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Specification for photometric data for luminaires —

Part 1. Photometric measurements

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Co-operating organizations

The Illumination Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

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British Glass Industry Research Association
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Building Research Station (Department of the Environment)
Civil Aviation Authority
Council of British Manufacturers of Petroleum Equipment
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National Illumination Committee of Great Britain

This British Standard, having been approved by the Illumination Industry Standards Committee, was published under the authority of the Executive Board on 31 July 1975

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Foreword

This specification is being prepared to combine in a single standard all aspects of the photometric measurement and classification of luminaires. The standard will be issued in a number of separate parts of which this is the first.

This Part of the standard, published under the authority of the Illumination Industry Standards Committee, is mainly concerned with the basic photometry of single general-purpose luminaires and with laboratory conditions, procedures and instrumentation; it also includes sections on the measurement of luminance and illuminance. It has been aligned as closely as possible with the CIE* recommendation on the photometry of street lighting luminaires† and it is hoped that it will form the basis of a revision of the CIE recommendation on the photometry of interior tubular fluorescent luminaires‡. This part of the standard replaces the photometric procedures covered by appendices C to G of BS 3820 but covers a much wider field.

Part 2 of the standard will deal with the processing of the photometric data obtained from measurements made in accordance with the requirements of Part 1 and with the classification of luminaires according to their photometric properties. It will include calculations for both single luminaires and for arrays of luminaires; BZ, Glare Index System etc., and it will replace BS 398.

Further Parts of the standard will deal with the presentation of published photometric data and with field measurements on arrays of luminaires. There will also be parts dealing with the photometry of special purpose luminaires such as road lighting lanterns and flood lights.

The committee responsible for this standard will maintain a continuing close liaison with the work of Technical Committee 2.4 of the CIE during the preparation of all further parts of the standard.

This standard will not include photometric performance requirements for luminaires, for which reference should be made to the appropriate sections of Part 2 of BS 4533.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

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* Commission Internationale de l'Eclairage

† CIE Publication No 27

‡ CIE Publication No 24

British Standard Specification for

Photometric data for luminaires

Part 1. Photometric measurements

Section one. General

1. Scope

This standard specifies laboratory conditions, procedures and instrumentation for making photometric measurements on single general-purpose luminaires and details methods of measuring luminance and illuminance.

2. References

The titles of the British Standards referred to in this standard are listed on the inside back cover.

3. Definitions

For the purpose of this British Standard the definitions given in BS 4727 : Part 4 : Groups 01, 02 and 03 shall apply, together with the following.

3.1 **specified practical conditions.** The test conditions prescribed in section 2 of this standard.

3.2 **reference conditions (lamps).** The conditions under which lamp light output is measured in accordance with the provisions of the appropriate lamp British Standard.

3.3 **reference lamp.** A lamp complying with the appropriate British Standard and having electrical characteristics within 1% of the objective values of that standard. A reference lamp need not be of known (absolute) light output.

3.4 **reference ballast.** A special inductive-type ballast designed for the purpose of providing comparison standards for use in testing ballasts, and for the selection of reference lamps; it is essentially characterized by a stable voltage-to-current ratio, which is relatively uninfluenced by variations in current, temperature and the magnetic surroundings.

3.5 **practical ballast.** A ballast which is representative of the range of production ballasts appropriate to a particular luminaire and selected in accordance with the requirements of clause 16.

3.6 **ballast lumen factor.** The ratio of the light output of a reference lamp operated under reference conditions on a test ballast to the light output of the same lamp operated under the same conditions on the appropriate reference ballast. *Abbreviation:* BLF

3.7 **light output ratio.** The ratio of the light output of a luminaire measured under specified practical conditions to the sum of the individual light outputs of the lamps operating outside the luminaire under reference conditions but not necessarily using a reference ballast. *Abbreviation:* LOR

NOTE. See also appendix A

3.8 **light output ratio luminaire.** The ratio of the light output of a luminaire measured under specified practical conditions, with the lamp(s) connected to a practical ballast, to the sum of the individual light output(s) of the lamp(s) when operating outside the luminaire under reference conditions but with the same ballast(s). *Abbreviation:* LORL

NOTE. See also appendix A.

3.9 **light output ratio working.** The ratio of the light output of a luminaire measured under specified practical conditions, with the lamp(s) connected to a practical ballast, to the sum of the individual light outputs of the lamp(s) when operating outside the luminaire under reference conditions and with a reference ballast. *Abbreviation:* LORW

NOTE. See also appendix A.

3.10 **upward [downward] flux fraction.** The fraction of the total luminous flux of a luminaire emitted above [below] the horizontal plane containing the photometric centre of the luminaire. *Abbreviation:* UFF [DFF]

NOTE. Also known as upper [lower] flux fraction.

3.11 **upward [downward] light output ratio.** The product of the light output ratio of a luminaire and the upward [downward] flux fraction. The light output ratio may be the light output ratio luminaire or the light output ratio working as appropriate. *Abbreviations:* ULOR [DLOR] ; ULORL [DLORL] ; ULORW [DLORW]

3.12 **flux fraction ratio.** The ratio of the upward flux fraction of a luminaire to the downward flux fraction. *Abbreviation:* FFR

NOTE. The FFR is numerically equal to the ratio of the ULOR to the DLOR.

3.13 **photometric centre.** The point in a luminaire or lamp from which the inverse-square law operates most closely in the direction of maximum intensity.

3.14 **cut-off angle (of a luminaire).** The angle, measured from nadir in a given vertical half-plane, between the vertical axis and the line of sight at which all surfaces of high luminance (of lamps and of the luminaire) just ceased to be visible.

NOTE. The 'shielding angle' is complementary to the cut-off angle.

3.15 per thousand total lumens. Per thousand lumens of the aggregate light output of the lamp(s) used in the luminaire when each lamp is measured separately under reference conditions, but with a practical ballast where relevant

NOTE. Values 'per thousand total lumens' are expressed as cd/klm, lux/klm etc.

3.16 luminance (of a luminaire or of a lamp). The luminous intensity per unit projected luminous area in a given direction of a luminaire or of a lamp (or of a designated portion of either).

NOTE. For a complete definition of luminance see BS 4727, term no. 401 2015.

3.17 intensity distribution (of a luminaire or of a lamp). The variation of luminous intensity with direction.

3.18 absolute measurement. A measurement scaled in the appropriate SI units.

3.19 calibrated measurement. A measurement, usually of intensity, luminance or illuminance, scaled in SI units per thousand total lumens, as opposed to a measurement scaled in arbitary units.

3.20 bare lamp measurement. A measurement in which a lamp is photometered separately from a luminaire in order to determine a light output ratio or to calibrate a measurement made with the same lamp in the luminaire.

3.21 measurement in arbitary units. A measurement in units the constant of proportionality of which in relation to SI units or to SI units per thousand total lumens is either not known or is not required.

3.22 designed attitude. The attitude with respect to a horizontal plane, in which a luminaire is designed to operate (as determined by reference to the manufacturer's instructions or to common practice).

3.23 lighting design lumens. The light output of a given lamp type stated by the lamp manufacturer as most appropriate for lighting design purposes.

4. Units and terminology

Only SI units shall be used. The principal photometric units are:

lumen; candela; lux; cd/m^2 (nit)

For the purposes of this British Standard all photometric quantities should be quoted 'per thousand total lumens', e.g. luminance values should be in units of cd/m^2 per thousand total lumens. During measurements it is also possible to use arbitrary units, see **3.21** and appendix B. Only arbitrary values are required for the determination of ratios. However, measurements in arbitrary units shall meet the same requirements for linearity between quantities measured and quantities indicated as measurements in standard or absolute units.

Areas may be expressed in cm^2 if their expression in m^2 would be less convenient.

Angular degrees (not radians) are usually employed in photometry. The term 'light source' (or 'source') is used to refer both to lamps and to luminaires (and sometimes to surfaces which are luminous by reflected light, known as secondary sources).

The singular should be interpreted as including the plural where appropriate. Most of the text of this British Standard is phrased as if referring to a single-lamp luminaire: the term 'lamp' should be taken to mean 'lamp or lamps as appropriate'. The term 'discharge lamp' includes tubular fluorescent lamps where appropriate.

5. Photometric centre

The position of the photometric centre of a lamp or luminaire, see **3.13**, may be difficult to determine. To eliminate preliminary search and to standardize the mounting of lamps and luminaires, the photometric centre shall be determined in accordance with the following rules and with reference to figure 1:

(a) *Filament lamps, clear or lightly diffusing bulb.* At the centre of the solid figure bounded in outline by the filament.

(b) *Filament lamps, diffusing bulb.* At the centre of the diffusing portion of the lamp envelope.

(c) *Discharge lamps, straight-arc.* At the mid-point of the centre line of the arc discharge.

NOTE. This category includes straight fluorescent lamps, blended lamps and discharge lamps with diffusing or colour-correcting envelopes.

(d) *Discharge lamps, curved-arc.* At the centre of the plane figure formed in outline by the centre line of the arc discharge.

NOTE. This category includes U-limb sodium lamps, and circular and bent fluorescent lamps.

(e) *Lamps with an internal reflector.* At the centre of the plane figure formed in outline by the main opening of the reflector.

(f) *Luminaires with substantially opaque sides.* At the centre of the main luminaire opening (or diffusing/prismatic member across the opening) if the lamp compartment is substantially white or luminous: but at the lamp photometric centre if it is outside the plane of this opening, or if the lamp compartment is substantially black or non-luminous and there is no diffusing or prismatic member across the opening.

(g) *Luminaires with diffusing/prismatic sides.* At the centre of the solid figure bounded in outline by the luminous surfaces: but at the lamp photometric centre, if it is outside this solid figure.

(h) *Luminaires with transparent sides or without side members.* At the lamp photometric centre.

NOTE 1. The photometric centre of a lamp as determined above is not necessarily the same as the point determined by the light centre length and commonly differs from the point in a lamp from which luminaire cut-off angles are measured (see clause **6**).

NOTE 2. For a luminaire with two or more lamps (of approximately equal light output), the 'lamp photometric centre' is the geometric centre of the individual lamp photometric centres.

NOTE 3. For luminaires of special types (e.g. road lighting lanterns) more detailed rules may be specified in later parts of this standard, and take precedence over the general rules.

6. Cut-off angle reference point (lamps)

To standardize results, the line of sight for lamps shall be taken from a point determined in accordance with the following rules.

(a) *Lamps with clear or lightly diffusing envelope.* The lowest point of the filament or of the arc discharge.

(b) *Lamps with envelopes of high luminance.* The lowest point of the envelope.

7. Co-ordinate systems for luminaires

For photometric measurements involving direction, it is necessary to standardize a co-ordinate system (spatial framework). The same system may also be used with lamps. Other co-ordinate systems may be more convenient for a particular measuring instrument, but they must be capable of translation to the standard system.

The co-ordinate system is established by reference to a specified attitude of the luminaire which is usually the designed attitude stated by the manufacturer. In some instances it may be necessary to repeat measurements for different attitudes of the luminaire. The origin of the co-ordinate system is the photometric centre of the luminaire, see clause 5.

Various co-ordinate systems are in general use for different applications but the system described here is the most satisfactory for general purpose luminaires and measurements on such luminaires shall be expressed in terms of this system. Other systems may be specified for use with particular types of luminaires, e.g. floodlights, in later parts of this standard.

The following explanation of the co-ordinate system shall be interpreted with the aid of figure 2, which shows axes and planes for a rectangular oblong luminaire. The luminaire shall be mounted, or imagined to be mounted, in the designed attitude or other specified attitude if appropriate.

The vertical axis is the vertical line which passes through the photometric centre of the luminaire. The principal vertical plane is the vertical plane which contains the vertical axis and divides the luminaire in the most symmetrical way. If there are two such vertical planes of symmetry, the principal vertical plane is the one which contains the principal mechanical axis of the luminaire; this is usually referred to as the 'axial' plane and the vertical plane at right angles is then referred to as the 'transverse' plane.

One half of the transverse vertical plane, i.e. a portion all to one side of the vertical axis, shall be chosen and specified by reference to a mechanical feature of the luminaire. This is taken as the 0° half-plane of azimuth. Other half-planes are denoted by other angles of azimuth up to 360°, measured from the 0° half-plane anticlockwise as viewed from above the luminaire.

The vertical axis in the direction of the nadir is taken as the 0° direction of angles of elevation, which are measured up to 180° in a given vertical half-plane. It follows that any direction in space, e.g. the direction of an intensity vector, can be specified by two angles, one of azimuth and one of elevation.

These are referred to in CIE publications as the *C*-angle and the γ-angle respectively and the co-ordinate system is then known as the *C*-gamma (C-γ) system.

NOTE. It is strongly recommended that all photometric reports involving direction should include an outline sketch of the luminaire showing the relevant attitude and labelled with the principal axes and planes.

Section two. Laboratory conditions and procedures

8. General

The standard test conditions and measuring procedures described in this section apply in principle to all types of electric luminaire. More detailed requirements for individual photometric measurements are given in the appropriate later sections of this standard.

Reference should also be made to the relevant later part of this standard if a luminaire is of a special photometric type, e.g. a road-lighting lantern or a floodlight.

9. Laboratory measurements

For most types of luminaires calibrated measurements are not necessary. If calibration is included it shall be in SI units per thousand total lumens and not in absolute SI units unless otherwise specified. This method of calibration is referred to as the relative method of calibration (see appendix B).

9.1 Principal photometric measurements. The following are the principal photometric measurements made in the laboratory on a single luminaire.

(a) *Light output ratio (including LORL and LORW).* Requires measurement of the light output of the luminaire and of the bare lamp. May be determined with a photometric integrator, see section four, or may be derived from the calibrated measurements of intensity distribution on a goniophotometer, see section three. The standard measurement is LORL (see appendix A).

(b) *Intensity distribution (non-calibrated).* Measured on a goniophotometer (see section three). Does not require measurement of the bare lamp.

(c) *Intensity distribution (calibrated).* As for (b) but also requires measurement of the bare lamp. Alternatively, measured as for (b) but calibrated by means of LOR determined in a photometric integrator.

(d) *Luminance data.* See section six. Comprises a record of luminance distribution, as for intensity distribution. Luminance measurements of individual areas of a luminaire may also be made. Measurements may be in arbitrary units or may be calibrated.

Luminance may be measured with a luminance meter, or may be derived from intensity and projected luminous area in the specified direction.

(e) *Illuminance distribution.* Measured on a plane or on a series of planes in accordance with section seven. Measurements may be in arbitrary units or may be calibrated.

9.2 Subsidiary measurements. The following subsidiary measurements may also be required.

(a) *Correction factors.* See section five. These may be either measurement correction factors, or factors for modifying standard data to allow for non-standard service conditions. They may be determined with any of the apparatus used for the principal photometric measurements.

(b) *Ballast lumen factor.* See section five. This ballast characteristic (mainly applicable in type testing) is usually determined for ballasts supplied with luminaires. It may be determined with any of the apparatus used for the principal photometric measurements.

9.3 Derived values. Other photometric characteristics of luminaires may be derived from the principal and subsidiary measurements listed in clauses 9.1 and 9.2.

In particular, the upward and downward flux fractions (UFF and DFF) may be derived from either the calibrated or uncalibrated intensity distribution. The following characteristics may also be derived:

Flux fraction ratio (FFR) $= \frac{UFF}{DFF}$

Upward light output ratio (ULOR) = LOR × UFF

Downward light output ratio (DLOR) = LOR × DFF

Upward light output ratio luminaire (ULORL) = LORL × UFF

Downward light output ratio luminaire (DLORL) = LORL × DFF

Upward light output ratio working (ULORW) = LORW × UFF

Downward light output ratio working (DLORW) = LORW × DFF

Further stages of derivation relating to the BZ classification of luminaires and to utilization factors for standard rooms are covered in Part 2.

To derive published data for most luminaires it is sufficient to measure only intensity distribution, light output ratio and luminous area for Glare Index (see Part 2).

10. Laboratory facilities

The principal apparatus for photometric measurements of luminaires are a goniophotometer and a photometric integrator. Sections three and four include guidance on the construction and operation of goniophotometers and photometric integrators respectively.

The laboratory should be so arranged as to minimize the possibility of stray light affecting measurements. Provision should also be made for control of air temperature. If an air-handling system is installed it may also be advantageous to filter the air.

11. Status of measurements

It is not possible to assign confidence limits to photometric measurements of luminaires. Repeatability is inferior to that of electrical measurements. For example, careful repeat measurements of the light output ratio of a fluorescent lamp luminaire in the same laboratory may have spreads of up to ± 2 % about the mean value, partly due to variations in measuring conditions and partly due to variations in the luminaire itself. Wider spreads will occur over a production series due to individual difference between products.

Attention must be paid to reducing the effect of variables. The recommendations in this standard for conditions and procedures are based on a good commercial standard of photometry of luminaires for adoption by manufacturers, users and testing authorities.

Frequent checks should be made of the overall performance of the measuring apparatus. The following are examples of common sources of error in photometry:

(a) non-linearity of the photocell system;

(b) inadequate control of supply voltage and/or ambient temperature;

(c) in measurements with goniophotometers, mirror sag and variations in mirror reflectance.

12. Electric power supply and indicating instruments

Electric power supplies for operating lamps and luminaires in photometry shall meet the following requirements.

(a) A power supply shall be of ample current handling capacity for the loads to be connected. In particular the supply, including ancillary transformers, shall be of very low impedance.

(b) The harmonic content of the voltage waveform of an a.c. supply shall be as low as possible, and shall not exceed 3 % of the r.m.s. supply voltage. This requirement may however be relaxed if only filament lamp luminaires are to be measured.

NOTE. The harmonic content is the r.m.s. sum of the individual harmonic components; methods of harmonic analysis are described in BS 2818.

(c) Preferably, a power supply should hold a set voltage within close limits, so that it is only necessary to make fine adjustments by hand before taking photometric readings. A voltage stabilizer, if used, should be of a type that does not introduce waveform distortion. A suitable arrangement is a stabilizer followed by a transformer with a controlled primary and a secondary which can add/subtract up to approximately 10 % of the supply voltage, i.e. the buck/boost method of providing fine control.

Voltmeters, ammeters and wattmeters shall comply with the requirements for Class Index 0.5 specified in BS 89. Instruments for indicating r.m.s. values in circuits with waveform distortion shall be substantially free from error due to this distortion: preferably instruments should be of the electrodynamic type, though some moving-iron types may be satisfactory.

NOTE. The requirement in clauses **20**(f) and **21**(f) to hold the supply voltage to filament lamps within 0.2 % of a set value does not imply a voltmeter of greater accuracy than Class Index 0.5: the requirement is related to the reading precision of a voltmeter and not to its accuracy.

Since electrical indicating instruments, however well cared for, are liable to changes of accuracy with time, attention is drawn to the necessity for periodical checking at appropriate intervals.

All leads and connections shall be securely made, and of very low impedance.

