Training Manual for JSMO Energy Efficient Laboratory

Global Efficient Lighting Centre
August 2017

Introduction

This project “Establishing the Foundations of a partnership to accelerate the Global market Transformation for Efficient Appliances and Equipment” is under the United for Efficiency (U4E) initiative which has been identified as top priority themes of the UN Secretary-General’s Sustainable Energy for All (SE4All) initiative to achieve the goal of doubling the global rate of improvement in energy efficiency, through the “SE4ALL Accelerators”.

This project is implemented by the Global Efficient Lighting Centre (GELC), and provided expertise to Jordan standard and Metrology Organization’s Energy Efficiency Laboratory (JSMO EEL) employees. JSMO EEL laboratory is responsible for testing the performance requirements and energy efficiency of different types of lamps to ensure the quality of lighting products entering into or existing within the national market. The laboratory will support the phasing-out of energy inefficient lamps, in order to increase the use of energy efficient lamps; which will be beneficial for the environment and in combating climate change.

The main objective of the technical assistance of this project is to enable the national efficient lighting laboratory in Jordan to ensure quality of lighting products on the market by testing the product performance, and to support Jordan National Energy Plan to phase out energy inefficient lamp from the market. This will be done by enhancing the capability of the laboratory and its personnel, with the following activities:

- Laboratory pre-assessment base on ISO/IEC 17025;
- Inter-laboratory comparison test;
- Technical assistance to laboratory employees – technical training.

GELC aims to support JSMO EEL laboratory in ensuring testing quality and enhancing the laboratory management.

This training is prepared by the Global Efficient Lighting Centre for addressed at managers and technical staff of JSMO EEL laboratory. It has been designed to provide the required technical background and laboratory management so as to build the capacity of JSMO EEL laboratory to:

- Understand how to establish effective quality management systems for lighting laboratory;
- Support Jordan’s monitoring, verification and enforcement schemes by providing reliable test results;
- Support the development of higher efficient lighting products by measuring the gains in energy efficiency related to specific innovations or techniques.

Content

1. Fundamentals of Photometry, Colormetry

1.1 Introduction

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Introduction : Quality parameters

- Safety
- Performance
  - Electrical parameters
  - Photometry
  - Colorimetry

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Quality parameters

- Performance

	Parameters	Conception
Photometry	Luminous flux	Amount of the light emitted
	Luminous efficiency	Efficiency for turning electricity to light
	Intensity distribution	Spacial distribution of light
	Luminance	Brightness
Colorimetry	Color coordinate	Coordinates indicating the color of the light
	CCT	Feeling related, warm, neutral, or cool
	CRI / Ra	Color rendering index, higher, more natural

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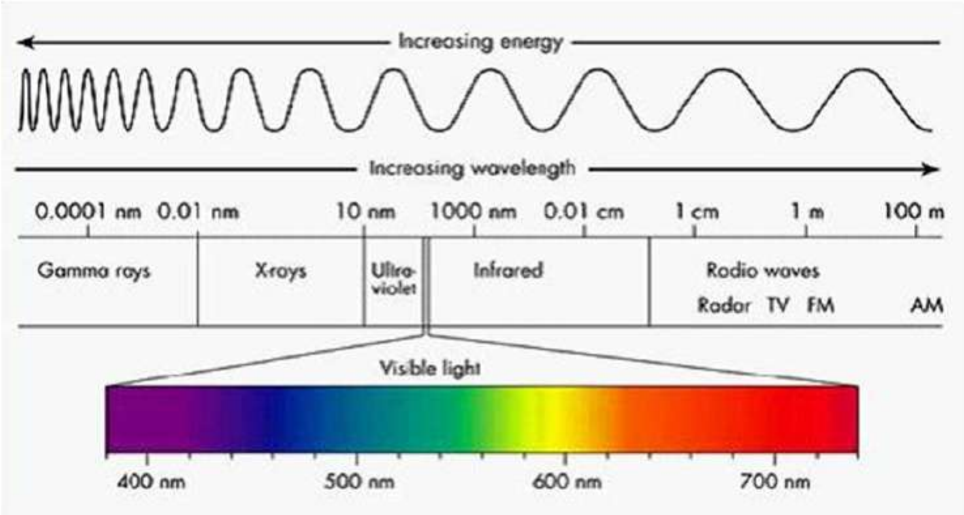
Light and radiation



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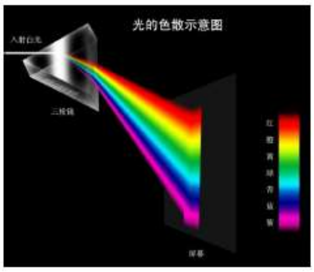
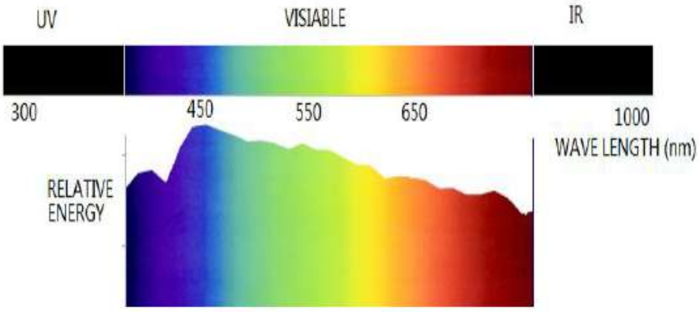
Light and radiation

- Daylight





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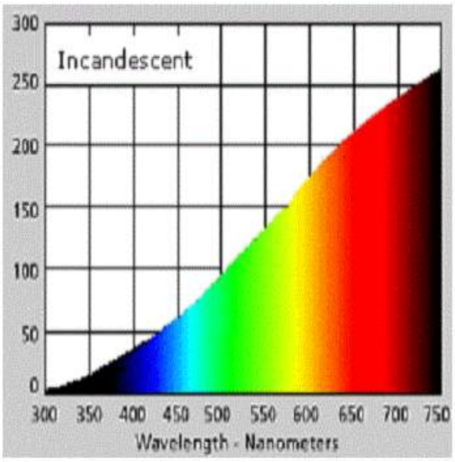
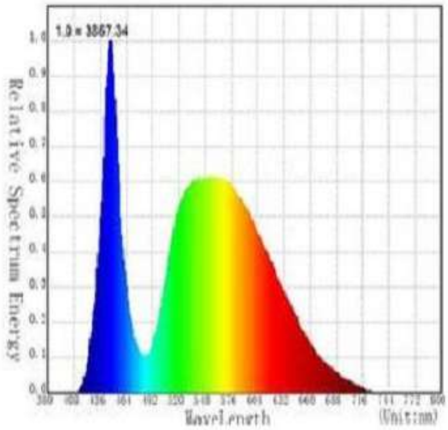
Light and radiation

- Incandescent and LED





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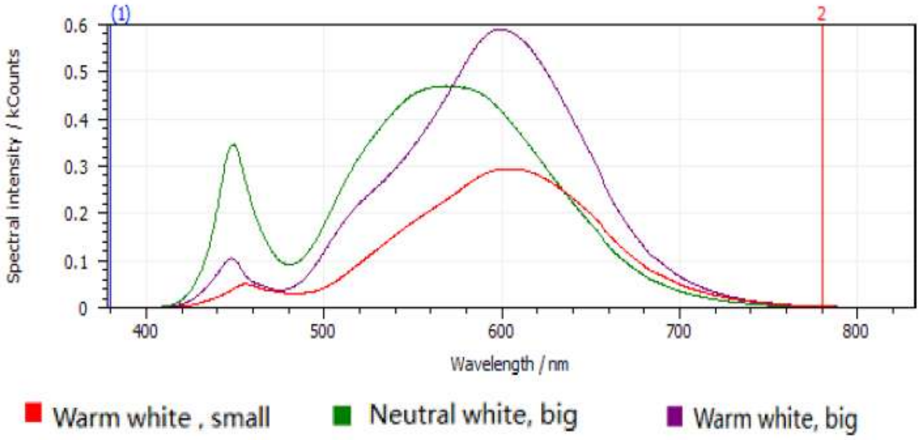
Light and radiation

- Typical LED SPD



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Light and radiation

- Light and radiation
  - Photometry, colorimetry
    - To express huaman eye reception
  - Photometry
    - To express the "quantity amount" of light
  - Colorimetry
    - To express the "color feeling" of light

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Photometry, general

- Human eye as detector
  - The huaman eye is NOT equally sensitive to different wavelength light in the visible range
- Photometry attempts to "simulate" this
  - By weighing the measured power at each wavelength with a factor that represents how sensitive the eye is at that wavelength
  - The standardized model of the eye's response to light as a function of wavelength is given by the luminosity function

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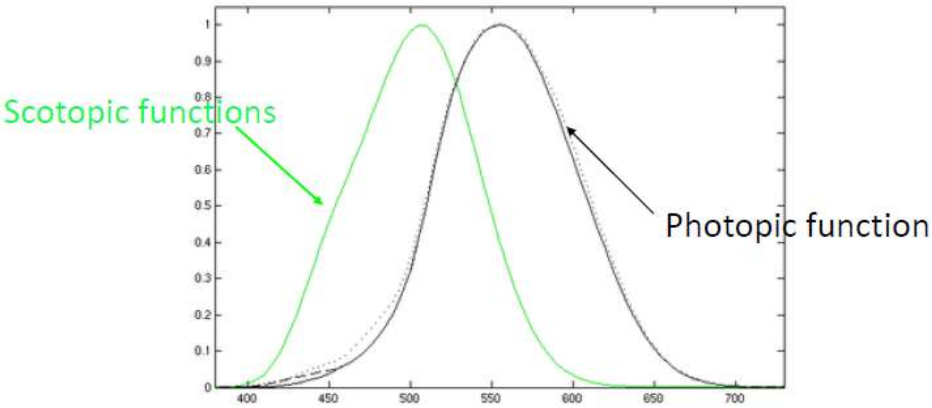
Photometry, general

"Sensitive Factor"



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Photometry, general

- Photopic vision & Scotopic vision
  - Human eye has different responses in different light conditions
- Photometry and the vision basis
  - Based on the eye's photopic response
  - MAY NOT accurately indicate the perceived brightness of sources in dim lighting conditions
    - such as under just moonlight or starlight
    - where colors are not discernible

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Colorimetry, general

- Colorimetry
  - Conception
    - Science / Technology to quantify and describe physically the human color perception
  - Expression
    - CIE 1931 XYZ color space tristimulus value, and etc.

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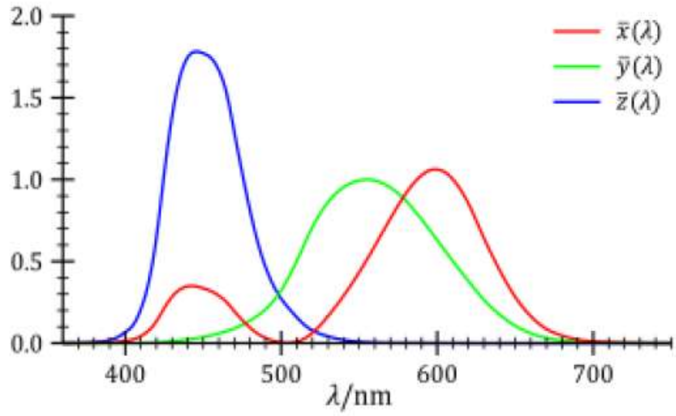
Colorimetry, general



The CIE standard observer color matching functions

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Summary

- Visible light is only a small part of electromagnetic wave
- Light emitted from a lighting source such as the sun, an incandescent lamp, though looked white, but maybe dispersed into colored light
- The "amount" of the light at each color may be different, a distribution, "total amount" also could be different
- Photometry is the "total amount" that can be seen by the eye
- Colorimetry for the relative "distribution" that can be detected by the eye

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1.2 Photometry

Photometry

- Parameters & definition
  - Flux, Intensity, Illuminance, Luminance
- Measurement method for total flux
  - Spacial integrating method
    - ➢Co-ordinates systems
    - ➢Gonio-photometers
  - Integrating sphere method
    - ➢Principle
    - ➢Integrating-sphere

Definition: flux

- Luminous flux
  - Quantity derived from radiant flux by evaluating the radiation according to its action upon the CIE standard photometric observer. For photopic vision is the spectral distribution of the radiant flux and is the spectral luminous efficiency
  - Unit: lm

$$\Phi_v = K_m \int_{380nm}^{780nm} V(\lambda)\Phi_{e\lambda} d\lambda \quad \begin{cases} \Phi_v = 683 \int_{380nm}^{780nm} V(\lambda)\Phi_{e\lambda} d\lambda \\ \Phi'_v = 1755 \int_{380nm}^{780nm} V'(\lambda)\Phi_{e\lambda} d\lambda \end{cases}$$

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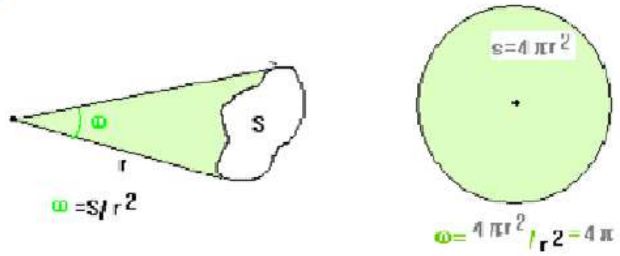
Definition: intensity

- Luminous intensity
  - Quotient of the luminous flux dΦ leaving the source and propagated in the element of solid angle dΩ' containing the given direction, by the element of solid angle
  - Unit: cd; lm/sr

$$I = \frac{d\Phi}{d\Omega'}$$



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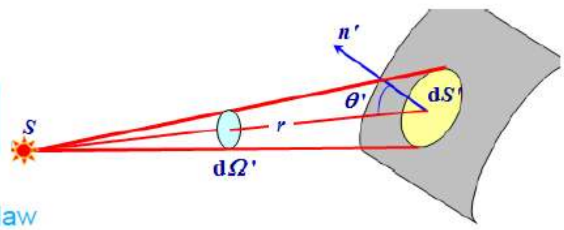
Definition: illuminance

- Illuminance
  - Quotient of the luminous flux dΦ' incident on an element of the surface containing the point, by the area dS' of that element
  - Unit: lx; lm / m²

$$E = \frac{d\Phi'}{dS'} = \frac{I\cos\theta'}{r^2}$$

Inverse square law



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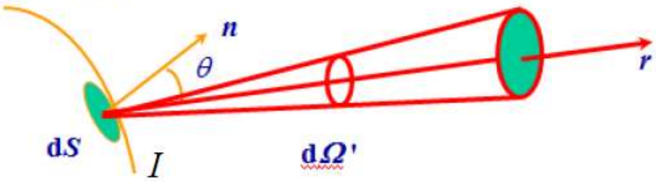
Definition: luminance

- Luminance
  - Quantity defined by the formula where dΦ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle dΩ' containing the given direction; dS is the area of a section of that beam containing the given point; θ is the angle between the normal to that section and the direction of the beam
  - Unit: cd/m^2



$$L = \frac{d\Phi}{d\Omega' \cdot dS\cos\theta} = \frac{I}{dS\cos\theta}$$

Parameters & definitions

- Precondition
  - Suppose the light source is ideal spot light source
- Practice application
  - if the distance is no less than 5 times of the size of light source, it could be considered as a spot light
  - The longer the measuring distance, the better

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Photometry

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    - ➢Co-ordinates systems
    - ➢Gonio-photometers
  - Integrating sphere method
    - ➢Principle
    - ➢Integrating-sphere

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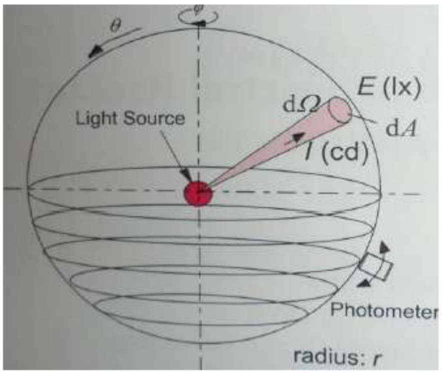
Spacial integrating

- Co-ordinates systems



Total luminous flux defined in these formula:

$$\Phi = \int_{\Omega} I d\Omega$$

$$\Phi = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} I(\theta,\phi) \sin\theta d\theta d\phi$$

$$\Phi = \int_{A} E dA$$

$$\Phi = r^2 \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} E(\theta,\phi) \sin\theta d\theta d\phi$$

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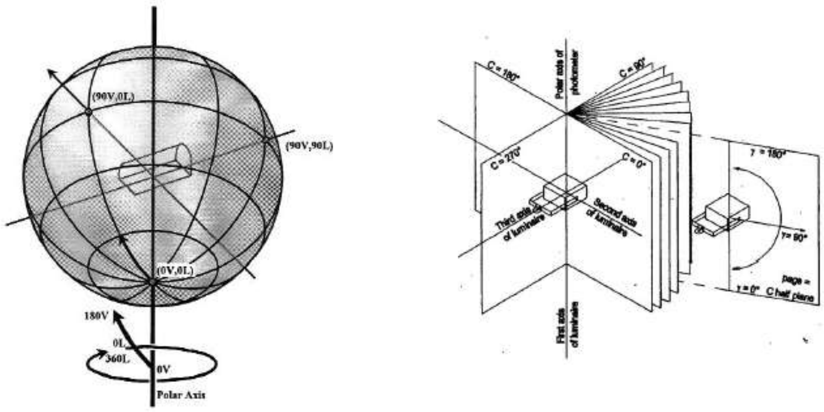
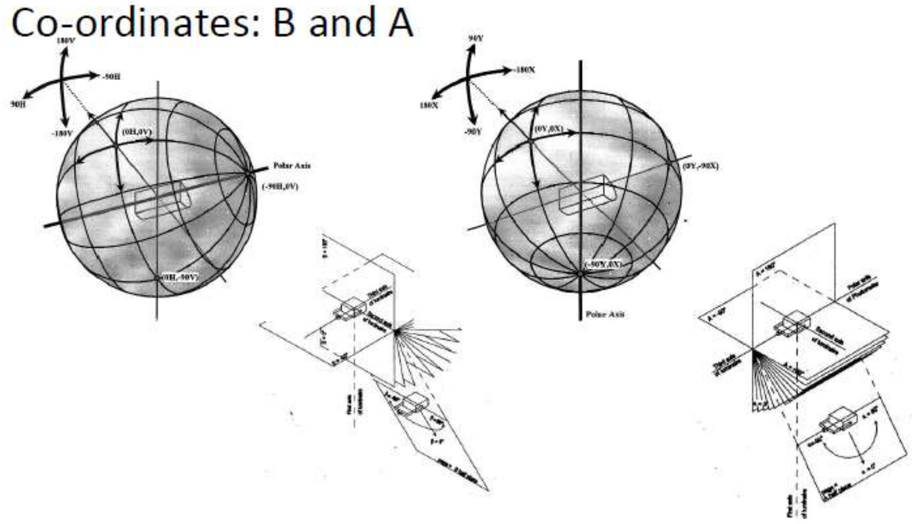
Spacial integrating

- Co-ordinates: C



Spacial integrating

- Co-ordinates: B and A



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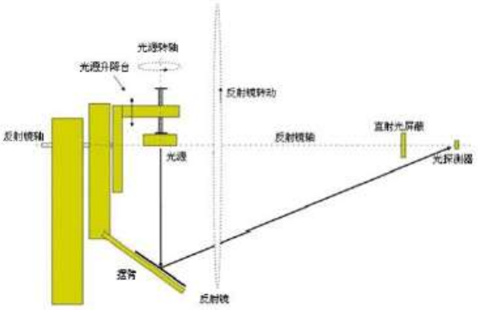
Spacial integrating

- Co-ordinate system
  - Two axes to make the detector performing "sphere surface scan"



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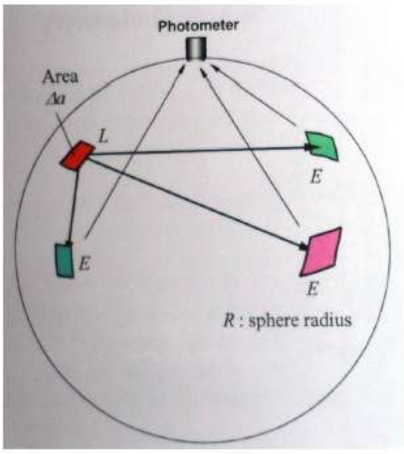
Integrating sphere

- Principal
  - Luminance L on an element Δa creates the same illuminance E all around the sphere surface: $E = L\,\Delta a / 4R^2$
  - Same amount of flux incident anywhere on the sphere wall creates an equal illuminance on the photometer port



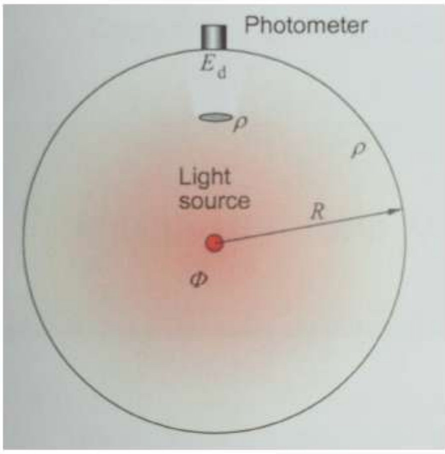
Integrating sphere

- Principal
  - Flux created by inter-reflections

$$\Phi\left(\rho+\rho^2+\rho^3 ......\right)=\Phi\frac{\rho}{1-\rho}$$

  - Illuminance Ed created by inter-reflections

$$E_d=\frac{\Phi\rho}{1-\rho}\cdot\frac{1}{4\pi R^2}$$



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Integrating sphere

- Premises of the principal
  - The integrating sphere is perfect
  - The sphere wall reflectance is perfectly Lambertian
  - The photometer has a perfect cosine response
  - There is no objects in the sphere
- Practice
  - "ρ" changes, not easy to get the accurate value
  - "R" always not that perfect

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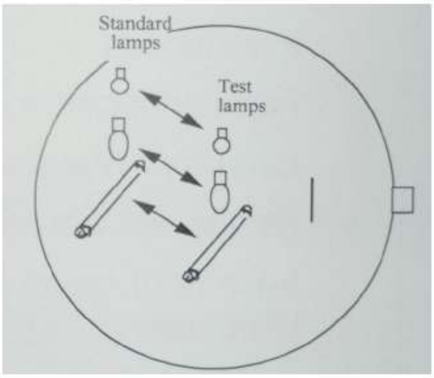
Integrating sphere

- Integrating sphere
  - Flux standard lamp is introduced

$$\Phi_T = \Phi_s \frac{E_T}{E_s}$$



Note:
Test lamp should be "similar" to the standard lamp
in shape, size
enclosure color
intensity distribution, etc.

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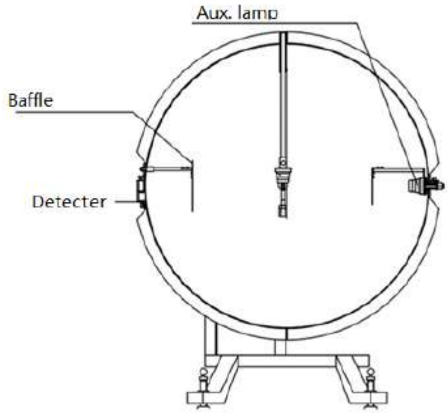
Integrating sphere

- Integrating sphere



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Summary

- Photometry
  - amount of "light"
- system to collect the light
  - Gonio-photometer
  - integrating sphere
- Detector to receive the light
  - sensor to make photopic function of human eye

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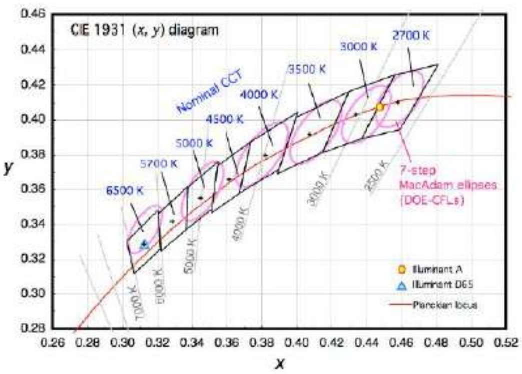
1.3 Colorimetry

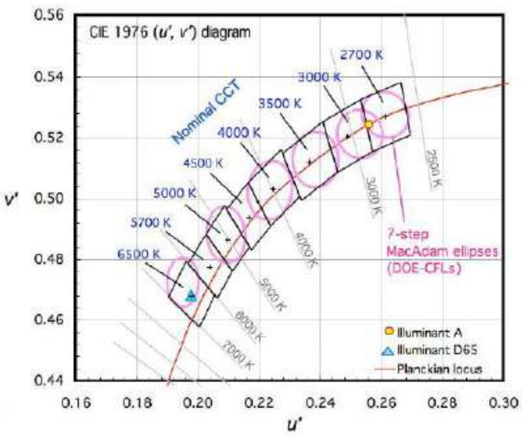
Colorimetry

- Parameters & definitions
  - Color coordinate, CCT, CRI
- Color
  - Expression & Space evolution
- "Calculation" of the Colorimetry parameters
  - Color coordinate
  - Tc & CCT
  - CRI, Ra

Parameters & definitions

- Color coordinate, CCT





Different color space

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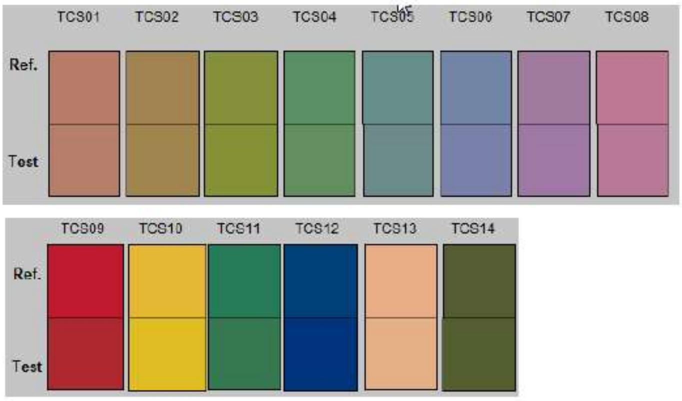
Parameters & definitions

- CRI



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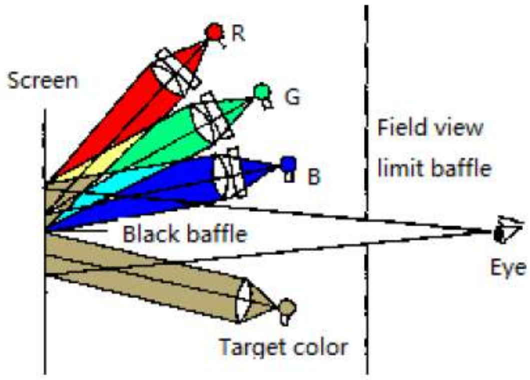
Colorimetry

- Parameters & definitions
  - Color coordinate, CCT, CRI
- Color
  - Expression & Space evolution
- "Calculation" of the Colorimetry parameters
  - Color coordinate
  - Tc & CCT
  - CRI, Ra

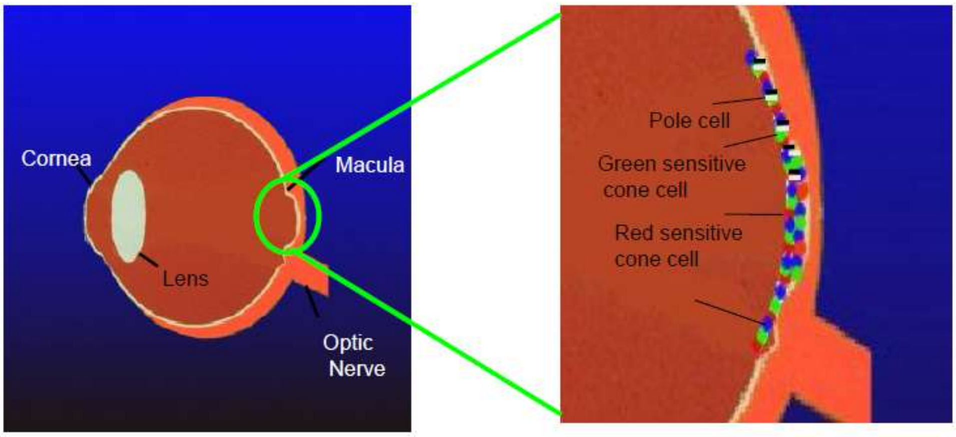
Color: Expression & Space evolution

- Expression of color
  - Color mixing principal: color matching test



Color: Expression & Space evolution

- Detector of color: Human eye



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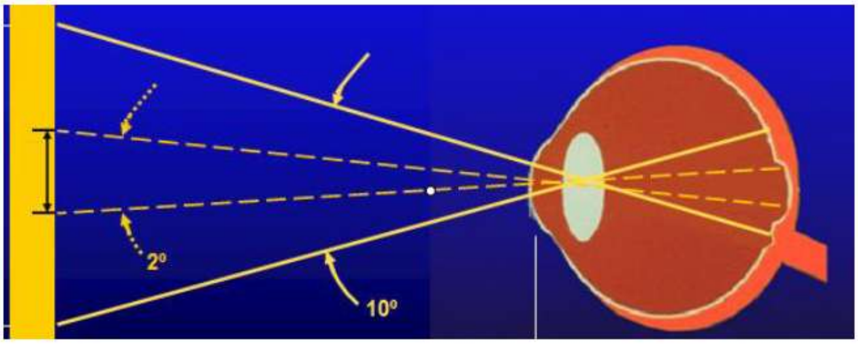
Color: Expression & Space evolution

- **Detector of color**: human eye
  - The tristimulus values depend on observer's field of view
  - Color-sensitive cones resided within 2° arc of the fovea



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Color: Expression & Space evolution

- **Color space & Evolution**: CIE 1931 RGB
  - CIE 1931 Standard (colormetric) observer
    - CIE defined color-mapping function
    - To represent an average human's chromatic response within a 2° arc inside the fovea
    - Known as the CIE 1931 2° Standard Observer

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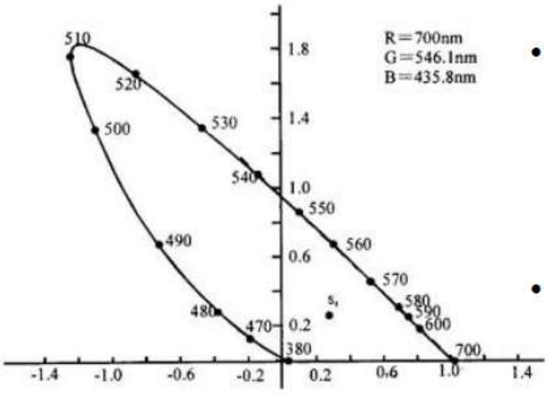
Color: Expression & Space evolution

- Color space & Evolution: CIE 1931 RGB



- the spectral locus passes through
  - rg=(0,0) at 435.8 nm
  - rg=(0,1) at 546.1 nm
  - rg=(1,0) at 700 nm
- the equal energy point (E) is at rg=xy=(1/3,1/3)

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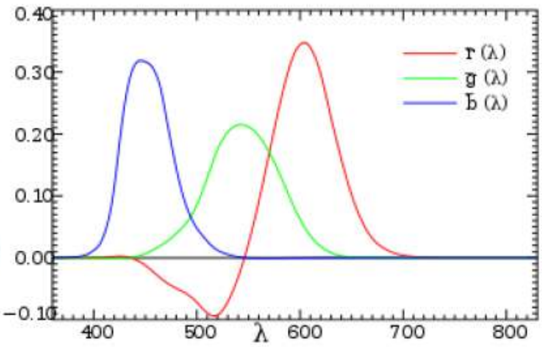
Color: Expression & Space evolution

- Color space & Evolution: CIE 1931 RGB
  - Color matching functions

Amounts of primaries needed to match the monochromatic test primary at the wavelength shown on the horizontal scale



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Color: Expression & Space evolution

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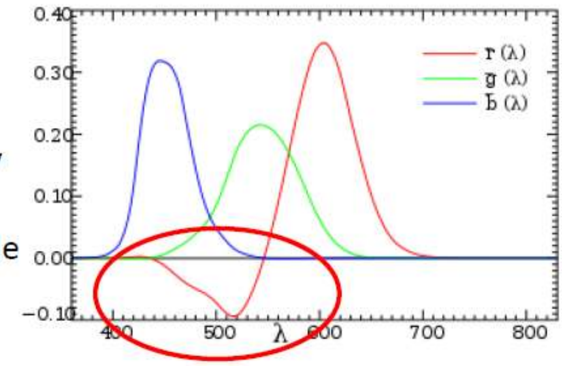

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Color: Expression & Space evolution

- Color space & Evolution: CIE 1931 XYZ
- For constant energy white point
  - $x = y = z = 1/3$
- To keep positive values of *x* and *y*
  - the gamut of all colors will lie inside the triangle [1,0], [0,0], [0,1]

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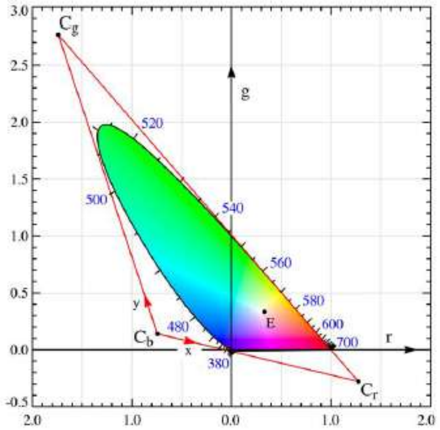
Color: Expression & Space evolution

- Color space & Evolution: CIE 1931 XYZ



- Triangle Cb-Cg-Cr is the xy=(0,0),(0,1),(1,0) triangle in CIE xy chromaticity space
- Line connecting Cb and Cr is the alychne
- The spectral locus passes through
  - rg=(0,0) at 435.8 nm
  - rg=(0,1) at 546.1 nm
  - rg=(1,0) at 700 nm
- Equal energy point (E) is at rg=xy=(1/3,1/3)

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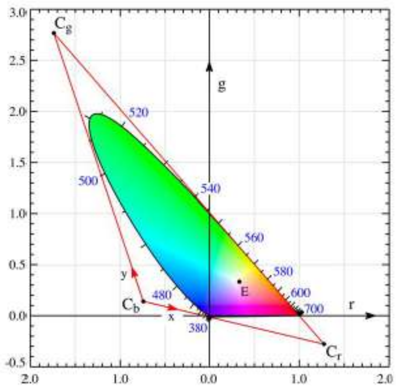
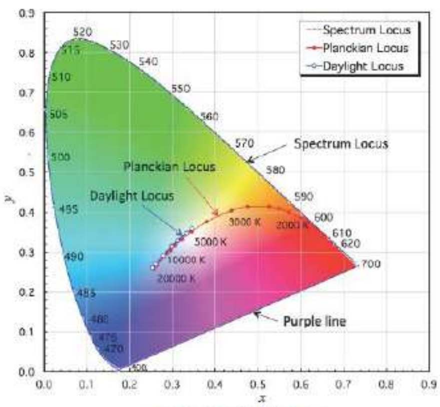
Color: Expression & Space evolution

- Color space & Evolution: CIE 1931 XYZ



rg coordinate



xy coordinate

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Color: Expression & Space evolution

- Color space & Evolution: CIE 1931 XYZ
  - Relationship between XYZ and RGB

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{1}{b_{21}} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \frac{1}{0.17697} \begin{bmatrix} 0.49 & 0.31 & 0.20 \\ 0.17697 & 0.81240 & 0.01063 \\ 0.00 & 0.01 & 0.99 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 0.41847 & -0.15866 & -0.082835 \\ -0.091169 & 0.25243 & 0.015708 \\ 0.00092090 & -0.0025498 & 0.17860 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix},$$

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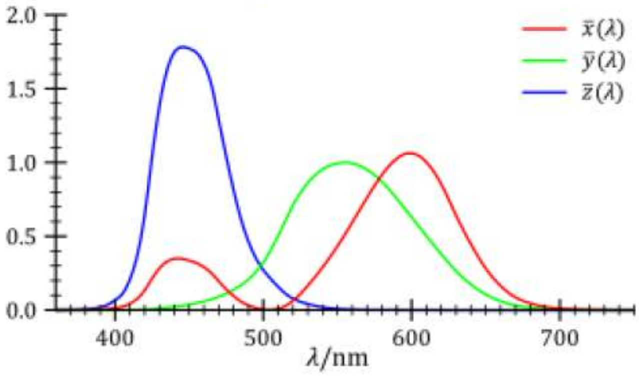
Color: Expression & Space evolution

- Color space & Evolution: CIE 1931 XYZ
  - Color matching functions



$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

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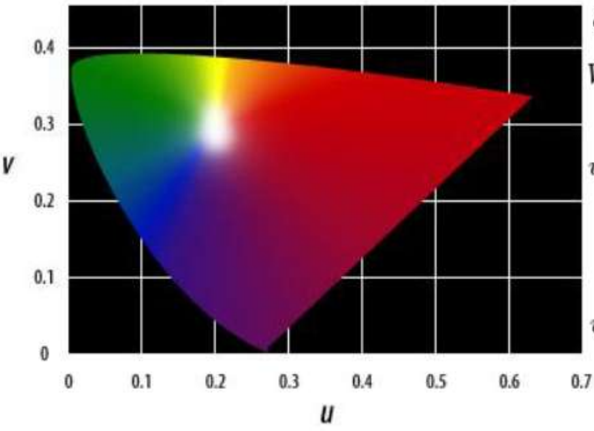
Color: Expression & Space evolution

- Color space & Evolution: CIE 1960 UCS



$$U = \tfrac{2}{3}X \qquad V = Y$$

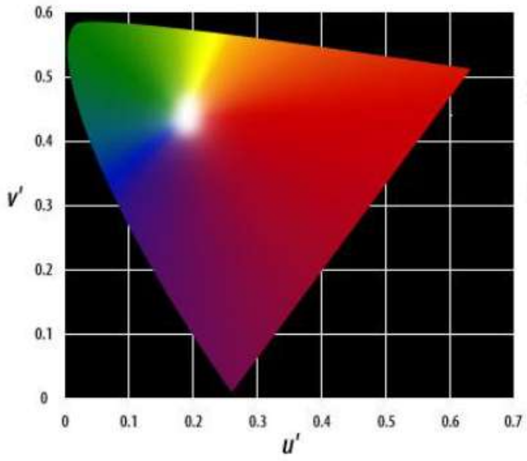
$$W = \tfrac{1}{2}(-X + 3Y + Z)$$

$$u = \frac{U}{U+V+W} = \frac{4X}{X+15Y+3Z} = \frac{4x}{12y-2x+3}$$

$$v = \frac{V}{U+V+W} = \frac{6Y}{X+15Y+3Z} = \frac{6y}{12y-2x+3}$$

Color: Expression & Space evolution

- Color space & Evolution: CIE 1960 LUV



$$L^* = \begin{cases} \left(\frac{29}{3}\right)^3 Y/Y_n, & Y/Y_n \le \left(\frac{6}{29}\right)^3 \\ 116\,(Y/Y_n)^{1/3} - 16, & Y/Y_n > \left(\frac{6}{29}\right)^3 \end{cases}$$

$$u^* = 13L^* \cdot (u' - u'_n)$$

$$v^* = 13L^* \cdot (v' - v'_n)$$

$$u' = \frac{4X}{X+15Y+3Z} = \frac{4x}{-2x+12y+3}$$

$$v' = \frac{9Y}{X+15Y+3Z} = \frac{9y}{-2x+12y+3}$$

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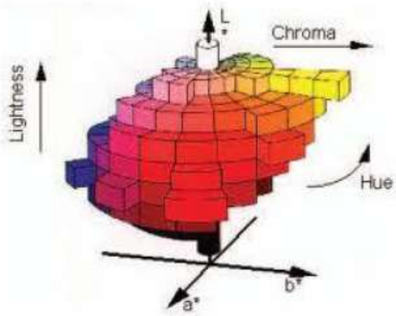
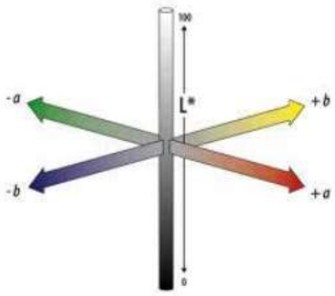
Color: Expression & Space evolution

- Color space & Evolution: CIE 1976 Lab





$$L^{\star} = 116 f(Y/Y_n) - 16$$
$$a^{\star} = 500\,[f(X/X_n) - f(Y/Y_n)]$$
$$b^{\star} = 200\,[f(Y/Y_n) - f(Z/Z_n)]$$

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Color: Expression & Space evolution

- Summary
  - CIE 1931 RGB was developed, based on color matching test
  - RGB transformed into XYZ, to get rid of minus stimulus value in function
  - XYZ transformed into UCS and LUV, LAB

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Colorimetry

- Parameters & definitions
  - Color coordinate, CCT, CRI
- Color
  - Expression & Space evolution
- "Calculation" of the Colorimetry parameters
  - Color coordinate
  - Tc & CCT
  - CRI, Ra

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"Calculation": Color coordinate

- Color coordinate
  - For light from light source / reflected / transmitted
  - For light combined
  - Metamerism
  - Dominant wavelength and purity

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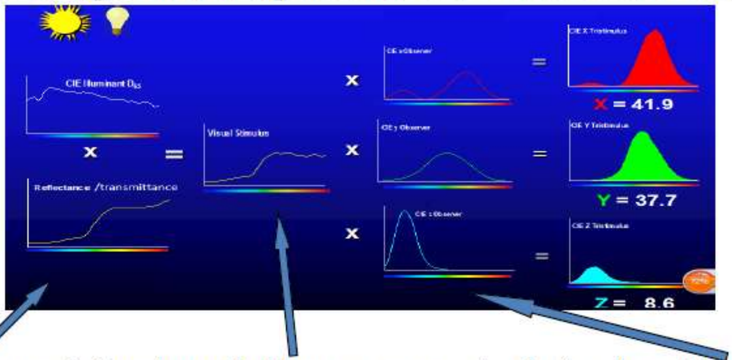
"Calculation": Color coordinate

- Color coordinate
  - For light from light source / reflected / transmitted



Light spectrum → Spectrum that human eye received → color mixting / separating

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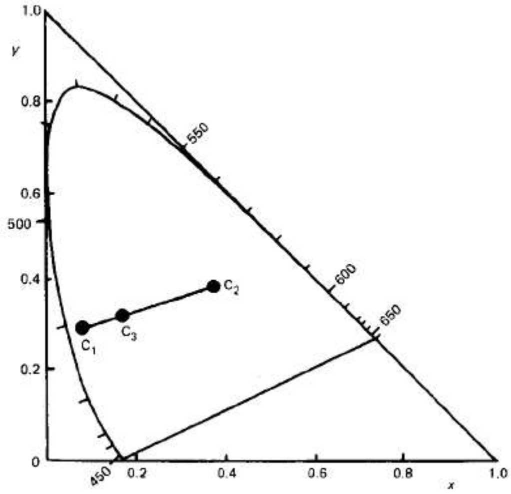
"Calculation": Color coordinate

- Color coordinate
  - For light combined



- C_1 : luminance m_1; (x_1 , y_1)
- C_2 : luminance m_2; (x_2 , y_2)
- C_3 : combined light of C_1 & C_2
- 1 luminace unit= $1/L_Y$

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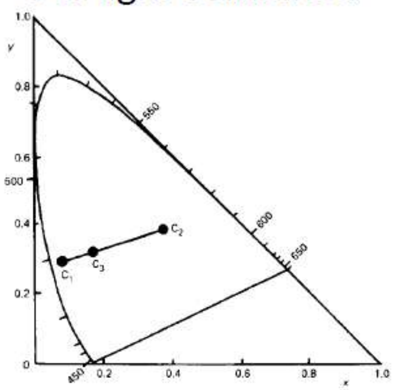
"Calculation": Color coordinate

- Color coordinate
  - For light combined



$$x=\frac{X}{X+Y+Z} \qquad y=\frac{Y}{X+Y+Z} \qquad z=\frac{Z}{X+Y+Z}$$

$$\frac{X}{x}=\frac{Y}{y}=\frac{Z}{z}=X+Y+Z$$

$C_1: X_1= m_1x_1/L_Yy_1,\ Y_1= m_1/L_Y,\ Z_1= m_1z_1/L_Yy_1$

$C_2: X_2= m_2x_2/L_Yy_2,\ Y_2= m_2/L_Y,\ Z_2= m_2z_2/L_Yy_2$

$C_3: X_3 = m_1x_1/L_Yy_1+m_2x_2/L_Yy_2$

$Y_3 = m_1/L_Y+m_2/L_Y$

$Z_3 = m_1z_1/L_Yy_1+m_2z_2/L_Yy_2$

$x + y + z =1$,

$X+Y+Z = m_1/L_Yy_1+m_2/L_Yy_2$,

then: $x = (m_1x_1/y_1 + m_2x_2/y_2)/ (m_1/y_1 + m_2/y_2)$

$y = (m_1 + m_2)/ (m_1/y_1 + m_2/y_2)$

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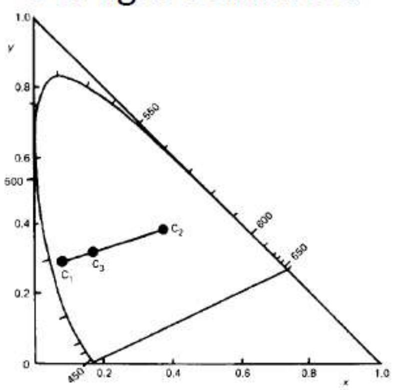
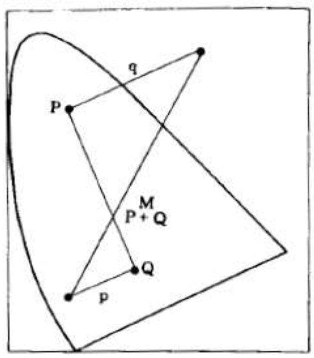
"Calculation": Color coordinate

- Color coordinate
  - For light combined





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"Calculation": Color coordinate

- Color coordinate
  - Metamerism
    - Different spectral power distribution, but same color

$$X = K\int_{380}^{780} S(\lambda)\rho_1(\lambda)\bar{x}(\lambda)d\lambda = K\int_{380}^{780} S(\lambda)\rho_2(\lambda)\bar{x}(\lambda)d\lambda$$

$$Y = K\int_{380}^{780} S(\lambda)\rho_1(\lambda)\bar{y}(\lambda)d\lambda = K\int_{380}^{780} S(\lambda)\rho_2(\lambda)\bar{y}(\lambda)d\lambda$$

$$Z = K\int_{380}^{780} S(\lambda)\rho_1(\lambda)\bar{z}(\lambda)d\lambda = K\int_{380}^{780} S(\lambda)\rho_2(\lambda)\bar{z}(\lambda)d\lambda$$

$$\rho_1(\lambda) = \rho_2(\lambda)$$

$$\rho_1(\lambda) \neq \rho_2(\lambda)$$

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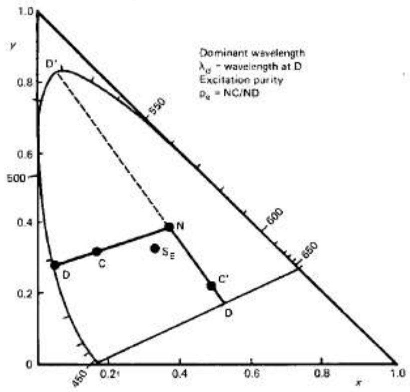
"Calculation": Color coordinate

- Color coordinate
  - Dominant wavelength andpurity



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Colorimetry

- Parameters & definitions
  - Color coordinate, CCT, CRI
- Color
  - Expression & Space evolution
- "Calculation" of the Colorimetry parameters
  - Color coordinate
  - Tc & CCT
  - CRI, Ra

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"Calculation": Tc & CCT

- Color temperature of a light source (Tc)
  - Temperature of an ideal black body radiator that radiates light of comparable hue to that of the light source
- Corelated color temperature (CCT)
  - Color temperature of a black body radiator which to human color perception most closely matches the light from the lamp

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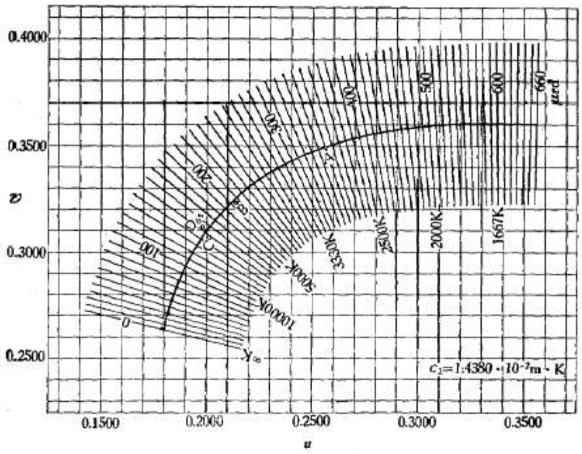
"Calculation": Tc & CCT



Mired lines in CIE 1960 UCS

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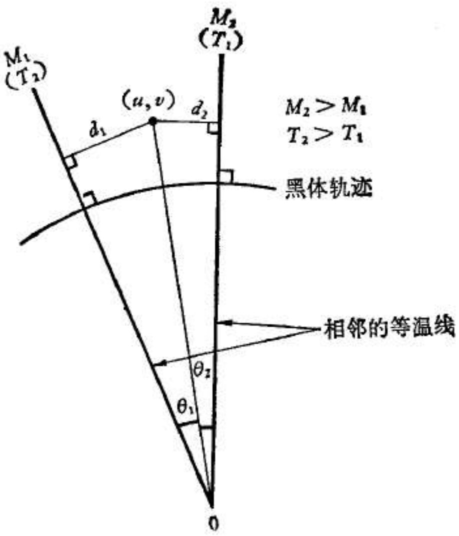
"Calculation": Tc & CCT



$$\frac{1}{T_{C48}} \approx \frac{1}{T_1} - \left(\frac{1}{T_1} - \frac{1}{T_2}\right)\left(\frac{d_2}{d_1 + d_2}\right)$$

$T_C = 1.4388\ T_{C48} / 1.4380$

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Colorimetry

- Parameters & definitions
  - Color coordinate, CCT, CRI
- Color
  - Expression & Space evolution
- "Calculation" of the Colorimetry parameters
  - Color coordinate
  - Tc & CCT
  - CRI, Ra

"Calculation": CRI, Ra

- CRI
  - Definition
  - CIE standard illuminants
  - Specific "color blocks" for comparison
  - Calculation steps for Ra

"Calculation": CRI, Ra

- CRI definition
  - Effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant
  - Calculated by comparing the color rendering of the test source to that of a "perfect" source which is a black body radiator for sources with correlated color temperatures under 5000 K, and a phase of daylight otherwise (e.g. D65)
  - Chromatic adaptation should be performed

"Calculation": CRI, Ra

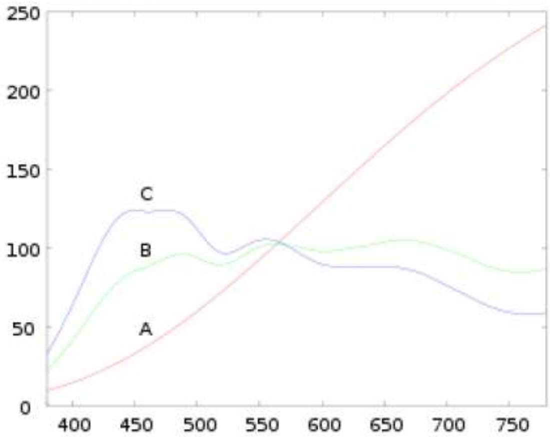
- CIE standard illuminants
  - CIE standard illuminant A
  - CIE standard illuminant B
  - CIE standard illuminant C
  - CIE standard illuminant D

"Calculation": CRI, Ra

- CIE standard illuminant A
  - Representing typical, domestic, tungsten-filament lighting
  - Relative spectral power distribution is that of a Planckian radiator at a temperature of approximately 2856 K
- CIE standard illuminant B & C
  - Daylight simulators, derived from A by using liquid filters
  - B representing noon sunlight, with CCT of 4874K
  - C representing average daylight with CCT of 6774K

"Calculation": CRI, Ra

- CIE standard illuminants A & B & C



Relative spectral power distributions (SPDs) of CIE illuminants A, B, and C from 380nm to 780nm.

