CIE S 025: Test Method for LED Lamps, LED Luminaires and LED Modules

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International Commission on Illumination
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Internationale Beleuchtungskommission

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Outline

- Background and purpose of CIE S 025
- What measurements it covers
- Standard test conditions and tolerance interval
- Operating conditions for device under test
- Requirements for test equipment
- Reporting uncertainties of measurement

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Importance of Quality Assurance of SSL Products

Various Solid State Lighting (SSL) products are introduced in many countries

Problems

- Some very low quality products in the market (dim, short life, bad colour)
- Inaccurate performance claims
- Insufficient product information (label)

- **Consumers' disappointment**
- **Delay of adoption of SSL**

Needs for good standards and regulations

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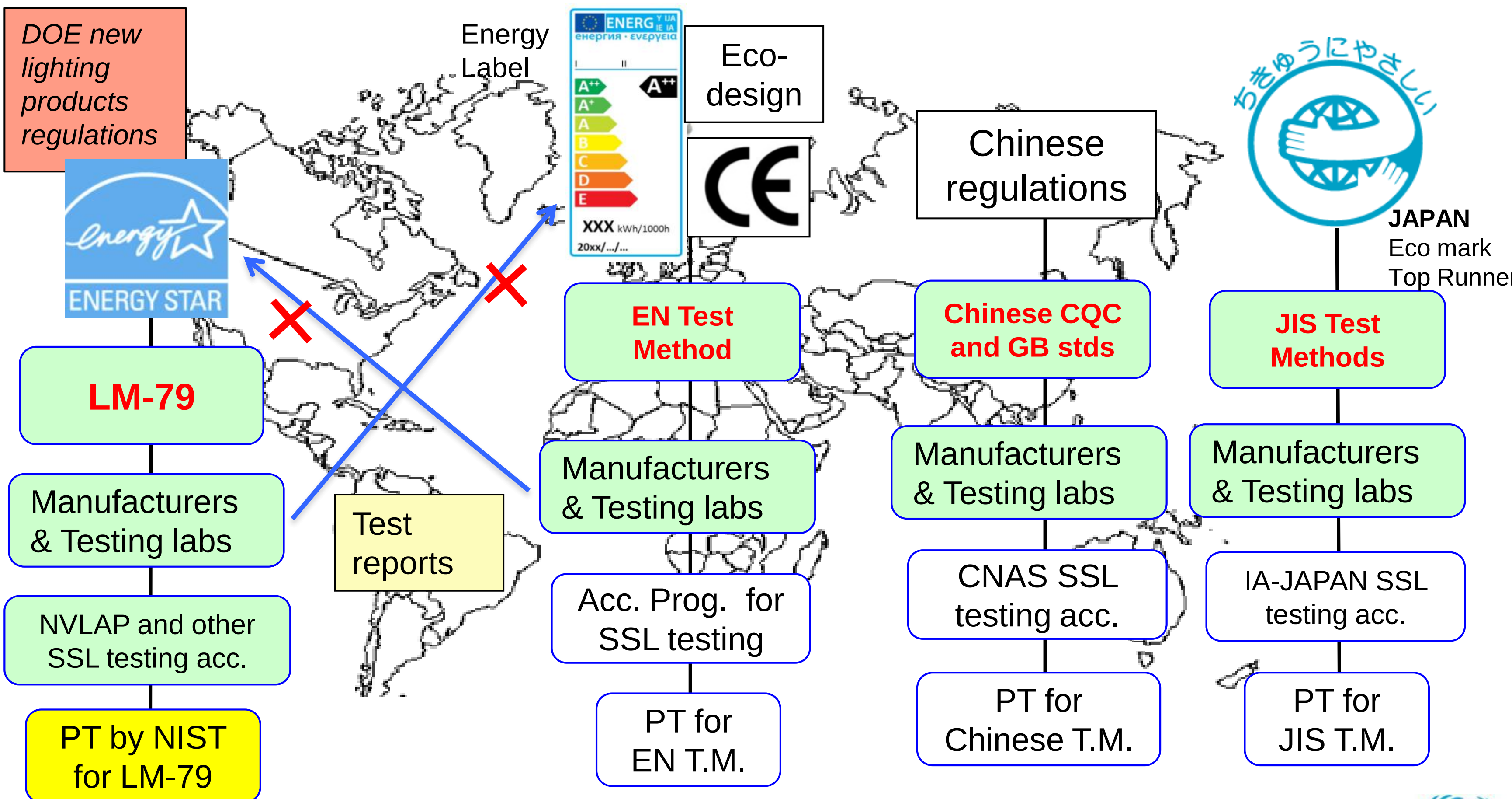
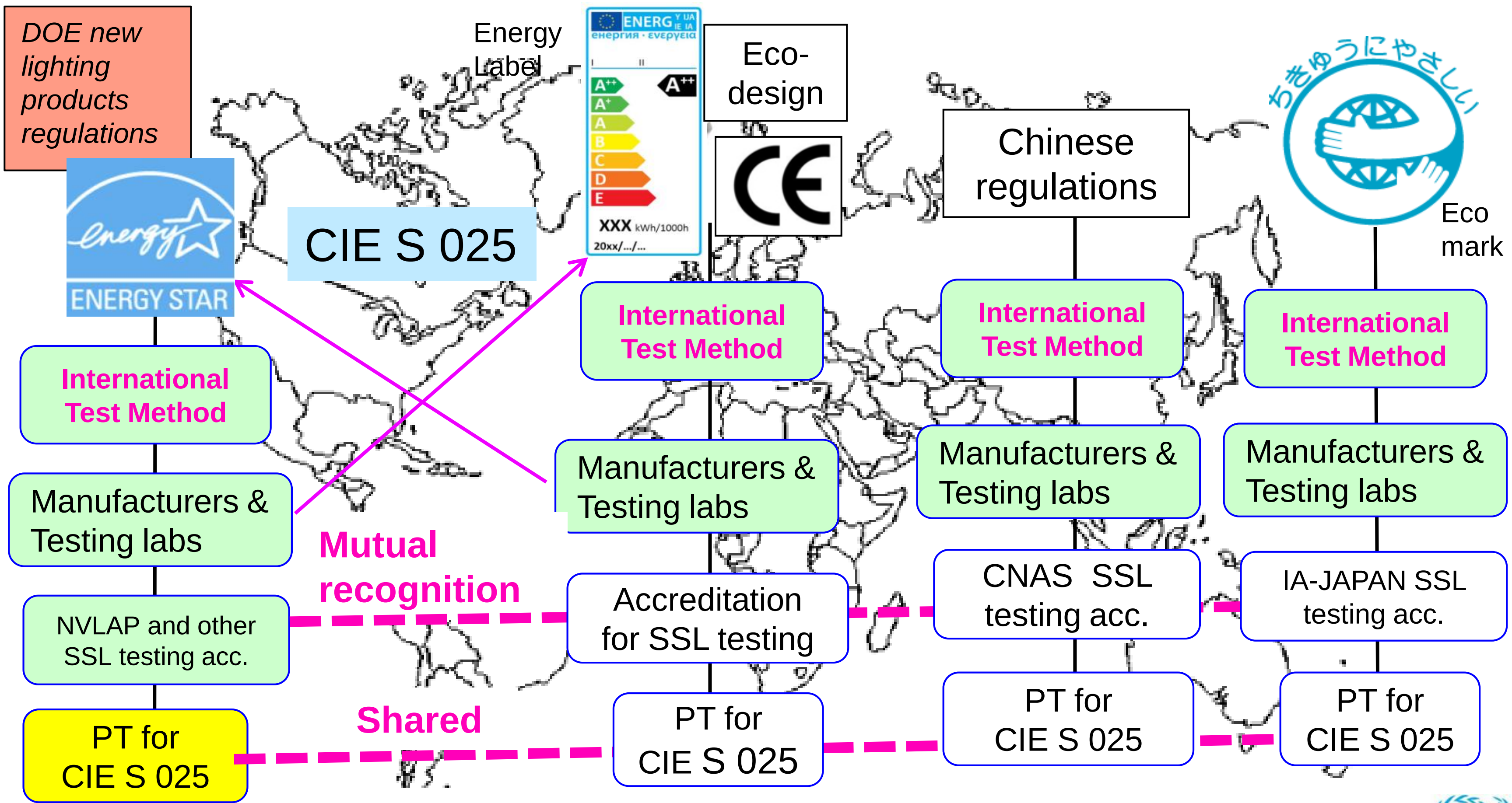
Need for International Harmonisation in SSL Testing and Accreditation: *Historical*



