

Australian/New Zealand Standard™

Interior and workplace lighting

**Part 3: Measurement, calculation and
presentation of photometric data**



AS/NZS 1680.3:2017

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee LG-001, Interior Lighting. It was approved on behalf of the Council of Standards Australia on 10 May 2017 and by the New Zealand Standards Approval Board on 7 June 2017.

This Standard was published on 30 June 2017.

The following are represented on Committee LG-001:

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This Standard was issued in draft form for comment as DR AS 1680.3:2016.

Australian/New Zealand Standard™

Interior and workplace lighting

Part 3: Measurement, calculation and presentation of photometric data

Originated as AS 1190—1972.
Previous edition AS 1680.3—1991.
Jointly revised and redesignated as AS/NZS 1680.3:2017.

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ISBN 978 1 76035 846 4

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee LG-001, Interior and Workplace Lighting, to supersede AS 1680.3—1991, *Interior lighting, Part 3: Measurement, calculation and presentation of photometric data*.

The objective of this Standard is to specify for the Australian and New Zealand lighting industries, laboratory conditions, procedures and instrumentation for making photometric measurements on luminaires for interior and workplace lighting, together with requirements for the derivation of certain photometric data needed for interior lighting calculations.

This edition is a minor revision from AS 1680.3—1991 to introduce the measurement of solid state lighting devices such as LED lamps, LED modules and LED luminaires. The main body of the Standard is substantially unchanged from AS 1680.3—1991 and the photometry of solid state lighting is covered in Appendix I. It is expected that a major revision of this whole document will occur within the next five years after the publication of relevant technical reports currently in development by the CIE.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A normative appendix is an integral part of a Standard, whereas an informative appendix is for information and guidance only.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	6
1.2 REFERENCED DOCUMENTS.....	6
1.3 DEFINITIONS.....	7
1.4 UNITS AND TERMINOLOGY.....	9
1.5 MEASUREMENT OF SOLID STATE LIGHTING DEVICES.....	10
1.6 PHOTOMETRIC CENTRE.....	10
1.7 CUT-OFF ANGLE REFERENCE POINT.....	10
1.8 COORDINATE SYSTEMS FOR LUMINAIRES.....	11
SECTION 2 LABORATORY CONDITIONS AND PROCEDURES	
2.1 SCOPE OF SECTION	15
2.2 LABORATORY MEASUREMENTS.....	15
2.3 LABORATORY FACILITIES.....	16
2.4 STATUS OF MEASUREMENTS	16
2.5 ELECTRIC POWER SUPPLY AND INDICATING INSTRUMENTS	17
2.6 TEMPERATURE CONTROL AND INDICATING INSTRUMENTS.....	17
2.7 PHOTOCELLS AND ASSOCIATED APPARATUS.....	18
2.8 SELECTION OF LUMINAIRES FOR TEST.....	20
2.9 SELECTION OF BALLASTS FOR USE WITH LUMINAIRES UNDER TEST.....	20
2.10 SELECTION AND PREPARATION OF LAMPS FOR USE WITH LUMINAIRES UNDER TEST	22
2.11 OPERATION AND HANDLING OF LAMPS.....	23
2.12 STANDARD MEASURING CONDITIONS FOR LUMINAIRES	23
2.13 STANDARD MEASURING CONDITIONS FOR BARE LAMPS	24
2.14 STABILIZATION	26
2.15 MEASURING PROCEDURES	27
2.16 RECORDING OF MEASUREMENTS.....	27
2.17 ISSUING OF TEST REPORTS	28
SECTION 3 MEASUREMENTS OF INTENSITY	
3.1 SCOPE OF SECTION	29
3.2 PURPOSE OF GONIOPHOTOMETER	29
3.3 DESIGN AND CONSTRUCTION	29
3.4 OPTICAL PATH LENGTH.....	29
3.5 GENERAL REQUIREMENTS.....	30
3.6 REQUIREMENTS FOR MIRRORS.....	30
3.7 SCREENING AGAINST STRAY LIGHT.....	31
3.8 CHECKING THE GONIOPHOTOMETER.....	31
3.9 SELECTION OF LAMPS, BALLASTS, LUMINAIRES	31
3.10 MOUNTING OF THE LUMINAIRE	31
3.11 MOUNTING OF THE BARE LAMP	31
3.12 MEASURING CONDITIONS	32
3.13 MEASUREMENT OF LUMINAIRE INTENSITY DISTRIBUTION	32
3.14 MEASUREMENT OF INTENSITIES FROM BARE LAMPS.....	33
3.15 RECORDING MEASUREMENTS	33