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"Calculation": CRI, Ra

- CIE standard illuminants D
  - Constructed to represent natural daylight
    - Difficult to produce artificially
    - Easy to characterize mathematically
  - Relative SPD can be derived from its chromaticity coordinates in CIE 1931 color space

$$x_D = \begin{cases} 0.244063 + 0.09911\frac{10^3}{T} + 2.9678\frac{10^6}{T^2} - 4.6070\frac{10^9}{T^3} & 4000K \le T \le 7000K \\ 0.237040 + 0.24748\frac{10^3}{T} + 1.9018\frac{10^6}{T^2} - 2.0064\frac{10^9}{T^3} & 7000K < T \le 25000K \end{cases}$$

$$y_D = -3.000x_D^2 + 2.870x_D - 0.275$$

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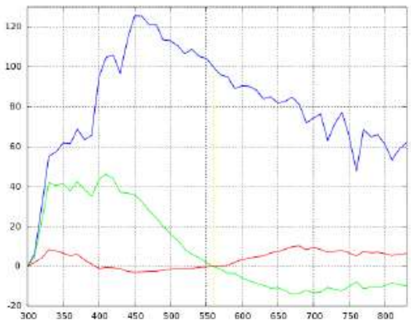
"Calculation": CRI, Ra

- CIE standard illuminants D



$$S(\lambda) = S_0(\lambda) + M_1S_1(\lambda) + M_2S_2(\lambda)$$
$$M_1 = (-1.3515 - 1.7703x_D + 5.9114y_D)/M$$
$$M_2 = (0.03000 - 31.4424x_D + 30.0717y_D)/M$$
$$M = 0.0241 + 0.2562x_D - 0.7341y_D$$

Characteristic vectors of illuminant D: component SPDs S0, S1, S2

- S0 is the mean of all the SPD samples, which is the best reconstituted SPD that can be formed with only a fixed vector
- S1 corresponds to yellow–blue variation, accounting for changes in the correlated color temperature due to presence or absence of clouds or direct sunlight
- S2 corresponds to pink–green variation caused by the presence of water in the form of vapor and haze

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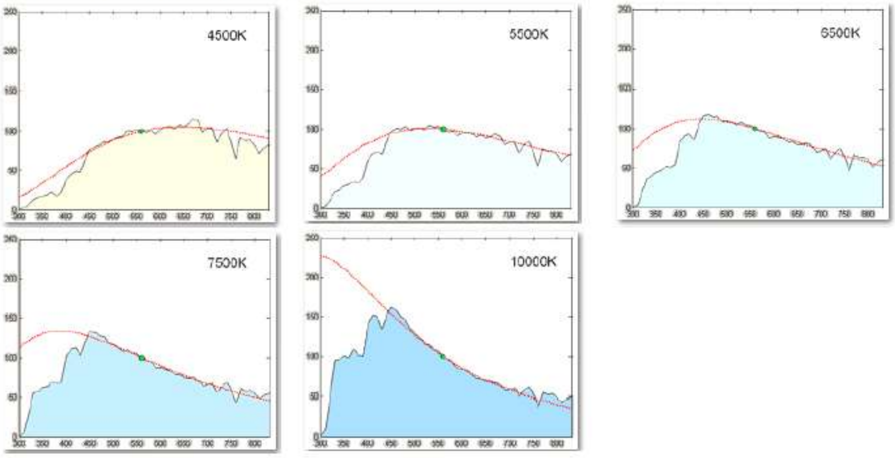
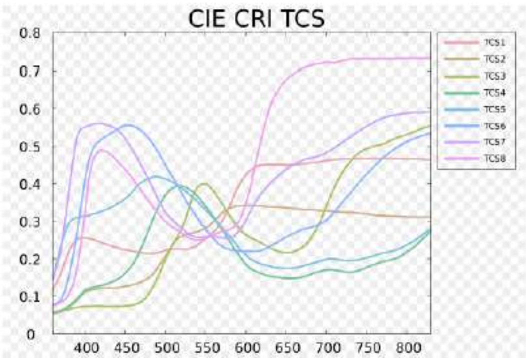
"Calculation": CRI, Ra

- CIE standard illuminants D



"Calculation": CRI, Ra

- Specific "color blocks"



Name	Appr. Munsell	Appearance under daylight	Swatch
TCS01	7,5 R 6/4	Light greyish red	
TCS02	5 Y 6/4	Dark greyish yellow	
TCS03	5 GY 6/8	Strong yellow green	
TCS04	2,5 G 6/6	Moderate yellowish green	
TCS05	10 BG 6/4	Light bluish green	
TCS06	5 PB 6/8	Light blue	
TCS07	2,5 P 6/8	Light violet	
TCS08	10 P 6/8	Light reddish purple	
TCS09	4,5 R 4/13	Strong red	
TCS10	5 Y 8/10	Strong yellow	
TCS11	4,5 G 5/8	Strong green	
TCS12	3 PB 3/11	Strong blue	
TCS13	5 YR 8/4	Light yellowish pink	
TCS14	5 GY 4/4	Moderate olive green (leaf)	

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"Calculation": CRI, Ra

- Calculation steps

1. Using the 2° standard observer, find the chromaticity co-ordinates of the test source in the CIE 1960 color space
2. Determine the correlated color temperature (CCT) of the test source by finding the closest point to the Planckian locus on the (u,v) chromaticity diagram
   - If the test source has a CCT<5000 K, use black body for reference
   - otherwise use CIE standard illuminant D
3. Ensure that the chromaticity distance (DC) of the test source to the Planckian locus is under 5.4×10^{-3} in the CIE 1960 UCS

$$DC = \Delta_{uv} = \sqrt{(u_r - u_t)^2 + (v_r - v_t)^2}$$

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"Calculation": CRI, Ra

- Calculation steps

4. Using the 2° standard observer, find the co-ordinates of the light reflected by each sample in the CIE 1964 color space
5. Chromatically adaption for each sample by a von Kries transform

$$u_{c,i} = \frac{10.872 + 0.404(c_r/c_t)c_{t,i} - 4(d_r/d_t)d_{t,i}}{16.518 + 1.481(c_r/c_t)c_{t,i} - (d_r/d_t)d_{t,i}}$$

$$v_{c,i} = \frac{5.520}{16.518 + 1.481(c_r/c_t)c_{t,i} - (d_r/d_t)d_{t,i}}$$

$$c = (4.0 - u - 10.0v)/v$$

$$d = (1.708v - 1.481u + 0.404)/v$$

In the formulas subscripts *r* and *t* refer to reference and test light sources, respectively

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"Calculation": CRI, Ra

- Calculation steps

6. For each sample, calculate the Euclidean distance between the pair of co-ordinates
7. Calculate the special (i.e., particular) CRI using the formula

$$R_i = 100 - 4.6\Delta E_i$$

8. Find the general CRI (Ra) by calculating the arithmetic mean of the special CRIs

Color: "Calculation"

- Summary
  - Based on spectrum power distribution
    - each wavelength light then expressed in RGB / XYZ
  - Specific color space is used
  - For Ra, standard illuminant is used
  - For Ra, standard color blocks is used

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Summary

- Colorimetry
  - Color cooridinate, CCT, Ra is widely used
  - Based on spectrum power distribution
    - each wavelength light then expressed in RGB / XYZ
  - Specific color space is used
  - For Ra, standard illuminant is used
  - For Ra, standard color blocks is used

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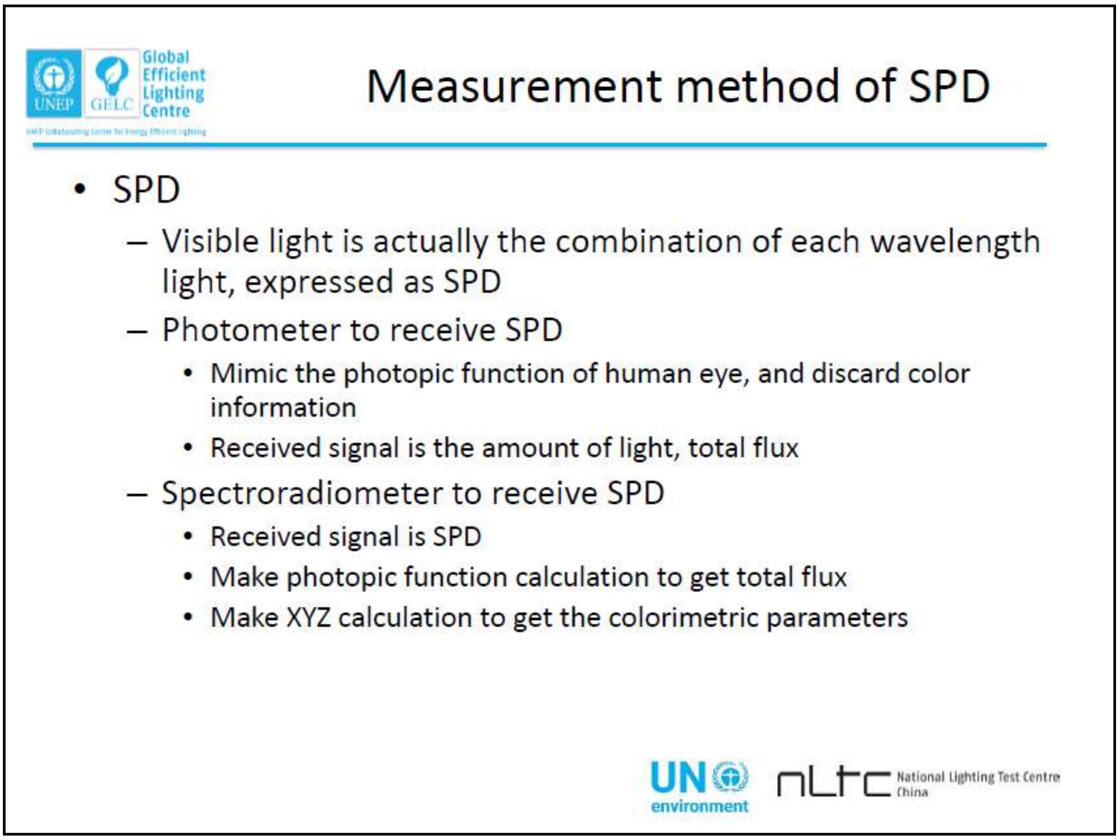
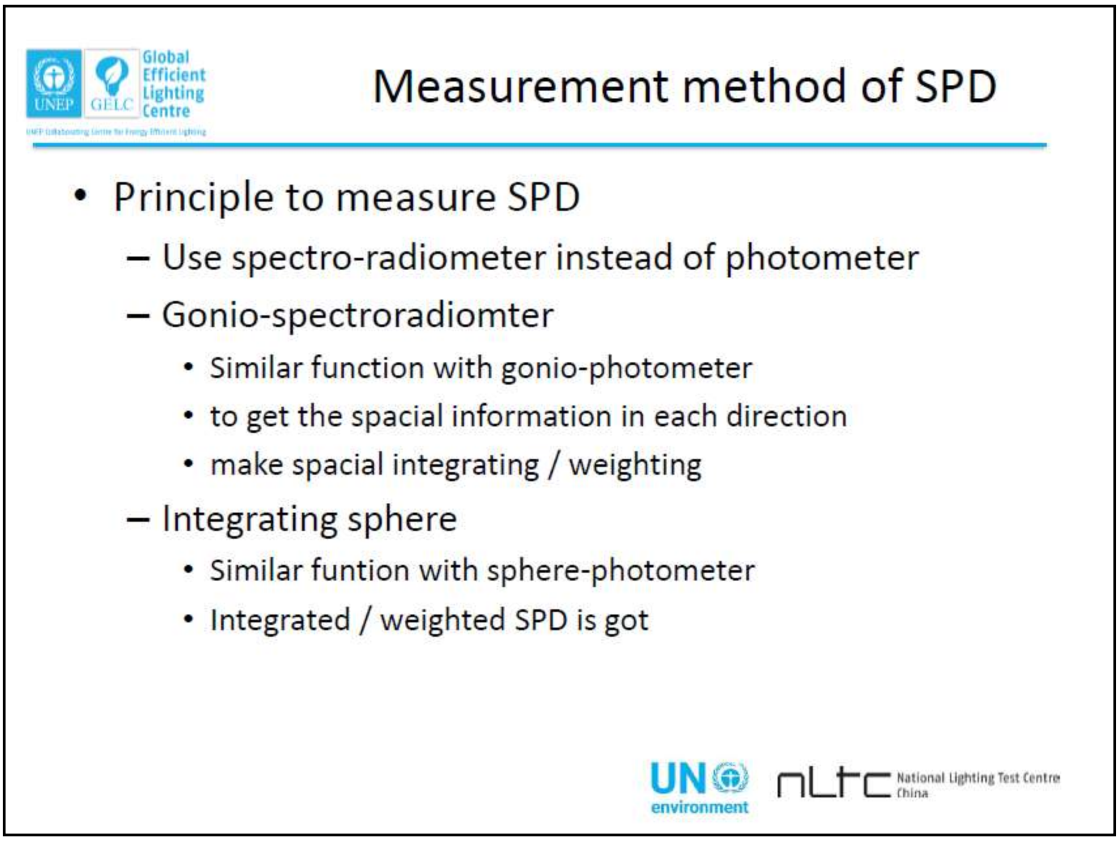
2. Key elements of testing process & main measurement differences between LEDs and CFLs

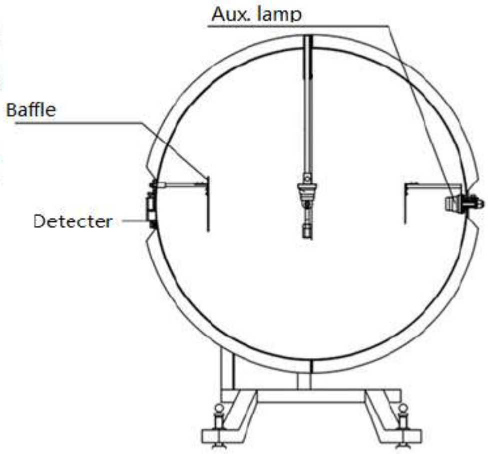
2.1 Measurement method of SPD



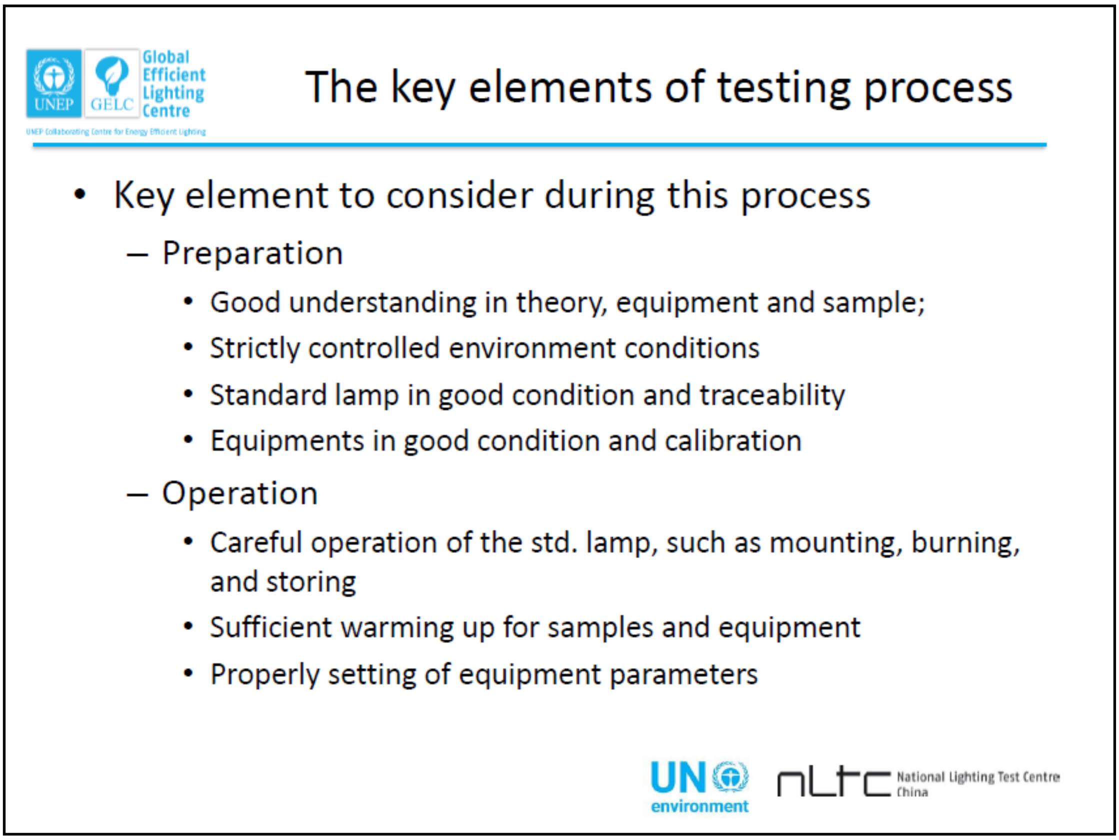


Measurement method of SPD

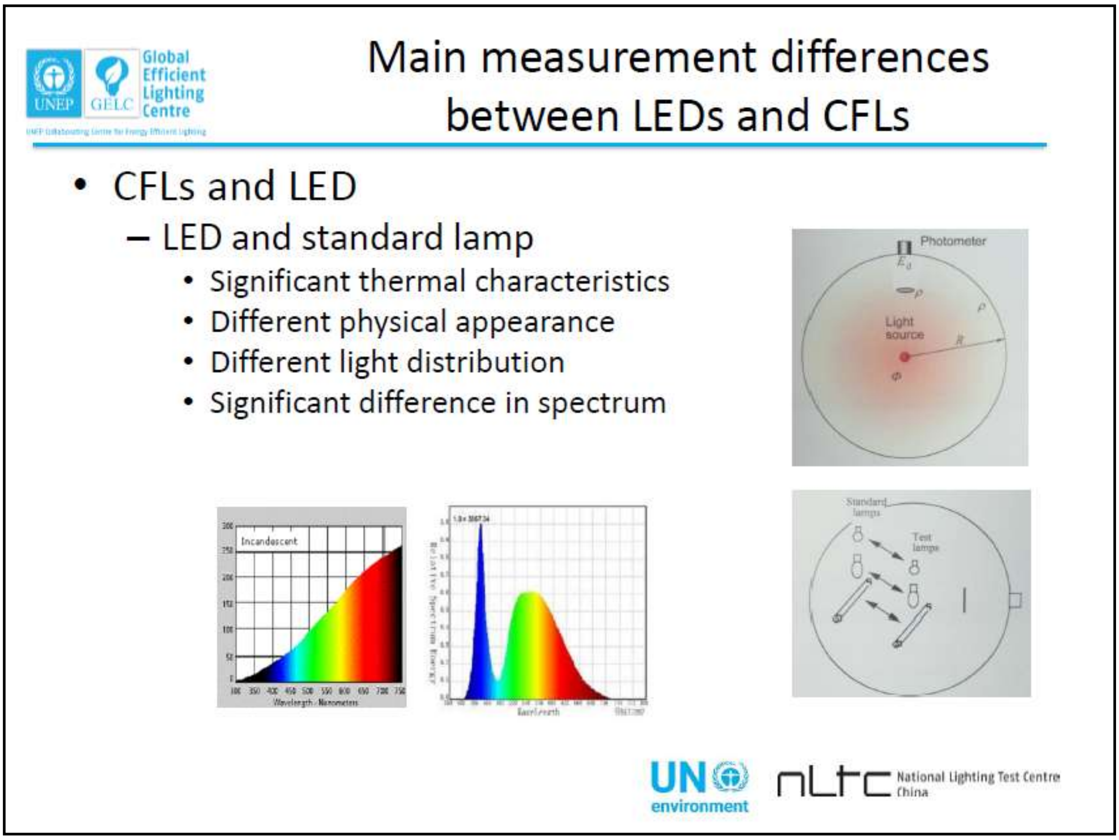
– Comparative method
  - Keep regular calibration of
  - Use standard lamp to calib
  - Make measurement
  - Perform corrections as sel



2.2 Key Elements in Testing Process

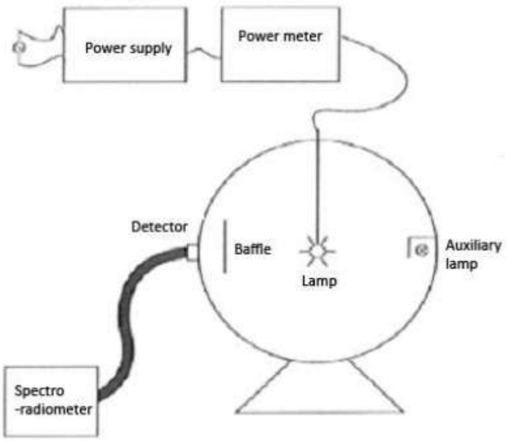


2.3 Main Measurement Differences between LEDs and CFLs



Main measurement differences between LEDs and CFLs

- Comparison of lab's equipments and operation
  - Equipments
    - –Source
    - –Input
    - –Circuit
    - –Detector
  - Procedures
    - –Testing
    - –Correction
    - –Characteristics of sample



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Main measurement differences between LEDs and CFLs

- Comparison of lab's equipments and operation
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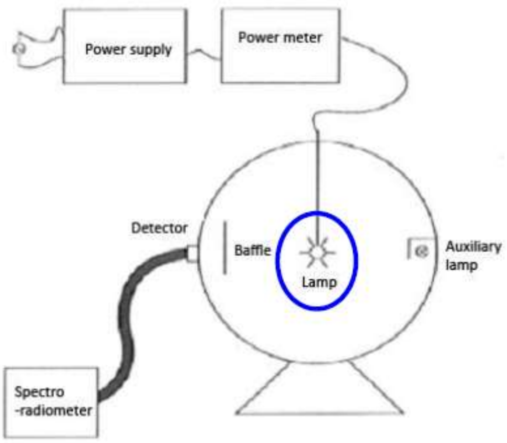

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Main measurement differences between LEDs and CFLs

- Comparison of lab's equipments and operation
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    - –Source
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    - –Detector
  - Procedures
    - –Testing
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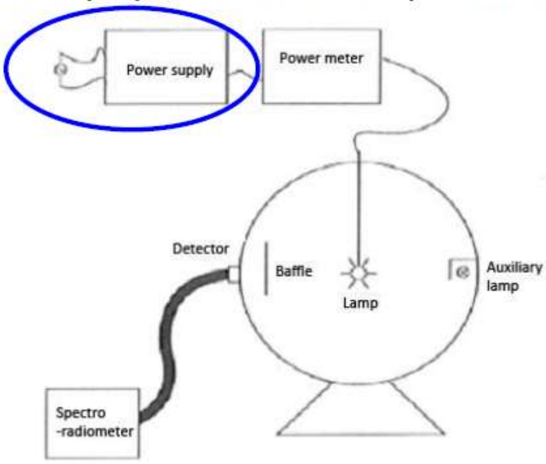
    - –Characteristics of the sample



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Main measurement differences between LEDs and CFLs

- Comparison of lab's equipments and operation
  - Equipments
    - –Source
    - –Input
    - –Circuit
    - –Detector
  - Procedures
    - –Testing
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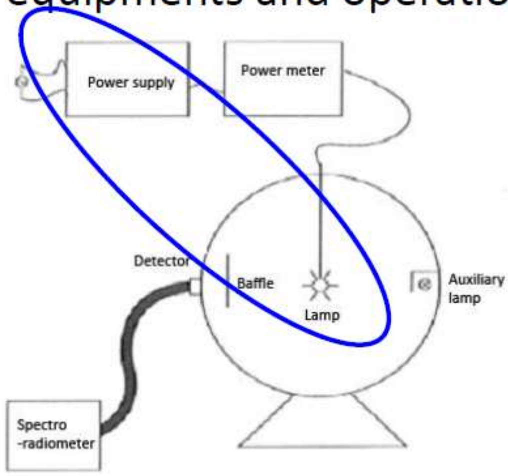
    - –Characteristics of the sample



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Main measurement differences between LEDs and CFLs

- Comparison of lab's equipments and operation
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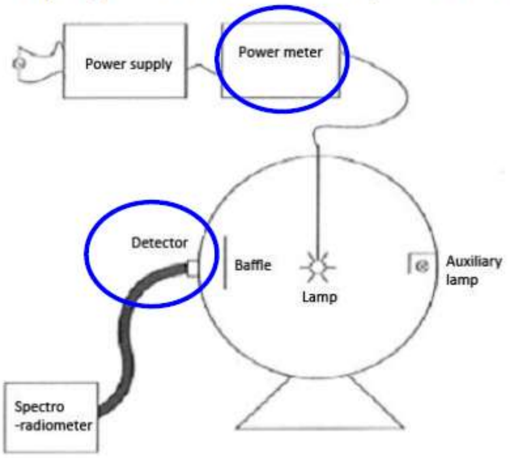

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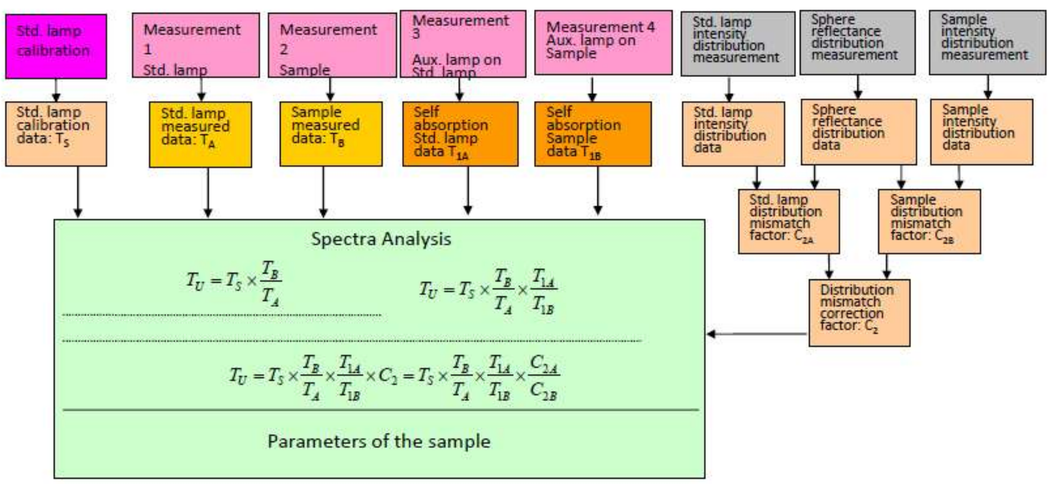
2.4 Summary

Summary

- Measure the SPD of the lamp.
- Use spectroradiometer instead of photometer.
- Use total radiant flux standard lamp instead of total luminous standard lamp. Spectral energy should be used.
- To get spacial distribution information, gonio-spectroradiomter should be used.

Keys in sphere-spectroradiometer system

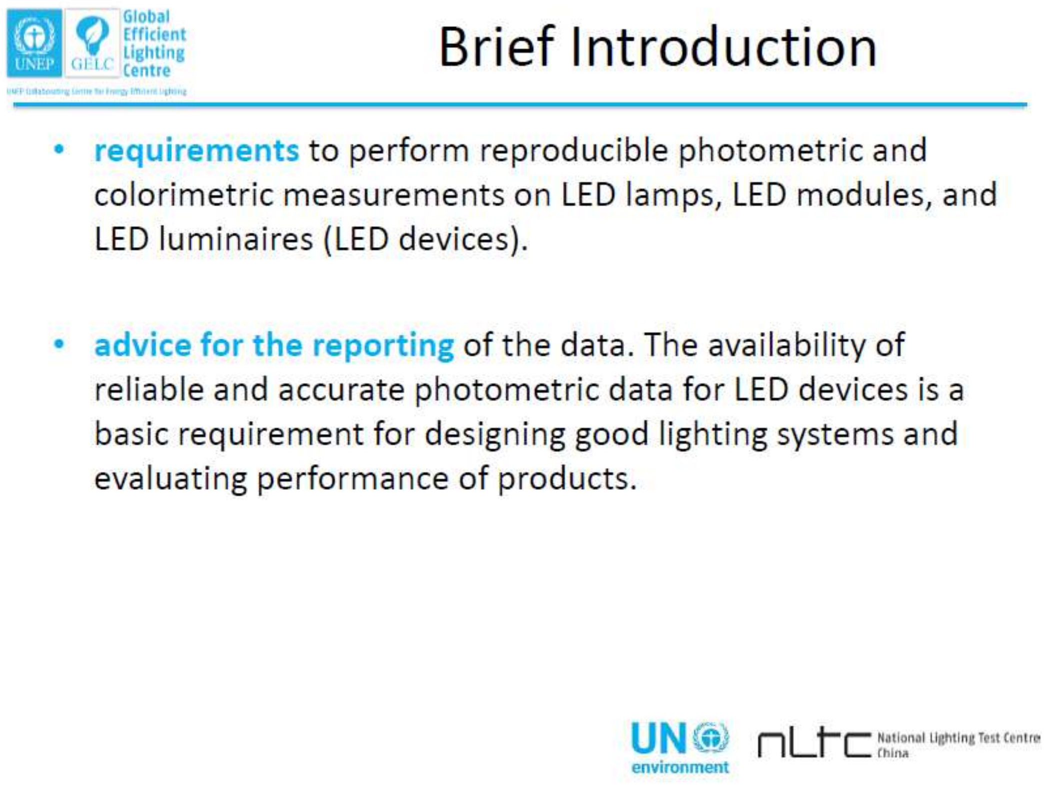


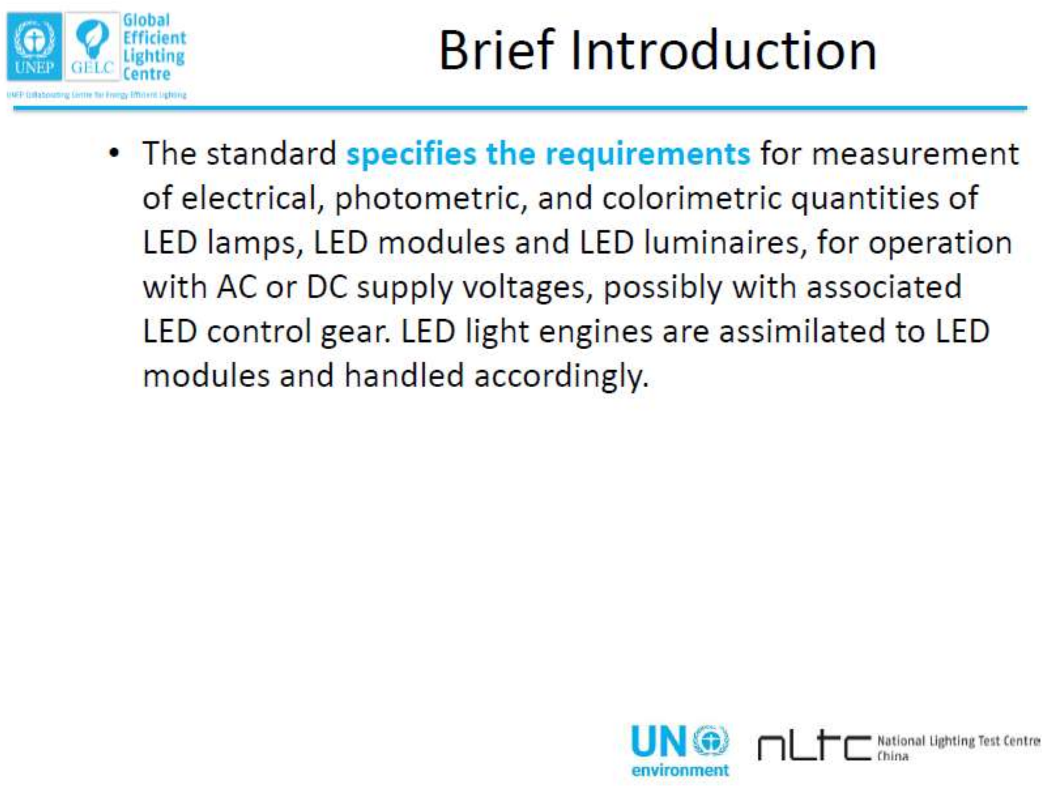
Summary

- Good understanding of the theory, method, equipment and sapmle;
- Reliable tracing data, such as std. lamp, power-meter;
- Strict control of the environment, such as the input power noise, ambient;
- Careful operation of the std. lamp, such as mounting, burning, and storing
- Sufficient warming up for samples and equipment.
- Properly setting parameters of equipment， such as Integration time， average times

3. Introduction to CIE S 025

3.1 Brief Introduction





Brief Introduction

- Photometric and colorimetric quantities covered in this standard include **total luminous flux, luminous efficacy, partial luminous flux, luminous intensity distribution, centre-beam intensity, luminance and luminance distribution, chromaticity coordinates, correlated colour temperature (CCT), colour rendering index (CRI), and angular colour uniformity**.

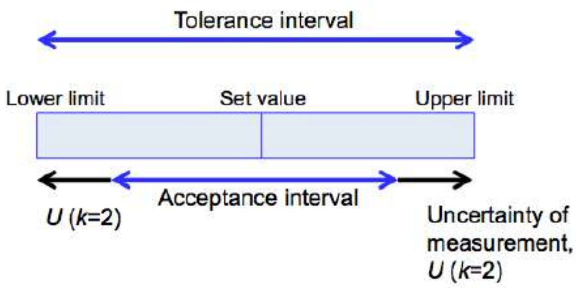
- This standard **does not cover** LED packages and products based on **OLEDs** (organic LEDs).

Special Requirement

- New conception

  $t_{p,n}$; $t_{q,n}$

  tolerance interval; acceptance interval



3.2 Main Text

Main Text

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- 4 Laboratory Requirements for Tests
- 4.1 General
- 4.1.1 Standard Test Conditions
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- 4.2.4 Air Movement
- 4.2.5 Operating Position

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- 4.3 Electrical Test Conditions and Electrical Equipment
- 4.3.1 Test Voltage and Test Current
- 4.3.2 Electrical Measurements

Specific requirement:
AC V I, DC V I,
POWER , BANDWITH;
INTERNAL IMPEDANCE

- 4.3.3 Electrical Power Supply

4.3.3.1 current handling capacity, very low impedance

4.3.3.2 regulated at the supply terminals of the DUT

Specific requirement: drift or fluctuation during measurement within the acceptance interval of the test voltage. If exceeds...correction.
power supply network, THD v 1.5% if PF<0.9, 3.0% IF PF>0.9; THD, Frequency

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4.3.3.3 regulated at the supply terminals of the DUT; drift or fluctuation during measurement

ripple free, AC component <=0.5%.

4.3.3.4 EMC

- **4.4 Stabilization before Measurement**

  DUT & EQUIPMENT

  1 minute interval

- **4.4.1 LED Lamps and LED Luminaires**

  30min, 15min 0.5%;

  45min, 150min ,report, but wait if gradient decrease

  related to thermal equilibrium ; "experience"

- **4.4.2 LED Modules**

  without heat sink, Tp, temperature-controlled heat sink or additional heating ,15min Tp

  with heat sink, 25 ° C ,Tp

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- **4.5 Photometric and Colorimetric Measurement Instruments**

  sphere-photometer

  sphere- spectroradiometer

  NOTE: hemisphere, tristimulus colorimeter head,

  goniophotometer

  gonio-spectroradiometer

  gonio-colorimeter

  NOTE on: near-field, Gonio-colorimeters ,

  Luminance mters

  NOTE on: ILMD

  ...acceptable if they are demonstrated to produce equivalent results as a conventional integrating sphere system or conventional goniophotometer system.

  selected depending on the types of product and measurement quantities to be measured.

calibrated to ensure traceability to the SI.

photometric measurements based on the spectral luminous efficiency function for photopic vision $V(\lambda)$

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- **4.5.1 Spectral Responsivity Requirements for Photometers**

  -*V(λ)-corrected detectors* (sphere-photometer, goniophotometer, luminance meter)

  $f_1^{'} \leq 3\%$

  white light LED, ...

  colored light ,...

  or:

  correction and report

  or: uncertainty

  correction , remaining uncertainty

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- **4.5.2 Integrating Sphere (all Types)**

  auxiliary lamp NOTE: self-absorption

  size of the integrating sphere should be large enough relative to the size of the DUT

  DUT *2 % of the total area of the sphere inner surface (1/10, 1/3)*

  linear shaped DUT ...

  coating of the integrating ...diffuse, high-reflectance, non-spectrally selective and should not show fluorescence. Coating reflectances> 90 % are recommended

  NOTE : non-uniformity of reflectance

  holder and auxiliary equipment -> smallest size, highest reflectance NOTE: baffle coating

  detector port's entrance optics...,

  sufficient mechanical repeatability , ≤0.5%, uncertainty

  sufficient stability , *appropriate intervals* ,<0.5%,

  similar intensity distribution ,...

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- 4.5.2.1 **Sphere-Spectroradiometer**

  ...calibrated with or verified against a total spectral radiant flux standard traceable to the SI.

  ...or spectral irradiance standard lamp(s) and total luminous flux standard lamp(s), both traceable to the SI . ...the derivation methods and related data (e.g. angular uniformity of spectrum or that of correlated colour temperature of the standard lamp) should be reported.

  The integrating sphere and the spectroradiometer together shall be calibrated as one system for total spectral radiant flux.

  wavelength range shall cover at least 380 nm to 780 nm

  wavelength uncertainty within 0,5 nm (k=2).

  bandwidth (full width half maximum) and scanning interval , 5 nm.

  linear response, nonlinearity ->uncertainty budget.

  internal stray light of the spectroradiometer ->uncertainty budget.

  auxiliary lamp wavelength range

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- **4.5.2.2 Sphere-Photometer**

  ...calibrated with a total luminous flux standard traceable to the SI. It is desirable , similar spectral distribution ,if available.

  ...total relative spectral responsivity (sphere plus photometer head) *V(λ)*

  correction if necessary, see Annex C.

  ...changes with time, especially when the sphere is new, or when the sphere is heavily used and subject to contamination. re-measured periodically , particularly important for reflectance >95%.

  NOTE: Guidance on measuring the relative spectral throughput of a sphere system is available in Annex B of IES LM-78 (2007).

  It is desirable that the auxiliary lamp for self-absorption measurement has a spectral distribution similar to that of the DUT measured, especially for single colour LED modules.

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- **4.5.3 Goniophotometer (all Types)**

  angular scan range

  The angular aiming of the DUT shall be adjusted and maintained within ±0,5° of the intended direction. Display resolution of 0,1° or better.

  *(FAR-FIELD):*DUT->effectively a point source

  test distance:

  – near cosine (Lambertian) distribution (beam angle ≥ 90°) in all C-planes: ≥ 5 × D

  – broad angular distribution different from a cosine distribution (beam angle ≥ 60°) in some of the C-planes: ≥ 10 × D

  – narrower angular distributions , steep gradients in the luminous intensity distribution or critical glare control: ≥ 15 × D

  – 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.

Main Text

- NOTE 1 **For these test distances** it may be expected that the photometric inverse square law is verified at better than 1 % in the optical axis, up to 3 % within twice of the beam angle. Other test distances verifying this rule may be applied without applying corrections. (See also Annex C.3.6.)

- NOTE 2 **For some LED products where individual LEDs are effectively acting as small floodlights pointing in different directions** (e.g. divergent LEDs on a linear luminaire or separate LED modules mounted within the one luminaire), the recommended test distances may be insufficient. In case of doubt it should be verified if the inverse square law applies correctly.

- **For near-field photometry**, the test distance is theoretically considered infinite, but it should be validated.

Main Text

- **For measurement of total luminous flux** (and not for luminous intensity distribution), the far-field condition is not required, as total luminous flux can be derived by integration of illuminance distribution.

- Goniophotometers in general have some angular region (called **dead angle**) where emission from a light source is blocked by its mechanism, e.g. an arm to hold the light source. Goniophotometers having a large dead angle exceeding a solid angle of 0,1 sr (corresponding to a cone angle of approximately 10° radius) should not be used to measure total luminous flux of omnidirectional lamps or such luminaires unless appropriate correction procedures are implemented.

Whole content

- **4.5.3.1 Goniophotometer Using a Photometer Head**
- The relative spectral responsivity of the photometer head (combined with the spectral reflectance of a mirror if it is used) shall match the spectral luminous efficiency function for photopic vision $V(\lambda)$. The general $V(\lambda)$ mismatch index of the photometer head (including the mirror if used) shall meet the requirements in 4.5.1.

- Where necessary, a spectral mismatch correction shall be applied. For this correction, the relative spectral distribution of the DUT and the relative spectral responsivity of the photometer head (including mirror if used) are necessary. See Annex C for spectral mismatch correction.

Main Text

- Goniophotometers shall be calibrated against a luminous intensity standard or illuminance standard traceable to the SI, and if total luminous flux is also measured, the measured total luminous flux value (expressed in lm) shall also be verified by measuring a total luminous flux standard traceable to the SI. Alternatively, the goniophotometer system for measurement of total luminous flux may be calibrated against a total luminous flux standard traceable to the SI, if the dead angle of the goniophotometer does not affect the measurement of the total luminous flux standard lamp.

- NOTE For mirror type goniophotometers, a luminous intensity standard lamp is normally used to calibrate the photometer head, in which case, the photometric distance and the reflectance of the mirror are automatically included in the calibration.

Main Text

- **4.5.3.2 Gonio-spectroradiometer**
- Gonio-spectroradiometers shall be calibrated against spectral irradiance or spectral radiant intensity standard traceable to the SI. For a mirror-type gonio-spectroradiometer, the spectral reflectance of the mirror shall be taken into account if a spectral irradiance standard is used. If total spectral radiant flux is also measured, the values (expressed in W/nm) shall also be verified by measuring a total spectral radiant flux standard lamp traceable to the SI.

- Alternatively, the gonio-spectroradiometer system for total luminous flux or total spectral radiant flux measurements may be calibrated against a total spectral radiant flux standard traceable to the SI, if the dead angle of the gonio-spectroradiometer does not affect the measurement of the total spectral radiant flux standard lamp.

Main Text

- The spectroradiometer used for the gonio-spectroradiometer system shall cover the visible wavelength range and have appropriate bandwidth and scanning interval for measurement of the LEDs being tested. The wavelength range shall cover at least 380 nm to 780 nm.
- *Specific requirement: The bandwidth (full width half maximum) and scanning interval shall not be greater than 5 nm. The spectroradiometer shall have a wavelength uncertainty within 0,5 nm (k=2).*
- The spectroradiometer shall have a linear response to the input radiation at each wavelength over the visible range. The influence of non-linearity shall be considered in the uncertainty budget.
- The internal stray light of the spectroradiometer shall be considered in the uncertainty budget.

Main Text

- **4.5.3.3 Gonio-colorimeter**
- Gonio-colorimeters employ tristimulus colorimeter heads (filter-detector combinations having spectral responsivity matched to the CIE colour matching functions) to measure tristimulus values *X*, *Y*, *Z*. The *Y*-channel of a gonio-colorimeter shall meet all requirements in 4.5.3.1.
- Unless otherwise demonstrated, a gonio-colorimeter alone shall not be used for absolute measurement of colour quantities, and may be used only for colour difference measurement (or relative colour measurement combined with calibration by a spectroradiometer for a particular DUT).

Main Text

- **4.5.4 Luminance Meters**
- A luminance meter shall be calibrated with a luminance standard traceable to the SI. The following applies to both classical luminance meters (single point luminance measurement devices) and imaging luminance measurement devices (ILMD).
- The relative spectral responsivity of the luminance meter shall match the spectral luminous efficiency function $V(\lambda)$ for photopic vision. The general $V(\lambda)$ mismatch index of the luminance meter shall meet the requirements in 4.5.1.
- Where necessary, a spectral mismatch correction shall be applied. For this correction, the relative spectral distribution of the DUT and the relative spectral responsivity of the photometer are necessary, see Annex C for spectral mismatch correction.
- If an ILMD is used, its measurement uncertainty shall be verified by comparing the results for luminance distribution of a typical LED device measured with a discrete luminance meter.

Main Text

- **5 Preparation, Mounting and Operating Conditions**

- **5.1 Ageing**

  Ageing shall be according to the appropriate LED product performance standard (Clause 2).

- 5.2 Test Device

  The applicant shall provide all necessary instructions for proper use. The optical parts of devices shall be clean, except if otherwise required by the applicant (e.g. determination of maintenance factors).

Main Text

- **5.3 Mounting**
- **5.3.1 Operating Orientation**
- LED lamps shall be operated in free air in a vertical base-up position, unless other operating orientation is specified by the applicant (or regulation). If an applicant has declared that the lamp is suitable for use in a specific orientation only, the lamp shall be mounted in the declared orientation during all tests. If a different operating position is used during the test the specifications of 4.2.5 apply.

- LED luminaires shall be mounted in the operating position recommended by the manufacturer for intended use so that their thermal condition due to air flow inside and outside the device will be the same as its normal use condition (in terms of operating position) and that their alignment is mechanically true and all components rigidly located in their designed positions. Adjustable parts shall be correctly set according to the manufacturer's instructions. If a different operating position is used during the test the specifications of 4.2.5 apply.

Main Text

- LED modules can be operated at any operating position if their temperature is set and maintained to performance temperature *tp*.
- The test device shall be mounted so that any thermal conduction through supporting elements holding the device causes negligible unintended cooling effects.

- NOTE 1 For example, a luminaire may be suspended in air by wire or held by support materials that have a low heat conductivity, e.g. Teflon.

  In all cases, the operating position of the device shall be reported.

- NOTE 2 The light emission process of a LED is not affected by orientation (with respect to gravity). However, the orientation of a LED lamp and LED luminaire can cause changes in thermal conditions for the LEDs used in the device, and thus the light output can be affected by the orientation of the device.

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- **5.3.2 Coordinate System**

  Photometric and colorimetric distributions of lighting devices are dependent on locations and directions. Therefore a coordinate system shall be linked to the DUT and the photometric/colorimetric distributions are referenced to this coordinate system. The mechanical position of the device referenced to the coordinate system shall be unique and declared. The coordinate system centre is coincident with the photometric centre of the DUT.

- General guidance on coordinate systems is given in CIE 121-1996.

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Main Text

- **5.3.3 Photometric Centre**
- The position of the photometric centre of a device shall be at the centre of the solid figure bounded in outline by the luminous surfaces.
- For LED luminaires with substantially opaque sides, where the lamp (or module) compartment is substantially white or luminous, the position shall be at the centre of the main luminaire opening, but for LED luminaires with substantially opaque sides, where the lamp (or module) compartment is substantially black or non-luminous, the position shall be at the lamp photometric centre (centre of the solid figure bounded in outline by the luminous surfaces of the lamp or centre of the module).
- When using a far-field goniophotometer and measuring devices with multiple light-emitting areas that have significant separation and which do not comply with the specific requirement for test distances in 4.5.3, the devices shall be measured in several steps with each light emitting area centred accordingly. Data for each lighting emitting area shall be reported.

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- NOTE Light emitting areas are considered to be significantly separated when the deviation from the inverse square law when measured together, are non-negligible.
- Complementary guidance for photometric centre is given in CIE 121-1996, Clause 5.3.2.

- **5.4 Operating Conditions of the LED Lighting Devices**
- **5.4.1 General**
- LED devices with dimming control shall be adjusted to maximum light output for all tests or to pre-defined levels if instructed by the applicant.
- LED devices with internal feedback-control circuits not externally adjustable shall be tested as provided.

Main Text

- LED devices with adjustable colour points shall be adjusted or set to the defined settings as indicated by the manufacturer or applicant.
- LED devices with a tuneable white spectrum shall be adjusted to the settings specified by the applicant or according to a relevant standard.
- For multicolour LED devices e.g. RGB LED devices, each colour shall be measured individually with the full-power setting and all colours together with the full-power setting.

Main Text

- **5.4.2 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 by a table or graph for those temperatures.
- **5.4.3 LED Modules**
- For LED modules provided without control gear, the applicant shall provide the necessary specifications for the auxiliary equipment to be used.
- LED modules are measured in standard test conditions at the rated performance temperature. The temperature at the *t*p-point shall be set at this value for the measurements. If not accessible, the manufacturer or the applicant shall indicate a temperature monitoring point. If heat sinks are needed for the correct operating of the LED module and the LED module does not have an own heat sink, a suitable temperature controlled heat sink may be used. Interpolation techniques may also be applied (see Annex C).

Main Text

- A LED module may show more than one rated maximum performance temperature values *t*p,n.
- Light engines that do not incorporate heat sink(s) are measured at the rated performance temperature as described above.
- Light engines incorporating heat sink(s) shall be measured first in standard test conditions for *t*amb = 25 ° C, with the value *t*p measured and reported. Then further measurements are made at specified performance temperatures at the *t*p-point. If the *t*p-point is not accessible, the applicant shall indicate a temperature monitoring point.

Main Text

- 5.4.4 LED Luminaires
- LED luminaires are measured in standard test conditions at *tamb* = 25 ° C.
-
- NOTE *tp* is not relevant for the LED luminaire end-user and is often not accessible.

- Data shall be reported for *tamb* = 25 ° C. If a rated maximum performance ambient temperature *tq,n* other than 25 ° C is declared, a service conversion factor shall be delivered for this temperature (see also 4.2.2 and Annex C.1.2). There can be more than one rated maximum performance ambient temperature declared.

Main Text

6 **Measurement of Photometric Quantities**

6.1 General

The measurement of the following photometric quantities is covered by this standard:

- total luminous flux,
- luminous efficacy,
- luminous intensity distribution and
- luminance.

Absolute photometry methods are required for all LED devices.

Main Text

- **6.2 Measurement of Total Luminous Flux**

  General guidance for luminous flux measurements is given in CIE 84-1989.

  The luminous flux of a light source can be determined by different methods. The method may be chosen depending on what other measurement quantities (colour, intensity distribution) are needed to be measured or depending on the geometrical dimensions of the DUT. The following methods are available:

  – **Method A:** Measurement with an integrating sphere (with a photometer head or a spectroradiometer). For the sphere theory, see CIE 84-1989, Clause 6.2.

  – **Method B: Calculation from the luminous intensity distribution. For calculation principles see CIE 84-1989, Clause 4.**

  Luminous intensity can be determined from integrated luminance. See CIE 70-1987 Clause 2.2.

  – **Method C:** Calculation from the illuminance distribution and photometric distance. For calculation principles see CIE 84-1989, Clause 5.

Main Text

- **6.3 Partial Luminous Flux**

  For the specified cone angle α, the partial luminous flux is obtained from summation of intensity distribution data $I(\theta i, \varphi j)$, with scanning intervals of Δθ and Δφ.

  – If the goniophotometer is not calibrated in absolute scale, the ratio of total luminous flux and partial flux can be obtained from the goniophotometer, the total luminous flux can be measured with an integrating sphere, and the partial flux can be calculated as the multiplication of total flux and the ratio.

  – For measurement of partial luminous flux in a cone of 90° or larger, the measurement should be made with scanning intervals of 5° or less for θ angles (γ angles in *C*,γ coordinate system) and 45° or less for *φ* angles (*C* angles in *C*,γ coordinate system). Smaller angle intervals may be needed for DUTs for specific applications (e.g. street lighting luminaires).

Main Text

- **6.4 Luminous Efficacy**

  The luminous efficacy ηv, expressed in lm/W, is determined by the ratio of the luminous flux Φ of the LED device to the electrical power *P*tot including all components required for the LED device operation.

  $\eta v = \Phi / P tot$ (8)

  The luminous flux of the LED product is measured according to 6.2. The electrical power is measured according to 4.3.2, or, for non-integrated and semi-integrated LED devices, as specified by the applicant or regulation

  NOTE The term "luminous efficacy" is used in this document in the meaning of *luminous efficacy of a source* as defined in the ILV.

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Main Text

- **6.5 Luminous Intensity Distribution and Data Presentation**

  Unless otherwise specified, the CIE *C,γ* coordinate system (see CIE 121-1996) shall apply (see 5.3).

  The angular interval between readings of intensity within the vertical planes and the angular spacing between adjacent vertical planes should be such that luminous intensity distribution can be accurately presented and as to permit interpolation of intensity values during post-processing (lighting calculations) with an acceptable accuracy. The number of planes should also be determined by the nature of the distribution having regard to symmetry or irregularity and to the end results desired from the test. Guidance for goniophotometry of luminaires in specific applications may be available in the appropriate CIE Technical Reports for lighting applications.

  Measurements of luminous intensity distributions are usually made with goniophotometers. The provisions for goniophotometers apply: see 4.5.3. For types of goniophotometers, see also CIE 121-1996.

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Main Text

- **6.5.2 LED Luminaires**

  The intensity distribution of these devices shall be expressed in cd.

  NOTE 1 For lighting calculation programs requiring luminous intensity distribution data in cd/klm, ...

  NOTE 2 LOR may be determined for LED luminaires using interchangeable sources (e.g. LED lamps) in some cases.

Main Text

- 6.6 Centre Beam Intensity and Beam Angles

  The luminous intensity distributions shall be measured according to 6.5. For guidance for determining the centre beam intensity and beam angles on the basis of the luminous intensity distributions, see IEC/TR 61341:2010.

  NOTE For intensity distribution measurements in a goniophotometer, the direction (0,0) is usually the direction of the design optical axis (mechanical reference axis) of the light source, the axis through the photometric centre and perpendicular to the light exit plane, unless otherwise specified by the manufacturer. In IEC/TR 61341, the centre beam intensity is determined in the direction of the observed optical beam axis (the axis about which the luminous intensity distribution is substantially symmetrical) and the beam angle is evaluated around the observed optical beam axis. The mechanical reference axis may be used for measurement but evaluation must be made around the observed optical beam axis. The method to determine this optical beam axis is described in Clause 6 of IEC/TR 61341. Mechanical reference axis and observed optical beam axis are not necessarily coincident and this should be accounted for in the evaluation of the beam angle.

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- **6.7 Luminance Measurements**

  For reasonably uniform light surfaces, the following measurements may be considered:

  a) Measurement of the average luminance of the whole luminaire in a stated direction, or in a series of directions: This method is often used, e.g. for the evaluation of glare. In this method the luminous intensity (distribution) is measured, usually with a goniophotometer, and the average luminance is calculated by dividing the luminous intensity by the projected luminous area.

  b) Measurement of "patch luminance": This method is often used for the evaluation of spatial non-uniformity of the luminance of large indoor luminaires – for details see CIE 121, Clause 6.5.3. The average luminance(s) of specified small areas within the luminous area of the luminaire, areas called "luminous patch" (only size and shape are specified, realized by a mask with an opening), are measured in stated direction(s). These patches are distributed over the luminous surface of the luminaire and the average luminance is determined for each patch. The maximum and minimum of these average luminances are usually reported. The measurements may be made either with a goniophotometer set to the stated direction, using such a physical mask moved around over the luminous area of the luminaire (using the principle described in method a), or with a luminance meter measuring the average luminances of the luminous patches at different locations.

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If the LED sources and LED luminaires have no diffusing covers and are observed as a sum of point sources (thus appearing as a mixture of luminous and non-luminous portions within the outer contour), method a) above for the determination of the average luminance from the luminous intensity in the viewing direction and the projected luminous area (the outer contour of the light output area) is not valid. For such LED devices, only measurements of the luminances of the luminous portions of the light output area are appropriate. Such measurements can be made using a luminance meter or an imaging luminance measurement device (ILMD).

NOTE The luminous area can be calculated while summing up the object area of all marked pixels if the ILMD is calibrated with respect to the object space. The algorithm to divide between luminous area and background should be defined depending on the application (e.g. fixed threshold, adaptive threshold).

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Main Text

- 7 Measurement of Colour Quantities
- 7.1 Colorimetric Measurements
- 7.1.1 General Aspects

The following colorimetric quantities are covered in this standard:

- Chromaticity coordinates,
- Correlated colour temperature,
- Distance from Planckian locus,
- Colour rendering indices and
- Angular colour uniformity.

Calculations of colorimetric quantities shall take into account the standards ISO 11664-1:2007(E)/CIE S 014-1/E:2007, ISO 11664-2:2007(E)/CIE S 014-2/E:2006 and ISO 11664-3:2012(E)/CIE S 014-3/E:2011. Spectroradiometers are used to measure these colour quantities. Tristimulus colorimeters normally do not have sufficient accuracy for absolute colour measurement but they may be used for evaluating changes of chromaticity in different directions.