Needs for International Harmonisation in SSL Testing and Accreditation: *Now*



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CIE standard S 025 provides a unified global test method for harmonisation of testing of LEDs and SSL products

Who is the CIE??

- CIE is the International Commission on Illumination (Commission Internationale de l'Eclairage)
- An independent, non-profit organisation recognised by the ISO as an international standardisation body in the field of light and lighting
- The CIE is about...
  - LIGHT & VISION & COLOUR
  - SCIENCE & STANDARDS
  - KNOWLEDGE TRANSFER & QUALITY ASSURANCE
- The CIE has been working for over 100 years

CIE Technical Committee TC2-71

- CIE Division 2 deals with physical measurement of light and radiation
- CIE TC2-71 CIE Standard on Test Methods for LED Lamps, Luminaires and Modules
- Established in 2011
- Chair: Dr. Yoshi Ohno (NIST, USA)
- The TC has 37 members from 16 countries in 5 continents: globally representative
- Standard was published in March 2015:
  CIE S 025/E:2015 Test Method for LED Lamps, LED Luminaires and LED Modules

CIE TC2-71 and CEN TC169 WG7

CIE TC2-71 CIE Standard on test methods for LED Lamps, luminaires and modules
Chair, Yoshi Ohno (US)

Joint work with

CEN TC169 WG7 Photometry, Chair, Guy Vandermeersch (BE)

CIE S 025/E:2015 Test Method for LED Lamps, LED Luminaires and LED Modules
Published 2015.3.20

EN 13032 Lighting Applications — Measurement and Presentation of Photometric Data of Lamps and Luminaires — Part 4: LED Lamps, Modules and Luminaires
In final approval process

CIE S 025 and LM-79

- IESNA LM-79-08 was one of the first test methods for SSL devices
- It became a default global test standard for SSL measurement
- However, LM-79 was developed by a regional organisation: many national standards could not adopt this
- CIE S 025 draws on the experience of LM-79:
  - it is more comprehensive; covers more measurement instruments; and has greater depth
- S 025 development was globally representative
- S 025 was developed by CIE, a recognised international standards organisation
- National and regional standardising bodies and regulators should now move to adopting S 025 for LED measurement