SECTION 4 MEASUREMENTS OF LUMINOUS FLUX

4.1	SCOPE OF SECTION	34
4.2	PURPOSE OF PHOTOMETRIC INTEGRATORS	34
4.3	CONSTRUCTION.....	34
4.4	REFLECTING SURFACES	34
4.5	COMPONENTS INSIDE AN INTEGRATOR	35
4.6	AIR TEMPERATURE MEASUREMENT	35
4.7	THE TEST PATCH	35
4.8	PHOTOCELLS AND ASSOCIATED APPARATUS	36
4.9	DIRECT LIGHT SCREEN	36
4.10	AUXILIARY LAMP	36
4.11	CHECKING THE INTEGRATOR	36
4.12	SELECTION OF LAMPS, BALLASTS, LUMINAIRES	36
4.13	MOUNTING THE LUMINAIRE	37
4.14	MOUNTING THE BARE LAMP	38
4.15	MEASURING CONDITIONS	38
4.16	MEASURING PROCEDURE FOR LIGHT OUTPUT RATIO (<i>LOR</i>)	38
4.17	RECORDING OF MEASUREMENTS.....	39

SECTION 5 PHOTOMETRIC FACTORS

5.1	SCOPE OF SECTION	40
5.2	MEASUREMENT CORRECTION FACTORS	40
5.3	SERVICE CORRECTION FACTORS	40
5.4	BALLAST LUMEN FACTOR (<i>BLF</i>).....	41

SECTION 6 MEASUREMENTS OF LUMINANCE AND CUT-OFF ANGLE

6.1	SCOPE OF SECTION	42
6.2	TYPES OF LUMINANCE MEASUREMENT	42
6.3	MEASURING APPARATUS	42
6.4	SELECTION OF LAMPS, BALLASTS, LUMINAIRES	43
6.5	AVERAGE LUMINANCE—MEASURING PROCEDURE	43
6.6	PATCH LUMINANCE—MEASURING PROCEDURE	43
6.7	PATCH LUMINANCE—ALTERNATIVE MEASURING PROCEDURE	44
6.8	RECORDING OF LUMINANCE MEASUREMENTS	44
6.9	DETERMINATION OF CUT-OFF ANGLE	44

SECTION 7 ILLUMINANCE MEASUREMENTS (SINGLE LUMINAIRE)

7.1	SCOPE OF SECTION	46
7.2	GENERAL.....	46
7.3	MEASURING APPARATUS	46
7.4	SELECTION OF LAMPS, BALLASTS, LUMINAIRES	46
7.5	MEASURING PROCEDURE.....	46
7.6	CALIBRATION OF MEASUREMENTS.....	47
7.7	RECORDING OF MEASUREMENTS.....	47

SECTION 8 DERIVED LUMINAIRE DATA

8.1	SCOPE OF SECTION	48
8.2	UTILIZATION FACTORS.....	48
8.3	SPACING/MOUNTING HEIGHT RATIOS.....	48
8.4	ELECTRONIC TRANSFER OF DATA	48

APPENDICES

A	LIGHT OUTPUT RATIOS OF LUMINAIRES	49
B	CALIBRATION OF MEASUREMENTS	51
C	RECOMMENDED METHOD OF CHECKING PHOTOCELL SPECTRAL RESPONSE	53
D	RECOMMENDED METHOD OF CHECKING PHOTOCELL LINEARITY	54
E	INFORMATION TO BE PROVIDED IN THE TEST REPORT	55
F	GUIDE TO THE SELECTION OF GONIOPHOTOMETERS	58
G	GUIDELINES FOR THE COMMISSIONING OF GONIOPHOTOMETERS	65
H	INITIAL CHECKING OF PHOTOMETRIC INTEGRATORS	68
I	PHOTOMETRY OF SOLID STATE LIGHTING DEVICES	69

STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Interior and workplace lighting

Part 3: Measurement, calculation and presentation of photometric data

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for laboratory conditions, procedures and instrumentation for making photometric measurements on luminaires for interior and workplace lighting. It also specifies requirements for the derivation of certain photometric data needed for interior lighting calculations.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

NOTE: Related documents, which may be of interest in relation to this Standard, are listed in the Bibliography.

AS	
60038	Standard voltages
AS ISO	
1000	The international system of units (SI) and its application
AS/NZS	
1680	Interior and workplace lighting
1680.1	Part 1: General principles and recommendations
3100	Approval and test specification—General requirements for electrical equipment
4782	Double-capped fluorescent lamps—Performance specifications
4782.1	Part 1: General (IEC 60081:2000 MOD)
60598	Luminaires
60598.1	Part 1: General requirements and tests (IEC 60598-1, Ed. 7.0 (2008) MOD)
60921	Ballasts for tubular fluorescent lamps—Performance requirements
IEC	
60050	International electrotechnical vocabulary
60050-845	Chapter 845: Lighting
60051	Direct acting indicating analogue electrical measuring instruments and their accessories (series)
60051-2	Part 2: Special requirements for ammeters and voltmeters
60051-3	Part 3: Special requirements for wattmeters and varmeters
ISO	
80000	Quantities and units
80000-7	Part 7: Light

CIE	
18.2	The basis of physical photometry
43	Photometry of flood lights
130	Practical methods for the measurement of reflectance and transmittance
S 025	Test method for LED lamps, LED luminaires and LED modules
BS	
354	Recommendations for photometric integrators
667	Specification for portable photoelectric photometers
1041	Code for temperature measurement
IES	
LM 63	Standard file format for electronic transfer of photometric data
CIBSE	
TM5	Calculation and use of utilization factors

1.3 DEFINITIONS

For the purpose of this Standard, the definitions given in AS/NZS 1680.1 and those below apply.

