

Ergonomics of human-system interaction

Part 305: Optical laboratory test methods for electronic visual displays (ISO 9241-305:2008)

ICS 13.180; 35.180

National foreword

This British Standard is the UK implementation of EN ISO 9241-305:2008. Together with BS EN ISO 9241-302:2008, BS EN ISO 9241-303:2008, BS EN ISO 9241-304:2008 and BS EN ISO 9241-307:2008, it supersedes BS EN ISO 13406-1:1999, BS EN ISO 13406-2:2002, BS EN 29241-3:1993, BS EN ISO 9241-7:1998 and BS EN ISO 9241-8:1998, which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PH/9, Applied ergonomics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Foreword

This document (EN ISO 9241-305:2008) has been prepared by Technical Committee ISO/TC 159 "Ergonomics" in collaboration with Technical Committee CEN/TC 122 "Ergonomics", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2009, and conflicting national standards shall be withdrawn at the latest by May 2009.

This document supersedes EN 29241-3:1993, EN ISO 13406-1:1999, EN ISO 13406-2:2001, EN ISO 9241-7:1998, EN ISO 9241-8:1997.

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Endorsement notice

The text of ISO 9241-305:2008 has been approved by CEN as a EN ISO 9241-305:2008 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9241-305 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

This first edition of ISO 9241-305, together with ISO 9241-302, cancels and replaces ISO 13406-1:1999 and ISO 9241-8:1997. Together with ISO 9241-302, ISO 9241-303 and ISO 9241-307, it also cancels and replaces ISO 9241-7:1998 and ISO 13406-2:2001, and partially replaces ISO 9241-3:1992. The following has been technically revised:

- terms and definitions related to electronic visual displays have been transferred to, and collected in, ISO 9241-302;
- while the areas previously covered in ISO 9241 and by ISO 13406 remain essentially unchanged, test methods and requirements have been updated to account for advances in science and technology;
- all generic ergonomic requirements have been incorporated into ISO 9241-303;
- the application of those requirements to different display technologies, application areas and environmental conditions — including test methods and pass/fail criteria — is specified in ISO 9241-307;
- methods for the laboratory testing of those requirements are specified in ISO 9241-305.

ISO 9241 consists of the following parts, under the general title *Ergonomic requirements for office work with visual display terminals (VDTs)*:

- *Part 1: General introduction*
- *Part 2: Guidance on task requirements*
- *Part 4: Keyboard requirements*
- *Part 5: Workstation layout and postural requirements*
- *Part 6: Guidance on the work environment*
- *Part 9: Requirements for non-keyboard input devices*

- *Part 11: Guidance on usability*
- *Part 12: Presentation of information*
- *Part 13: User guidance*
- *Part 14: Menu dialogues*
- *Part 15: Command dialogues*
- *Part 16: Direct manipulation dialogues*
- *Part 17: Form filling dialogues*

ISO 9241 also consists of the following parts, under the general title *Ergonomics of human-system interaction*:

- *Part 20: Accessibility guidelines for information/communication technology (ICT) equipment and services*
- *Part 110: Dialogue principles*
- *Part 151: Guidance on World Wide Web user interfaces*
- *Part 171: Guidance on software accessibility*
- *Part 300: Introduction to electronic visual display requirements*
- *Part 302: Terminology for electronic visual displays*
- *Part 303: Requirements for electronic visual displays*
- *Part 304: User performance test methods for electronic visual displays*
- *Part 305: Optical laboratory test methods for electronic visual displays*
- *Part 306: Field assessment methods for electronic visual displays*
- *Part 307: Analysis and compliance test methods for electronic visual displays*
- *Part 308: Surface-conduction electron-emitter displays (SED) [Technical Report]*
- *Part 309: Organic light-emitting diode (OLED) displays [Technical Report]*
- *Part 400: Principles and requirements for physical input devices*
- *Part 410: Design criteria for physical input devices*
- *Part 920: Guidance on tactile and haptic interactions*

For the other parts under preparation, see Annex A.

Introduction

This part of ISO 9241 was prepared with the support of the flat panel display measurements (FPDM) task group of VESA (Video Electronics Standards Association, USA). Contributions from its FPDM standard ^[10] are identified in Annex C.

The methods specified in this part of ISO 9241 are provided to assist test laboratories (either suppliers' facilities or test institutes) in deciding whether a specific electronic display conforms to the other relevant parts of ISO 9241, insofar as such a decision can be made in a laboratory setting. This part of ISO 9241 does not specify how to select display adjustment parameters or software for making a test representative of intended actual use. That judgement has to be made by the test laboratory and described in the test report.

ISO 9241 was originally developed as a seventeen-part International Standard on the ergonomics requirements for office work with visual display terminals. As part of the standards review process, a major restructuring of ISO 9241 was agreed to broaden its scope, to incorporate other relevant standards and to make it more usable. The general title of the revised ISO 9241, "Ergonomics of human-system interaction", reflects these changes and aligns the standard with the overall title and scope of Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*. The revised multipart standard is structured as series of standards numbered in the "hundreds": the 100 series deals with software interfaces, the 200 series with human centred design, the 300 series with visual displays, the 400 series with physical input devices, and so on.

See Annex A for an overview of the entire ISO 9241 series.

Ergonomics of human-system interaction —

Part 305:

Optical laboratory test methods for electronic visual displays

1 Scope

This part of ISO 9241 establishes optical test and expert observation methods for use in predicting the performance of a display vis-à-vis the ergonomics requirements given in ISO 9241-303.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9241-302, *Ergonomics of human-system interaction — Part 302: Terminology for electronic visual displays*

ISO 9241-303, *Ergonomics of human-system interaction — Part 303: Requirements for electronic visual displays*

ISO 9241-307, *Ergonomics of human-system interaction — Part 307: Analysis and compliance test methods for electronic visual displays*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9241-302 apply.

4 General

4.1 Measurements — Basic measurements and derived procedures

The collection of (optical) lab measurements necessary for the compliance evaluations given in this part of ISO 9241 are divided into *basic measurements* — identified by M and a measurement number — and *measurement procedures* — identified by P and a procedure number (and letter in the case of supplementary procedures) — briefly described below. Additional information, including decisions on developing the methods and their use for the definition of compliance procedures, can be found in Annex B.

4.1.1 Basic measurements (or evaluation) — Method M

Basic measurements should describe a fundamental method in as simple a form as possible. Most of the essential measurement parameters (such as screen location, viewing direction, test pattern) are not specified. The specified result is a physical quantity or some other directly measured property, and does not involve any processing of the collected data. These results are usually not directly used in a compliance procedure of the sort specified in ISO 9241-307. Rather, in a compound measurement procedure (see 4.1.2), a basic measurement will be used to achieve sets or collections of data.

These basic measurements define the types of meters acceptable for use, meter parameters, and any default parameters ("fixed measurement conditions"), and list the parameters that are to be varied by the compound measurement procedure ("configurable measurement conditions"). These latter parameters are often defined by the compliance procedure (see ISO 9241-307).

4.1.2 Compound measurement procedures — Procedure P

Compound measurement procedures are methods that collect and evaluate physical quantities that were measured using a basic method (see 4.1.1). These procedures reference basic measurements, and may specify the specific requirements for the "configurable measurement conditions". They also include any special preparation procedures. The result of a procedure is a collection of basic quantities (e.g. area or angular distribution of luminance), or derived quantities (e.g. luminance contrast, colour difference). In many cases, the measurement procedures could have some of the configurable measurement conditions defined by the compliance procedure (see ISO 9241-307).

4.2 Structure

The measurement methods given in this part of ISO 9241 are structured as follows.

- a) **Objective:** this describes the purpose and quantities measured.
- b) **Applicability:** this describes the type of displays/applications in which the particular measurement is relevant.
- c) **Preparation and set-up:** this describes fixed and configurable measurement conditions, optional accessory equipment, and any special preliminary requirements.
- d) **Procedure:** this describes the measurement or references basic measurement method.
- e) **Analysis:** this describes any analysis of the measured data.
- f) **Reporting:** this describes the form of reporting, including the number of significant digits, where appropriate.
- g) **Comments:** this describes any special concerns or relevant information not contained elsewhere.

4.3 Matrix of measurement conditions methods and procedures

A matrix of measurement conditions, methods and procedures comparing various source documents (including earlier International Standards) can be found in Annex C.

NOTE Many of the procedures in this document have been incorporated, in whole or in part, from ISO 9241-3:1992. See Annex C and the Bibliography for further references.

5 Measurement conditions

5.1 Preparations and procedures

5.1.1 CRT (cathode ray tube) monitor standard preparation

Allow sufficient time for the display luminance to stabilise, with a minimum of 20 min.

5.1.1.1 Technology dependent parameters

Manual degauss in measurement position (for colour displays only). This refers to externally applied degauss (not manual activation of an internal system).

5.1.1.2 Cleaning

Ensure that the display is clean.

5.1.1.3 Alignment

The display screen should be aligned such that a plane tangential to the screen centre is parallel to the axes of the measurement system(s).

Tilt: the active display area shall be aligned such that a horizontal line through the screen centre is parallel to the horizontal axis of the measurement instrument and/or of the measurement instrument travel.

5.1.1.4 Brightness and contrast control settings

Adjust the brightness control until the raster is at cut-off.

Adjustment should be performed under the lighting conditions for the specific compliance route as specified in ISO 9241-307.

After adjusting the display brightness to its default, adjust the centre-screen luminance to 100 cd/m² at 20 % screen loading. If this is not achievable, report the centre-screen luminance.

The controls shall remain at these settings for all measurements.

5.1.1.5 Image size

Use the factory setting or default, if available. Otherwise, adjust to a specified size.

5.1.1.6 Video drive levels

If the display uses an analogue interface, then the drive level(s) shall be specified for video signal lines.

Most applications drive the standard RGB interface with either 0,47 V or 0,7 V (corresponding to 2/3 video and full video respectively) and the use of one of these values is recommended. The value used should be specified.

5.1.2 LCD (liquid crystal display) monitor standard preparation

The flat panel display unit to be tested shall be physically prepared for testing.

5.1.2.1 Display warm-up

Allow sufficient time for the display luminance to stabilise, with a minimum of 20 min. When indicated by the manufacturer, the display shall be warmed up for the specified time (not to exceed 1 h).

5.1.2.2 Technology dependent parameters

Testing shall be conducted under normal user conditions for power supply. The bias settings (if any) of the display shall be set to those expected under typical use. Any reflection treatment or filter that is in place for the test specified in 6.5 shall be in place for every test.

One adjustment setting shall be used for each complete test sequence. If multiple settings are provided, this implies multiple complete test sequences.

5.1.2.3 Cleaning

Ensure that the display is clean.

5.1.2.4 Alignment

The display screen should be aligned such that a plane tangential to the screen centre is parallel to the axes of the measurement system(s).

Tilt: the active display area shall be aligned such that a horizontal line through the screen centre is parallel to the horizontal axis of the measurement instrument and/or of the measurement instrument travel.

5.1.2.5 Brightness and contrast control settings

The display shall be adjusted to its default or preset brightness and contrast. The controls shall remain at these settings for all measurements. Adjustment should be performed under the lighting conditions for the specific compliance route as specified in ISO 9241-307.

5.1.2.6 Image size

Use the factory setting or the default, if available. Otherwise, adjust to a specified size.

5.1.2.7 Video drive levels

If the display uses an analogue interface, then the drive level(s) shall be specified for video signal lines.

Most applications drive the standard RGB interface with either 0,47 V or 0,7 V (corresponding to 2/3 video and full video respectively) and the use of one of these values is recommended. The value used should be specified.

5.1.3 Front projection display standard preparation (fixed resolution systems)

5.1.3.1 Display warm-up

Measurements are carried out after 100 h operation of the projection lamp (burn-in time). After switching on, the minimum warm-up time shall be 1 h unless otherwise specified in ISO 9241-307.

5.1.3.2 Technology depending parameters

Testing shall be conducted under normal user conditions for power supply. The bias settings (if any) of the display shall be set to those expected under typical use. Any reflection treatment or filter that is in place for the test specified in 6.5 shall be in place for every test.

One adjustment setting shall be used for each complete test sequence. If multiple settings are provided, this implies multiple complete test sequences.

5.1.3.3 Cleaning

Ensure that the display screen is clean.