Main Text

Colour rendering indices require spectral data.

The value of the colorimetric quantities of LED lamps, LED modules and LED luminaires may be angularly non-uniform.

Colorimetric or spectral measurements may basically be performed using one of the following geometries:

a) along a specific direction;
b) as a directional distribution using gonio-colorimetric or gonio-spectroradiometric measurements equipment;
c) as spatially averaged values (i.e. from the total spectral radiant flux), using an integrating sphere or numerically averaging the gonio-spectroradiometric data or the gonio-colorimetric data.

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Spatially averaged colour quantities are used for all LED lamps, light engines, and LED luminaires except otherwise specified by the manufacturer or applicant.

Spatially averaged colour quantities may be obtained using one of the following methods:

① Sphere-spectroradiometer measurements provide spatially averaged colour quantities calculated from the total spectral radiant flux;

② If gonio-spectroradiometric data are available, total spectral radiant flux is calculated as a basis for the calculation of spatially-averaged colour quantities;

③ If gonio-colorimetric data $X(\theta,\phi)$ $Y(\theta,\phi)$, and $Z(\theta,\phi)$ are available, ...

Colour rendering indices can only be derived using either method 1) or 2).

The chromaticity coordinates (*x*,*y*) and/or (u'， v') are calculated according to CIE 15. ,*u'v'*

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- 7.1.2 Correlated Colour Temperature (White LED Light Sources)

  The chromaticity can also be expressed by the correlated colour temperature (*Tcp*) and the parameter *Duv*. Correlated colour temperature is calculated according to CIE 15. *Duv* is the signed distance from the Planckian locus on the CIE () diagram, which is positive for above and negative for below the Planckian locus. 23,*u'v'*

- 7.1.3 Colour Rendering Indices (White LED Light Sources)

  Calculation of colour rendering indices shall be made in accordance with CIE 13.3.

- 7.1.4 Angular Colour Uniformity

  Angular colour uniformity is measured as the largest deviation of chromaticity (u',v') of a LED device emitted in different directions, from its spatially averaged chromaticity () calculated as, （*ua'*, *va'*）。。。

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The chromaticity coordinates (*u′,v′*) are measured with a gonio-colorimeter or gonio-spectroradiometer at a vertical angle interval of 10° or less (2,5° is recommended) and a horizontal angle interval of 90° or less (22,5° is recommended). For reflector lamps, the angle increments shall be 1/10 or less of the beam angle (diameter of the angular cone emitting more than 1/2 of the peak intensity) but no larger than 10°. The data at angle points where the luminous intensity is less than 10 % (unless otherwise specified by a relevant product standard) of the peak intensity shall be ignored in the calculation.

Main Text

- The average chromaticity () for this calculation is obtained from the gonio-colorimetric measurement points described above using the calculation procedures in 7.1.1. (3), not from a different measurement system (e.g. sphere-spectroradiometer). If data from a different measurement system is used, there may be some errors, as low intensity points may be included in other results. Also, the absolute accuracy of chromaticity measurement for this angular colour uniformity is not as critical as that for chromaticity measurement for DUT described in 7.1.1. aa,*uv″*

- NOTE General guidance on colour difference specification for light sources is available in CIE TN 001:2014.

Main Text

- **8 Measurement Uncertainties**

  The uncertainties shall be evaluated according to ISO/IEC Guide 98-3 and its supplements. Guidance is also available from CIE 198.

  For all measured quantities the expanded uncertainty shall be given and expressed for a confidence level of 95 %. The expanded uncertainty is stated to at most two significant digits.

  For the purposes of testing, each test report may report uncertainty values for a typical product of the similar type having similar spectral distributions and intensity distributions to the DUT (see NOTE 1). In this case the type of the product used in the uncertainty budget shall be stated in the test report (see NOTE 2). Laboratories shall have a detailed uncertainty budget for the similar type of product and keep them available on demand. If such uncertainty budget is made for a range of products (e.g. CCT from 2 700 K to 4 000 K), the largest uncertainty value within the range shall be stated.

Main Text

- NOTE 1 In this context, products could be considered similar type if the following properties are the same as the DUT: phosphor type or RGB(A) type; similar geometrical shape (e.g. compact or tubular type for lamps); similar intensity distributions; omnidirectional or directional (beam angle between +50 % and -25 % of the value of the DUT); CCT within ±15 % of the CCT value of the DUT.

- NOTE 2 An example statement in the test report: "The uncertainty values stated in this test report are those for a similar type of product: phosphor type LED lamp (compact), directional (beam angle 60°), CCT 3 500 K." If the type of DUT does not match the type categories listed in NOTE 1, the product type should be described specifically.

- NOTE 3 When corrections are applied to the measurement results, the correction must always use the characteristics of the DUT (or product of the same model), and not of the similar type product.

Main Text

- For practical reasons, it is not always possible to estimate or measure the influence of the DUT repeatability between different cold-start operations; however this information shall be known from type investigations and shall be included in the uncertainty evaluation. It shall be mentioned in the uncertainty budget whether this parameter is estimated from type specific data or from individual measurements of the DUT.
- For luminous intensity distributions, the measurement uncertainty shall be reported at least in one given representative direction where the luminous intensity is fairly flat. The uncertainty on angular setting (including alignment of the DUT in the goniometer) or measurements shall be reported separately.
- For luminance distributions, measurement uncertainty shall be reported at least in one representative point where the luminance distribution is fairly flat.

Main Text

- **8.1 Guidance for Measurement Uncertainty Budgets**
- **8.1.1 Common Parameters to all Measurements**

At least the following contributions shall be considered:

- ☐ Temperature setting and uncertainty on temperature measurement
- ☐ Electrical settings and uncertainty on electrical measurements (power supply, electrical measuring instruments)
- ☐ Fluctuation of light output of the DUT (if significant)
- ☐ Calibration standard (calibration certificate)
- ☐ Operating of the calibration standard (ageing, electrical measurements, calibration process)
- ☐ Linearity of measuring instruments
- ☐ Reproducibility and repeatability (if applicable, default value for the equipment and generic device type may be used if this is not evaluated for the specific DUT)

For all measurements not only the contributions from the measurement system and procedures but also the contributions from the specific characteristics of the DUT (or similar type) must be taken into account.

Main Text

- **8.1.2 Luminous Flux**

In addition to 8.1.1 at least the following contributions shall be considered (where appropriate):

Measurement (depending on the method)

a) Goniophotometer

- ✓ Flatness of mirrors and polarization effects
- ✓ Spectral reflectance of mirrors
- ✓ Stray light (spatial)
- ✓ Positioning accuracy
- ✓ Spectral matching (detector + mirror, different spectral power distributions of the calibration standard and DUT)
- ✓ Detector acceptance area
- ✓ Cosine response (illuminance integration)
- ✓ Uncertainty of photometric distance if the photometer head is calibrated for illuminance responsivity
- ✓ Uncertainty of the reflectance of the mirror if it is used, if the photometer head is calibrated for illuminance responsivity

Main Text

b) Sphere Photometer

- ✓ Self-absorption
- ✓ Thermal behaviour
- ✓ Spatial non-uniformity of sphere responsivity
- ✓ Sphere reflectance (influence to the spectral matching)
- ✓ Spectral matching (detector + sphere, different spectral power distributions of calibration standard and DUT)
- ✓ Mechanical repeatability when the sphere is opened and closed
- ✓ Stability of sphere responsivity during the period between recalibrations
- ✓ Cosine response of photometer head
- ✓ Fluorescence effects from sphere coating

Main Text

c) Sphere-spectroradiometer

- ✓ Self-absorption
- ✓ Thermal behaviour
- ✓ Spatial non-uniformity of sphere responsivity
- ✓ Sphere reflectance
- ✓ Wavelength accuracy
- ✓ Stray light of the spectroradiometer
- ✓ Bandpass of the spectroradiometer
- ✓ Cosine response of the spectroradiometer entrance port
- ✓ Mechanical repeatability when the sphere is opened and closed
- ✓ Stability of the sphere responsivity during the period between recalibrations
- ✓ Fluorescence effects from sphere coating

Main Text

d) Gonio-spectroradiometer

- ✓ Flatness of mirrors and polarization effects
- ✓ Spectral reflectance of mirrors
- ✓ Stray light (spatial)
- ✓ Positioning accuracy
- ✓ Detector acceptance area
- ✓ Cosine response (illuminance integration)
- ✓ Wavelength accuracy
- ✓ Stray light of the spectroradiometer
- ✓ Bandpass of the spectroradiometer
- ✓ Uncertainty of photometric distance if the spectroradiometer is calibrated with a spectral irradiance standard
- ✓ Uncertainty of the spectral reflectance of the mirror if it is used, if the spectroradiometer is calibrated with a spectral irradiance standard

Main Text

8.1.3 Luminous Intensity and Luminance

Similar parameters as in 8.1.2 shall be considered.

8.1.4 Colour Quantities

This includes chromaticity coordinates, correlated colour temperature, and colour rendering indices. In addition to 8.1.1 at least following contributions shall be considered:

- Correlations due to the colour temperature uncertainty of the calibration source
- Stray light of the spectroradiometer
- Bandwidth (influence, correction)
- Wavelength accuracy
- Dynamic range over the spectral range

Main Text

8.1.5 Electrical Power

In addition to 8.1.1 at least the following contribution shall be considered:

- Bandwidth of the AC power meter (influence, correction)
- Input impedance of the AC power meter

8.1.6 Luminous Efficacy

The correlations between the luminous flux value and the electrical power measurement should be taken into account to reduce the associated measurement uncertainty. For example, if supply current affects both luminous flux output and electrical power of a DUT in the same direction with same sensitivity, the uncertainty in luminous efficacy for this component will be cancelled out.

Main Text

- 9 Presentation of Test Results
- 9.1 Test Report
- 9.1.1 General Information
- 9.1.2 Information on the Device(s) under Test
- 9.1.3 Information on the Test Procedure
- 9.1.4 Photometric and/or Colorimetric Data

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Main Text

- Annex A (informative) Guidance on the Application of this Standard
- Annex B (informative) Stray Light — Screening against Stray Light in a Goniophotometer
  Annex C (informative) Practical Laboratory Conditions
- C.1 Correction Factors
- C.1.1 Measurement Correction Factors
- C.1.2 Service Conversion Factors
- C.2 Sensitivity Coefficients
- C.3 Typical Sensitivity Coefficients and Tolerance Intervals
- C.3.1 Ambient Temperature
- C.3.3 Air Movement
- C.3.4 Test Voltage
- C.3.5 Spectral Mismatch of Photometer
- C.3.6 Model for Luminous Intensity

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Main Text

- Annex D (informative) Guidance on Calculating Measurement Uncertainties
- D.1 General
- D.2 Uncertainty Budget
- D.3 Example of Measurement Uncertainties
- Annex E (informative) Guidance for Determining Rated Values of Photometric Quantities of LED Luminaires
- E.1 Introduction
- E.2 Rating and Tolerance of LED-Luminaire Data

Highlight Points

Common components of uncertainty for measurement of LED devices are listed

Common Parameters to all Measurements

- Temperature setting and uncertainty on temperature measurement
- Electrical settings and uncertainty on electrical measurements (power supply, electrical measuring instruments)
- Fluctuation of light output of the DUT (if significant)
- Calibration standard (calibration certificate)
- Operating of the calibration standard (ageing, electrical measurements, calibration process)
- Linearity of measuring instruments
- Reproducibility and repeatability (if applicable, default value for the equipment and generic device type may be used if this is not evaluated for the specific DUT)

3.3 Uncertainty

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Luminous Flux Uncertainty

a) Goniophotometer

- Flatness of mirrors and polarization effects
- Spectral reflectance of mirrors
- Stray light (spatial)
- Positioning accuracy
- Spectral matching (detector + mirror, different spectral power distributions of the calibration standard and DUT)
- Detector acceptance area
- Cosine response (illuminance integration)
- Uncertainty of photometric distance if the photometer head is calibrated for illuminance responsivity
- Uncertainty of the reflectance of the mirror if it is used, if the photometer head is calibrated for illuminance responsivity

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Luminous Flux Uncertainty

c) Sphere-spectroradiometer

- Self-absorption
- Thermal behaviour
- Spatial non-uniformity of sphere responsivity
- Sphere reflectance
- Wavelength accuracy
- Stray light of the spectroradiometer
- Bandpass of the spectroradiometer
- Cosine response of the spectroradiometer entrance port
- Mechanical repeatability when the sphere is opened and closed
- Stability of the sphere responsivity during the period between recalibrations
- Fluorescence effects from sphere coating

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Colour Quantities Uncertainty

This includes chromaticity coordinates, correlated colour temperature, and colour rendering indices. In addition to 8.1.1 at least following contributions shall be considered:

- Correlations due to the colour temperature uncertainty of the calibration source
- Stray light of the spectroradiometer
- Bandwidth (influence, correction)
- Wavelength accuracy
- Dynamic range over the spectral range

Some Advice

- D.2 — Example of uncertainty budget summary for luminous flux measurement of an LED lamp using a sphere-spectroradiometer

Name of the quantity X_i	Relative contribution to the output standard uncertainty $u_{rel,i}(y)$	
	Broad [a]	Narrow [b]
Luminous flux uncertainty of NMI traceable total spectral radiant flux standard	1,0 %	
Ageing of luminous flux standard lamp (tungsten halogen lamp)	0,3 %	
DC current uncertainty for standard lamp	0,4 %	
Ambient temperature (and uncertainty of thermometer)	0,3 %	
Supply voltage of LED (and uncertainty of volt meter)	0,2 %	
Nonlinearity of spectroradiometer	0,8 %	
Wavelength uncertainty (0,5 nm (k=2))	0,4 %	
Stray light of spectroradiometer (2 700 K to 6 500 K source)	1,0 %	
Reproducibility of spectroradiometer	0,1 %	
Self-absorption correction (residual uncertainty) [c]	0,3 %	
Spatial non-uniformity of sphere (difference in intensity distribution from the standard lamp)	0,9 %	1,8 %
Repeatability of the sphere system	0,3 %	
Stability of the sphere system (between calibrations)	0,3 %	
Near-field absorption	0,3 %	
Reproducibility of test lamp (including stabilization condition)	0,3 %	
Stability of standard lamps	0,2 %	
Relative combined standard uncertainty	2,1 %	2,6 %
Total expanded uncertainty (k=2)	**4,2 %**	**5,2 %**

[a] Values for sources having broad angular intensity distribution are shown in the left column.

[b] Values for sources having narrow beam distribution, and if standard lamp is omnidirectional and no correction is made, are shown in the right column.

[c] Values for the case of 1,5 m sphere with 95 % reflectance measuring a typical compact LED lamp. This will change for different sphere condition and for DUTs of larger sizes.

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Some Advice

- **D. 5 — Example of uncertainty budget summary for colorimetric measurements of a LED lamp or LED luminaire using a sphere-spectroradiometer or gonio-spectroradiometer**
- (Values are shown for products with white LEDs of phosphor technology for Tcp = 3 000 K and 6 000 K.)

Name of the quantity X_i		Absolute contribution to the output standard uncertainty $u_i(x)$	$u_i(y)$	$u_i(u')$	$u_i(v')$	$u_i(T_{cw})$ 3 000 K	$u_i(T_{cw})$ 6 000 K	u_i(Duv)	$u_i(R_a)$
Calibration uncertainty of SI traceable secondary spectral radiant flux standard or spectral irradiance standard		0,001 4	0,001 9	0,000 5	0,001 2	26,6	67,8	0,000 5	0,44
Ageing of standard lamp		0,000 1	0,000 1	0,000 0	0,000 1	2,1	5,4	0,000 0	0,00
Wavelength uncertainty		0,000 4	0,000 7	0,000 1	0,000 4	6,9	17,5	0,000 2	0,08
Reproducibility of lamp and spectroradiometer		0,000 2	0,000 3	0,000 2	0,000 2	3,7	9,4	0,000 1	0,10
Nonlinearity of spectroradiometer		0,000 7	0,000 3	0,000 5	0,000 2	11,8	30,2	0,000 1	0,23
Bandpass of spectroradiometer		0,000 1	0,000 1	0,000 0	0,000 1	1,1	2,7	0,000 0	0,03
Stray light of spectroradiometer	3 000 K	0,000 6	0,001 0	0,000 0	0,000 5	5,3	—	0,000 3	0,25
	6 000 K	0,001 9	0,002 9	0,000 3	0,001 7	—	101,5	0,000 6	0,14
Combined standard uncertainty	3 000 K	0,001 7	0,002 3	0,000 7	0,001 4	30,7	—	0,000 7	0,57
	6 000 K	0,002 5	0,003 6	0,000 8	0,002 1	—	127	0,000 8	0,53
Total expanded uncertainty (k=2)	**3 000 K**	**0,003 5**	**0,004 7**	**0,001 4**	**0,002 7**	**61**	**—**	**0,001 4**	**1,1**
	6 000 K	**0,005 0**	**0,007 2**	**0,001 6**	**0,004 2**	**—**	**255**	**0,001 6**	**1,1**

Note For the uncertainty of chromaticity coordinates as distances from the true point on the (x, y) or (u', v') chromaticity diagram, a coverage factor k=2,45 should be used for expanded uncertainty at 95 % confidence interval.

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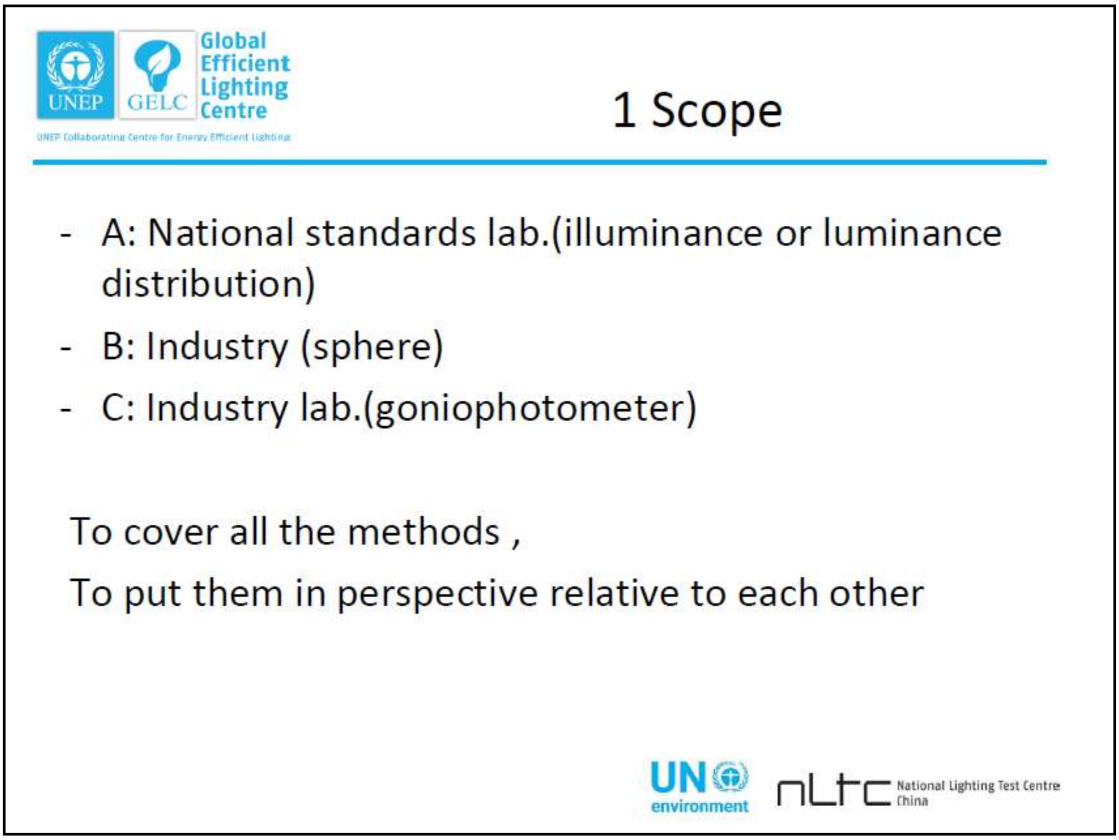
4. Introduction to CIE 84

4.1 Scope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1 Scope
- A: National standards lab.(illuminance or luminance distribution)
- B: Industry (sphere)
- C: Industry lab.(goniophotometer)
To cover all the methods ,
To put them in perspective relative to each other
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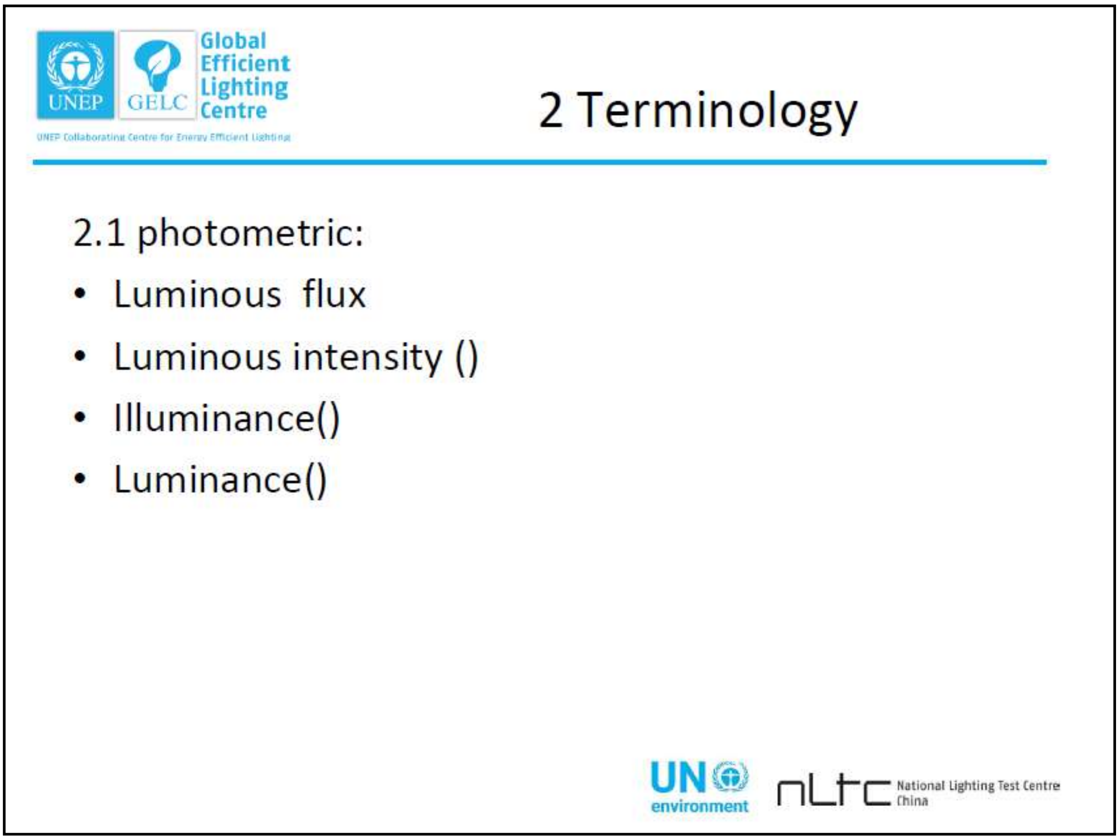
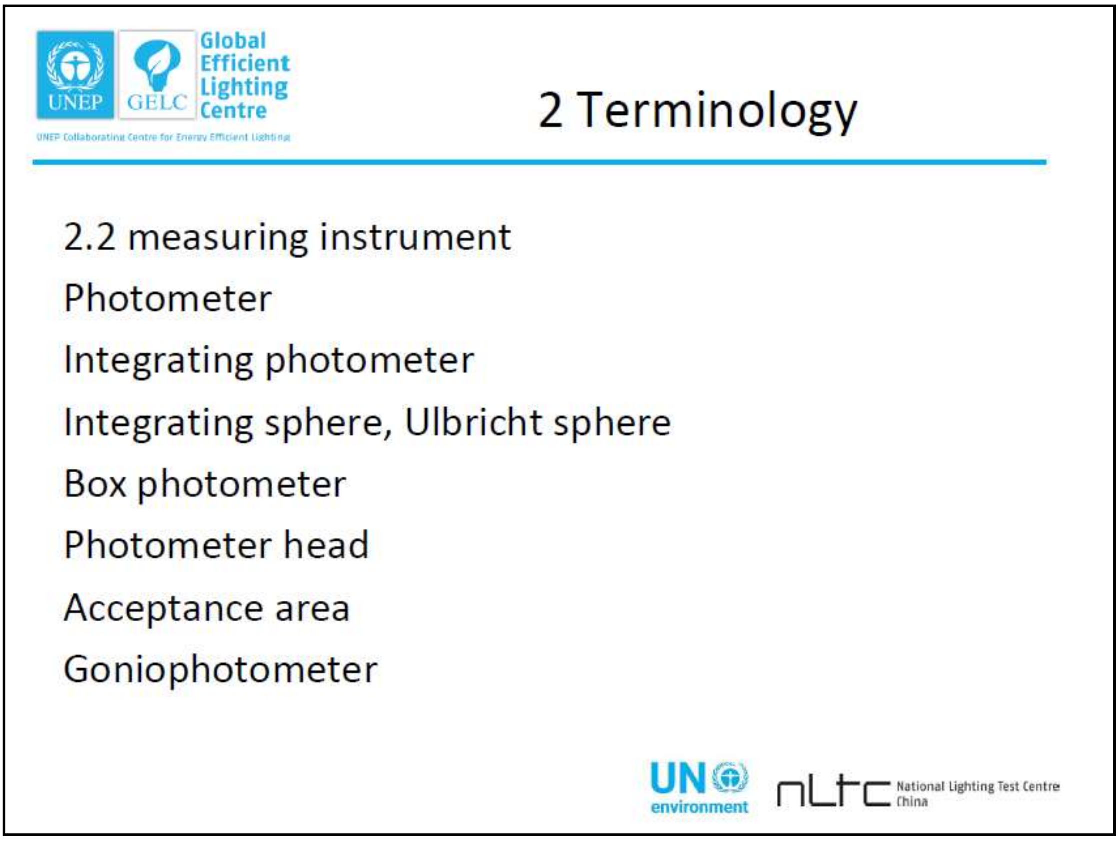
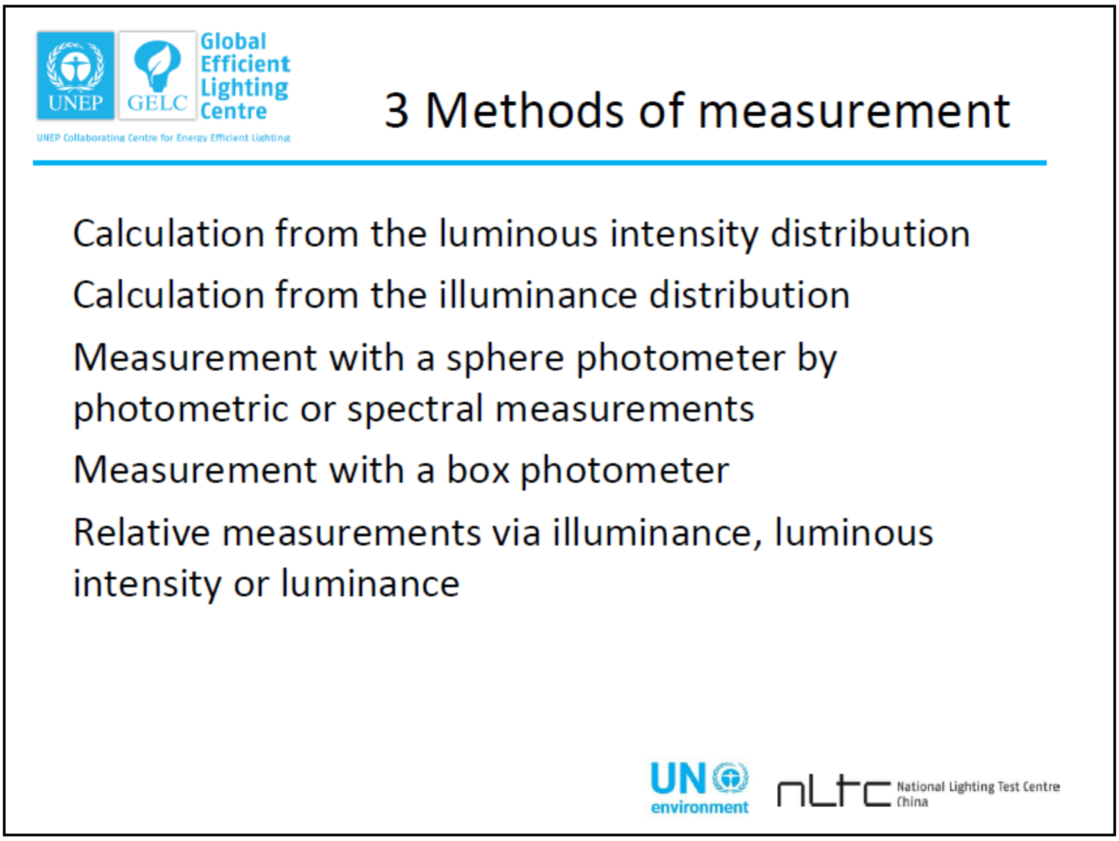
4.2 Terminology





4.3 Methods of Measurement



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3 Methods of measurement

Calculation of the luminous flux from the luminous intensity distribution is appropriate where measurements of the latter are already being made.(e.g. for luminaires)

The derivation of the luminous flux from a measurement of the illuminance distribution of a lamp is the method used in many national standards laboratories to set up the basic standards of luminous flux. The unit of luminous flux, the lumen, is thus established in terms of the SI base unit o f luminous intensity , the candela. An accurate measurement of the spatial variation of the colorimetric properties of light sources and of their spectral power distribution can also be made using this method.

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3 Methods of measurement

Luminous flux measurements using a sphere photometer are appropriate for:

- Measurements in industrial laboratories f o r production control
- Measurements by test houses and users
- The calibration of standard lamps (e.g. working standards) against higher order standard lamps, making extra corrections for errors due t o geometric, spectral and light distribution differences between the lamps to be compared.
-The measurement of light sources with luminous fluxes varying with time (e.g. adjustable lamps, flashlamps)
- The measurement of luminous flux as a function of time.

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3 Methods of measurement

A luminous flux measurement with a box photometer only presents a direct relationship between the luminous flux of the light source and the indirect illuminance at an arbitrary point at an inside surface of the box, if the reference light source and the light source to be measured have the same spatia l luminous intensity distribution, the same spectral distribution and same dimensions.

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3 Methods of measurement

Measurements of spectral radiant flux can be made with an integrating sphere photometer, for light sources where the spectral power distribution varies with direction (e.g. metal halide lamps). This method gives all the information necessary for the calculation of:

- Spectral power distribution
- Luminous flux
- Radiant flux
- Colour
- Colour rendering indices

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3 Methods of measurement

The determination of the luminous flux of light sources via a measurement of illuminance, luminous intensity or luminance is often carried out in practice to determine the influence of specific parameters (e.g. ageing, temperature, position) . It usually takes the form of **a relative measurement**.

The method can also be used for measuring the luminous flux of fluorescent lamps in lighting installations.

3 Methods of measurement

The **method used** for the measurement of luminous flux **depends on the available equipment**. Equipment and method used are influenced by:

-The task o f the photometric laboratory

-Economy

- Time consumption

- Acceptable measurement uncertainty.

4.4 Luminous Flux Calculation-Luminous Intensity Distribution

4 Calculation of luminous flux
from luminous intensity distribution

4.1 Measurement principle

According to the definition, the luminous flux Φ can be derived from the spatial distribution of the luminous intensity I by the relation

$$\Phi = \int_{\Omega} I d\Omega$$

where Ω = 4π sr, Total solid angle

The luminous intensity distribution can be measured with a goniophotometer

4.2 Measurement of luminous intensity distribution

The measurement of luminous intensity distribution is described in a separate Technical Report of the CIE. That report contains information about goniophotometers used for the measurement of luminous intensity distribution as well as data about the execution of the measurements.

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4.3 Method of calculation

In order to evaluate the luminous flux, the luminous intensity should be integrated over the full solid angle as shown in the equation.

$$\Phi = \int_{\Omega} I d\Omega$$

The element of solid angle dΩ can be expressed trigonometrically as

$$d\Omega = \sin\varepsilon \, d\varepsilon \, d\eta$$

with

dΩ Element of solid angle

ε,η Angles depending on the chosen coordinate system;

ε elevation angle with ε=0 at zenith and η azimuth angle

The angles ε and η should be substituted to accord with the coordinate system used during the measurement of luminous intensity distribution.

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4 Calculation of luminous flux from luminous intensity distribution

- In a practical evaluation the integrals are replaced by sums. In that case the luminous flux can for example be calculated according to the following formulae:
- A-PLANES:...
- B-PLANES:..
- C-PLANES: $\Phi = \Delta C \sum_{m=1}^{M} \sum_{n=1}^{N} I(\gamma, C) \{ \cos[(n-1)\Delta\gamma] - \cos(n\Delta\gamma) \}$

Δγ corresponds to π/N, while ΔC are given by 2 π /M

The smaller the angular steps that are chosen, the more accurate will be the resulting determination of luminous flux. Steep luminous intensity distributions require smaller angular steps.

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4 Calculation of luminous flux from luminous intensity distribution

4.4 **Sources of error**

Specific errors in the determination of the luminous flux through an evaluation of the luminous intensity distribution can be caused by:

- Errors in the measurement of luminous intensity
- Too large step angles
- Shading of the light source by mechanical parts of the goniophotometer and the holder for the light source
- Instability of the light source during measurement
- Instability of the mechanical arrangement of the photometer.

4.5 Luminous Flux Calculation-Illuminance Distribution

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5 Calculation of luminous flux from the illuminance distribution

5.1 Measurement principle

By definition , the luminous flux Φ can be derived from the distribution of illuminance E over a closed surface A around the light source using the relation

$$\Phi = \int_A E dA$$

The illuminance distribution can be measured by means of a goniophotometer over a spherical surface around the light source. It is not necessary for the light source to be exactly at the centre of the imaginary sphere. It is , however, recommended that it should be positioned as close to the centre *of* the sphere as possible.

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5 Calculation of luminous flux from the illuminance distribution

The minimum distance between the centre of the sphere and the photometer head depends on the largest dimension of the light source to be measured, for purely mechanical reasons. It may be smaller than the limiting photometric distance as long as the illuminance meter still evaluates illuminance correctly in terms of direction (cosine response), etc.

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5 Calculation of luminous flux from the illuminance distribution

5.2 Types of goniophotometer

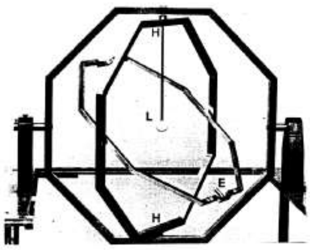
It is possible to distinguish between the different types of goniophotometer used for the measurement of illuminance distribution. In all of them the light source to be measured is operated in the prescribed burning position.

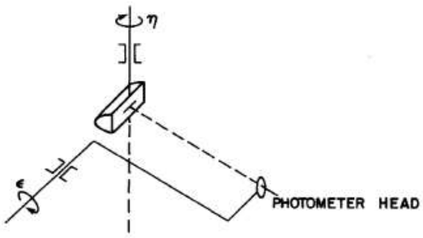
5.2.1 Goniophotometer with light source in a fixed position

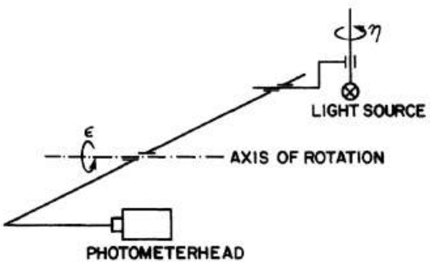
5.2.2 Goniophotometer with the light source rotated about a spatially fixed light centre

5.2.3 Goniophotometer with the light source rotated about a vertical axis with a moving light centre

5 Calculation of luminous flux from the illuminance distribution







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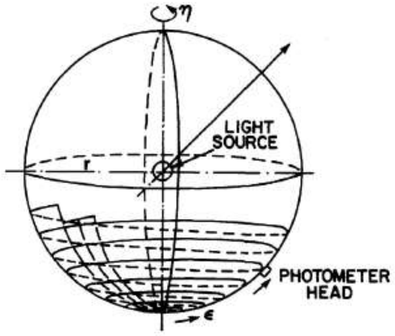
5 Calculation of luminous flux from the illuminance distribution

5.3 Measurement of illuminance distribution

5.3.1 Movement of the photometer head

There are several possibilities for measuring illuminance distribution:

…



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5 Calculation of luminous flux from the illuminance distribution

5.3.2 Angular step sizes

The determination of the luminous flux becomes the more accurate the smaller the step sizes for rotation in the polar **(ΔC)** and azimuth **(Δγ)** angles.

For an accurate measurement, especially for light sources with a steep luminous intensity distribution, angular step sizes of **ΔC** = **Δγ** = **0.1** could be required. For light sources with a broad luminous intensity distribution larger angular step sizes can be chosen.

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5 Calculation of luminous flux from the illuminance distribution

5.3.3 Speed of rotation

Light sources, the luminous flux of which depends on the ambient temperature and the air speed, may only be turned around the vertical axis at a limited speed of rotation. Some light sources can also be influenced by material moving inside the light source. Where there is a possibility of moving particles, especially drops of e.g. Na, Hg, the accelerations should be less than one tenth of standard gravity.

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5 Calculation of luminous flux from the illuminance distribution

Note:

The permitted speed of rotation can be determined by:

- Measuring the luminous flux of the light source as a function of the speed of rotation
- Measuring the illuminance at a position along the axis of rotation of the light source, which is not shaded by parts of the lamp holder, as a function of the speed of rotation.

The speed of rotation, at which the luminous flux starts changing (usually decreasing), should not be exceeded during the measurement. A uniform movement of the photometer head without vibration is required. For this the mechanical system has to be well balanced.

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5 Calculation of luminous flux from the illuminance distribution

5.4 Angle encoding

In order to measure the illuminance at a defined position of the photometer head, two angles have to be set and measured. The use *of* absolute angle encoders, where the starting position need not be adjusted, is recommended.

The set positioning is maintained even after switching off the power supply. Other means of angle encoding, e.g. stepping motors, are also in use. The indication of the angles should be accurate to within approximately $0{,}1^0$.

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5 Calculation of luminous flux from the illuminance distribution

5.5 Illuminance meter

The accuracy of luminous flux measurements made by means of an evaluation of the illuminance distribution is determined decisively by the quality of the illuminance meter used. It should be of a very high quality.

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5 Calculation of luminous flux from the illuminance distribution

5.6 Data acquisition and calculation of luminous flux

In all goniophotometers where luminous flux is determined by evaluating the illuminance distribution, this distribution is measured on a spherical surface around the light source. In that case the luminous flux is given by equation as:

$$\Phi = \int_{(A)} E \, dA = r^2 \int_{\varepsilon=0}^{\pi} \int_{\eta=0}^{2\pi} E(\varepsilon,\eta) \sin\varepsilon \, d\varepsilon \, d\eta$$

A Sphere surface

E Illuminance on area element dA of the sphere surface

r Sphere radius

ε Polar angle

η Azimuth angle

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5 Calculation of luminous flux from the illuminance distribution

When the light source or the detector is moving continuously during a measurement there can be quite large changes in the illuminance at the photometer head due to spatial or, in the case of AC powered lamps, temporal changes in the output. An exact measurement of the local illuminance is therefore only possible if the light source and the detector head are stationary during the measurement. This leads to long measuring times and is therefore not generally practicable .

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5 Calculation of luminous flux from the illuminance distribution

Methods for the determination of the "correct" illuminance, which is applicable for a defined area element or a defined direction (characterized by the angles ε and η), differ and cannot be described in a generalized way.

On the whole the measurement accuracy is influenced significantly by the angular step sizes Δε and Δη, the angular velocities dε/dt and dη/dt and the integration time of the illuminance meters (for 50 Hz AC supplies usually > 20 ms) .

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5 Calculation of luminous flux from the illuminance distribution

The illuminance integration given by equation can be carried out by:

- Direct electronic integration with display of the luminous flux after evaluation of the illuminance distribution over the whole surface of the sphere.

-Acquisition of the measured illuminance values at all the positions of the photometer head, storage of these values and evaluation e.g. by means of a desktop computer.

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5 Calculation of luminous flux from the illuminance distribution

In a direct electronic integration weighting of the illuminance according to the sine of ε is usually achieved by using a sinepotentiometer. In these potentiometers, even with precision components, large errors can occur at small values of ε, which reduce the accuracy when measuring light sources with steep luminous intensity distributions. For equal angular step sizes numerical calculation will therefore usually be more accurate than direct electronic integration.

In numerical calculation it is also possible to determine partial luminous fluxes in certain sections of solid angle, e.g. the upper or lower hemisphere, separately.

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5 Calculation of luminous flux from the illuminance distribution

5.7 Stray light…

5.8 Missed luminous flux…

5.9 Summary of error sources

- Deformation of mechanical parts of the goniophotometer (frame, revolving arm)
- Uncertainty regarding the distance between the acceptance area of the photometer head and the centre of revolution
- Uncertainty with respect to the position of the photometer head Irregular rotation
- **Too** large angular steps
- Measurement uncertainty of the illuminance meter

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5 Calculation of luminous flux from the illuminance distribution

- Too great an angular velocity : Influence on the light output of the source. Prevention of the proper temporal integration of the luminous **flux**
- Missed luminous flux and shading
- Stray light
- Uncertainty regarding the photometric calibration of the calibration standard
- Instability of the light source or other parts of the system (e.g. amplifier) during the measurement.

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5 Calculation of luminous flux from the illuminance distribution

5.10 Characterization checklist

Mechanical construction:...

Geometry:...

Positioning:...

Illuminance meter and data processing:...

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5 Calculation of luminous flux from the illuminance distribution

5.11 Calibrating and testing

5.11.1 Calibration

Goniophotometers f o r the determination of luminous flux from the illuminance distribution are usually calibrated by means of **luminous intensity standard lamps**. The calibration applies to the illuminance meter used in the goniophotometer, for which the illuminance is calculated from the luminous intensity of the standard lamp via the photometric distance law.

5 Calculation of luminous flux from the illuminance distribution

5.11.2 Testing

In addition the goniophotometer can be tested by three different methods:

5.11.2.1 Luminous flux standard lamp

5.11.2.2 Luminous intensity standard lamp

5.11.2.3 Calibrated illuminance meter

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5 Calculation of luminous flux from the illuminance distribution

5.11.3 Intercomparison

A good method for finding the uncertainty of the measurement of luminous flux obtained with a specific goniophotometer is to compare results for the same lamps measured at different well qualified laboratories. A comparison of the results of measurements on the same lamps obtained with different photometers (e.g. a goniophotometer and an integrating sphere photometer) may also give useful information.

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4.6 Measurement with an Integrating Sphere

6 Measurement with an integrating sphere

6.1 Measurement principle

The luminous flux of a light source can be measured in a sphere photometer by a comparison with a luminous flux standard lamp. In making the measurement, the light source and the standard lamp are placed successively at the same location in the integrating sphere. **The indirect illuminance** on the sphere surface is taken as a measure of the luminous flux.

A sphere photometer consists of an integrating sphere, a photometer head with read-out unit and - if applicable - means for data acquisition, as well as an electrical supply for the measuring equipment.

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6 Measurement with an integrating sphere

6.2 Sphere theory

Luminous flux can be measured in a sphere photometer by means of a comparison with the luminous flux of a luminous flux standard lamp. According to Ulbricht's theory, the luminous flux of the light source is related to the indirect illuminance E_{ind} on the internal surface of the integrating sphere by

$$\Phi = E_{ind} \cdot \frac{1-\rho}{\rho} A$$

$$k = \frac{1-\rho}{\rho} A \qquad k = \frac{\Phi_N}{E_{ind,N}} \qquad \Phi = \Phi_N \cdot \frac{E_{ind}}{E_{ind,N}}$$

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6 Measurement with an integrating sphere

6.3 Spectral method

An important parameter of a light source is the spectral radiant flux $\Phi_{e\lambda}$, from which several quantities can be calculated:

- Luminous flux
- Radiant flux
- Radiant flux effective for photobiological effects
- Colour (tristimulus values, correlated colour temperature)
- Colour rendering properties (special (Ri) and general (Ra) colour rendering indices)

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6 Measurement with an integrating sphere

The spectral radiant flux of a light source can be measured with an integrating sphere photometer, where the V(λ)-evaluating photometer head is replaced by a monochromator combined with an appropriate detector. In this way, the spectral irradiance $\Phi_{e\lambda,ind}$ is measured - instead of the indirect illuminance E_{ind} - as a function of the wavelength.

When spectral measurements are used in this way, **the spectral reflectance of the sphere wall and the relative spectral responsivity of the radiometer head do not influence the results.** The effect of a difference in the spatial flux distributions between the standard lamp and the light source to be measured is the same as for luminous flux measurements with an integrating sphere photometer.

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6 Measurement with an integrating sphere

A standard lamp o f known spectral radiant flux $\Phi_{e\lambda,N}$ must be used.

The spectral radiant flux $\Phi_{e\lambda,X}$ of a light source to be measured can be obtained from the relation

$$\Phi_{e\lambda,X} = \Phi_{e\lambda,N} \frac{Y_{\lambda,X}}{Y_{\lambda,N}} = \frac{1}{s(\lambda)} \cdot Y_{\lambda,X}$$

- $s(\lambda) = Y_{\lambda,N}/\Phi_{e\lambda,N}$ Spectral responsivity of the sphere radiometer
- $Y_{\lambda,x}$ Output signal for light source X at wavelength λ
- $Y_{\lambda,N}$ Output signal for standard lamp N at wavelength λ
- $\Phi_{e\lambda,N}$ Spectral radiant flux of the standard lamp **N.**

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6 Measurement with an integrating sphere

The luminous flux ax o f the light source to be measured can be calculated from the known luminous flux Φ_N and known relative spectral power distribution $S_{\lambda,N}$ of the standard lamp:

$$\Phi_X = \Phi_N \frac{\int_0^\infty S_{\lambda,N} \cdot (Y_{\lambda,X} / Y_{\lambda,N}) \cdot V(\lambda) \cdot d\lambda}{\int_0^\infty S_{\lambda,N} \cdot V(\lambda) \cdot d\lambda} =$$

$$= K_m \int_0^\infty (Y_{\lambda,X} / s(\lambda)) \cdot V(\lambda) \cdot d\lambda$$

K_m = 683 lm/W Maximum spectral luminous efficacy.

For color,...

Other than spectral solutions,...

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6 Measurement with an integrating sphere

6.4 Box-photometer

A comparison of the luminous flux of light sources of the same type can also be performed using a box-photometer, in which an arbitrarily shaped box or rectangular cavity is used instead of an integrating sphere.

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6 Measurement with an integrating sphere

6.5 Integrating sphere

6.5.1 Sphere diameter

…sufficient distance between the light source and the sphere wall to permit adequate multiple reflections of the light within the sphere without undue interference from the source itself. .. for compact lamps should be **at least 10 times** and for tubular lamps at **least twice the largest dimension** of the light source. Thus the sphere diameter for measuring fluorescent lamps o f 1,5 m length should be **3 m** (for less critical measurements *…2* m …).

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6 Measurement with an integrating sphere

The choice of sphere diameter is also determined by the power dissipation of the light source t o be measured.

The responsivity of a sphere photometer varies with the inverse square of the sphere diameter.

The integrating sphere should be made i n such a way that no stray light can enter the sphere from the outside.

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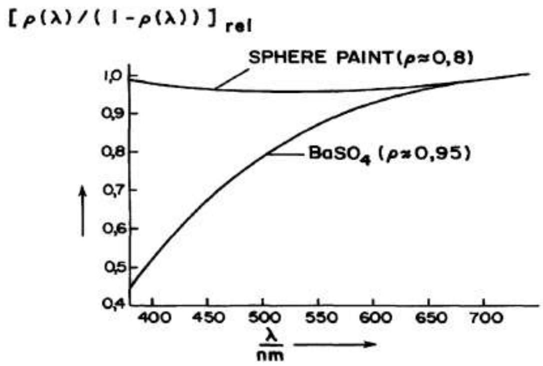
6 Measurement with an integrating sphere

6.5.2 Sphere paint



…repainted as often as once a year, depending on the application and the environment, to keep the influence o f ageing and pollution to a minimum.

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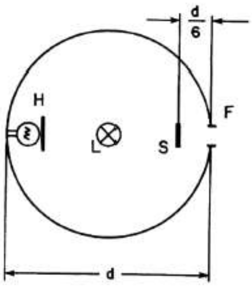
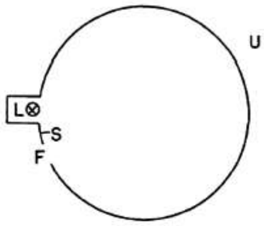
6 Measurement with an integrating sphere

6.5.3 Arrangement of l i g h t source and screen

A screen should be mounted inside the integrating sphere in such a way that no direct light from the source can reach the photometer head.





L Light source
S Screen
F Sphere port for photometer head
H Auxiliary lamp with screen
d Sphere diameter

L Light source
F Sphere port for photometer head
S Screen
U Integrating sphere

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6 Measurement with an integrating sphere

6.5.4 Influences of objects in the sphere and auxiliary lamp.

All objects in the sphere influence the result of the measurement. They should therefore be as small as possible. The light source itself also absorbs radiation.

The influence can be determined and corrected by making an additional measurement with an auxiliary lamp.

...should be positioned opposite to the photometer head and should illuminate the inside surface of the sphere diffusely.

... a small white screen ...

...with a top reflectorized bulb then ...

...flux of the auxiliary lamp must not change with time.

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6 Measurement with an integrating sphere

6.6 Illuminance meter

The acceptance area … a good diffusing material, …and fitted tightly into and flush with the inner wall of the sphere. …size small. ..thermostated photometer head is recommended. …at about the same height as the light source.

… high quality …. It i s especially important: relative spectral responsivity closely approximates t o the **CIE *V(λ)* …**

…Spectral method, a spectroradiometer i s employed instead of an illuminance meter

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6 Measurement with an integrating sphere

6.7 Data acquisition

…digital…

Electrical parameters

calculation

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6 Measurement with an integrating sphere

6.8 Luminous flux standard lamps

The results of luminous flux measurements made in the sphere photometer by the substitution principle will be correct if the light source to be measured and the luminous flux standard lamp used have

- The same spectral distribution
- The same dimension and shape
- The same spatial light distribution.

OR?

recommended that at least 3 standard lamps

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6 Measurement with an integrating sphere

6.9 Execution o f measurements

$$\Phi = \Phi_N \cdot \frac{Y}{Y_N} \cdot \frac{Y_{HN}}{Y_H}$$

Same type and dimension

Same spectral distributions

Light distribution...

large power dissipation...

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6 Measurement with an integrating sphere

6.10 Testing and correction

6.10.1 Correction for the influence of the sphere paint

6.10.2 Corrections for incandescent lamp measurements

6.10.3 Correction for measuring fluorescent lamps

6.10.4 Test for stability with time

6 Measurement with an integrating sphere

6.11 Sources of error

Different spectral distributions...

Different spatial luminous flux distributions...

Different dimensions and absorption ...

Changes in the reflectance of the inner sphere wall (ageing)...

Uncertainty of the illuminance measurement...

Instability of the light source during the ....

6 Measurement with an integrating sphere

6.12 Characterization of sphere photometers

-Sphere diameter

-Positioning of screens and any auxiliary lamp

-Data on any auxiliary lamp (type, nominal voltages etc.)

-Spectral function $\rho(\lambda) / (1- \rho(\lambda))$ of the sphere paint

-Data on the illuminance meter used

-Details on data acquisition and display

-Data on the smallest measurable luminous flux

4.7 Determination of Luminous Flux

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7. Determination of luminous flux via illuminance, luminous intensity or luminance

7. Determination of luminous flux via illuminance, luminous intensity or luminance

7.1 Measurement principle

$$\Phi = c_E \cdot E = c_I \cdot I = c_L \cdot L$$

...the applicable factor of proportionality (C_E, C_I, C_L) is determined.

For some lamps a proportionality between Φ and E, I or L may also hold for the lamp type, and not only for the individual lamp

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7. Determination of luminous flux via illuminance, luminous intensity or luminance

7.2 Measurement and calibration

...the measuring geometry, for which the factors of proportionality apply, has to be fixed...

7.3 Characterization

-Lamp type, for which the facility is used

- Quantity to be measured
- Measurement geometry and measuring arrangement
- Factor of proportionality and it s standard deviation
- Data on the illuminance or luminance meter used.

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4.8 General Measurement Conditions

8. General measurement conditions

8.1 Operating conditions

...unless otherwise agreed, **under the conditions specified in the relevant IEC recommendations and national standards.** Specifically, it must be stated whether the measurements are to be made at nominal voltage, current or power. This ensures that within the unavoidable measurement uncertainty, the results can be compared with values measured at other locations.

The measuring and operating facilities should influence the values of the quantities to **be fixed as little as possible.** Unavoidable influences should be taken into account in the evaluation of the measurements uncertainties.

- Calibrations... directly or indirectly by comparison with internationally recognized standards.

8. General measurement conditions

8.2 Ageing

The operating parameters of lamps change over their life-time to varying degrees. Changes are especially pronounced over the first part of their life-time. In order to achieve sufficient repeatability of measurements it is therefore necessary to age the lamps.

The duration of ageing for the different types of lamps is specified in the relevant IEC recommendations and national standards.

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8. General measurement conditions

8.3 Burning Position

The operating position of a light source should comply with the relevant IEC recommendation and national standards or with the specification laid down by the manufacturer and appropriate t o the application. The burning position must be stated in the measurement report.

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8. General measurement conditions

8.4 Ambient temperature

Discharge lamps…a draught-free … that the convection flow of the surrounding air is not impaired.

… ambient temperature of **25 ⁰C**. …strongly temperature dependent…tolerance ± **1 ⁰C**, other light sources **….**± **3 ⁰C**.

If measurements are made at different ambient temperatures this temperature should be stated.

…a resolution at least **0.1 ⁰C** . …at about the same height…

…goniophotometer, exceed half the largest horizontal dimension by **0,5** m..

