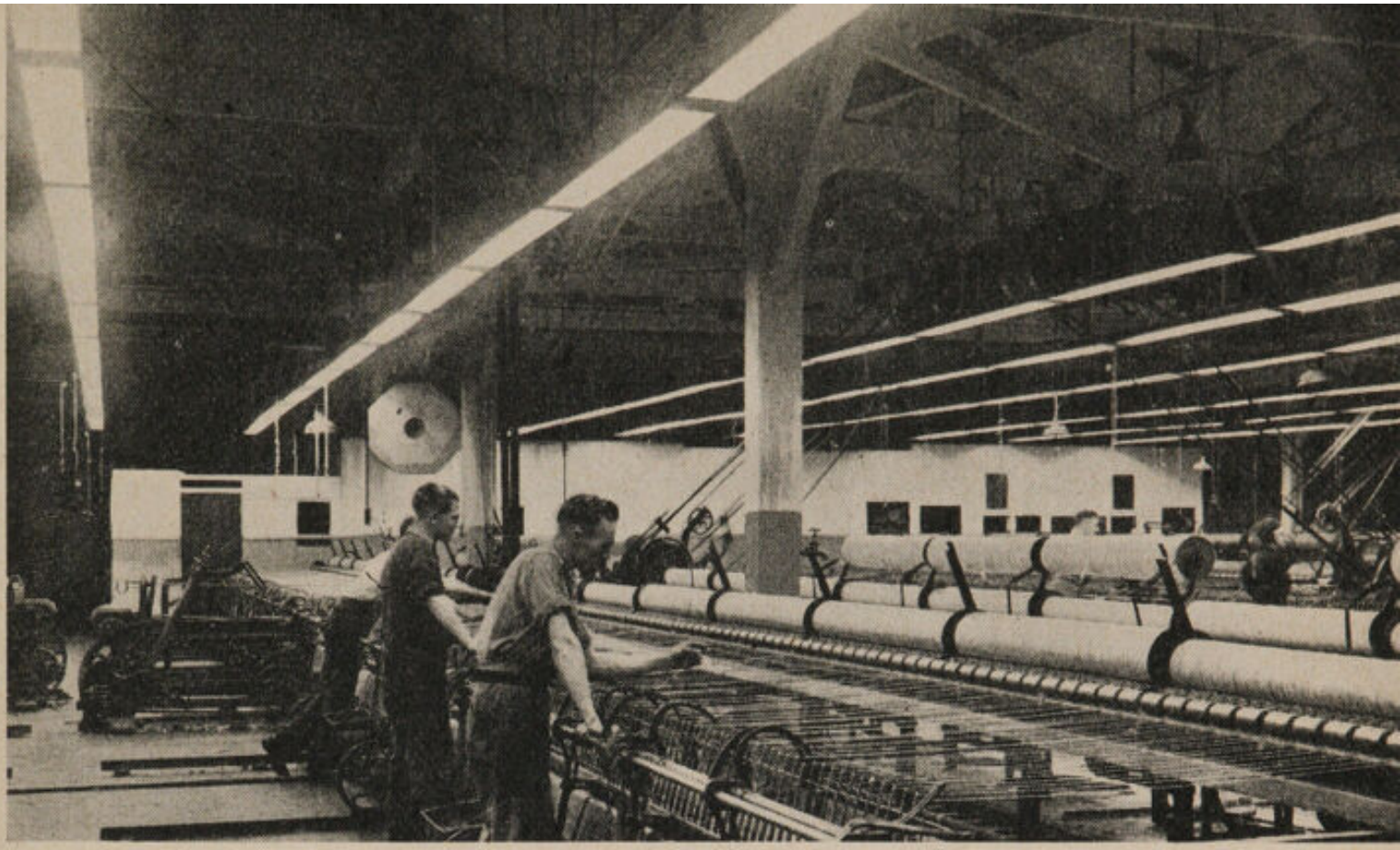
Slight flicker (stroboscopic) effect.

Tube replacements probably have to be obtained from original supplier.

Tubes operate at high voltage and need rather bulky transformers.

Generally, cold-cathode fluorescent lighting is excellent for high-quality supplementary or localised general lighting, and it is particularly effective when used in long runs above benches or machines.