5.1.3.4 Alignment

All optics, convergence controls and focus shall be adjusted so that the projected image appears sharp over the largest percentage of the illuminated area. Front projection systems shall be positioned relative to the screen according to the manufacturer's specifications for angle, height, and distance. Rear-projection systems shall be adjusted so that the image fills the screen completely (not overfill).

5.1.3.5 Brightness and contrast control settings

The control designed to adjust brightness shall be set to the point where the maximum number of signal level blocks on the top line, representing 0 %, 5 %, 10 % and 15 % signal levels, are visible and distinct from the adjacent signal level blocks.

The control designed to adjust contrast shall be advanced from minimum until the maximum number of signal level blocks in the lower line of the pattern (representing the 85 %, 90 %, 95 % and 100 % signal levels) are visible and distinct from the adjacent signal level blocks or until the picture no longer increases in brightness, as limited by automatic brightness circuitry.

The controls shall remain at these settings for all measurements. Adjustment should be performed under the lighting conditions for the specific compliance route as specified in ISO 9241-307.

5.1.3.6 Image size

Use the factory setting or the default, if available. Otherwise, adjust to a specified size.

5.1.3.7 Video drive levels

Connect the projector to a notebook computer or other signal generator. The signal generator shall offer a typical signal voltage on RGB of $0,7\text{ V} \pm 0,07\text{ V}$. Adjust the focus for the sharpest image.

5.1.4 PDP (plasma display panel) monitor standard preparation

Allow sufficient time for the display luminance to stabilise, with a minimum of 20 min.

5.1.4.1 Technology depending parameters

Testing shall be conducted under normal user conditions for power supply. The bias settings (if any) of the display shall be set to those expected under typical use. Any reflection treatment or filter that is in place for the test specified in 6.5 shall be in place for every test.

One adjustment setting shall be used for each complete test sequence. If multiple settings are provided, this implies multiple complete test sequences.

5.1.4.2 Cleaning

Ensure that the display is clean.

5.1.4.3 Alignment

The display screen should be aligned such that a plane tangential to the screen centre is parallel to the axes of the measurement system(s).

Tilt: the active display area shall be aligned such that a horizontal line through the screen centre is parallel to the horizontal axis of the measurement instrument and/or of the measurement instrument travel.

5.1.4.4 Brightness and contrast control settings

Adjust the brightness control until the raster is at cut-off. Adjustment should be performed under the lighting conditions for the specific compliance route as specified in ISO 9241-307.

After adjusting the display brightness to its default, adjust the centre-screen luminance to 100 cd/m^2 at 20 % screen loading. If this is not achievable, report the centre-screen luminance.

The controls shall remain at these settings for all measurements.

5.1.4.5 Image size

Use the factory setting or the default, if available. Otherwise, adjust to a specified size.

5.1.4.6 Video drive levels

If the display uses an analogue interface, then the drive level(s) shall be specified for video signal lines.

Most applications drive the standard RGB interface with either 0,47 V or 0,7 V (corresponding to 2/3 video and full video, respectively) and the use of one of these values is recommended. The value used should be specified.

5.1.5 Hand-held devices

The flat panel display unit to be tested shall be physically prepared for testing.

5.1.5.1 Display warm-up

Allow sufficient time for the display luminance to stabilise, with a minimum of 20 min. When indicated by the manufacturer, the display shall be warmed up for the specified time (not to exceed 1 h).

5.1.5.2 Technology depending parameters

Testing shall be conducted under normal user conditions for power supply. The bias settings (if any) of the display shall be set to those expected under typical use. Any reflection treatment or filter that is in place for the test specified in 6.5 shall be in place for every test.

One adjustment setting shall be used for each complete test sequence. If multiple settings are provided, this implies multiple complete test sequences.

5.1.5.3 Cleaning

Ensure that the display is clean.

5.1.5.4 Alignment

The display screen should be aligned such that a plane tangential to the screen centre is parallel to the axes of the measurement system(s).

Tilt: the active display area shall be aligned such that a horizontal line through the screen centre is parallel to the horizontal axis of the measurement instrument and/or of the measurement instrument travel.

5.1.5.5 Brightness and contrast control settings

The display shall be adjusted to its default or preset brightness and contrast. The controls shall remain at these settings for all measurements. Adjustment should be performed under the lighting conditions for the specific compliance route as specified in ISO 9241-307.

5.1.5.6 Image size

Use the factory setting or the default, if available. Otherwise, adjust to a specified size.

5.1.5.7 Video drive levels

If the display uses an analogue interface, then the drive level(s) shall be specified for video signal lines.

Most applications drive the standard RGB interface with either 0,47 V or 0,7 V (corresponding to 2/3 video and full video respectively) and the use of one of these values is recommended. The value used should be specified.

5.2 Test accessories

Several objects and devices are required or useful for carrying out the measurements described in this part of ISO 9241. Some are introduced here.

5.2.1 Mirror standard

Mirror standards are mainly used for checking the geometrical alignment and for redirecting light from a source into a light-measuring device (LMD).

Any flat and plane substrate with the front surface coated with, e.g. silver or aluminium, and protected by a thin layer of a transparent dielectric forms a surface mirror with a reflectance of 95 % or more. Standard mirrors with backside coating should not be used, since multiple reflections occur that make those mirrors unsuitable for most calibration purposes.

Another type of mirror that is particularly useful for display metrology is generally made from plane-polished black glass (i.e. highly absorbent glass). The specular reflectance of such a surface mirror without coating is given by the index of glass refraction as a function of the wavelength of light, and is in the range of 4 % to 5 % for normal incidence and increasing with angle of inclination.

Such mirrors are useful for measuring the reflectance properties of display devices, since the reflectance of a display device is rather in the range of some percent than in the range of 90 % and is thus in the same order of magnitude as the reflections of the EUT (equipment under test).

Calibration: in order to assure low uncertainties in the measurement, mirror standards should be calibrated explicitly for the task they will be used for (e.g. for the same angle of inclination).

IMPORTANT — It shall be assured that specular mirrors do not exhibit any directionality, i.e. they shall show the same specular reflectance for angles of rotation of the mirror about its surface normal. For the same reason, cleaning shall be done carefully and the result checked visually.

5.2.2 Haze standard

Characterisation and evaluation of the haze of display devices is strongly dependent on the geometry of illumination (e.g. angular extent of the light source) and of the receiver aperture. A haze standard is used to compare and correlate the measurements of different arrangements for measuring haze.

A haze standard is usually a flat surface that has been treated in order to scatter incident light around the specular direction. Haze standards are made by creating microstructures in the previously polished surface of e.g. a black glass mirror.

Commercial haze standards are usually calibrated in terms of gloss units. In order to make them useful for display measurements they have to be recalibrated, e.g. by the directional scattering for a specific arrangement of source and receiver.

NOTE Haze standards are extremely sensitive to surface contamination as applied by, e.g. fingerprints, and need to be treated with care and stored in a suitable container.

5.2.3 Diffuse reflectance standard

Ideal diffuse reflectance standards scatter all incident light equally into all directions (Lambertian characteristics); thus, they exhibit a constant luminance when viewed from different directions (under constant illumination). Diffuse reflectance standards are used to measure incident illumination (illuminance) via the luminance of the standard. The diffuse reflectance of a sample object can be determined by comparison with the calibrated standard.

Diffuse reflectance standards can be purchased with a wide range of reflectance values (from some percent to 99 %). Diffuse reflectance standards were formerly made from carefully refined BaSO₄ or MgO powder pressed into a tablet with plane surfaces. Such realisations, however, are very sensitive to ageing and to adsorption at their surfaces, making their use quite impractical. Modern diffuse reflectance standards are made from pressed PTFE powder and thus are quite robust with respect to handling and use.

Three aspects need to be considered pertaining to diffuse reflectance standards: the directional distribution of scattered light (ideally isotropic), the amount of light reflected by the standard (ideally 100 %) and the variation of reflectance with wavelength of light. Technical realisations of diffuse reflectance standards can reach high values of diffuse reflectance (99 %), but unfortunately they are far from being ideal scatterers.

Reflectance standards can be used for making illuminance from a luminance measurement of the standard ($E = \pi L_{\text{STD}}/\beta_{\text{STD}}$) only for the measurement geometry used to determine the standard's luminance factor, β , the geometry used for its calibration. If the reflectance (or diffuse reflectance) is associated with the standard — as the number 98 % or 99 % usually does refer to the reflectance — then that value can only be used for a uniform hemispherical illumination. If an isolated source is used at some angle, there is no reason to expect that the 99 % will be even close to the proper value of the luminance factor for that geometrical configuration. Measurement and calibration of the diffuse reflectance standard should therefore be carried out using the same geometry as will be used for the actual measurement (see 6.5.8).

NOTE Diffuse reflectance standards are sensitive to surface contamination as applied by e.g. fingerprints and need to be treated with care and stored in a suitable container. Some such standards can be carefully sanded (some require water with the sanding) or otherwise cleaned to refresh the surface back up to its maximum scattering, should the surface become soiled or contaminated (see supplier instructions).

5.2.4 Degaussing device

The colour appearance of a CRT monitor is affected by the static magnetic field of the earth. In particular, turning the CRT monitor when switched on can cause changes in the colour appearance. The CRT can be “zeroed” to its default state using a degaussing device. To improve repeatability of testing, it is good laboratory practice to degauss a CRT monitor under test using an external degaussing device, rather than the monitor's built-in degaussing device.

A degaussing device consists of a strong magnet that creates a static magnetic field. In manual degaussing, this magnet is moved circularly in front of the display and gradually moved away from the monitor. The circular movement resets the monitor appearance and the moving away from the monitor reduces the impact of the magnet on the CRT, resulting in an even colour appearance.

5.2.5 Veiling glare frustum

Previous work corroborates the effectiveness of frustums as a tool in reducing the amount of stray light corrupting light-output measurements of displays [13]. The frustums, or truncated cones, have apex angles of 90° and are constructed from 10 mm black vinyl plastic with a gloss surface on both sides, using the procedure shown in Figure 1.

The equations of Figure 1 relate the frustum apex angle and inner/outer diameters to a flat surface that can be easily cut using a mechanical compass with a sharpened edge for cutting the plastic. Place one point at the centre and rotate around the centre with the cutter until the material becomes separated. Alternatively, back and forth bending along a partial cut with a little stress can separate the material. Be sure to cut out the outer diameter first; otherwise the centre reference is lost.