…sphere, *20* cm and 1/3 o f the sphere diameter, shielded..

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8. General measurement conditions

8.5 Vibration and shock

When switched on, the lamp should not be subjected to accelerations exceeding 10 m/s2 (4-3000 **Hz)** or positional changes exceeding 30 mm (up **to** 4 **Hz).** These constraints will be adequate for most lamps.

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8. General measurement conditions

8.6 Stabilization period

…to ensure that all important parameters have reached a steady state by the time the measurements commence. During stabilization same operating. avoiding changes in the burning position and in the specified operating parameters (e.g. nominal voltage, power or current) The stabilization period required **depends on the type of light source and the operating conditions**. It should be checked initially by continuous monitoring of the readings. A light source can be considered to be stabilized, i f these **readings no longer show a trend in a particular direction**.

Step….final state…

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8. General measurement conditions

8.7 Electrical measurements

8.7.1 Measurement uncertainty

Loading error,

Report loading method

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8. General measurement conditions

8.7.2 Power supply and operating mode

It is usually possible to measure DC more accurately than AC, since for AC, both the light source and the electrical measuring instruments are influenced by a number of variables, such as frequency, wave form and phase shift. Because of the strong dependence of the photometric quantities on the electrical parameters, the power supplies used should be as stable as possible.

The waveform of AC power supplies should be closely sinusoidal with a minimum of harmonics a t other frequencies.

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8. General measurement conditions

8.7.3 Wiring

Wiring, ballasts and electrical measuring instruments should be positioned and, if necessary, screened in such a way that any influence from external fields is avoided. For the measurement of lamp voltage or power, the use of a specially constructed lamp holder is recommended.

The special lamp holder should have four contacts, two for the current supply (I_L) and two separate ones for the voltage (U_L) directly at the lamp cap. **A four-electrode lamp holder** reduces the voltage measuring error to zero, because no measurable current flows through the measuring contacts, when a high impedance digital voltmeter is used.

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8. General measurement conditions

8.7.4 Execution of the electrical measurements

...current measured by the ammeter must include the current through the voltmeter ... is generally to be preferred. If the current through the voltmeter is significant, however, it will be necessary t o apply the appropriate correction.

The capacity of the circuit may influence the results , especially if higher frequencies occur as in the case of low pressure sodium vapour lamps. Grounding errors can substantially influence the measurements.

For accurate AC measurements on discharge lamps, instruments must be of the true rms type so as t o take proper account of the harmonics. When measuring high frequency discharge lamps, special methods and instruments must be used .

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8. General measurement conditions

8.7.5 Measurement circuit

In the case of discharge lamps IEC recommendations or corresponding national standards specify the circuits for the light sources to be measured.

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8. General measurement conditions

8.8 Ballasts

Measurements on discharge lamps **must** be made with reference ballasts unless the lamp is controlled on current or power instead of voltage. If other ballasts are used (e.g. for measurements on luminaires), the ballast used

should be stated in the measurement report.

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8. General measurement conditions

8.9 Supply voltage

Measurements on incandescent lamps should preferably be performed with a DC supply because of the higher accuracy of the electrical measurements. Discharge lamps generally have t o be operated on AC.

The supply voltage during ageing should be stable to within 0.5%, during the actual measurement to within 0.1 % and for calibrations with incandescent lamps as standards to within 0.02 %.

The total harmonic content of the AC supply should not exceed 3**%.** For the operation of high pressure lamps with a high proportion of reactive power the power supply should be chosen in such a way that the required reactive power can be met.

This implies that the source of supply shall have a sufficiently low impedance compared with the ballast impedance and care should be taken that this applies under all conditions of measurement.

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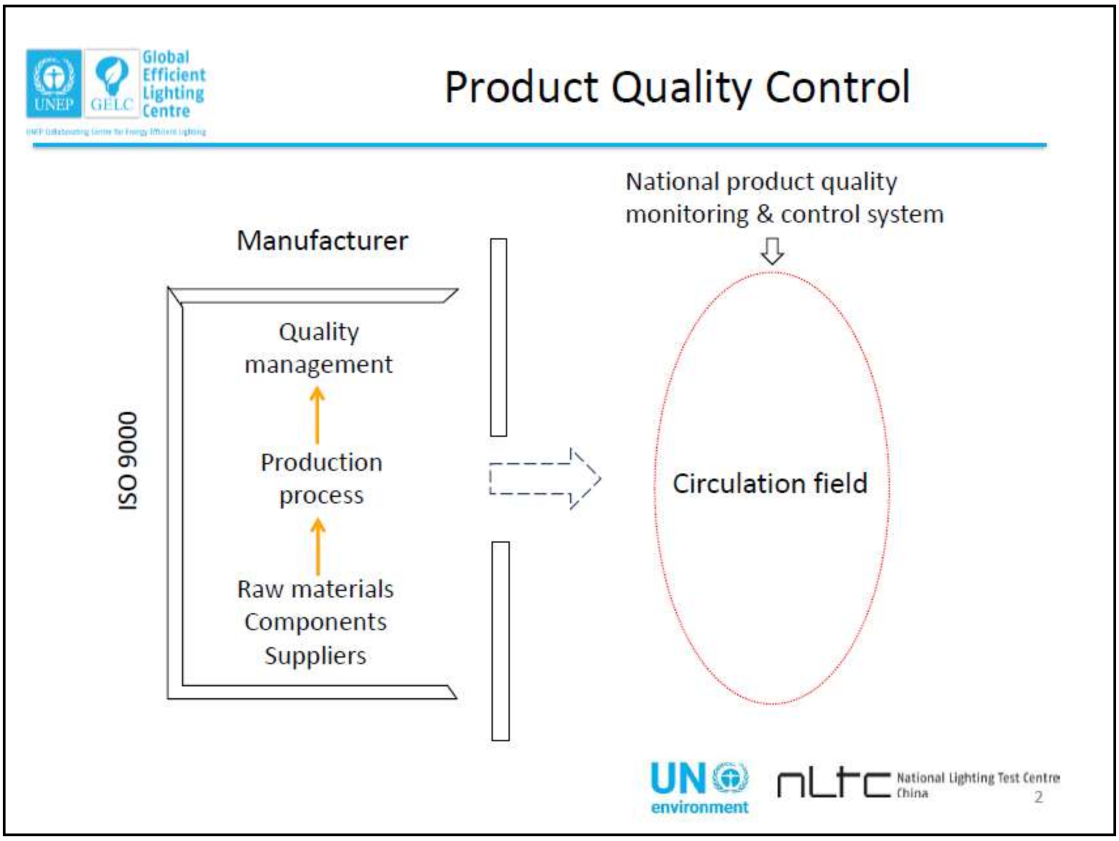
5. How Does A Lighting Laboratory Play Its Role in MVE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Lighting
Centre
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GELC
Product Quality Control
National product quality
monitoring & control system
Manufacturer
Quality
management
Production
process
Raw materials
Components
Suppliers
ISO 9000
Circulation field
UN environment
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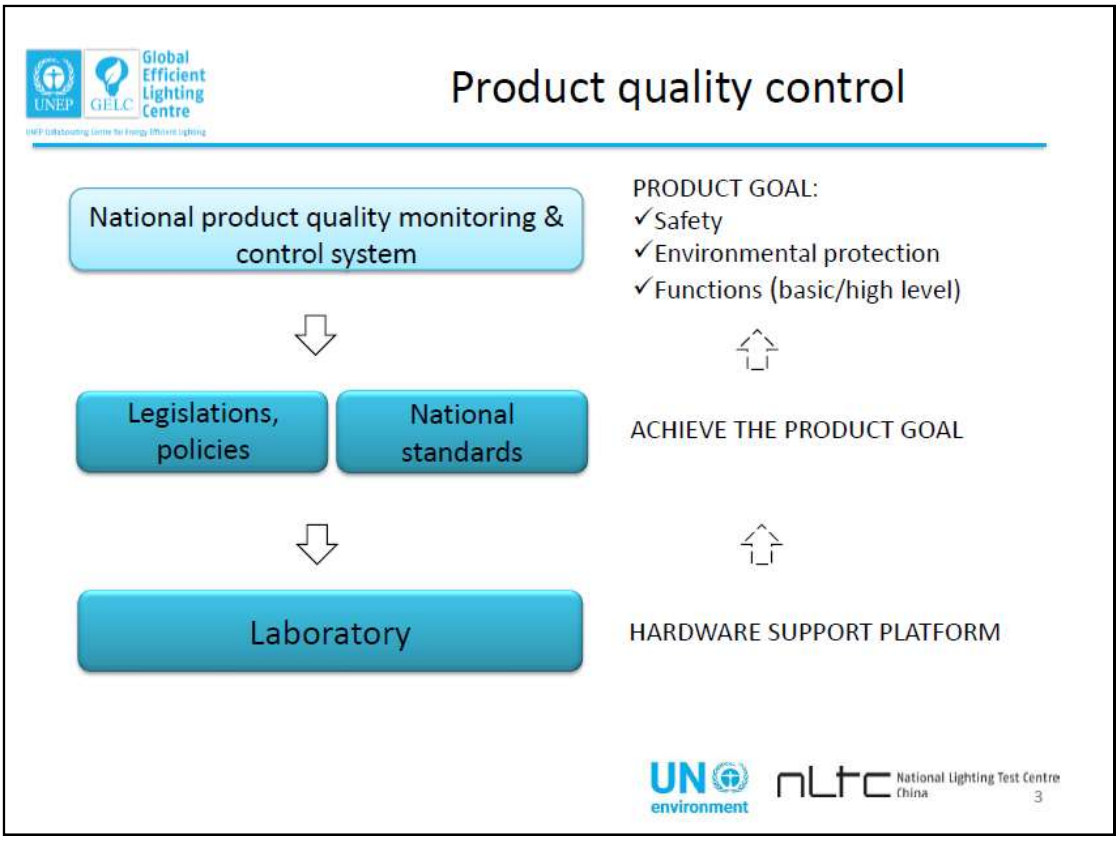
2


Global
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Lighting
Centre
UNEP
GELC
Product quality control
National product quality monitoring & control system
PRODUCT GOAL:
✓Safety
✓Environmental protection
✓Functions (basic/high level)
Legislations, policies
National standards
ACHIEVE THE PRODUCT GOAL
Laboratory
HARDWARE SUPPORT PLATFORM
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International standard organization

IEC	CIE	ISO
International Electrotechnical Commission(IEC）,1906	International Commission on Illumination	International Organization for Standardization
Scope :International Standards for all electrical, electronic and related technologies TC 34: Lamps & related equipment	Scope: the science and art of light and lighting, colour and vision, photobiology and image technology. Division 1,2,3,4,5,6,8	Scope: covering almost every industry, from technology, to food safety, to agriculture and healthcare. ISO TC 274 Light and lighting
Chracteristics of Products	Fundamental, including testing method	Application

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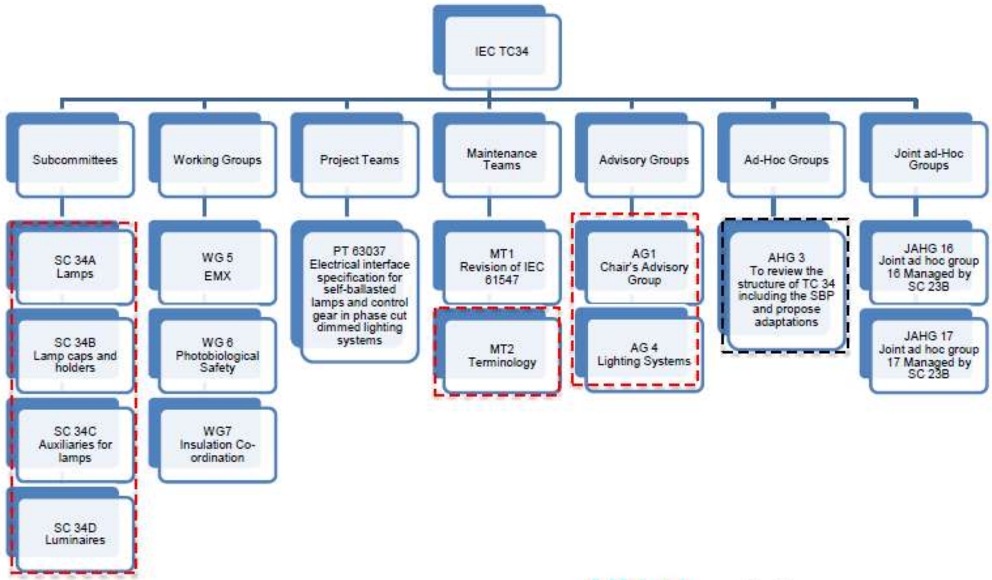
IEC lighting standardization



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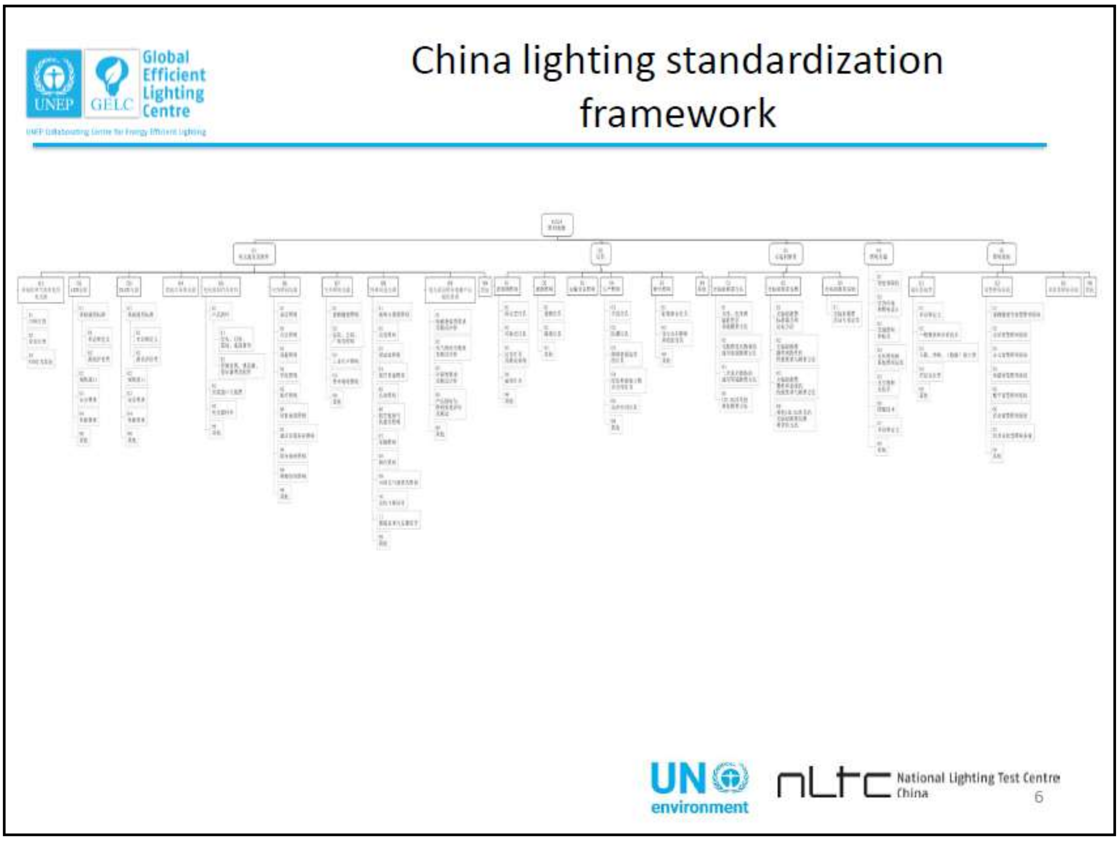
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Centre
UNEP
GELC
China lighting standardization framework
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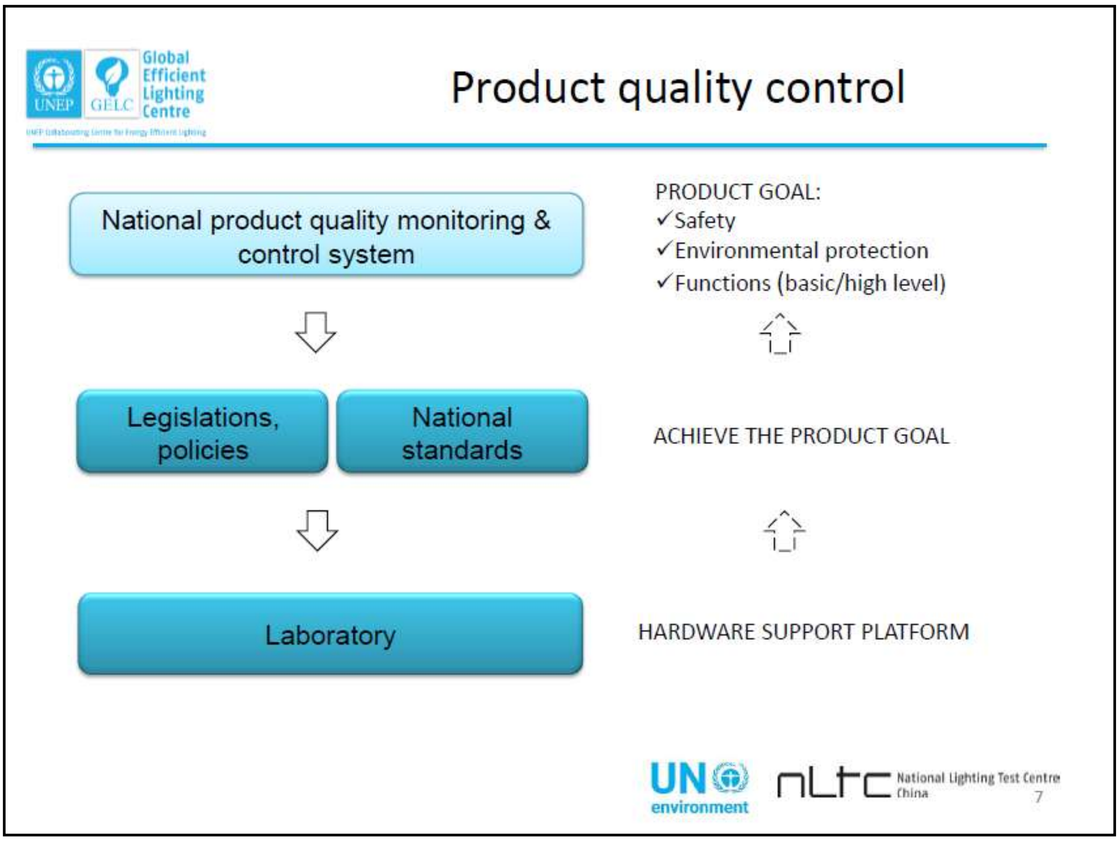
6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Centre
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GELC
Product quality control
National product quality monitoring & control system
Legislations, policies
National standards
Laboratory
PRODUCT GOAL:
✓Safety
✓Environmental protection
✓Functions (basic/high level)
ACHIEVE THE PRODUCT GOAL
HARDWARE SUPPORT PLATFORM
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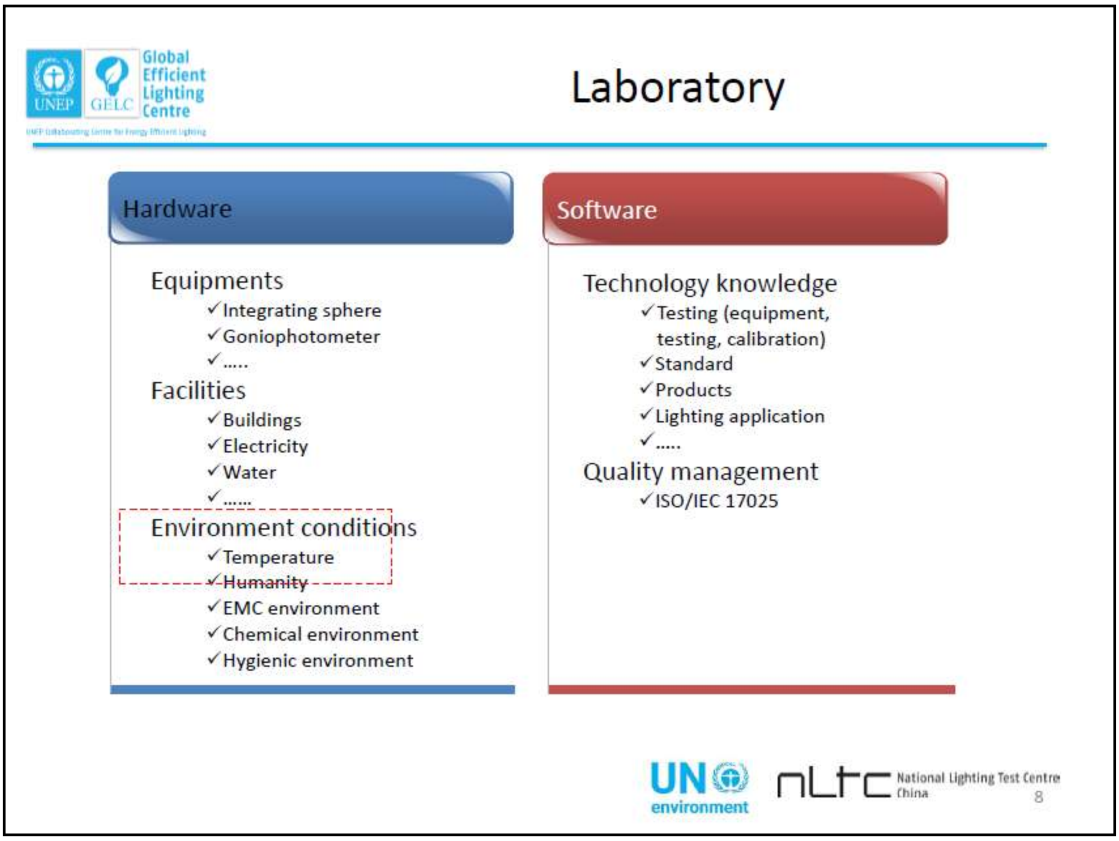
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Laboratory
Hardware
Equipments
✓Integrating sphere
✓Goniophotometer
✓.....
Facilities
✓Buildings
✓Electricity
✓Water
✓......
Environment conditions
✓Temperature
✓Humanity
✓EMC environment
✓Chemical environment
✓Hygienic environment
Software
Technology knowledge
✓Testing (equipment, testing, calibration)
✓Standard
✓Products
✓Lighting application
✓.....
Quality management
✓ISO/IEC 17025
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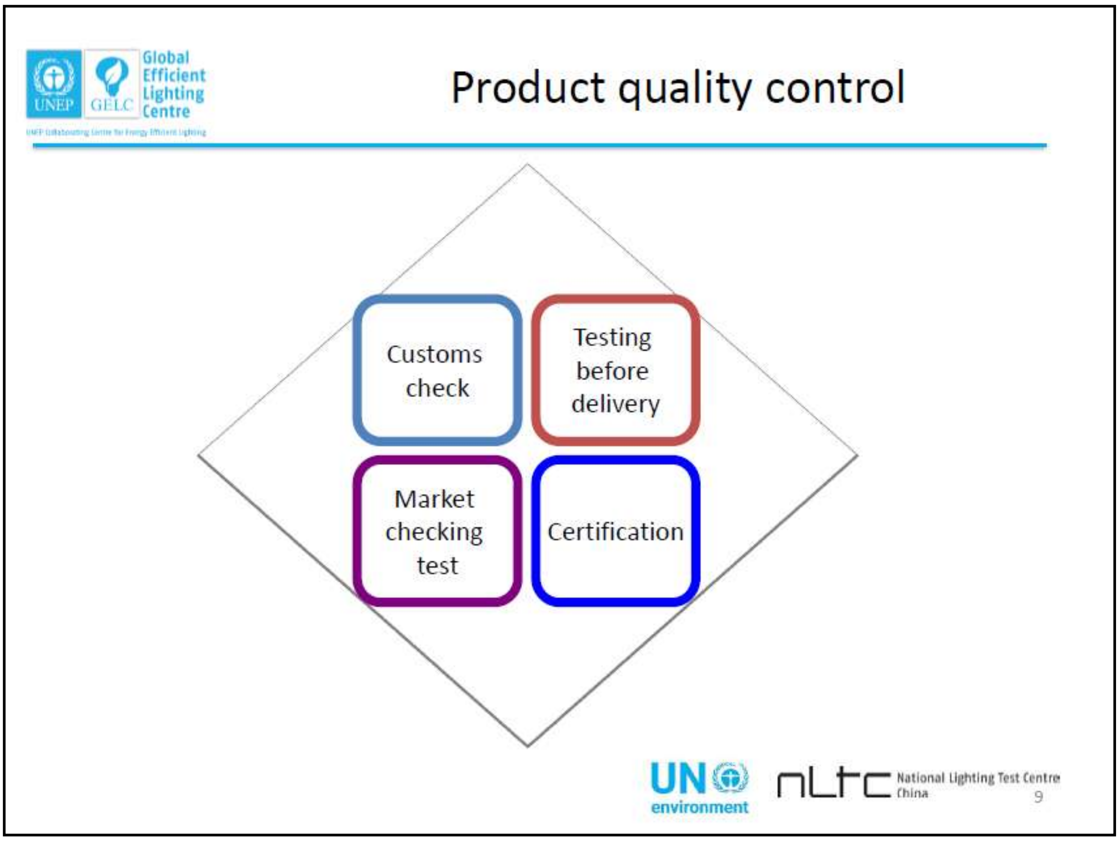
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Product quality control
Customs check
Testing before delivery
Market checking test
Certification
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Customs check

- First protective screen
- Radom check

- Lighting is a very small part but with different kinds of products
- Technical issue? Testing issue?

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Testing before delivery

Testing through an entrusted laboratory

- Develop sampling and conformity scheme
- Testing according to standards

A. Sampling by batch

B. Factory check

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Market checking test

The last checking before it goes to the consumers

Shows good effect

- Lots of brands
- Large coverage
  - ➢ City
  - ➢ Countryside
  - ➢ Remote area
- High cost
  - ➢ Travels, HRs
  - ➢ Rigorous testing
  - ➢ Procedure (legal, reasonable, strict)
- Risk

The sward of Damocles

12

Market checking test

The sward of Damocles

- Media release
- Economic punishment
- Recall
- Legal redress
- Criminal liability

13

Market checking test --- CFL standards

China CFLs standards:

- Safety standard: equal to IEC 60968
- EMC standard: equal to IEC 61000-3-2, IEC 61547, CISPR15
- Performance standard requires
  - efficacy
  - luminous maintenance
  - colour characteristics
  - power factor
  - mercury content
- Energy efficiency standard

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Market checking test --- LED standards

IEC

- IEC 62504
- IEC 62031
- IEC 62717
- IEC 62560
- IEC 62612
- IEC 62776
- IEC 60050-845
- IEC 62663-1
- IEC 62663-2
- IEC 62722-2-1
- IEC 62838
- IEC 62931
- IEC/TS 62861
- IEC 63013

China

- GB 7000.1
- GB/T 24907
- GB 7000.203
- GB 7000.202
- GB/T 29294
- GB/T 29293
- GB 24906
- GB/T 29296
- GB/T 31111
- GB/T 29295
- GB 24906
- GB/T 24908
- GB 30255
- GB/T 31112
- GB 19651.3
- GB 19510.14
- GB 24819
- GB/T 24823
- GB/T 24824
- GB/T 24825
- GB/T 24826
- GB/T 24909
- GB/T 30104.207
- GB/T 30413
- QB/T 4057
- QB/T 4146

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Certification

A. System certification

- ISO 9000
- ISO 14000
- ISO 18000

B. Product certification

a) Design qualification
b) Type test (key components/materials and product structure fixed)
c) Sampling test or inspection in the production field
d) Sampling test or inspection in the market
e) Product consistency check with product quality guarantee ability
f) Follow up inspection after obtaining the certificate
   - ➢Regular inspection
   - ➢Non-regular inspection
   - ➢Market inspection

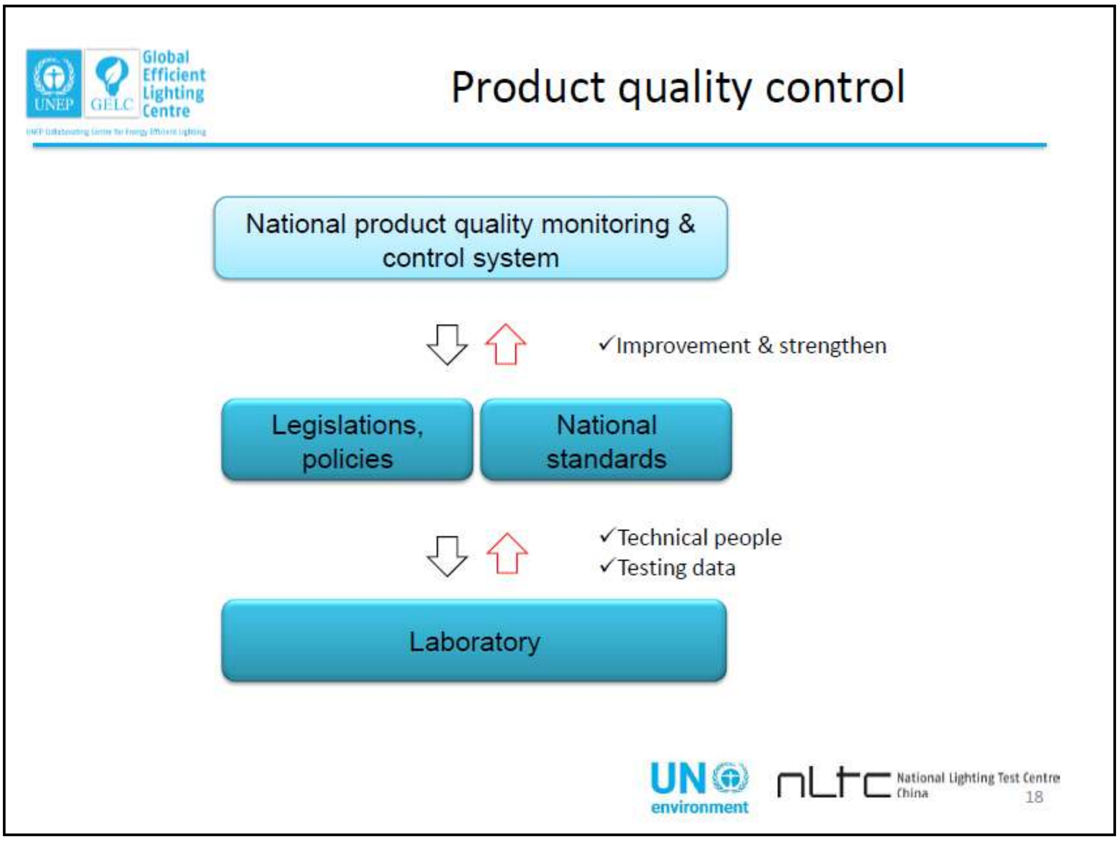
Certification

Safety certification

- GB 7000.1
- GB 7000.201
- GB 7000.202
- GB 7000.203
- GB 24906
- GB 16843
- GB 18774
- GB 16844
- GB 17743
- GB 17625.1

Energy saving certification

- CQC 3147 (LED panel)
- CQC 3127 (LED street lighting & tunnel lighting)
- CQC 3128 (LED downlight)
- CQC 3129 (LED reflector)
- CQC 3148 (LED tube)
- CQC 3130 (LED bulb)
- GB/T 17263 (CFL)


Product quality control
National product quality monitoring & control system
✓Improvement & strengthen
Legislations, policies
National standards
✓Technical people
✓Testing data
Laboratory
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6. Introduction to Laboratory Quality Management

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- When you receive a new lamp for testing
- What should you do? Why?

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What is Quality?

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What is Quality?

Quality is defined as conformance to requirements, not as "goodness" or "elegance"

Philip Crosby

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What is Quality?

- Quality & Technology
  - Certification and Accreditation are both based on the quality management system

- Quality & Business

- Quality & Standard

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What is Quality Management?

Quality management is not to prove anything wrong, but is the management expectations.

- On the basis of technology
- In accordance to standards management organization
- Requirements to technology, administration and quality

Appropriate objectives

For example

	Lab 1	Lab 2
The qualification rate of the test report	100%	60%
The timely rate of the test report	100%	60%

Too high

Too low

There is no best, only the most appropriate

Quality Management is everywhere in the laboratory

Quality control

- Quality control is a process / system to monitor the testing quality and to correct and accurate of the testing results

- Quality control makes sure the instant implementation of the corrective actions

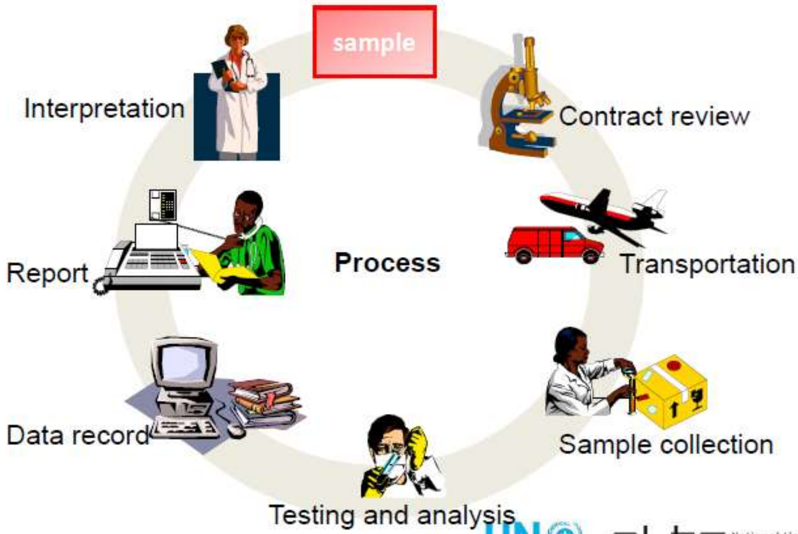
Process

- A process is a set of resources or activities associated with each other that transforms an input into an output
  a) Any process includes both input and output
  b) The process must be done by resources and activities
  c) The inspection, evaluation, measurement shall be conducted in all sessions, in order to control the quality of the process

- All work is done through the process

Process

- Process 1 The management of samples



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Sample

The basic principle

The laboratory should develop sample management procedure and the work instruction.

In the delivery and processing, it shall ensure the original nature of the sample, protecting the interests of the laboratory and the customers

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Sample

Reception of the sample

ISO/IEC 17025:2005 4.6, 5.7, 5.8.

The receiver should check the package and status of the samples carefully.
If the customer has any special requests to the test, it should provide detailed written instructions/info.
The quantity of the samples cannot be less than the requested number, otherwise, it should be noted in the agreement.

Sample

Flow of the sample

The samples shall be marked with the unique identifications, and design and usage of the marking should be such as ensure that there is no confusion in the samples or in the records involved.

The identification system ensures that the sample is not confused during the delivery process; should contain the breakdown of the item and the control method that is passed inside and out of the laboratory

The environmental conditions for sample preservation should be controlled, monitored and recorded

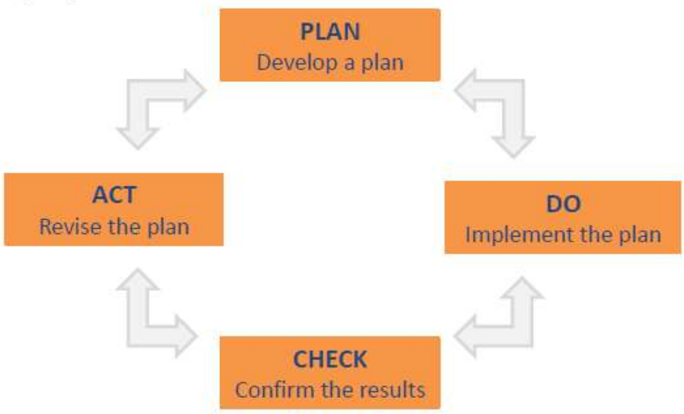
WHAT to be considered in the laboratories?

The **entire process** of managing a sample must be considered:

- the beginning: sample collection
- the end: reporting and saving of results
- all processes in between.

Deming Cycle

The Deming Cycle



Continuous improvement is the eternal theme

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UNEP Collaborating Centre for Energy Efficient Lighting

Essential to all aspects are **laboratory results** that are

- **accurate**,
- **reliable**, and
- **timely**

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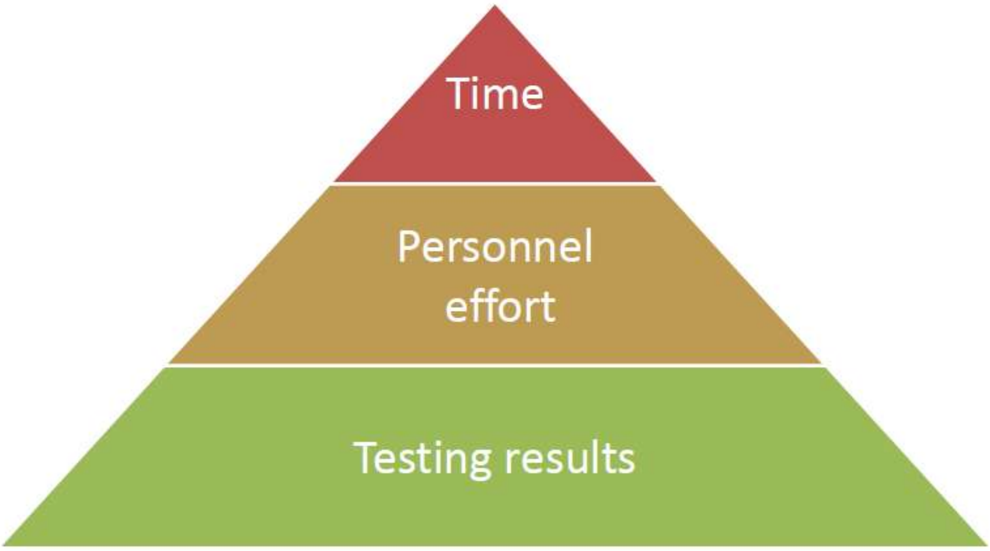
UNEP Collaborating Centre for Energy Efficient Lighting

Laboratory errors cost in



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How do we achieve excellent performance in the laboratory?

Quality Management System

Coordinated activities to direct and control an organization with regard to quality (ISO).

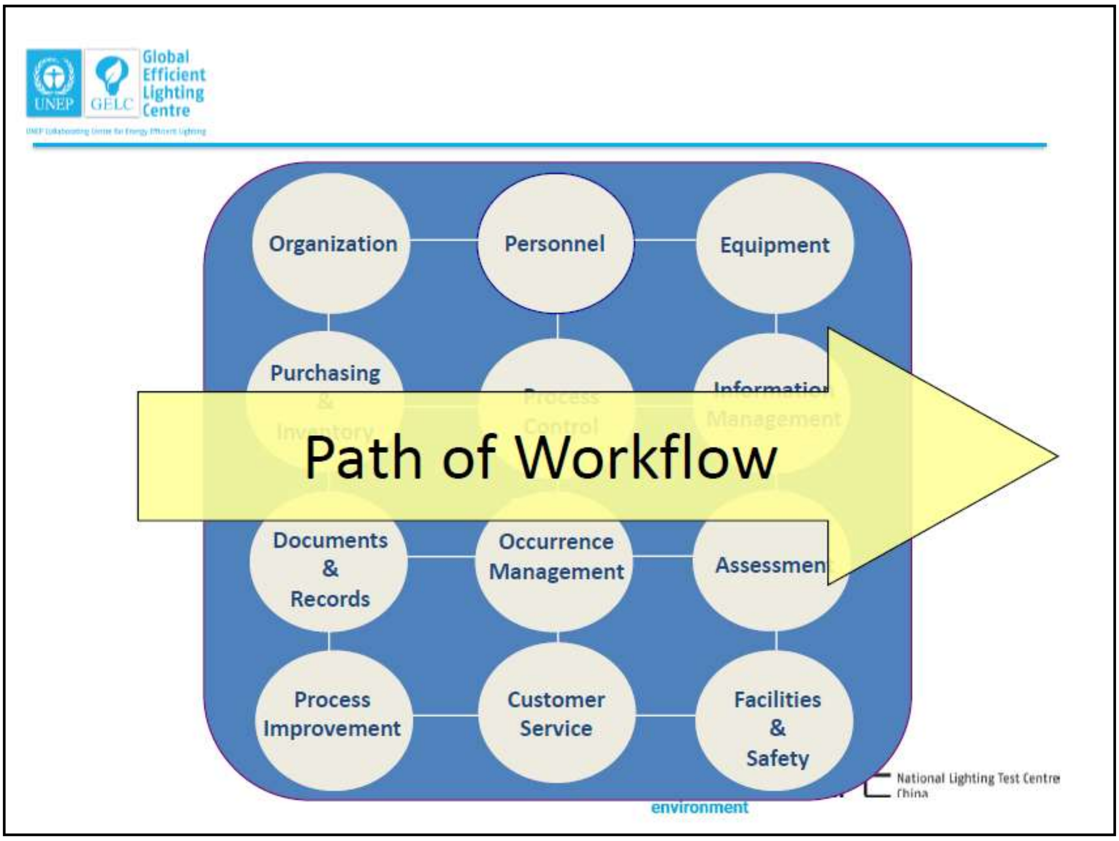
All aspects of the laboratory operation need to be addressed to assure quality; this constitutes a quality management system.

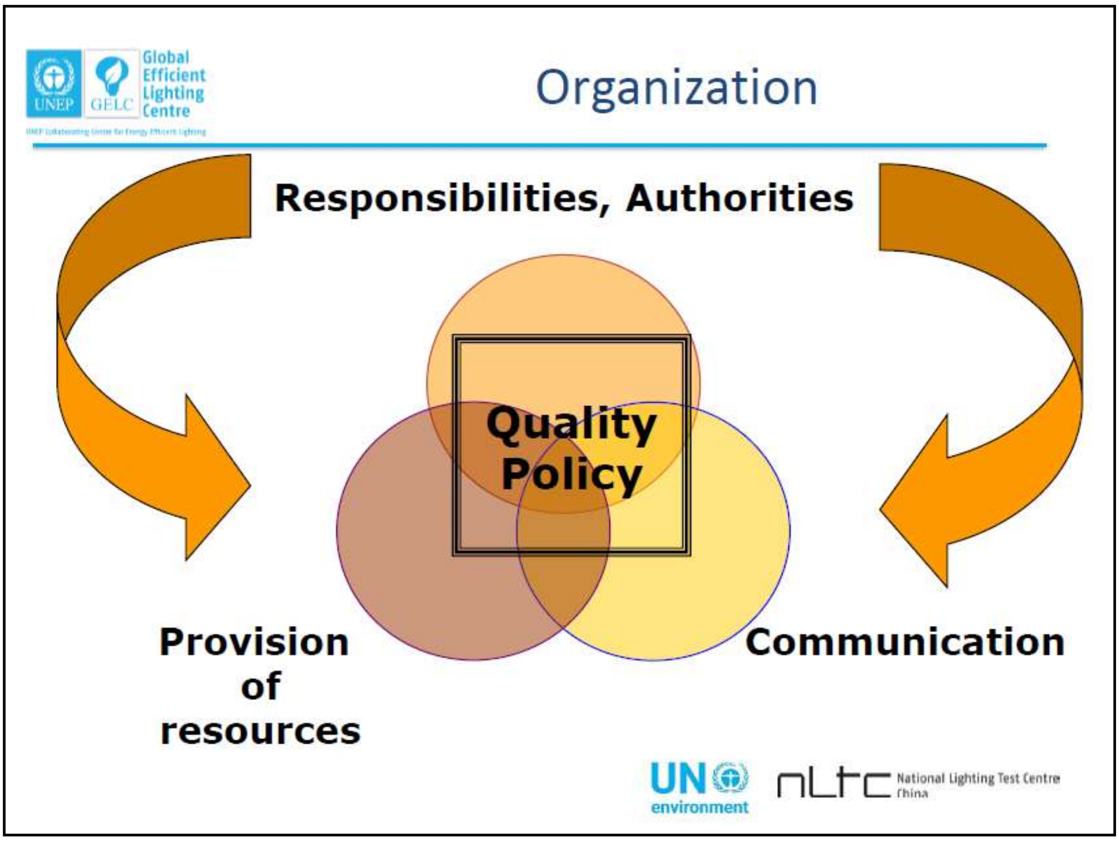
Laboratory tests are influenced by

- laboratory environment
- knowledgeable staff
- competent staff
- equipment and materials
- quality control
- communications
- process management
- occurrence management
- record keeping

Quality System Essentials

set of coordinated activities that function as building blocks for quality management


Global Efficient Lighting Centre
Organization
Personnel
Equipment
Purchasing & Inventory
Process Control
Information Management
Path of Workflow
Documents & Records
Occurrence Management
Assessment
Process Improvement
Customer Service
Facilities & Safety
National Lighting Test Centre China


Global Efficient Lighting Centre
Organization
Responsibilities, Authorities
Quality Policy
Provision of resources
Communication
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Personnel

- human resources
- job qualifications
- job descriptions
- orientation
- training
- competency assessment
- professional development
- continuing education

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Equipment

- acquisition
- installation
- validation
- maintenance
- calibration
- troubleshooting
- service and repair
- records

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Purchasing and Inventory

- vendor qualifications
- supplies
- critical services
- contract review
- inventory management

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Process Control

- quality control
- sample management
- method validation
- method verification

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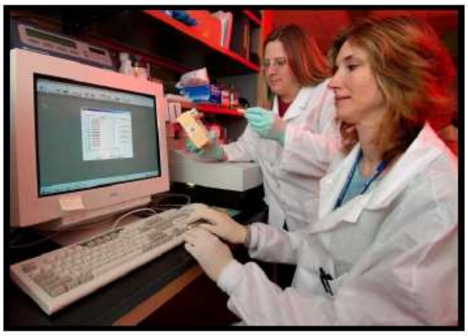
Information Management

- confidentiality
- requisitions
- logs and records
- reports
- computerized laboratory information systems (LIS)



Documents	Records
creation	collection
revisions and review	review
control and distribution	storage
	retention

Occurrence Management

- complaints
- mistakes and problems
- documentation
- root cause analysis
- immediate actions
- corrective actions
- preventive actions

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Laboratory Assessment

External

Proficiency testing

Inspections

Accreditations

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Process Improvement

- opportunities for improvement
- stakeholder feedback
- problem resolution
- risk assessment
- preventive actions
- corrective actions

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Customer Service

- customer group identification
- customer needs
- customer feedback

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Facilities and Safety

- safe working environment
- transport management
- Security
- waste management
- laboratory safety

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Implementing Quality Management **does not** guarantee an ***ERROR-FREE*** Laboratory

But it detects errors that may occur and prevents them from recurring

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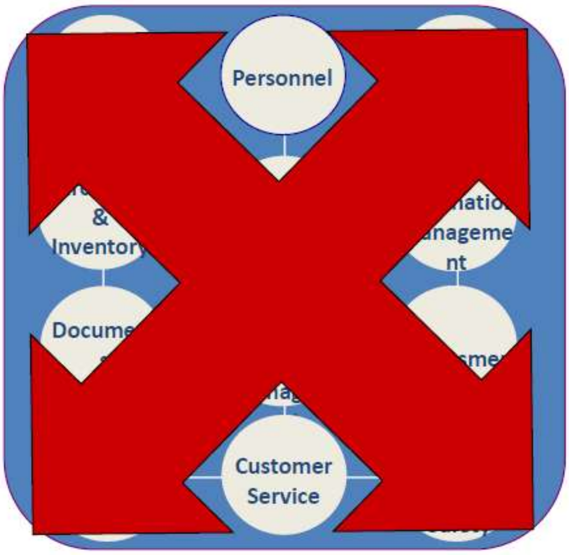

Laboratories is ***not*** implementing a quality management system guarantees UNDETECTED ERRORS

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Laboratory Quality Management System

Coordinated activities to direct and control an organization with regard to quality.

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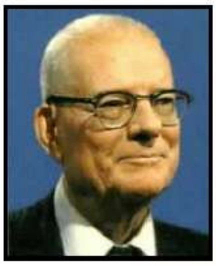
Innovators of Quality

Walter Shewhart
1891-1967



W. Edwards Deming
1900-1993

Joseph Juran
1904-2008 (103 years)

Philip Crosby
1926-2001

Robert Galvin
b. 1922

A Brief History of Quality Management

Quality Management is not new.

Innovator	Date	Cycle
Walter A.Shewhart	1920s	Statistical Process Control
W. Edwards Deming	1940s	Continual Improvement
Joseph M. Juran	1950s	Quality Toolbox
Philip B. Crosby	1970s	Quality by Requirement
Robert W. Galvin	1980s	Micro Scale Error Reduction

Standards Organizations

ISO International Organization for Standardization
Guidance for quality in manufacturing and service industries
Broad applicability; used by many kinds of organizations
Uses consensus process in developing standards

ISO Documents - Laboratory

ISO 9001:2000 Quality Management System Requirements
Model for QA in design, development production, installation, and servicing

ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories

ISO 15189:2007 Quality management in the clinical laboratory

In summary

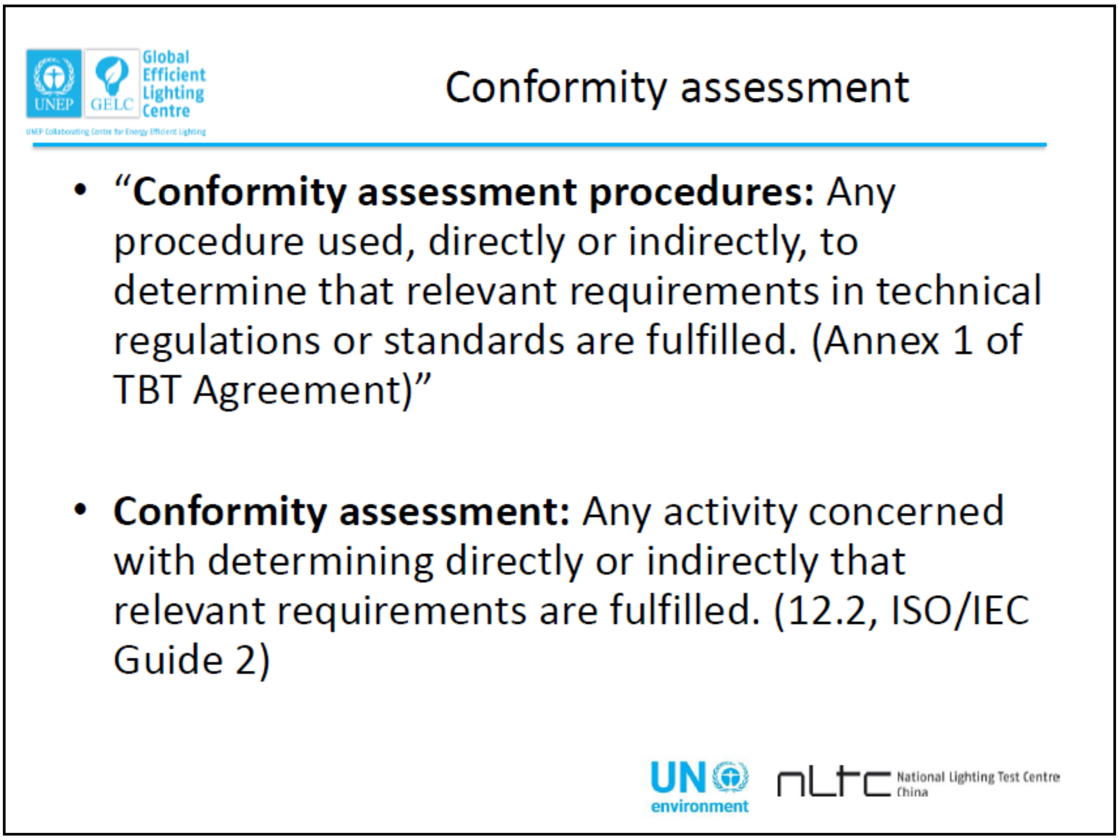
- Quality management is not new.
- Quality management grew from the good works of innovators who defined quality over a span of 80 years.
- Quality management is as applicable for the testing laboratory as it is for manufacturing and industry.

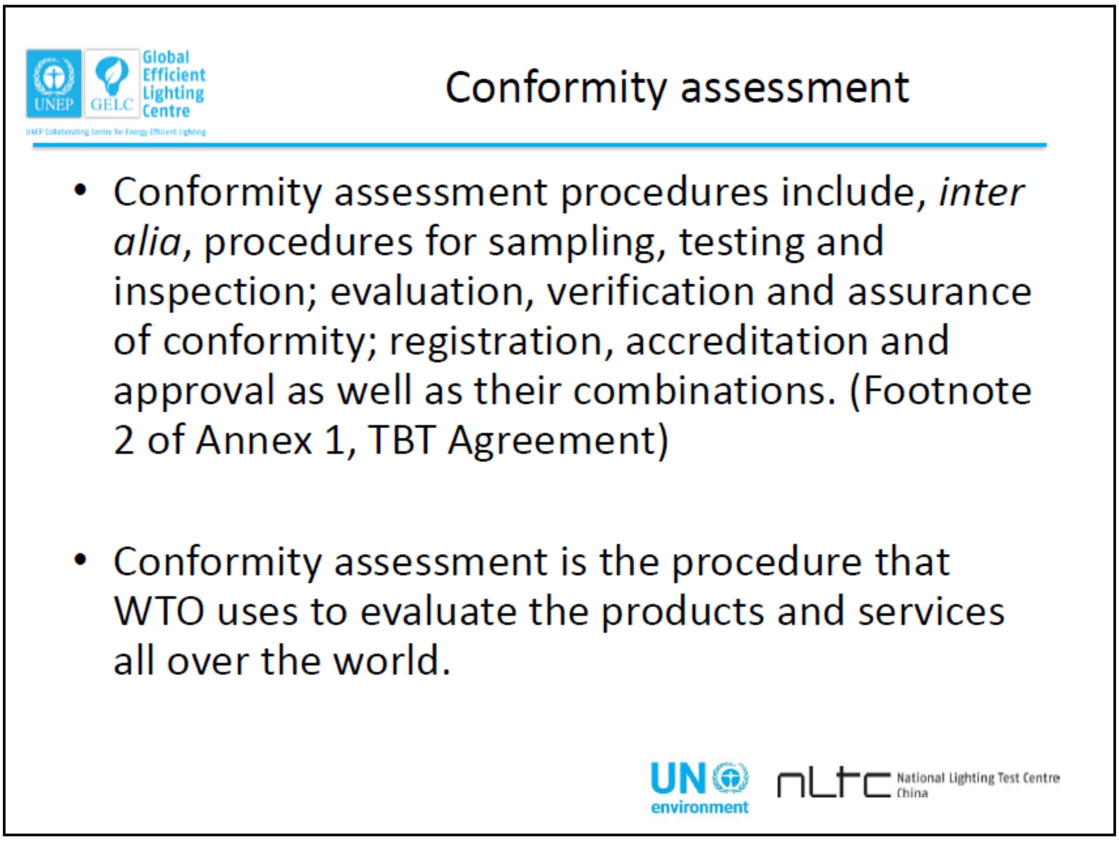
Key Messages

- A laboratory is a complex system and all aspects must function properly to achieve quality.
- Approaches to implementation will vary with local situation.
- Start with the easiest, implement in stepwise process.
- Ultimately, all quality management system elements must be addressed.