13. Temperature control and indicating instruments

Changes in ambient temperature may have a marked effect on the photometric performance of fluorescent lamps and luminaires and may also affect other types of lamps and luminaires. Limits are prescribed in clauses **20** and **21** for ambient air temperature, and suitable arrangements shall therefore be made for its measurements and control.

Air temperature shall be measured by a thermometer of any convenient type (mercury-in-glass, thermocouple, thermistor) which is accurate within ± 0.5 °C. The thermometer should be enclosed in a metal housing polished on its outside surface so as to reflect radiation (and baffled, if necessary, to prevent reflected light reaching a photocell). Instruments and techniques shall generally be in accordance with BS 1041. BS 4533 : Section 1.12 includes guidance on the measurement of air temperature (and the temperatures of lamps, ballast and luminaires).

The air temperature in a photometric integrator shall be measured by a thermometer positioned near the centre of one of the side walls. The air temperature around a goniophotometer shall be determined from the mean of the readings of two diametrically opposed thermometers, each placed on a level with the photometric centre of the luminaire or lamp, at a distance of about 0.5 m. If the luminaire or lamp is translated in a vertical plane while being measured, the thermometers should be positioned on a level with the centre of rotation. Thermometers shall be similarly placed for other photometric measurements.

The operation of some types of photocell is affected by ambient air temperature. In such a case, air temperature shall be measured and controlled in accordance with clause **14**.

Attention is drawn to the necessity for periodical checking of all indicating instruments at appropriate intervals.

14. Photocells and associated apparatus

Reliability of the photocell and of its associated apparatus is of crucial importance in a photometric measuring system. Overall performance shall be checked initially in accordance with requirements (a) to (k) of this clause, and repeat checks at regular intervals shall be made to ensure that performance is kept within the required limits.

If a photocell is changed the new combination of photocell and associated apparatus shall be checked. Throughout this standard the term 'photocell' usually implies 'and associated apparatus'.

For the purposes of this standard, the readout need only be scaled in arbitrary units unless otherwise specified, see appendix B.

(a) The apparatus associated with the photocell e.g. potentiometer, amplifier, indicating instrument, shall be selected with attention to the performance of the combination. For example, with common photovoltaic photocells it is usual to employ a circuit of the Campbell-Freeth type or an operational amplifier so as to present zero impedance to the photocell. Methods of range changing, e.g. by a potentiometer with fixed positions, or of adjusting sensitivity shall not degrade performance.

(b) The photocell and associated apparatus shall respond promptly to a change in illuminance. They shall be stable when receiving a constant illuminance, during any one measuring sequence.

Response to a light source of stable output shall be checked at points throughout the measuring ranges, up to the maximum illuminance for which the photocell is suitable. The reading shall remain constant within ± 1 % for a period of at least one hour. This check shall be made with dark periods interposed between repeat readings to detect whether the photocell is unduly affected by long periods of light or darkness. Photocells shown by this test to exhibit excessive fatigue shall be discarded.

NOTE. For measurements by the relative method it is not necessary for a photocell to give the same readout indefinitely on each occasion that is is exposed to a given illuminance. In effect, the photocell is rescaled in each measuring sequence.

(c) Care shall be taken to avoid exposure of the photocell to an illuminance above the safe limit stated by the manufacturer. Stops, if used, or a calibrated neutral filter, shall reduce illuminance evenly over the whole sensitive surface. For an iris diaphragm, for example, this may be achieved by the insertion of a diffuser between the stop and the photocell. Each setting of a stop shall be located uniquely and held firmly. The operation of the stop shall not affect the 'view' of the photocell or of an attachment of the photocell e.g. for correcting for oblique light incidence. The effect of each stop position on the readout shall be shown separately for each measuring range.

(d) The readout shall not be unduly affected by differences of ambient air temperature. For example a selenium photovoltaic photocell can show a variation of output for a given illuminance of approximately minus 0.3 % per °C. As correction factors are not reliable, means shall be provided (if required) for controlling the air temperature in the vicinity of such a photocell within the following limits.

(1) Uncalibrated measurements. Air temperature to be held within ± 2 °C of any convenient objective value (preferably 25 °C).

(2) Light output ratio and calibrated measurements. As for (a); and the objective value shall be the same for the main measurement and for the calibrating measurement.

(e) The spectral sensitivity of the photocell shall closely follow the CIE photopic luminous efficiency function $V(\lambda)$* when the two curves are normalized at 555 nm. The difference between corresponding ordinates at any wavelength from 400 nm to 680 nm shall not exceed 5 % of the normalized ordinate at 555 nm. The requirement arises because a luminaire may modify spectrally the light of a lamp used in a calibrating measurement.

The initial check of spectral sensitivity is usually made by the manufacturer of the photocell. The user should check at intervals that there has been no significant change; a recommended method is described in appendix D. The photocell should first be checked in isolation. A second check should be carried out in such a way as to include any reflecting or transmitting media in the usual light path, e.g. of a goniophotometer or a photometric integrator.

(f) The response of the photocell to a given illuminance shall not vary significantly over the working range of angles of incidence. This requirement implies that common types of photocell will need correction if the photocell as installed receives light at angles of incidence greater than about 20 ° to the normal. Methods of correction are described in textbooks.

A check shall be made using a small light source at a distance. The measured value should vary only with the cosine of the angle of incidence. The error shall not exceed 1 % at angles of incidence within 20 ° to the normal or 5 % at any other angles at which the photocell is to be used. The photocell should first be checked in isolation. A second check should be carried out so as to include any reflecting or transmitting media in the usual light path. For further guidance on a test arrangement see BS 667.

(g) Each pair of successive measuring ranges shall be checked for inter-range consistency at a number of common points. No reading on the less sensitive range above 10 % of its full-scale value shall differ by more than 1 % from the corresponding reading on the more sensitive range.

(h) The photocell response shall be linear over its working range of illuminance.

A method of checking linearity is described in appendix C. The percentage non-linearity (as defined in the appendix) shall not exceed 1 % at any checkpoint within the usable portion of the scale (e.g. above 10 % of the full-scale value of the range). The check should be carried out so as to include any reflecting or transmitting media in the usual light path. Common types of photocell tend to show increasing nonlinearity with age, and it is particularly important that this check should be repeated at regular intervals.

(i) If automatic equipment is used for recording the readings of the photocell it shall be checked for dynamic errors. Examples of such errors are delays in recording a change in photocell signal, and a lack of response (a 'dead zone') to small changes. Provision should be made for rapid variation of the illuminance during the checks. These checks should be repeated at regular intervals. Where angle is recorded as well as illuminance, it is necessary to check also that there are no dynamic errors in recording the appropriate angle.

(j) It is recommended that a shutter be provided so that the photocell can be completely screened from light except during a measurement. Before the shutter is opened, a check shall be made for zero readout.

In some measuring instruments it may be useful to have adjustable baffles at the front of the photocell housing so as to restrict the view to the surround of the light source being measured, to avoid stray light. In some cases, it is necessary to be able to remove the photocell for visual checks and then to relocate it in the same position.

(k) A monitoring photocell (see appendix G) need not have correction for spectral response or oblique light incidence. It shall however be highly stable. An auxiliary photocell offers a means of checking that there is no variation other than in the quantity being measured, e.g. variation of intensity with angle.

15. Selection of luminaires for test

For the purposes of type testing, luminaires shall be selected which are representative of production luminaires.

Attention shall be paid to all features which may affect photometric performance. If a luminaire incorporates or is supplied with a ballast the requirements of clause 16 shall apply. Similar requirements shall apply to transformers for filament lamp luminaires.

* See table 1 of BS 4727 : Part 4 : Group 01.

16. Selection of ballasts for use with luminaires under test

Ballasts for type testing of luminaires shall be selected in accordance with requirements (a) to (d) of this clause. In the case of a luminaire with more than one ballast, the requirements apply to each ballast individually. For the purposes of this clause the term 'ballast' shall be taken to include components (such as capacitors) which may influence the light output of the lamp or luminaire.

Item (a) applies to the measurement of light output ratio working and items (b) to (d) apply to the measurement of light output ratio luminaire and to all other measurements requiring only the use of practical ballasts.

(a) *Measurement of light output ratio working (LOR W).* This measurement is usually made only for luminaires with the ballast(s) incorporated. Ballasts shall be representative of the range of production ballasts in setting (lamp power delivered under reference conditions) and in power loss. The ballast shall be positioned and fixed as in normal production.

(b) *Ballast supplied with the luminaire.* This requirement applies to ballasts incorporated in the luminaire or supplied with it for external operation.

The ballasts shall preferably meet the same requirements as for (a); the ballast setting however need only be within ± 5 % of representative setting, provided that the difference in power loss from that of a representative ballast has negligible effect on light output. For multi-lamp luminaires, the settings of the selected ballasts shall be the same. The ballast (if incorporated) shall be positioned and fixed as in normal production.

If the luminaire is offered with a choice of ballast type (e.g. switch start or starterless ballasts), and if there is an effect on light output, due to a difference in power loss or positioning, measurements shall be made and reported for each ballast type separately.

(c) *Ballast to be selected and operated externally.* This requirement applies where the ballast is not supplied with the luminaire and is to be selected by the user for external operation. Such a ballast selected for test purposes shall comply with the electrical requirements of the appropriate British Standard and shall be as typical as possible of ballasts likely to be used in service. The setting shall be as close as possible to unity.

(d) *Ballast to be selected and incorporated.* This requirement applies where the ballast is not supplied with the luminaire and is to be selected and incorporated by the user. A ballast shall be selected as for (c) above and shall be fitted in the luminaire. It shall be as typical as possible of ballasts likely to be used in service in respect of power loss, shape, and (if relevant) surface reflectance.

17. Selection of ballasts for bare lamp measurements

Ballasts for bare lamp measurements, i.e. as required in the determination of light output ratio working and light output ratio luminaire, and for measurements calibrated by reference to the lamps, shall be selected in accordance with the following requirements.

(a) *Measurement of light output ratio working (LOR W).* The ballast shall be a reference ballast as prescribed in the appropriate lamp or ballast British Standard. Alternatively, a selected production ballast may be used, provided that the lamp power delivered and the lamp current waveform are within the same tolerances as for the reference ballast.

(b) *Measurements other than of light output ratio working.* The ballast shall be the same as that used in measurements of the luminaire (see clause **16**). For multi-lamp luminaires each ballast shall be operated in conjunction with the appropriate lamp.

18. Selection and preparation of lamps for use with luminaires under test

Lamps selected as test lamps shall comply with the relevant British Standards (where applicable) and with the following requirements (a) to (d). If no British Standard is relevant, lamps shall comply with the manufacturer's specification.

(a) The dimensions and electrical characteristics of the lamp(s) shall be as close as possible to the nominal values and their power shall be within ± 2 % of nominal. Lamp caps and lamp bulbs shall be assembled as closely as possible on their nominal alignments. For the purposes of this standard, there is no requirement for test lamps to be of known (absolute) light output unless otherwise specified.

(b) Lamps shall be as free as possible from inhomogeneities. For example, low-pressure sodium lamps shall have an even distribution of sodium globules; lamps with phosphor coating shall be selected for uniformity of phosphor density. Tubular fluorescent lamps shall have no apparent end-blackening, and in the central plane normal to the lamp axis the intensity in any direction shall not differ by more than ± 3 % from the mean intensity.

(c) For measurement of multi-lamp luminaires for one type of lamp, the test lamps shall match as closely as possible in all respects, and in particular the light output of each lamp shall be within ± 2 % of the mean. Where lamps of dissimilar type are required, light output shall be in the same ratio as published lighting design lumen values.

(d) Wherever possible, tubular fluorescent lamps shall be 'daylight' (see BS 1853).

Test lamps shall be aged for at least the following periods, with occasional off periods during their ageing:

filament lamps : 100 h at rated voltage for lamps with nominal lives of 1000 h and above and pro rata for shorter life lamps;

discharge lamps : 100 h on a ballast complying with the relevant British Standard, operated at rated circuit voltage.

Lamps shall provisionally be regarded as stable and suitable for test purposes if, after thermal stabilization, the differences in light output between three successive readings at intervals of 15 min are less than 1 %. After this test lamps shall then be allowed to cool to room ambient temperature, and shall be reoperated. When the light output has become steady its value shall be within ± 2 % of the last of the three former readings. Such lamps may be taken as test lamps provided that they continue to meet requirements (a) to (c) above; repeat checks shall be made regularly.

It is recommended that test lamps be numbered and a note kept of operating hours to aid routine replacement.

19. Operation and handling of lamps

During successive bare lamp measurements, a test lamp shall be operated in a consistent position and with consistent electrical connections. To facilitate this, lamps should be suitably marked. As far as possible, lamps should be inserted in luminaires with consistency of electrical connection.

Special care is needed in handling low-pressure and high-pressure sodium lamps, mercury halide lamps and amalgam lamps. Such lamps should be moved and stored in the laboratory in the same attitude as that used in the bare lamp measurements. They shall not be moved while hot: this applies in particular to low-pressure sodium lamps so as to avoid redistribution of molten sodium. They shall also be moved carefully when cold. At all times when operating, lamps of these types shall be screened from draughts.

20. Standard measuring conditions for luminaires

To promote compatability between measuring stations, the conditions of photometric measurement of luminaires are standardized. As far as possible measurements shall be in accordance with all the requirements of this clause. If it is not possible to achieve a given condition, a measurement correction factor shall be applied - see section five - this is permissible for conditions (b), (d) and (g) only.

Where information is required of the characteristics of luminaires under service conditions, these data shall be provided in the form of service correction factors, each measured separately, to be applied to the values measured under standard conditions.

Correction factors (measurement and service) may be applied only if there is no variation in the pattern of intensity distribution (but only in total light output). Otherwise, it will be necessary to provide non-standard data suitably labelled.

Unless otherwise specified, the optical parts shall be clean.

The standard conditions for photometric measurements on luminaires are as follows.

(a) *Measuring location.* A luminaire shall be measured in surroundings so arranged that the photocell receives only light from the luminaire direct or with intended reflection.

(b) *Mounting attitude.* Unless otherwise specified, a luminaire shall be mounted and operated in its designed attitude. A luminaire may have more than one designed attitude and repeat measurements may be necessary if its photometric characteristics vary with attitude.

With some goniophotometers, the luminaire has to be photometered in an abnormal attitude; a series of measurement correction factors may be required.

(c) *Support.* A luminaire for suspended operation shall be supported in a manner representative of service conditions, but so as to cause minimum obstruction to light output. Supports are usually finished matt black (except in a photometric integrator). Luminaires for close-ceiling mounting (or for similar mounting on walls) shall be mounted on a standard mounting board as described in appendix E.

NOTE. Mounting arrangements for recessed and semi-recessed luminaires have not yet been standardized: for the present, these luminaires shall be treated as suspended luminaires.

(d) *Test lamps.* Test lamps for use in a luminaire shall be selected in accordance with clause **18**. As far as possible, test lamps shall be of standard type, and service correction factors shall be provided for lamps with differing total light output, e.g. amalgam fluorescent lamps (see section five).

(e) *Test ballasts.* Test ballasts for use with a luminaire shall be selected in accordance with clause **17**. If a ballast is for operation external to the luminaire, it shall be suspended in free air at approximately 25 °C.

(f) *Operating voltage.* The supply voltage to a luminaire shall be measured in accordance with the requirements of clause **12**, and shall be controlled within the following limits according to the luminaire type.

(1) *Luminaires for filament lamps (including blended lamps).* The objective voltage shall be within the range 90 % to 100 % of the lamp rated voltage (or transformer primary voltage, if applicable). During measurement the voltage shall be held within ± 0.2 % of the objective voltage, as indicated.

NOTE 1. A reduced objective voltage (preferably 95 % rated) is recommended, to improve consistency of lamp operation and to reduce the risk of lamp failure. This reduction does not apply to blended lamps or if the luminaire is strongly coloured.

NOTE 2. For measurements in absolute units, the objective voltage shall be the rated voltage.

(2) *Luminaires for discharge lamps (including fluorescent lamps).* The objective voltage shall be the rated circuit voltage of the luminaire. During measurement the voltage shall be held within ± 0.5 % of the objective voltage, as indicated.

(g) *Ambient air temperature.* The air temperature around a luminaire shall be measured in accordance with the requirements of clause 13 and shall be controlled within the following limits according to the luminaire type. During an extended measurement (e.g. with a goniophotometer) the temperature shall be controlled so as to vary as little as possible from its mean value.

(1) *Luminaires for filament lamps (including 'blended lamps').* The objective temperature (preferably 25 °C) shall be within the range 20 °C to 30 °C. During a set of measurements the temperature shall be within ± 5 °C of the objective.

(2) *Luminaires for fluorescent lamps.* The objective temperature shall be within the range 23 °C to 27 °C. During a set of measurements the temperature shall be within ± 1 °C of the objective.

(3) *Luminaires for other discharge lamps.* The objective temperature shall be within the range 23 °C to 27 °C. During a set of measurements the temperature shall be within ± 2 °C of the objective.

(h) *Air movement.* The air around a luminaire shall be as free as possible from draughts. There shall be no forced air movement. Air handling luminaires shall be stabilized and measured without forced air flow; service correction factors should be provided for selected air flow rates, as required.

If the safe operation of a luminaire requires air flow, it cannot be measured under standard conditions: data shall, therefore, be labelled with the condition chosen.

(i) *Circuit conditions.* Circuit conditions in a luminaire shall not be altered for purposes of measurement. In particular, any starter switch should be left in position.

21. Standard measuring conditions for bare lamps

For the purposes of this standard, bare lamp measurements are made in order to calibrate photometric measurements of luminaires in SI units per total lamp lumens; measurement of light output ratio is in principle similar. The conditions for a bare lamp measurement shall, therefore, be those prescribed in the relevant lamp British Standard for measurement of lamp light output except as otherwise specified in this clause. For a multi-lamp luminaire each lamp shall be photometered separately in a bare lamp measurement.

Preferably there shall be no deviation from standard measuring conditions. If a deviation is unavoidable, a measurement correction factor shall be applied; this is permissible for conditions (b) and (g) only.

Lamps shall be clean.

The standard conditions for photometric measurements on bare lamps are as follows:

(a) *Measuring location.* As for luminaires, see clause 20(a).

(b) *Mounting attitude.* The lamp shall be operated in the attitude prescribed in the relevant lamp British Standard for measurement of light output (or as prescribed by the lamp manufacturer if there is no relevant British Standard).

With some goniophotometers the lamp may have to be photometered in an abnormal attitude and a measurement correction factor may be required. It is preferable, however, to photometer the lamp by means of a single reading in its standard attitude, see 38.2.

(c) *Support.* The lamp shall be suspended in free air. The support shall hold the lamp securely but shall be such as to affect the measured values as little as possible.

(d) *Test lamp.* The test lamp shall be the identical lamp used in the measurement of the luminaire, see clause 20(d). If two lamps are interconnected (e.g. electrically in series), the second lamp shall be operated (baffled) under the same conditions as the lamp being photometered, see also clause 18(c).