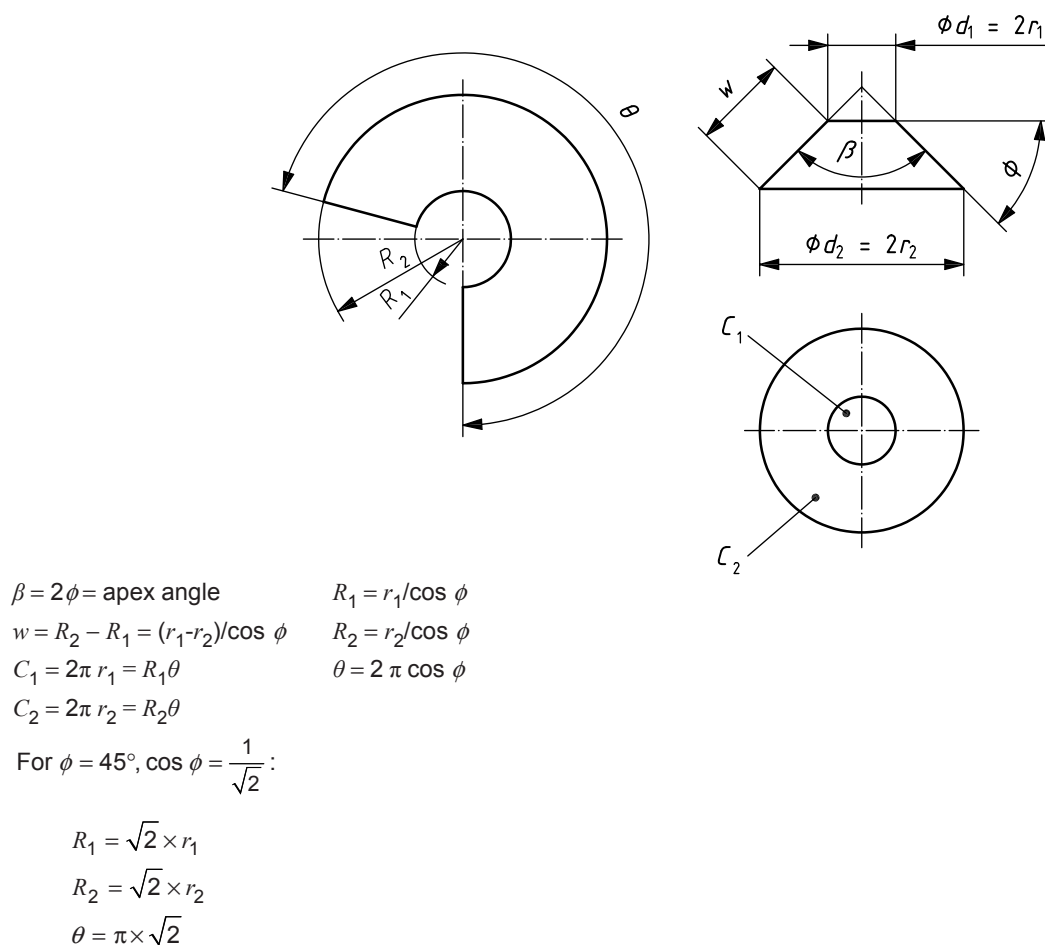


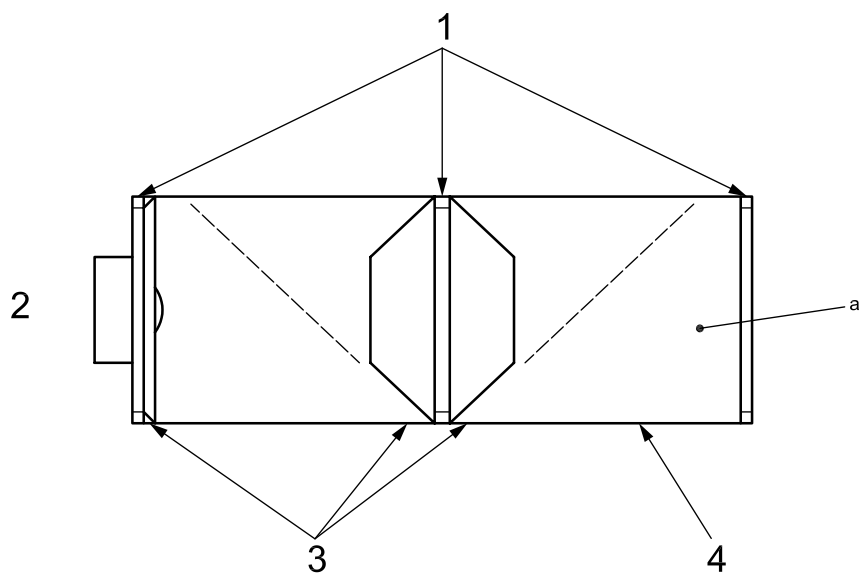
Figure 1 — Pattern for veiling glare frustum

5.2.6 Stray light elimination tube and projection masks

Stray light can result from veiling glare, ambient lighting conditions or light from the display reflecting off the room features and back onto the display surface. In most situations, this produces an undesirable effect as far as the performing of measurements is concerned and is especially significant when attempting to measure black level luminance or illuminance. Two options are presented here to reduce the stray light corruption: the stray-light elimination tube (SLET) and the projection mask.

The SLET consists of a long piece of plastic tubing as shown in Figure 2. Several frustums have been inserted to provide for the baffling and redirecting of stray light. The tube length and diameter, and the aperture of the frustums, are dependent upon measurement parameters, but are, typically, 9,5 cm for the inside diameter, 30,5 cm for the length, and 5 cm for the aperture. The entire tube shall be glossy black: the glossy surface provides for approximately 0,2 % diffuse (non-specular) reflection; whereas, flat black offers at best around 2 % to 3 % diffuse reflection. By careful positioning of the glossy black frustums, the SLET can be made to direct the specular reflections off the interior tube surface and away from the illuminance meter measurement head. The back plate needs to be thin enough so that reflections off its edge do not contribute to the illuminance measurement.

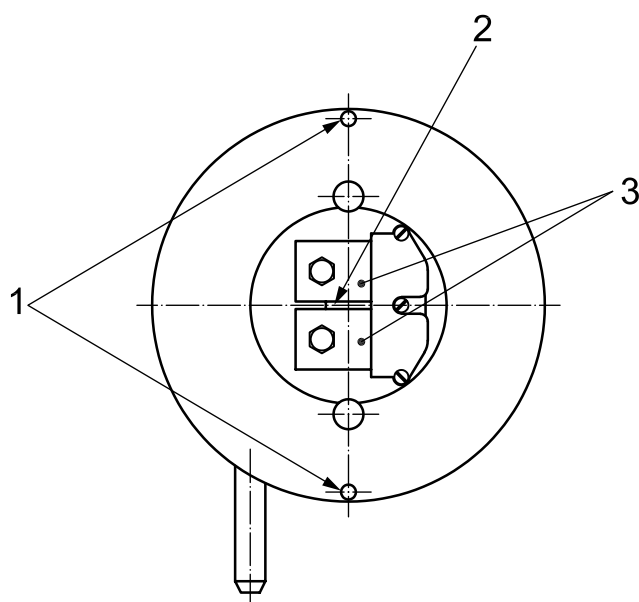
For performing small-area illuminance measurements for front-projection displays, a slit adapter can be used. The slit adapter shown in Figure 3 was built using black acetal plastic to mount the illuminance meter, so that various detector heads could be centred at the rear of the SLET. To accommodate the small measurement areas, a slit was devised, using razor blades painted in glossy black, to create an adjustable aperture. The blades are secured with setscrews to provide for adjustment. This allows the user to control the area of the projected image to be measured. Thus, measure contrast modulation could be measured by adjusting the aperture to allow only either the black or the white portion of the image to illuminate the detector head.



Key

- 1 rings
- 2 illuminance meter
- 3 glossy black frustums
- 4 glossy black tube
- a From the projector.

Figure 2 — Stray light elimination tube



Key

- 1 SLET (stray-light elimination tube) mounting holes
- 2 LMD (light-measuring device) head
- 3 adjustable blade

Figure 3 — Slit mount for illuminance meter

5.2.7 Replica masks

Because the glossy black cone mask is not effective for measuring small-area black luminance, another mask can be utilised. This mask, called a replica mask, is a piece of black material that has the same dimension as the area that it is desired to measure. If the screen is rugged, the mask is placed on the display screen in close proximity to the pixel surface (see Figure 4). If it is assumed that the replica mask is absolutely black, then any luminance measured from this mask is the veiling glare contribution. This contribution can then be subtracted from the measured value of the display image to obtain a more accurate measurement of the true luminance. That is, for a given black pixel area, A_p , the corrected measured black luminance is

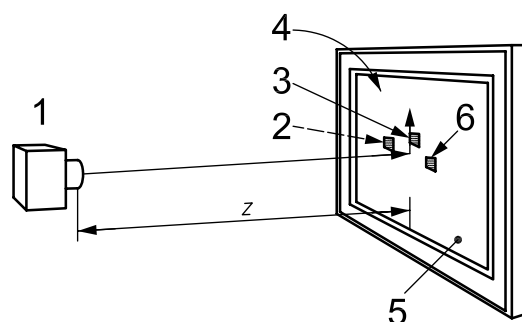
$$L'_b = L_b - L_g \quad (1)$$

where

L_b is the luminance of the black pattern (without glare correction);

L_g is the luminance contribution resulting from veiling glare (the measured replica luminance).

Figure 4 also shows a neutral density filter (NDF), which serves as a check of the replica mask measurements. The filter and replica mask shall be the same size as the black pixel area being measured. The square masks were cut from opaque glossy black plastic (approximately 0,25 mm thick), although other black material may be used. Glossy material was preferred due to its ability to reduce diffuse reflections from the surrounding environment. Care was taken to avoid any specular reflections off the glossy surface. The line replica mask can be created using black thread; nylon, human hair, horsehair, thin wire or pencil "lead" (graphite), or fine striping tape (darkened with a black marker if the material is not sufficiently black) can also be used.



Key

- 1 CCD (charge-coupled device) imaging system
- 2 replica mask
- 3 black pixels
- 4 white background
- 5 display surface
- 6 NDF (neutral density filter)

NOTE For z , see Table 1.

Figure 4 — Use of replica masks for veiling glare compensation

5.2.8 Data acquisition

LMD samples as a function of time are typically collected, stored, processed and displayed by a storage device such as a computer or storage oscilloscope.

5.2.9 Vibration-damped measurement bench

Both the display and the LMD could need to be seated on a vibration-damped aluminium-slab measurement bench. The motion of the test bench should be at least a factor of 10 times smaller than the jitter motion being measured.

5.2.10 Dimensional measurement devices

5.2.10.1 Reticle: a simple ruled magnifier marked with straight-line rules of known unit length, for the measurement of very small dimensions. The reticle is usually placed at the field stop within the eyepiece of a measuring microscope.

5.2.10.2 Ruler: Use of a steel ruler (mm resolution) or equivalent linear or digital micrometer can be used for small measurements. For large measurements, such as a steel tape measure (with mm resolution) can be used for determining large area dimensions, such as the size of a projected image.

5.2.10.3 Graduated scales: linear and rotational scales are recommended for achieving accurate alignment.

5.2.11 Uniform light source

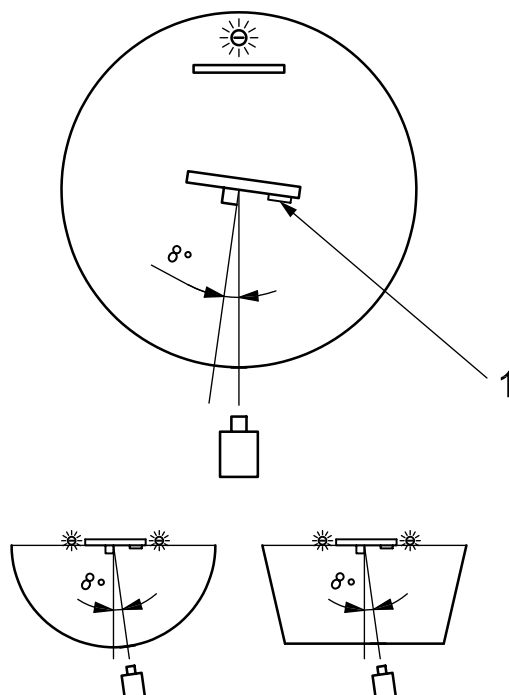
An integrating sphere light source can be useful in providing

- a) a source of calibrated luminance, if properly calibrated, and
- b) a source of luminance that is uniform over the exit port.

An exit port diameter of $1/3$ the sphere diameter or less will provide a $\pm 1\%$ to $\pm 2\%$ non-uniformity of luminance across the exit port if the interior of the integrating sphere is covered with a diffuse white reflectance material having a 96 % reflectance or greater. This source is very handy for many diagnostics [10]. If it is well designed, its stability over long periods of time can be impressive, and its uniformity can hardly be replicated with other sources.

5.2.12 Surrounds

Ideally, an integrating sphere is best to use for a surround. However, it may be possible to use a surround that is less than perfect (see Figure 5). The success of using a surround that is other than an integrating sphere depends upon how uniform the illumination is from all directions in front of the display. A white hemisphere that is evenly illuminated is preferred if an adequate integrating sphere is not available. If that is not possible, a box can be constructed and painted with the whitest matt paint available. A number of configurations can be used (even a hemisphere or integrating-sphere device smaller than the screen height or width), but it is most important that the surround have a relatively uniform luminance distribution over that part of it in the vicinity ($\pm 30^\circ$) of the perpendicular of the display surface. The hole diameter should be larger than the diameter of the lens of the LMD — the entrance pupil of the LMD — by 20 % to 30 %. However, care shall be exercised to avoid any direct light from the sources or any bright reflections off any surface (other than the screen itself) from hitting the lens of the LMD, in order to minimise veiling glare contamination of the reflected luminance measurement. Since the hole is larger than the lens, the LMD should be moved back from the hole so that only a fraction of the screen is visible to the LMD. This will assure that there is no veiling-glare corruption in the measurement. Check for reflections off the inside diameter of the hole that can also contribute to glare corruption. The hole may have to be bevelled away from the lens.