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- Background and purpose of CIE S 025
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- Reporting uncertainties of measurement

What it Covers

- Products covered:
  - LED lamps
  - LED luminaires
  - LED modules
- Products not covered:
  - LED packages
  - OLED products

Measurements it Covers

- Total luminous flux
- Partial luminous flux (useful lumens)
- Centre beam and beam angles
- Electrical measurements
- Luminous efficacy (efficiency)
- Luminous intensity distribution
- Chromaticity coordinates
- Correlated colour temperature
- Distance from Planckian locus
- Colour rendering indices
- Angular colour uniformity

What it Doesn't Cover

- The Standard does not cover or only partially covers:
  - Dimmable, internal feedback, adjustable colour, adjustable white, multicolour
  - Maintained luminous flux
  - Omni-directional assessment
  - Maintained colour measurements
  - Harmonics & EMC
  - Start time / activation time
  - Switch withstand
  - Lamp Life
  - Temperature cycling shock
  - Endurance
  - Photobiological hazards
  - Flicker
  - Dimmer compatibility
- Note: Many of these are already covered satisfactorily in other Standards

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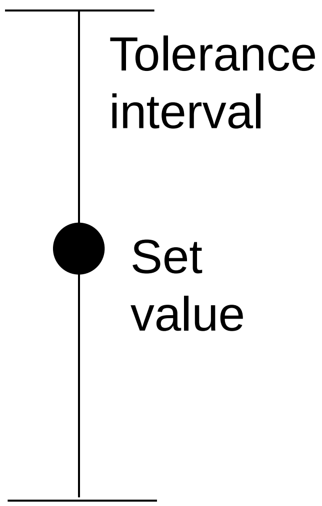
Standard test conditions and tolerance interval

4.1 General

4.1.1 Standard Test Conditions

Measurements of the photometric, colorimetric and electrical characteristics of a LED device shall be performed by means of appropriate equipment and procedures under defined *standard test conditions* for operation of the DUT (Device Under Test). A standard test condition includes a ***set value*** and a ***tolerance interval***.

Measurement results are expressed for the set value of the standard test conditions.



Standard Test Conditions

(For operation of DUT)

- Ambient temperature (LED lamps, luminaires)
  25 °C ±1.2 °C
- Surface temperature (LED module) ±2.5 °C from specified t_p
- Air movement 0 to 0.25 m/s
- Test voltage ± 0.4 % from rated supply voltage

Set value ± tolerance interval

Need to Consider

- What is the uncertainty of your instrument (eg: thermometer, anemometer)?
- How does the uncertainty affect the tolerance interval?

4.1.2 Tolerance Interval

The measurement uncertainty of the related parameter shall be taken into account to ensure that the parameter is within the ***tolerance interval***. For this purpose, an ***acceptance interval*** is defined as the tolerance interval reduced by the expanded uncertainty (95% confidence) of the measurement of the parameter on both limits of the tolerance.

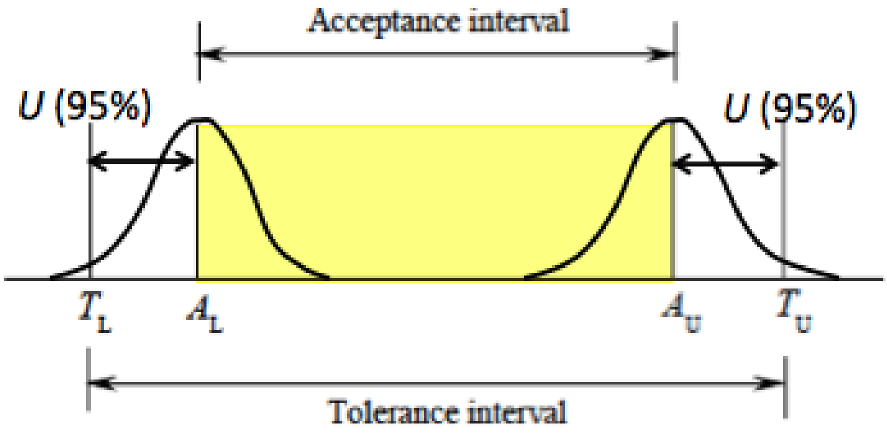
Tolerance Interval and Acceptance Interval