(e) *Test ballast.* A test ballast for use in a bare lamp measurement shall be selected in accordance with the requirements of clause 17.

Except for measurement of light output ratio working, the ballast for the bare lamp measurement is the identical ballast used in the measurement of the luminaire; this difference from the standard conditions for lamp measurement in the appropriate lamp British Standard is allowed for by the determination of the ballast lumen factor (see appendix A).

All ballasts shall be operated separate from the lamp so that the one cannot affect the other thermally. A reference ballast shall be operated in air at approximately 25 °C. A ballast external to the luminaire (or a ballast incorporated by the user), shall be suspended in free air at a temperature of approximately 25 °C. A ballast supplied incorporated in the luminaire shall be operated still incorporated in the luminaire, which shall be suspended in free air at a temperature of approximately 25 °C; all lamps shall be removed and no other ballast circuit shall be operating.

The ballast is operated in the luminaire since there may be a designed magnetic link between the two.

(f) *Operating voltage.* The supply to the bare lamp circuit shall be measured in accordance with the requirements of clause 12 and shall be controlled within the following limits according to the lamp type.

(1) *Filament lamps (including 'blended' lamps).* The objective voltage shall be the objective voltage of the measurement of the luminaire. During measurement the voltage shall be held within 0.2 % of the objective voltage, as indicated. A lamp operated from a transformer (when in the luminaire) shall be operated at its rated voltage reduced by the same percentage as the supply voltage was reduced for measurement of the luminaire.

NOTE. The objective voltage may be below the lamp rated voltage (except as stated in clause 20(f). This difference from reference conditions is allowed for since the voltage is reduced to the same extent in the measurement of the luminaire.

(2) *Discharge lamps (including fluorescent lamps).* The objective voltage shall be the rated circuit voltage appropriate to the ballast in use. During measurements the voltage shall be held within ± 0.5 % of the objective voltage, as indicated.

(g) *Ambient air temperature.* The air temperature around the lamp shall be measured in accordance with the requirements of clause 13 and shall be controlled within the following limits according to the lamp type. During an extended measurement (e.g. with a goniophotometer) the temperature shall vary as little as possible from the mean value.

NOTE. The objective temperature is 25 °C in cases (b) and (c) for compatibility with the British Standard lamp specifications.

(1) *Filament lamps (including 'blended' lamps).* The objective temperature shall be within the range 20 °C to 30 °C. During measurement the temperature shall be within ± 5 °C of the objective.

(2) *Fluorescent lamps.* The objective temperature shall be 25 °C. During measurement the temperature shall be within ± 1 °C of the objective.

(3) *Other discharge lamps.* The objective temperature shall be 25 °C. During measurement the temperature shall be within ± 2 °C of the objective.

(h) *Air movement.* The air around a lamp shall be as free as possible from draughts; this is particularly important for fluorescent and for some discharge lamps.

(i) *Circuit conditions.* Circuit conditions for lamp measurement shall be as prescribed in the relevant lamp British Standard. If so required, a starter switch shall be removed after lamp starting, and the appropriate lamp contacts connected together.

22. Stabilization

Reported measurements shall not be made until the luminaire or lamp has stabilized photometrically. The measuring instruments also should be stabilized before use.

Check readings (e.g. of an intensity) should be taken at regular intervals such as every 5 min. The criterion for photometric stabilization is that the differences between successive regular readings at 15-min intervals are less than 1 %.

Before a check of stabilization is made, it is important that the supply voltage should be held as close as possible to the objective supply voltage. As apparent stabilization is reached, the voltage should be controlled as closely as during a measurement. At other times during stabilization the supply voltage should be held within ± 1 % of objective voltage, except that an increase up to 5 % above objective voltage is permitted at the beginning of the stabilization period.

The ambient temperature should be monitored at regular intervals during stabilization. During the later stages of stabilization of fluorescent and discharge lamps and luminaires the ambient temperature should be held as close as possible to objective temperature.

23. Measuring procedures

Luminaires and lamps shall be photometered under the standard measuring conditions prescribed in clauses 20 and 21 and in accordance with the requirements of the appropriate sections of this standard. Lamps shall be handled in accordance with the requirements of clause 19. Reported measurements shall not be made until stabilization has been achieved (see clause 22). A photocell shall be operated in accordance with clause 14; if necessary, the ambient temperature near a photocell shall be controlled. Before reported readings are taken, checks shall be made for stray light and for zero reading with the photocell covered.

During a reading, and for a preceding period that may affect results, supply voltage and ambient temperature shall be closely controlled in accordance with the requirements of clauses 20 and 21. If reactive circuits are being operated on an a.c. supply, a check shall also be made of supply frequency; reported measurements shall only be taken if the frequency is within ± 0.5 % of rated frequency during a reading, and for a preceding period that may affect results.

During an extended measurement (e.g. with a goniophotometer), regular checks should be made that stabilization is maintained (see clauses 14(k) and 22). At the end of the measurement (and regularly during a long series) a return should be made to the initial position (e.g. 0 ° in elevation with a goniophotometer) to check that the initial photometric reading is maintained within ± 1 %; this check is of particular importance.

Special requirements apply to multi-lamp luminaires, especially if the lamps make substantially unequal contribution to the light output of the luminaire. Reference should be made to 38.3 and 55.2.

If it is not possible to achieve a standard measuring condition, a measurement correction factor shall be determined in conjunction with the main measurement, see section five. It shall be applied to readings before they are used at any further stage in calculations. Where relevant, a ballast lumen factor should also be determined.

If a lamp or component affecting light output fails during a series of measurements, the series shall be repeated. Other components may be replaced without invalidation of previous readings, provided that readings are checked as repeating after restabilization.

The following requirements apply when a bare lamp measurement is made in conjunction with a measurement of a luminaire.

(a) The same supply voltmeter shall be used for the two measurements, and the supply voltage shall be controlled so that there is the same indication for the two measurements. This does not necessarily apply if a reference ballast or a transformer is used.

(b) The same photocell shall be used for the two measurements and, if applicable, shall be operated at the same ambient temperature.

24. Reporting of measurements

Measurements should be reported in a form suitable for processing into finished data for publication. Any relevant measurement correction factor shall be applied before reporting. Separate laboratory notes should be kept of details such as test lamp and test ballast. For filament lamps with clear bulbs, details should include filament type and light centre length.

It is important to attach to the measurements a full description of the luminaire, especially if it is available in several versions (e.g. number of lampways, choice of positions or attachments). Prototype luminaires should be distinguished from luminaires selected as representative of production. It should be made clear what was the attitude of the luminaire during measurement, and it should be clear how the co-ordinate system (e.g. angles of elevation and azimuth) is arranged in relation to the luminaire. The units of measurement should be quoted. If they are arbitrary units, the relation between units in the measurement of the luminaire and units in the measurement of the bare lamp should be stated. At this stage, readings are conveniently reported in tabular (rather than graphical) form. Readings may be to three significant figures, for later rounding for publication.

The following information should be added, where appropriate.

(a) The ballast lumen factor of a ballast should be quoted with measurements of light output ratio luminaire and calibrated photometric values.

(b) Service correction factors (if required).

Section three. Goniophotometers

25. General

The procedures described in this section apply in principle to all types of electric luminaire. Reference should also be made to the relevant later Part of this standard if a luminaire is of a special photometric type, e.g. a road lighting lantern or floodlight.

26. Purpose of goniophotometer

In the photometry of luminaires, a goniophotometer is principally used to measure the intensity of a luminaire in selected directions. The measurements may be used to derive photometric characteristics or may be transformed for publication in graphical form, such as a 'polar curve'. The curves may be uncalibrated (i.e. scaled in arbitrary units) or may be calibrated in cd per thousand total lumens. To obtain the derived photometric characteristics (see 9.3) only an uncalibrated record is needed.

A goniophotometer may also be used to measure the light output ratio of a luminaire. This requires measurement of the bare lamp and the luminaire in the same units. For measurement of light output ratio a goniophotometer and a photometric integrator, each complying with the requirements of this standard, should be regarded as of equal standing.

Alternatively, light output ratio may be found in a photometric integrator (see section four) and only an uncalibrated intensity distribution measured on the goniophotometer; this distribution may be calibrated via the light output ratio.

A goniophotometer may also be used in the determination of photometric factors, see section five, and in the measurement of luminance, see section six.

27. Construction

For the design of a goniophotometer, the principal objectives are to achieve an adequate optical path length in the space available and to maintain luminaires in their designed attitudes. It is also an advantage, for use during luminaire design, if the photocell position is readily accessible. These and other factors are discussed in more detail in appendix G; in table 1 various types of goniophotometer are listed together with some of their more important characteristics. See also figure 3.

A goniophotometer should be designed for ease of mounting of luminaires and lamps. It is an advantage if luminaires can be prestabilized and transferred to the mounting position without disconnection.

The number of angular positions for readings, where these are not continuously adjustable, will depend upon the types of luminaire to be measured; for guidance as to angular positions see clause 37.

28. Optical path length

Measurements of intensity shall be made at a distance such that the inverse square law applies within practical limits. It is generally accepted that the optical path length should be at least five times the largest luminous portion of any lightsource for which the goniophotometer is designed. If luminaires with concentrating distribution are to be measured, the optical path length should be at least fifteen times the critical dimension of the flashed portion, e.g. the height of the prism bank of a road lighting lantern.

29. General requirements

The goniophotometer shall comply with the following requirements which are in terms of a simple apparatus for measurements in the *C-γ* mode, see clause **7**, and shall be suitably transposed for other goniophotometers.

(a) The goniophotometer shall be capable of supporting the luminaire rigidly.

(b) The axis of rotation of the luminaire shall be vertical to within ± 0.5 °.

(c) The axis of rotation of the arm moving the mirror system or photocell shall be horizontal to within ± 0.5 °.

(d) The above two axes should intersect at the effective centre of rotation of the photocell. Any separation between these 2 axes shall not exceed 10 mm.

(e) The largest luminaire (or its image) that the goniophotometer is designed to measure shall be completely visible from every point of the sensitive surface of the photocell at all angles of elevation and azimuth and for types 4,6, 7, 8 and 9, (see table 2) at all distances of the photocell.

(f) Angles of elevation and azimuth shall be correctly indicated to within ± 0.5 °.

(g) The following requirements apply to luminaires which are moved while being measured. Movement of the luminaire shall be smooth, free from rocking and (where light output is affected by air temperature) sufficiently slow not to alter the air temperature within the luminaire.

In many goniophotometers, part of the luminaire support structure will cause obstruction to the light path. This obstruction should be minimized.

Reference should be made to section two for requirements in respect of the power supply and indicating instruments, circuit connections, and the control and measurement of temperature.

The requirements of section two in respect of photocells and associated apparatus shall be carefully observed. The photocell shall be spectrally corrected, since some luminaires may alter the spectral power distribution of the lamp. Correction for oblique light incidence is unlikely to be necessary.

30. Requirements for mirrors

All mirrors used in a goniophotometer shall be rigidly supported and held flat in all positions of rotation. They shall have a constant reflectance over their usable surface, as different areas of the mirror are used during measurements. For a method of checking see appendix F.

The spectral sensitivity of the combination of mirror and photocell normalized at 555 nm shall closely follow the standard CIE photopic luminous efficiency function $V(\lambda)$*, see **14**(e).

Checks shall be made for unacceptable errors introduced by mirrors, if any, of the following types.

(a) General non-flatness, e.g. due to sag.

(b) Local non-flatness, e.g. due to ripples in glass.

(c) Light scattering due to scratches.

(d) Variation of reflectance with wavelength.

(e) Variation of reflectance over the surface.

(f) Polarization (only of significance when making measurements on polarizing luminaires).

Unprotected front-surface silvered or aluminized mirrors are likely to deteriorate. It is recommended that they should have a protective coating, e.g. silicon monoxide.

31. Screening against stray light

Stray light reaching the photocell shall be minimized. The photocell shall be screened so that as far as possible it sees only the luminaire and, where appropriate, the lower surface of the standard mounting board. Where a mirror is used the photocell shall be screened to see only the image of the luminaire and so as not to receive light directly from any part of the luminaire itself. Any surface such as the edges of screens which are parallel with the photocell/luminaire axis, should be grooved, angled or chamfered to a sharp edge to minimize reflections onto the photocell. All surfaces that the photocell sees should be finished matt black, including the bevelled edges of mirrors. Screens should be arranged so that stray light from the luminaire only reaches the photocell after two or more reflections. Where this is not possible surfaces should be covered with black velvet, black carpet, etc.

All that part of the background to the luminaire which might be viewed by the photocell shall be matt black. This may include the floor and ceiling. The remainder of the room may be lighter coloured provided that precautions have been taken to eliminate stray light.

NOTE. Many 'matt' black paints have a luminance factor near the normal to the surface as high as 4 % and higher at glancing angles of incidence.

32. Checking the goniophotometer

A goniophotometer shall be checked for compliance with the requirements of clauses **29**, **30** and **31** Guidance in respect of commissioning is given in appendix F. Reference should also be made to section two.

The check of linearity of response of the photocell system shall be repeated regularly. Other checks need only be repeated at infrequent intervals.

33. Selection of lamps, ballasts, luminaires

The requirements of section two shall apply.

* See table 1 of BS 4727 : Part 4 : Group 01.

34. Mounting of the luminaire

The luminaire shall be mounted on the goniophotometer in its designed attitude (see clause 20). Its photometric centre shall be coincident with the effective centre of rotation of the photocell. Its orientation shall be correct with respect to the azimuth scale of the goniophotometer and to the azimuth reference of the luminaire (see clause 7).

A check shall be made that parts of the luminaire, e.g. diffusers, cannot move during measurement.

35. Mounting of the bare lamp

The bare lamp (the same as that used in the measurement of the luminaire) shall be mounted on the goniophotometer in accordance with the requirements of clause 21.

Its photometric centre shall be at the effective centre of rotation of the goniophotometer. The orientation shall be correct with respect to the azimuth scale of the goniophotometer and to the azimuth reference of the lamp. The latter may be determined by a principal mechanical feature, e.g. a filament gap, arc tube support etc. The lamp shall be correctly aligned. Some lamps, e.g. lamps fitted with bayonet caps, may require a modified lampholder to provide a sufficiently rigid support

36. Measuring conditions

The requirements of clauses 20, 21 and 22 shall apply.

If the optical path length is variable, it may be kept short in order to increase the photocell reading, provided that the requirements of clause 28 are met.

37. Measurement of luminaire

The requirements of clause 23 shall apply. Unless otherwise specified the C-γ co-ordinate system shall apply (see clause 7).

Readings of intensity shall be taken in a number of well-spaced directions. It is standard practice to take readings at intervals in vertical planes (or half-planes) which are themselves spaced at intervals in azimuth. It is advisable to make a trial run so as to find the location and rate of the maximum changes in intensity.

The following guidance refers to general-purpose luminaires; a greater number of readings may be required for special luminaires, e.g. road lighting lanterns.

Measurements shall be corrected for the effects of any obstruction due to supports or to the framework of the goniophotometer. This may require a temporary change in the attitude of the luminaire.

37.1 Spacing of measurements in azimuth. Intensity readings shall be taken in a series of vertical planes at intervals in azimuth.

The angular spacing in azimuth of the measuring planes for luminaires which are nominally symmetrical about a vertical axis shall be 45 ° or less.

Where a slight photometric asymmetry is present owing, for example, to obstruction by a lamp support or to a lamp filament not being a complete circle, one of the planes of measurement should pass through the element of asymmetry. This may require an extra plane of measurement; the mounting of the luminaire shall not be altered, and for preference the lampholder position should not be modified.

The angular spacing in azimuth of the measuring planes for other luminaires, e.g. a horizontal linear luminaire, shall be 30 ° or less. One of the measuring planes shall contain a principal horizontal axis of such a luminaire.

The number of planes may be fewer if it is known from previous experience with luminaires of a similar type that the results are the same as with measurements in more planes.

37.2 Spacing of measurements in elevation. For luminaires not having a concentrating distribution it is usually sufficient to take readings every 10 ° in elevation. For luminaires having a concentrating distribution readings shall be taken at least every 5 °.

Where zonal multipliers are to be used (see Part 2) readings shall be taken at 5 °, 15 °, 25 ° etc for 10 ° zones and at 2.5 °, 7.5 °, 12.5 ° etc for 5 ° zones respectively.

Where values between adjacent readings at the selected intervals are changing rapidly, it may be necessary to introduce additional readings. Further guidance on this point is given in later parts of this standard dealing with measurements of particular types of luminaires, e.g. road lighting lanterns and floodlighting luminaires.

A measurement at 0 ° elevation (or at 180 ° if the luminaire is supported from below) shall be included for each vertical plane, as a check that stabilization is maintained.

38. Measurement of bare lamp

The requirements of clause 23 shall apply.

Measurement of the bare lamp shall be made just prior to or immediately after measurement of the luminaire. Measurements of intensity shall be made in the same units as for the measurement of the luminaire. Either a complete measurement of the intensity distribution of the lamp may be made, or a simplified method used which relates the intensity in a selected direction to the light output of the lamp.

38.1 Complete measurement. Readings of intensity shall be taken in a number of directions. The procedure is analogous to that for measurement of the luminaire (see clause 37).

38.2 Simplified method. This requires a previously calibrated lamp. Most lamps if carefully handled maintain a nearly constant ratio of light output (A) to the luminous intensity in a selected direction (B). This ratio can be established during a complete measurement as in 38.1. For subsequent measurements, only the intensity in the selected direction is measured (C). The light output (D) of the bare lamp is then determined from the expression

$$D = C \times \frac{A}{B}$$

It is recommended that *B* and *C* are both measured in two directions and the mean value calculated. The directions chosen should be in regions where the intensity from the lamp is near the maximum but where the intensity does not change rapidly with direction. Measurements are usually made at 90° to the axis of the lamp, on opposite sides. If the intensity of the lamp changes rapidly with direction, multiple readings should be taken and averaged. The ratio A/B shall be checked regularly for all lamps except tubular fluorescent lamps.

NOTE. The ratio A/B for tubular fluorescent lamps is approximately 9.2 provided that it is measured at 90° to the horizontal axis of the lamp and that the optical path length is at least five times the lamp length.

38.3 Multi-lamp luminaires. In the case of a multi-lamp luminaire, it will be necessary to repeat the measurement for each lamp separately (where relevant, each on its appropriate ballast).

Particular care is needed if the lamps are of different types or are so arranged in the luminaire that they do not have equal effect on the total light output. The supply voltage in the bare lamp tests shall be adjusted so that the lamps have the same ratios of light output as the corresponding lighting design lumen values. These adjusted voltages shall be separately maintained when the lamps are operated together in the measurement of the luminaire.