Key

1 white standard

Figure 5 — Spherical and hemispherical surrounds

5.2.13 Magnification device

Jeweller's loupe: a magnification eyepiece that can be used to inspect pixels. A 10× magnification is standard and should suffice for most applications. Be aware of possible image distortions.

5.3 Test patterns

The test patterns that are used by the measurement procedures in Clause 6 are described below. The parameters for each pattern are defined by either the measurement procedure or the compliance procedure given in ISO 9241-307. These parameters include specification of foreground colour (colour of figure or text) and background colour. In these cases, the colour should be defined in terms of the display primaries; grey and colour levels will be expressed accordingly.

EXAMPLE 1 For RGB, red is $R = 100\%$, $G = 0\%$, $B = 0\%$.

EXAMPLE 2 50 % grey is $R = 50\%$, $G = 50\%$, $B = 50\%$.

NOTE Any pixel representations in the figures of the test patterns are shown for illustrative purposes only.

5.3.1 Character width target H

The parameters for this test pattern are foreground colour, background colour and font. The pattern consists of an unaccented upper case "H". See Figure 6.

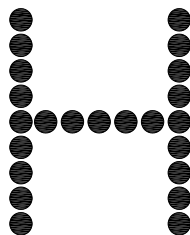


Figure 6 — Character width target H

5.3.2 Character width target block

The parameters for this test pattern are foreground colour, background colour, block size and block locations. This consists of a simple block of specified size.

5.3.3 Character height target E:

The parameters for this test pattern are foreground colour, background colour and font. The pattern consists of an unaccented upper case “E”. See Figure 7.

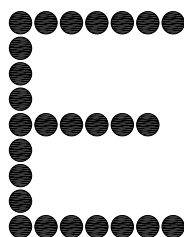


Figure 7 — Character height target E

5.3.4 Character height target block

The parameters for this test pattern are foreground colour, background colour, block size and block locations. This test pattern consists of a simple block of specified size.

5.3.5 Block

The parameters for this test pattern are foreground colour, background colour, block size and block locations. The pattern consists of a block on a specified background and location. This pattern can exhibit image-dependent luminance variation in some technologies. See Figure 8.

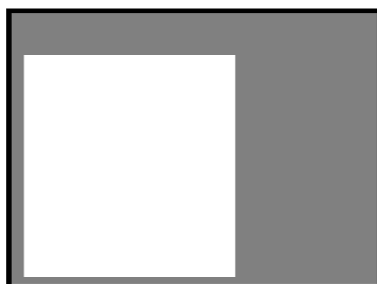


Figure 8 — Block

5.3.6 Character format

The parameters for this test pattern are foreground colour, background colour, font and matrix location. The pattern consists of a character matrix (width $\times$ height) based on the task requirements defined in ISO 9241-307.

5.3.7 Between-character spacing

The parameters for this test pattern are foreground colour, background colour, font and pattern location. The pattern consists of two adjacent “M” targets. See Figure 9.

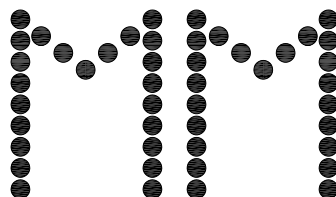


Figure 9 — Between-character spacing target

5.3.8 Between-word spacing

The parameters for this test pattern are foreground colour, background colour, font and pattern location. The pattern will consist of an unaccented upper case “H” unless the character font is designed as a representation of designed print fonts or proportional spacing is used. When simulating a print font, the spacing used in the font design may be used. The number of pixels in the width of the character “N” is recommended as between-word spacing for proportionally spaced fonts. See Figure 10.

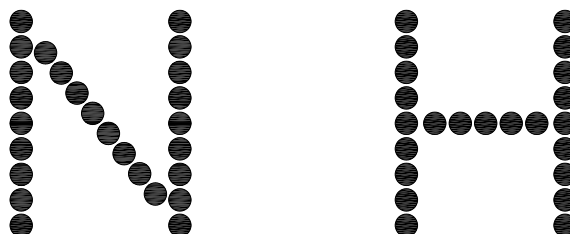


Figure 10 — Between-word spacing

5.3.9 Between-line spacing

The parameters for this test pattern are foreground colour, background colour, font and pattern location. The pattern consists of two “E” targets, each on a single line, one above the other. See Figure 11.

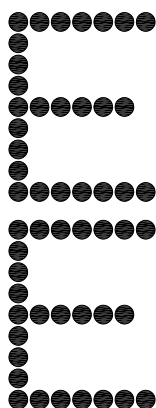
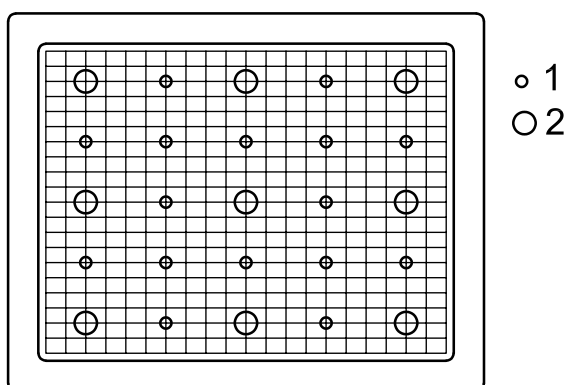


Figure 11 — Between-line spacing target

5.3.10 Grid pattern

The parameters for this test pattern are foreground colour, background colour, line width and measurement locations. See Figure 12.



Key

- 1 p-point locations
- 2 25-point locations

Figure 12 — Grid pattern (20 × 20 single-pixel-wide grid)

5.3.11 Screen full of H

The parameters for this test pattern are foreground colour, background colour, font and pattern location. An example of an unaccented upper case character “H” is shown in Figure 13.

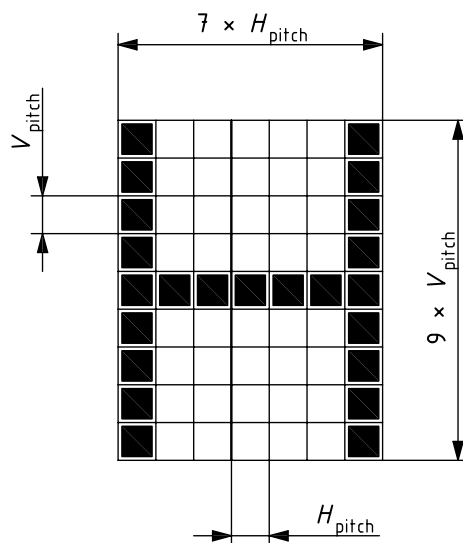


Figure 13 — Screen full of H

5.3.12 Orthogonality

The parameters for this test pattern are foreground colour, background colour, line locations.

EXAMPLE White lines on black background; vertical and horizontal lines along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centrelines (major and minor axes). See Figure 14.

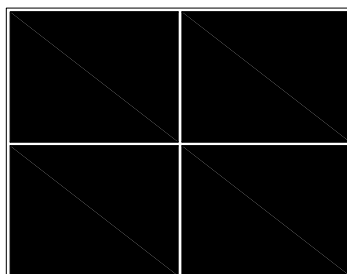


Figure 14 — Orthogonality test pattern

5.3.13 “eee” picture

The parameters for this test pattern are foreground colour, background colour, font and pattern location. The pattern consists of a screen full of “e” targets. See Figure 15.

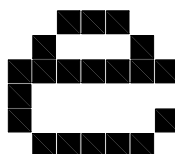


Figure 15 — “e” picture

5.3.14 “mmm” picture

The parameters for this test pattern are foreground colour, background colour, font, pattern location. The pattern consists of a screen full of “m” targets. See Figure 16.

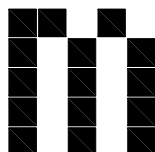


Figure 16 — “m” picture

5.3.15 Horizontal bars

The parameters for this test pattern are foreground colour, background colour, width 1, width 2 and pattern locations. Examples are shown in Figure 17.

5.3.16 Vertical bars

The parameters for this test pattern are foreground colour, background colour, width 1, width 2 and pattern locations. Examples are shown in Figure 17.



Figure 17 — Examples of horizontal and vertical bar patterns

5.3.17 Full-screen

The parameter for this test pattern is colour. The pattern fills the entire addressable area of the display with a single colour.

5.3.18 Dot

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. The pattern consists of a pixel dot at the specified measurement location.

5.3.19 Convergence test pattern

The parameter for this test pattern is the line locations. A test pattern (a white grid of intersecting lines) shall be displayed in the five screen locations described in 5.4.3. The test pattern should consist of a line that is three pixels wide, with the outside pixels 0,5 times the luminance of the centre pixel. If this pattern cannot be displayed, a single pixel line pattern, or a character approximation using the plus (“+”) character, may be used.

NOTE The use of this structure minimises the error that can occur from moiré luminance non-uniformity. It also minimises the differences that arise from different algorithms used for finding the centres of the three beams.

5.3.20 Dot raster

The parameters for this test pattern are foreground colour, background colour, dot size and dot locations. This bitmap pattern consists of a series of dots. Allow one blank column and row between each dot.

5.3.21 One-dot raster

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. This bitmap pattern consists of a single dot at the specified measurement locations.

5.3.22 Response time pattern

The shape, position, colour, intensity, size and blink rate of an appropriate test pattern depend on the display technology.

- a) The test pattern should alternately switch between white, L_w , and black, L_b , luminance, unless otherwise noted. Some technologies exhibit fast response times for white–black transitions, but much slower response for grey-scale transitions. If a white–black (on–off) transition is not used, it shall be clearly specified to all interested parties.
- b) The test pattern blink rate should be slow enough to ensure that both the leading and trailing edges of the recorded positive and negative electro-optical step response function (SRF) waveforms are flat, so that L_{100} (steady-state on) and L_0 (steady-state off) can be accurately determined. If this requirement cannot be met, L_{100} and L_0 may be measured separately, as long as they do not drift significantly during the SRF measurements.
- c) In the event that the luminance asymptotically approaches the steady state value and thereby does not lend itself to a reasonable measurement of these response times, it is permissible to use a level line that is 5 % away from the steady-state level line as the 0 % or 100 % level line.

As a criterion for implementing a 5 % shift, use the following: if the 10 % to 90 % response time is more than three times 20 % to 80 % response time, then the 5 % shifted level reference line may be used. Alternatively, the 20 % to 80 % response time may be employed as a replacement for the 10 % to 90 % response time. Such usage shall be noted in any reporting document.

- d) The test pattern may be smaller than the detector image area if the filtered luminance contribution of the background (detector image area not covered by the test pattern) is constant. Alternatively, non-constant backgrounds may be removed using image-processing techniques.
- e) In general, the test pattern should be as small as possible, since (ideally) the response of a single pixel is being measured. As a practical matter, LMD often produce larger signal-to-noise ratios and more repeatable measurements when larger targets are used. Larger targets may be used if the following applies.
 - 1) When multi-pixel test patterns are generated and displayed in a raster based display system, it is possible for the test pattern update to be occasionally split across two or more display refresh cycles. When this problem cannot be eliminated, it should be reduced as much as is practical (typically, by using targets with a small number of rows). Anomalous large measurements of the image formation time, T_f , caused by test pattern splitting should be discarded.
 - 2) Even within a single display refresh cycle, some time is typically required to electrically address/command the pixels in the test pattern from the on state to the off state. The test pattern update time, T_{TPU} , is the time between the first and last pixel updates in the selected test pattern. The size, shape and position of the test pattern should be selected so that $T_{TPU} < 0,1T_f$, where T_f is the image formation time.

For most display technologies, the largest possible value for T_{TPU} is the refresh time, T_R . In this case, if $T_R < 0,1T_f$, the T_{TPU} requirement is met. The test pattern should not span the seam on dual-scanned displays or tiled displays, since this will cause T_{TPU} to equal T_f . Since T_{TPU} can be difficult to calculate or measure, the following diagnostic may be used instead of an actual T_{TPU} measurement/calculation.

- Measure T_f twice, once using the intended test pattern, and the second time using a very small test pattern (a single pixel if possible). If the two measurements agree within 5 %, then the T_{TPU} requirement is met.

5.3.23 Box patterns

The parameters for this test pattern are foreground colour, background colour and box size. Examples are shown in Figure 18.