7. Laboratory Related Knowledge

7.1 Conformity Assessment

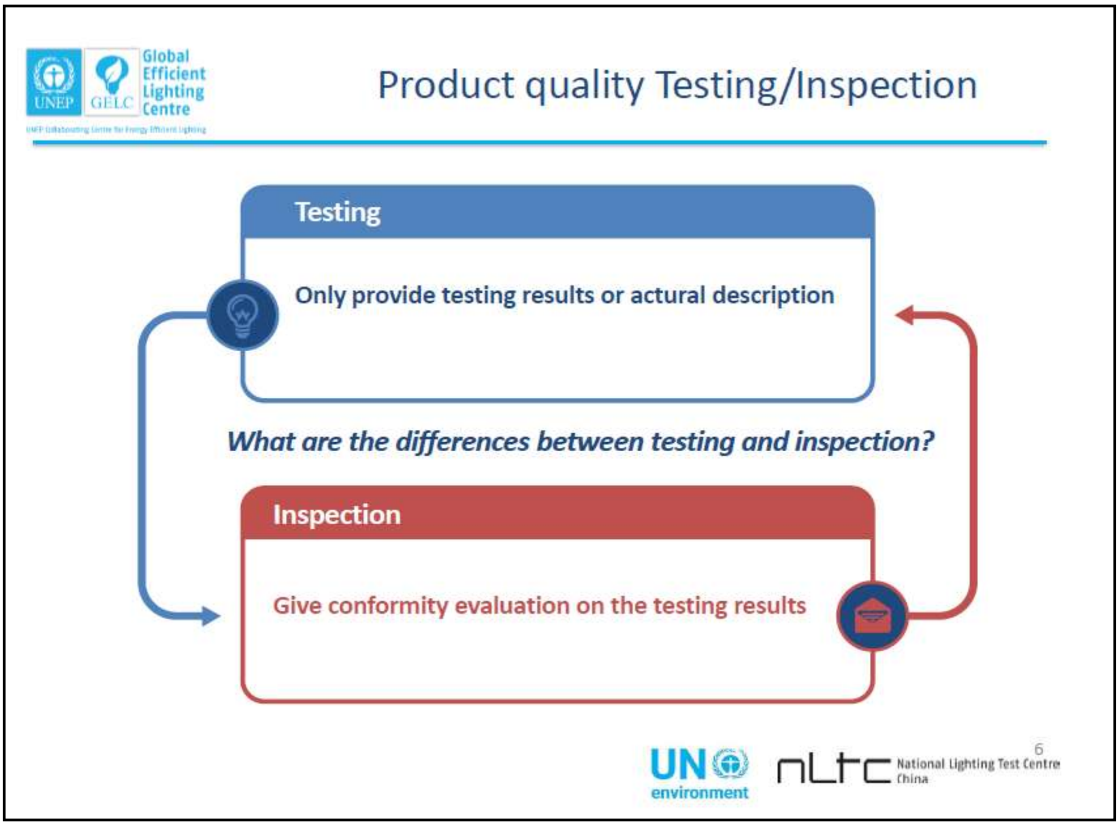




7.2 Product Quality Testing/Inspection

Product quality Testing/Inspection

- **Test:** Technical operation that consists of the determination of one or more characteristics of a given product, process or service according to a specified procedure. (13.1, ISO/IEC Guide 2)
- **Testing:** Action of carrying out one or more **tests**.(13.1.1, ISO/IEC Guide 2)
- **Inspection:** Conformity evaluation by observation and judgment accompanied as appropriate by measurement, testing or gauging. (14.2, ISO/IEC Guide 2)



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Product quality Testing/Inspection

- The functions of product quality testing/inspection
  - The identification function

    Determine whether the product quality meets the specified quality characteristics
  - Check function

    Remove the unqualified products and to be isolated, so that it does not put into production
  - Decision-making function

    Summarize, collate, analyze and verify the data and information obtained for quality control, quality improvement and provide the proves for quality decision-making

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Business Mission

- Five steps of product quality testing/inspection.

Understand the technical requirements

Converting your business from Good to Great.   UN environment   National Lighting Test Centre China   8

Product quality Testing/Inspection

- Product arbitration inspection: Commissioned by customer, the product quality inspection agency conducts the specific test on the quality questioned product
  - The purpose of arbitration test is to judge the quality of the product. The object is the product, the result is to issue the inspection report to determine the quality and as a product quality arbitration evidence.
  - Evaluation based on:
    - Laws, regulations or national mandatory standard requirements
    - The standards or relevant quality requirements agreed by the parties
    - The quality requirements specified clearly by the product provider

Product quality Testing/Inspection

- Sampling inspection: Use the extracted samples to carry out the inspection of the product or process
  - Sampling inspection is in accordance with the provisions of the sampling program, randomly selects part of the products from one batch, for testing. The test results will be compared with the evaluation criteria defined in the sampling program, in order to decide whether the batch of products are qualified

7.3 Standard and Standardization

Standard and standardization

- Standard is the essential basis for all testing and inspection work. A document that obtains the best order within a certain range and provides for a common, reusable rule, guideline, or characteristic of the activity or its results is called a standard.
- The document must be agreed upon and approved by a recognized body, and the development and application of the standards have been carried out in all areas of production and work, particularly in the area of quality inspection.
- Standardization helps to solve problems such as quality, safety, reliability and interchangeability in product exchange. The degree of standardization directly affects the formation and elimination of barriers in trade.

Standard and standardization

- By level
  - International standards
  - Regional standards
  - National standards
  - Consortium standards
  - Industry Standards
  - Local standards
  - Enterprise standards

Standard and standardization

- By subject of standardization
  - Technical standards
  - Management standards
  - Working standards

Standard and standardization

- **Technical standard:** standards made for technology items that are need to be unified, including fundamental technology standards, products standards, test method standard, workman standard, safety, sanitary and environment protection standards.
- **Management standard**: standards made for management items that are need to be unified, including fundamental management standards, technology management standards, economy management standard, administration standard.
- **Working standard:** standards made for responsibility, right, range, quality requirement, procedure, effect, examination methods, evaluation methods. Working standards for department and individual are included.

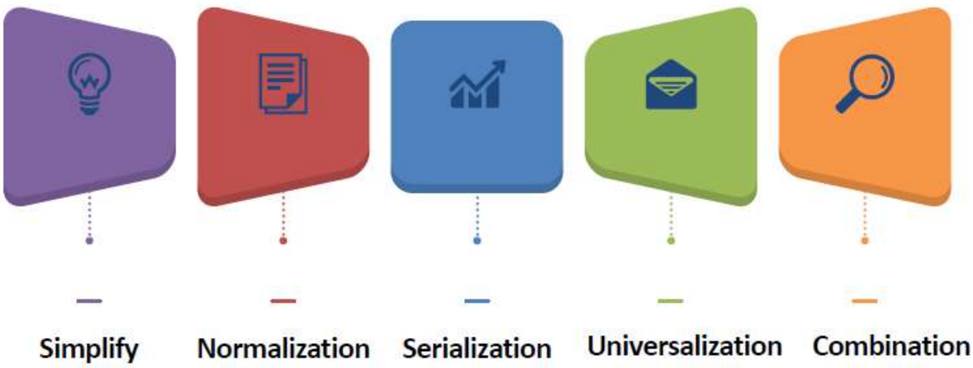
Standard and standardization

- By character of standard
  - **Mandatory standards**
  - **Voluntary standards**
  - **Directives**

- Standards concerning protection of human health, personal property and safety and those enforced by laws and administrative regulations are **mandatory standards**, others are **voluntary standards**.
  Directives: Documents providing information for standardization which is related to rapid developing technology and providing reference for scientific research, design, manufacture and the management person.

Standard and standardization

- Standardization form



Standard and standardization

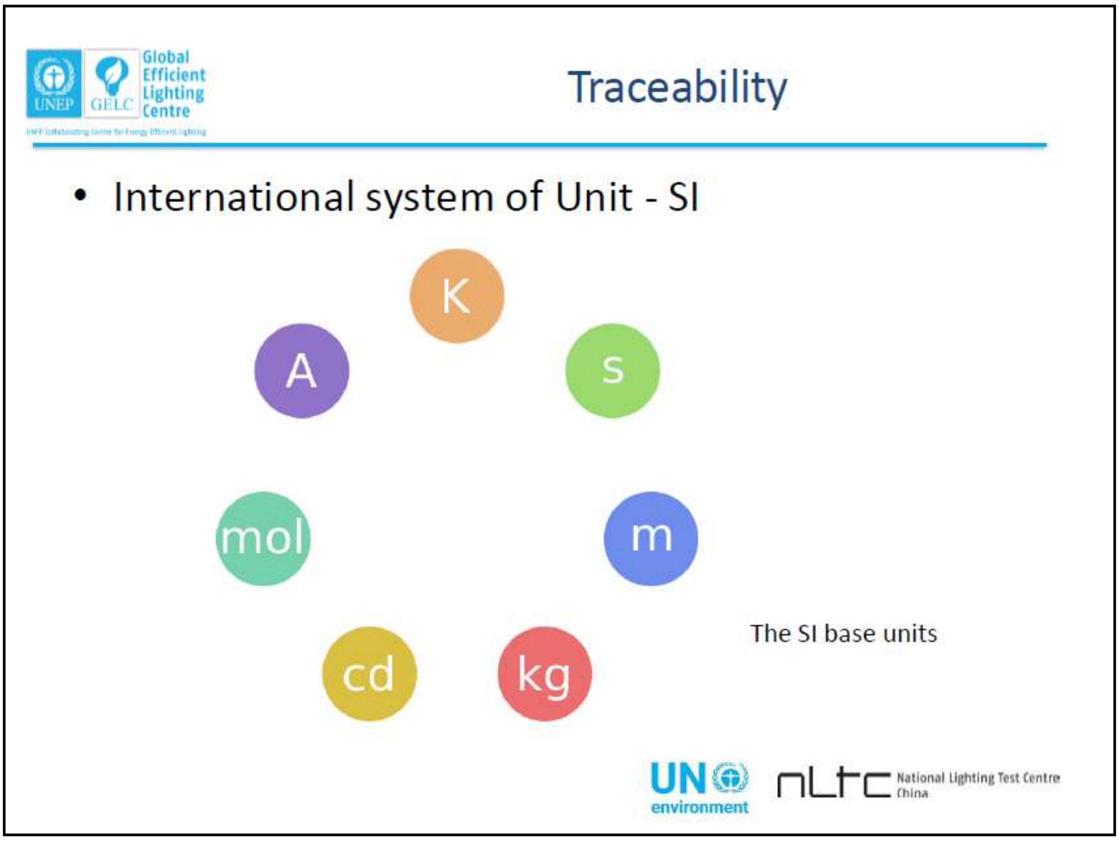
- Adopting international standards

17

Standard and standardization

- When adopting non-standard testing method
  - Methods verification
  - Agreed by the customers
  - When the customer does not specify the method, it shall select appropriate methods that have been published either in international/regional/national standards, or by reputable technical organizations, or in relevant scientific texts or journals, or as specified by the manufacturer of the equipments.
  - The laboratory shall inform the customer when the method proposed by the customer is considered to be inappropriate or out of date.

7.4 Traceability



Named units derived from SI base units				
Name	Symbol	Quantity	Expressed in terms of other SI units	Expressed in terms of SI base units
radian	rad	angle		$m \cdot m^{-1}$
steradian	sr	solid angle		$m^2 \cdot m^{-2}$
hertz	Hz	Frequency		s^{-1}
newton	N	force, weight		$kg \cdot m \cdot s^{-2}$
pascal	Pa	pressure, stress	N/m^2	$kg \cdot m^{-1} \cdot s^{-2}$
joule	J	energy, work, heat	$N \cdot m$	$kg \cdot m^2 \cdot s^{-2}$
watt	W	power, radiant flux	J/s	$kg \cdot m^2 \cdot s^{-3}$
Coulomb	C	electric charge or quantity of electricity		$s \cdot A$
Volt	V	voltage (electrical potential difference), electromotive force	W/A	$kg \cdot m^2 \cdot s^{-3} \cdot A^{-1}$
Farad	F	capacitance	C/V	$kg^{-1} \cdot m^{-2} \cdot s^4 \cdot A^2$
Ohm	Ω	electric resistance, impedance, reactance	V/A	$kg \cdot m^2 \cdot s^{-3} \cdot A^{-2}$
Siemens	S	electrical conductance	A/V	$kg^{-1} \cdot m^{-2} \cdot s^3 \cdot A^2$
Weber	Wb	magnetic flux	$V \cdot s$	$kg \cdot m^2 \cdot s^{-2} \cdot A^{-1}$
Tesla	T	magnetic flux density	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
Henry	H	inductance	Wb/A	$kg \cdot m^2 \cdot s^{-2} \cdot A^{-2}$
degree Celsius	°C	temperature relative to 273.15 K		K
lumen	lm	luminous flux	$cd \cdot sr$	cd
lux	lx	illuminance	lm/m^2	$m^{-2} \cdot cd$
becquerel	Bq	radioactivity (decays per unit time)		s^{-1}
gray	Gy	absorbed dose (of ionizing radiation)	J/kg	$m^2 \cdot s^{-2}$
sievert	Sv	equivalent dose (of ionizing radiation)	J/kg	$m^2 \cdot s^{-2}$
katal	kat	catalytic activity		$mol \cdot s^{-1}$

Traceability

Measurements are defined as a set of operations for the purpose of determining the magnitude.

Measurement instrument + Measurement procedure

Traceability

- **Traceability:** The ability to correlate a measurement result or a metrological standard with a specified reference standard (usually a national measurement basis or an international measurement basis) through an uninterrupted comparison chain with defined uncertainty
- In the laboratory accreditation, traceability reflects a character of the measurement results and the values of metrological standard, that is, any measurement results and the values of metrological standard, ultimately must be linked to national or international measurement criteria, to ensure that the unit of measurement is unified, and the value of measurement standards are accurate and reliable, so that the measurement results are comparable, repeatable and reproducible , and the way is to follow this comparison chain, trace back to the metrological standard

Traceability

- **Object**: All measuring instruments and equipments (including support equipments), and standard materials that affect the accuracy or effectiveness of the test results.
- **Purpose**: To ensure the accuracy and consistency of the measurement results. This is the basis of the credibility of the measurement results, but also the premise of the international mutual recognition of measurement results.
- **Approach**: Send the objects to the qualified, capable body, which can also provide traceability for verifying and calibration. The qualification refers to the statutory metrological authority, the authorized metrological authority, the accredited calibration laboratory. The measurement capability refers to their measurement uncertainty meets the requirements.

Traceability

- **Evidence of traceability:** Calibration Certificate, etc.
- How the laboratory selects the appropriate metrological or calibration laboratory?
  - a) **Reference standard -** a statutory metrological authority or an accredited calibration laboratory
  - b) **Measuring instruments** - a statutory metrological authority or accredited calibration laboratory, or authorized industry metrological institution
  - c) **Reference materials -** traceable to SI unit or certified reference materials
  - d) **In exceptional circumstances** – traceable to recognized standards or participating the inter-laboratory comparison test or proficiency test
  - e) **International laboratory**
    - ✓ Traceable to the highest metrology basis of a country or economy who signed the MRA and can show evidence to trace to SI units
    - ✓ The calibration laboratory that recognized by the members of APLAC, ILAC Multilateral Accreditation Agreement

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Traceability

- What are the differences between Metrological Verification and Calibration?

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Traceability

Metrological Verification	Calibration
Metrological verification procedures	Calibration procedures or calibration methods
Fully assess the metrological characteristics of measuring instruments and compliance with technical requirements	Determine the indication error or assignment of the measuring instruments
Give the conclusion of pass or failed	Only provide the calibration data (when necessary, determine whether to meet the expected requirements)
If pass, issue the Metrological Verification Certificate If failed, issue a notice of failure	Issue Calibration Certificate
Specify the Metrological verification period	Not specified
With legal, administrative and law enforcement	Voluntary actions

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7.5 Measurement Uncertainty

Measurement uncertainty

- Measurement uncertainty is a degree of doubt about the measurement results

For example:

37.2 ℃ ±0.1 ℃ (95%)

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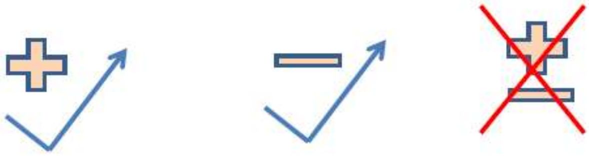
Measurement uncertainty

- **Error:** The difference between the measured result and true value



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Measurement uncertainty

- **Random error**: The difference between measurement results and the mean (average) of the results obtained by infinitely measurements on the same object and under repeated conditions
- **System error**: The difference between the mean (average) of the results obtained by infinitely measurements on the same object under repeated conditions, and the true value.

Measurement uncertainty

Error = Measurement results – true value

= Measurement results – mean value + mean value – true value

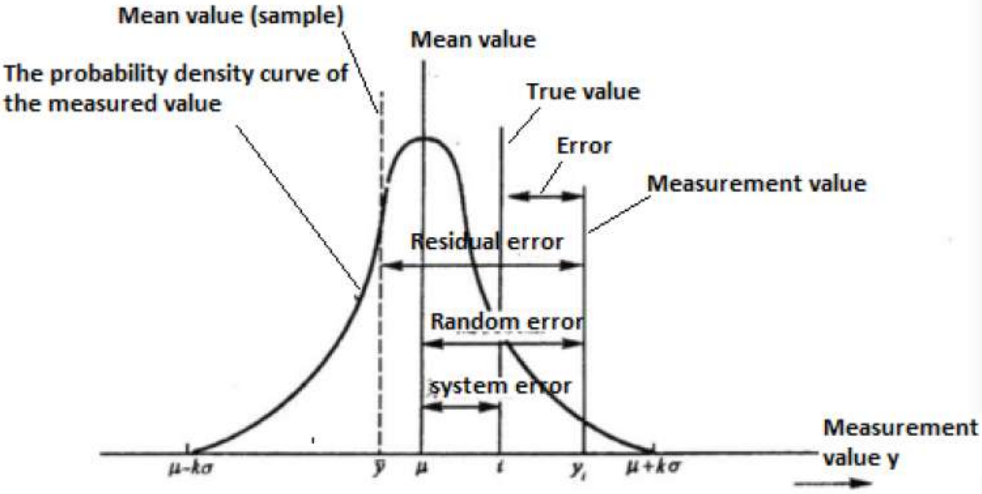
= Random error + system error

Measurement results

= True value + error

= True value + random error + system error

Measurement uncertainty



Measurement error diagram

Measurement uncertainty

- Uncertainty of the measurement results: Characterize the dispersion of the measured value reasonably, the parameters associated with the measurement results.
- The measurement uncertainty can be expressed by the standard deviation, or its multiple, or the half width of the confidence level interval

$U=k\sigma=ku$ （k:coverage factor）

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Measurement uncertainty

- A type of Uncertainty: refers to evaluating the uncertainty by statistical analysis; the standard uncertainty is expressed by standard deviation.
- B type of Uncertainty: refers to evaluating the uncertainty by other methods;

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Measurement uncertainty

The main differences between Error and Uncertainty

No	Content	Error	Uncertainty
1	Definition	Indicating that the measurement result deviates from the true value and is a definite value	Indicating the dispersion of the measured value and is an interval. Expressed by a standard deviation, a multiple of the standard deviation, or a half width of the confidence level interval
2	Classification	According to the laws appear in the measurement results, divided into random errors and system errors, they are the ideal concept of the infinite measurements	According to whether obtained by the statistical method, divided into A class and B class, they are expressed by standard uncertainty.
3	Operability	Since the true value is unknown, the value of the measurement error can not always be obtained.	Measurement uncertainty can be evaluated by information such as experiment, data, experience, etc., so that the measurement uncertainty can be quantitatively determined
4	Numerical symbol	Either positive or negative (or zero) , can not be indicated by a sign ±	Is an unsigned parameter, always expressed as a positive value; When obtained by variance, use the positive square root

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Measurement uncertainty

The main differences between Error and Uncertainty

No	Content	Error	Uncertainty
5	Correction	When the estimated system error is known, the measurement result can be corrected	The measurement results can not be corrected with measurement uncertainty. When calculate the uncertainty, it should consider the imperfect correction introduced to the uncertainty component
6	Results	Error is exist. The error belongs to a given measurement result and has no relationship with the instrument or method	Uncertainty is related to people's knowledge and understanding on the object under measurement, the influences, and the measurement process. It is reasonably given to any of the measured values, all have the same measurement uncertainty

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Measurement uncertainty

- Measure the length

Steel rulers 10.0mm

Caliper 10.00mm

Which error is smaller?

What about the uncertainty?

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Measurement uncertainty

Both error and uncertainty can be used to describe the measurement results, but there is no definite relationship in between.

Measurement uncertainty

- The performance of the measuring instrument can be expressed by the indication error and the maximum allowable error.
- The different instruments, even with the same model number, their indication error is generally different. The indication error must be obtained by verification or calibration. Each instrument needs to be verified or calibrated.
- If knowing the indication error, you can correct the measurement results, the inverse sign of indication error is the correction. The uncertainty of the corrected value is related to the uncertainty of the measured value.
- The maximum allowable error is the permissible error limit for a given measuring instrument, specification, procedure, etc. The maximum allowable error is abbreviated as MPE or mpe, which is specified by the manufacturer of the instrument. Obviously, it is not the actual error of an instrument, and therefore can not be used for correction.
- The MPE can be obtained from the instrument manual, and its value is usually signed as ± and can be expressed in absolute error, relative error, reference error, or their combination
- MPE itself is not a measurement uncertainty, it gives the qualified interval of indication error, which can be used for calculating the uncertainty. When the indication value is used directly as the measurement result, the standard uncertainty component introduced by the instrument can be obtained use MPE and according to the B type method.

Measurement uncertainty

For example:

$\pm$0.1 μV,

$\pm$0.1 μm,

$\pm$0.1%,

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Measurement uncertainty

- Uncertainty is a parameter associated with the measurement result, that is to say that only the measurement results have uncertainty.
- "measurement instrument uncertainty“?
- If the measuring instrument has been calibrated, then we sometimes call the uncertainty introduced by the instrument's indication error from the calibration as the instrument's uncertainty

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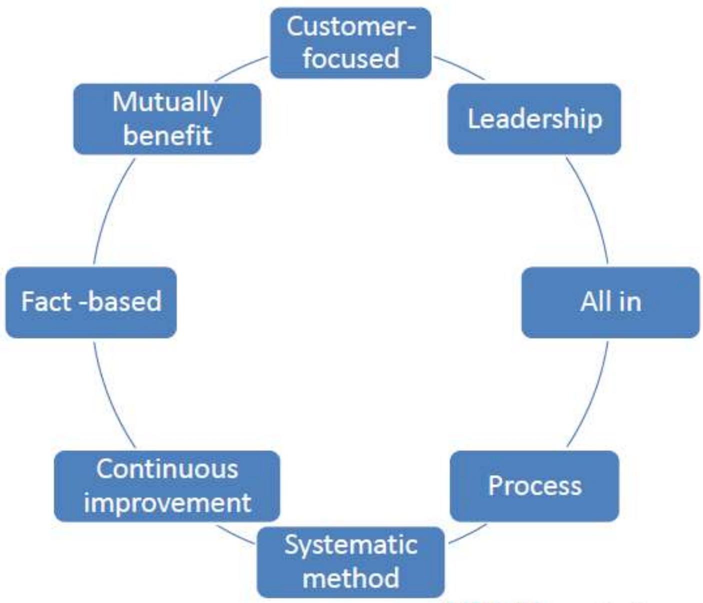
8. Quality Management Principles

Quality management Principles

- The theory basis of quality management
- Support laboratory to establish and improve quality management system

Quality management Principles



Customer-focused

- Customer: the organization or individual that accepts the product
- Customer of laboratory:
  - Government
  - Certification body
  - Manufacturer
  - Producer
  - Agent
  - Consumer
  - End user
  - Retailer
  - Purchaser

Customer-focused

- Customer demand is constantly changing

Safety certificate

Customer-focused

- What the laboratory should do?
  - Identify and understand the customer demand and expectation
  - Ensure the laboratory objective and goals meet customer's demand and expectation
  - Ensure the internal communication on customer's demand and expectation
  - Communicate with customer, and ensure the measure the customer's satisfaction degree and take necessary actions
  - Protect customer's confidential information and ownership

Customer-focused

- 1.4
- 4.1.2
- 4.1.5 c)
- 4.2.2 a)
- 4.2.2 note
- 4.4.1
- 4.4.1 c)
- 4.4.1 note
- 4.4.2
- 4.4.2 note
- 4.4.4
- 4.5.2
- 4.5.3
- 4.7
- 4.7.2
- 4.7 note
- 4.8
- 4.9.1
- 4.9.1 note
- 4.11.1 note
- 4.11.2 note
- 4.13.2.1 note
- 4.14.2
- 4.15.1
- 5.2.1 note
- 5.4.1
- 5.4.2
- 5.4.4
- 5.4.5.3
- 5.4.5.3 note
- 5.4.6.2 note
- 5.7.2
- 5.8.1
- 5.8.3
- 5.10.1
- 5.10.2 d)
- 5.10.3.1 c)
- 5.10.3.1 e)
- 5.10.4.4
- 5.10.5 note

4.2, 4.4, 4.7, 4.8, 5.10

Leadership

- The top of laboratory unify the purpose, direction and internal environment of the lab and should encourage the employees to fully involved in achieving the laboratory goals

4.1, 4.2, 4.4, 4.10, 4.15, 5.1

All in

- All of the people, whatever position they are at, are the basis of the organization, only their full participation can bring the greatest benefits to the organization.

5.2, 4.1.5.a), f), g), k), 4.2.1, 4.2.2.d)

Process

- Managing the relevant resources and activities as a process, you can get the expected results more efficiently.
- Through management of resources and activities, transfer the input into a set of activities, it can be regarded as a process. Such as contract review, testing, the report, all these can be regarded as a process. The output of a process is often directly into the next process or the input of several processes. Inputs such as procurement, inspection method selection, subcontracting, personnel, equipment, facilities and environmental conditions, sampling, sample, result report, etc. can be entered. The output of the device can also be used as a traceability input. System identification and management of the application of the organization, especially the interaction between these processes, known as the process method

4.14，5.9

Systematic method

- Similar to the process approach. The process focuses on studying the process of a single process, ie the input, output, activity, required resources of the process, and the relationship between the process and other processes.
- The systematic method focuses on the development of a number of processes and even the composition of the process network, and how the system works effectively to achieve the objectives of the laboratory, through a systematic process to achieve the objectives of the laboratory. Such as the test results to achieve the process of planning the input is human, machine, material, law, ring, measurement, etc., to determine the system of special activities of the measurement and evaluation, continuous improvement system

4.1，5.1

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Continuous improvement

- Continuous improvement is an eternal goal of the organization. The laboratory continually improves the effectiveness of the quality management system through quality policy, quality objectives, audit results, data analysis, corrective action and preventive actions, and management review. It can also use technical verification methods to achieve quality control, use of data analysis to find trends to prevent the occurrence of nonconformity, to achieve continuous improvement. Provide staff the trainings on continuous and methods. Improve the technical capacity of the laboratory, so as to dynamically adapt to internal and external environmental changes.

4.10，4.11，4.12，4.14，4.15，5.9

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Fact -based

- According to the analysis, laboratory ensures that data and information is sufficient, accurate and reliable, based on the analysis of the facts, experience judgments, make decisions and take measures. For example, the laboratory can conduct verification by PT or IC; using the same or different methods; re-testing of the retained samples; the evaluation of the relevance of different characteristics of different samples, the evaluation of the effectiveness of the technical verification; and the collection of data and information in the form of statistical techniques. These are the basis for improving the testing results quality.

4.13，4.14，4.15，5.4.7，5.9

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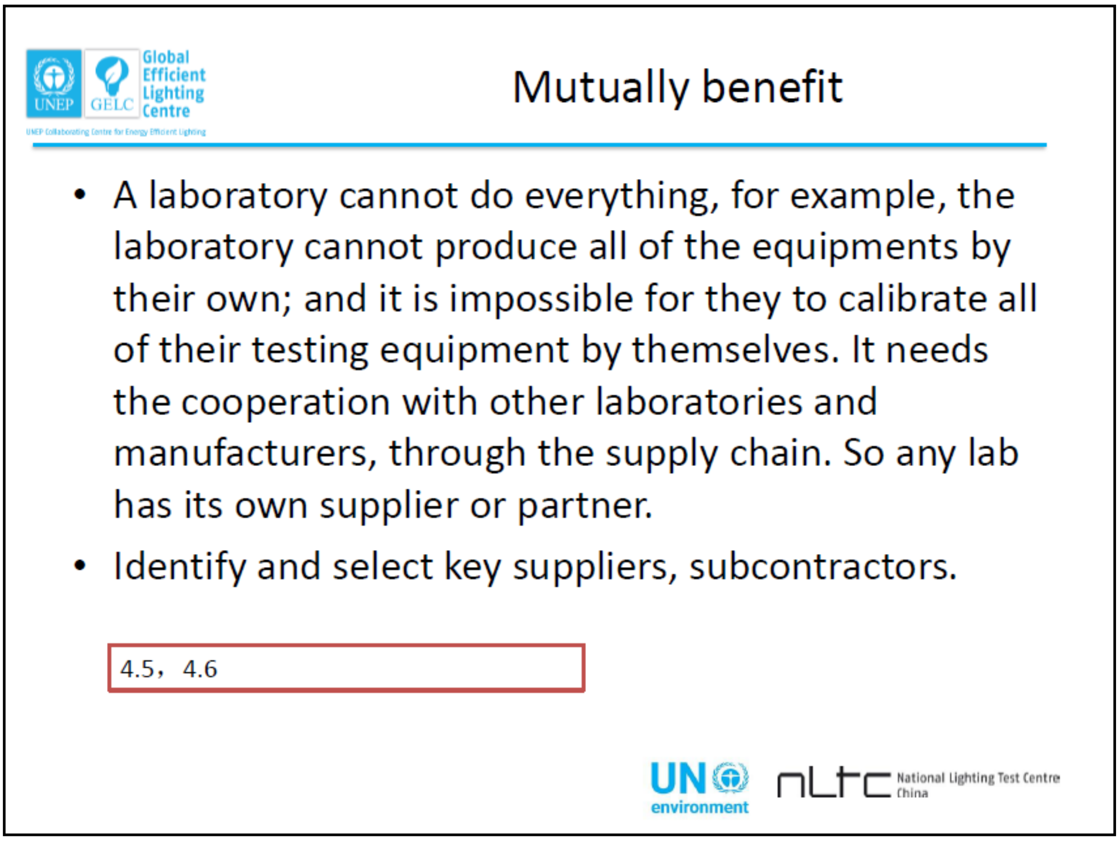
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Mutually benefit
• A laboratory cannot do everything, for example, the laboratory cannot produce all of the equipments by their own; and it is impossible for they to calibrate all of their testing equipment by themselves. It needs the cooperation with other laboratories and manufacturers, through the supply chain. So any lab has its own supplier or partner.
• Identify and select key suppliers, subcontractors.
4.5， 4.6
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9. Establishment, Implementation and Improvement of Quality Management System

Management system

- *"The laboratory shall establish, implement and maintain a management system appropriate to the scope of its activities. The laboratory shall document its policies, systems, programmes, procedures and instructions to the extent necessary to assure the quality of the test results. The system's documentation shall be communicate to, understood by, available to, and implemented by the appropriate personnel."*

Determine Quality policies and objectives

- Quality policies: Top management
- Quality objectives: measurable, challenge, achievable

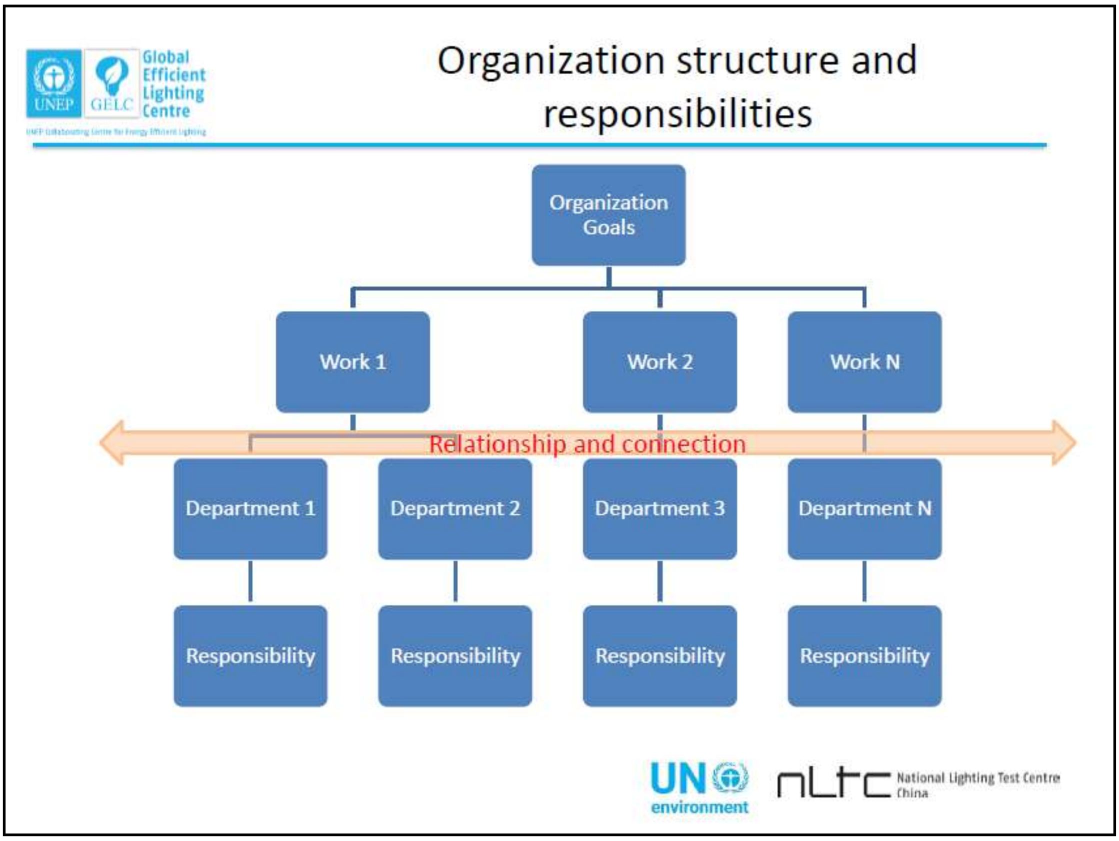
> Example:
>
> Qualification rate of test report≥98%,
> Customer satisfaction ≥98%

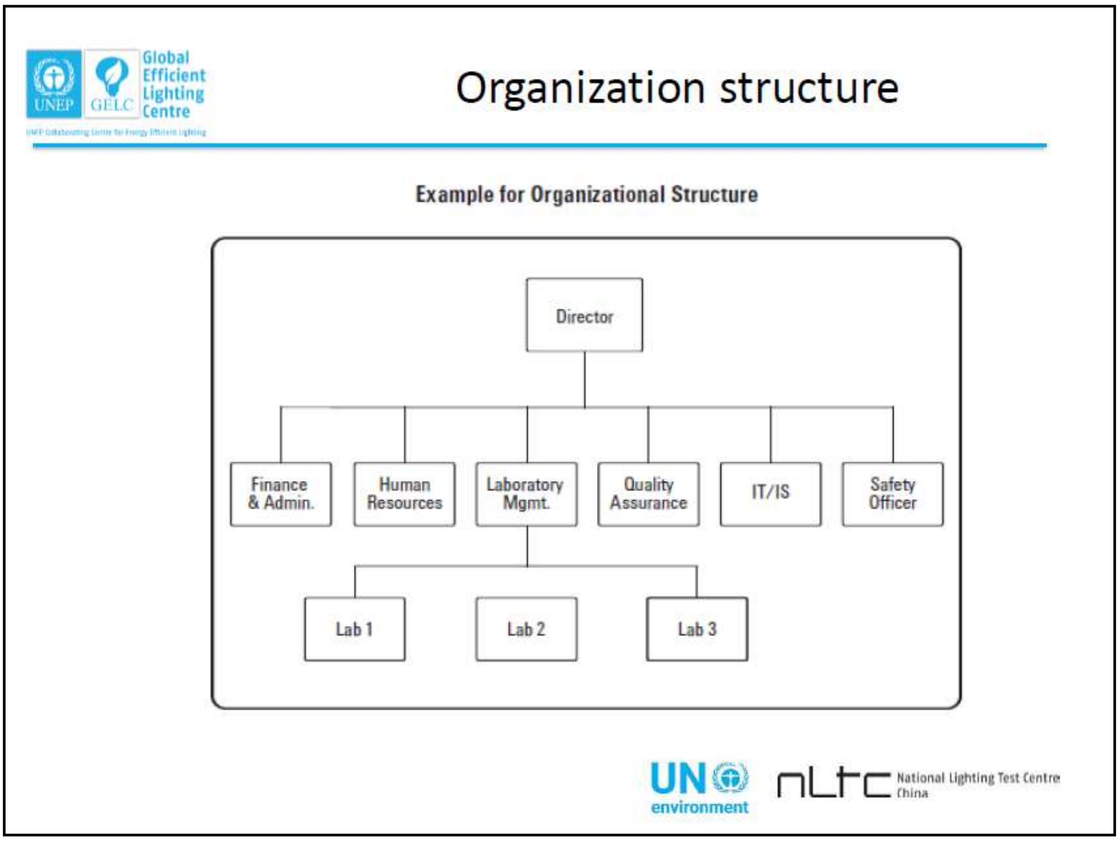
System elements selection

- The system elements selection
  - Meet the statutory and regulatory requirements
  - In accordance with Standards
  - Meet the costumer's requirements
  - Suitable for testing activities (working scope, workload, personnel...)
  - Suitable for the capabilities and responsibilities of providing data and results

Organization structure and responsibilities

- How to design the organization structure?
  - Span of Management
  - Scalar principle (report to whom? Supervision?)
  - Job description (who do what?)
  - Appropriate authorization
  - Right with responsibility


Global Efficient Lighting Centre
UNEP
GELC
Organization structure and responsibilities
Organization Goals
Work 1
Work 2
Work N
Relationship and connection
Department 1
Department 2
Department 3
Department N
Responsibility
Responsibility
Responsibility
Responsibility
UN environment
nLtc National Lighting Test Centre China


Global Efficient Lighting Centre
UNEP
GELC
Organization structure
Example for Organizational Structure
Director
Finance & Admin.
Human Resources
Laboratory Mgmt.
Quality Assurance
IT/IS
Safety Officer
Lab 1
Lab 2
Lab 3
UN environment
nLtc National Lighting Test Centre China

Organization

- Define legally responsible
- The QMS must cover all activities for which accreditation is sought
- Organizational structure might cause a conflict of interest
- Sufficient authority and resources
- How do you define “undue pressure”? And where might it come from?

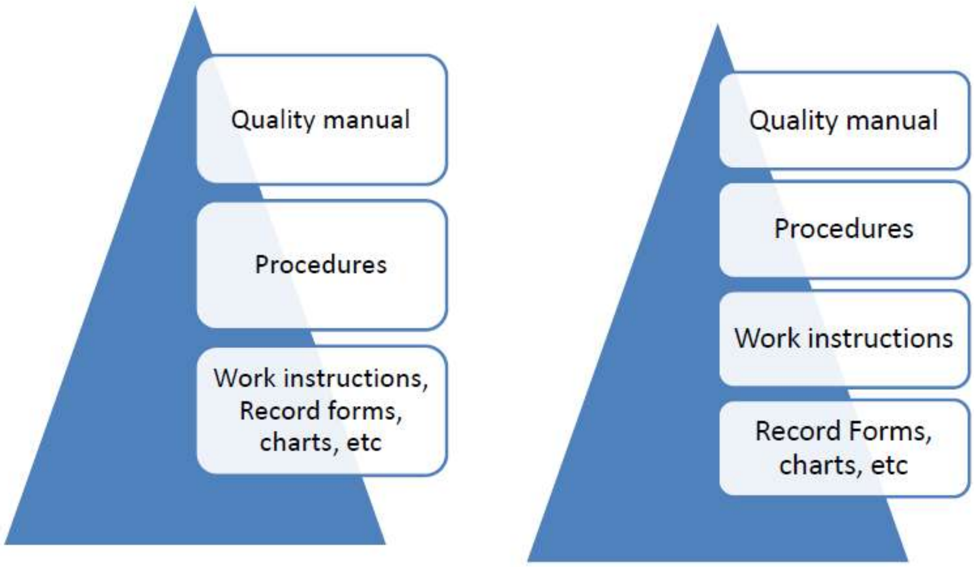
Organization

- Protect client confidential information and proprietary rights?
- Activities would diminish confidence in competence, impartiality, judgment or integrity
- Define adequate supervision
- How would you identify whether the QA manager has sufficient authority
- Deputies for key personnel
- Management involvement in management system

Key points

- An organizational structure, as well as responsibilities and tasks of both management and staff should be defined.
- The organizational structure should be such that departments having conflicting interests do not adversely influence the laboratory's work quality. Examples include commercial marketing or financing departments.
- A quality assurance manager should be appointed.
- All personnel should be free from any commercial or financial pressure that could adversely impact the quality of calibration and test results.

Develop quality system documents



Develop quality system documents

- Quality management system documents (any forms) include:
  - Quality policies and objectives
  - Quality manual
  - Procedures
  - Work instructions
  - Forms
  - Quality plan
  - Specifications
  - External documents
  - Records

Any forms – hard copy, electronic version, photographs, etc.

Develop quality system documents

- The general structure of Quality Manual
  - Title
  - Contents
  - Commitment (Release)
  - Preface (laboratory introduction)
  - Description of scope, deletion, rationality
  - Referenced standards
  - Definition (if necessary)
  - Organization structure, responsibility and authority
  - Elements description of quality management documents
  - Structure description of quality management documents
  - The interaction description of processes of the quality management
  - Annex

Develop quality system documents

- Procedures required
  - Protection of its customers' confidential information (4.1.5.c)
  - Avoid involvement in any activities that would diminish confidence in its competence, impartiality, judgment or operational integrity (4.1.5.d)
  - Control all documents (4.3.1)
  - Describe how changes in documents maintained in computerized systems are made and controlled (4.3.3.4)
  - Review of requests, tenders and contracts (4.4.1)

Develop quality system documents

- Procedures required (cont.)
  - Selection and purchasing of services and supplies (4.6.1)
  - Resolution of complaints received from customers, or other parties (4.8)
  - Control of nonconforming testing (4.9.1)
  - Designate appropriate authorities for implementing corrective action (4.11.1)
  - Preventive actions (4.12.2)
  - Control of record (4.13.1.1)
  - Internal audits (4.14.1)
  - Management review (4.15.1)

Develop quality system documents

- Procedures required
  - Identify training needs and providing training of personnel (5.2.2)
  - Housekeeping in the laboratory when necessary (5.3.5)
  - Test method and method validation (5.4.1)
  - New test methods and method validation (5.4.4 note)
  - Estimation of uncertainty of measurement (5.4.6.1, 5.4.6.2)
  - Data protection (5.4.7.2.b)
  - Safe handling, transport, storage, use and planned maintenance of measuring equipment (5.5.6)

Develop quality system documents

- Procedures required
  - Calibration of equipments (5.6.1)
  - Calibration of reference standards (5.6.3.1)
  - Additional procedures for testing outside of permanent sites as necessary (5.3.1, 5.5.6 note, 5.6.3.4 note)
  - Intermediate checks (5.5.10, 5.6.3.3)
  - Safety handling, transport, storage and use of reference standards and reference materials (5.6.3.4)
  - Sampling (5.7.1)
  - Handling of testing items (5.8.1)

Develop quality system documents

- Procedures include:
  - Purpose and scope
  - What?
  - Who?
  - When?
  - Where?
  - How?
  - What materials, equipments, documents?
  - How to control the activities and record?

Develop quality system documents

- Work instruction: detailed descriptions of how to implement and record
  - Testing method and additional documents
  - Operation instruction of the equipments
  - Preparation and handling of samples
  - Intermediate checks method
  - ……

Develop quality system documents

- The purpose of Procedures and Work instructions
  - Define the activities, responsibilities, workflow, and method
  - Easy to implement in the laboratory
  - Easy to train the new staff
  - Easy to track the problems and eliminate unnecessary differences of doing the same thing in different ways

Clear
In Practically

Easy to use
Reach a consensus

Develop quality system documents

- Record: Clarify the results obtained or provide evidence of the completed activities
  - Record is a special document. The record form is controlled by the document control. When the record form is filled in data or info, it becomes a record.
  - Quality record & technical record
  - Record requires sufficient information, and clearly written, easy to access, and has a keeping period.
  - Original record shall be recorded when testing.
  - If there is any error in the record, it can be changed, and shall not be rubbed off.
  - There should avoid any missing or changing of the original record for the electronic copy.

Develop quality system documents

- Record in the laboratory includes
  - Records of Reviews of requests, tenders and contracts (4.4.2)
  - A register of all subcontractors and keep records of the evidence of compliance of their work with the standards (4.5.4)
  - Records of conformity check activities taken for purchasing services and supplies, records of supplier evaluations and list of approved suppliers (4.6.4)
  - The complaints from customers and other investigations, and corrective actions (4.8)
  - Internal audit report, corrective action taken and follow-up audit activities to verify the implementation and effectiveness of the corrective actions (4.14)
  - Management review report and record of corrective action taken (4.15)

Develop quality system documents

- Record in the laboratory includes
  - Records of authorization(s), competence, educational and professional qualifications, training, skills and experience of all technical staff (5.2.5)
  - Monitoring and control records of environmental conditions (5.3.2)
  - Method validation records (5.4.5.2)
  - Records of each item of equipment and its software significant to the tests(5.5.5)
  - Record the status of the sample upon receipt (5.8.3)

Develop quality system documents

- Form: A document used to record the data required by the quality management system
- Form includes:
  - Title
  - Identification number
  - Revision status and date
  - The form should be referenced or attached to the Quality Manual, the Procedures and/or Work instructions

Develop quality system documents

- External documents: relevant documents from the outside of the laboratory
  - In the quality management system document, it should specify which are the external documents and to be controlled
  - External documents could be laws, regulations, standards, specifications, manuals, the pattern provided by the customer, etc
  - It needs to track the external documents to ensure use the latest valid version or appropriate version.

Develop quality system documents

- The Quality Manual is generally written by one person. Verify the compliance in accordance with the standards.
- Procedures and work instructions may written by different people.

Implement quality system

1. Appointment a Quality Manager
2. Document Propaganda
3. Trial run (the period is determined by the laboratory, normally at least 3 months)
4. Internal audit and management review

Implement quality system

- **Internal audit**: evaluate the compliance and effectiveness of the quality management system; implement correction actions and improvements to the nonconformity in order to make sure the effective running of the quality management system

ISO/IEC 17025
Quality manual
Laws, regulations

	1	2	3	4	5	6	7	8	9	10	11	12
4												
4.1		△										
4.2		△								△		
4.3			△							△		
4.4				△						△		
4.5					△							
4.6				△						△		
4.7			△							△		
4.8			△									
4.9			△							△		
4.10			△								△	
4.11			△								△	
4.12			△									
4.13				△							△	
4.14											△	
4.15												△

Implement quality system

	1	2	3	4	5	6	7	8	9	10	11	12
5												
5.1		△								△		
5.2		△								△		
5.3			△							△		
5.4			△							△		
5.5			△							△		
5.6			△							△		
5.7								△				
5.8								△				
5.9										△		
5.10										△		
Additional audit as necessary												

△Planned ▲implemented ○Developed the corrective actions plan □adopted corrective actions ●Verified the corrective actions

Implement quality system

- **Management reviews**: ensure the continuing suitability and effectiveness of the laboratory's management system
  - The suitability of policies and procedures
  - Reports from managerial and supervisory personnel
  - The outcome of recent internal audits
  - Corrective and preventive actions
  - Assessments by external bodies
  - The results of IC or PT
  - Changes in the volume and types of work
  - Customer feedback
  - Complaints
  - Recommendations for improvement
  - Other relevant actors, such as quality control activities, resources and staff training

Quality system

- How would you know if a system is established, implemented and maintained? What is appropriate?
- How would you identify whether the system is communicated and understood? Available?
- Do we need to see a quality manual?
- What about a Quality Policy & objectives? Their content? Management involvement & approval
- What are supporting procedures?
- Responsibility of technical and Quality manager in manual

Key points

- There should be policies, standard procedures and work instructions to ensure the quality of test results.
- There should be a quality manual with policy statements that are issued and communicated by top-level management.
- The effectiveness of the management system should be continually improved.

10.Understanding of ISO/IEC 17025

10.1 General

Quality system

- 1963, MIL-Q-9858A, United States
- 1979, BS 5750, United Kingdom
- The ISO 9000 series of quality standards was established in 1987 for implementing and maintaining a quality system

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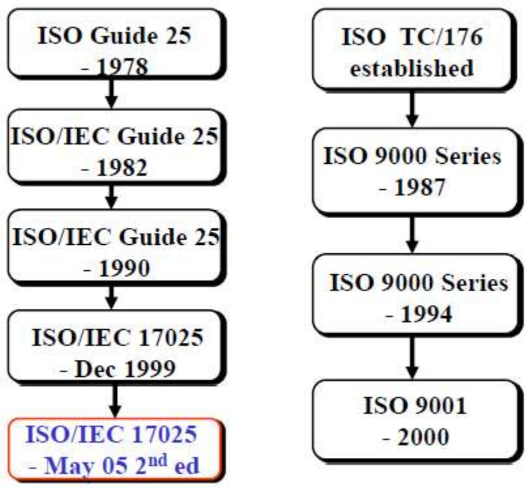
ISO/IEC 17025 History

Background



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The relationship with ISO 9001

Joint ISO-ILAC-IAF Communique on the Management Systems Requirements of ISO/IEC 17025:2005

ISO-International Standardization Organization

ILAC –International Laboratory Accreditation Cooperation Organization

IAF-International Accreditation Forum


Joint ISO-ILAC-IAF Communiqué on the Management Systems Requirements of ISO/IEC 17025:2005, General Requirements for the competence of testing and calibration laboratories

A laboratory's fulfilment of the requirements of ISO/IEC 17025:2005 means the laboratory meets both the technical competence requirements and ***management system requirements*** that are necessary for it to consistently deliver technically valid test results and calibrations. The ***management system requirements*** in ISO/IEC 17025 (Section 4) are written in language relevant to laboratory operations and meet the principles of ISO 9001:2000 ***Quality Management Systems – Requirements*** and are aligned with its pertinent requirements.

ISO Secretary General ILAC Chair IAF Chair

2005-06-18

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- A laboratory's fulfillment of the requirements of ISO/IEC 17025 means the laboratory meets both the technical competence requirements and management system requirements that are necessary for it to consistently deliver technically valid test results and calibrations.
- The management system requirements in ISO/IEC 17025 are written in language relevant to laboratory operations and operate generally in accordance with the principles of ISO 9001.