39. Reporting of measurements

Measurements of intensity of a luminaire and of bare lamps where appropriate shall be reported in accordance with the requirements of clause 24. Measurements may conveniently be reported in the form of a table of intensities arrayed by angles of elevation and azimuth.

Section four. Photometric integrators for luminaires

40. General

This section covers the construction and operation of photometric integrators for luminaires and complements the information contained in BS 354.

The procedures described in this section for the determination of light output ratio (LOR) apply in principle to all types of electric luminaires. Reference should also be made to other relevant later parts of this standard if a luminaire is of a special photometric type, e.g. a road lighting lantern or a floodlight.

41. Purpose of photometric integrators

In the photometry of luminaires, a photometric integrator is principally used for determining light output ratio. The measurement of LOR with an integrator involves considerably fewer readings than measurement with a goniophotometer. In addition, a determination of LOR in an integrator makes it unnecessary to calibrate the readings of the goniophotometer with reference to the bare lamp. An integrator may also be used to find photometric factors, including a ballast lumen factor (see section five).

For most luminaires, the LOR values obtained by an integrator and a goniophotometer are of equal standing and should agree within the range of repeatability of either method. With a highly concentrating type of luminaire, a practical integrator may give a value of LOR a few percentage points different from the value which would be obtained in an integrator responding equally to light emitted in all directions.

NOTE. It is not recommended that an integrator be used directly for measurement of upward and downward light output ratios. The upward and downward flux fractions should be measured with a goniophotometer and multiplied by the LOR.

42. Construction

An integrator should be large and preferably spherical in shape but, owing to practical problems of constructing a large-size spherical integrator, it is usual to make an integrator of box-shape (for example see figure 5) which experience has shown to give satisfactory results. The text of this section relates to integrators of this shape.

An integrator shall be of adequate size relative to the largest luminaires for which it is to be employed. The length shall be at least 1.5 times the largest horizontal dimension to be accommodated, and the width and height shall be at least three times the corresponding largest dimensions; preferably they should be equal and each not less than 0.6 times the length. For example, an integrator for common types of luminaires for fluorescent lamps (up to 2.4 m long) would be 4 m in length and 2.5 m in width and height. All inside surfaces shall be smooth; preferably each join between adjacent surfaces should be covered with a small infill (see figure 5) and the eight inside corners should be smoothed over.

NOTE. Some authorities recommended large infills, to approximate to a sphere, but the merit of this construction is not generally agreed for integrators of practical size.

It should be possible to set up luminaires easily, without soiling the interior of the integrator. For example, an overhead track could be used, or the integrator could be in two portions which move apart from one another. It is usual to provide means for controlling the air temperature within the integrator, and this is a requirement in the case of luminaires and lamps with light output which is temperature sensitive. Rapid change of air temperature may be obtained by the use of an air handling system.

It is an advantage if the room in which the integrator is placed has a filtered air supply.

43. Reflecting surfaces

The interior surfaces of the integrator shall preferably be finished in accordance with BS 354 except that the (optional) black component in the paint should preferably not be included.

NOTE. The black component was introduced in BS 354 to reduce the effect of the absorption by the luminaire of inter-reflected light. Allowance is now made for absorption by the auxiliary lamp technique (see clause 49) and the reflectance should therefore be as great as possible in order to maximize inter-reflection and to minimize variations in surface luminance. The black component is however retained for spherical integrators used for absolute measurement of light output.

Other finishes are acceptable provided that they meet, and continue to meet, the same requirements of being substantially non-selective, (non-fluorescent if exposed to ultraviolet radiation), diffuse, and with high reflectance, e.g. over 0.85.

It is important that the reflecting surfaces should not be impaired by the method of cleaning. The finish shall be renewed regularly in accordance with checks made with a reflectometer (see BS 3900 : Part D2). As a guide, the average reflectance of each of the six surfaces should not be allowed to fall more than 10 % from its original value, and the average reflectance of any one surface should be within 5 % of that of any other surface.

44. Components inside an integrator

Supports inside the integrator shall present as little obstruction as is compatible with adequate strength for holding lamps, luminaires and other components in the specified positions. All exposed components (e.g. screens, baffles and wiring) shall be matt white in finish.

45. Air temperature measurement

Means shall be provided for measuring the interior air temperature in the integrator if used for measuring temperature-sensitive lamps and associated luminaires (see clause 13).

46. The test-patch

The illuminance at a selected part of the inside surface of the integrator, the test-patch, is proportional to the light output of a source when receiving only reflected light.

The test-patch shall be screened against direct light and shall be located at the centre of one of the end walls (see figure 5) and shall be as small as is compatible with adequate response of the photocell.

It shall be possible to view from the position of the test-patch, e.g. by removing the photocell housing, to check that the direct light screen fully intercepts direct light from the luminaire or lamp.

The illuminance at the test-patch shall be measured by one of the three following arrangements, of which the first two are the most common.

(a) The test-patch shall be a sharply-defined aperture leading to an auxiliary integrator with photocell (see figure 5).

NOTE. This arrangement has the advantages that response is independent of direction of light, that the aperture is not spectrally selective, and that its area can readily be varied (e.g. by an iris diaphragm) to control the illuminance at the photocell.

(b) A translucent diffusing plate (previously known as the window) is inserted at the location of the test-patch flush with the interior of the integrator, with the photocell immediately behind it. The plate shall be of non-selective diffusing material depolished on the surface facing into the integrator, and preferably on both surfaces. Suitable materials are opal glass flashed on both sides and some opal acrylics. Materials other than glass should be checked periodically, e.g. to check that spectral transmission has not altered.

Alternatively, a photocell with a flat diffusing cover to correct for oblique light incidence may meet the above requirements without a plate. The diffusing cover shall be flush with the interior of the integrator.

(c) The test-patch is viewed by a luminance meter. The test-patch is a small area of the reflecting surface, e.g. a circle of 100 mm diameter. The luminance meter is restricted to view only the test-patch, since a larger area may not be screened by the direct light screen.

47. Photocells and associated apparatus

Photocells and associated apparatus used with photometric integrators shall meet the requirements of clause 14 and shall be regularly checked in accordance with clause 14.

48. Direct light screen

A means shall be provided to screen the test-patch from direct light from all sizes of luminaires for which the integrator is designed. It shall be possible to position the screen and to hold it steady about half-way between the test-patch and the nearest part of the luminaire being measured. The finish of the screen shall meet the same requirements as those for the inside surfaces of the integrator, and should be renewed at least as frequently. The screen area should be as small as is necessary for each luminaire under test. In practice, screens of various sizes may be used or one screen adjusted in area so that, when viewed from any part of the test-patch, all luminous parts of the luminaire being measured are just screened. In this context, a luminous part is any part having a measurable luminance due solely to light emitted directly by the luminaire.

49. Auxiliary lamp

An auxiliary lamp shall be provided so that a correction can be made for absorption of inter-reflected light by the luminaire or lamp under test. It is recommended that the auxiliary lamp be a filament lamp and that it be positioned near the ceiling of the integrator. It shall be baffled so that no direct light can fall on the test-patch, the side of the screen facing the test-patch, or pass through space which could be occupied by a luminaire. Preferably the direct light should fall on the floor and lower walls of the integrator to simulate the direct distribution pattern of common types of luminaire.

For large luminaires, especially of the concentrating type, a group of recessed spotlights may provide the light distribution described above more readily than a single source.

Range switching can usually be avoided if the light output of the auxiliary lamp can be selected to be close to that expected for the luminaire.

A separate lamp should be used to provide working light inside the integrator, e.g. for mounting or cleaning.

50. Checking the integrator

Before the integrator is used, the measuring circuits associated with the photocell, the power supplies, and (if fitted) the temperature controls shall be carefully checked. An initial check shall also be made of overall performance in accordance with appendix H.

At regular intervals during service, the reflecting surfaces should be renewed (see clause 43) and the photocell should be checked in accordance with clause 14. From time to time, the value of light output ratio obtained for a given luminaire in the integrator should be compared with the value obtained on a goniophotometer which complies with the requirements of section three.

51. Selection of lamps, ballasts, luminaires

The requirements of section two shall apply.

52. Mounting the luminaire

The requirements of clause 20 shall apply.

The luminaire shall be positioned with its photometric centre (see clause 5) at the centre of the integrator. A concentrating luminaire shall not be aimed towards the test-patch but preferably at 90 ° away from it.

If the luminaire is linear in shape and is operated horizontally, it should be positioned parallel with the line from the centre of the integrator to the centre of the test-patch. External non-luminous surfaces of the luminaire, if large and not already white in finish, should be temporarily covered with white material which may be stood off the surface to reduce thermal effects. A check shall be made that the direct-light screen is securely fixed and just screens the luminaire and mounting board when viewed from any part of the test-patch. If the bare lamp is to be operated in an attitude different from its attitude in the luminaire, the direct light screen shall be adjusted so that it will also cover the bare lamp.

53. Mounting the bare lamp

The requirements of clause 21 shall apply.

The bare lamp shall be positioned with its photometric centre (see clause 5) at the centre of the integrator. If the lamp is operated horizontally, its axis shall be parallel with the line from the centre of the integrator to the centre of the test-patch. The direct-light screen shall be secured in the same position for measurements on the bare lamp as for measurements on the luminaire (see clause 52).

54. Measuring conditions

The requirements of clauses 20, 21 and 22 shall apply.

The supply voltage to the auxiliary lamp, to improve stability, should always be below the rated voltage, e.g. 0.95 times rated voltage. This voltage shall be held steady during measurements and shall be the same (within at most ± 0.2 %) for measurements with the bare lamp and with the luminaire.

55. Measuring procedure for light output ratio (LOR)

The requirements of clause 23 shall apply.

55.1 Single-lamp luminaires. To determine the LOR of a luminaire, the following measurements of light output shall be made, preferably but not necessarily in the order given in table 1.

Table 1. Determination of LOR of a luminaire

	Luminaire	Bare lamp	Auxiliary lamp	Reading (symbol)
(1)	In position. ON	(In luminaire)	OFF	*A*
(2)	In position. OFF	(In luminaire)	ON	*B*
(3)	-	ON	OFF	*C*
(4)	-	OFF	ON	*D*

The readings are in arbitrary units but shall be in the same units for (3) as for (1), and in the same units for (4) as for (2). Preferably it should be arranged that no change of measuring range is required. For example, for a single lamp luminaire overall sensitivity should be set so that the reading for (3) is near full-scale deflection.

A check shall be made that the value D is greater, but only slightly greater, than the value B.

The reported LOR of the luminaire shall be calculated from the formula:

$$\text{LOR} = \frac{A}{B} \div \frac{C}{D}, \text{ i.e. } \text{LOR} = \frac{A}{B} \times \frac{D}{C}$$

55.2 Multi-lamp luminaires. The LOR for a multi-lamp luminaire shall be measured in the same way as for a single-lamp luminaire. The bare lamp measurements (3) and (4) of table 1 shall be made separately for each lamp, leading to readings of C_1, C_2 . . . etc. and D_1, D_2 . . . etc.

The reported LOR of the luminaire shall be calculated from the formula:

$$\text{LOR} = \frac{A}{B} \div \left(\frac{C_1}{D_1} + \frac{C_2}{D_2} + \ldots \text{etc.}\right)$$

$$\text{i.e. LOR} = \frac{A}{B} \times \left(\frac{1}{\frac{C_1}{D_1} + \frac{C_2}{D_2} + \ldots \text{etc.}}\right)$$

Where the lamps are of different types or are so arranged that they do not have an equal effect on total output, each bare lamp shall, if necessary, have its supply voltage so adjusted that the values of C_1, C_2 . . . etc. are in the same ratio as the declared lighting design lumen outputs of the corresponding lamps. Each supply voltage shall be individually maintained for the same lamp when all lamps are operated together in measurements (1) and (2) of table 1.

56. Reporting of measurements

Measurements shall be reported in accordance with the requirements of clause 24.

Section five. Photometric factors

57. General

Photometric factors are of 3 types.

(a) *Measurement correction factors.*These apply when it is not possible to measure a luminaire or a bare lamp in the laboratory under standard test conditions. The measured values are corrected before the work is reported.

(b) *Service correction factors.* These apply when the service conditions differ from the standard test conditions. They are measured in the laboratory for subsequent use to allow for service conditions.

(c) *Ballast lumen factor.* This factor is to allow for the effect on light output of a luminaire of a practical ballast which does not deliver the same lamp power as the reference ballast.

58. Measurement correction factors

58.1 **Purpose.** These factors may be required to correct light output ratios or calibrated photometric values. They are not relevant for uncalibrated values, e.g. intensity distribution in arbitrary units, nor for dimensionless quantities not involving calibration. The following are examples of conditions for which measurement correction factors are required.

(a) When measurements have to be made at an ambient temperature different from 25 °C.

(b) When the mounting attitude is not standard. This arises with certain designs of goniophotometer, e.g. types 8 and 9 of appendix G, which require a series of correction factors during monitoring.

58.2 **Determination.** The requirements of clause 23 shall apply. To determine a measurement correction factor, one measurement shall be made under standard test conditions and a second corresponding measurement shall be made with a single variation (as appropriate) from the standard test conditions. These two measurements may be, for example, of intensity in a given direction or of total light output, or of illuminance at a give position. The correction factor is the ratio of the measurement under standard test conditions to the measurement under the varied condition.

59. Service correction factors

59.1 **Purpose.** These factors are determined in the laboratory so that light output ratios and calibrated photometric values may be corrected to allow for a service condition which differs from the standard conditions. As for measurement correction factors, service correction factors are not required for uncalibrated values. The following are examples of conditions for which service correction factors are required.

(a) When the ambient temperature in service differs from 25 °C.

(b) When the mounting attitude in service is different from the standard attitude and affects the photometric data.

(c) When the lamp to be used in the luminaire in service has light output versus temperature characteristics differing from those of the test lamp. For factors for amalgam lamps see appendix J.

(d) When air-handling luminaires are to be used in service at selected rates of air flow. The standard test condition is without forced air flow. See also clause 20(h).

(e) When the mean supply voltage in service differs from the rated voltage of the lamp or luminaire.

59.2 **Determination.** The requirements of clause 23 shall apply. A service correction factor shall be determined in the same way as a measurement correction factor (see 58.2) except that the ratio is reversed, i.e. it is the ratio of the measurement under the varied condition to the measurement under standard test conditions. Where there are two or more different service conditions each correction factor shall be determined separately.

60. Ballast lumen factor (BLF)

For definition of BLF see 3.6. Reference should also be made to appendices A and B.

A ballast lumen factor is mainly required for publication with other photometric data on a luminaire so that users may correct calibrated photometric values for ballast setting. LORL and derived quantities such as utilization factors (see Part 2) should also be so corrected. The factor does not apply to uncalibrated values nor to dimensionless quantities not involving calibration, e.g. flux fractions.

60.1 **Determination.** The requirements of clause 23 shall apply. The test lamp shall meet the requirements of clause 18. The reference ballast may, if necessary, be replaced with a selected production ballast (see clause 17(a)). Determination of BLF is usually associated with the type test of a luminaire with a particular ballast incorporated; if so, the test ballast shall be selected as for the measurement of LORW (see clause 16(a)) and shall remain in the luminaire (see clause 21(e)).

The test lamp shall be operated in turn on the test ballast and on the reference ballast under the standard measuring conditions for bare lamps prescribed in clause 21. A measurement of the light output of the test lamp, or of a proportional quantity such as an intensity, shall be made in turn for the two arrangements. The BLF is the ratio of the measurement with the test ballast to the measurement with the reference ballast.

Section six. Luminance measurements

61. General

This section standardizes procedures for making luminance measurements on a luminaire and covers the determination of cut-off angle.

62. Types of luminance measurement

One or both of the following types of luminance measurement may be required.

(a) The average luminance of the luminaire in a stated direction, or in a series of directions. The procedure is to measure intensity with a goniophotometer and to calculate luminance by dividing by projected luminous area. Areas of negligible contribution to the intensity in the specified direction shall not be included.

(b) The luminance of a stated luminous patch in a stated direction, usually part of a scan of the luminaire to find the maximum luminance in a stated direction; the scan may be repeated for other directions. The measurements may be made either with a goniophotometer or with a luminance meter. The patch shall be an orthogonally projected area of between 450 mm^2 and 550 mm^2, substantially circular or square.

NOTE. An area of this size is not necessarily suitable for detailed luminance mapping of a light source.

Both types of measurement may be calibrated (unit: cd/m^2 per thousand total lumens or uncalibrated if only a pattern of luminance distribution is required. Directions shall be identified as for measurement of intensity (see clause 7) with the origin of the co-ordinates at the photometric centre of the luminaire. If a luminous patch is measured from close range, directions shall be identified by translating the system of co-ordinates, without rotation, from the photometric centre of the luminaire to the centre of the patch.

Unless otherwise specified, the directions for both types of measurement, in azimuth and elevation, should be spaced approximately as for measurements of intensity, see section three.

63. Measuring apparatus

A luminance meter should preferably be of a type not requiring subjective judgement. It is an advantage if the meter forms an image of the part being measured, to assist aim. The relevant requirements of clause 14 shall apply.

The test plate required for the measurements of clause 66.1 shall be a white uniformly diffusing surface of stable reflectance; e.g. depolished pot-opal glass or a magnesium carbonate block. The angle of incidence shall be 0° to the normal to the surface, and the angle of view shall be 45° to the normal. The luminance factor for the two angles must be known. Alternatively, if the test plate is a pressed surface of barium sulphate or magnesium oxide or of smoked magnesium oxide, the value of the luminance factor may be taken as unity.

If the luminance meter is used for measurement in absolute units, its calibration shall be regularly checked. A lamp of known lumen output as measured under BS reference conditions will also be required. In some cases, a calibrated neutral filter may be required: comparison should be made with the methods described in clauses 71 and 74.

64. Selection of lamps, ballasts, luminaire

The requirements of section two shall apply.

65. Average luminance: measuring procedure

The requirements of clause 23 shall apply.

Intensity in the relevant directions shall be measured in accordance with section three.

For each direction the intensity shall be divided by the orthogonally projected area (m^2) of all the parts of the luminaire which emit light in that direction. Areas of negligible contribution to the intensity shall not be included. Figure 6 shows examples of projected width for typical fluorescent lamp luminaires viewed by the photocell transversely; in this view the projected length of the luminous part is equal to its actual length.

Certain luminaires are measured on standard mounting boards (see clause 20). If light reflected from the mounting board contributes to the intensity in the relevant direction, the appropriate parts of the ceiling board shall be included in the calculation of projected area, see figure 6.

66. Patch luminance: measuring procedure

The requirements of clause 23 shall apply.

A luminance meter shall be set so that the measured area is as specified for a luminous patch in clause 62. The distance between a patch and the entrance pupil of the luminance meter should be at least 100 mm. The luminaire shall be traversed by the meter, which shall be aimed in a constant direction. The meter may, however, be aimed at the photometric centre of the luminaire and swivelled if the distance is at least five times the luminous length being scanned. It may be necessary to scan the luminaire several times in order to include all the projected luminous area. Checks shall be made that initial measurements repeat.