Annex A

Tolerance Interval

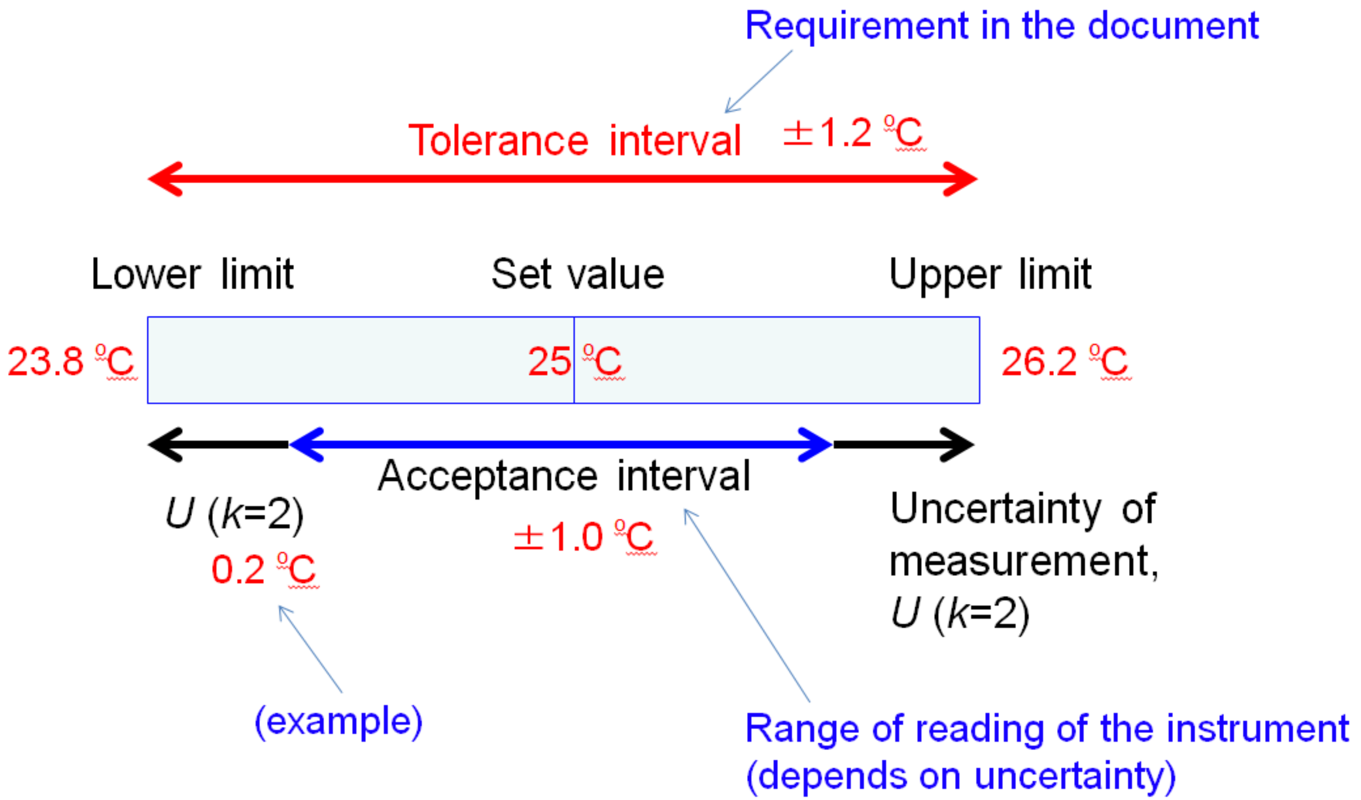
"*tolerance interval*" defined in ISO/IEC Guide 98-4 Role of measurement uncertainty in conformity assessment.

Tolerance interval is an acceptable range of the true value of the parameter (not the range of readings of instrument). Therefore, to ensure this requirement is fulfilled, measurement uncertainty of the parameter needs to be taken into account.



Tolerance Interval and Acceptance Interval

Example: Ambient temperature 25 ºC ±1.2 ºC



Examples of Acceptance Intervals

(example values only)

	Tolerance Interval	**Instrument uncertainty (k=2)**	**Acceptance interval**
Ambient temperature	± 1.2 °C	0.2 °C 0.5 °C	± 1.0 °C ± 0.7 °C
Surface temperature (LED module)	± 2.5 °C	0.5 °C	± 2.0 °C
Air movement speed	± 0.25 m/s	0.05 m/s	± 0.20 m/s
Supply voltage (AC)	± 0.4 %	0.2 %	± 0.2 %
(DC)	± 0.2 %	0.1 %	± 0.1 %

- There are no requirements for the instrument uncertainties
- The larger the uncertainty, the smaller the acceptance interval

Tolerance Interval and Acceptance Interval

3.38
tolerance interval
interval of permissible values of a property

Note 1 to entry: Unless otherwise stated in a specification, the tolerance limits belong to the tolerance interval.

Note 2 to entry: The term "tolerance interval" as used in conformity assessment has a different meaning from the same term as it is used in statistics.

[SOURCE: ISO/IEC Guide 98-4, 3.3.5]

3.39
acceptance interval
interval of permissible measured quantity values

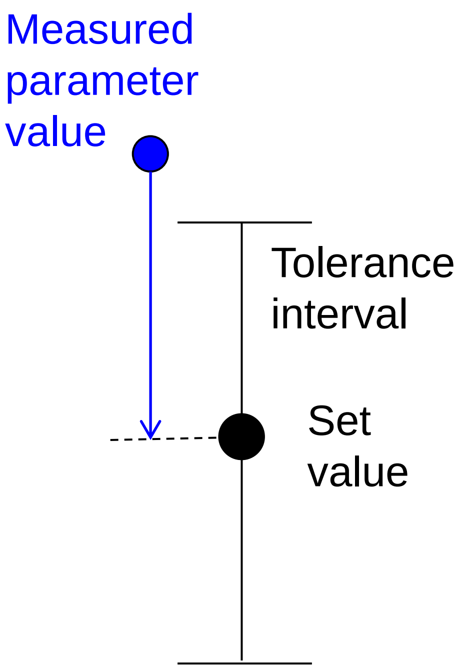
Note 1 to entry: Unless otherwise stated in the specification, the acceptance limits belong to the acceptance interval.