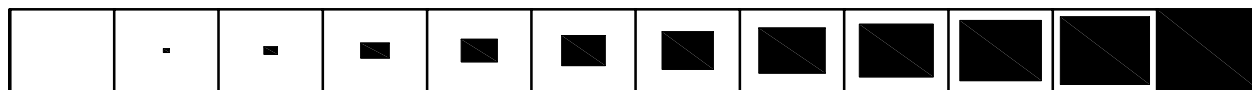


Figure 18 — Examples of box patterns

5.3.24 Checkerboard pattern

The parameters for this test pattern are colour 1, colour 2, number of vertical rectangles and number of horizontal rectangles. It is a checkerboard pattern of equal-sized rectangles, alternating colour 1 and colour 2. Note that for the 4×4 test pattern shown in Figure 19, the upper left rectangle is white.

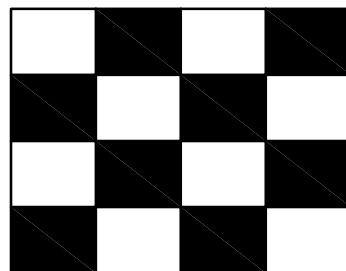


Figure 19 — Example of a checkerboard pattern

5.3.25 Latin characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. See Figure 20.



Figure 20 — Latin characters

5.3.26 Arabic characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. See Figure 21.



Figure 21 — Arabic characters

5.3.27 Chinese characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. See Figure 22.



Figure 22 — Chinese characters

5.3.28 Japanese characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. Because Japanese character patterns depend on the number of the character matrix elements, three (3) patterns, 11×11 , 16×16 , 72×72 , should be used, as shown in Figure 23, which also shows representative hiragana and katakana characters.



Figure 23 — Japanese characters (11×11 , 16×16 , 72×72 points) and representative hiragana and katagana characters

5.3.29 Korean characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. See Figure 24.

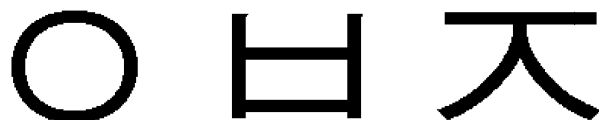


Figure 24 — Korean characters

5.3.30 Cyrillic characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. See Figure 25.

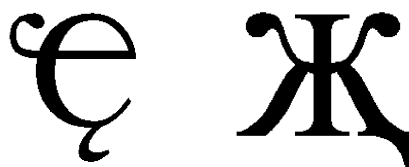


Figure 25 — Cyrillic characters

5.3.31 Greek characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. See Figure 26.



Figure 26 — Greek characters

5.3.32 Thai characters

The parameters for this test pattern are foreground colour, background colour, size and pattern locations. Characters shall be adequate representatives of the character set, displaying horizontal and/or vertical strokes and curved lines as appropriate. See Figure 27.



Figure 27 — Thai characters

5.3.33 5 × 5 checkerboard pattern with crosses

The parameters for this test pattern are fixed. This pattern applies to goniometric measurements of non-stereoscopic displays that produce a virtual image. The test target consists of a 5 × 5 black-and-white checkerboard pattern with white corners. Four straight, thin lines are drawn through the centre of the image, connecting the midpoint of each side with the one opposite it, and each corner with the one opposite it. See Figure 28.

The centre and the endpoints of the crossing lines mark the standard nine measurement locations (see 5.4.5). The 5 × 5 checkerboard pattern is helpful in navigating across the screen, focusing the meter and determining image quality.

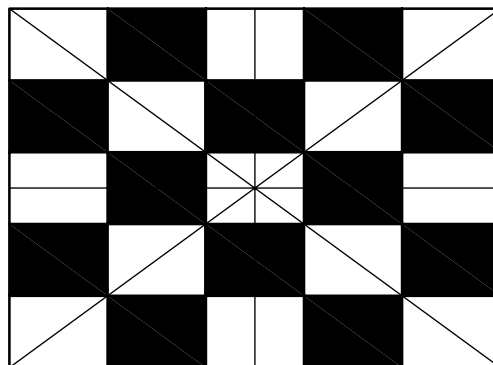


Figure 28 — 5 × 5 checkerboard pattern with crosses

5.3.34 Shadowing set-up

The parameters for this test pattern are foreground colour, background colour, size and grey levels. The pattern is a series of diagonal boxes of eight grey shades. See Figure 29.



Figure 29 — Shadowing set-up pattern

5.3.35 Shadowing measurement

The pattern consists of a series of diagonal boxes of eight grey shades. There are a total of ten patterns used in this measurement: five single box patterns and five full-screen grey-level patterns interleaved. See Figure 30.

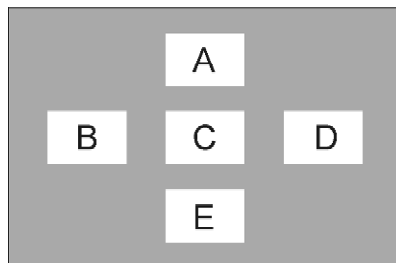


Figure 30 — Shadowing box pattern

As shown in Figure 30, the sequence of five box patterns has a box placed, sequentially, above (A), to the left of (B), to the right of (D), below (E) and at the centre (C) of the screen, with one box for each pattern. This, left-to-right, top-to-bottom, is the reading order in several languages. The edge boxes are centred along the closest side. The box sides are approximately 1/5 to 1/6 the width and height of the screen, and the box is separated from the edge of the screen by approximately half its width or height.

Placement of the boxes should be $\pm 5\%$ of the linear dimensions of the screen. The command level of the boxes is represented by G_s and the background command level by G_{bkg} . Each one-box pattern is separated in the sequence by a blank full screen of grey level G_{bkg} .

5.3.36 Projector set-up pattern

The parameters for this test pattern are foreground colour and background colour. This pattern is used for the set-up of projectors: The brightness control shall be set to the point where the maximum number of signal level blocks on the top line, representing 0 %, 5 %, 10 % and 15 % signal levels, are visible and distinct from the adjacent signal level blocks. See Figure 31.

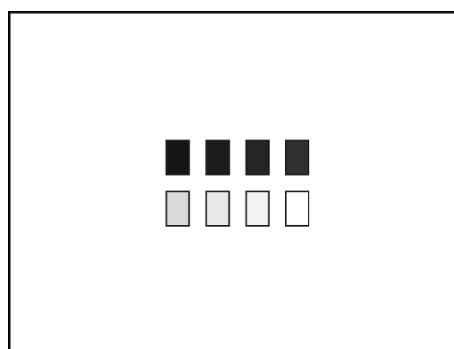


Figure 31 — Projector set-up pattern

5.3.37 Projector colour adjustment pattern

This colour bar pattern consists of the default 16 colours. See Figure 32.

100% Black
100% Blue
100% Cyan
100% Green
100% Magenta
100% Red
100% Yellow
100% White
50% Blue
50% Cyan
50% Green
60% Magenta
50% Red
50% Yellow
50% White
50% Black

Figure 32 — Projector colour bar pattern

5.4 Alignment — Measurement location and meter position

5.4.1 Normal to display screen

LMD is aligned normal to the surface of the display screen.

5.4.2 Light source

To measure the light source, align the LMD normal to it. Focus on the exit port of the display, filling the measurement area of the LMD with as much of the exit port as possible.

5.4.3 Standard five locations

Five standard measurement locations are defined for making measurements of various types (see Figure 33). The locations are the following:

- at the centre (i.e. at the intersection of the two diagonals of the addressable area);
- at the locations on the diagonals that are 10 % of the diagonal length in from the corners of the addressable area of the display.

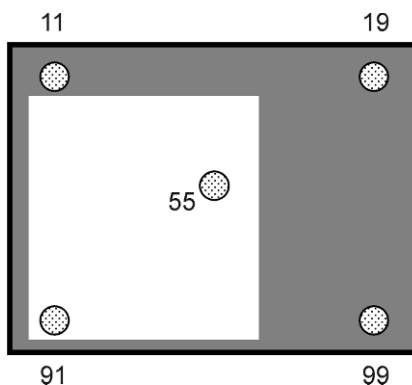


Figure 33 — Standard five locations

5.4.4 Standard 11 locations

Eleven standard measurement locations are defined for making measurements of various types (see Figure 34). The locations are the following:

- nine points equally spread across the diagonal from the upper left corner of the display to the lower right of the display (of the addressable area of the display);
- two points at the opposite corners of the addressable area of the display.

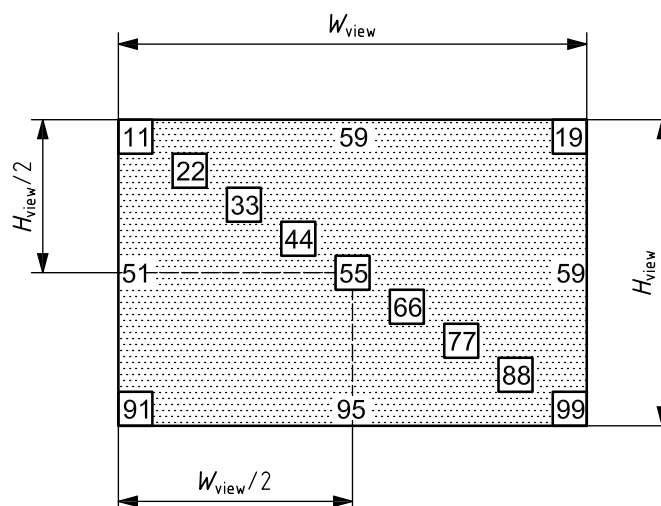


Figure 34 — Standard 11 locations

5.4.5 Standard nine locations

Nine standard measurement locations are defined (see Figure 34). The locations are the nine points equally spread across the diagonal from the upper left corner of the display to the lower right of the display (of the addressable area of the display). These are the same as the locations defined in 5.4.4, except for positions 19 and 91.

5.4.6 Projector: 16 locations

The measurement points are at the centre of each of the 16 rectangles in the 4×4 checkerboard pattern (see 5.3.24).

5.4.7 Projector: 13 locations

The screen is divided into nine equal-sized rectangles. Nine measurement points fall at the centre of each of the respective rectangles. The last four positions are at the corners of the screen, at a distance from the corner of 5 % of the diagonal of the screen. See Figure 35 — the circles are for positioning only and should be removed when measuring.

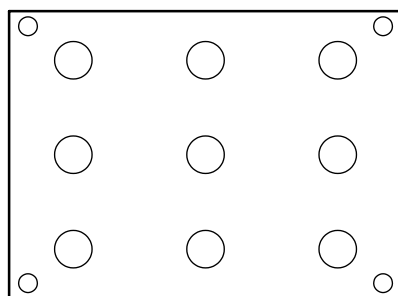


Figure 35 — Standard 13 locations

5.4.8 Centre-screen

The measurement location is at the centre of the display screen.

5.4.9 Visual determination

The determination of measurement test locations is based on visual observation.

5.4.10 Standard nine locations for virtual image displays

This applies to

- goniometric measurement of virtual image geometric distortions and QVS (qualitative vector space) in near-to-eye displays, and
- NED (dichoptic viewing with the non-dominant eye) types, both monocular and binocular, but not stereoscopic or two-eye monocular, devices.

The standard nine measurement locations of the virtual image are the image centre, and the corners and midpoints of each edge. See Figure 36.

See also 5.3.33 and 6.11.1.

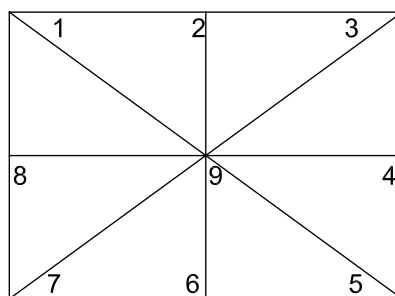


Figure 36 — Standard nine locations for virtual image displays

5.4.11 Alternative nine-point locations

An alternative set of nine standard measurement locations is defined by VESA (US Video Electronics Standards Association). See Figure 37 and Reference [10].