66.1 Calibration. If calibrated readings of the luminance meter are required, the procedure shall be as specified in clause 74 for calibration of illuminance measurements by the bare lamp or by the luminaire.

The place of the illuminance meter is taken by the test plate specified in clause 63. The illuminance at the test plate is calculated in lux per thousand total lumens. The luminance in the measuring direction in cd/m² per thousand total lumens (see clause 62) is equal to this value multiplied by the appropriate luminance factor and divided by π.

If the luminance readings have been made directly in absolute units (see clause 62) the readings shall be changed to the standard form (cd/m² per thousand total lumens). The procedure is as specified in clause 74.

67. Patch luminance: alternative measuring procedure

The requirements of clause 23 shall apply. The procedure is similar to that of clause 65.

The goniophotometer shall be set for the relevant direction. A large mask finished matt black, and with an aperture of patch size (see clause 62 shall be inserted orthogonally in front of the luminaire. The luminaire shall then be traversed by the aperture, possibly several times in order to include all the projected luminous area. The luminance at any position is proportional to the intensity reading. Measurements of the mounting board (see clause 65) are not usually included. Care shall be taken that only light from the aperture reaches the photocell.

If calibrated results are required, comparison should be made with one value of intensity of the whole luminaire, calibrated in cd per thousand total lumens. The intensity of a patch is then known in cd per thousand total lumens and division by the area of the aperture in m² leads to luminance in cd/m² per thousand total lumens.

68. Reporting of luminance measurements

The requirements of clause 24 shall apply. Values and directions shall be reported in accordance with clause 62.

69. Determination of cut-off angle

Cut-off angle (see 3.14) is mainly determined for industrial luminaires with opaque reflectors, e.g. for 'high bay' lighting. The luminaire is assumed to be in its designed attitude. Cut-off angle is determined in a given vertical half-plane by measurement of the luminaire or from drawings. One typical half-plane is sufficient for rotationally symmetrical luminaires. For other luminaires, two half-planes at 90° are usually sufficient, and shall be suitably identified in reporting.

For measurement of angle, the reference point in lamps shall be as specified in clause 6. If there is more than one lamp, the apparent lowest point shall be taken. If an area of high luminance can be seen, when the luminaire is operating, below the reference point of the lamp, the lowest part of this area shall be taken as the reference point.

NOTE. It is not usually satisfactory to estimate cut-off angle from a record of intensity distribution or of luminance distribution.

Section seven. Luminaire measurements (single luminaire)

70. General

The direct illuminance from a luminaire is normally calculated using the inverse square law or by aspect factors or similar area source formulae where the luminaire is large compared with mounting heights typical of service conditions. Where a direct measurement is preferred or where the luminance of the luminaire is not uniform over the area facing the measuring plane, the procedure specified in this section shall be used.

Measurements of illuminance should be made at one or more mounting heights typical of service conditions. The mounting height is the vertical distance between the measuring plane and the photometric centre of the luminaire.

71. Measuring apparatus

Arrangements shall be made to ensure that the photocell receives only direct light. It is convenient to mount the photocell on a trolley, which may also have an adjustment for height. Co-ordinates of a measuring grid, usually rectangular, shall be set out from an origin vertically below the photometric centre of the luminaire, with a suitable orientation relative to the luminaire.

The photocell and associated apparatus shall comply with the requirements of clause 14. Special attention should be paid to correction for oblique light incidence. A lightmeter (illuminance meter) may be used, provided that it complies with the requirements of clause 14. If measurements are to be calibrated the photocell should preferably incorporate a calibrated neutral filter; the filter factor should be such that the calibrating measurement, with filter removed, falls within the range of measurements on the plane.

If calibrated measurements are made with a lightmeter scaled in absolute units, the lightmeter calibration should be checked regularly, in accordance with BS 667. It is also necessary to employ a lamp of known lumen output as measured under British Standard reference conditions.

72. Selection of lamps, ballasts, luminaire

The requirements of section two shall apply.

73. Measuring procedure

The requirements of clause 23 shall apply.

Measurements of illuminance shall be made at appropriate intervals on the measuring grid, and shall include checks that measurements repeat at the starting point.

Intermediate measurements shall be made wherever the difference in illuminance between any two adjacent positions is greater than about 20 % of the maximum. The area covered should include all positions having an illuminance greater than about 2 % of the maximum.

74. Calibration of measurements

Measurements are usually in arbitrary units, especially if the information is for deriving uniformity ratios (see Part 2). If calibration is required, it shall be in terms of the light of the bare lamp (see appendix B) in units of lux per thousand total lumens. Alternatively it is possible to calibrate measurements in the same units by means of the luminaire itself, provided that a calibrated intensity distribution (in cd per thousand total lumens) is available. Calibration by the luminaire is particularly suitable for a multi-lamp luminaire.

Measurements made in absolute units (see clause 71) shall be changed to the standard form, i.e. lux per thousand total lumens. This requires values to be divided by the lamp light output (per 1000 lumens) and, where applicable, by the ballast lumen factor (BLF) of the individual ballast employed in the measurement. (This should be distinguished from later multiplication of measured values by the BLF of the ballast type.)

74.1 Calibration by the bare lamp. The requirements of clause 23 shall apply.

A calibrated intensity distribution of the lamp in cd per thousand total lumens should be available. The ballast, where applicable, shall be as prescribed in clause 21. A measurement of the illuminance due to the lamp shall be made at a convenient distant position. The distance should be such that the inverse-square law applies (as determined by check: for this purpose, five times the largest luminous dimensions may not be adequate). If the distance is not adequate for the inverse-square law to apply, an appropriate area-source formula (e.g. with aspect factors) shall be used.

The photocell and associated apparatus should differ as little as possible for measurement of the luminaire and for the calibrating measurement. Differences in illuminance at the photosensitive surface may be reduced by the use of a filter (see clause 71).

From the calibrated intensity distribution of the lamp, illuminance for the relevant direction and distance shall be calculated.

The calibrated illuminance for the bare lamp shall be compared with the measured value in order to find the scale factor. This factor shall then be applied to the illuminance measurements made with the luminaire.

74.2 Calibration by the luminaire. The procedure is as for calibration by the bare lamp, but with the luminaire as calibrating source.

75. Reporting of measurements

The requirements of clause 24 shall apply.

Preferably the measurements should be reported in tabular form, with ·· ates related to measuring positions on a rectan ;rid; the orientation of the grid should be descri

The following dat be included:

(a) mounting hei;

(b) spacing of mc g positions,

(c) principal dim· s of the luminous area of the luminaire faci measuring plane.

Appendix A

Light output ratios of luminaires

There are three effects due to which the light output of a luminaire is different from that of its lamp(s) alone measured under reference conditions.

(a) Light absorption within the luminaire.

(b) Change in lamp light output due to change in operating temperatures.

(c) Difference between the lamp power delivered by the practical ballast and the lamp power delivered by the reference ballast.

The first two effects are taken into account in the determination of LORL, and all three effects are taken into account in the determination of LORW; these two ratios apply to luminaires for fluorescent and discharge lamps. Although the effect of change of operating temperature is taken into account in the determination of LOR for filament lamp luminaires, this effect is usually negligible.

NOTE. The ratio 'Optical LOR' refers to effect (a) alone. It represents the ratio of the light output of the luminaire to the instantaneous light output of the lamp. The ratio is not employed in this standard, since it is associated more with design work than with published data. Also, determination of this ratio for fluorescent and discharge lamp luminaires is difficult and may entail construction of simulated lamps.

Especial care has to be taken in measurement of LOR of luminaires incorporating (or for use with) a ballast, since practical ballasts do not necessarily deliver the same lamp power as reference ballasts; ballast specifications permit divergence up to approximately ± 10 % of objective power.

Ballast setting (power delivered to the lamp) is allowed for in the method of LORW, which represents LOR for working purposes, i.e. as required by the lighting engineer. It has not, however, proved possible to standardize on measurement of LORW, for the following reasons.

(1) Some luminaires require separate ballasts, which are selected by the user; these ballast characteristics cannot be taken into account during photometric measurements of the luminaire.

(2) Luminaires incorporating ballasts may be offered with a choice of ballast types, and ballast designs may be changed during the production of a luminaire.

For these reasons therefore the determination of LORL has been adopted internationally as the standard method of determining LOR. Published values should be in terms of LORL and should be so annotated; if LOR is quoted without qualification the user should assume that LORL is implied. Values of LORL of luminaires incorporating ballasts should be accompanied by a statement of BLF (see section five) for the ballast as a type. BLF should also be quoted by ballast manufacturers for ballast types for use separate from luminaires, e.g. in road lighting columns.

It is necessary for users of published photometric data to multiply LORL by the appropriate BLF to obtain LOR for working purposes. Quantities derived from LORL (e.g. DLORL and utilization factors) should also be so multiplied. In instances where LORW is quoted, the appropriate BLF has already been taken into account in the method of measurement.

The definition of LOR is intentionally worded to cover both methods of measurement, i.e. it is compatible with either the practical ballast or a reference ballast being used in the bare lamp measurement. If a practical ballast delivers objective lamp power (i.e. BLF is unity) the values of LORW and LORL are equal. The basic relationship is

$$\text{actual luminaire output} = \text{actual lamp output (reference ballast)} \times \frac{K_1 \times \text{luminaire output}}{K_2 \times \text{lamp output (practical ballast)}} \times \frac{K_1 \times \text{lamp output (practical ballast)}}{K_2 \times \text{lamp output (reference ballast)}}$$

where K_1 and K_2 are scale factors of the measuring system, see appendix B.

The second term on the right-hand side is LORL and the third term is BLF. The relation does not require the same lamp for all three terms; provided that lamps are of the same type. For any one practical ballast LORL X BLF = LORW. The relation holds for two different ballasts, e.g. a test ballast and an average production ballast, provided that they are of the same type.

There is no lumen factor for transformers for filament lamp luminaires. Power delivered is allowed for in the method of measurement, see clause 21(f).

Appendix B

Calibration of measurements

For the general purposes of this British Standard, measurements are not made in absolute units. This would require test lamps of known output, as well as photocells calibrated in absolute units.

For many purposes in photometry, calibrated results also are not needed. For example, an intensity distribution may be in arbitrary units if only the shape of the distribution curve is needed. Also, arbitrary units are suitable for the determination of ratios. Arbitrary units are however subject to the usual requirements for linearity within any one range, and between ranges.

When calibration is needed, e.g. of intensity, luminance or illuminance, the standard method is the 'relative method of calibration'. This method involves a measurement of the bare lamp under reference conditions, as well as the measurement of the luminaire. The latter is then expressed in terms of the former, and the units of measurement are SI units per thousand total lumens. In effect, a lamp of 1000 lumen output is used, and an adjustment is made by users of photometric information for the actual light output published for the lamp. For a multi-lamp luminaire, the aggregate of the light output of the lamps, each measured under reference conditions, is equated to 1000 lumens. This method of expressing results as a ratio allows for all photometric measurements from which they are derived to be made in arbitrary units because, provided that the same measuring instrument is used for measuring the output of the luminaire and of the bare lamp, the scale factor of the instrument will cancel. Measuring errors also tend to cancel.

A measurement of LOR is similar to a measurement calibrated by the relative method, in that it entails comparison with the bare lamp (see appendix A). Measurements which involve calibration may either be calibrated against the bare lamp, or alternatively may be made in arbitrary units and calibrated by a measurement of LOR made separately.

In the calibrating measurement of the bare lamp, it is standard practice to introduce one variation from reference conditions, if a luminaire incorporates, or is for use with, a ballast. The ballast used in the luminaire measurement is used in the bare lamp measurement, in place of a reference ballast. The reason for this variation is as for the adoption of LORL (see appendix A) and a similar correction has to be made by means of BLF: see also section five. Unless otherwise stated, users of photometric information should assume that calibration has been with the practical ballast, and should multiply calibrated values by the appropriate BLF.

The basic relation, corresponding to that quoted in appendix A, is

$$\text{actual value (e.g. intensity)} = \frac{\text{actual lamp output (reference ballast)}}{1000}$$

$$\times \frac{K_1 \times \text{measured value} \times 1000}{K_2 \times \text{lamp output (practical ballast)}}$$

$$\times \frac{K_1 \times \text{lamp output (practical ballast)}}{K_2 \times \text{lamp output (reference ballast)}}$$

where K_1 and K_2 are scale factors of the measuring system.

On the right-hand side, the second term is the value (e.g. intensity) per thousand total lumens, and the third term is BLF.

Appendix C

Check of photocell linearity

A recommended method of checking photocell linearity as prescribed in clause **14** is the 'multiple source summation' method in which the photocell is illuminated in turn by a number of individual light sources and then by combinations of these light sources. For a linear system the reading for any combination of light sources must equal the sum of the readings of each of the individual light sources in that combination.

One convenient form of apparatus consists of a housing containing five filament lamps of the same type and wattage, each baffled from the others and covered by a shutter. The shutters permit the photocell to be illuminated either by individual lamps or by combinations of them. All the lamps are operated simultaneously at a voltage controlled to within ± 0.1 % of a convenient value. (The objective voltage may be altered for each measuring range being checked).

The procedure is as follows: Expose each of the lamps 1 to 5 individually and record the readings. Combinations of the lamps (e.g. 1 plus 2; then 1 plus 2 plus 3 etc.) are then exposed and the readings are compared with the sum of the individual readings of the same lamps. This checks for linearity at approximately equally spaced points over a range of illuminances on the photocell up to the illuminance of all the lamps exposed together. Before taking each set of readings a check must be made that there is zero indication with all lamps on but all shutters closed.

It is recommended that the sensitivity should be adjusted so that the reading is just below full-scale deflection with all lamps exposed. Additional points at the lower end of the scale may be checked by arranging for the indication of all-lamp output to occur at approximately half-scale. By adjustment of voltage and suitable choice of lamp rated wattage, the check can be made to cover the spread of illuminances at the photocell during laboratory work. Each range of the photocell system should be checked, and allowances should be made for diaphragms and calibrated filters.

NOTE. Lamps of high power may give rise to problems of heat dissipation and may require an inconveniently large housing: the use of reflector lamps should be considered.

The percentage non-linearity at each check point shall be evaluated in accordance with the formula:

$$\text{percentage non-linearity} = \frac{A - B}{B} \times 100$$

where

A is the reading with the appropriate number of lamps exposed together;

B is the sum of the individual readings of the corresponding lamps.

Appendix D

Check of photocell spectral response

Following an initial check that photocells meet the requirements of clause 14(e), further periodic checks are required to ensure that there has been no shift in their spectral response. This may be conveniently done by measuring with the photocell the luminous transmittances of three stable colour filters blue, green and red. The relative transmittances can then be expressed in terms of three ratios (e.g. red transmittance to blue transmittance). The three ratios should be measured initially and subsequently at intervals: if any ratio changes by more than 2 % from its initial value, a more detailed investigation should be made.

Conditions of measurement should be standardized. The light source should be a filament lamp operated at the same colour temperature (e.g. 285 6K) on each occasion. The illuminances at the photocell should be arranged to be in a linear portion of its operating range, and to be typical of illuminances occurring during laboratory work.

The following filters have been found to be satisfactory for this purpose, but others with similar characteristics may be suitable.

Blue filter:	Corning Colour Specification No CS1-62, Glass No 5900 or Schott Type BG28, 1 mm thick
Green filter:	Corning Colour Specification No CS4-64, Glass No 4010 or Schott Type VG6, 1 mm thick
Red filter:	Corning Colour Specification No CS2-61, Glass No 2412 or Schott Type RG1, 3 mm thick

NOTE. 1 The thickness of the Corning glasses is not specified since the manufacturer supplies polished filters in a standard stock thickness which, for the particular glass melt, has been adjusted to provide the published spectral transmission characteristics identified by the colour specification number.

NOTE 2. The red filters may be sensitive to high temperatures and should not be mounted close to the light source.

Appendix E

Standard mounting boards

When a luminaire is to be measured as if mounted direct to a ceiling (see clause 20), it shall be mounted on a board as described below. (Similar arrangements should be made for wall-mounting or corner mounting.)

The board shall be approximately 15 mm thick and made of wood or wood fibre (or asbestos-based material if required). It shall be of the same outline as the plan view of the luminaire; minor corrugations of outline may be ignored. The lower surface of the board shall be smooth and shall be painted with a matt neutral grey non-metallic paint of Munsell value 9, i.e. Munsell N9. Boards for use in a photometric integrator shall be finished matt white on their upper surface and sides.

NOTE. This ceiling-board is not of quite the same area or reflectance as the board prescribed in BS 4533 : Section 1.12 for thermal measurements of luminaires.

Standard mounting boards are used in the photometry of luminaires because of effects which may occur with some luminaires:

(a) to make some allowance for the thermal effect of mounting on the light output of the luminaire;

(b) to make some allowance for the light reflected from a typical ceiling within the confines of the luminaire which may affect its photometric performance. (No allowance is made for light reflected from a ceiling outside the confines of a luminaire.)

For more detailed instructions on the ceiling board and its inclusion in measurements, reference should be made to section six.

Appendix F

Commissioning of goniophotometers

For requirements for goniophotometers see clauses 29 to 32.

F.1 Requirement (a) of clause 29. The rigidity of the luminaire mounting arrangement is tested by applying an out-of-balance load equal to the maximum out-of-balance load likely to be applied in practice and the change in the axis of rotation of the spindle measured. The change should not exceed 1° for any angle in azimuth.

F.2 Requirements (b) and (c) of clause 29. Tests for requirements (b) and (c) of clause 29 may be made by extending the axes of rotation by optical means, e.g. by a simple projector attached to the spindle by a knuckle joint, see figure 4.

The condenser lens is focused on the lamp and the projector lens (focal length about 250 mm) is focused to throw an image of the cross-wires onto a plane, usually the floor or a wall. When the spindle is rotated the image of the cross-wires will describe a circle if the plane is at right-angles to the axis of the spindle, or an ellipse if the plane is inclined. The centre of the circle or ellipse should be marked; it indicates a point through which the spindle axis would pass if extended. The projector is next aligned so that the cross-wires are centred on this point. When the spindle is rotated the position of the cross-wires should not move: movement indicates that the spindle is moving in its bearings.

If the goniophotometer is designed to have a vertical azimuth spindle, a plumb-bob dropped from the centre of this spindle should lie over the point marking the extension of the spindle axis. Similarly, if the arm carrying the photocell rotates about a horizontal axis, the centre of its spindle and the point marking its extension should be on the same level. This can be checked by using a tube-level. This method can also be used to check the alignment of the azimuth spindle if designed to be horizontal.

F.3 Requirement (d) of clause 29. Requirement (d) of clause 29 may be checked by straining wires between the centres of the spindles and their respective extensions.

F.4 Requirement (e) of clause 29. Requirement (e) of clause 29 may be checked by viewing a large luminaire or a series of luminaires from the photocell position.