1.3.1 Reference conditions (lamps)

The conditions under which lamp light output is measured in accordance with the provisions of the appropriate lamp Standard.

1.3.2 Reference lamp

A discharge lamp selected for the purpose of testing ballasts and which, when associated with a reference ballast under specified conditions, has electrical values that are within a specified tolerance of the objective values given in the appropriate Standard. A reference lamp need not be of known (absolute) light output.

1.3.3 Reference ballast

A special inductive type ballast designed for the purpose of providing comparison standards for use in testing ballasts, for the selection of reference lamps and for testing regular production lamps under standardized conditions.

1.3.4 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 2.9.

1.3.5 Ballast lumen factor (*BLF*)

Ratio of the luminous flux emitted by a reference lamp when operated with a particular production ballast to the luminous flux emitted by the same lamp when operated with its reference ballast.

1.3.6 Ballast output factor (for luminaires with discharge lamps)

The ratio of the light output of the bare test lamp operated with the luminaire controlgear at its rated voltage to the light output of the same lamp operated under reference conditions.

1.3.7 Light output ratio (*LOR*)

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.

NOTE: See also Appendix A.

1.3.8 Light output ratio luminaire (*LORL*)

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).

NOTE: See also Appendix A.

1.3.9 Light output ratio working (*LORW*)

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 and with a reference ballast.

NOTE: See also Appendix A.

1.3.10 Upward (downward) flux fraction [*UFF(DFF)*]

The fraction of the total luminous flux of a luminaire emitted above (below) the horizontal plane containing the photometric centre of the luminaire.

NOTE: Also known as upper (lower) flux fraction.

1.3.11 Upward (downward) light output ratio [*ULOR(DLOR)*]

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 [*ULORL(DLORL)*] or the light output ratio working [*ULORW(DLORW)*] as appropriate.

1.3.12 Flux fraction ratio (*FFR*)

The ratio of the upward flux fraction of a luminaire to the downward flux fraction.

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

1.3.13 Photometric centre

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

1.3.14 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 cease to be visible.

NOTE: The term 'shielding angle' is sometimes used to refer to the degree of cut-off with respect to the horizontal, i.e. shielding angle = 90°—cut-off angle.

1.3.15 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, for example, as candela per kilolumen; lux per kilolumen.

1.3.16 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 IEC 60050-845.

1.3.17 Intensity distribution (of a luminaire or of a lamp)

The variation of luminous intensity with direction.

1.3.18 Absolute measurement

A measurement scaled in the appropriate SI units.

1.3.19 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.

1.3.20 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.

1.3.21 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.

1.3.22 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).

1.3.23 Solid state lighting (SSL)

A group of devices that embody p-n junctions that emit visible radiation when excited by an electric current. They can be further defined by the type of technology used, i.e. light-emitting diodes (LEDs), organic light-emitting diodes (OLEDs) or polymer light-emitting diodes (PLEDs).

1.3.24 Light-emitting diode (LED)

Solid state device embodying a p-n junction emitting visible radiation, when excited by an electric current.

1.4 UNITS AND TERMINOLOGY

Only SI units shall be used—see AS ISO 1000 and ISO 80000-7. The principal photometric units are—

lumen; candela; lux; candela per square metre.

For the purposes of this Standard, all photometric quantities should be quoted 'per thousand total lumens', e.g. luminance values should be in units of candela per square metre per thousand total lumens. During measurements it is also possible to use arbitrary units.

NOTE: See Clause 1.3.22 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.

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 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.

1.5 MEASUREMENT OF SOLID STATE LIGHTING DEVICES

For measurement of solid state lighting devices such as LED luminaires, the provisions of Appendix I shall apply. Where aspects of the measurement of these devices are not covered in the clauses or references of Appendix I, the provisions of the remaining sections of this document shall apply provided they do not conflict with the provisions of Appendix I.

1.6 PHOTOMETRIC CENTRE

The position of the photometric centre of a lamp or luminaire may be difficult to determine (see Clause 1.3.14). To eliminate preliminary search and to standardize the mounting of lamps and luminaires, the photometric centre shall be deemed to be located at the appropriate position described below:

- (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 integral 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.

NOTES:

- 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 1.7).
- 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.
- 3 See Figure 1.1 for examples showing how to determine the photometric centre of various types of luminaire.

1.7 CUT-OFF ANGLE REFERENCE POINT

For measurements of the cut-off angle of a luminaire, the line of sight for lamps shall be taken from the following point, as appropriate:

- (a) *Lamps with clear or lightly diffusing envelopes*—the lowest point of the filament or of the arc discharge.
- (b) *Lamps with envelopes of high luminance*—the lowest point of the envelope.