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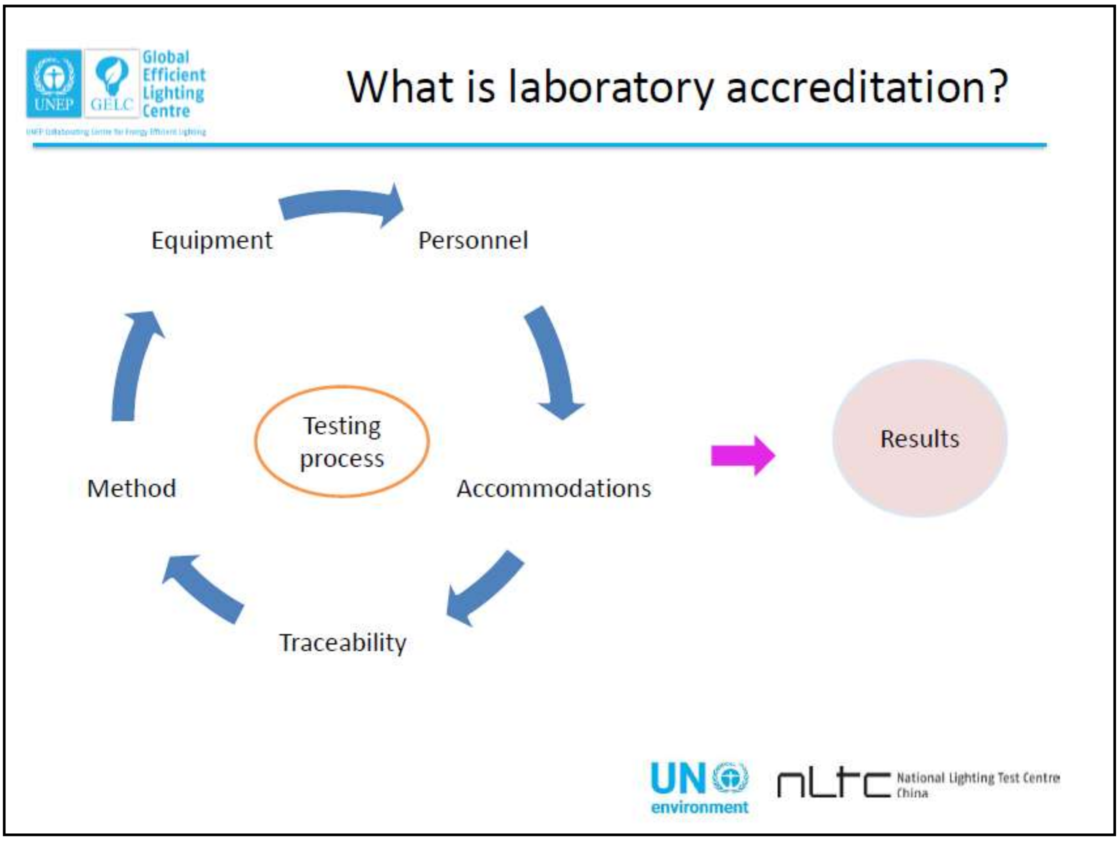
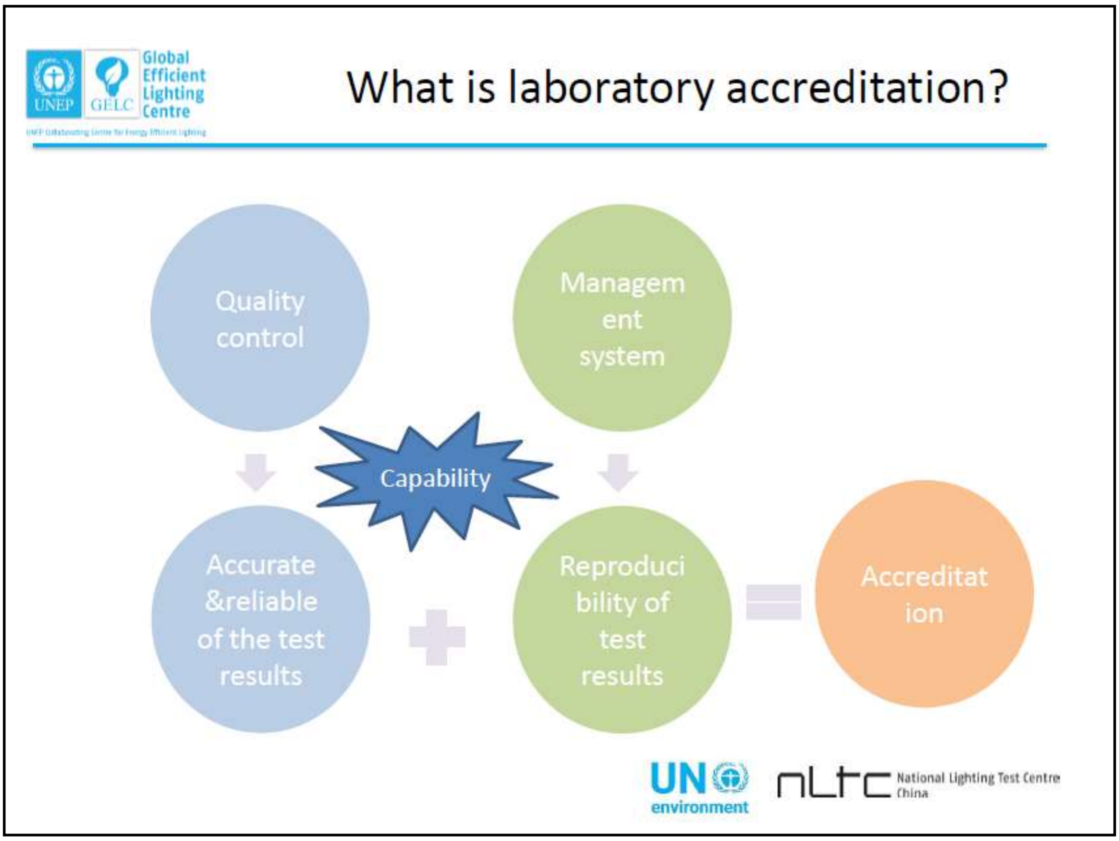
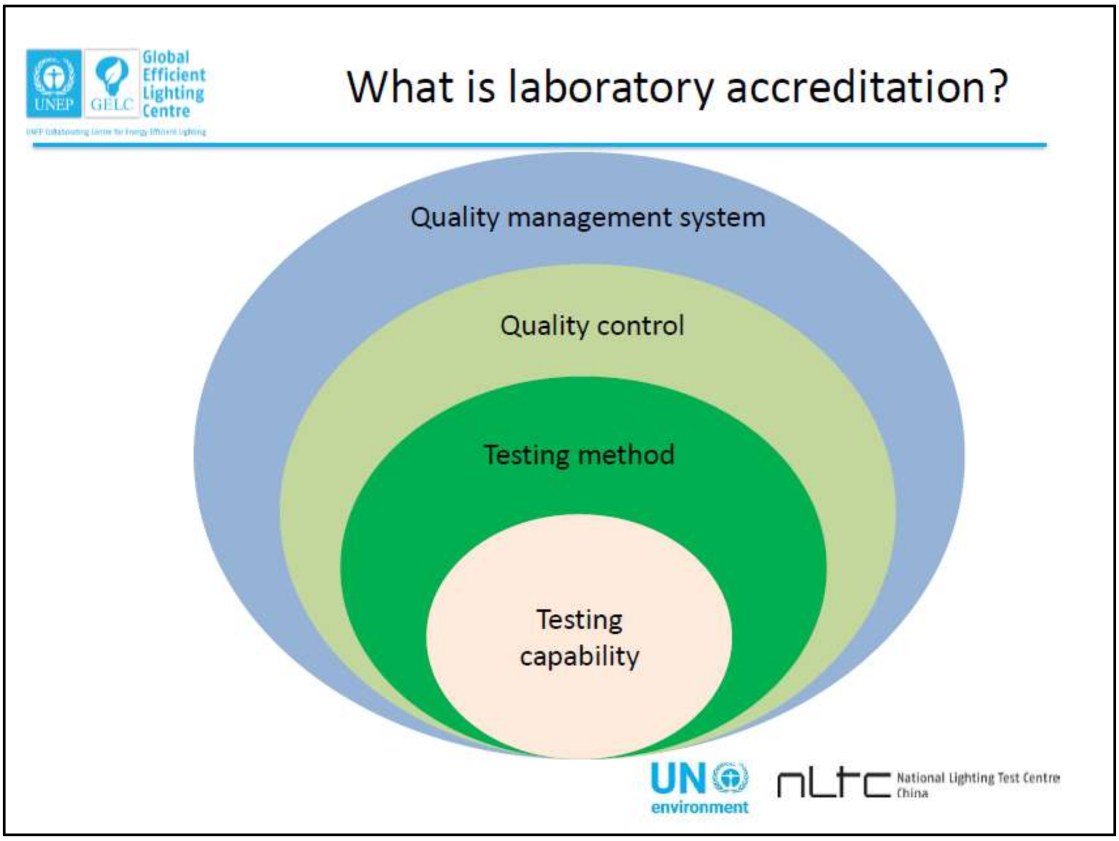
- ISO/IEC 17025 is a global quality standard for testing and calibration laboratories
- It is the basis for accreditation from an accreditation body
- Management requirements & Technical requirements
- Implementing ISO/IEC 17025 has benefits for laboratories, but the work and costs involved should be considered before proceeding.

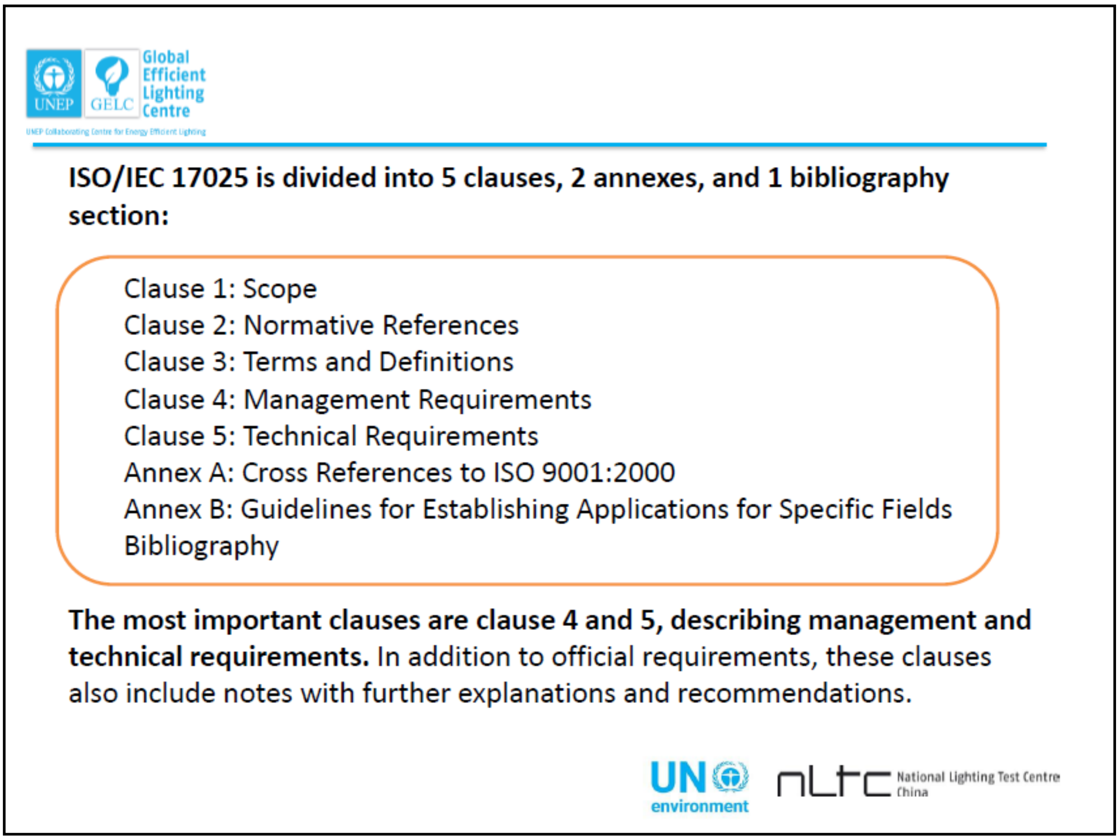
- **Benefits**
- Having access to more contracts for testing..
- Improved national and global reputation and image of the laboratory.
- Continually improving data quality and laboratory effectiveness.
- Having a basis for most other quality systems related to laboratories, such as Good Manufacturing Practices and Good Laboratory Practices.

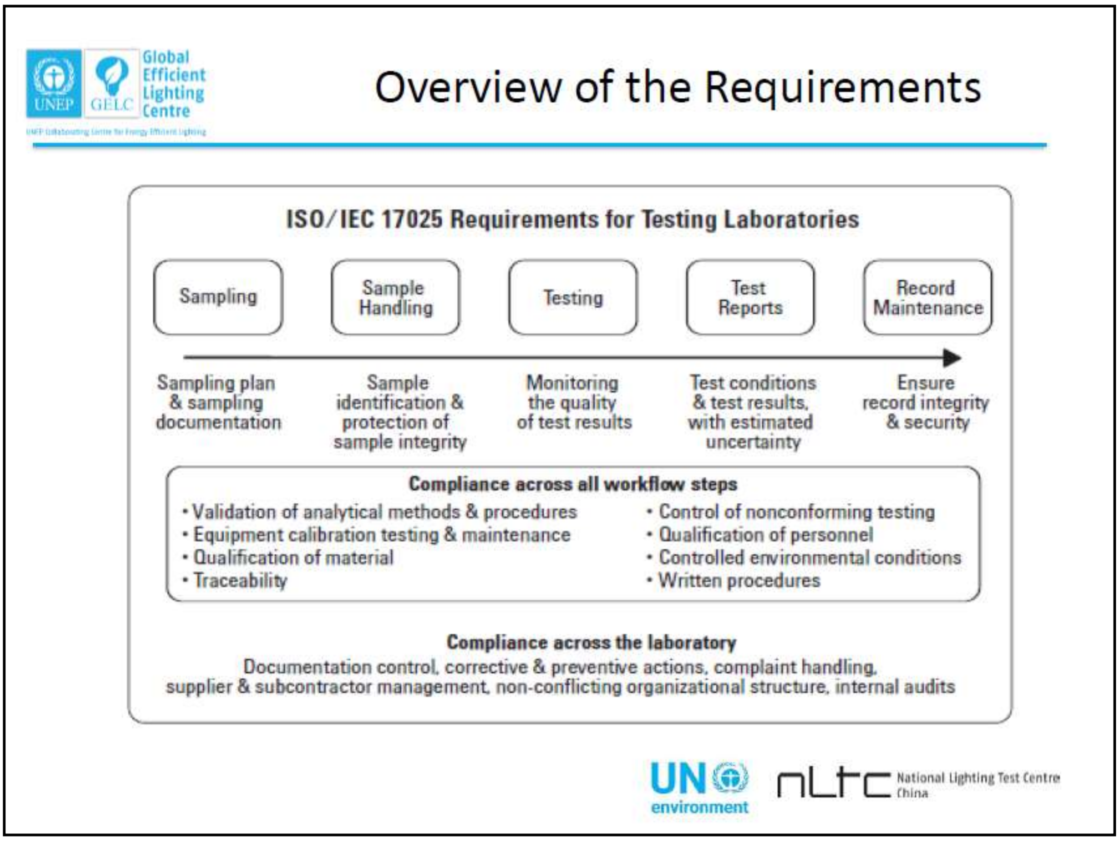

What is laboratory accreditation?
Equipment
Personnel
Testing process
Method
Accommodations
Results
Traceability
National Lighting Test Centre China

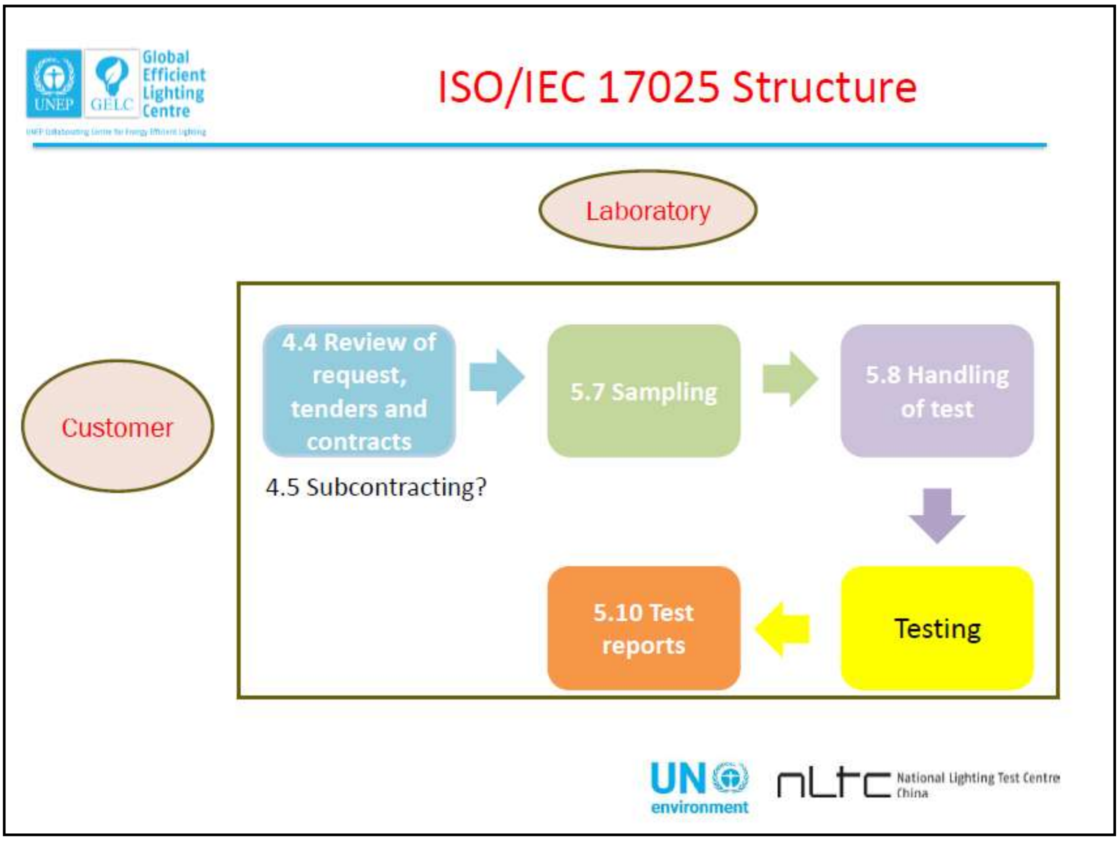

What is laboratory accreditation?
Quality control
Management system
Capability
Accurate &reliable of the test results
Reproducibility of test results
Accreditation
National Lighting Test Centre China

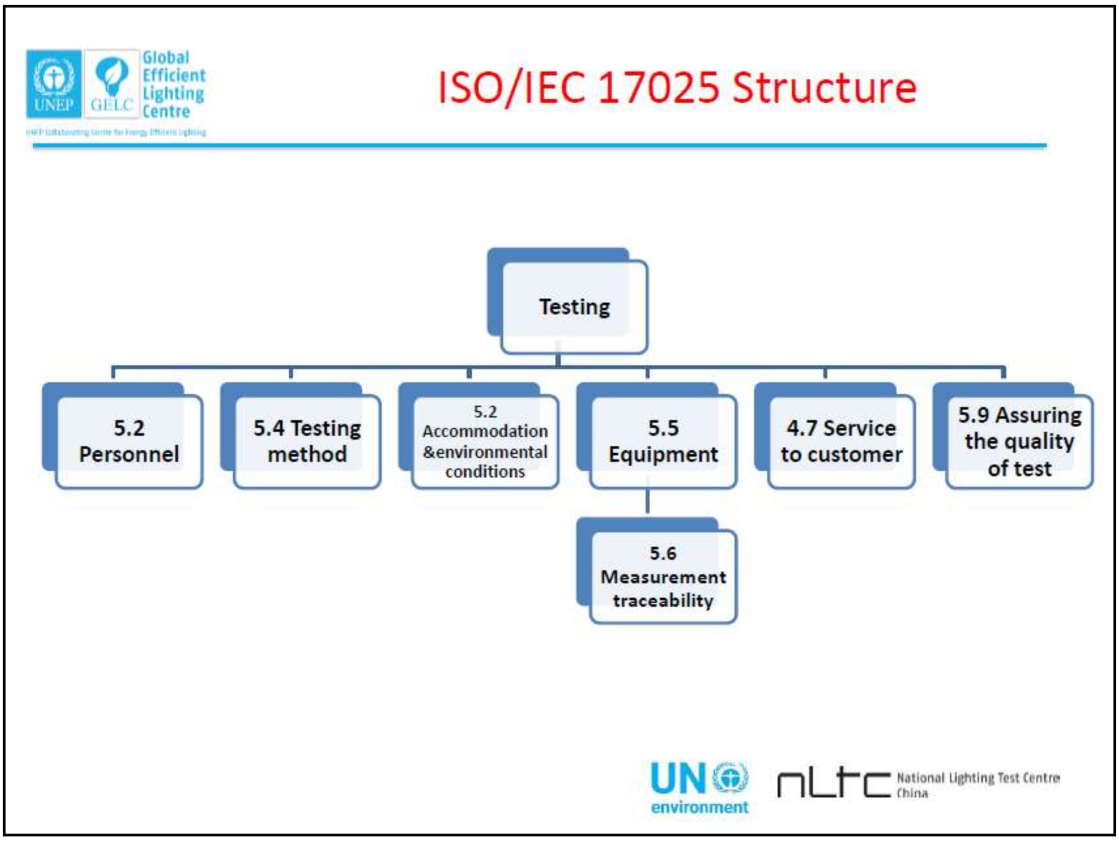

What is laboratory accreditation?
Quality management system
Quality control
Testing method
Testing capability
National Lighting Test Centre China

10.2 Introduction






ISO/IEC 17025 Structure
Laboratory
Customer
4.4 Review of request, tenders and contracts
5.7 Sampling
5.8 Handling of test
4.5 Subcontracting?
Testing
5.10 Test reports
UN environment
National Lighting Test Centre China


ISO/IEC 17025 Structure
Testing
5.2 Personnel
5.4 Testing method
5.2 Accommodation &environmental conditions
5.5 Equipment
4.7 Service to customer
5.9 Assuring the quality of test
5.6 Measurement traceability
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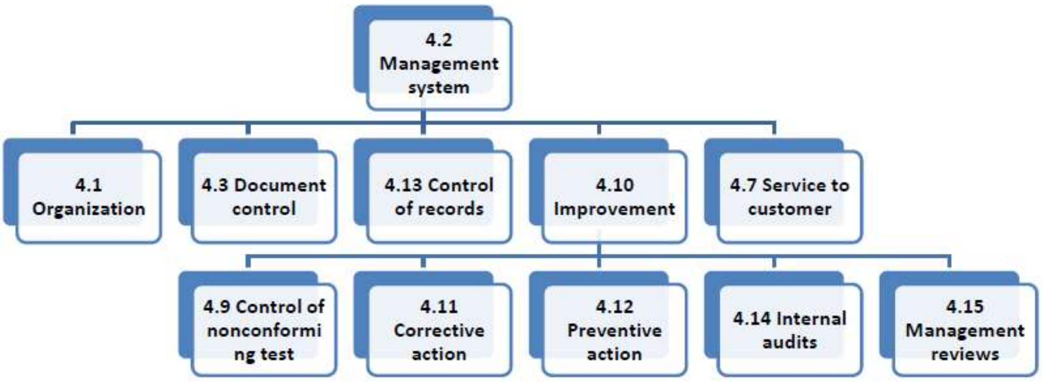
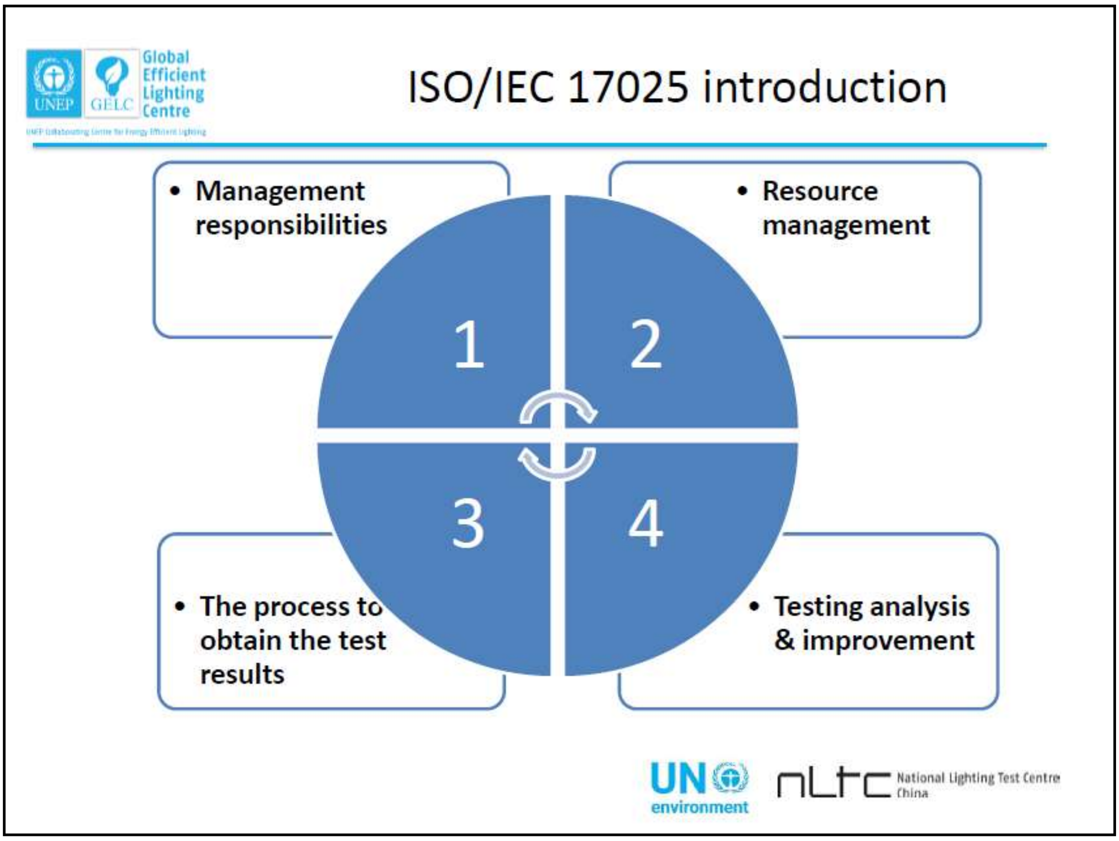
ISO/IEC 17025 Structure

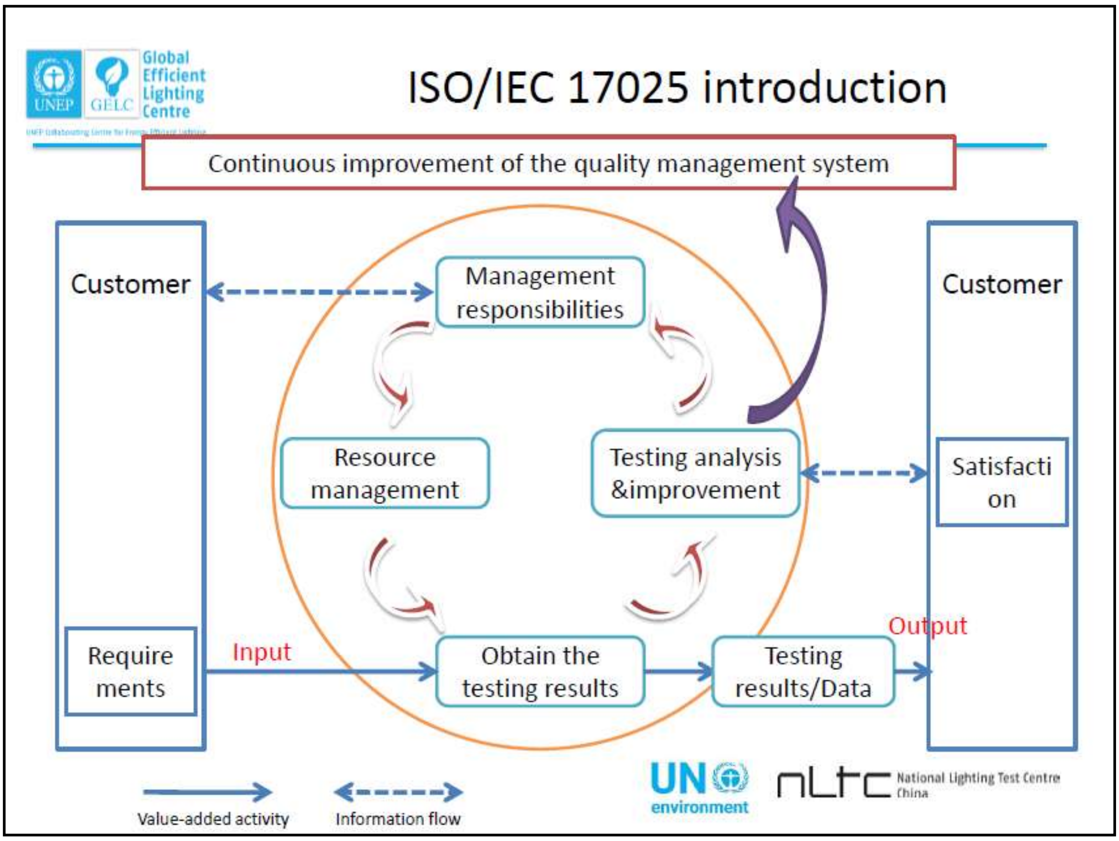


ISO/IEC 17025 introduction

ISO/IEC 17025

Process-based quality management system model

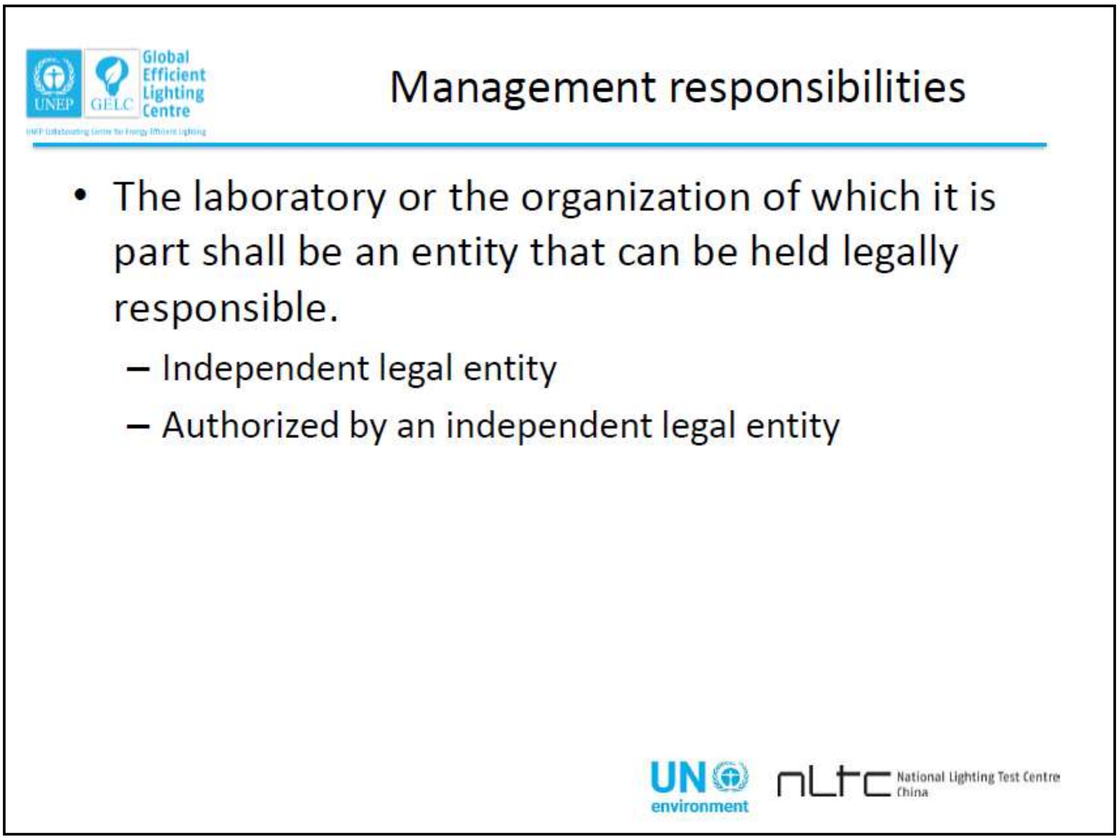

Global Efficient Lighting Centre
ISO/IEC 17025 introduction
• Management responsibilities
• Resource management
1
2
3
4
• The process to obtain the test results
• Testing analysis & improvement
UN environment
nLtc National Lighting Test Centre China

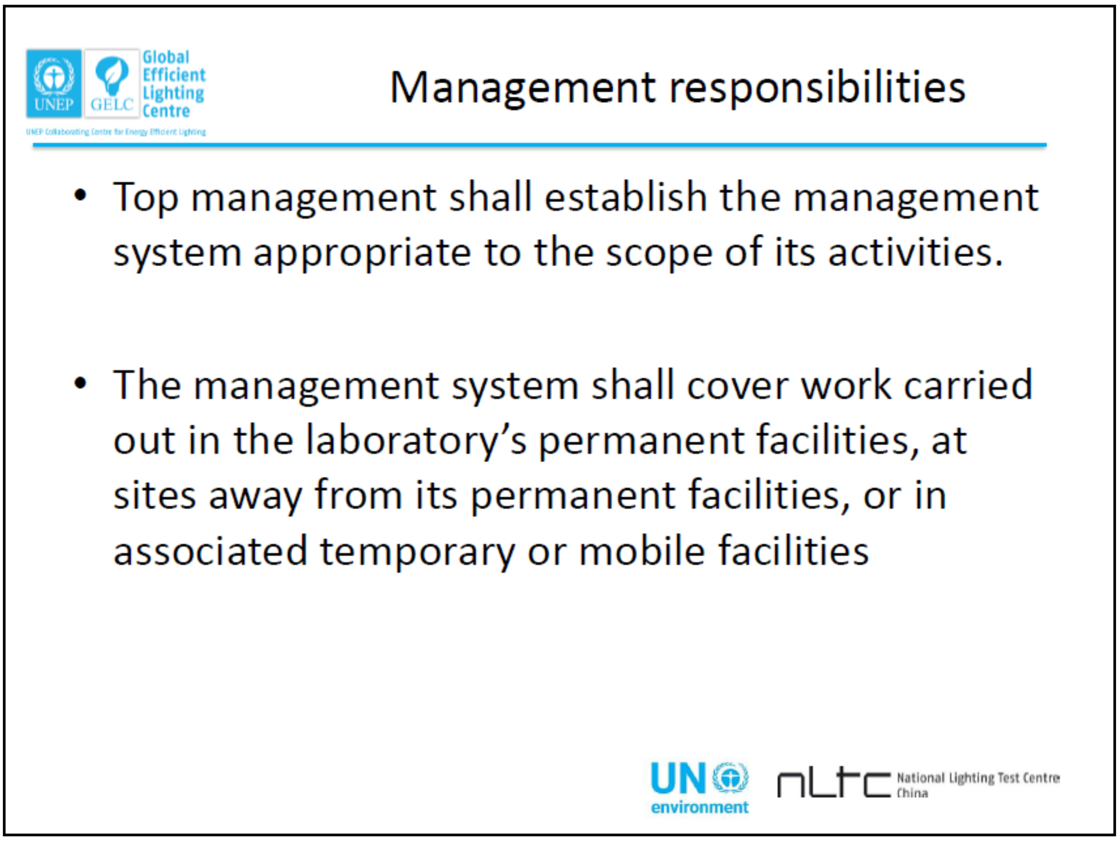

Global Efficient Lighting Centre
ISO/IEC 17025 introduction
Continuous improvement of the quality management system
Customer
Management responsibilities
Customer
Resource management
Testing analysis &improvement
Satisfaction
Output
Require ments
Input
Obtain the testing results
Testing results/Data
Value-added activity
Information flow
UN environment
nLtc National Lighting Test Centre China

ISO/IEC 17025 introduction

- **Management responsibilities**
  - **4.1, 4.2, 4.8, 4.10, 4.15, 5.1**
- **Resource management**
  - **4.6 (equipment purchasing), 5.2, 5.3, 5.5, 5.6**
- **The process to obtain the test results**
  - **4.4, 4.5, 4.6, 4.7, 5.1, 5.4, 4.13, 5.7, 5.8, 5.10**
- **Testing analysis & improvement**
  - **4.8, 4.9, 4.10, 4.11, 4.12, 4.14, 5.4.7, 5.9**

10.3 Management Responsibilities





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Management responsibilities

- Top management shall specify responsibility, authority, and interrelationships of all personnel, who manage, perform or verify the work, and provide appropriate resources (e.g. Materials, HRs, Information)

- Identify the potential deviations to testing and management and take prevention actions.

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Global Efficient Lighting Centre
UNEP Collaborating Centre for Energy Efficient Lighting

Management responsibilities

- Top management shall commit to customers that have arrangements to ensure that its management and personnel are free from any undue internal and external commercial, financial and other pressures and influences that may adversely affect the quality of their work

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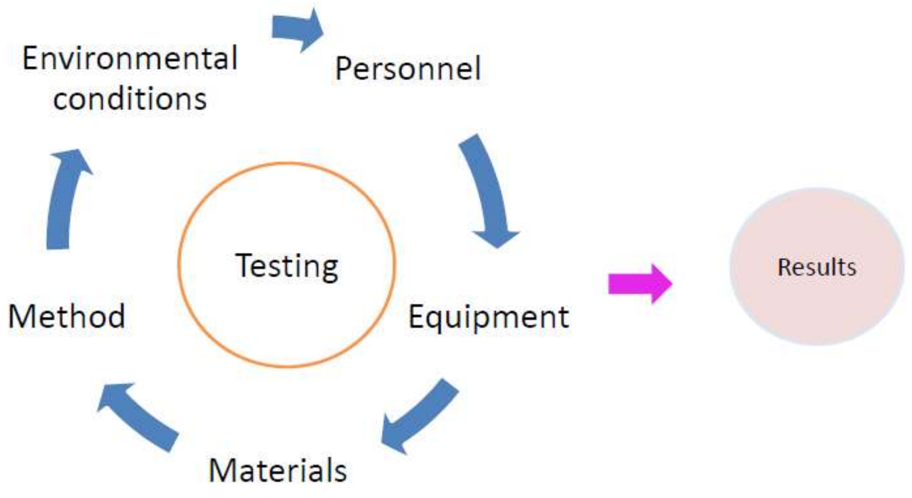
Management responsibilities

- Top management develop the Quality manual and quality policies and objectives, ensure they are appropriate to the laboratory.
- Top management commit to continually improve the effectiveness of the management system.
- Top management shall periodically conduct a review of the laboratory's management system and testing activities to ensure their continuing suitability and effectiveness, and to introduce necessary changes or improvements

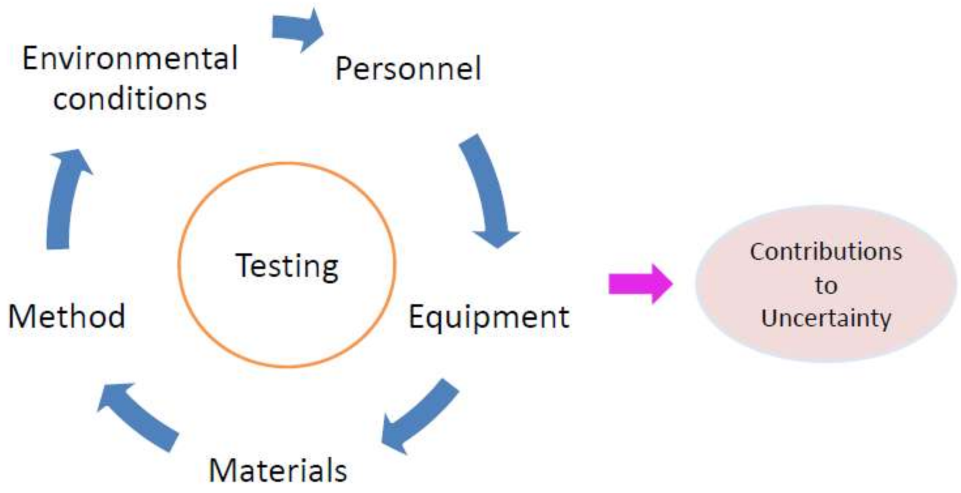
Management responsibilities



Management responsibilities

- Personnel - all personnel, who manage, perform or verify the work
- Equipment – testing equipments
- Materials – samples, consumable materials
- Method – testing method
- Environment conditions

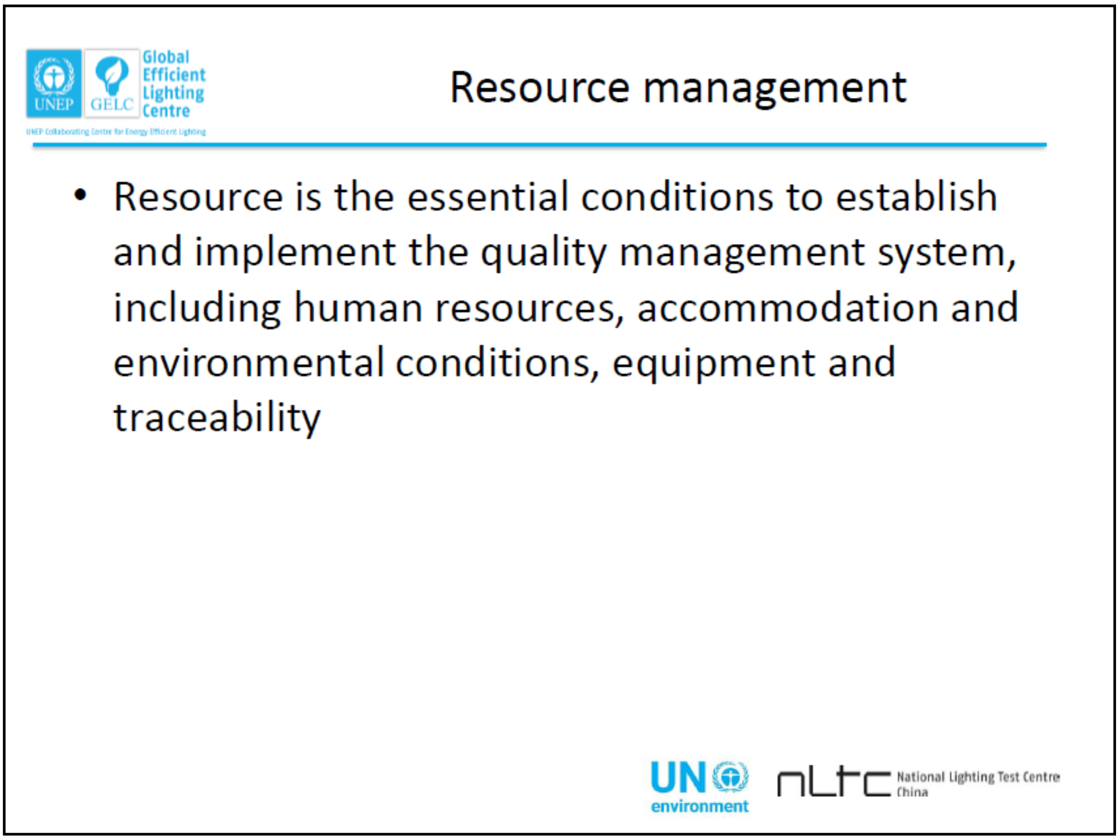
Management responsibilities

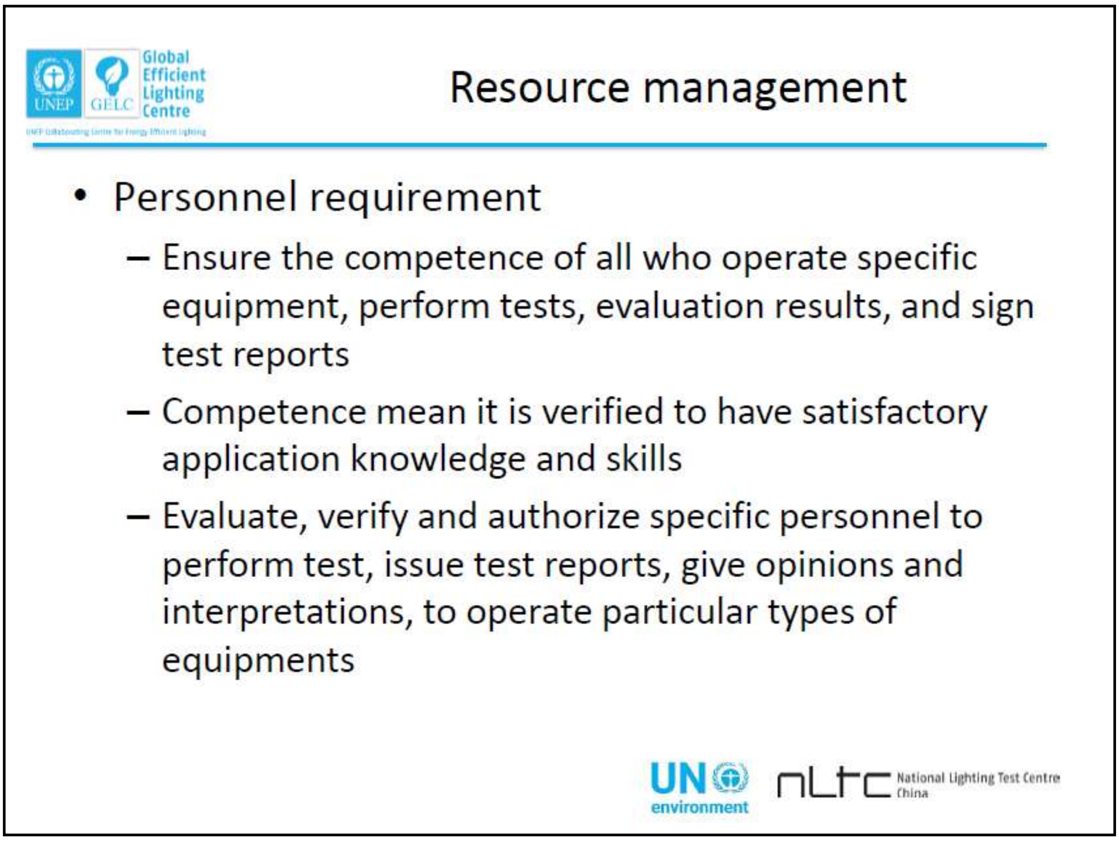


Management responsibilities

- Different laboratory, those contributions to uncertainty are different
  - For example: in calibration laboratory, the environment conditions will provide higher influence to the results than the testing laboratory
- In the same laboratory, for different testing items, those contributions are different

10.4 Resource Management





Resource management

- Personnel requirement
  - The laboratory shall use personnel who are employed by, or under contract to, the laboratory.
  - When using staff who are undergoing training, appropriate supervision shall be provided.
  - Maintenance records of the relevant authorization(s), competence, educational and professional qualifications, trainings, skills and experiences

Key points

- Only competent personnel should perform testing and calibrations. This includes part-time as well as full-time employees, as well as all management levels.
- Competence can come from education, experience, or training.
- Management should define and maintain tasks, job descriptions, and required skills for each job.
- Based on required skills and available qualifications, a training program should be developed and implemented for each employee.

Key points

- The effectiveness of the training should be evaluated. If the training is related to a specific test method, the trainee can demonstrate adequate qualification through successfully running a quality control or proficiency test sample. A statement from the trainee such as 'I have read through the test procedure' is not enough.
- Management should authorize personnel to perform specific tasks, for example, to operate specific types of instruments, to issue test reports, to interpret specific test results, and to train or supervise other personnel.
- The date of this authorization should be recorded. The associated tasks should not be performed before the authorization date.

Resource management

- Facility requirement
  - Laboratory facilities, including but not limited to electricity, water, lighting, IT, office equipments, security measures.

Resource management

- Equipment requirement
  - The equipment and its software used for testing and significant to the test results, when practicable, be uniquely identified.
  - Whenever practicable, all equipment under the control and requiring calibration shall be labeled, coded or otherwise identified to indicate the status of calibration, including the date when last calibrated and the date or expiration criteria when recalibration is due.
  - Develop the calibration plan
  - Calibrate or verify the equipment before use it

Resource management

- Equipment requirement
  - The laboratory shall have procedures for safe handling, transport, storage, use and planned maintenance of measuring equipment to ensure proper functioning and in order to prevent contamination or deterioration
  - Equipment that has been subjected to overloading or mishandling, gives suspect results, or have been shown to be defective or outside specified limits, **shall be taken out of service. It shall be isolated to prevent its use or clearly labeled or marked as being out of service** until it has been repaired and shown by calibration or test to perform correctly

Resource management

- Equipment requirement
  - For whatever reason, equipment goes outside the direct control of the laboratory, it should be checked the function and calibration status and shown to be satisfactory before the equipment is returned to service
  - When intermediate checks are needed to maintain confidence in the calibration status of the equipment, these checks shall be carried out according to a defined procedure. (e.g. key performance, poor stability, high frequency of use, poor environment of use)

Resource management

- Equipment requirement
  - When calibrations give rise to a set of correction factors, the laboratory shall have procedures to ensure that copies (e.g. in computer software) are correctly updated.
  - Test equipment, including both hardware and software, shall be safeguarded from adjustments which would invalidate the test results. (how?)
  - Up-to-date instruction on the use and maintenance of equipment shall be readily available for use by the appropriate personnel

Key points

- Equipment should conform to specifications relevant to the tests. This means that equipment specifications should first be defined so that when conforming to defined specifications the equipment is suitable to perform the tests.
- Equipment and its software should be identified and documented.
- Equipment should be calibrated and/or checked to establish that it meets the laboratory's specification requirements.
- Records of equipment and its software should be maintained and updated if necessary. This includes version numbers of firmware and software. It also includes calibration and test protocols.
- Calibration status should be indicated on the instrument along with the last and the next calibration dates.

Resource management

- Environmental conditions requirement
  - For example: temperature, humidity, dust, vibration, electromagnetic disturbances, radiation, electrical supply;
  - The laboratory shall monitor, control and record environmental conditions as required by the relevant specifications, methods, and procedures or where they influence the quality of the results.
  - Tests shall be stopped when the environmental conditions jeopardize the results of the tests.

Resource management

- Environmental conditions requirement
  - There shall be effective separation between neighboring areas in which there are incompatible activities
  - The laboratory shall ensure that the environmental conditions do not invalidate the results or adversely affect the required quality of any measurements. The technical requirements for environmental conditions that can affect the results shall be documented.

Resource management

- Environmental conditions requirement
  - Access to and use of areas affecting the equality of tests shall be controlled. And the laboratory determine the extent of control based on its particular circumstances.

Key points

- Environmental conditions should not adversely affect the required quality of tests. This means, for example, that equipment should operate within the manufacturer's specifications for humidity and temperature.
- The laboratory should monitor, control, and record environmental conditions. Tests should be stopped when the environmental conditions are outside specified ranges.
- Areas with incompatible activities should be separated.
- Access to test areas should be limited to authorized people. This can be achieved through pass cards.

10.5 The Process to Obtain the Test Results

The process to obtain the test results

- Testing process requirement
  - All the processes (review of requests, tenders and contracts, subcontracting, service to customer, complaints, test methods and method validation, sampling, purchasing services and supplies, handling of test items, reporting the results)

The process to obtain the test results

- Testing process requirement – review of requests, tenders and contracts
  - This is the source of the testing process
  - Through the review to ensure the laboratory correctly understands the testing related requirements (including methods,), has capability and resource to meet the requirements, and select appropriate test method
  - A contract may be any written or oral agreement to provide a customer with testing service

The process to obtain the test results

- Testing process requirement – review of requests, tenders and contracts
  - Any differences between the request/tender/contract shall be resolved before any work commences
  - If a contract needs to be amended after work has commenced, the same contract review process shall be repeated and any amendments shall be communicated to all affected personnel.

The process to obtain the test results

- Testing process requirement – review of requests, tenders and contracts
  - Records of reviews, including any significant change, shall be maintained.
  - **The results of review of requests/tenders/contracts are the input to the other processes**

Service to the client

- What cooperation might be included?
- Client Feedback, both positive & negative

Key points

- The laboratory should communicate with customers to clarify requests and get customer input.
- The laboratory should have a formal program to collect feedback from customers on an ongoing basis.
- The laboratory should allow customers to audit the laboratory.

The process to obtain the test results

- Testing process requirement – Test methods and method validation
  - Test methods include sampling, handling, transport, and preparation of items to be tested, and where appropriate, an estimation of measurement uncertainty as well as statistical techniques for analysis of test data
  - Selection of methods

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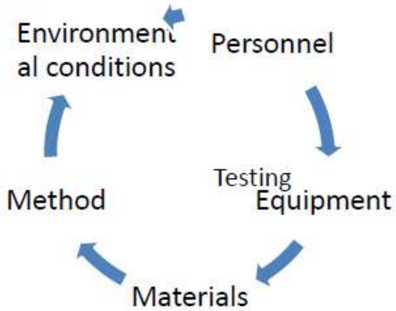
The process to obtain the test results

- Testing process requirement – Test methods and method validation
  - Validation if the confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled



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The process to obtain the test results

- Testing process requirement – Test methods and method validation
  - The laboratory shall have instructions on the use and operation of all relevant equipment, and on the handling and preparation of items for testing, where the absence of such instructions could jeopardize the results.
  - All instructions, standards, manuals and reference data shall be kept up to date and made readily available for personnel

The process to obtain the test results

- Testing process requirement – Test methods and method validation
  - Deviation from test methods shall occur only if the deviation has been documented, technically justified, authorized and accepted by the customer.
  - Testing laboratories shall have and shall apply procedures for estimating uncertainty of measurement

Key points for accurate test results

- Methods and procedures should be used within their scope. This means the scope should be clearly defined.
- The laboratory should have up-to-date instructions on the use of methods and equipment.
- If standard methods are available for a specific sample test, the most recent edition should be used.
- Deviations from standard methods or from otherwise agreed-upon methods should be reported to the customer and their agreement obtained.
- When using standard methods, the laboratory should verify its competence to successfully run the standard method. This can be achieved through repeating one or two critical validation experiments, and/or through running method specific quality control and/or proficiency test samples.

Key points for accurate test results

- Standard methods should also be validated if they are partly or fully out of the scope of the test requirement.
- Methods as published in literature or developed by the laboratory can be used, but should be fully validated. Clients should be informed and agree to the selected method.
- Introduction of laboratory-developed methods should proceed according to a plan.
- The following parameters should be considered for validating in-house developed methods: limit of detection, accuracy, selectivity, linearity, repeatability and/or reproducibility, robustness, and linearity.

The process to obtain the test results

- Testing process requirement – Technical record
  - The laboratory shall retain records of original observations, derived data and sufficient information to establish an audit trial, staff records, and a copy of reach test report issued, for a defined period.
  - The record for each test shall contain sufficient information to facilitate, if possible, identification of factors affecting the uncertainty and to enable the test to be repeated under considerations as close as possible to the original.

The process to obtain the test results

- Testing process requirement – Technical record
  - The records shall include the identity of personnel responsible for the sampling, performance of each test and checking of the results
  - When mistakes occur in records, each mistake shall be crossed out, not erased, made illegible or deleted, and correct value entered alongside. All such alteration to records shall be signed or initialed by the person making the correction.

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Key points

- There should be procedures for identification, collection, indexing, storage, retrieval, and disposal of records.
- Records should be stored such that their security, confidentiality, quality and integrity are ensured throughout the required retention time.
- For technical records such as test reports of analytical measurements, original observations should be retained, along with processing parameters that will allow tracking final results back to the original observations.
- Record format can be hard copies or electronic media. There should be procedures to protect and back-up electronic records and to prevent unauthorized access.

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Key points

- Records can be corrected if there are mistakes. The original record should be crossed out, but still visible.
- When electronic record systems are used, the same principle applies. The laboratory should ensure that original records are not overwritten by the system and that corrections are recorded together with the original records. Using a system that prevents overwriting original records and stores changes in an electronic audit trail that can be viewed and printed is highly recommended.