F.5 Requirement (f) of clause 29. The position of the photocell is checked at 0° elevation, e.g. by dropping a plumb-bob line from the centre of the spindle and viewing the plumb-bob from the central point of the photocell, when the plumb-bob or its image should appear in the centre of the end of the spindle.

The 0° indication of the azimuth spindle is checked by aligning the mounting bar for luminaires along the spindle axis.

The position of 90° elevation can be checked by using the projector to cast a horizontal beam of light at 0° azimuth and finding whether the image of the cross-wires falls on the centre of the photocell when the arm is set to 90° Other angles can be checked by inclining the projector using an inclinometer.

The calibration of the azimuth spindle can be checked by direct angular measurement from a bar attached to the spindle: the horizontal extension of the goniophotometer should be the datum line.

F.6 Testing of mirrors for variation in reflectance and flatness

F.6.1 *Test source.* This should be a light source having a substantially constant intensity in the cone subtended at the photocell by the largest luminaire for which the goniophotometer is designed. A suitable source is an opal filament lamp or a spherical luminaire. The test source should present a projected area of between 1500 mm^2 and 5000 mm^2 in the direction of the optical path to the photocell.

The test source should be rigidly fixed on a bar having a length equal to that of the longest luminaire for which the goniophotometer is designed, so that the whole of the usable part of the mirror can be covered.

F.6.2 *Procedure.* The goniophotometer is set at 0° elevation. The test source is fixed in the vertical axis of rotation and an intensity reading is taken.

The test source is then repositioned on the test bar at a distance from the central position equal to 0.1 times the length of the largest luminaire for which the goniophotometer is designed and redirected towards the photocell. Intensity readings, corrected for the increase in distance between the photocell and the test source, are taken at every 30° in azimuth.

The above procedure is repeated with the test source at distances from the centre position equal to 0.2, 0.3, 0.4 and 0.5 times the length of the luminaire.

F.6.3 *Criterion of acceptability.* The standard deviation of the readings expressed as a percentage of the mean should not be greater than 1.5 % and each reading should not differ by more than 5 % from the mean.

F.7 Screening of stray light. A check may be made by viewing from the position of the photocell as a generally diffusing luminaire is rotated on the goniophotometer. A screen, finished matt white on both sides, should then be placed in front of the luminaire and a check made for zero reading at all positions.

F.8 Presence of obstructions. A generally diffusing luminaire of the maximum size for which the goniophotometer is designed should be mounted on the goniophotometer and viewed from the position of the photocell for the presence of obstructions in all directions in elevation and azimuth.

Appendix G

Selection of type of goniophotometer

The factors outlined in this appendix should be considered when a design of a goniophotometer is being selected.

G.1 Luminaire attitude. In general it is desirable that the luminaire is tested in its designed attitude to avoid changes in light output with certain types of discharge lamp and to avoid movement of suspended components. A fixed luminaire attitude also is useful for access, particularly when the goniophotometer is to be used for development work on luminaires. The change in light output with attitude of a luminaire using certain discharge lamps is partly due to the change in light output of the lamp itself and partly due to the change in thermal conditions within the luminaire. There may be a change in shape of the arc as well as a change in the distribution of air temperature around the lamp. It is sometimes possible to compensate for these changes by monitoring light output (particularly applicable to types 8 and 9 of table 2) but not if the shape of the light distribution changes with operating attitude, e.g. in multi-lamp luminaires or if the lamp only operates within certain angular limits, e g low pressure sodium lamps.

Moving a temperature sensitive luminaire through the air can cause additional cooling and affect its light output, so all movements must either be made slowly with adequate stabilizing time or be made quickly so that measurements can be made before the light output of the lamp has time to change. Although the luminaire is rotated about a vertical axis in most goniophotometers, these movements are usually over small angular increments and can be made slowly so that the light output of the luminaire is unaffected.

In general, therefore, a fixed luminaire position, but permitting rotation about a vertical axis, is recommended.

G.2 Photocell position. It is desirable to have a fixed photocell position, preferably one from which the luminaire can be easily viewed by eye. With a travelling photocell it is more difficult than with a fixed or relatively fixed photocell to make electrical connections, attach filters and calibration equipment and eliminate stray light.

In most goniophotometers, the view of the background to the luminaire from the direction of the photocell is constantly changing. Screening is difficult in these circumstances and it is usually

Table 2. Features of goniophotometer types

Type	Descriptions	Fixed luminaire position	Stationary cell	Viewing by eye (see note 3)	Direct measurement (no mirrors)	Variable optical path length	Photometer size (m) Optical components only (see note 4) Height	Width	Length	Mirror (s) size (m)
1	Fixed luminaire position: travelling cell	Yes	No	No	Yes	No	20	2	11	-
2	Fixed luminaire position; rotating cell at fixed position; travelling mirror	Yes	Yes	Yes	No	No	10	2	6	1 × 1
3	Fixed luminaire position; rotating mirror; fixed cell position	Yes	Yes	Yes	No	No	5	3.5	9	2.8 × 2
4	Fixed luminaire position; one travelling, one rotating mirror; fixed cell position or can be moved along axis	Yes	Yes	Yes	No (two mirrors)	Yes	7.5	5	6	1.5 × 1.5 1.5 × 0.8
5	Travelling luminaire kept vertical, travelling cell	No	No	No	Yes	No	10	2	10	-
6	Travelling luminaire kept vertical, rotating mirror, fixed cell or can be moved along axis	No	Yes	Yes	No	Yes	5	3.5	9	2.8 × 2
7	Travelling luminaire, one travelling, one fixed mirror. Fixed cell or can be moved along axis	No	Yes	Yes	No	Yes	6	6	4.5	1.8 × 1.8 1.0 × 1.0
8	Rotating luminaire; fixed cell position	See note 1	Yes	Yes	Yes	Yes	2	2	11	-
9	Rotating luminaire; fixed cell position	See note 2	Yes	Yes	Yes	Yes	2	2	11	-
10	As 1, with fixed luminaire position but travelling collimating receptor	Yes	No	No	Yes	No	Dependent upon collimator 3.5	3.5	2	-

NOTE 1. Luminaire stood on end for measurement of its transverse plane. Luminaire turned on its side and rotated about the vertical for measurement of its axial plane.

NOTE 2. Luminaire rotated about the horizontal axis for measurement of its transverse plane. Luminaire turned on its side and rotated about the vertical for measurement of its axial plane.

NOTE 3. Column 5 'Viewing by eye' refers to the ease of viewing the luminaire from the photocell position. 'Yes' implies ease of viewing; 'No' implies difficult viewing.

NOTE 4. Dimensions based on 2 m diameter sphere as light source and 10 m optical path length.

necessary to house the goniophotometer in a special enclosure with black interior surfaces (see clause **31**).

Visual checks from the photocell position for stray light and for obstruction and visual examination of the behaviour of the luminaire, often essential during development work, are easier if there is a fixed and easily accessible photocell position.

In general, therefore, a fixed photocell position is advantageous, but moving or rotating the photocell is better than moving the luminaire.

G.3 Use of mirrors. The use of mirrors to achieve compact construction may introduce errors (see clause **30**) and they also require cleaning and checking for alignment. Nevertheless, the advantages of using mirrors frequently outweighs their disadvantages.

Strong constructions are necessary to support the weight of large glass mirrors. Mirrors of metallized plastics sheet are considerably lighter than glass; they are more susceptible to surface damage than glass mirrors but are more readily renewed.

G.4 Types of goniophotometer. Characteristics of the main types of goniophotometer are summarized in table 1. These types are illustrated schematically in figure 3. The arrangements shown are for measurement in whole planes; measurement in half planes is sometimes more convenient. All types (excepting types 8 and 9) effectively measure at selected angles of elevation in vertical planes spaced in azimuth.

Type 1, the simplest type of goniophotometer, is particularly suitable where adequate height is available and ready access to the photocell is not required. The photocell may be rotated either on an arm or (preferably) on a track. In an alternative arrangement, there is an array of fixed photocells which are switched in turn; this arrangement, however, requires frequent matching of the sensitivities of the photocells.

Goniophotometers employed in luminaire design are usually of types with mirrors, see types 2 to 7 inclusive. A further mirror may be incorporated so that the photocell is at a more convenient position. Also, a hollow bearing may be used, so that light rays may be directed to the axis. In types 5, 6 and 7 the luminaire is moved in position but is held at constant attitude.

It is possible to reduce the height required for types 1 to 4 inclusive by having two mounting locations, an upper one for measurements in the lower hemisphere and a lower one for measurements in the upper hemisphere. Care must be taken in moving the luminaire between the measuring locations; in the lower location there is a high risk of stray light affecting readings.

Types 8 and 9 are used where height is restricted. The luminaire is not operated in its correct attitude.

All the above goniophotometers require a long optical path. It is also possible to measure intensity at short range with a collimating receptor (type 10). In practice, such a goniophotometer may be difficult to construct and maintain. For details see references 11 and 13.

Appendix H

Initial checking of integrators

H.1 In principle, an integrator may be regarded as satisfactory if, in addition to meeting the requirements listed in clause **50**, the reading for a given light output is the same whatever the distribution of the light and if the correct allowance is made for the absorption of inter-reflected light by a large luminaire. Compliance with these requirements may be checked by the tests described in **H.1.1** and **H.1.2**.

H.1.1 A small luminaire incorporating a vacuum filament lamp of concentrating type and with no backward light is positioned at the centre of the integrator. Readings of light output, without use of the auxiliary lamp, are taken with the luminaire aimed in turn at the centres of the six principal surfaces and in at least twelve other well-spread directions. Before commencing this test one screen size and position should be found which covers all the orientations of the luminaire.

No reading should depart by more than ± 10 % from the average of all the readings taken and over two-thirds of the readings should be within ± 2 % of the average.

Failure to pass this test is likely to be due to dissimilar reflectances of the principal surfaces or to the reflectance of the direct light screen being too low.

H.1.2 A reading of light output is taken with the luminaire of **H.1.1** above aimed vertically downwards, followed by a reading taken with the auxiliary lamp only. A test obstruction, finished matt white and representing in shape and volume the largest luminaire for which the integrator is designed, is then fixed round the luminaire in such a way that it does not intercept direct light. Readings are again taken with the luminaire only and with the auxiliary lamp only.

The ratio of the second pair of readings should not differ from the ratio of the first pair of readings by more than ± 2 %.

Failure to pass this test is likely to be caused by too much direct light from the auxiliary lamp being emitted towards the central portion of the integrator.

H.2 Additionally, a comparison may be made of results obtained in the integrator with the corresponding results obtained with a goniophotometer which complies with the requirements of section three. Luminaires of various sizes and light distribution should be used. For each luminaire the value of LOR obtained by each of the two methods should not differ by more than ± 2 % from their mean value. In the event of a greater difference, the two methods are equally likely to be in error and a detailed investigation should be made.

Appendix J

Amalgam lamps

J.1 Definition. For the purposes of this appendix, the following definition applies.

amalgam lamp. A fluorescent lamp containing an amalgam for the control of vapour pressure during operation.

J.2 General. The ambient temperature at which the declared light output, e.g. the lighting design lumens, of amalgam lamps is to be measured has not yet been standardized. A temperature above that of the 25 °C standardized for normal lamps is appropriate.

There are difficulties in carrying out full photometric measurements of a luminaire incorporating amalgam lamps. Stabilization may take considerably longer than for a normal lamp; and it may be impractical, especially for measurements of a bare amalgam lamp on a goniophotometer, to achieve the ambient temperature applicable to the declared light output of the lamp.

The standard procedure is to make photometric measurements of the luminaire with normal lamps incorporated, and to determine an amalgam lamp factor in accordance with J.4. The amalgam lamp factor is then applied as a measurement correction factor (see section five) and photometric data are reported as if the measurement had been made with an amalgam lamp in the luminaire. An amalgam lamp factor may also be determined for luminaires for which information is already published in terms of normal lamps. The amalgam lamp factor is issued as a service correction factor to be applied by users of the data.

J.3 Amalgam test lamps. Amalgam test lamps should be selected with special care to ensure that the light output versus temperature characteristics are typical of production lamps. Test lamps should be aged for at least 200 h.

J.4 Amalgam lamp factor. The amalgam lamp factor is a factor for converting photometric measurement of a luminaire with a normal fluorescent lamp to the values which would be obtained with an amalgam lamp in the luminaire.

The amalgam lamp factor is calculated as follows:

$$\text{Amalgam lamp factor} = \frac{A}{B} \times \frac{C}{D}$$

where

A is the measured quantity with an amalgam lamp in the luminaire. Standard measuring conditions for luminaires (see clause **20**).

B is the measured quantity with a normal lamp in the luminaire. Standard measuring conditions for luminaires (see clause **20**).

C is the calibration reading for bare normal lamp. Standard measuring conditions for lamps (see clause **21**).

D is the calibration reading for bare amalgam lamp. Measuring conditions as for C but with the lamp in an ambient temperature as for its declared light output.

Measurements of A and B shall be of the same quantity and in the same units. The measured quantity may be relative light output; or intensity, luminance or illuminance per thousand total lumens. Measurement of C and D shall also be paired measurements and in the same units, but not necessarily the units of A and B. It is recommended that measurements of C and D should be made in a photometric integrator to facilitate control of the ambient temperature for D.

The photometric measurements of the luminaire are made with a normal test lamp: quantities calibrated per thousand total lumens and light output ratios are then multiplied by the amalgam lamp factor (as a measurement correction factor) before reporting.

When an amalgam lamp factor is published as a service correction factor for data based on normal lamps, users of published information should apply the factor as follows.

(a) *Photometric quantities per thousand total lumens.* Multiply by the amalgam lamp factor, and by the declared light output (per thousand lumens) of the amalgam lamp.

(b) *Light output ratios and utilization factors.* Multiply by the amalgam lamp factor. These modified ratios and factors then refer to the declared light output of the amalgam lamp.

J.4.1 *Example.* For a particular luminaire published photometric data are based on measurements with a normal fluorescent lamp. There is a requirement for the luminaire manufacturer to issue an amalgam lamp factor, in advance of publication of repeat data based on an amalgam lamp. The information published by the lamp manufacturer is as follows:

declared light output for normal fluorescent lamp	5000 lumens
declared light output for amalgam lamp	4900 lumens

Measurements are made in accordance with **J.4** to determine the amalgam lamp factor of the luminaire and have the following values:

A = 150 lux per thousand total lumens (illuminance at a selected position)

B = 120 lux per thousand total lumens (illuminance at the same position as for A)

C = 24 units (relative light output in a photometric integrator)

D = 25 units (relative light output as for C but at the appropriate temperature)

NOTE. As in the example, it is not necessary for the light outputs of the two test lamps to be in the same ratio as the declared values.

Amalgam factor $= \frac{150}{120} \times \frac{24}{25} = 1.2$

With lamps of declared light output, the absolute illuminance at the selected position would be:

illuminance with normal lamp;
120 x 5.0 = 600 lux

illuminance with amalgam lamp;
120 x 4.9 x 1.2 = 706 lux

Let the published LOR of the luminaire with a normal lamp be 0.50. With lamps of declared light output the absolute light output of the luminaire would be:

light output with normal lamp;
5000 x 0.50 = 2500 lumens

light output with amalgam lamp;
4900 x 0.50 x 1.2 = 2940 lumens

J.5 Reported measurements. Photometric measurements of luminaires for amalgam lamps should be reported in the standard form, i.e. the amalgam lamp factor should be applied before reporting. An amalgam lamp factor may also be reported as a service correction factor to be applied to existing data.

In both instances, the data should be accompanied by a statement of the type of amalgam lamp and of the ambient temperature adopted for the bare lamp measurement.

J.5.1 *Published data.* Users of the published data should check carefully that lamp data and luminaire data (and/or amalgam lamp factor) refer to the same type of amalgam lamp operated at the same ambient temperature during bare lamp measurement.

Appendix K

Correction calculation for lamps whose luminous flux is specified for temperatures other than 25 °C

Some lamps are specified by International Standards for operation at ambient temperatures other than 25 °C, for instance 35 °C. For these lamps the measured luminous characteristics of the luminaire shall be multiplied by a factor supplied by the manufacturer of the lamp. The factor for a given lamp is the ratio of the luminous flux at 25 °C divided by the luminous flux at the specified operating temperature.

All published photometric information for a luminaire using such a lamp shall be scaled by the factor for the lamp(s) used.

For example the light output ratio of a luminaire, LOR, is given by the following equation:

$$\text{LOR} = \frac{L_1}{L_2} \times \text{Factor}$$

where

L_1 is the light output of the luminaire at 25 °C

L_2 is the total light output of the lamp(s) at 25 °C

As manufacturers publish lamp data, which give lumen values measured at the specified temperature (other than 25 °C), then failure to apply the correction factor will result in errors when the photometric data is used for lighting design.

Bibliography

This bibliography contains references to some textbooks and specialized papers which may be of interest in relation to both this Part and to later Parts of this standard. Additional references will be included in later Parts as appropriate. The references are listed in reverse date order.

1. HENDERSON S T and MARSDEN A M. *Lamps and Lighting.* 2nd edition, Arnold 1972.
2. CLARKE F J J. High accuracy spectrophotometry at the NPL, *J. Res. Nat. Bur. Stand.* (USA), 76A 1972, pp. 375-403.
3. SANDERS C L. Accurate measurement of and corrections for non-linearities in radiometers. *J. Res. Nat. Bur. of Stand.* (USA), 76A 1972, pp. 437-453.
4. KEITZ H A E. *Light calculations and measurements.* 2nd edition, Macmillan 1971.
5. NONAKA M. Polarization errors in distribution measurements on luminaires. *CIE Compte Rendu* 1971, p. 105.
6. MISSEN L. Photometric requirements for luminaires. *CIE Compte Rendu* 1971, p. 43.
7. MISSEN L. *Principles of Light Measurement.* CIE Publication No 18, 1970.
8. JONES O C and PRESTON J S. *Photometric Standards and the Unit of Light.* Notes on Applied Science No 24, HMSO 1969.
9. MORREN L. The effect of polarization of light on the photometry of lighting fittings. *Lighting Research and Technology* 1 1969, pp. 53-54.
10. BEAN A R and SIMONS R H. *Lighting Fittings, Performance and Design.* Pergamon 1968.
11. FREDERIKSEN E. Unidirectional sensitive photometer. *Light and Lighting*, 2 1967.
12. FREDERIKSEN E. Photometric requirements for luminaires. *CIE Compte Rendu* 1967, p. 250.
13. FREDERIKSEN E. New light distribution photometer. *CIE Compte Rendu* 1967, p. 258.
14. EINHORN H D. Zonal method and linear sources. *Trans. IES* (UK) 30 1965, p. 125.
15. EINHORN H D. Sector flux calculation for line sources. *International Lighting Review* 16 1965 p. 24.
16. FAIRBANKS K E and ANSLEY D A. Polarization and photometry, *J. IES* (USA) 59 1964, pp. 255-266.
17. RIGGS W R and LAMPERT Adelene R. Correlating ten-foot photometry. *J. IES* (USA), 58 1963, pp. 736-738.