[SOURCE: ISO/IEC Guide 98-4, 3.3.9]

Outside the Tolerance Interval

4.1 General
4.1.1 Standard Test Conditions

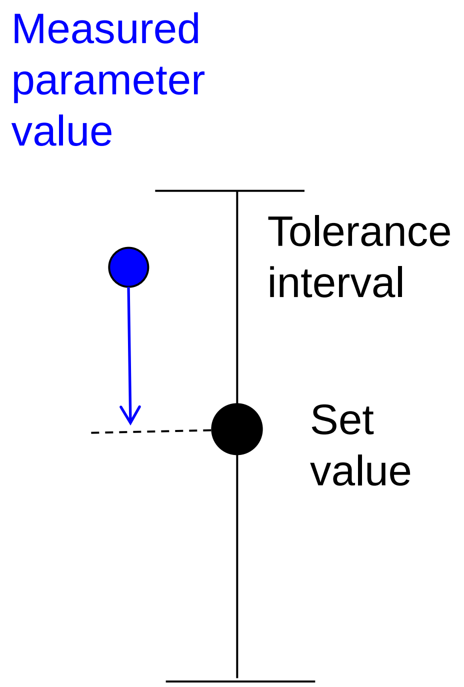
In case where some of the standard test conditions or requirements cannot be fulfilled, deviations outside the tolerance intervals or requirements <u>are permitted</u> if the related measurements are corrected to the standard test conditions. In such cases, the specific uncertainty component for the corrected parameter shall be evaluated and incorporated into the final uncertainty budget. The actual measurement condition and the fact that correction is made to the standard test condition for the parameter shall be reported in the test report.



Correction to the Standard Condition

4.1 General
4.1.1 Standard Test Conditions

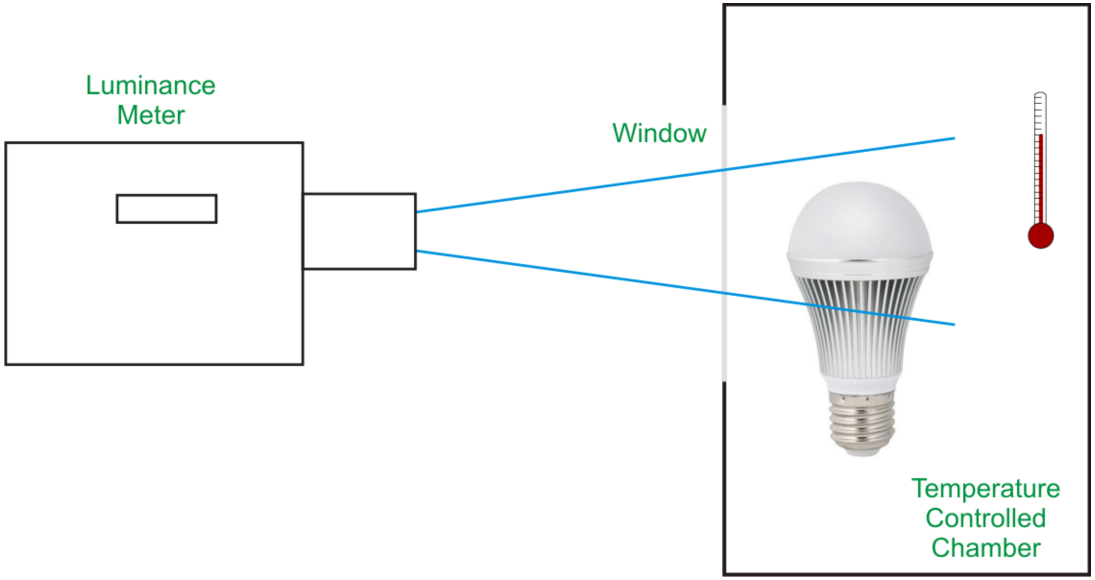
(Even if the tolerance is met) To further reduce the uncertainty of measurements, the results may be corrected for the deviation within the tolerance interval, to conditions at the set value of the standard test condition. The set value is normally the centre value of the tolerance interval, though not always so.



