

Specification for photometric data for luminaires —

Part 1. Photometric measurements

ICS 29.140.40

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 | Institution of Electrical Engineers |
| British Railways Board | Institution of Municipal Engineers |
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National Illumination Committee of Great Britain

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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.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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 arbitrary 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 arbitrary 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/m² (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/m² 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 cm² if their expression in m² 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:

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

$$\text{Upward light output ratio (ULOR)} = \text{LOR} \times \text{UFF}$$

$$\text{Downward light output ratio (DLOR)} = \text{LOR} \times \text{DFF}$$

$$\text{Upward light output ratio luminaire (ULORL)} = \text{LORL} \times \text{UFF}$$

$$\text{Downward light output ratio luminaire (DLORL)} = \text{LORL} \times \text{DFF}$$

$$\text{Upward light output ratio working (ULORW)} = \text{LORW} \times \text{UFF}$$

$$\text{Downward light output ratio working (DLORW)} = \text{LORW} \times \text{DFF}$$

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 $\pm 2\%$ 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 $\pm 0.5^\circ\text{C}$. 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 $\pm 1\%$ 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 it 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 (LORW).* 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 $\pm 5\%$ 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 (LORW).* 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 $\pm 2\%$ 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 $\pm 3\%$ 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 $\pm 2\%$ 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 $\pm 2\%$ 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 compatibility 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 $\pm 0.2\%$ 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 $\pm 0.5\%$ 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 $\pm 5^{\circ}\text{C}$ 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 $\pm 1^{\circ}\text{C}$ 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 $\pm 2^{\circ}\text{C}$ 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.