18. CRAWFORD B A. *Physical Photometry*. Notes on Applied Science No 29, HMSO 1962.

19. WILMAN D. Practical photometry of lighting fittings. *Trans. IES* (UK), 27(3) 1962.

20. DUNLOP D and FINCH D M. Photometry of fluorescent luminaires - rotating photocell method. *J. IES* (USA), 56 1961, p. 571.

21. WALSH J W T. *Photometry*. 3rd edition, Constable 1958.

22. HORTON G A, SPECK R C, ZAPHYR P A and WENDT R E. Automatic photometer for street lighting and other luminaires. *J. IES* (USA), 53 1958, pp. 591-597.

23. SMITH Doreen. A method of calculating flux from an isocandela diagram using a system of discrete points. *Trans. IES* (UK), 22(4) 1957.

24. PRESTON J S and GORDON-SMITH G W. Discontinuities in the saturation curves of vacuum photocells. *Brit. J. Appl. Phys.*, 6 1955, pp. 329-333.

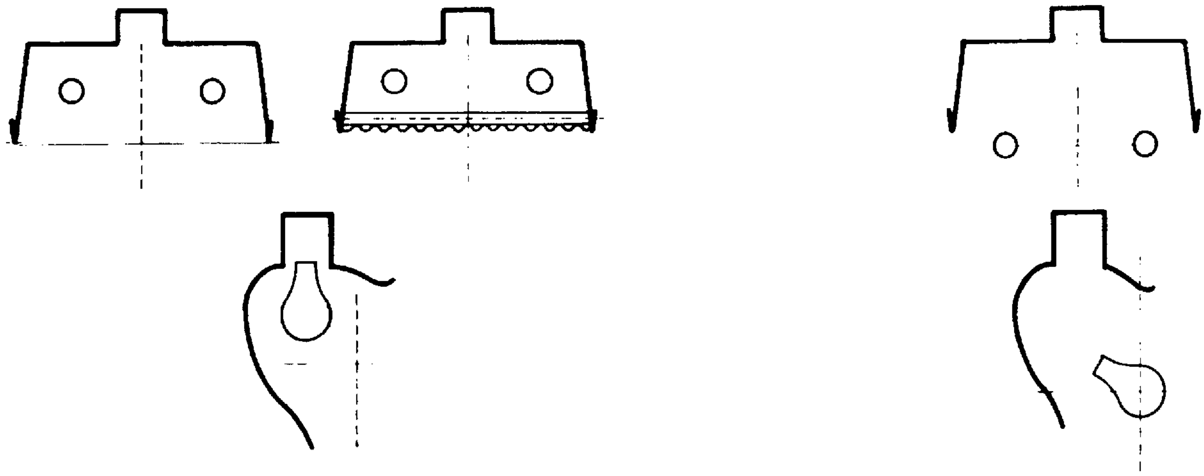
25. STEPHENSON H F. The equipment and function of an illumination laboratory. *Trans. IES* (UK), 17(1) 1952.

26. HORTON G A. Modern photometry of fluorescent luminaires. *J. IES* (USA), 45 1950, pp. 458-467.

27. BAUMGARTNER G R. New semi-automatic distribution photometer and simplified calculation of light flux. *J. IES* (USA), 45 1950, pp. 253-261.

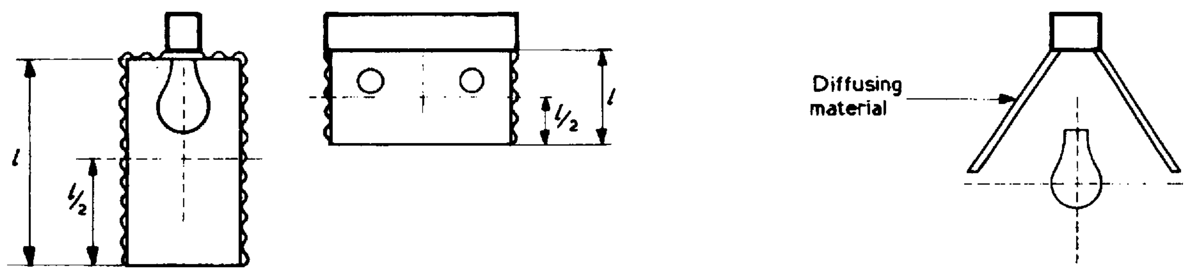
28. ATKINSON J R, CAMPBELL N R, PALMER E H and WINCH G T. The accuracy of rectifier-photoelectric cells. *Proc. Phys. Soc.*, 50 1938, pp. 934-946.

Luminaires with opaque sides, lamp compartment substantially white.



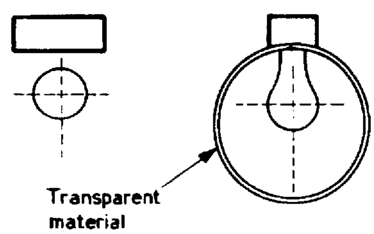
Luminaires with opaque sides, lamp compartment substantially black.

Luminaires with diffusing/prismatic sides.



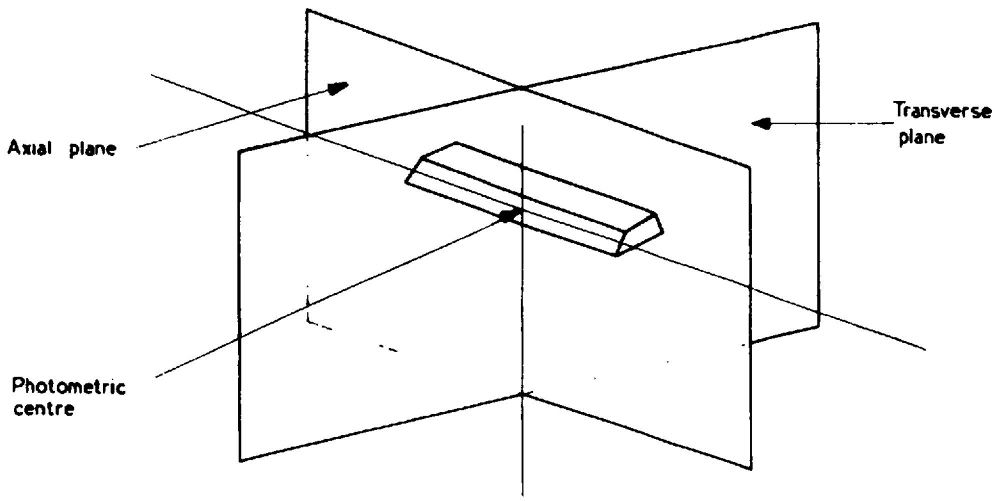
Luminaires with transparent sides or without side members.

(all at lamp photometric centre)

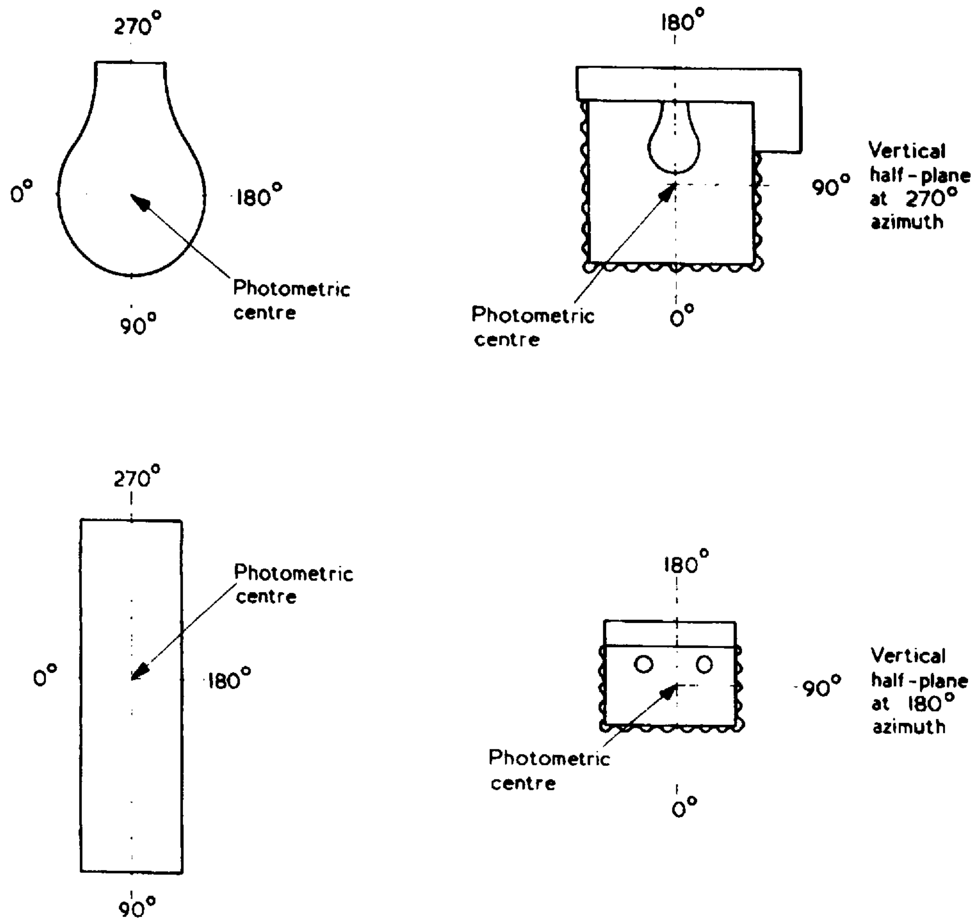


NOTE 1. Schematic examples only (see clause 5).
NOTE 2. The position of the photometric centre is indicated by the crossing of the dashed lines.

Figure 1. Photometric centre of a luminaire



Principal planes for linear luminance



Angles of azimuth (counter-clockwise from above)
270° direction identified by mechanical feature e.g. nameplate.

Angles of elevation (measured from nadir)
Typical half-plane of elevation identified by angle of azimuth.

NOTE. Examples of the azimuth elevation system of co-ordinates (see clause 7)

Figure 2. Co-ordinate system for luminaires

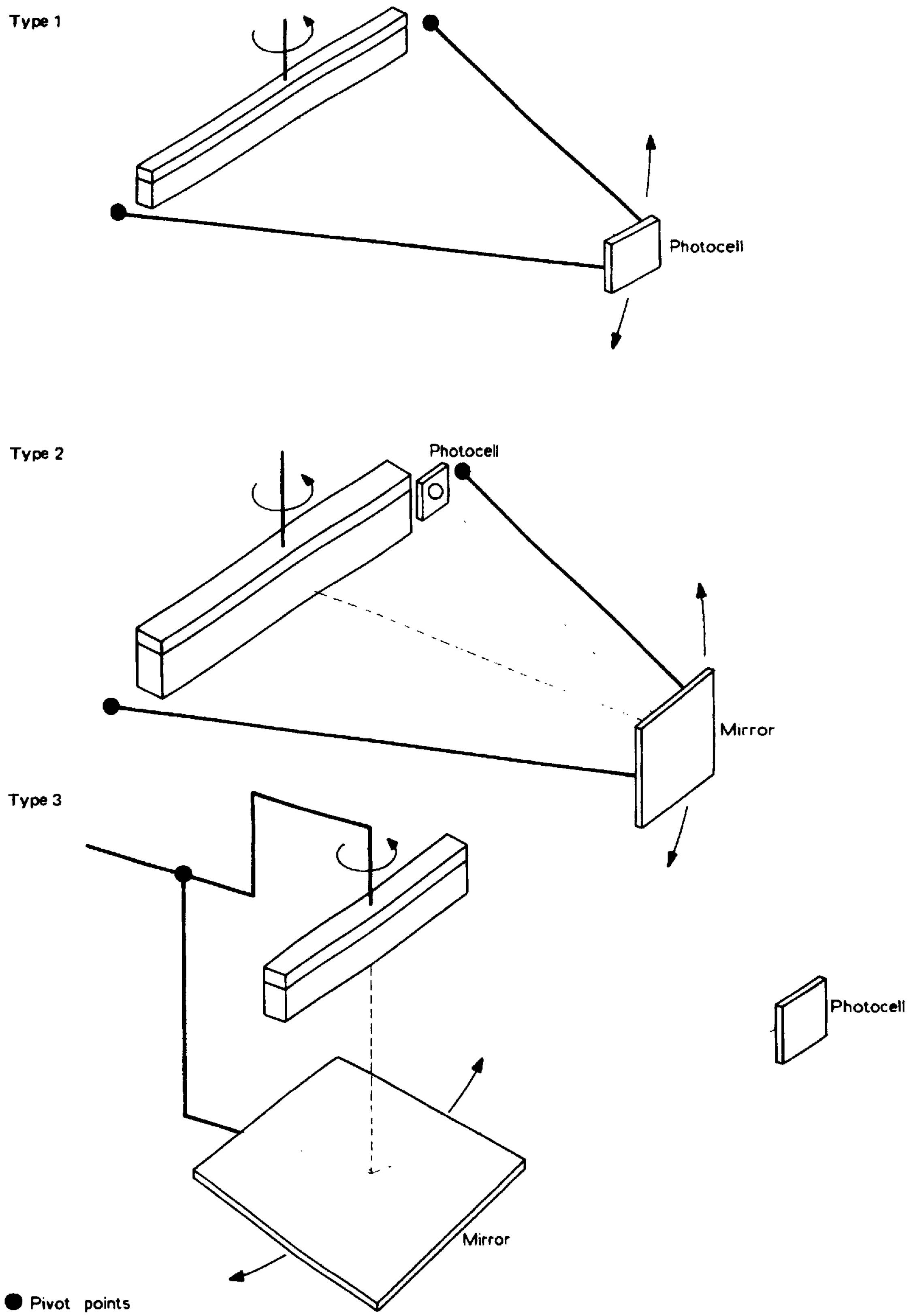


Figure 3. Types of goniophotometer

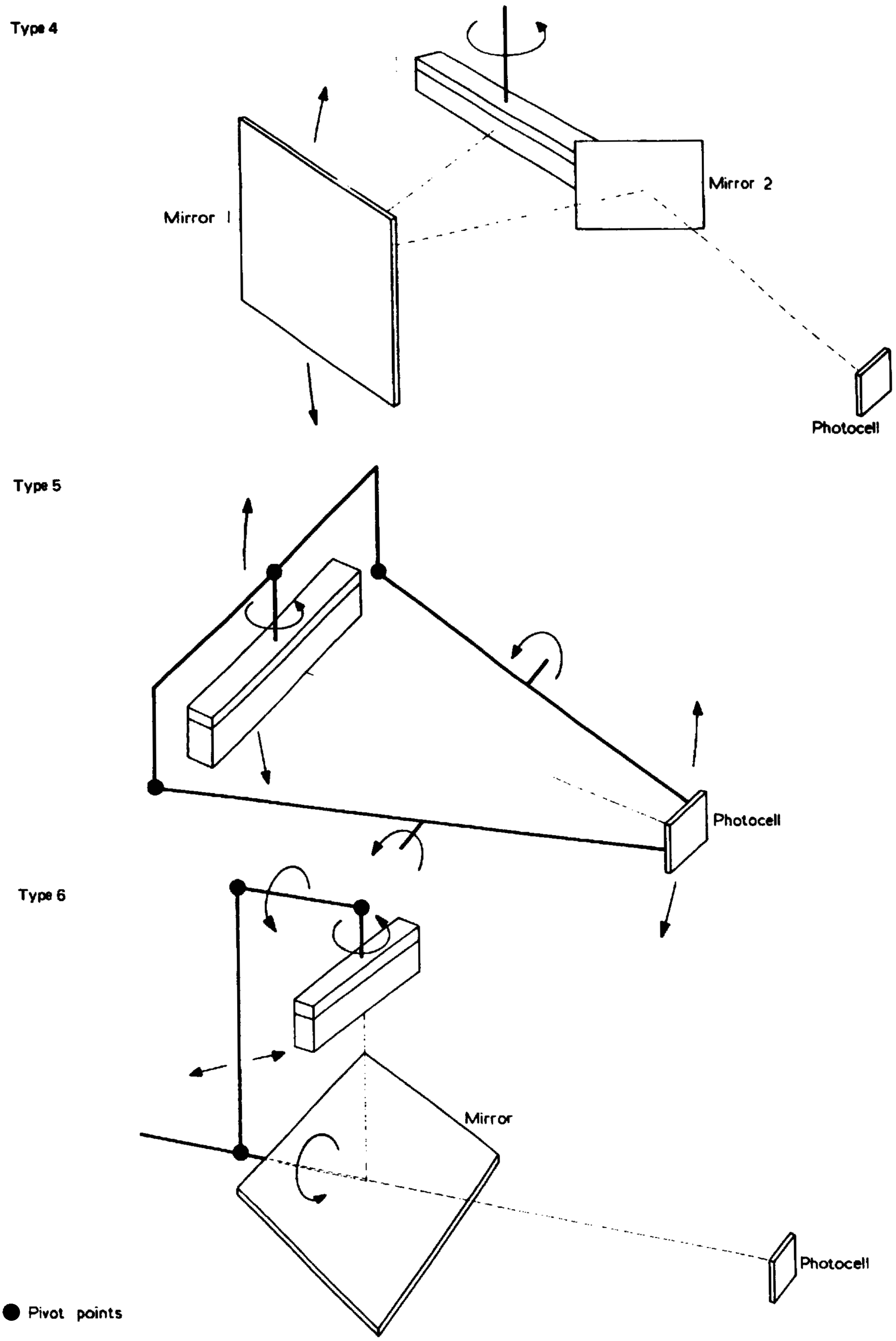
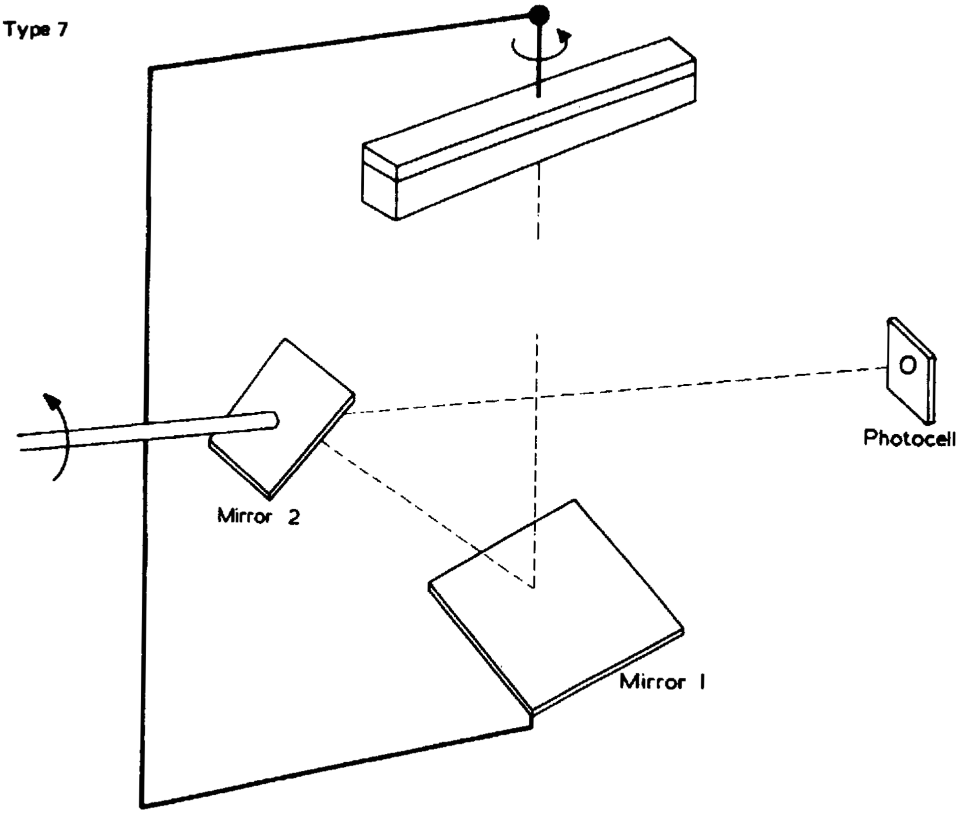