If specular reflections of the lamp are visible on a reflecting surface, the cut-off angle should be measured to this reflected image of the lamp even though the lamp itself may be concealed.

1.8 COORDINATE SYSTEMS FOR LUMINAIRES

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

The coordinate 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 coordinate system is the photometric centre of the luminaire (see Clause 1.6). Various coordinate 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.

The following explanation of the coordinate system shall be interpreted with the aid of Figure 1.2, 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.

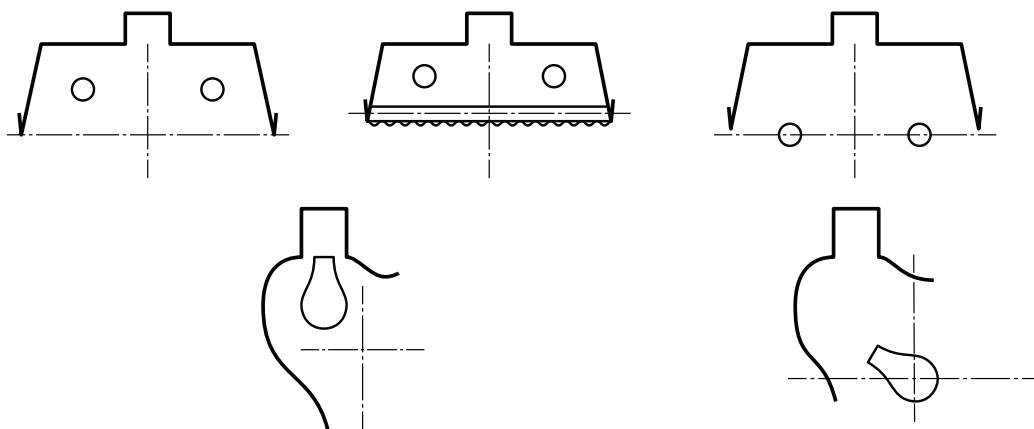
The vertical axis in the direction of the nadir is taken as the 0° direction of angles of elevation, which are measured up to 180° in a given vertical half-plane. It follows that any direction in space, e.g. the direction of an intensity vector, can be specified by two angles, one of azimuth and one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

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

All photometric reports involving direction shall include an outline sketch of the luminaire showing the relevant attitude and labelled with the principal axes and planes.

Where the photometric data is to be stored in a machine readable form, Clause 8.4 recommends that the data be formatted in accordance with IES LM 63. It should be noted that IES LM 63 uses a different coordinate system from that specified above; the system is illustrated in Figure 1.3.

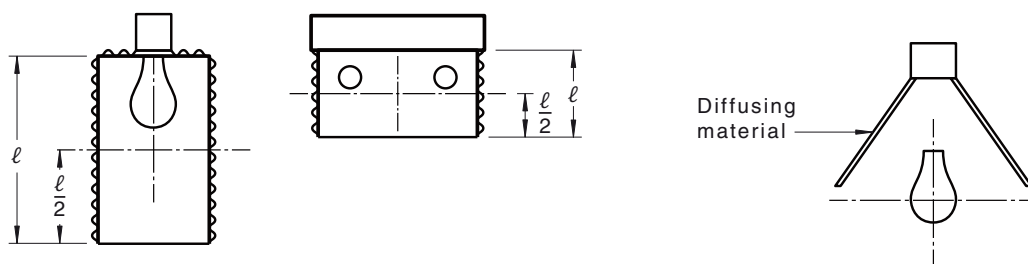
NOTE: The CIE and the IES differ in their definition of the origin of the coordinate system. Consequently, the alignment of luminaires according to the CIE definition will be rotated 90° from that of the IES definition. The alignment used in this standard corresponds with the CIE definition. This means that the "length" of luminaires will often, counter-intuitively, be shorter than the 'width' as shown in Figure 1.3. It is important to be aware of this issue when using the measured data and where necessary to rotate the data by 90° and/or to swap the length and width dimensions.



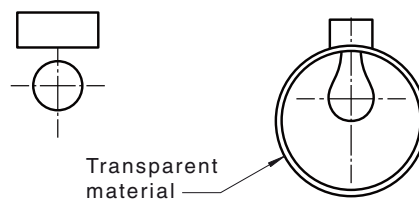
(a) Luminaires with opaque sides, lamp compartment substantially white