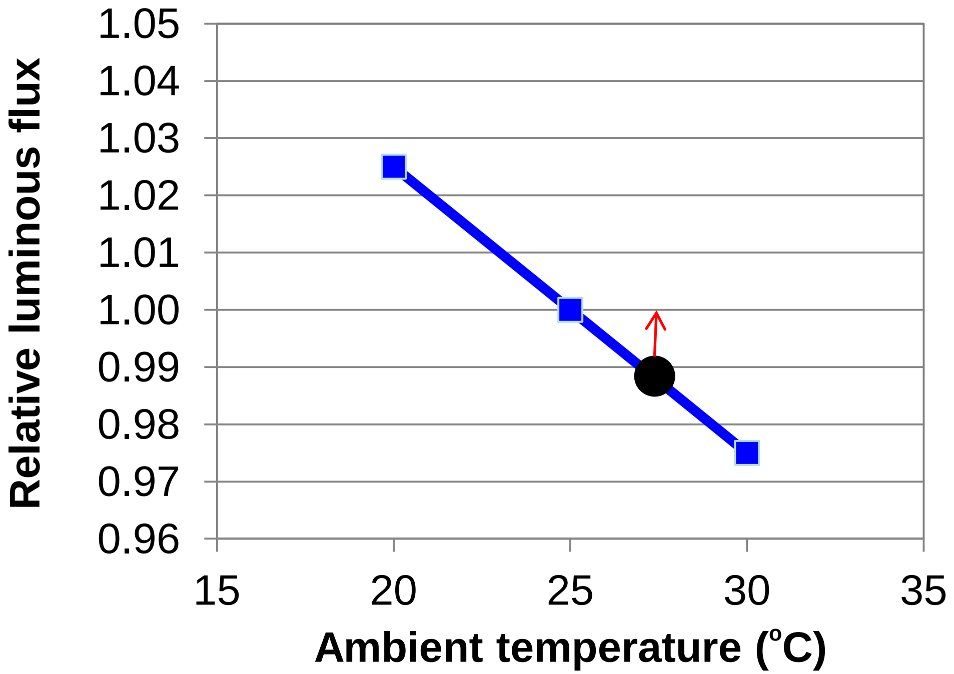
Direct Correction of the Measurement Result

Example: In a goniophotometric measurement, room temperature = 27.3 ^{o}C

Use a temperature controlled chamber and a luminance meter to make a correction factor to correct the measured result to what it would be at 25.0 ^{o}C



Correction Using Sensitivity Coefficient



Sensitivity coefficient
= -0.5% / °C

Set value = 25 °C   Measured value = 27.3 °C

Measured luminous flux: Φ = 1243 lm

Corrected luminous flux: Φ(25 °C) = 1257 lm

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Temperature Conditions for Operation of DUT

LED Lamps

LED lamps are measured in standard test conditions and data shall be reported for t_{amb} = 25 °C. If other operating temperatures are declared by the manufacturer, the measured results at the given temperature shall be reported or a service conversion factor shall be provided.

LED Modules

LED modules are measured in standard test conditions at the rated performance temperature t_p. The temperature at the t_p-point shall be set at this value for the measurements. …… a suitable temperature controlled heat sink may be used. Interpolation techniques may also be applied (see Annex C).

LED Luminaires

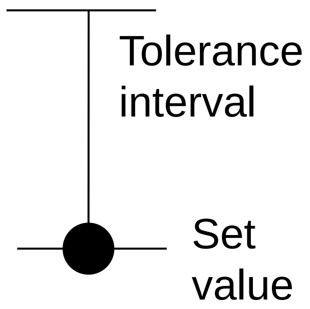
LED luminaires are measured in standard test conditions at t_{amb} = 25 °C.

Air Movement

Air Movement

Measurements shall be made in still air. (Set value: air velocity is zero).

Tolerance interval: 0 m/s to 0.25 m/s



This is an example of a tolerance interval where the set point is not in the centre!

Operating Position of Device Under Test (DUT)

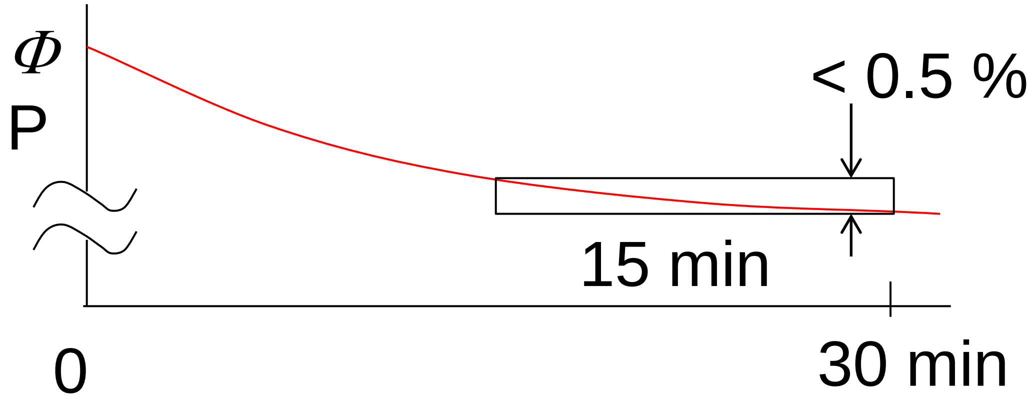
Operating Position
Specific requirement: The DUT shall remain in its designed operating condition (with respect to gravity direction) throughout the stabilization and testing period.

If this requirement is not met, the measurements shall be corrected to the performance in the designed operating position.

Stabilization of Device Under Test (DUT)