Figure 3. *(continued)*

Type 7



● Pivot points

Figure 3. *(continued)*

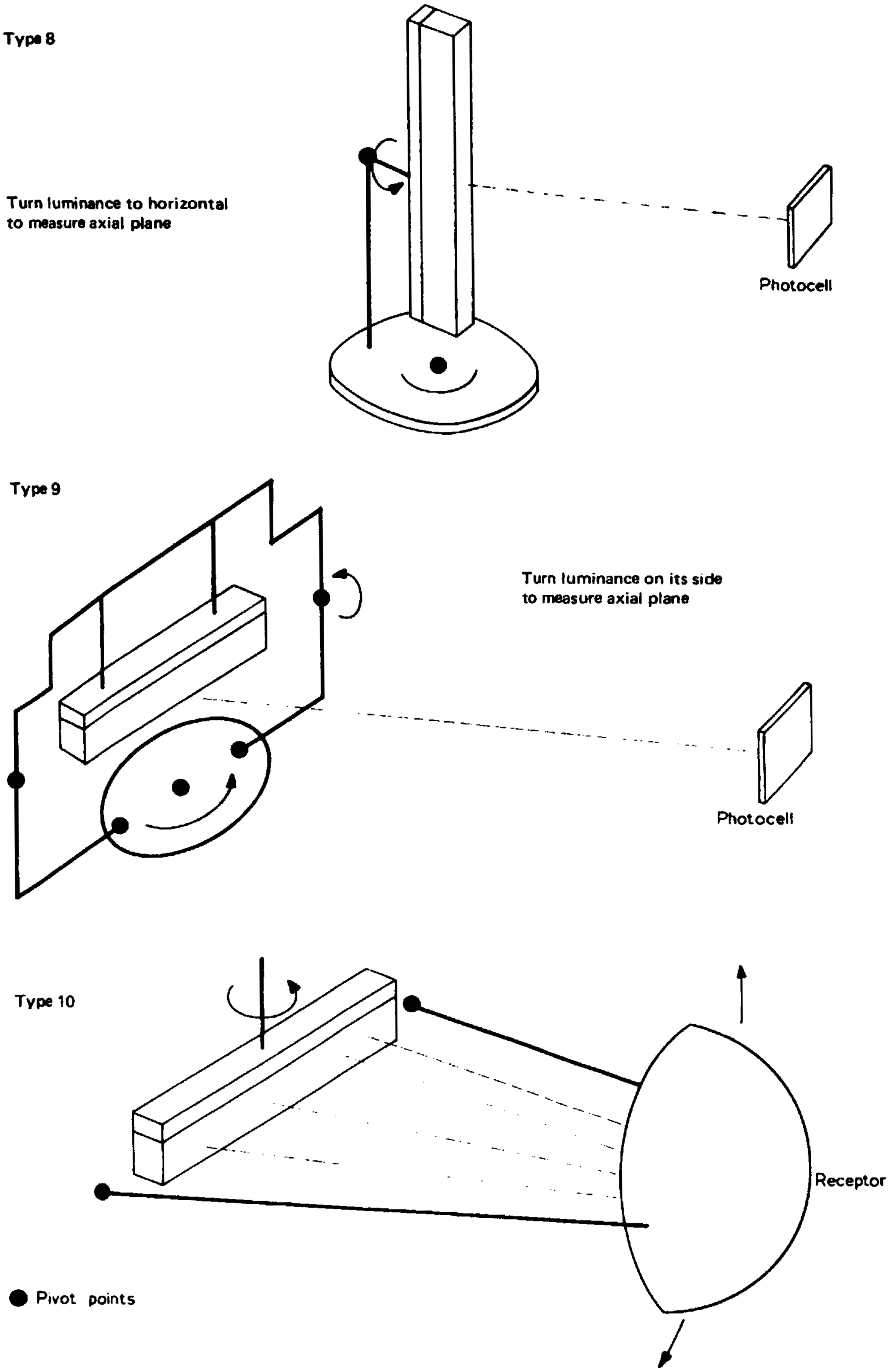


Figure 3. *(concluded)*

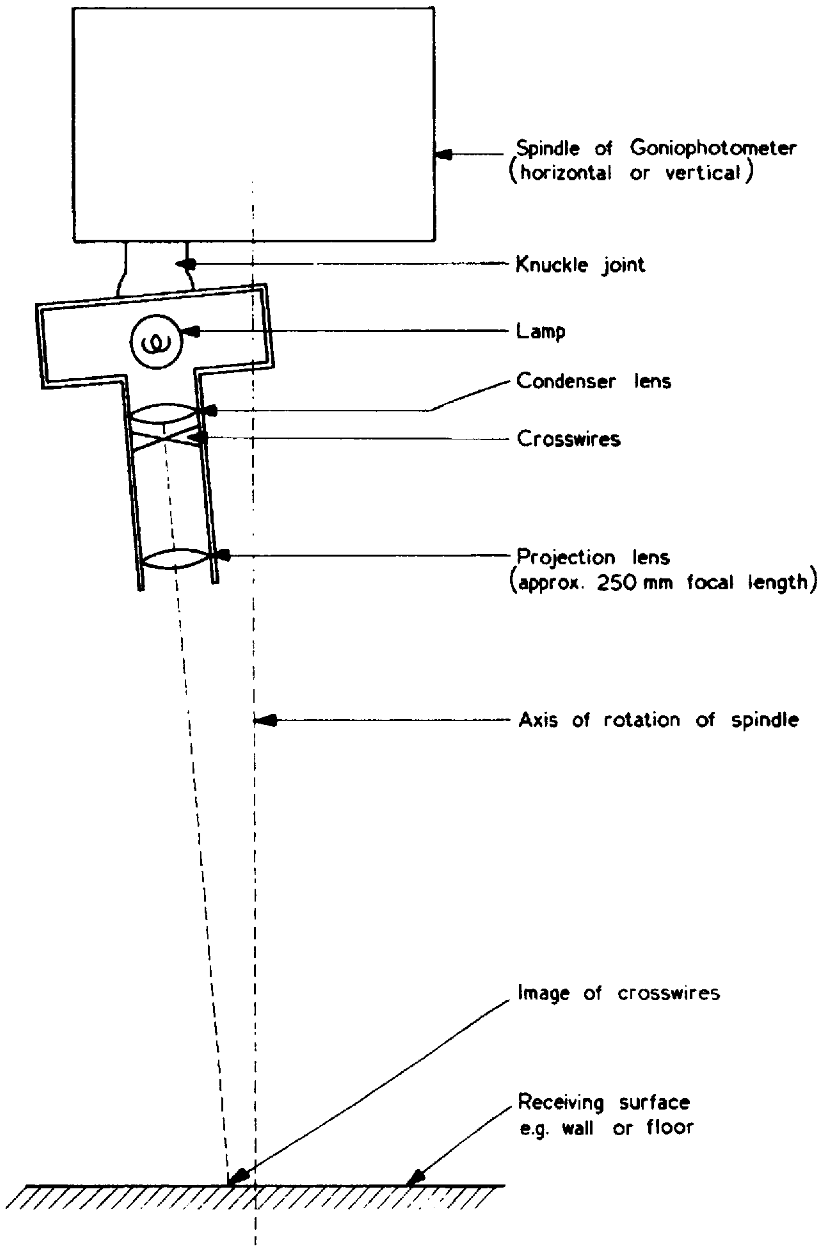
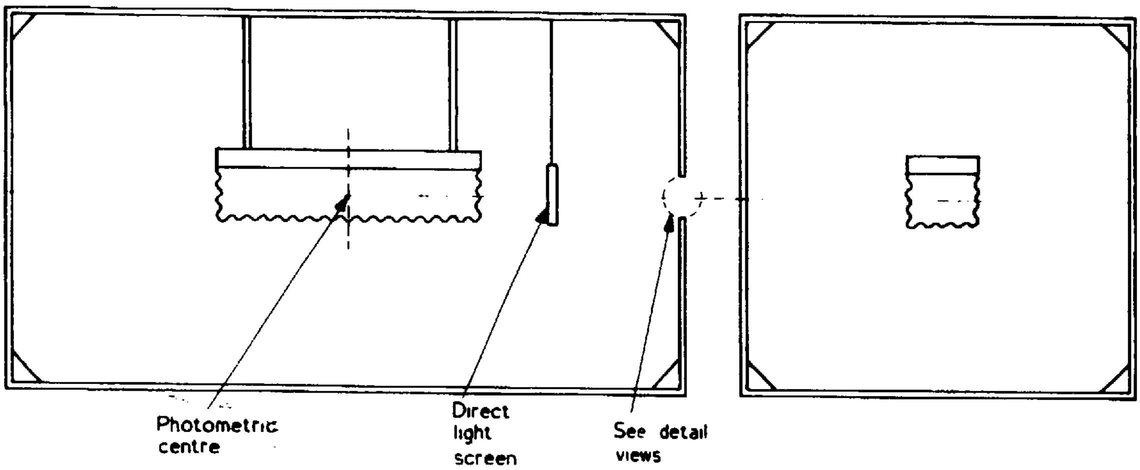
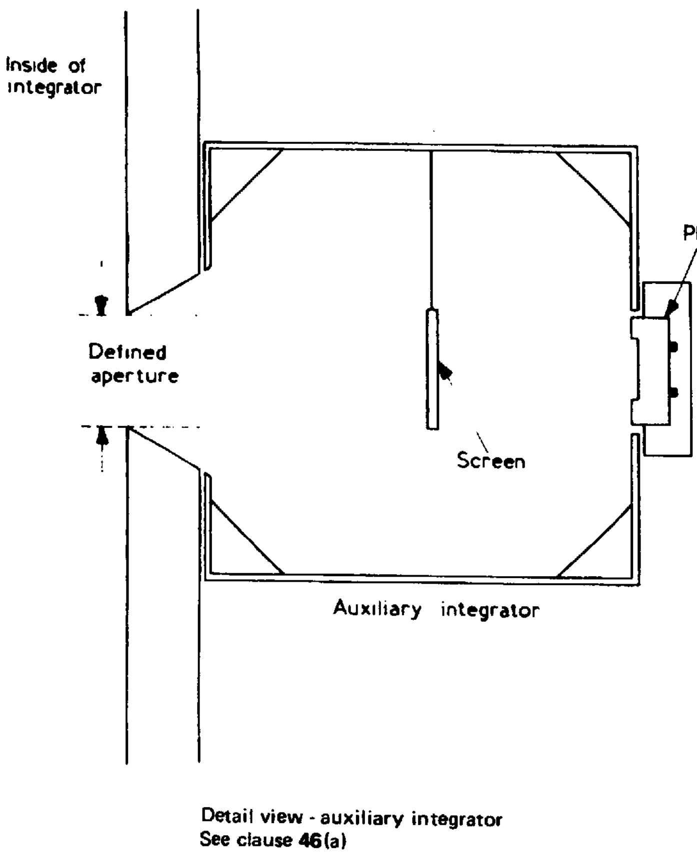


Figure 4. Alignment projector for goniophotometer





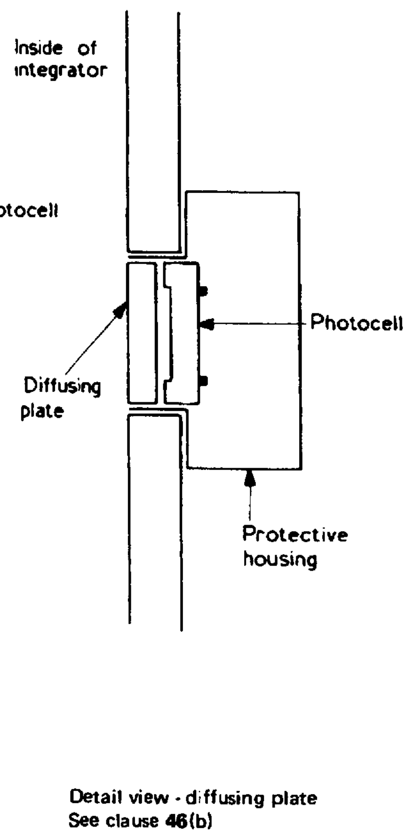
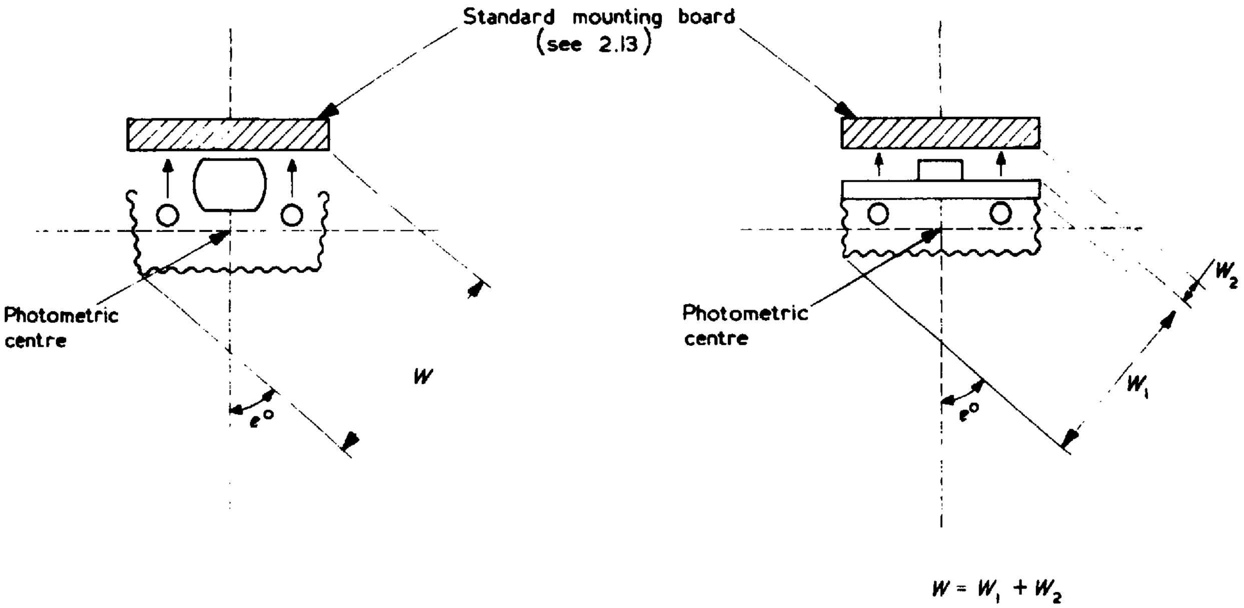
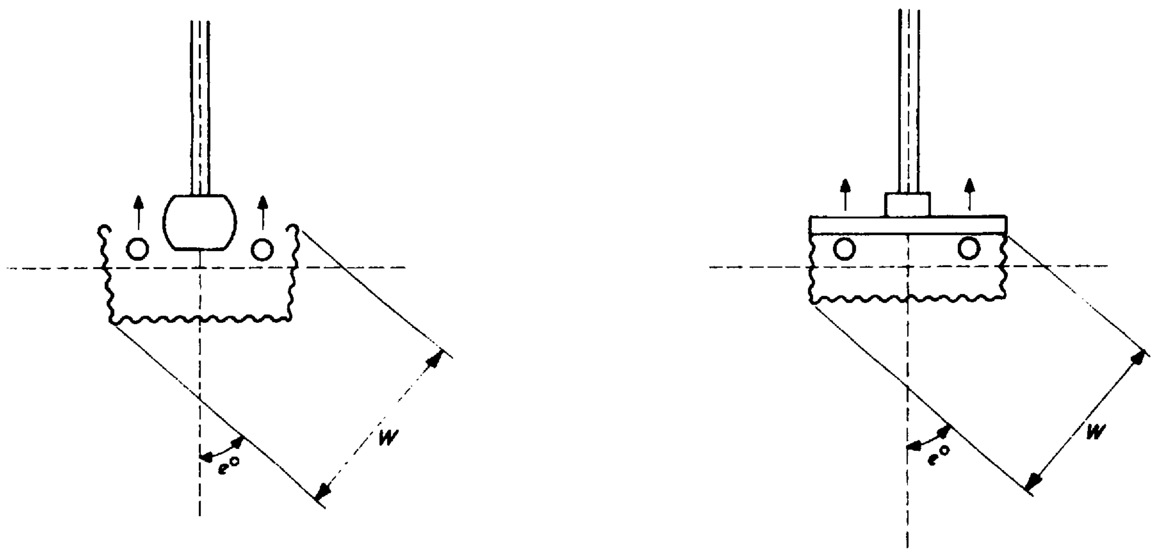


Figure 5. Photometric integrator: schematic layout



(a) Close-ceiling mounting

NOTE. Luminaires shown have upward light.



(b) Suspended mounting

NOTE. *W* is the orthogonally projected width at angle elevation for linear luminaires viewed transversely.

Figure 6. Projected width of luminaire: examples

BSI publications referred to in this standard

This standard makes reference to the following British Standards:

BS 89 Electrical indicating instruments
BS 354 Recommendations for photoelectric integrators
BS 667 Portable photoelectric photometers
BS 1041 Code for temperature measurement
BS 1853 Tubular fluorescent lamps for general lighting service
BS 2818 Ballasts for the operation of tubular fluorescent lamps on a.c. 50 Hz and 60 Hz supplies
BS 3900 Methods of test for paint
Part D2 Gloss (specular reflection value)
BS 4533 Electric luminaires
BS 4727 Glossary of electrotechnical, power, telecommunications, electronics, lighting and colour terms
Part 4 Terms particular to lighting and colour

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