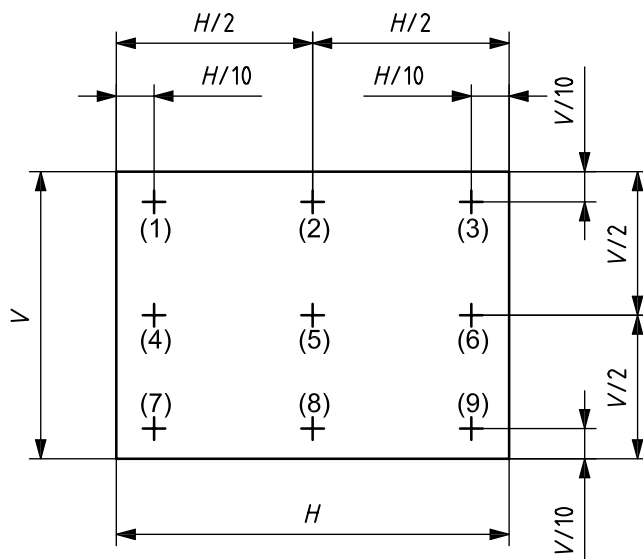


Figure 37 — Alternative nine-point locations (VESA)

5.5 Light measuring device (LMD)

Many factors contribute to the confidence that the measurements made actually reflect the value of the measurand. A complete description of all the factors that can affect measurement uncertainties is found in the GUM [6]. For a discussion of the propagation of errors and uncertainty estimation, see VESA-2005-5 [10], section A108 and, for terminology, section A221. Any uncertainty values are expressed using an expanded uncertainty with a coverage factor of $k = 2$ (a “two-standard-deviation” or “two-sigma” estimate).

The luminance relative expanded uncertainty of measurement with coverage factor of two shall be at least $u_{\text{LMD}} = \pm 5\%$ of the luminance or less, and the luminance measurement repeatability shall be less than either a maximum of $\rho_{\text{LMD}} = \pm 0,5\%$ of the luminance or the uncertainty introduced by any digitisation — whichever is larger — over a 5 min interval.

For colour, the expanded uncertainty of the measurement with coverage factor of two of chromaticity coordinates for tungsten-type CIE illuminant A above 10 cd/m^2 shall be at least $\pm 0,002$.

For devices that use array photodetectors to provide spatially-resolved luminance measurements, in addition to the above requirements, such a system shall provide, either in hardware or after software processing, no more than a $\pm 2\%$ nonuniformity ($1 - \min./\max.$) for all detection elements employed in a measurement of luminance. If such LMD are used to resolve fine detail at the pixel level, then the array pixel shall measure no more than $1/10$ the size of the smaller of the horizontal and vertical subpixel image pitch on the display, i.e. the smallest feature of interest should be rendered by at least ten detector pixels in the horizontal or vertical direction. The array shall be filtered to make it photopic (whenever luminance measurements are made). The CIE criterion for specifying the relative spectral responsivity from the human photopic response curve $V(\lambda)$, should be used so that $f_1' \leq 5\%$ (see Reference [9]).

Ambient lighting shall be controlled to avoid errors caused by direct (instrumentation, room lighting, windows, and other sources) and indirect (walls, tables, equipment, lab personnel clothing, and other surfaces) reflections from the display screen. Additional errors can be contributed by lens flare or veiling glare from the rest of the screen. For screens that exhibit strong viewing-angle dependence, the glare contributions can be particularly significant. Measurement of front-projection display systems are also subject to corruption due to stray light from ambient lighting and back reflections from room surfaces. Stray light elimination techniques should be employed to minimise the impact, see References [13], [14], [15] and [16] and VESA-2005-5 [10], section A101, for a discussion of possible solutions.

This list of devices given in 5.5.1 to 5.5.6 is not exhaustive, and other devices exist that could be applicable to the particular measurement application. However, any LMD device shall meet the minimum above requirements.

5.5.1 Spot meter

The spot meter creates an image of the object on a photodetector using a lens, then sample part of that image to produce the measurement. Many of these LMD have a viewing port or viewfinder (either optical or video) such that the lens focuses the image of the object to be measured onto the detection aperture. It is always important to properly focus the device so that the image lies essentially in the plane of the measurement aperture.

NOTE Any instrument with a lens is sensitive to stray light and thus to methods taken to minimise any corruption.

5.5.2 Luminance microprofile meter

The effective width of the photometer measuring field should be no more than 1/8 the width of a pixel, for pixels of either continuous or discontinuous luminance distribution.

For pixels of continuous luminance distribution, a slit aperture or spot aperture measuring field may be used. If a spot aperture is used, the measurement path shall pass through the centre(s) of the pixel(s) to be measured.

For displays to which the provisions of 6.10.9 (M 21.10) may apply, a spot aperture should be used.

For pixels of discontinuous luminance distribution (especially multicolour shadow-mask CRT), a photometer with a slit aperture or an equivalent instrument shall be used. The length of the slit shall be at least four times the width of a single pixel. The slit shall be oriented parallel to the long axis of the features to be measured.

A special display-measuring device may be used. Measurements made with the device shall be equivalent to those defined for photometers.

5.5.3 Conoscopic light measuring device

Conoscopic LMD measure the directional distribution of light without goniometric directional scanning by the projection of a directions image on a two-dimensional detector array (e.g. electronic camera). These devices can be used for the measurement of luminance and colour stimuli, which can then be further evaluated for luminance contrast, transmittance, reflectance, chromaticity, colour difference, and other quantities.

NOTE Any instrument with a lens is sensitive to stray light and thus to methods taken to minimise any corruption.

5.5.4 Collimated optics system

LMD that employ collimated optics do not image the source. Instead, such devices place a detector at the position of the focal length of the lens (not at the focus of an image). The size of the detector and the focal length of the lens determine the angles of the rays of light that contribute to the measurement. Thus, the LMD may be placed close to the surface of the display, yet not accept light from a wide angle of view.

Because collimated optics systems does not require focusing, it may be used either close to the display (as in a goniometer), or farther from the display (to facilitate reflectance measurements), as long as the resulting measurement area is appropriate to the measurement.

5.5.5 Array devices

In addition to the general requirements already outlined for all LMD above, there are complications particular to the use of array detectors such as charge-coupled devices (CCD). Several sources of error are associated with array detector imaging systems. Note that the imaging system includes the lens. A calibrated CCD can have exactly the same response for each array pixel. But when it is put into a system with a lens, the entire imaging system likely no longer preserves that uniformity because of the performance of the lens, reflections, etc. Thus, there are several factors to consider when using an array photodetector including: 1) non-uniform response over the array, 2) non-uniform imaging from lens system, 3) glare, veiling glare and lens flare, 4) background subtraction, 5) flat-field corrections, 6) photopic response, 7) aliasing between the detector pixel and the display pixel, and 8) calibration in luminance. For a further description of these complications, see VESA-2005-5^[10], section A111.

5.5.6 Virtual image display goniometer

This LMD is used to measure monocular (single-eye) and binocular (both eyes with separate optics, identical image), near-to eye, displays that produce a virtual image. It is mounted on a five-axis positioning system that simulates the movement of the eye: Cartesian coordinates (eye position) and rotational position (pitch and yaw, gaze angle). Requirements for this LMD are related to the performance of the human eye, and are specified in ISO 9241-302.

5.6 Measurement field

5.6.1 Many pixels

Measure a minimum of 500 pixels. If fewer pixels are used, it needs to be proven that any spatial non-uniformity is insignificant. Using the LMD, measure the luminance variation over an area of 500 pixels or the area of a box that is 10 % of the height and 10 % of the width of the display, at the desired measurement field. The area should centre around the measurement locations. If the variation is 1 % or better, then any spatial non-uniformity is insignificant, and the smaller measurement field can be used.

5.6.2 Within a pixel

For an array detector, there should be 10 or more detector pixels per display pixel.

For a spot meter, the diameter of the measurement spot should be less than 1/3 of the pixel area.

5.6.3 Exit port of light source

Always focus on the exit port of the light source, and measure normal to the exit port. The uniformity of the source can be determined using the procedure specified in 6.6.3 (P 17.3), measuring at five points. The non-uniformity should be 1 % or better. The temporal stability of the light source can be determined using the procedure specified in 6.4.8 (P 15.7), allowing the source to warm up for 1 h before taking data. The temporal stability should be better than 0,1 %.

5.6.4 Section of large illumination surface

For measuring the illuminance of a display projected onto an external screen, the minimum specified in 5.6.1 is not always practical. In this case, one should measure as many as feasible, but at minimum the meter head shall be filled with a 3×3 array of visually uniform pixels.

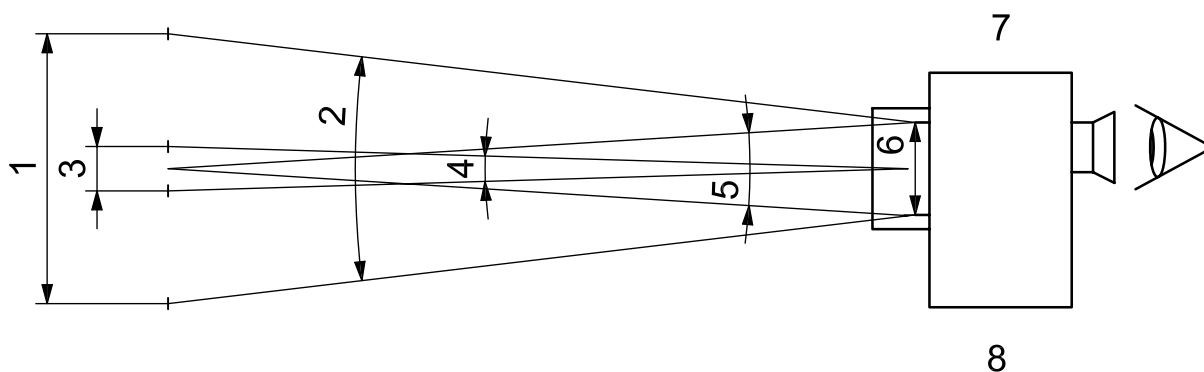
5.6.5 Luminance profile

For a scanning LMD, the averaging window width should be as close as possible to the pixel pitch.

5.7 Angular aperture

The angular aperture (see Figure 38) of the measurement instrument shall be 5° or less. Certain measurements may require the angular aperture to be 2° or less, unless it can be demonstrated that it is equivalent to measurements made at 2° or less.

If the detector head is used for illuminance measurements, it shall be fitted with a cosine-correcting accessory.



Key

- 1 field of view
- 2 angular field of view
- 3 measurement field
- 4 measurement field angle
- 5 angular aperture
- 6 acceptance area
- 7 luminance meter with view-port
- 8 focus on object being measured

Figure 38 — Measurement parameters

5.8 Meter time response

5.8.1 Fast response meter

The LMD shall have a response time of better than 1/10 the fastest part of the parameter under measurement, i.e. a signal bandwidth that is at least 10 times the highest frequency component. The rise time of the meter should be 1/10 the rise time of the measured signal to capture the signal with minimal rise time error. The LMD shall be capable of producing a linear response to rapid changes in luminance. Response time and sample time should be fast enough to avoid aliasing with the display.

5.8.2 Time-averaging meter

The measurement time interval shall be long enough so that the standard deviation of ten or more luminance measurements is no greater than 1 %. The instrument can be time-synchronised to trigger a measurement with the refresh rate of the display. Measurement interval should be a multiple ($n \geq 1$) of the refresh rate.

Be aware that some meters can provide erroneous results if the instantaneous power of the measurement area is significantly large. Such a problem could occur in flying-spot displays such as laser displays or some CRTs. This situation arises due to saturation of the detector, such as a PMT (photomultiplier tube) or clipping of the instrument amplifier.

5.9 Test illumination

5.9.1 Parameters and tolerances

The various parameters referenced in this section are listed in Table 1 for reference. The tightness of the tolerances will depend upon the characteristics of the display. The tolerances should be adequately set to provide a ± 5 % reproducibility of the particular measurement.