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The process to obtain the test results

- Testing process requirement – data control
  - Data and results are the products of the laboratory.
  - When computers or automated equipment are used for the acquisition, processing, recording, reporting, storage, or retrieval of test data, the laboratory shall ensure:
    - Commercial off-the shelf software (e.g. word-processing, database, statistical programmes) in general use within their designed application range may be considered to be sufficient validated
    - Laboratory self-developed software is documented in sufficient details and is suitably validated as being adequate for use
    - Procedures are established and implemented for protecting data
    - Computers and automated equipment are maintained to ensure proper functioning and are provided with the environmental and operation conditions necessary to maintain the integrity of test data.

Key points for control of data

- Calculations used for data evaluation should be checked. This is best done during software and computer system validation. As an example, spreadsheet formulas defined by a specific user should be verified with an independent device such as a handheld calculator. Data transfer accuracy should be checked.
- Computer software used for instrument control, data acquisition, processing, reporting, data transfer, archiving, and retrieval developed by or for a specific user should be validated. The suitability of the complete computer system for the intended use should also be validated.

Key points for control of data

- Any modification or configuration of a commercial computer system should be validated. Examples include defining report layouts, setting up IP addresses of network devices, and selecting parameters from a drop-down menu.
- Electronic data should be protected to ensure integrity and confidentiality of electronic records. For example, computers and electronic media should be maintained under environmental and operating conditions to ensure integrity of data.

Purchasing services and suppliers

- What constitutes services and supplies?
- What constitutes inspected prior to use?
- What kind of records would be needed?
- Purchase documents should contain what information?
- What methods could the laboratory use to evaluate suppliers?

Key points

- Suppliers should be selected and formally evaluated to ensure that services and supplies are of adequate quality.
- Records of the selection and evaluation process should be maintained.
- The quality of incoming material should be verified against predefined specifications.

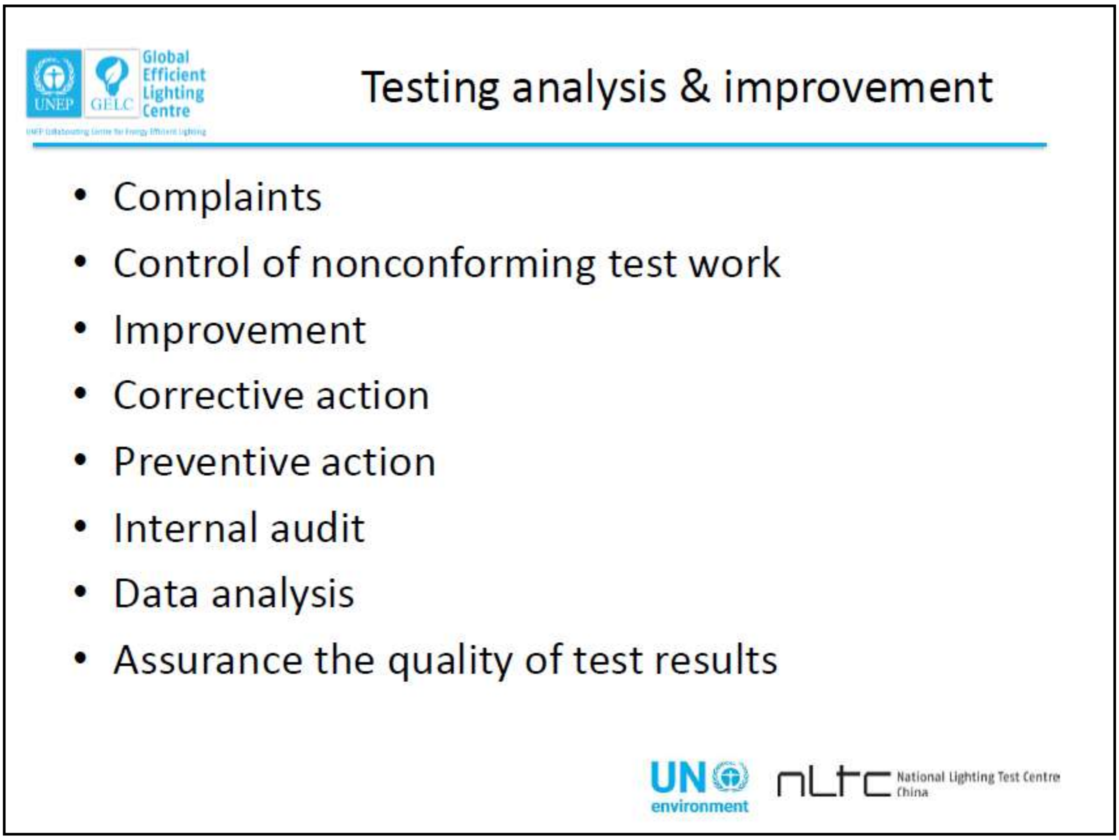
The process to obtain the test results

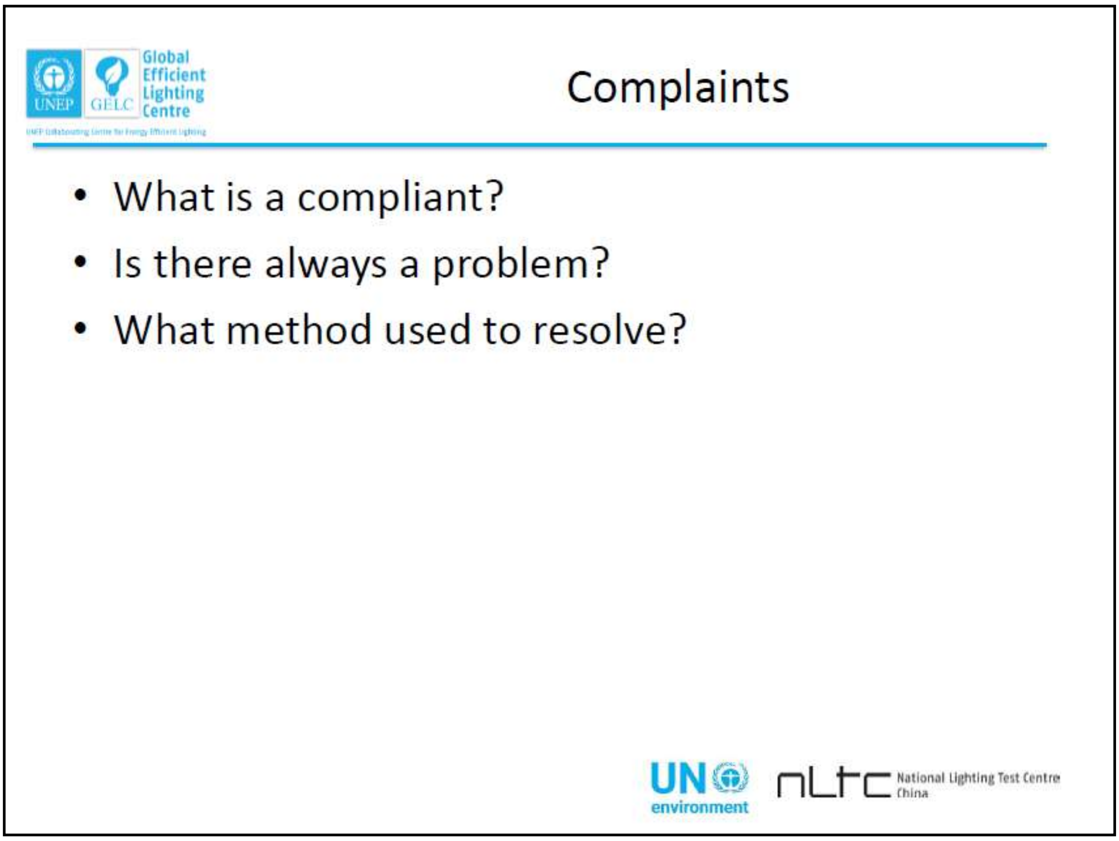
- Testing process requirement – handling of samples
  - The laboratory shall have procedures for the transportation, receipt, handling, protection, storage, retention and disposal of test samples.
  - The laboratory shall have a system for identifying test samples, The identification shall be retained throughout the life of the item in the laboratory.
  - Abnormalities or departures from normal or specified conditions, as described in the test method, shall be recorded.

The process to obtain the test results

- Testing process requirement – reporting the results
  - The output of the testing process
  - The test reports shall include requests by the custom, and all the necessary information for stating the specific methods, opinions and interpretations

10.6 Testing Analysis & Improvement





Testing analysis & improvement

- Complaints
  - The laboratory shall have a policy and procedure for resolution of complaints received from customers other parties.
  - Survey the feedbacks from consumers (either positive and negative)

Control of nonconforming work

- What constitutes nonconforming work?
- What should be done when nonconforming work is noted? Who is responsible?

Testing analysis & improvement

- Control of nonconforming test work
  - The laboratory shall have a policy and procedure that shall be implemented when any aspect of its testing work, or results do not conform to its own procedures or the agreed requirements of the customer.
  - The responsibilities and authorities
  - An evaluation of the significance
  - Correction is taken immediately
  - When necessary, the customer is notified and the work is recall
  - The responsibility for authorizing the resumption of the work

Key points

- There should be a policy and process that come into effect when results do not conform to procedures.
- Corrective actions should be taken immediately to avoid recurrence.
- The significance of nonconforming work should be evaluated, for example, the possible impact on other testing work.
- If necessary, customers should be notified.

Testing analysis & improvement

- Improvement
  - The laboratory shall continually improve the effectiveness of its management system through the use of the quality policy, objectives, audit results, analysis of data, corrective and preventive actions and management review.

Improvement

- The laboratory shall show evidence of improvement:
- Continuous improvement program
- Addressed and items identified during management review and other activity
- All documented and evidence of follow-up or effective improvement

Key points

- Suggestions for improvements should be taken from audit reports, analysis of data, customer complaints and suggestions, corrective and preventive actions, and management reviews.
- Suggestions should be collected over time and reviewed by management for suitable actions.

Testing analysis & improvement

- Corrective action
  - A problem may be identified through a variety of activities, such as control of nonconforming work, internal or external audits, management reviews, feedback from customers and from staff observations.
  - Implement corrective actions when the nonconforming work has been identified

Testing analysis & improvement

- Problems may be identified through?
- Steps for a good corrective action procedure are:
  - Cause analysis

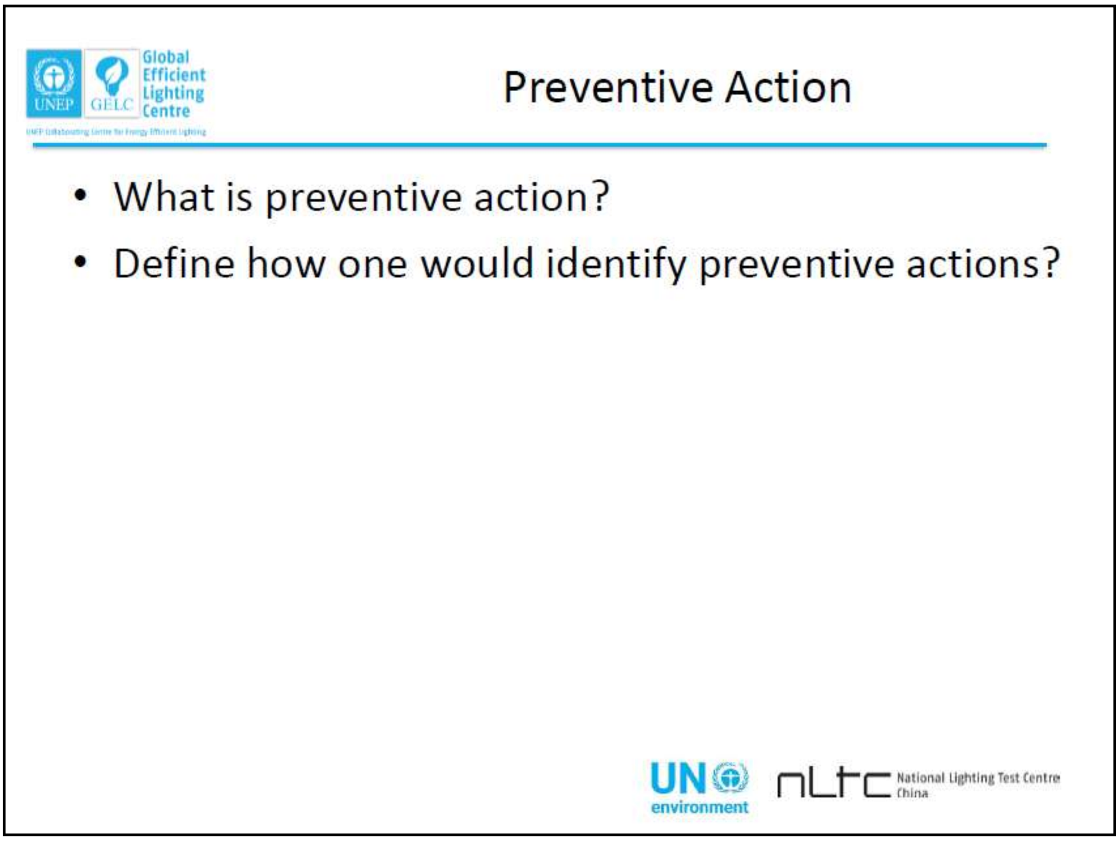
    is there always a problem?
  - Selection and implementation of corrective actions

    What is the goal of the corrective action?
  - Monitoring of corrective actions

    How might a laboratory monitor corrective actions?
  - Additional audits

Key points

- Corrective actions can be triggered through nonconforming tests or other work, customer complaints, internal or external audits, management reviews, and observations by staff.
- Corrective actions should be selected and implemented to eliminate the specific problem and prevent recurrence of the same problem.
- As the first step in the process, the root cause of the nonconformity should be identified.
- The effectiveness of the corrective action should be monitored and evaluated.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Preventive Action
• What is preventive action?
• Define how one would identify preventive actions?
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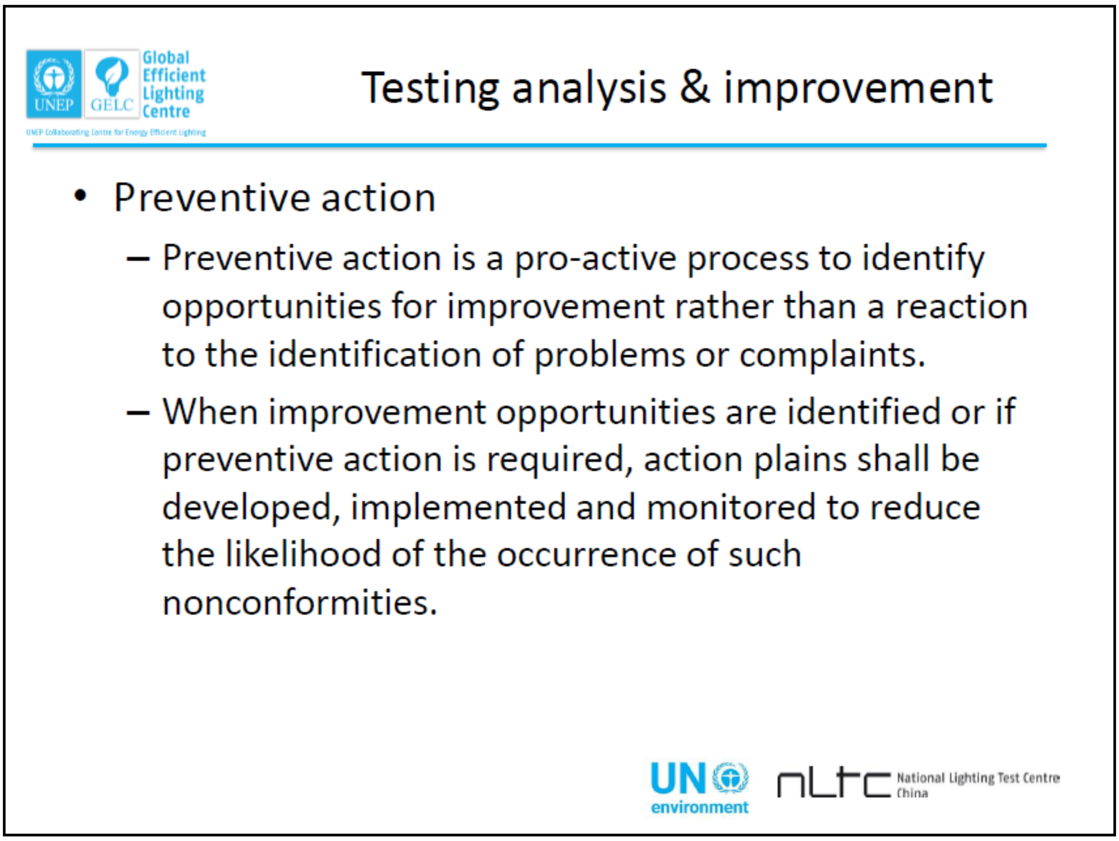
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Testing analysis & improvement
• Preventive action
– Preventive action is a pro-active process to identify opportunities for improvement rather than a reaction to the identification of problems or complaints.
– When improvement opportunities are identified or if preventive action is required, action plains shall be developed, implemented and monitored to reduce the likelihood of the occurrence of such nonconformities.
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Testing analysis & improvement

- Preventive action
  - Identify the potential nonconformity work and conduct cause analysis (including trend and risk analysis and PT results)
  - Selection and implementation of preventive actions
  - Monitoring of preventive actions

Key points

- There should be a procedure to identify potential sources of nonconformities and define preventive actions to prevent occurrence of these nonconformities.
- The effectiveness of the preventive action should be monitored and evaluated.

- Define corrective & Preventive Actions

- What are the primary differences?

Testing analysis & improvement

- Internal audit
  - The laboratory shall periodically, and in accordance with a predetermined schedule and procedure, conduct internal audits to verify its operations continue to comply with the requirements of the management system

Key points

- Internal audits can either cover the whole laboratory and all elements of the quality system at one specific period of time or can be divided into several subsections.
- The schedule should be such that each element of the quality system and each section of the laboratory are audited yearly.
- The audit program should be managed by the quality manager.
- Audit findings related to the quality of test and calibration results should be reported to customers.
- Audit follow-up activities should include corrective and preventive action plans (CAPA). The effectiveness of the plans should be monitored.

Testing analysis & improvement

- Data analysis
  - The laboratory shall identify, collect and analysis appropriate data to verify the suitability and effectiveness of the quality management system.
  - Custom satisfactory, compliance to the requirements, process characteristics and development trend, suppliers

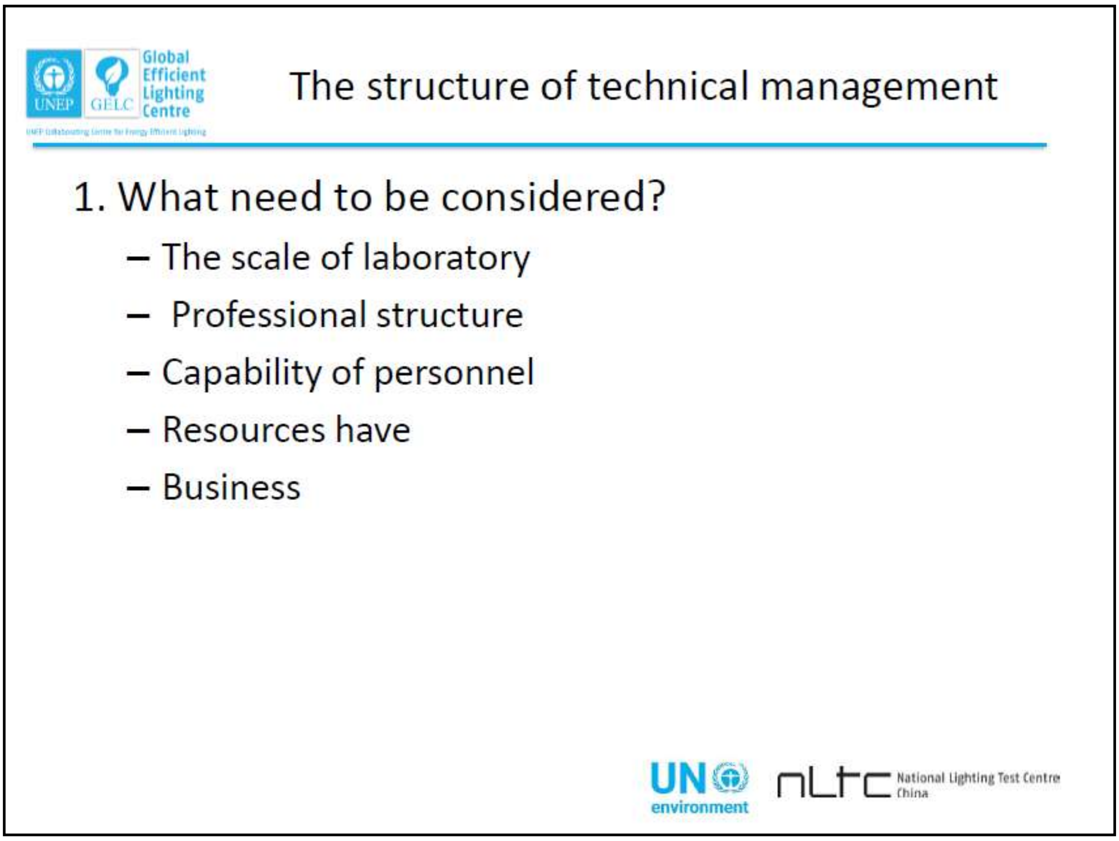
Testing analysis & improvement

- Assurance the quality of test results
  - Monitoring and measurement of the process
  - Participation in IC or PT
  - Replicate tests using the same or different methods
  - Retesting of retained items
  - Correlation of results for different characteristics and an item
  - Quality control data should be analyzed and where they found to be outside pre-defined criteria, planned action shall be taken to correct the problem and to prevent incorrect results from being reported

Key points

- The validity of test results should be monitored on an ongoing basis.
- The type and frequency of tests should be planned, justified, documented, and reviewed.
- Quality control checks can include the regular use of certified reference materials, replicating tests or calibrations using the same or different methods, and retesting or recalibration of retained items.

10.7 The Structure of Technical Management

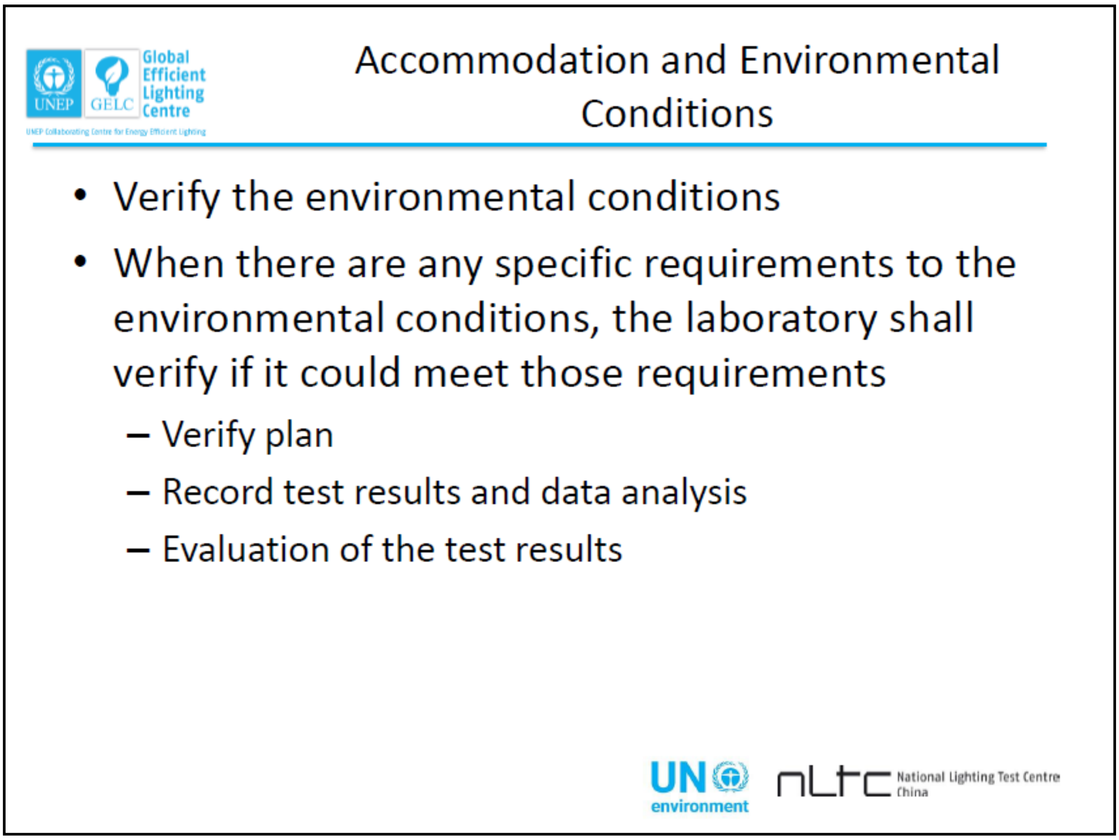


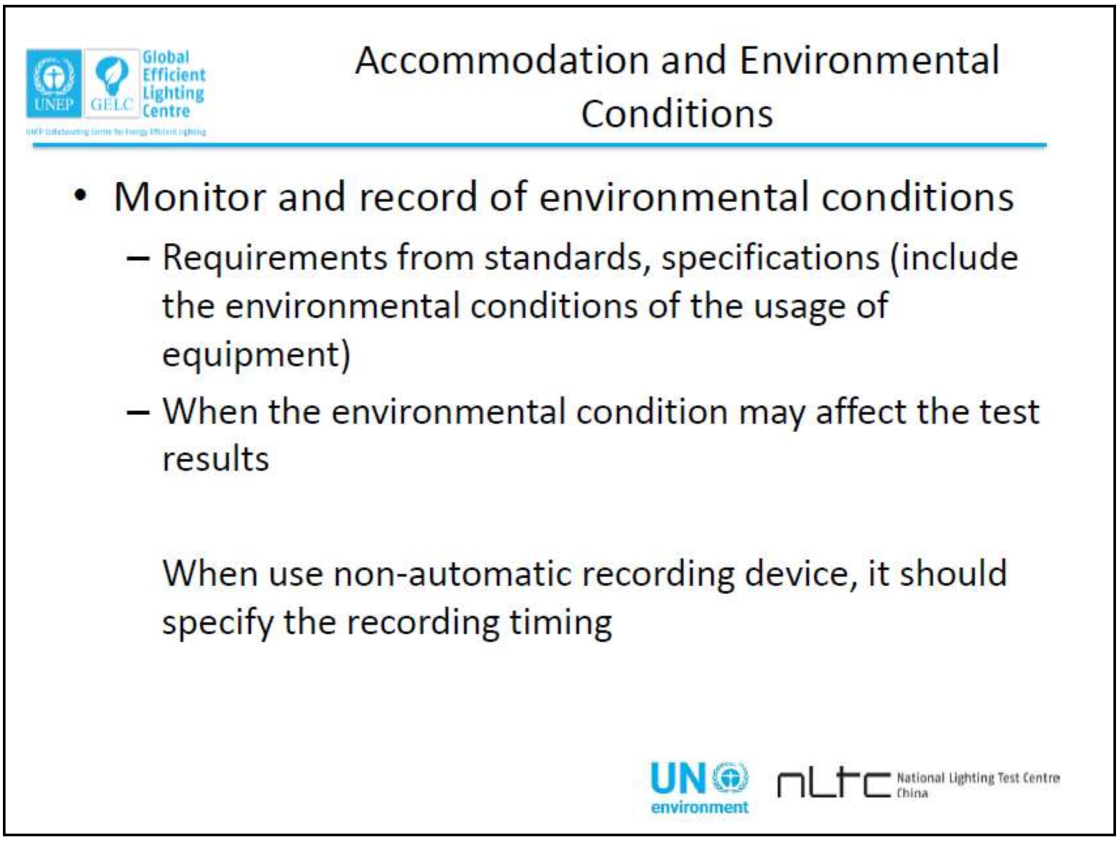
The structure of technical management

2. Structure of technical management
   - Mechanism
   - Functions
   - Levels
   - Operation model

Technical control in the process of achieving the data and test results

10.8 Accommodation and Environmental Conditions





10.9 Control of Test Method

Control of test method

- Management of the standards, and documents used for testing
  - Establish a stable and effective track for standards
  - Establish the list(s) of controlled documents and standards
  - There should be a unique identification for a self-developed document (for example: work instruction). There is a instruction for how to identify the documents.
  - All the documents under controlled shall be approved before issued.
  - Review the testing related document (internal, external) at a regular period, and revise as necessary.

Control of test method

- Management of the standards, and documents used for testing
  - Invalid or obsolete documents are promptly remove from all points of issue of use
  - Obsolete documents retained for either legal or knowledge preservation purpose are suitably marked

Control of test method

- Select of test method
  - Methods published in international, regional or national standards shall be preferably be used.
  - The laboratory shall confirm that it can proper operate standard methods before introducing the test. If the standard method changes, the confirmation shall be repeated.

Control of test method

- The laboratory shall confirm that it can proper operate standard methods before introducing the test. If the standard method changes, the confirmation shall be repeated.
  - The analysis on the differences of new and old standard
  - Evaluation on human resources, conduct training and evaluation if necessary
  - Evaluation on equipment, purchasing new equipment if necessary
  - Review and revise the work instruction
  - Review of the record form and test report form
  - Participate in IC or retesting, if there are large differences between the new and old standard

Control of test method

- Deviations of standard method
  - In order to ensure the correct implementation of standard method, the laboratory shall provide effective control to the deviation of standard method.
  - The laboratory shall document the content, scope and testing steps of deviations.
  - Using an effective method to make a technical evaluation, until it shows that the deviation does not affect the test requirements
  - Authorization
  - Agreed by customer
  - The deviation from the standard method, should be clearly stated in its test report

Control of test method

- Validation of non-standard method
  - Validation is the confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled
  - Validation method: 1) calibration using reference standards or reference materials; 2) comparison of results achieved with other methods; 3) IC; 4)systematic assessment of the factors influencing the results; 5) assessment of uncertainty of the results based on scientific understanding of the theoretical principals of the method and practical experience

Control of test method

- Validation of non-standard method
  - Validation requirement:
  - The scope and accurate of the test results obtained meet the particular requirements for a specific indented use
  - The validation is as much completed as possible
  - Record any results and method used for validation
  - Conclusion of the validation
  - When some changes are made in validation, he influence of such changes should be documented and, if appropriate, a new validation should be carried out.

Control of test method

- Development of work instruction
  - Why to develop the work instruction?
  - in which cases, it will need to develop work instruction?
    - The standards or manual is not very clear for operation
    - The detailed document is missing which may affect the test results during the operation

Control of test method

- Development of work instruction
  - The common work instruction may include
    - Operating instruction of the equipments (including maintenance)
    - Sample preparation
    - Testing
    - Self-calibration
    - Intermediate checks
    - Evaluation of uncertainty

Control of test method

- Development of work instruction
  - Operating instruction manual of the equipment includes:
    - Accommodations and environmental conditions
    - Preparation and precautions
    - Start, initial commissioning or self-checking steps
    - The necessary preheating operation and the preparation steps for the measurement
    - The adjustment of the measurement range and the method of reducing the indication error
    - Read timing of the measured value
    - Preparation before shutdown and shutdown steps
    - Equipment maintenance requirements (maintenance plan) and storage conditions

Control of test method

- Development of work instruction
  - The testing method is not clear in the standard, it needs to further detail, otherwise it would bring different operations
  - It does not specify the test method in the existing standards, it would need to refer to the generally used test method standard or the standard of a similar product (same type or same group)
  - There is no test method, and it would need to refer to reputable technical organization, or in relevant scientific texts or journal, or as specified by the manufacturer of the equipment

Control of test method

- Development of work instruction
  - In a standard, it defines many test methods, while in the laboratory it only can use one of them
  - The deviation to the standard method
  - Self-developed testing method

Control of test method

- Development of work instruction
  - The content of the work instruction:
    - Title
    - Scope
    - Reference standard
    - The type of products applied to
    - Testing items
    - Testing equipment
    - Environmental conditions
    - Test conditions (e.g. timing, frequency)
    - Testing steps
    - Security measures
    - Handling of anomalies
    - Data analysis (if necessary, provide the evaluation of uncertainty)
    - Evaluation of test results

Control of test method

- Development of work instruction
  - Development of intermediate checks instruction
    - Title
    - Scope
    - Intermediate check items
    - Technical requirements
    - Referenced standard
    - Operation steps
    - Data analysis
    - Conclusions
    - Period

10.10 Control of Evaluation of Uncertainty

Control of evaluation of uncertainty

- The uncertainty evaluation procedure
  - Establish the mathematic model (determine the functional relationships between outputs and inputs)

$$y = f(x_i, x_2, \ldots, x_n)$$

  - Identify the components of uncertainty
  - Calculate the best estimate of the measured value

Calculate the best estimate of x

- Equally accurate measurement (at same test conditions)

$$\bar{x} = \frac{1}{n}(x_1 + x_2 + \cdots + x_n) = \frac{1}{n}\sum_{i=1}^{n} x_i$$

- Unequally accurate measurement (at different test conditions, or different testing times)

$$\overline{x_p} = \frac{p_1 x_1 + p_2 x_2 + \cdots\cdots + p_n x_n}{p_1 + p_2 + \cdots\cdots + p_n}$$

$$P_i = \frac{c}{\sigma_i^2}$$

Pi: The weights of the measured values, are inversely proportional to their own variances

C: coefficient, normally is 1

Calculate the best estimate of y

- If there is only one direct input,

  Y=cx

- If there are several indirect input, means, y is calculated by x_i , $y = f(x_1 、x_2 \cdots\cdots x_n)$

$$y = \frac{1}{n}\sum_{k=1}^{n} y_k = \frac{1}{n}\sum f(x_{1k}, x_{2k}, \cdots, x_{Nk})$$

$$y = f(\overline{x_1}, \overline{x_2} \cdots\cdots \overline{x_n})$$

Control of evaluation of uncertainty

- The uncertainty evaluation procedure
  - Listed the calculate formulation of the uncertainty
  - Evaluate the uncertainty one by one

Control of evaluation of uncertainty

- A type uncertainty

(1). Calculate the σ of each measurement

$$\sigma = \sqrt{\frac{\sum_{1}^{n}(x_i-\bar{x})^2}{n-1}}$$

(2). Calculate the σ arithmetic mean of measurement values

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} = \sqrt{\frac{\sum_{1}^{n}(x_i-\bar{x})^2}{n(n-1)}}$$

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Example

Times	x_i (%)	υ_i (%)	Times	x_i (%)	υ_i (%)
1	0.42	0.016	9	0.40	0.004
2	0.43	0.026	10	0.43	0.026
3	0.40	0.004	11	0.42	0.016
4	0.43	0.026	12	0.41	0.006
5	0.42	0.016	13	0.39	-0.014
6	0.43	0.026	14	0.39	-0.014
7	0.39	-0.014	15	0.40	0.004
8	0.30	-0.104	Mean	0.404	

$$\bar{x} = \frac{\sum_{1}^{15} x_i}{15} = 0.404\%$$

$$\sigma = \sqrt{\frac{\sum_{1}^{15}(x_i-\bar{x})^2}{15-1}} = 0.033\%$$

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{15}} = 0.009\%$$

Control of evaluation of uncertainty

- Key points

A.If one test is not the routine test in the laboratory, then A type uncertainty should be evaluated along with the testing.

B.If the laboratory use the same equipment and same method, at the same conditions to conduct the normal test, there is no need to evaluate A type uncertainty at each test, but can use the value that evaluated before.

Control of evaluation of uncertainty

- If test m times for the customer, then the A type uncertainty is

$$u(x) = \frac{\sigma}{\sqrt{m}}$$

- If test 1 time for the customer, then the A type uncertainty is

$$u(x) = T \cdot \sigma = 1.06\sqrt{\frac{\sum_{1}^{n}\left(x_i - \bar{x}\right)^2}{n-1}}$$

T------t-distribution correction factor

If *k*=1, *n*=10, T=1.06;
If *k*=1, *n*=5, T=1.14;

T correction factor table

n	*k*=1	*k*=2	*k*=3	*n*	*k*=1	*k*=2	*k*=3
3	1.32	2.27		12	1.05	1.13	1.28
4	1.20	1.66	3.07	13	1.04	1.12	1.25
5	1.14	1.44	2.21	14	1.04	1.11	1.23
6	1.11	1.33	1.84	15	1.03	1.10	1.21
7	1.09	1.26	1.63	16	1.03	1.09	1.20
8	1.08	1.22	1.51	17	1.03	1.09	1.18
9	1.07	1.19	1.43	18	1.03	1.08	1.17
10	1.06	1.16	1.36	19	1.03	1.08	1.16
11	1.05	1.14	1.32	20	1.03	1.07	1.15

An example

Current Test: n=10, $s(x)$=0.074mA

Measured value

Times	1	2	3	4	5	6	7	8	9	10	Mean
Value (mA)	46.4	46.5	46.4	46.3	46.5	46.3	46.3	46.4	46.4	46.4	46.39

① n'=1, x'=46.3mA， Calculate - $u(x)$

$$u(x) = T \cdot s(x) = 1.06 \times 0.074 = 0.078mA$$

Test result: 46.3mA

An example

Current Test: n=10, $s(x)$=0.074mA

Measured value

Times	1	2	3	4	5	6	7	8	9	10	Mean
Value (mA)	46.4	46.5	46.4	46.3	46.5	46.3	46.3	46.4	46.4	46.4	46.39

② n'=3, $\bar{x} = \frac{45.4+45.3+45.5}{3} = 45.4$, Calculate - $u(x)$。

$$u(\bar{x}) = \frac{s(x)}{\sqrt{n'}} = \frac{0.074\text{mA}}{\sqrt{3}} = 0.043\text{mA}$$

Test result: 45.4mA

Control of evaluation of uncertainty

- Key points

C. If the testing times are too small, it will bring the uncertainty itself.

If the measurement system is stable, and it would not be able to increase the testing times at the same conditions, it could adopt the combination of standard deviations of the samples in order to obtain more reliable standard deviation for one measurement.

Control of evaluation of uncertainty

- An example

Testing *m* samples for *n* times of each, the combination variance $s_p^2(x_i)$ is the average of each sample's variance $s_j^2(x_i)$

$$s_p^2(x_i) = \frac{\sum_1^n s_j^2(x_i)}{m} \qquad s_j^2(x_i) = \frac{\sum_1^n (x_{ji} - \overline{x_j})^2}{n-1}$$

$$s_p^2(x_i) = \frac{1}{m(n-1)} \sum_{j=1}^{m} \sum_{ii=1}^{n} (x_{ji} - \overline{x_j})^2$$

$$u = \sqrt{\frac{s_p^2(x_i)}{n}}$$

Control of evaluation of uncertainty

- Key points

D. If there is an unexpected event or human error in the measurement process, an abnormal value may appear in the measurement column, and its presence will distort the measurement and should be removed. There are many ways to determine the outliers..

Control of evaluation of uncertainty

- **1.** Laiyin Da guidelines: If there is a maximum residual in the measurement column $|\upsilon_i| > 3\sigma$, the value is recalculated without this data

- **2.** Grubbs' Criterion: If there is a maximum residual in the measurement column $|\upsilon_i| > g(\alpha, n)\sigma$, the value is recalculated without this data

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Control of evaluation of uncertainty

- $g(\alpha, n)$, α significance level, σ standard deviation of one measurement

n	$g(\alpha,n)$ α=0.01	$g(\alpha,n)$ α=0.05	n	$g(\alpha,n)$ α=0.01	$g(\alpha,n)$ α=0.05	n	$g(\alpha,n)$ α=0.01	$g(\alpha,n)$ α=0.05
3	1.15	1.15	12	2.55	2.29	21	2.91	2.58
4	1.49	1.46	13	2.61	2.33	22	2.94	2.60
5	1.75	1.67	14	2.66	2.37	23	2.96	2.62
6	1.91	1.82	15	2.70	2.41	24	2.99	2.64
7	2.10	1.94	16	2.74	2.44	25	3.01	2.66
8	2.22	2.03	17	2.78	2.47	30	3.10	2.74
9	2.32	2.11	18	2.82	2.50	35	3.18	2.81
10	2.41	2.18	19	2.85	2.53	40	3.24	2.87
11	2.48	2.24	20	2.88	2.56	50	3.34	2.96

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An example

n	x_i (%)	υ_i (%)	n	x_i (%)	υ_i (%)
1	0.42	0.016	9	0.40	0.004
2	0.43	0.026	10	0.43	0.026
3	0.40	0.004	11	0.42	0.016
4	0.43	0.026	12	0.41	0.006
5	0.42	0.016	13	0.39	-0.014
6	0.43	0.026	14	0.39	-0.014
7	0.39	-0.014	15	0.40	0.004
8	0.30	-0.104	平均值	0.404	

σ: 0.033% υ_8 max

- **Laiyin Da guidelines:** $3\sigma = 0.099\%$ $\upsilon_8 > 3\sigma$, taking out 8, and recalculate the following 14 results, until there is no abnormal value
- **Grubbs' Criterion:** if α =0.05 $g(\alpha, n)$: 2.41,

$$g(\alpha, n) \cdot \sigma = 2.41 \times 0.033\% = 0.079\%$$

It still need to take out 8, and recalculate

Note: in each time, it can only take out one abnormal value. If the testing is too small, it would not use Laiyin Da guidelines.

Evaluation of A type uncertainty

	Steps	Formula
1	Correction of all measurement results	
2	Calculate the mean of the corrected measurement results. That is, the sum of the measured results after the correction divide the measurement times n	$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$
3	Calculate the residual of each measurement result, which means each measurement ... minus its average	$... = (x_i - \bar{x})$
4	Calculate the square sum fo... results, and then calculate the s... residuals and then divide n-1... called variance V.	$... x)^2 / n-1$
5	The positive square root gives the standard deviation of a set of measurements	$\sigma(x) = \sqrt{V} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$
6	Calculate the standard deviation of the mean Standard uncertainty synthesis	$u(x) = \frac{\sigma(x)}{\sqrt{n}} = \sqrt{\frac{\sum_{1}^{n}(x_i - \bar{x})^2}{n(n-1)}}$

If there is any abnormal results, it needs to be taken out

Control of evaluation of uncertainty

- B type uncertainty

Useful information

– Pervious testing data

– Relevant documents, and knowledge and experience on the equipment characteristics

– Specification or manual

– Calibration certificate or other technical documents

– Standard data and its uncertainty

– The repetitive or reproducible limits given by the testing method technical document

....

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Examples

Components	Distribution	Half-width a	Coverage factor k
Calibration certificate: U, p	Normal	U	k_p
Calibration certificate: U, k	Normal	U	k
Calibration certificate: U, p, ν	t	U	$t_p(\nu)$
Equipment Resolution: R	Evenly	$R/2$	$\sqrt{3}$
Repeatability limits of two measurements: r Reproducibility limits of two measurements: R	Normal Normal	$r/\sqrt{2}$ $R/\sqrt{2}$	2

Commonly used distribution, and relationship with *k* and *u*

Distributio n	p(%)	*k*	Uncertainty *u*
Normal t	99.73	3 $t_\rho(\gamma)$	$\alpha/3$ $\alpha/t_\rho(\gamma)$
Rectangle (even)	100	$\sqrt{3}$	$\alpha/\sqrt{3}$
Anti-sine	100	$\sqrt{2}$	$\alpha/\sqrt{2}$
Triangle	100	$\sqrt{6}$	$\alpha/\sqrt{6}$
Two points Trapezoid β = 0.71	100 100	1 2	α α

Control of evaluation of uncertainty

Example:

For a equipment, maximum allowable error is ±1%, and the errors of all the measured values located within [–0.01, +0.01] with the rectangular distribution

$$k = \sqrt{3}$$

a=0.01(1%)

Therefore

$$u(x_i) = \frac{a}{k} = \frac{1.0\%}{\sqrt{3}} = 0.58\%$$

Control of evaluation of uncertainty

- Synthetic uncertainty

If the measurement uncertainty has several components, the total uncertainty should be composed of all the uncertainty components (A type and B type) to synthesis, known as the synthetic uncertainty. The synthetic uncertainty is, given by the square root of the synthetic variance.

Control of evaluation of uncertainty

- Synthetic uncertainty

According to the mathematical model, it can list uncertainty component expression of input

$$u_i(y) = \left| \frac{\partial f}{\partial x_i} \right| u(x_i)$$

Control of evaluation of uncertainty

- **Evaluation of the direct measurement**

Direct measurement $y = x$ $u(y) = u(x)$

If $y = cx$, *c: constant* $u(y) = |c|u(x)$

C is the sensitivity coefficient, indicating that the contribution of x to the uncertainty of y is $|c|$ *times* 。

Control of evaluation of uncertainty

- **An example: Calibrating an energy meter with a standard energy meter**

According to the mathematic model $\gamma_H = \gamma_{WO}$

γ_H Related error of Energy meter --- output

γ_{WO} Related error of Standard Energy meter --- input

Uncertainty components of γ_{WO} includes:
① u_A;
② The error of standard energy meter u_{B1};
③ The resolution of standard energy meter u_{B2}。
u_A, u_{B1} and u_{B2} are independent

$$u_c(\gamma_{WO}) = \sqrt{u_A^2 + u_{B1}^2 + u_{B2}^2}$$

Control of evaluation of uncertainty

- **Evaluation of the indirect measurement**

  1) Inputs are not relevant

y is obtained by measuring the input

$$y = f(x_1, x_2 \ldots\ldots x_n)$$

$$u_a^2(y) = \sum_1^n \left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) = \sum_1^n c_i^2 u^2(x_i)$$

$\frac{\partial f}{\partial x_i}$ Uncertainty propagation coefficient or sensitivity coefficient, expressed as c. The meaning is change of y caused by the unit change of the input xi. If Ci is different, the contribution of each input xi to the y uncertainty is also different.

Control of evaluation of uncertainty

- **Evaluation of the indirect measurement**

  1) Inputs are not relevant

Calculate the each uncertainty value $u(x_i)$

then calculate c_i

then calculate

$$u_i(y) = |c_i| = \left|\frac{\partial f}{\partial x_i}\right| u(x_i)$$

i) **Rule 1**: if $y = c_1x_1 - c_2x_2$ use the absolute uncertainty $u(x_i)$

$$u^2(y) = c_1^2 u^2(x_1) + c_2^2 u^2(x_2)$$

Example: $y=(p-q+r)$，其中$p=6.02$， $q=6.45$， $r=9.04$;
$u(p)=0.13$, $u(q)=0.05$， $u(r)=0.22$.