(b) Luminaires with opaque sides, lamp compartment substantially black

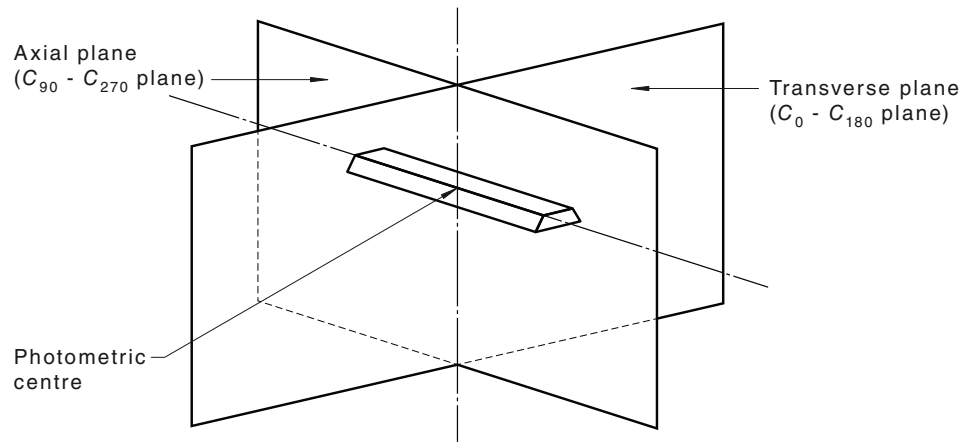


(c) Luminaires with diffusing/prismatic sides

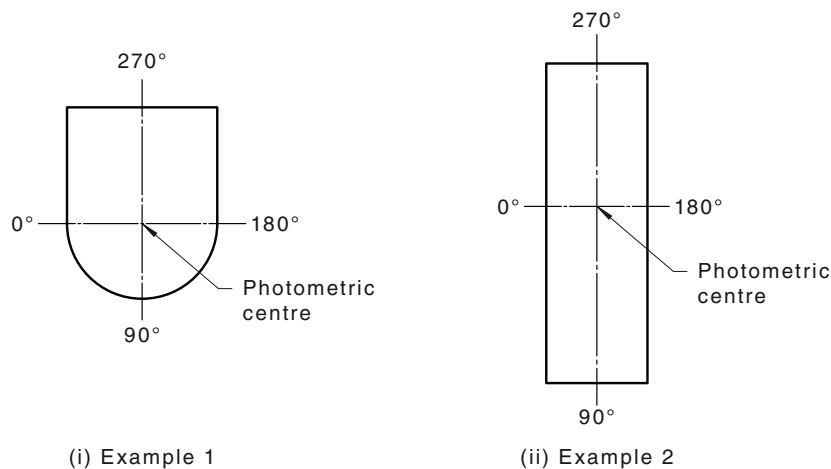
(d) Luminaires with transparent sides or without side members
(photometric centre in all cases at lamp photometric centre)

NOTE: The position of the photometric centre is indicated by the crossing of the dashed lines.

FIGURE 1.1 EXAMPLES SHOWING THE DETERMINATION OF THE
PHOTOMETRIC CENTRE OF A LUMINAIRE



(a) Principal planes for linear luminaires

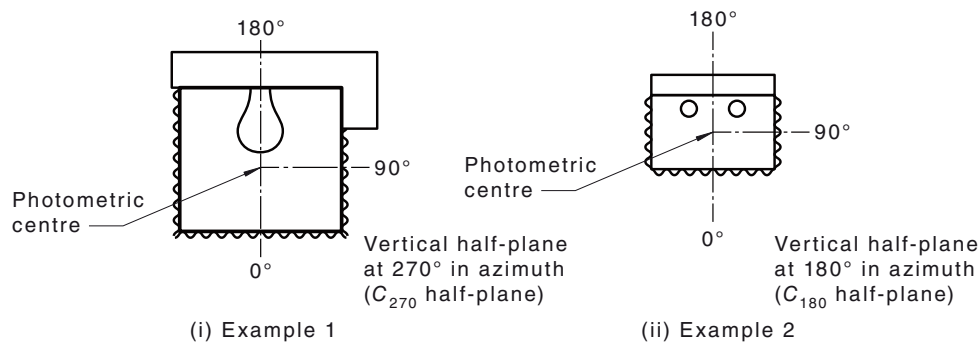


(i) Example 1

(ii) Example 2

NOTE: Azimuth angles are assigned in an anti-clockwise direction from above; the 270° direction being identified by a reference to a recognizable feature, e.g. nameplate.

(b) Plan views showing azimuth angles (C-angles)