Table 1 — Detector and source parameters

Symbol	Description
Detector/LMD parameters	
θ_R	Inclination angle of detector from z -axis
z	Distance of centre of detector front surface (or lens) from centre (often z_d when detector on optical axis)
a	Diameter of source exit port (outer diameter of ring light source)
Source parameters	
d	Distance of centre of source exit port from centre of coordinate system
θ_S	Rotation angle of source from z -axis
θ_a	Subtense of entrance pupil of detector or angular aperture
θ_r	Angle from normal of ring light outer diameter

5.9.2 Darkroom

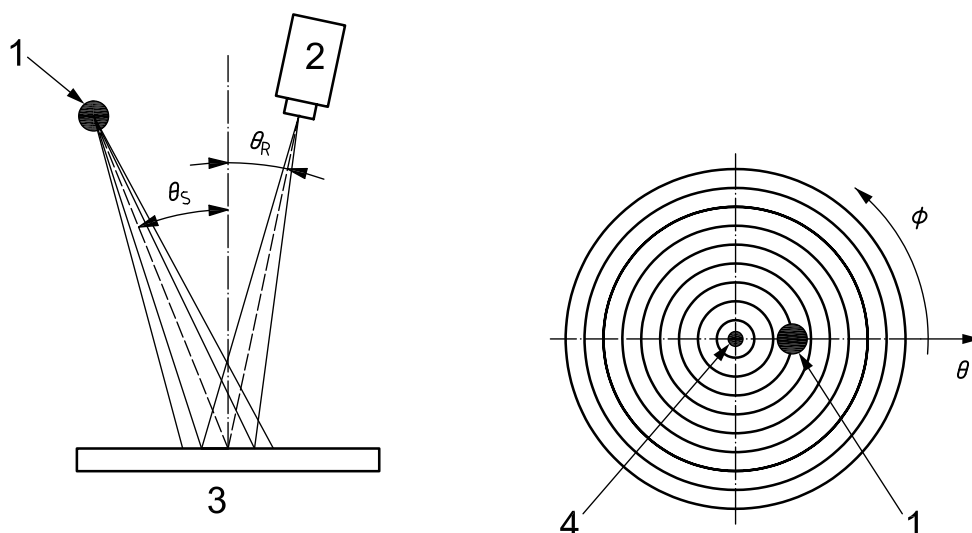
Ensure not only that all room lights are turned off, but that light from equipment in the room, and reflections from surrounding objects back to the screen are controlled such that they are at a negligible level. Illuminance, E , on the screen should be 1 lx or less ($E \leq 1$ lx). This is equivalent to stating that the luminance of a diffuse white surface at the position of the screen should have a luminance of less than 0,32 cd/m². However, there are cases where this specification is insufficient. In general, the goal is to avoid corruption of measured dark colours due to ambient light or reflections. Avoid measuring as screen luminance reflections off the screen from clothing and equipment lights. Ambient lighting — direct (instrumentation, room lighting, windows, and other sources) and indirect (walls, tables, equipment, lab personnel clothing, and other surfaces) — shall be controlled to avoid errors caused by reflections from the display screen. Additional errors can be contributed by lens flare or veiling glare from the rest of the screen. For screens that exhibit strong viewing-angle dependence, the glare contributions can be particularly significant.

For luminance measurements less than 3 cd/m², it is recommended that a diffuse white standard placed at the position of the screen have a reflected luminance of $< 1/10$ of the lowest luminance reading to be measured. This is equivalent to requiring the illuminance to be $E < 0,1 \pi L$ for luminance values $L < 3$ cd/m².

“Best conditions” assume a room that is completely dark and filled only with dark objects. Reflections from light-emitting devices or from bright or reflective surfaces could reflect off the surface of the EUT, corrupting the measurement. This includes white clothing, lightly coloured objects in the room, lights on instruments, computer displays, bright spots or light leaks in distant areas, etc.

5.9.3 Directional illumination

A light-source with a small diameter (compared to the distance to the measurement field) is aligned to form an angle, θ_S , with respect to the surface-normal of the EUT. This light source illuminates the EUT to form a directional illumination for the measurement field. In the plane of light incidence, aligned at an angle θ_R with respect to the surface normal of the EUT is the LMD. The measurement field on the EUT is defined by the area element that is imaged on the detector of the LMD. The intensity across the cross-section of the beam shall be constant within 5 %. The angle between the axis and any ray of the illuminating beam shall not exceed $\pm 5^\circ$. See Figure 39.



Key

- 1 light source
- 2 LMD
- 3 EUT
- 4 ring light
- θ angle from normal
- ϕ azimuth angle in relation to θ

NOTE For the meaning of other symbols, see Table 1.

Figure 39 — Directional illumination^[18]

5.9.4 Small aperture source

A single small-diameter light source (lamp) is required. Figure 40 shows the configuration with the display rotated 15° so that the angle between the normal of the screen and either the centre of the source or the LMD is 15°. Only one source is employed. A large-aperture source may be covered with an opaque black disk with a small hole at its centre to act as a small-diameter light source. A fibre-optic light source of the same diameter or other light sources can be used as well, provided they are adequately uniform and stable. The goal is that the small source subtend 1° as viewed from the centre of the screen.

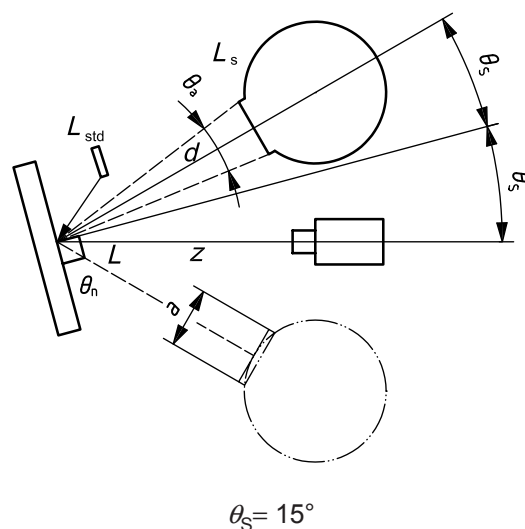
 θ_n angle of LMD relative to normal

NOTE For the meaning of other symbols, see Table 1.

Figure 40 — Small aperture source configuration

5.9.5 Extended source, 5°

A single light source (lamp) is required. Figure 41 shows the general extended source configuration. For the specific case, the display is rotated 15° so that the angle between the normal of the screen and either the centre of the source or the LMD is 15° . The goal is that the source subtend 5° as viewed from the centre of the screen.



Key

- L luminance of screen
- L_s luminance of light source
- L_{STD} luminance of standard
- θ_n angle of LMD relative to normal

NOTE For the meaning of other symbols, see Table 1.

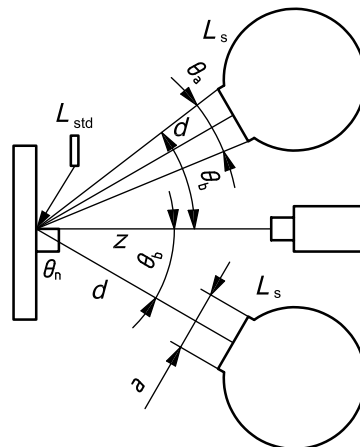
Figure 41 — Extended source — General configuration

5.9.6 Extended source 15° to 30°

A single light source (lamp) is required. Figure 42 shows the general extended source configuration. For the specific case, the display rotated 15° so that the angle between the normal of the screen and either the centre of the source and the LMD is 15°. Only one source is employed. The goal is that the source subtend 15° as viewed from the centre of the screen.

5.9.7 Two extended sources 15° to 30°

Figure 42 shows the configuration with the display rotated 15° so that the angle between the normal of the screen and either the centre of the source or the LMD is $\theta_b = 15^\circ$. Two sources are employed. The goal is that the source subtend $\theta_a = 15^\circ$ as viewed from the centre of the screen.



Key

L_S luminance of light source

L_{STD} luminance of standard

θ_n angle of LMD relative to normal

NOTE For the meaning of the other symbols, see Table 1.

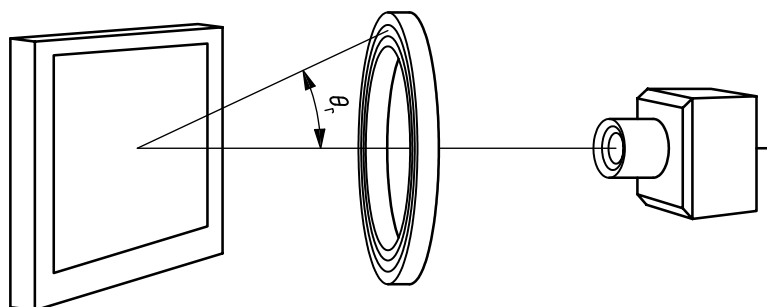
Figure 42 — Two extended light sources

5.9.8 Ring light

A usually diverging beam of white light is directed at the EUT from all azimuth angles in the range of 0° to 360°. Such an illumination scheme is also called *ring-light illumination*. The intensity of illumination as a function of the azimuth angle shall be constant within XY %. The inclination angle of light incidence has to be specified.

The measuring spot on the EUT as “seen” by the LMD shall be enclosed and centred in the illuminated spot on the EUT. The LMD shall not accept light with a deviation from the optical axis of more than $\pm 2,5^\circ$.

This set-up is used with the source fixed and the LMD can remain movable within the limits of the opening of the illuminating ring of light. See Figure 43.



Key

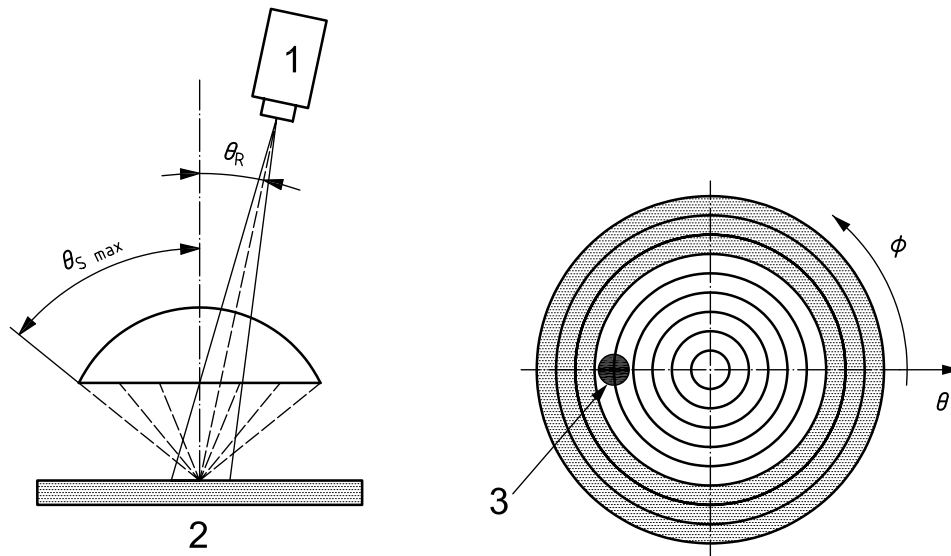
θ_r angle from normal to centre of ring's edge

Figure 43 — Ring light configuration

5.9.9 Conical source

A light-source centred about the surface normal of the EUT illuminates the EUT from a range of inclination angles, θ_S ($0^\circ < \theta_S < \theta_{S\max}$), for all azimuthal angles, $\phi_S = 0^\circ$ to 360° . The LMD is aligned to form the angle, θ_R , with respect to the surface normal of the EUT. The measurement field on the EUT is defined by the area element that is imaged on the detector of the LMD.

The illumination is provided out of a solid angle, Ω_{SC} , with the apex of this solid angle fixed to the centre of the measuring spot on the EUT. The variation of the intensity of incident light with direction inside this solid angle shall be specified. The cone of illumination itself is specified by the direction of the axis of the cone and the maximum inclination with respect to the axis (i.e. cone angle). Figure 44 shows the side-view of the measuring setup (left) and its representation in a polar coordinate system (right) for an angle of LMD inclination, $\theta_R = 50^\circ$ and a subtense of the source, $2 \times \theta_{S\max} = 120^\circ$.



Key

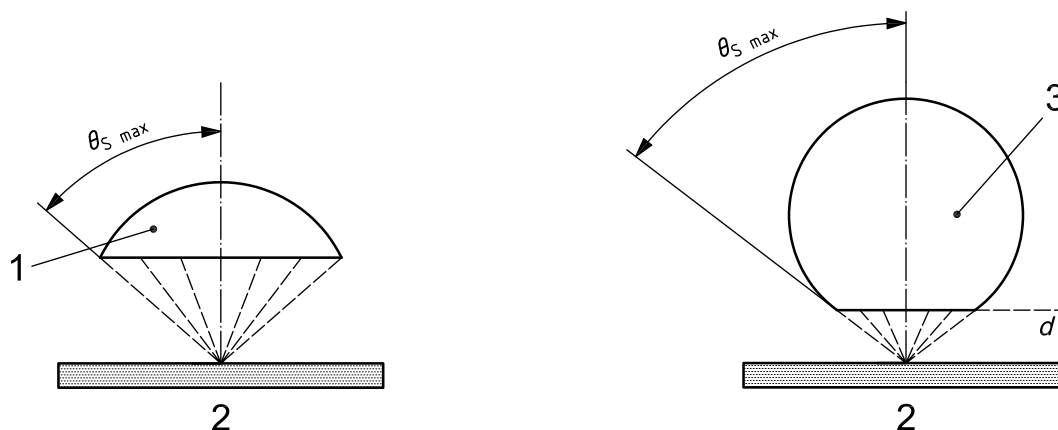
- 1 LMD
- 2 EUT
- 3 ring light
- θ angle from normal
- ϕ azimuth angle in relation to θ

NOTE For the meaning of the other symbols, see Table 1.