LED Lamps and LED Luminaires

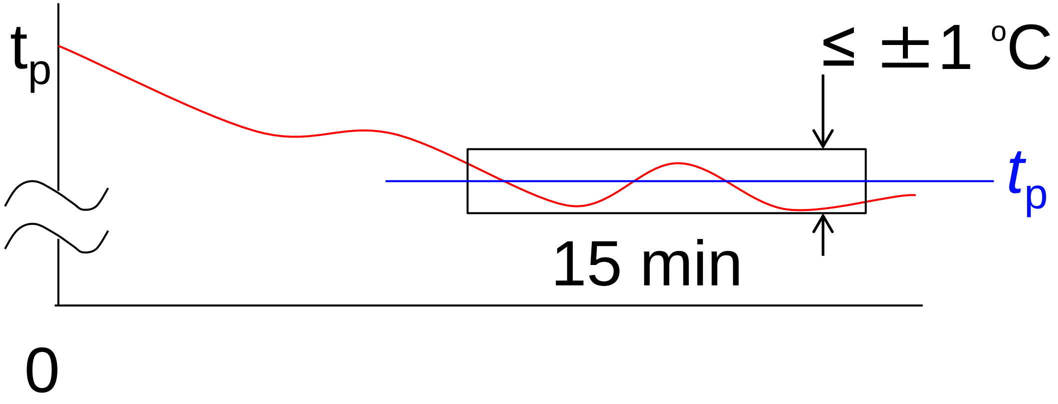
The DUT shall be operated (at ambient temperature 25 °C) for at least 30 min and it is considered as stable if the relative difference of maximum and minimum readings of light output and electrical power observed over the last 15 minutes is less than 0,5 % of the minimum reading.



Stabilization of Device Under Test (DUT)

LED Modules

When the temperature reaches and maintains the specified performance temperature t_p within ±1 °C for 15 min, the LED module is considered to be stabilized in temperature.



The temperature of LED modules is commonly adjusted using a temperature-controlled heat sink.

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Laboratory Requirements for Tests

All measurements shall be traceable to the SI* when instruments are used to measure absolute values of a quantity relevant to the measurement.

3.37
traceability
property of a measurement result whereby the result can be related to a reference (usually NMI's calibration) through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

* Note: SI is an abbreviation for Système International d'Unités (International System of Units) is defined by the CGPM (General Conference of Weights and Measure) and includes the units used internationally today.

Electrical Test Conditions and Electrical Equipment

Specific requirements (summary)

- *Calibration uncertainty of AC Voltmeters and ammeters* ≤ 0.2 % for AC, ≤ 0.1 % for DC
- *Calibration uncertainty of AC power meter* ≤ 0.5 %
- *Bandwidth of AC power meter* ≥ *100 kHz.*
- *Internal impedance of the voltage measurement:* ≥ 1 MΩ
- AC power supply THD ≤ 1.5% (≤ 3 % for PF > 0.9) at DUT terminal
- AC power supply frequency uncertainty ≤ 0.2 %
- DC power supply voltage AC ripple ≤ 0.5 %

Electrical Test Conditions and Electrical Equipment

The voltage of the AC power supply shall be regulated (tested) at the supply terminals of the DUT. (not at the output terminal of power supply. Cables included).

Specific requirement: Any drift or fluctuation of the supply voltage during measurement of a DUT shall be within the acceptance interval of the test voltage (4.3.1).

Photometric and Colorimetric Measurement Instruments

Integrating sphere systems:

- Sphere-photometer (photometer head as detector)
- Sphere-spectroradiometer (spectroradiometer as detector)

Goniophotometer systems:

- Goniophotometer (photometer head as detector)
- Gonio-spectroradiometer (spectroradiometer as detector)
- Gonio-colorimeter (tristimulus colorimeter as detector)

Other types of measurement instruments including integrating hemisphere, near-field goniophotometer and ILMD, are acceptable if they are demonstrated to produce equivalent results as a conventional integrating sphere system or conventional goniophotometer system.

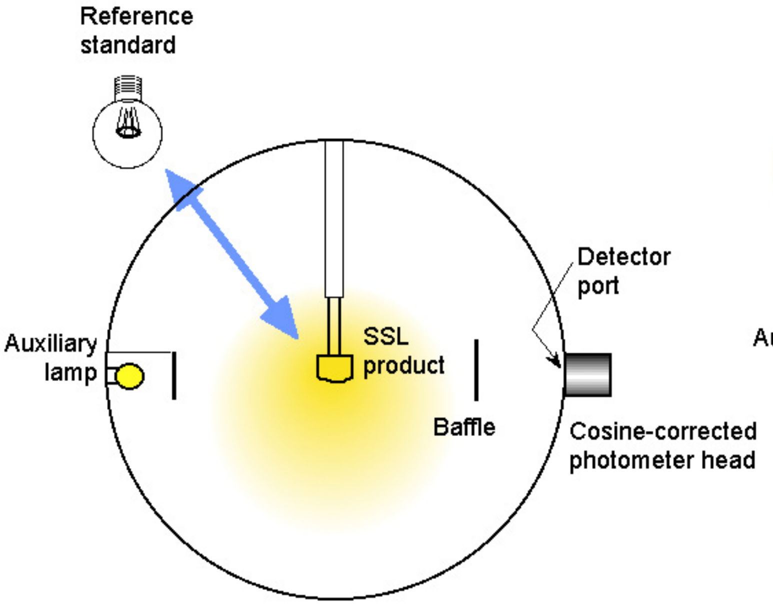
Photometric and Colorimetric Measurement Instruments

Specific requirements (summary)