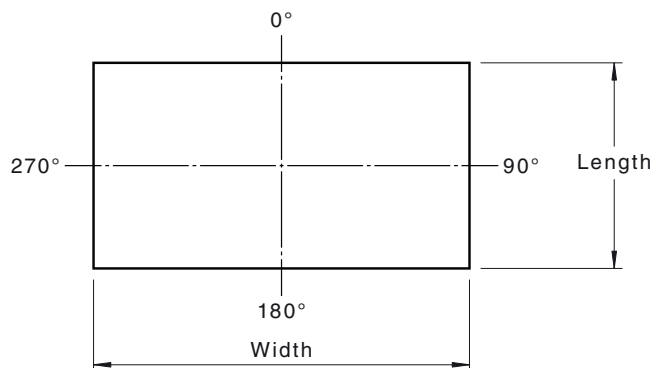
(i) Example 1

(ii) Example 2

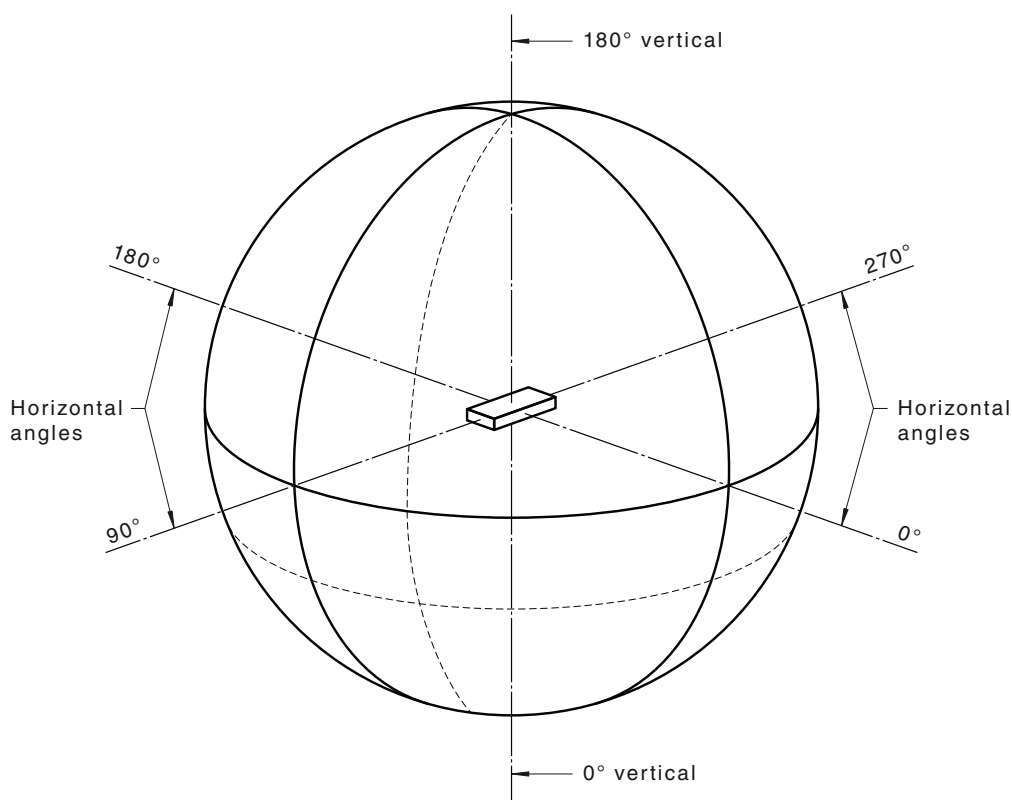
NOTE: Angles of elevation are measured from nadir. The relevant half-plane of elevation is identified by the angle of the half-plane in azimuth.

(c) End views showing angles of elevation (γ-angles)

FIGURE 1.2 REQUIRED COORDINATE SYSTEM FOR THE PHOTOMETRY OF LUMINAIRES



(a) Plan view of luminaire showing length and width in relation to horizontal angles



(b) Schematic showing vertical and horizontal angles

NOTES:

- 1 IES LM 63 defines the 'length' and 'width' of the luminous opening by reference to the azimuth plane of photometry, as illustrated above, without regard to the actual physical proportions of the luminaire. However, in North American practice for the photometry of luminaires with tubular fluorescent lamps, it is customary for the longer dimension of the luminous opening to be aligned parallel with the 0°/180° photometric plane.
- 2 See Note to Clause 1.8.

FIGURE 1.3 CONVENTIONS FOR ANGLES AND DIMENSIONS USED IN IES LM 63 FOR ELECTRONIC TRANSFER OF DATA

SECTION 2 LABORATORY CONDITIONS AND PROCEDURES

2.1 SCOPE OF SECTION

This Section specifies standard laboratory test conditions and procedures, which apply to photometric measurements for all types of electric luminaires.

For solid state lighting devices, the provisions of Appendix I apply and take precedence over the provisions of this Section. Where there are aspects of the test conditions and measurement of solid state lighting devices that are not covered by the provisions of Appendix I, but are covered in this Section, then the provisions of this Section apply. More detailed requirements are given in the appropriate sections of this Standard.

2.2 LABORATORY MEASUREMENTS

2.2.1 Calibration of 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.

NOTE: See Appendix B

2.2.2 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)* The determination of light output ratio requires measurement of the light output of the luminaire and of the bare lamp. It may be determined with a photometric integrator (see Section 4) or may be derived from the calibrated measurements of intensity distribution on a goniophotometer (see Section 3). For practical purposes, the measurement will normally be in terms of *LORW* but, for certain applications, a measurement in terms of *LORL* will be appropriate.

NOTE: See Clause 2.9 and Appendix A.