Figure 44 — Conical source configuration^[18]

Conical illumination can be realised with three different geometries:

- the exit port of an integrating sphere at some distance to the measuring spot produces a conical illumination with constant intensity from all directions of light incidence (see Figure 45);
- a spherical dome (reflective or transmissive section of a sphere) produces conical illumination (up to angles of inclination of, for example, 80°), usually with variations of the intensity versus direction of light incidence (see Figure 45);
- a flat, Lambertian, luminance source parallel to the EUT surface produces an illumination of the measuring spot that drops with $\cos^4 \theta$ (where θ is the angle of inclination of the direction of light incidence).

**Key**

- 1 spherical dome
- 2 EUT
- 3 integrating sphere with large aperture

Figure 45 — Realisation of conical illumination^[18]**5.9.10 Hemispheric, specular included**

A light source centred about the surface normal of the EUT illuminates the EUT from a range of inclination angles $0^\circ \leq \theta_S \leq 60^\circ$ for all azimuthal angles $\phi_S = 0^\circ$ to 360° . The LMD is aligned to form an angle, $\theta_R < \theta_S$, with respect to the surface normal of the EUT. The measurement field on the EUT is defined by the area element that is imaged on the detector of the LMD.

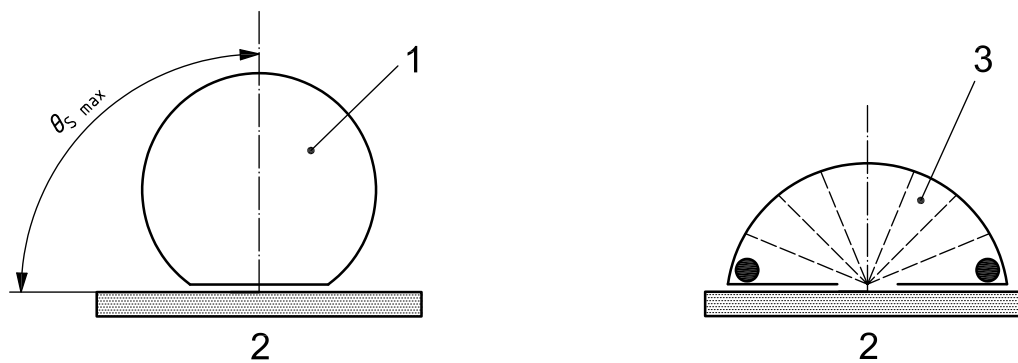
Illumination is provided out of a solid angle, Ω_{SH} , with the apex of this solid angle fixed to the centre of the measuring spot on the EUT. In the hemispherical case, solid angle Ω_{SH} extends to an angle of inclination of 90° . For the purposes of this part of ISO 9241, the term *hemispherical illumination* is applicable when illumination is provided such that the intensity of illumination does not drop below 50 % of the maximum value at an angle of inclination of 85° . The variation of the intensity of incident light with direction inside Ω_{SH} shall be specified.

Good approximation of ideal hemispherical illumination (i.e. constant intensity from all directions up to 90°) can only be provided by integrating spheres with a small exit port diameter compared to the diameter of the sphere. The exit port shall be directly adjacent to the surface of the EUT in order to assure good hemispherical illumination (up to inclination angles of 90°).

Other approximations of hemispherical illumination may be realised by

- a) diffusing hemispheres with diffuse reflective coatings, or
- b) transmissive diffusing spheres and domes.

See Figure 46.



Key

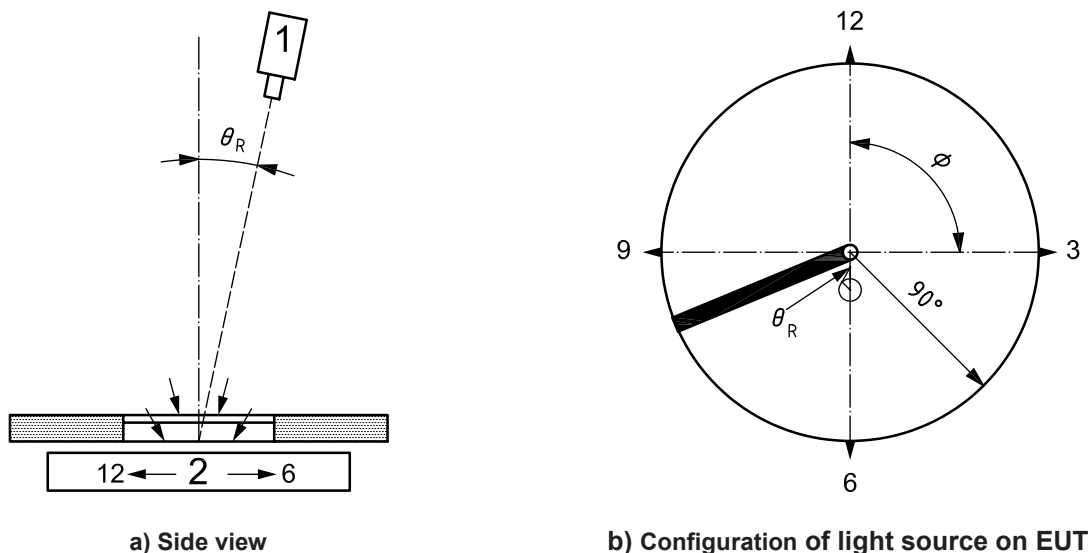
- 1 integrating sphere
- 2 EUT
- 3 diffusing hemisphere

Figure 46 — Realisation of hemispherical illumination^[18]

5.9.11 Hemispheric, specular excluded by hardware

This modification introduces a “shading slit” (gloss-trap) into the illumination system, as shown in Figure 47. The slit rotates together with the detector and is always parallel to the plane of incidence.

By excluding the mirror angle, a contrast number is achieved which is closer to real use conditions. The obtained LCD characteristics is also closer to the theoretical behaviour of LCD cells. With this method the optimum viewing angle and the usable viewing angle range can be easily measured and analysed. Recommended width of slit: not yet determined.



Key

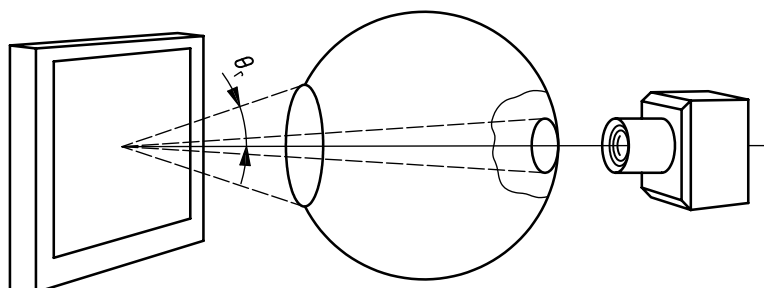
- 1 photometer
- 2 EUT
- θ_R inclination angle of detector from z-axis

NOTE The numbers 12, 3, 6 and 9 refer to the cardinal directions on the face of a clock (“12 o’clock”, etc.)

Figure 47 — Hemispheric configuration

5.9.12 View port

Not a very robust configuration, except for simplest reflection properties (Lambertian and specular, but not haze). There is strong sensitive to geometry when haze is non-trivial because the view port image is in vicinity of the haze peak. See Figure 48.

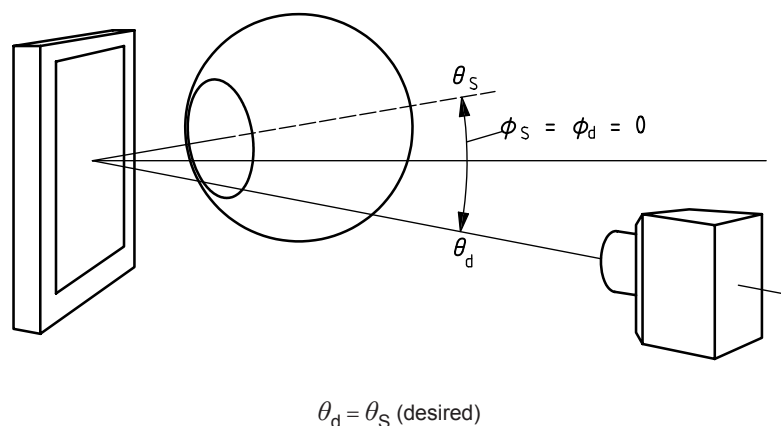
**Key**

θ angle from normal to centre of ring's edge

Figure 48 — View-port configuration

5.9.13 Proximal specular

The source is placed closely proximal to the display screen. In the standard position, it is placed so that the horizontal axis of the display surface and the normal of the display intersect it. This configuration is somewhat robust, but it combines much of any Lambertian component that might be present. However, if only making contrast measurements (or specular) it may be useful. See Figure 49.

**Key**

ϕ_s azimuth angle of source

ϕ_d azimuth angle of detector

Figure 49 — Proximal specular configuration

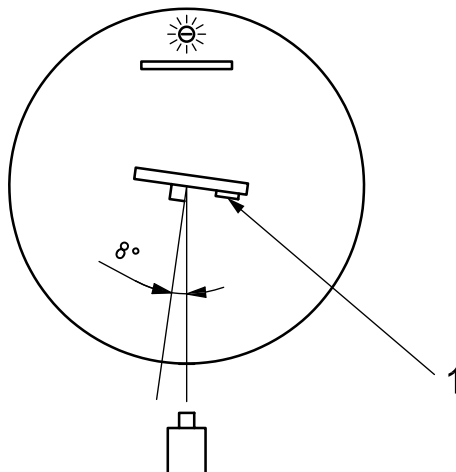
5.9.14 Inside diffuse sphere

A diffuse ambient light is provided to illuminate the screen from all directions as uniformly as is practical. The LMD is arranged such as to view the centre of the surface of the display through a hole in the surround from an angle of 8° ($-0^\circ, +2^\circ$) from the normal, or by rotating the display for an integrating sphere. The LMD is focused on the display surface.

Figure 50 shows the use of 8° — here, probably the safest angle to use, in order that the measurement hole will not affect the reflection — yet the measurement is made as close to the normal of the screen as possible.

The use of the 8° (-0° , $+2^\circ$) angle can be important, depending upon the reflectance properties of the display and the uniformity of the illuminating surface. Ideally, it is desired to be infinitesimally small and located along the perpendicular of the centre of the screen, for the measurement to be made perfectly. Since the LMD has a finite size, the measurement cannot be made along the perpendicular, because the reflection of the LMD would interfere with the reflection (unless the screen was truly Lambertian). The problem with this measurement arises because of the haze term. If the display reflection were characterised by only Lambertian and (distinct-image) specular reflections (no haze), then simpler measurements could be used to characterise reflections. Which is the preferred angle? It is an angle that is as close to the perpendicular as possible but that will not interfere with the measurement of the reflection. If the angle is too great, say, 20° or more, then a good portion of the light hitting the display relative to the 20° viewpoint will come from angles greater than 90° , which is not representative of someone sitting in front of the display. Because of the haze, an error can be introduced in the measurement. Conversely, if less than 8° to 10° is used, then it might be found that the hole through which the measurement is taken starts to affect the measurement — again, because of the haze reflection. In many cases, 5° would probably work just as well; however, -8° is the safe choice.

The error in this measurement comes primarily from the error in the measured luminance, L , of the screen. It is not that the LMD is in error, but that unless an integrating sphere is used with care, the non-uniformity of the illumination can cause difficulties. If a hemisphere (or equivalent) is used, it can be a challenge to obtain an even illumination of the hemisphere. How well this method works depends upon the reflectance properties of the screen — and haze introduces much of the error — so that a measurement of the reflectance, ρ_H , can be expected to exhibit a reproducibility of $\pm 5\%$ at best.



Key

1 white standard

Figure 50 — Diffuse sphere configuration