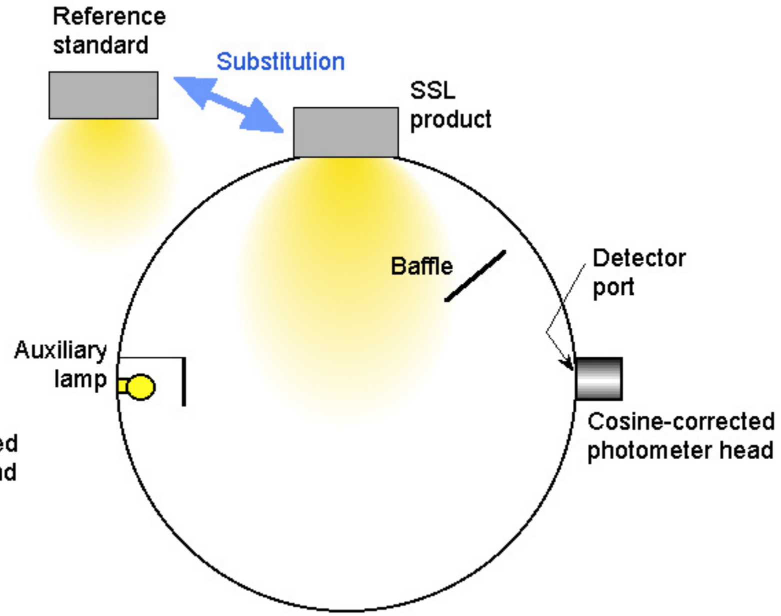
- f_1' of the photometer system (gonio, sphere) ≤ 3 %
- f_2 of the detector head of sphere system ≤ 15%
- Repeatability of sphere (open/close) ≤ 0.5 %
- Stability of the sphere between recalibrations ≤ 0.5 %
- Spectroradiometer bandwidth and interval ≤ 5 nm
- Spectroradiometer wavelength uncertainty ≤ 0.5 nm
- Angle uncertainty of goniophotometers ≤ 0.5 °

Integrating Sphere Measurements

- Covers both 4π and 2π integrating sphere systems



<4 π geometry>



<2 π geometry>

From IES LM-79

Integrating Sphere Measurements

- Gives guidance for:
  - Self-absorption measurements
  - Size of DUT with respect to size of sphere
  - Orientation of DUT in sphere
  - Sphere reflectance uniformity
  - Cosine response
  - Repeatability of closure
  - Calibration interval
  - Spectral responsivity (including coating reflectance)

Goniophotometer Measurements

- Gives guidance for:
  - Angular scan range and dead angle
  - Angular aiming and accuracy
  - Stray light
  - Spectral responsivity (including mirror reflectance)
  - Test distance for far-field measurements (see next slide)

Distance requirements for goniophotometers

Luminous intensity measurements according to the inverse square law require a sufficient photometric distance.

Specific requirements for test distance in far-field photometry:

- *For DUT having near cosine (Lambertian) distribution (beam angle ≥ 90°) in all C-planes: ≥ 5 × D*
- *For DUT having a broad angular distribution different from a cosine distribution (beam angle ≥ 60°) in some of the C-planes: ≥ 10 × D*
- *For DUT with narrower angular distributions , steep gradients in the luminous intensity distribution or critical glare control: ≥ 15 × D*
- *For DUT where there are large non-luminous spaces between the luminous areas: ≥ 15 × (D+S)*

where D is the maximal luminous dimension of the DUT and S is the largest distance between two adjacent luminous areas.

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Reporting of Measurement Uncertainties

- It is a simple fact of life that no measurement is ever perfect
- For each measurement there is an uncertainty of measurement, which is like an estimate of the possible error that could be associated with the measurement result
- CIE S 025 requires that all measurement reports **shall include a statement of uncertainties of measurement**

Reporting of Measurement Uncertainties

- A statement of uncertainties consists of a magnitude and an associated probability

Magnitude	**Probability**
May be relative (eg: 5%)	May be a coverage probability, eg: 95%
May be absolute (eg: 14 lm)	May be a coverage factor, eg: k = 2

- "The measured luminous flux is 783 lm ± 4.2% with a coverage factor k = 2"
- "The correlated colour temperature is 3012 K ± 55 K with a confidence interval of 95%"

Reporting of Measurement Uncertainties

- Ideally, for best practice, measurement uncertainties would be evaluated for each test
- However for practical purposes, it is permitted to use uncertainty values for a typical product of the similar type, with a statement that indicates so in the test report
- If a lab does this, they must keep a detailed uncertainty budget and evidence of how they evaluated this “typical” product

Reporting of Measurement Uncertainties

- The measurement uncertainties shall be evaluated according to ISO/IEC Guide 98-3 and its supplements
- Guidance for evaluating measurement uncertainties for LED lighting devices is given in Chapter 8 and Annex D of CIE S 025
- Guidance is also available in CIE 198:2011 “Determination of Measurement Uncertainties in Photometry” and its supplements

Summary

- CIE has recently published the Standard **CIE S 025/E:2015**, which is a standard test method for photometric testing of LED lamps, luminaires and modules
- CIE S 025 can be used for worldwide harmonised testing of LED lighting products
- It contains test conditions and requirements for equipment used to perform the tests
- It requires mandatory reporting of measurement uncertainties
- Standardising bodies and regulators are encouraged to move to adopting CIE S 025 for LED measurement
- http://div2.cie.co.at/?i_ca_id=563&pubid=491

Upcoming CIE Conferences

- CIE's 28th Quadrennial Session, Manchester/UK, June 28 - July 4, 2015
- CIE Lighting Quality and Energy Efficiency Conference, Melbourne/Australia, March 3-5, 2016
- More information: http://www.cie.co.at/

Thank you for your kind attention.
Any questions?

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