- (b) *Intensity distribution (non-calibrated)* Measurements of intensity in selected directions are made on a goniophotometer in accordance with Section 3. Measurement of the bare lamp is not required.
- (c) *Intensity distribution (calibrated)* Measurements are made as in Item (b) but measurement of the bare lamp is also required. Alternatively, measurements may be made as in Item (b) but calibrated by means of *LOR* determined in a photometric integrator.
- (d) *Luminance data (see Section 6)* Luminance data comprise 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* Measurements of illuminance distribution are made on a plane or on a series of planes in accordance with Section 7. Measurements may be in arbitrary units or may be calibrated.

2.2.3 Subsidiary measurements

The following subsidiary measurements may also be required:

- (a) *Correction factors (see Section 5)* These factors 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 5)* This ballast characteristic (mainly applicable for 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.

2.2.4 Derived values

Other photometric characteristics of luminaires may be derived from the principal and subsidiary measurements listed in Clauses 2.2.2 and 2.2.3.

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

- (a) Flux fraction ratio (*FFR*) $= UFF \div DFE.$
- (b) Upward light output ratio working (*ULORW*) $= LORW \times UFF.$
- (c) Downward light output ratio working (*DLORW*) $= LORW \times DFE.$
- (d) Upward light output ratio luminaire (*ULORL*) $= LORL \times UFF$
- (e) Downward light output ratio luminaire (*DLORL*) $= LORL \times DFE.$

To derive published data, for most luminaires it is sufficient to measure only intensity distribution, light output ratio and, for glare index calculations, the dimensions of the luminous parts.

2.3 LABORATORY FACILITIES

The principal apparatus for photometric measurements of luminaires are a goniophotometer and a photometric integrator. Sections 3 and 4 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.

2.4 STATUS OF MEASUREMENTS

Repeatability of photometric measurements 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 differences between products.

Attention should be paid to reducing the effect of variables. The provisions 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 or ambient temperature, or both.
- (c) In measurements with goniophotometers, mirror sag and variations in mirror reflectance.

Test reports shall include a statement of the uncertainties of measurement for each of the measurements for which data are provided.

2.5 ELECTRIC POWER SUPPLY AND INDICATING INSTRUMENTS

Electric power supplies for operating lamps and luminaires in photometry shall comply with 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 using the fundamental as 100%.

- (c) Preferably, a power supply should hold a set voltage within close limits, so that it is not 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 0.5 in the IEC 60051 series or equivalent measures for digital devices. Instruments for indicating r.m.s. values in circuits with waveform distortion shall be substantially free from error due to this distortion.

NOTE: The requirement in Clauses 2.12(f) and 2.13(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 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 periodic checking at appropriate intervals.

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

2.6 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 specified in Clauses 2.12 and 2.13 for ambient air temperature, and suitable arrangements shall therefore be made for its measurement 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. Information on the measurement of air temperatures and the temperatures of components (e.g. lamps, ballasts and luminaires) is provided in AS/NZS 3100 and AS/NZS 60598.1.

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 thermometers, placed on either side of the luminaire or lamp, at a distance of about 0.5 m, level with the photometric centre. 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 2.7.

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

2.7 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 the requirements of Items (a) to (j) 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 'photocell and associated apparatus'.

For the purposes of this Standard, the readout need only be scaled in arbitrary units unless otherwise specified.

NOTE: See Appendix B for information on the calibration of measurements.

The following provisions apply:

- (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 appropriately 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 1 h. 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.

- (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 -0.3% per degree Celsius. 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:
 - (i) *Uncalibrated measurements* The air temperature shall be held within $\pm 2^\circ\text{C}$ of any convenient objective value (preferably 25°C).
 - (ii) *Light output ratio and calibrated measurements* As for Item (i) 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 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.

NOTE: A recommended method is described in Appendix C.

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.

A check may be made using an effective point source.

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

NOTE: A recommended method of checking linearity is described in Appendix D.

The percentage non-linearity (as defined in Appendix D) 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).

* See CIE Publication No. 18.2.

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 non-linearity with age, and it is particularly important that this check should be repeated at regular intervals.

- (h) 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.

- (i) A shutter should 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 light source being measured and intended reflections, 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.

- (j) A monitoring photocell need not have correction for spectral response or oblique light incidence. It shall 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.

NOTE: See Appendix F.

2.8 SELECTION OF LUMINAIRES FOR TEST

Unless otherwise stated, luminaires shall be selected which are representative of production luminaires.

Attention shall be paid to all features that may affect photometric performance. If a luminaire incorporates or is supplied with a ballast, the requirements of Clause 2.9 shall apply. Similar requirements shall apply to transformers for filament lamp luminaires.

2.9 SELECTION OF BALLASTS FOR USE WITH LUMINAIRES UNDER TEST

For the type testing of luminaires, ballasts shall be selected in accordance with the appropriate situation described in Items (a) to (d) of this Clause.

For luminaires with more than one ballast, the specified requirements apply to each ballast. For the purpose 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.

For Situations 1 and 2 [see Items (a) and (b)], 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 the light output due to a difference in power loss or positioning, measurements shall be made and reported for each ballast type separately.