Then $y=6.02-6.45+9.04=7.61$

$$u(y) = \sqrt{0.13^2 + 0.05^2 + 0.22^2} = 0.26$$

ii) **Rule 2**: if $y = \frac{x_1^2 x_2}{x_3}$, use the relative uncertainty $u_{rel}(y)$

$$u_{crel}^2(y) = 2^2 u_{1rel}^2(x_1) + u_{2rel}^2(x_2) + u_{3rel}^2(x_3)$$

- An example

$$\sigma = \frac{F}{A} = \frac{F}{\frac{1}{4}\pi d^2} = \frac{4F}{\pi d^2}$$

$$\frac{u_c(\sigma)}{\sigma} = \sqrt{\left(\frac{u(F)}{F}\right)^2 + \left(-2\frac{u(d)}{d}\right)^2} = \sqrt{\left[\frac{u(F)}{F}\right]^2 + 4\left[\frac{u(d)}{d}\right]^2}$$

Control of evaluation of uncertainty

- **Evaluation of the indirect measurement**
  2) Inputs are relevant

  y is obtained by measuring the input

$$y = f(x_1, x_2 \ldots\ldots x_n)$$

$$u_c^2(y) = \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\partial f}{\partial x_i}\cdot\frac{\partial f}{\partial x_j}\cdot u(x_i, x_j)$$

$$= \sum_{1}^{n}\left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{\partial f}{\partial x_i}\cdot\frac{\partial f}{\partial x_j}\cdot u(x_i, x_j)$$

$$r(x_i, x_j) = \frac{u(x_i, x_j)}{u(x_i)\cdot u(x_j)}$$

If r: Correlation coefficient

$$u_c^2(y) = \sum_{1}^{n}\left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{\partial f}{\partial x_i}\cdot\frac{\partial f}{\partial x_j}\cdot u(x_i)\cdot u(x_j)\cdot r(x_i, x_j)$$

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Control of evaluation of uncertainty

- **Evaluation of the indirect measurement**
  2) Inputs are relevant

If $y = x_1 + x_2$

Then $u_c^2 = u_1^2 + u_2^2 + 2u_1 u_2 \cdot r(1,2)$

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Control of evaluation of uncertainty

- **Evaluation of the indirect measurement**
  2) Inputs are relevant

Standard deviation $$u_c = \sqrt{u_1^2 + u_2^2 + 2u_1u_2 \cdot r(1,2)}$$

If r=0 $$u_c = \sqrt{u_1^2 + u_2^2}$$

If r=1 $$u_c = \sqrt{(u_1 + u_2)^2}$$

If r=-1 $$u_c = \sqrt{(u_1 - u_2)^2}$$

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Control of evaluation of uncertainty

- **Evaluation of the indirect measurement**
  2) Inputs are relevant

x, and x2 has been tested independently for n times, then the Covariance

$$u(\overline{x_1}, \overline{x_2}) = \frac{\sum_{1}^{n}(x_{1k} - \overline{x_1})(x_{2k} - \overline{x_2})}{n(n-1)}$$

and

$$r(\overline{x_1}, \overline{x_2}) = \frac{u(\overline{x_1}, \overline{x_2})}{u(\overline{x_1})u(\overline{x_2})}$$

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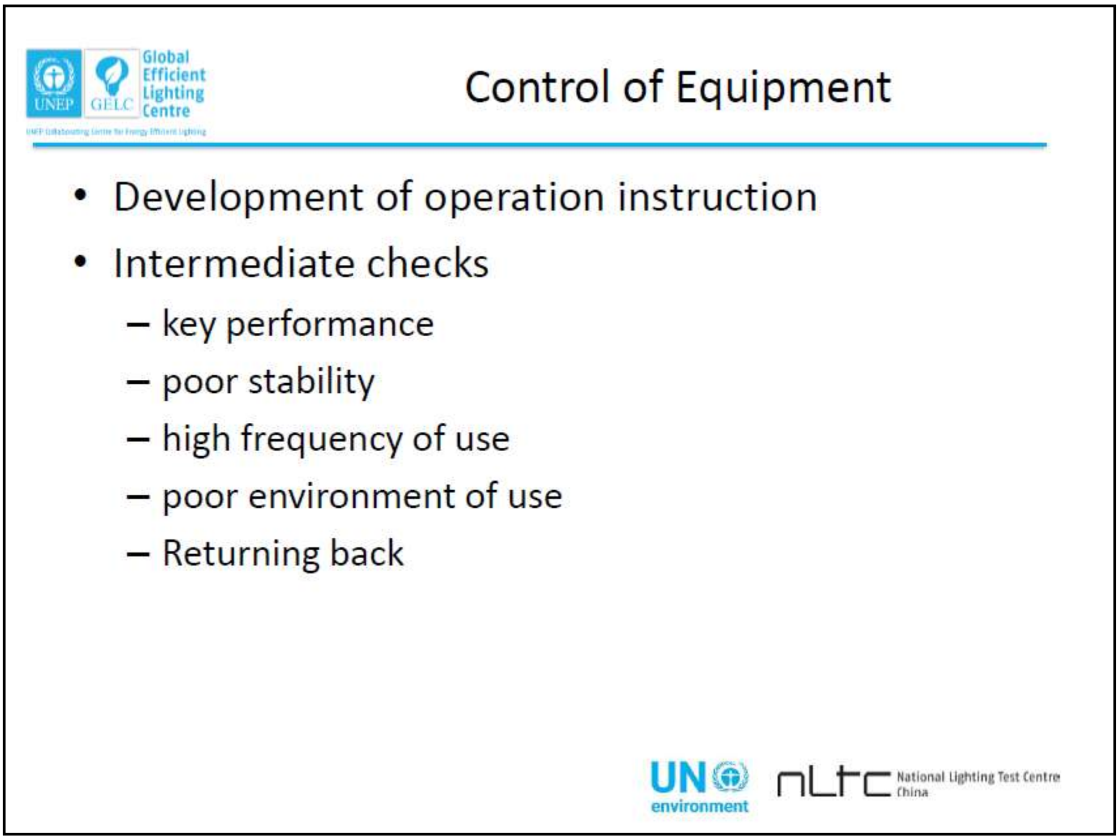
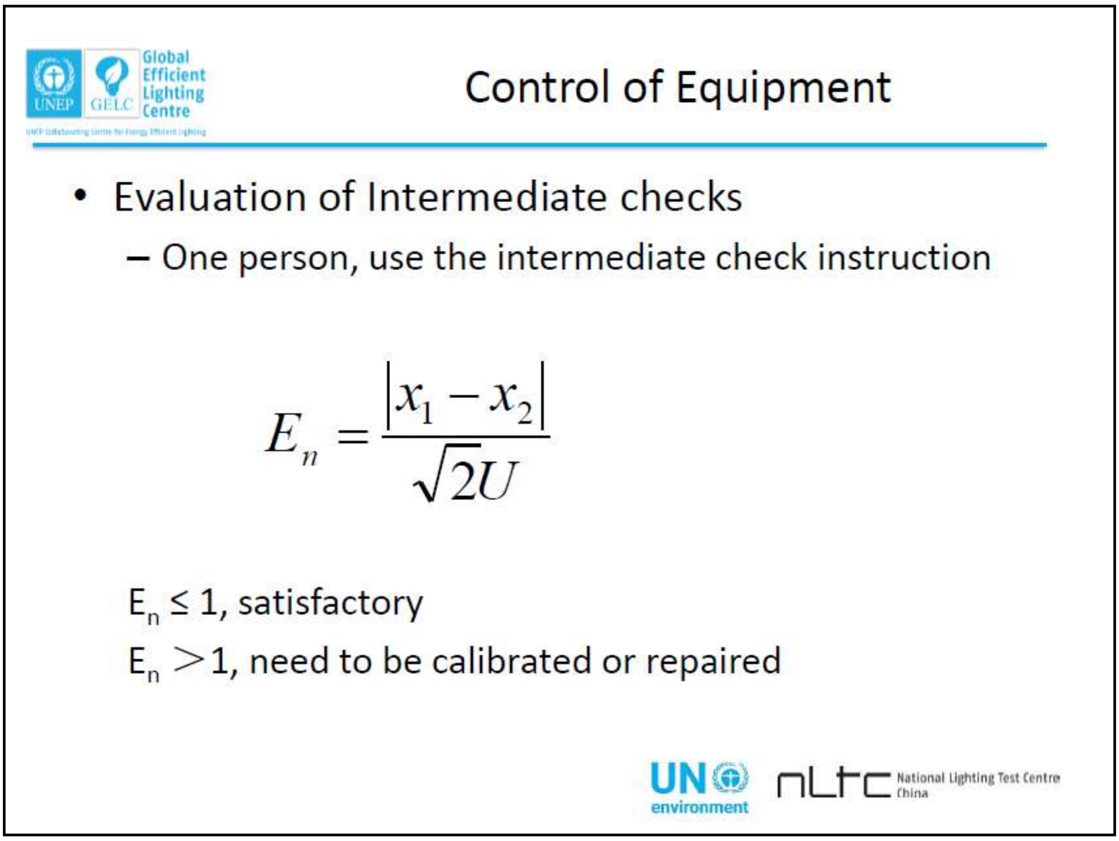
10.11 Control of Equipment





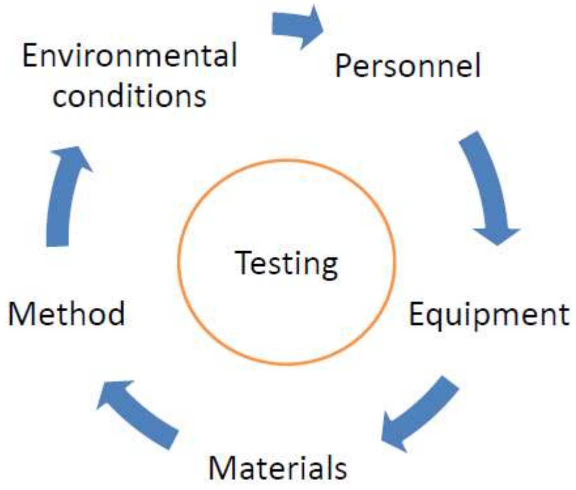
Control of Equipment

- Intermediate checks is not calibration, and can not replace calibration
- The period is not always the same, should be determined according to the usage frequency

10.12 Assuring the Quality of Testing Results

Assuring the quality of testing results

- The application of statistical process control



Consistent with the statistical laws of random phenomena

Assuring the quality of testing results

- 1. usage of control chats

  The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation

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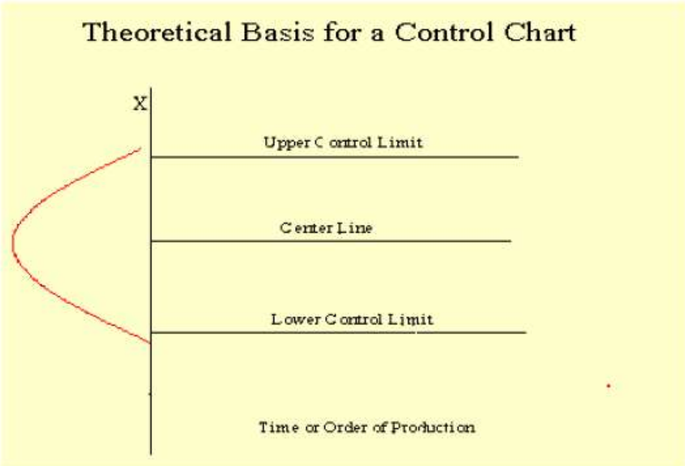
Assuring the quality of testing results

- 1. usage of control chats



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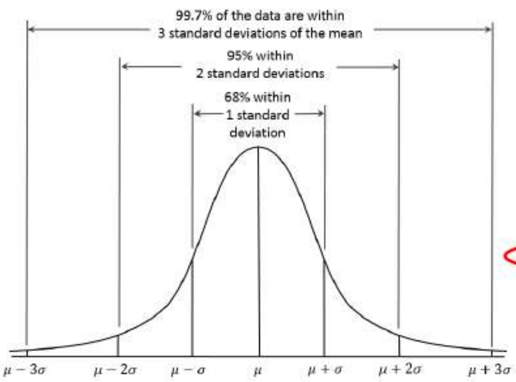
Assuring the quality of testing results



界限	界内概率	界外概率
±0.67σ	50.00%	50.00%
±1.00σ	68.26%	31.74%
±2.00σ	95.45%	4.55%
±3.00σ	99.73%	0.27%
±6.00σ	99.99966%	0.00034%

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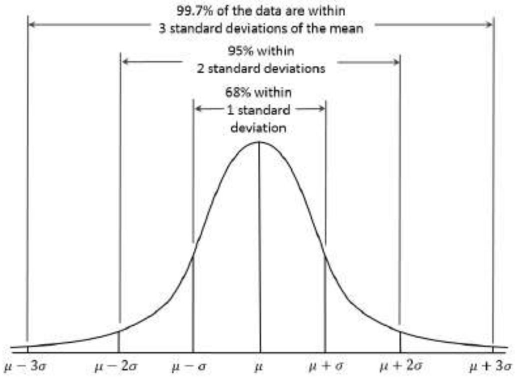
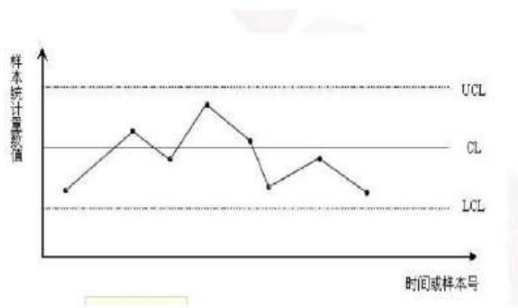
Assuring the quality of testing results

- 1. usage of control chats





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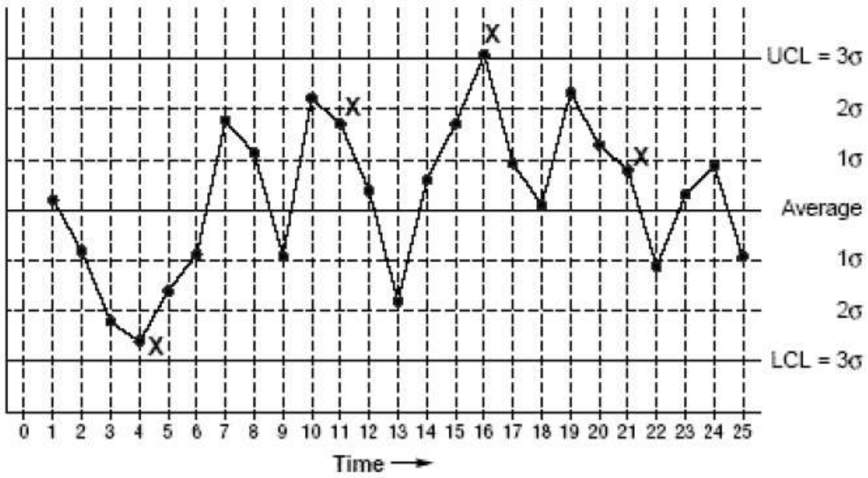
Assuring the quality of testing results



Control Chart: Out-of-Control Signals

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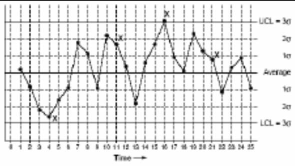

Assuring the quality of testing results

Out-of-control signals

- A single point outside the control limits. Point 16 is above the UCL (upper control limit).
- Two out of three successive points are on the same side of the centerline and farther than 2 σ from it. Point 4 sends that signal.
- Four out of five successive points are on the same side of the centerline and farther than 1 σ from it. Point 11 sends that signal.
- A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14 or 16 out of 20. Point 21 is eighth in a row above the centerline.
- Obvious consistent or persistent patterns that suggest something unusual about your data and your process.

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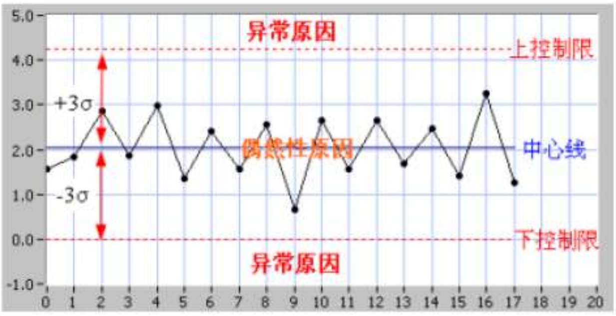

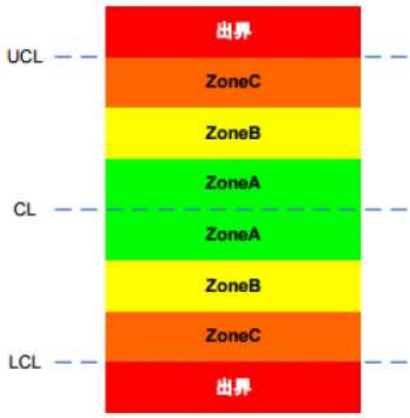

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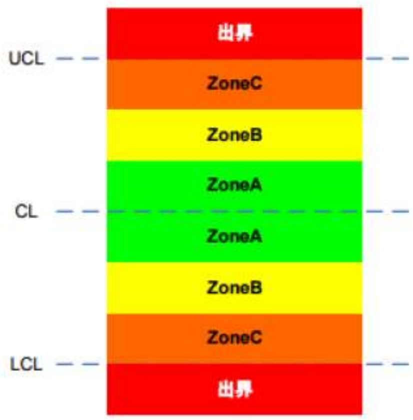
Assuring the quality of testing results



Out of control

1. One point outside the control limits
2. Continuous chain appears, means, more than 7 consecutive points located in one side of the central line;
3. Intermittent chain appears, means, most of the points located in the same side of the central line;
4. Tendency appears, means, 6 consecutive points located as a trend of increasing or decreasing;
5. Periodicity appears, means, the ups and downs are staggered
6. These phenomena are events with a probability less than 0.27%, and a small probability event occurs, indicating that the process is abnormal.

Assuring the quality of testing results

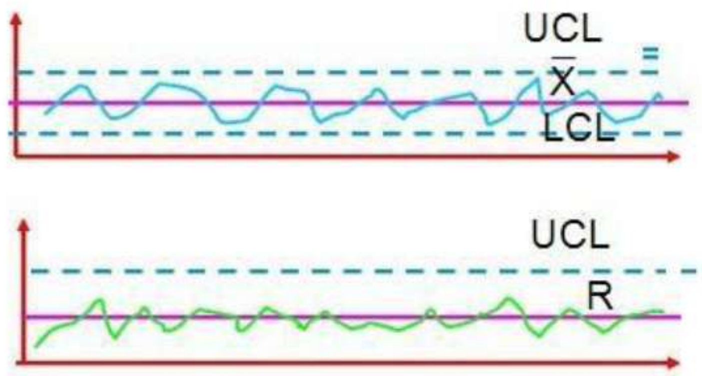
- Xbar-R Control Chart
- Xbar-s Control Chart

$\overline{X}$-R control chart

- Xbar-R control chart is the basic but widely used control chart
- Used for small sample size (normally no more than 9)
- Xbar chart is used for controlling the mean (average） value
- R (Range) chart is used for controlling the dispersion

$\overline{X}$-R control chart

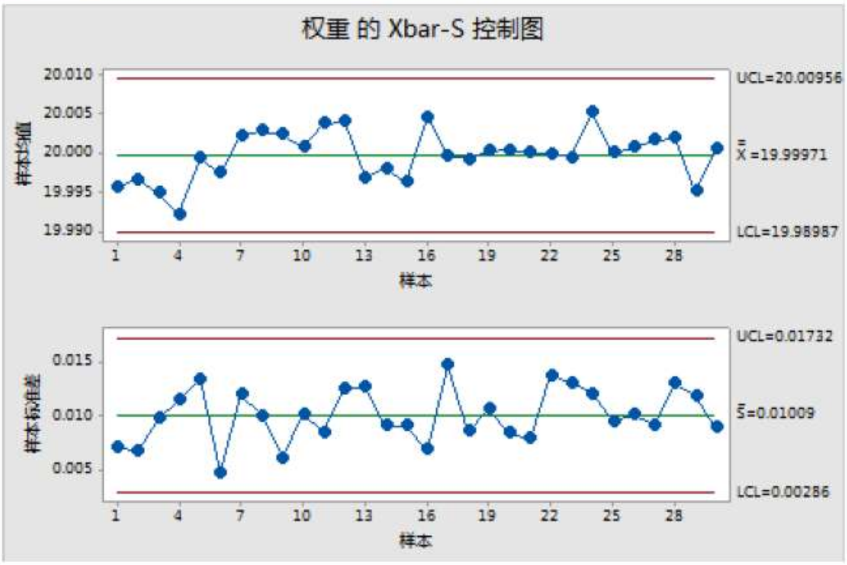
An example



$\overline{X}$-s control chart

- Similar like Xbar-R Chart, while use s (standard deviation) instead of R
- Sample size (normally no less than 9)
- Xbar chart is used for controlling the mean (average） value
- s chart is used for controlling the dispersion

$\overline{X}$-s control chart



Assuring the quality of testing results

- 2. Participating PT

  Proficiency testing determines the performance of individual laboratories for specific tests or measurements and is used to monitor laboratories' continuing performance.

  The results of PT is one of the most important inputs

Assuring the quality of testing results

- Evaluation of PT results

  The z-score is calculated for all testing results, and is determined by:

$$z = \frac{x - X}{\hat{\sigma}}$$

is Standard Deviation for Proficiency Assessment (SDPA value), determined as nIQR (normalized interquartile range),

$$nIQR(x) = 0.7413 \times (Q_3(x) - Q_1(x))$$

Q1(x): the 25th percentile of xi (i=1,2, ...p);
Q3(x): the 75th percentile of xi (i=1,2, ...p);

z|≤2.0 satisfactory;
2.0 <|z-score|< 3.0 questionable;
|z-score| ≥ 3.0 unsatisfactory

Assuring the quality of testing results

3. Inter-laboratory comparison test
   - Ensure the capacity of specific testing and monitor laboratories' continuing performance
   - Identify the potential problem and conduce the corrective actions, for example the operation of personnel, or calibrations
   - Validate the test method
   - Increase the confidence of the consumer
   - ……

Assuring the quality of testing results

- The differences between Proficiency testing and inter-laboratory comparison test
  - The purpose is different
  - The organizer is different
  - Evaluation method
  - Confidential consideration

Assuring the quality of testing results

4. Repetitive testing
   - Using same method
   - Using different methods

Assuring the quality of testing results

- Using same method

$$\frac{|x_1 - x_2|}{\sqrt{U_1^2 + U_2^2}} = \frac{|x_1 - x_2|}{\sqrt{2}U} \leq 1$$

Assuring the quality of testing results

- Using different methods

$$\frac{|x_1 - x_2|}{\sqrt{U_1^2 + U_2^2}} \leq 1$$

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Assuring the quality of testing results

4. Re-test on the retained sample

$$\frac{|x_1 - x_2|}{\sqrt{U_1^2 + U_2^2}} = \frac{|x_1 - x_2|}{\sqrt{2}U} \leq 1$$

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11. Main Changes in ISO/IEC DIS 17025

Introduction

- Initialed in February 2015
- Published ISO/IEC DIS 17025 in December 2016
- Plan to publish ISO/IEC FDIS 17025 in Autumn 2017

Structure of ISO/IEC DIS 17025

Forward
Introduction
1. Scope
2. Normative references
3. Terms and definitions
4. General requirements
4.1 Impartiality
4.2 Confidentiality
5. Structure requirements

Structure of ISO/IEC DIS 17025

6. Resource requirements

6.1 General

6.2 Personnel

6.3 Accommodations and environmental conditions

6.4 Equipment

6.5 Measurement Traceability

6.5 Purchasing services and suppliers

Structure of ISO/IEC DIS 17025

7. Process requirements

7.1 Review of requests, tenders and contracts

7.2 Selection of methods and method verification and validation

7.3 Sampling

7.4 Handling of test and calibration items

7.5 Technical records

7.6 Estimation of uncertainty of measurement

Structure of ISO/IEC DIS 17025

7.7 Assuring the quality of test and calibration results

7.8 Reporting the results

7.9 Complaints

7.10 control of nonconforming testing and/or calibration work

7.11 Control of records- information management

Structure of ISO/IEC DIS 17025

8. Management requirements

8.1 Approaches

8.2 Management system documents

8.3 Control of management system documents

8.4 Control of records

8.5 management measures on risk and opportunities

8.6 Improvement

Structure of ISO/IEC DIS 17025

8.7 Corrective actions

8.8 Internal audit

8.9 management review

Annex A (informative) Traceability

Annex B (informative) management system

Reference

Main changes

- The statement of "relationship with ISO 9001"
  - It deletes the "relationship with ISO 9001" statement in the Introduction and Clause 1.6.
  - Only keep the sentence "Testing and calibration laboratories that comply with this International Standard will therefore also operate in accordance with ISO 9001"
  - Fully considered the requirements of the ISO/IEC 9001:2015, especially for the management requirements

Main changes

- The statement of "relationship with ISO 9001"
  - In the Annex B, it was explained the relationship of 17025 and 9001
  - Keep the sentence "Conformity of the quality management system within which the laboratory operates to the requirements of ISO 9001 does not of itself demonstrate to the competence of the laboratory to produce technically valid data and results" in Annex B

Main changes

- Simplify the Scope
  - Delete "1.5 Compliance with regulatory and safety requirements on the operation of laboratories is not covered by this International Standard"
  - Delete the description of first-, second- and third-party, but only make it clear that this International Standard is applicable to all organizations performing testing and/or calibrations, regardless of the number of personnel

Main changes

- Simplify the Scope
  - Delete "This International Standard is not indented to be used as the basis for certification of laboratory"(1.4)
  - Delete "1.3 The notes given provide clarification of the text……."
  - Delete the explanation of 1.2 "such as sampling and the design/development of new methods, the requirements of those clauses do not apply"

Main changes

- Normative reference
  - Only keep the VIM (according to the ISO new requirement, all the referenced ISO standards will all put into the Bibliography

Main changes

- Added Terms and definitions
  - There is no terms in the ISO/IEC 17025:2005
  - In the ISO/IEC DIS it has added the terms
    - Impartiality
    - Compliant
    - Inter-laboratory comparison test
    - Proficiency test
    - Laboratory (Laboratory activity)
    - Decision rule

Main changes

- Impartiality and confidentiality requirement
  - In the ISO/IEC 17025:2005, the requirements of impartiality and confidentiality are principal and simple
  - In the ISO/IEC DIS 17025:

    4.1 Impartiality

    4.2 Confidentiality

Main changes

- Structure requirement
  - The structure requirements are mainly from Clause 4.1 in ISO/IEC 17025:2005
    - Cancel the title "Quality management" and "Quality Manager" (only emphasize the their position's functions, no matter what the titles they have
    - Add "The laboratory shall make any laboratory activity documental that apply to this Standard"
    - Delete the "appoint deputies for key managerial personnel" (not a mandatory requirement)
    - Move the supervision requirement of personnel to Clause 6.2 Personnel

Main changes

- Personnel requirement (simplified and combined)
  - Delete the description of the supervision to the under training personnel
  - Not use the word "employed by or under contract to the laboratory" (as in may have different understanding in different countries)
  - Delete the note 1 and note 2 of 5.2.1 in ISO/IEC 17025:2005
  - Simplified the training requirements, it only requires the laboratory clearly specifies the training requirements of each position that will affect the results, and keep the records. It deletes some detailed requirements, such as training procedure, training plan and evaluation of the effectiveness of the training.

Main changes

- Personnel requirement (simplified and combined)
  - Delete the 5.2.4 note of ISO/IEC 17025:2005 Job description (the job description will be defined by the laboratory according to its own situation)

Main changes

- Accommodation and environmental conditions
  - There is no significance difference, but with more refined language, and states clearly the regular evaluation of the accommodation control measures.
  - Delete the housekeeping requirements

Main changes

- Equipment requirement
  - There is no significance difference, but made the necessary simplification.
  - Main changes:
    - Make it more clear that the equipment does not include measurement instrument, but also software, reference materials, reference data, consumable materials and other support device.
    - Use the work "Verification" instead of "Check/calibration" before use.
    - Delete the authorization of using the equipment (as it has been stated in Clause 6.2)

Main changes

- Equipment requirement
  - Main changes:
    - Make it clear to review the calibration plan, and do any necessary adjustment if necessary
    - It only requires the calibration mark and be identified the calibration status or valid period
    - In the equipment record, it delete the manual from manufacturer (as this is an external document, not a record)
    - In the equipment record, it add the requirements of reference materials (record of date, results, document, acceptable criteria, valid period)

Main changes

- Equipment requirement
  - Main changes:
    - Delete the 5.5.4 of ISO/IEC 17025:2005 (as this has been required in 6.4.9b)
    - Intermediate checks apply to all the equipments (not only for the calibrated equipments)
    - Delete the 5.5.9 of ISO/IEC 17025:2005 (in 6.4.2 of DIS, has been covered)
    - Add the selection requirements of reference materials

Main changes

- Measurement traceability requirement
  - Simplify the content, and the put the explanation into the Annex A
  - It does not require separately for the testing and calibration laboratory, but emphasize the traceability of the results
  - Delete 5.6.1 of ISO/IEC 17025:2005 the requirement of equipment calibration and calibration plan (as it has been covered in Clause 6.4)

Main changes

- Measurement traceability requirement
  - For the 5.6.2.1.2 of ISO/IEC 17025:2005 "……establishing traceability to appropriate measurement standards……", it make give more clear description of measurement standards that shall be acceptable by authorized organization, and give an example of authorization organization.

Main changes

- Purchasing services and supplies
  - Combine the Clause 4.6 and Clause 4.5 of ISO/IEC 17025:2005 into one Clause, and some content of Clause 4.5 moved into Review of requests, tenders and contracts
  - There are two parts, one is for supporting the laboratory operation, one is for providing to customers directly (subcontracting)
  - Except the evaluation to the suppliers, it also requires to monitor and re-evaluate, and take necessary measures according to the monitoring and re-evaluation results.

Main changes

- Review of requests, tenders and contracts
  - In the DIS version, this covers the Clause 4.4, 4.5 and 4.7 of ISO/IEC 17025:2005
  - New add content
    - The deviation requested by the customers shall not affect the integrity of laboratory or integrity of the results
    - If the customer requires to give evaluation to the results, it should define clearly on the reference standard and decision rule.

Main changes

- Testing methods and method validation
  - Generally the same as the Clause 4.4 of ISO/IEC 17025:2005
  - Main changes:
    - Modification method development plan shall be approved and authorized
    - Specify the contents to be included in the method validation record
    - Delete the recommendation on contents to be included in the testing or calibration method

Main changes

- Sampling
  - Main changes:
    - Sampling record shall include date, and time as necessary, and relevant data of the sample, for example: identification number, quantity and name
    - Delete the customer's deviation requirements from the sampling procedure

Main changes

- Handling of test and calibration items
  - Added: when custom knows the sample has deviations from the specified conditions, and insists to conduct the test or calibration, the laboratory shall state the disclaimer in the test report, and indicate that the results may be affected.

Main changes

- Technical record
  - Considered that there are more and more laboratories use the automatic equipments and information management system, it may be flexible for the data amendment. It is not to do the "crossed out", but to keep the original data or observations, and show the alterations and signed or initialed by the person making the correction

Main changes

- Evaluation of uncertainty
  - It does not need to have the procedure of evaluation of uncertainty, but requires to evaluate the measurement uncertainty
  - It is added the notes for the evaluations
  - The DIS version firstly proposes the uncertainty evaluation for sampling

Main changes

- Assuring of quality of test and calibration results
  - Non significant change
  - Expressed by internal quality control and external quality control
    - For internal quality control, it adds some measurement: the function check of the equipment, intermediate check of equipment, review of the testing data, comparison test inside of the laboratory, blind sample test, etc.
    - For external quality control, it emphases the programme and evaluation

Main changes

- Reporting the results
  - All the reports shall be recorded as technical records
  - It makes clear that laboratory shall take the responsibility of all information in the report or certificate, except those information provided by the customer. The information provided by the customer shall be identified clearly, and if those information may affect the test results, it should make a disclaim in the test report

Main changes

- Reporting the results
  - The language changing regarding the test report content:
    - Use contact information instead of customer address
    - When this is very important to the validness or application of results, except the receiving sample date, it may also need to include the sampling date
    - It does not need to give the title/position of authorized signatory, but it requires to identify the signatory clearly
    - Add the issuing date of the test report

Main changes

- Reporting the results
  - For the sampling report, it requests to include the uncertainty information
  - Delete “when a calibration has been subcontracted, the laboratory performing the work shall issue the calibration certificate to the contracting laboratory”
  - It requests the laboratory to consider the risk of Declaration of Conformity, it shall make it documental of decision rule.

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Main changes

- Reporting the results
  - The opinions and interpretations shall be based on the results.
  - For the amended report, it shall state the amendment information
  - Delete the electronic transmission requirement in Clause 5.10.7 of ISO/IEC 17025:2015
  - Delete the test report format requirement in Clause 5.10.8 of ISO/IEC 17025:2015

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Main changes

- Complaints
  - Significant changes in Complaints
  - It gives clear requirements on each step from deal with the complaint, evaluate the complaints, decisions of complaints and inform the Complainant
  - Based on ISO/CASCO

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Main changes

- Control of nonconforming testing and/or calibration work
  - Almost the same as the Clause 4.9 of ISO/IEC 17025:2005

Main changes

- Data control
  - Comprehensive requirements
  - Most are from ISO 15189:2012

Main changes

- Management requirement
  - Most are from ISO 9001:2015
  - Give two ways: one is A (the laboratory does not establish ISO 9001 management system), another is B (the laboratory has established ISO 9001 management system)
  - Add Clause 8.5, introduce the risk and opportunity management requirement
  - Delete the detailed contents included in distribution of controlled documents, amendment of documents, and document identification

Main changes

- Management requirement
  - Delete the preventive actions, and incorporate it into the improvement
  - Delete the recommended internal audit period, and more the requirements of training and qualification of internal auditor to Personnel requirement.
  - Delete "the internal audit programme shall address all elements of the management system, including the testing and/or calibration activities"

Main changes

- Management requirement
  - Delete "it is the responsibility of the quality manager to plan and organize audits as required by the schedule and requested by management"
  - Delete the requirement of auditor shall be independent of activities to be audited
  - Delete the additional audit
  - Delete the recommendation of management review period
  - Give detailed requirements to the output of management review

Main changes

- Management requirement
  - There are no substantive changes for corrective actions and improvement, but there are some changes on the expressions.

12. Information Sharing on Laboratory Accreditation

ISO 17025 for Laboratory Accreditation

- ISO 17025 Certification ISO/IEC 17025 is the global quality standard for testing and calibration laboratories. It is the basis for accreditation from an accreditation body.
- There are two main clauses in ISO 17025 – Management Requirements and Technical Requirements. Management requirements are related to the operation and effectiveness of the quality management system within the laboratory. Technical requirements address the competence of staff; testing methodology; equipment and quality; and reporting of test and calibration results.

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ISO 17025 for Laboratory Accreditation

- Accreditation is an objective way to assure that you have demonstrated technical competence to provide reliable and accurate test results.
- Accreditation is objective because an independent, third party accreditation body performs annual assessments to verify whether your system is meeting all of the requirements of ISO/IEC 17025. This independent evaluation is important, because it is an unbiased guarantee that your laboratory is performing at its highest level.

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ISO 17025 for Laboratory Accreditation

- The accreditation body is responsible for assessing the quality system and technical aspects of your system to determine your compliance to the requirements of ISO/IEC 17025. It is the accreditation body that ultimately decides whether or not a laboratory is complying with the standard.

4

ISO 17025 for Laboratory Accreditation

- Time require achieving ISO 17025 Accreditation Typically, it takes a laboratory six months to one year to prepare for the accreditation assessment. The assessment itself, from the day of closure of any applicable non conformances to the issuance of a certificate, takes approximately 8 weeks to complete. This includes Executive Committee review and administrative time required for paperwork and approval.

5

About ILAC

- ILAC is the international organization for accreditation bodies operating in accordance with ISO/IEC 17011 and involved in the accreditation of conformity assessment bodies including calibration laboratories (using ISO/IEC 17025), testing laboratories (using ISO/IEC 17025), medical testing laboratories (using ISO 15189) and inspection bodies (using ISO/IEC 17020)..

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About ILAC

- The regional arrangements are managed by the recognized regional co-operation bodies that work in harmony with ILAC and IAF. The recognized regional co-operations are also represented on the ILAC and IAF Executive Committees. ILAC works closely with the regional co-operation bodies involved in accreditation, notably IAAC in the Americas.

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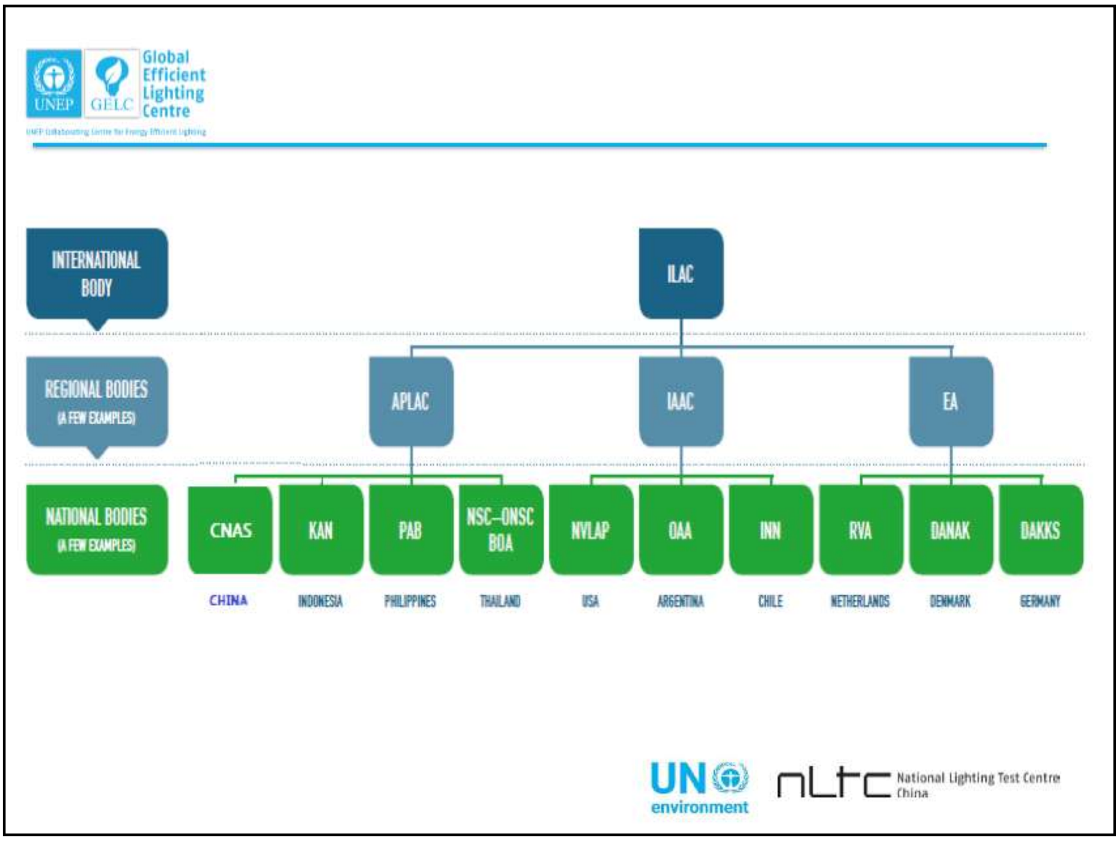
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INTERNATIONAL BODY
REGIONAL BODIES (A FEW EXAMPLES)
NATIONAL BODIES (A FEW EXAMPLES)
ILAC
APLAC
IAAC
EA
CNAS
KAN
PAB
NSC–ONSC BOA
NVLAP
OAA
INN
RVA
DANAK
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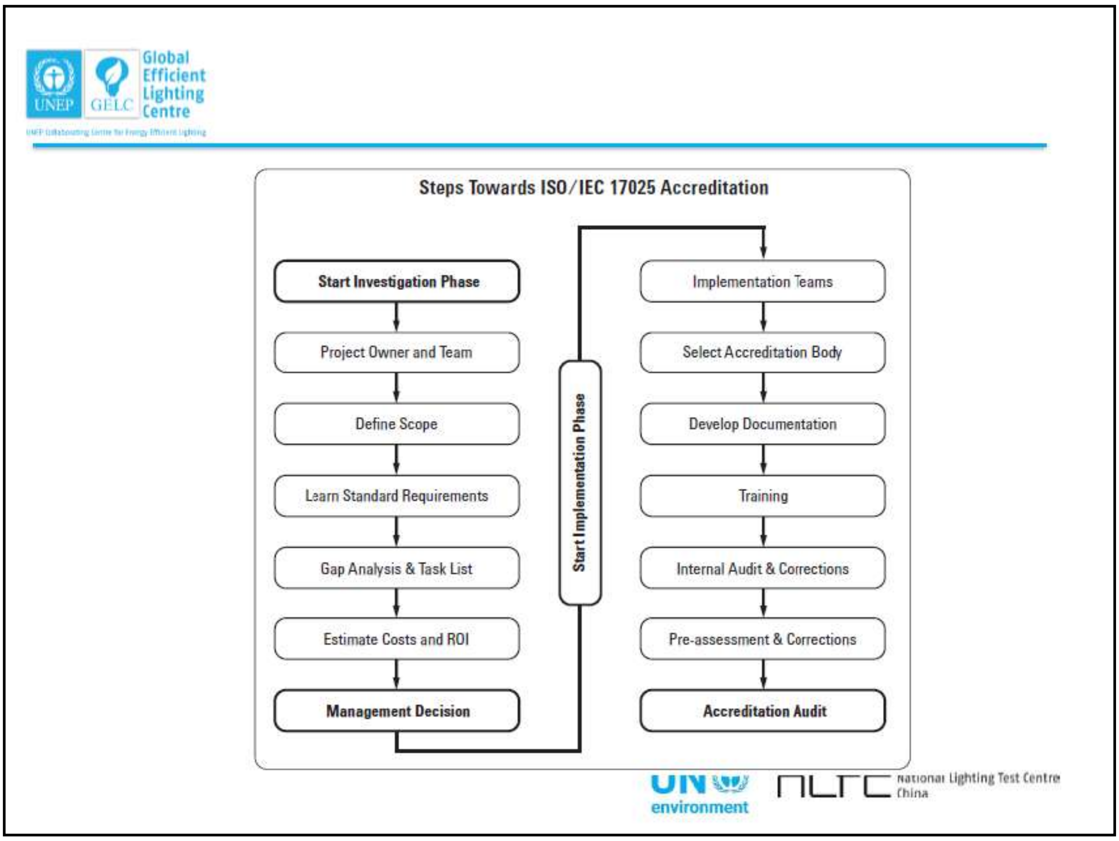
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Steps Towards ISO/IEC 17025 Accreditation
Start Investigation Phase
Project Owner and Team
Define Scope
Learn Standard Requirements
Gap Analysis & Task List
Estimate Costs and ROI
Management Decision
Start Implementation Phase
Implementation Teams
Select Accreditation Body
Develop Documentation
Training
Internal Audit & Corrections
Pre-assessment & Corrections
Accreditation Audit
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CNAS Laboratory Accreditation Process

Accreditation Rules

- **CNAS-R01 Rules for the Use of Accreditation Symbols and for Claims of Accreditation Status**
- **CNAS-R02 Rules for Impartiality and Confidentiality**
- **CNAS-R03 Rules for Dealing with Appeals,. Complaints and Disputes**
- **CNAS-RL01 Rules for the Accreditation of Laboratory**
- **CNAS-RL02 Rules for Proficiency Testing**
- **CNAS-RL03 Rule for Accreditation Fees For Laboratories and Inspection Bodies**
- **CNAS-RL04 Rules for Accepting Application from Overseas Laboratories and Inspection Bodies**

Accreditation Criteria

- CNAS-CL01 General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025: 2005)
- CNAS-CL06 Requirements for Measurement Traceability
- CNAS-CL07 Requirements for Measurement Uncertainty.
- CNAS-CL11 Guidance on the Application of Laboratory Accreditation Criteria in the Field of Electrical Testing
- CNAS-CL52 Application ofCNAS-CL01 <Accreditation Criteria of the competence of testing and calibration laboratories>

Accreditation Process

Step 1
Establishment of quality management system and running effectively

Step 2
Submission of application form and related documents

Step 3
Application document review by the secretariat and make acceptance decision

Step 4
Application document review by the auditor team and determine the on-site assessment

Step 5
On-site assessment

Step 6
Non-conformity rectification and acceptance

Step 7
Evaluation, approval, and issue the certificate

Step 8
Supervision and re-assessment

Step 1 Establishment of quality management system and running effectively

- Establishment of quality management system
  - Quality management system document should be completed, and systemic and coordinated;
  - organization structure and responsibilities are clear;
  - quality activities are under control;
  - quality management system can running effectively;
  - Process control is completed;
  - support service elements are effective

Step 1 Establishment of quality management system and running effectively

- Establishment of quality management system
  - Take into account of the accreditation criteria when developing the quality management documents;
  - There is no inconsistent among the different level documents
  - The quality management system shall cover all the places of testing activities
  - The laboratory management system shall formally and effectively running for at least 6 months

Step 1 Establishment of quality management system and running effectively

- Establishment of quality management system
  - Take into account of the accreditation criteria when developing the quality management documents;
  - There is no inconsistent among the different level documents
  - The quality management system shall cover all the places of testing activities

Step 1 Establishment of quality management system and running effectively

- The laboratory management system shall formally and effectively running for at least 6 months
  - For the new laboratory, it would need the pre-running, internal audit and management review, to make adjustments and improvements to the management system, and then to start running formally
  - Effectively running, means, all the elements in the quality management system are running and it keep all the related records.

Step 2 Submission of application form and related documents

- Application
  - Download the application form
  - Complete the application form and prepare all the required documents
  - Submit all the application documents online, and mail the hard copies to the CNAS
  - Pay the application fee

Step 3 Application document review by the secretariat and make acceptance decision

- Acceptance decision
  - The CNAS secretariat check the integrity of the application documents
  - Check the legal status
  - Check the effectiveness of the quality management system
  - Check the PT experience
  - Check the resources of conducting the testing activities

Step 3 Application document review by the secretariat and make acceptance decision

- Acceptance decision
  - Check the traceability of the equipments
  - Check the testing experience
  - Check the competence of the laboratory

Step 3 Application document review by the secretariat and make acceptance decision

- Initial assessment
  - It cannot ensure if the applicant meet the acceptance conditions by the submitted documents; or unsure if the laboratory has relevant equipments, accommodations
  - It cannot ensure the application scope by the submitted documents
  - It cannot ensure if the applicant agree to conduct the assessment within 3 months

Step 3 Application document review by the secretariat and make acceptance decision

- Acceptance decision
  - Before the CNAS secretariat makes the decision, they will inform the applicant any problems they find
  - The laboratory shall provide written responds to the CNAS secretariat for each problem found in the review concerning their actions or measures within 2 months
  - Submit the rectification documents within 3 month after the written responds

Step 4 Application document review by the auditor team

- Document review
  - The compliance of Quality management system
  - Application documents
  - The compliance of application scope, personnel, equipments, traceability, PT, test reports
  - If there is non-conformity found, the CNAS secretariat or the leader of the auditor team will inform the applicant in written, to take any corrective actions

Step 4 Application document review by the auditor team

- After review, suggestions from auditor
  - Implement pre-assessment
  - Implement on-site assessment
  - Suspense on-site assessment
  - Do not implement on-site assessment

Step 4 Application document review by the auditor team

- Pre-assessment
  - Pre-assessment is an assessment, this is for clarifying the questions or problems found in the document review

Step 5 On-site assessment

- On-site assessment
  - On-site assessment will be conducted in the place that under accreditation
  - The on-site assessment date will agreed by the auditor team and the laboratory; the days will be depend on the application scope
  - Sometimes, the CNAS will arrange an observer
  - The audit tem develop the assessment agenda and get agreement by the laboratory

Step 5 On-site assessment

- On-site assessment
  - On-site assessment starts by the opening meeting, which is moderated by the leader of audit team
  - Audit team and laboratory personnel participate the opening meeting
  - During the on-site assessment, the audit team will summarize and inform the laboratory every day
  - Before the closing meeting, the audit team will communicate with the laboratory of the general results

Step 5 On-site assessment

- On-site assessment
  - During the on-site assessment, the auditor team will confirm each of technical capability that laboratory applies
  - The auditor team will arrange the on-site testing according to the application scope (items/parameters, equipments, testing methods, technicians, samples)
  - Evaluation of the authorized signatory
  - On-site assessment is closed by the closing meeting
  - The conclusion of the on-site assessment is the recommendations to CNAS

Step 6 Non-conformity rectification and acceptance

- Non-conformity rectification period
  - Initial assessment: 3 months
  - Supervision assessment: 2 months
  - Re-assessment: 2 months
- On-site verification
  - Related to the effective of the test results, or the integrity of laboratory
  - Environmental conditions (can correct in a short time)
  - Equipment failure (can correct in a short time)
  - Personnel competence (can correct in a short time)
  - Cannot ensure from the written document

Step 6 Non-conformity rectification and acceptance

- Corrective actions
  - For all the non-conformities, the laboratory should correct and do the cause analysis, develop the corrective actions
  - The conclusions of on-site assessment may amended according to the rectification results

Step 7 Evaluation, approval, and issue the certificate

- Evaluation
  - The on-site assessment report will reviewed by CNAS, and decide the conclusion
- Approval
  - The CNAS secretariat will approve and issue the certificate if CNAS accepts and approves.
  - The validity period accreditation certificate is normally six years

Step 8 Supervision and re-assessment

- Supervision
  - Within 12 months after the laboratory obtains the accreditation certificate
  - On-site assessment is requested
- Re-assessment
  - Within 24 months and 48 months after the laboratory obtains the accreditation certificate
  - The application procedure is the same as initial application

Step 8 Supervision and re-assessment

- Expand accreditation scope
  - The application procedure is the same as initial application
  - Only answer the expand related question in the form
- Amendment of accreditation scope
  - Inform CNAS, if any changes in the name, address, organizations, technical capabilities
  - Can conduct at the same time of supervision or re-assessment

13. Lamp Testing Guide

13.1 Preparations for Lamp Testing

Before testing, preparation work should be done to make sure the testing process conduct fluently. This part will describe preliminary work for the testing, such as requirements of the test engineer, the equipment, environmental conditions and so on.

13.1.1 Testing standards preparation

Before testing, tester should confirm the lamp type and the relevant standards.

13.1.2 Testing environment preparation

Air movement, ambient temperature

It would need to make sure the test room air is free from smoke, dust and high humidity. Monitoring the air temperature around the lamp to maintain it at 25±1℃ or otherwise specified. The measurement point should not be more than 1 meter from the lamp and at the same height as the lamp. Air movement for CFL lamp testing usually should not exceed 5m/min, for LED lamp testing usually suggested not exceeding 0.2m/s. It normally requires that the air flow around the lamp is normal convective air flow, vibration or shock of the lighting products are not allowed.

13.1.3 Test equipment preparation

1) Equipment requirement

Check the integrity of the testing system

Electrical testing equipment: power supply, power meter (ampere meter and voltmeter);
Photometric and colorimetric testing equipment:

- Integrating sphere systems
- Sphere-spectroradiometer
- Goniophotometer
- Gonio-spectroradiometer

Make sure the accuracy index of the testing equipment conforms to the requirements of performance testing

It would need to check the specification or the calibration certificate of the equipments, in order to make sure all the equipment accuracy index used in testing conforms to standards. For example, harmonic distortion of the power supply should be less than 3%, and the calibration uncertainties of the power meter should be less than 0.2% if used to test a light emitting diode (LED) lamp.

Make sure all the testing equipment to be calibrated

In order to check and monitor the reliability or accuracy of the testing results, laboratory should have all the testing equipments calibrated by a National Measurement Institute (NMI).

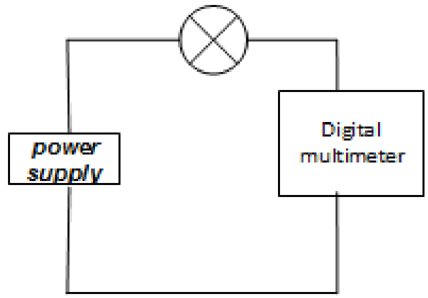
2) Equipment installation

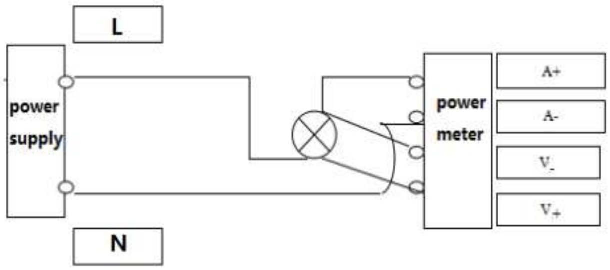
Temperature monitor

It would need to make sure the thermometer is installed no more than 1 meter from the testing position of the lamp and at the same height as the testing position.

Testing system

It would need to make sure the circuit and interface of the testing system are installed correctly and safely. The following graphs are the referenced testing schematic diagram and the testing circuit.





a) Schematic diagram b) Testing circuit

Fire and electrical safety and protection of testers

Equipments used in the laboratory should be checked and maintained regularly. In order to ensure human and equipment safety during testing, equipment grounding protection system and electric leakage protection system should be reliable and be always on the safe side. The measurement of grounding resistance is of great importance for safe operation of power system and electronic equipment. Laboratory should be equipped with safety protection measures and tools, such as the insulation protective pads. Testers must be familiar with the equipment performance and operation method, and should be in accordance with the operating procedures. If electrical failure occurs during the testing, testers should cut off power supply immediately.

3) Equipment preheating

Before testing, the test engineer should operate the testing system to make it stabilized. Usually the preheating time of the equipment is no less than 30 minutes.

4) Equipment start-up sequence

The start-up sequence of the equipment depends on the precision of the equipment: high-precision equipment should be started in the end. Following is the suggested sequence to start the testing equipment:

- Computer
- Power supply
- Power meter (power meter, ampere meter)
- Spectroradiometer

13.1.4 Testing lamp preparation

Before any measurements taken, CFL and LED lamps shall be preheated to reach stabilization and temperature equilibrium.

13.1.5 Test engineer preparation

Before testing, the test engineer should know clearly the requirements of the international test method(s) that will be used, including the testing condition, the operating position and the scheme of electric power supply.

The test engineer should be familiar with the testing methods for different types of lighting products.

13.2 Equipments & environmental conditions

Performance characteristics of lighting products are sensitive to the ambient conditions and the accuracy of the equipment. The test engineer shall ensure that there is appropriate accommodation for the operation of testing. This includes facilities and equipments for test items: manufacturing, handling, accuracy, calibration, testing and storage. The test engineer also should ensure that the environmental conditions do not compromise the required quality of operations.

13.2.1 Testing environment requirement

Measurements should be taken at an ambient temperature of 25℃±1℃, and maximum relative humidity is 65%. The testing standards require that the air movement for CFL lamp testing should not exceed 5m/min, for LED lamp testing usually suggested not exceed 0.2m/s. The air flow around the lamp is normal convective air flow, vibration or shock of the lighting products are not allowed.

13.2.2 Testing equipment and facilities

1) Electrical testing equipment

The AC power supply for operating the products should have a 50Hz sinusoidal 220V voltage, and RMS summation of the harmonic components should not be exceeded 3% of the fundamental. Regulation of the voltage should be within ±0.5% under load for stabilization, within ±0.2% for measurements.

2) Photometric and colorimetric testing equipment

The following systems are used for the photometric and colorimetric testing:

- Integrating sphere systems
- Sphere-spectroradiometer
- Goniophotometer
- Gonio-spectroradiometer

Integrating sphere

There are several factors to be considered, such as the size of the sphere, the interior coating reflectance, the baffle in the sphere, etc.

Generally, the total surface area of the lamp should be less than 2% of the total area of the sphere wall. Interior coating reflectance is suggested to be 90% to 98%. The size of the baffle is suggested the smaller the better, but it should be shield the direct illumination from the lamp, and for the distance from the baffle to the detector is usually 1/3 to 1/2 of the radius of the sphere.

Spectroradiometer

The wavelength range of the spectradiometer is suggested to be at least 380 nm to 780 nm, and the bandwidth and scanning interval to be at least 5 nm.

Goniophotometer system

Considering the testing position of the lamp, general type of the goniophotometer is the type C goniphotometer, in which the operating position of the lamp under test with respect to gravity is not changed.

The construction of the goniophotometer should be designed to measure angular measurement of the lamp position relative to the photometer head. The measure position should be correct within ±0.5°.

Scanning resolution fine enough to accurately define the test sample shall be used. For typical wide-angle, smooth intensity distributions, a 22.5°lateral (horizontal) and 5° longitudinal (vertical) grid may be acceptable.
In general, the test distance which from the photometric centre of the lamp to the surface of the photometer head should not be less than 15 times the maximum dimension of the light emitting area of the lamp (normal to the lamp axis or 5 times dimension of the light emitting area parallel to the lamp axis).

13.3 Lamp Testing Processes and Testing Tips

13.3.1 Lamp Testing Processes

1) Principle
Basic principle of the measurement: the standard lamp and measured lamp are measured by spectrometer, and the luminous intensity of each wavelength is compared and calculated so as to obtain the optical and colour parameters of the lamp source. The electrical parameters are measured by corresponding power meter.
2) Environmental requirements
The inside and outside ambient temperatures of the integrating sphere are 25℃±1℃ with relative humidity no more than 65％ and Air movement for CFL lamp testing should not exceed 5m/min, for LED lamp testing usually suggested not exceed 0.2m/s. The air flow around the lamp is normal convective air flow, also vibration or shock of the lighting products are not allowed.
3) Preheating of measurement sample
The preheating of measured lamp is conducted on the preheating shelf which shall be placed within 3 meters from the integrating sphere.
4) Calibration of integrating sphere testing system

- Installation of standard lamp
- The standard lamp shall be handled carefully.
- The test engineer shall wear gloves before taking the standard lamp out of its package.
- Install the standard lamp: make the filament gap of the standard lamp to face the baffle.
- Adjust the installation height of standard lamp so as to locate the standard lamp at the centre of the integrating sphere.
- Testing of standard lamp
- Start the spectrometer software and keep it in the spectrum scanning state.
- Observe the standard lamp current data on the power meter. When the current reaches the specified value, click the software to testing.
- After testing, the standard lamp documents shall be stored and named. The standard information will be used for the testing lamp.
- Turn the power supply knob to reduce the voltage slowly until the power supply voltage reaches 0V and then turn off the power supply.
- The standard lamp should not be handled until it is cool. Because after burning the filament the standard lamp is fragile.

5) Lamp testing

- Take down the measured lamp from the preheating shelf. The whole movement shall be rapid and stable.
- Installation of testing lam p
- During the installation of measured lamp, make sure the socket is fixed.
- After the installation of lamp, test the measured lamp at the time interval of 1 minute.

- At the same time, voltage, current, power factor displayed in power meter, and the temperature in the sphere shown by thermometer shall be recorded.
- Compare the luminous flux values and product power in documents measured. If the deviation is within 0.5%, the lamp parameters shall be regarded as stable and the lamp measurement is completed.
- If the deviation exceeds 0.5%, repeat the above procedures of measurement until the deviation meets the requirements.

6) Completion of testing

- After the measurement, take off the measured lamps and put the lamps back in their specific sample area.
- Turn off the spectrometer, power meter and power supply. Shut down all the application programs and close documents in computer.

13.3.2 Testing Tips

Environment temperature and humidity: environment temperature is required to be maintained between 25℃±1℃. Humidity should not exceed 65%.
Device verification: Ensure the power load capacity, the precision of voltage and current equipment adjust to the meet of requirements; switch order of equipment should be according to the precision degree of equipment instrument, from low to high in turn. In the operation of the power supply, prevent the instantaneous voltage on the impact of the standard lamp.
Make sure the inside coating of sphere coating is clean without any dust.
The installation of the standard lamp should be careful: make sure no electric shock effect occurs when installing the standard lamp. After the installation of the standard lamp, confirm that the lamp is located at the centre of the sphere. Pay attention to the electrical parameters of standard lamp, which should not exceed the rated value. Ensure the rated current of the standard lamp remain when reading the testing data. Otherwise, a weak electric current shock may lead to a deviation of the data, which has a great influence on the optical parameters of the test lamps.
Ensure that the transfer time of the measured lamp from the preheating shelf to the testing position is as short as possible.
Confirm that the measured lamp is located in centre of the sphere.
Shut down the entire system: when the test is completed, turn off the devices in order according to the degree of precision equipment, carried in descending order.

13.4 Explanation of the Test Results Analyses Procedures

13.4.1 Test Results Analyses

1) Photometric data analyses

The photometric data provided in the test report relates to a particular lamp, but its purpose is to provide the basis for further calculations, e.g. for the design of practical lighting installations. The information may include luminous flux values for the bare lamp(s), light intensity distributions, etc.
Usually, the testing lab will do the correction (self-absorption and the light distribution matching correction) to the photometric data, especially for the luminous flux. For self-absorption correction, in view of the inconsistency of the shape, size and colour of the standard lamp and lamp under test, a wide spectrum light lamp should be adopted as an auxiliary lamp. The lamp should maintain a stable performance in the process of the self-absorption correction.

2) Colorimetric parameter analyses

Colorimetric parameter with the integral spectroradiometer method

Use an integral spectroradiometer method to measure the relative spectral power distribution curve. Calculate the chromaticity performance with reference to the colour coordinates, correlated colour temperature and colour Rendering Index specified in the CIE 15.

Colorimetric parameter with the spatial spectrum scanning method

Apply the distribution photometer or optical bench system to cooperate with the spectral radiation meter. Calculate the average colour coordinates (x, y) and (u', v') with the same angle interval set as the measurement of light intensity distribution.

Calculate the correlated colour temperature (CCT) of the lamp by reference to CIE 15.

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