The greater light-output of hot-cathode fluorescent tubes (four 40-watt tubes and four 100-watt tubes, respectively, approach the light-outputs of 500-watt and 1000-watt incandescent lamps) as compared with the cold-cathode variety, is such that they can be used in a reasonable size of fitting to produce a light-output suitable for general lighting or localised general lighting. The smaller-sized hot-cathode fluorescent lamps, i.e., 20 or 40 watt, are useful for supplementary lighting of tasks.



Cold-Cathode Lighting in Woollen Weaving

Fig. 27. The efficiency of these textile workers is increased by the installation of continuous rows of cold-cathode tubing, each 48 feet long, producing 15 foot-candles on the task. Rows are spaced 7 ft. 6 in. apart and 9 ft. high. Photo: *Dundas Woollen Mills, Sydney, N.S.W.*

Wool in its True Colours

Fig. 28. Grading wool according to fibre diameter, texture, and colour is a fine seeing task that requires good-quality light, shadowless and of daylight colour. This installation of 80-watt hot-cathode lighting closely reproduces daylight conditions. Photo: *Technical College, Melbourne, Vic.*

VII. NATURAL LIGHTING

SOFT, comfortable daylight is the most satisfactory and economical method of ensuring good seeing conditions in industrial buildings. There is, however, no single formula that can be used in designing buildings to ensure satisfactory natural lighting.

Design has been based largely on glass area as a percentage of floor area and, even on this basis, the ten per-cent standard often adopted has proved inadequate for buildings in which fine visual tasks are performed. Considerable research is now being undertaken on this subject and pending the issue of a code for the Natural Lighting of Buildings by the Standards Association of Australia, the following provisional standards are recommended.

A. Areas of Glass

Most Factories Acts require that in work-rooms the glass area should equal an absolute minimum of one-tenth of the floor area. However, to make the best use of daylight, most well-lit modern factories now provide a glass area equal to 20 or 30 per cent in roof lights and a still greater percentage for a combination of wall and roof lights.

In calculating the glass area of windows, the sill level should be assumed to be not lower than that of the working-plane (usually at about 3 ft. 3 in. from the floor) and any glass below that level should be disregarded. The glass area should receive as much unobstructed light from the sky as possible; if any external object of appreciable width extends above a line projected from sill level to 15° above the horizontal, it should be considered an obstruction, and the window area should be increased above the minimum to compensate for it. The heads of windows should be as near the ceiling as possible to ensure the maximum penetration of daylight into the rooms.

B. Avoidance of Glare

Direct sunlight inside work-rooms is warm and cheerful, but as workers usually cannot change their positions, it results in eye fatigue due to the high brightness of sunlit objects and the strong contrast between them and other objects in shadow. Windows in work-rooms should, therefore, preferably be planned to face south. In places where there is cold winter weather, windows on the east side or even the north side are reasonably satisfactory, provided that proper steps are taken to control and diffuse direct sunlight; light-coloured venetian blinds have proved particularly effective for this purpose, but light-coloured translucent blinds are also reasonably satisfactory.

Blinds that pull up from the bottom will often screen work-tasks near the windows from direct sunlight, without seriously reducing the penetration of daylight to the far side of the room from the tops of the windows. In using blinds to control lighting, care must be taken not to impair natural ventilation. Where it is important to get the benefit of breezes, use is made of blinds that are held out from the window at an angle.

Working-areas should be located relative to windows so that workers will face neither the light nor sunlit external surfaces. Diffusion of sunlight by means of figured glass is not the solution of the glare problem, as the glass becomes dazzling.

C. Adequacy of Light

It can generally be assumed that daylight will be inadequate at any place where the sky is not visible from the working-plane, or where the distance from the nearest window is greater than twice the height from floor level to the head of the window.

If in inner areas where natural lighting is poor or in working areas generally during overcast weather or dull winter afternoons, the natural illumination at any place where work is done is lower than the minimums set out in the "Australian Standard Code for the Interior Illumination of Buildings by Artificial Light," then artificial lighting should be used in accordance with the requirements of the Code.

D. Maintenance

Structural arrangements should be provided for cleaning windows and should give access to both sides of saw-tooth glazing. Ventilation systems should be planned so that fumes and smoke do not pass over the glass of windows. A regular cleaning schedule is also essential.

FOR FURTHER INFORMATION

Additional information on the subject-matter of this bulletin and most recent technical developments, the application of recommended practice to industrial factories and existing installations, and the availability of materials can be obtained from:

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MELBOURNE, VIC.
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