For all of the situations described, if the lamp is a type for which reference ballast specifications have not yet been determined, a production ballast should be used when testing the lamp and luminaire. The light output ratio luminaire (*LORL*) should be determined and a statement included in the report indicating that, as no reference conditions exist, the lamp manufacturer should be consulted to determine initial rated lumen output conditions.

Situations 1 to 4, and the applicable provisions, are as follows:

- (a) *Situation 1: The luminaire is supplied for test or is intended for sale with a ballast incorporated* Luminous intensity measurements shall be made in a way that will derive a value of light output ratio working (*LORW*). Measurements of the bare lamp shall be made using a reference ballast mounted away from the lamp to minimize obstructions and proximity effects but connected by leads of negligible impedance.

The reference ballast shall be constructed to conform to the limiting values specified in the appropriate lamp Standard. Alternatively, a selected production ballast may be used provided that the power delivered to the lamp is within the same tolerance as specified for the reference ballast and the lamp current waveform is similar to that provided by a reference ballast. Measurements of the intensity distribution from the luminaire shall be made using the production ballast supplied or, where a selection is to be made by the testing laboratory, the ballast that is closest to the average of the batch of production ballasts in terms of lamp power and power loss. The ballast shall be incorporated in the luminaire during testing.

- (b) *Situation 2: The luminaire is supplied for test or is intended for sale with a ballast for external operation* Luminous intensity measurements shall be made in a way that will derive a value of light output ratio working (*LORW*). All the conditions specified in Item (a) shall apply except that, when determining the luminous intensity distribution of the luminaire, the production ballast shall be mounted away from the luminaire to avoid proximity effects but connected by leads of negligible impedance.

- (c) *Situation 3: The luminaire is supplied for test or is intended for sale without a ballast (i.e. the ballast needs to be selected by the user and incorporated in the luminaire)* Luminous intensity measurements shall be made in a way that will derive a value of light output ratio working (*LORW*) but the measured values shall all be corrected by the application of a measured ballast output factor. The data are therefore published as if a reference ballast had been used thus giving a value for light output ratio luminaire (*LORL*).

Ballast shall be constructed to conform to the limiting values specified in the appropriate lamp Standard. Alternatively, a selected production ballast may be used provided that the power delivered to the lamp is within the same tolerances as specified for the reference ballast and the lamp current waveform is similar to that provided by a reference ballast.

Measurements of the intensity distribution from the luminaire shall be made using a production ballast selected by the testing laboratory as representative of the type used for the operation of the lamp, and of appropriate electrical rating and physical size. The selected ballast shall be fitted in the luminaire to give an attempted representation of expected proximity effects. The selected ballast may have a published ballast lumen factor; if not, the ballast output factor should be determined by repeating the test on the bare lamp using the selected production ballast as a replacement for the reference ballast.

Intensity values derived from measurements of both the luminaire and the bare lamp, using the relative method of photometry, should be divided by either the ballast lumen factor or the ballast output factor. The light output ratio luminaire (*LORL*) can be determined from these corrected values.

For Situation 3, details of the selected ballast should be presented in the test report along with the published ballast lumen factor or measured ballast output factor to aid lighting designers in determining the expected light output. A statement should be included in the report indicating that, if the user chooses a different ballast from the one nominated in the test report, the ballast lumen factor for that ballast would be required in order to determine the light output.

- (d) *Situation 4: The luminaire is supplied for test or is intended for sale without a ballast (i.e. the ballast needs to be selected by the user for external operation)* Luminous intensity measurements shall be made in a way that will derive a value of light output ratio luminaire (LORL).

The luminous intensity distribution of both the bare lamp and the luminaire shall be determined using a reference ballast mounted away from the light source to minimize obstructions and proximity effects but connected by leads of negligible impedance. The reference ballast shall be constructed to conform to the limiting values specified in the appropriate lamp Standard. Alternatively, a selected production ballast may be used provided that the power delivered to the lamp is within the same tolerances as specified for the reference ballast and the lamp current waveform is similar to that provided by a reference ballast.

The luminous intensity distribution data can be assigned units of candelas per 1000 lamp lumens but a statement shall accompany the data indicating that, after a ballast has been selected, either a ballast lumen factor or ballast output factor (for this lamp) is required. The lamp manufacturer's initial rated lumen output should be multiplied by this factor before being applied to the intensity data.

2.10 SELECTION AND PREPARATION OF LAMPS FOR USE WITH LUMINAIRES UNDER TEST

Lamps selected as test lamps shall comply with the relevant Standards (where applicable) and with the requirements given in Items (a) to (d); if no relevant Standard is available, 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 defects. 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 the published initial values of rated luminous flux.
- (d) Unless otherwise specified, tubular fluorescent lamps shall be of the colour 'white' in accordance with AS/NZS 4782.1.

Test lamps shall be aged by operation for at least the period specified in the relevant lamp Standard for initial readings of photometric quantities.

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 the requirements of Items (a) to (c) above; repeat checks shall be made regularly.

Test lamps should be numbered and a note kept of operating hours to aid routine replacement.