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Ergonomics of human-system interaction —

Part 305: Optical laboratory test methods for electronic visual displays

Ergonomie de l'interaction homme-système —

Partie 305: Méthodes d'essai de laboratoire optique pour écrans de visualisation électroniques

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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/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.

5.1.1.5 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 V ± 0,07 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 that 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 $BaSO_4$ 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 ($E = \pi L_{STD}/\beta_{STD}$) 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

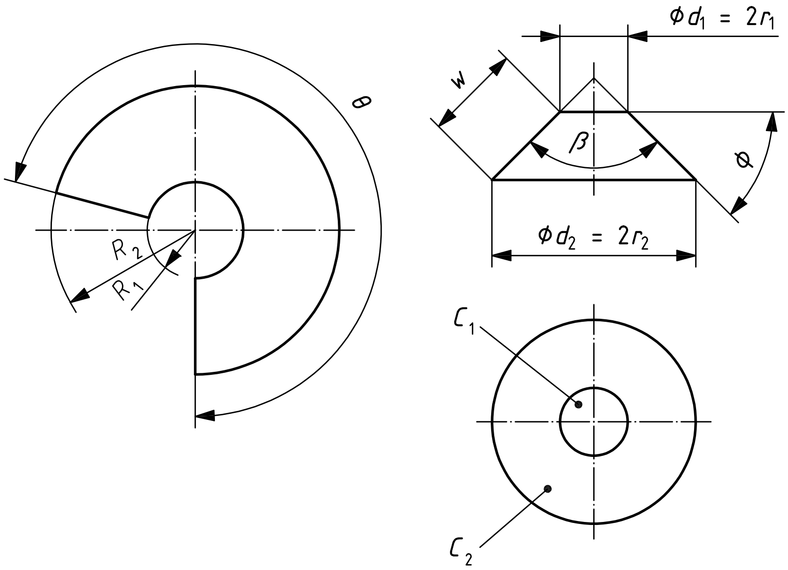
The colour appearance of a CRT monitor is affected by the static magnetic field of the earth. In particular, turning the CRT monitor when switched on can cause changes in the colour appearance. The CRT can be "zeroed" to its default state using a degaussing device. To improve repeatability of testing, 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.



$\beta = 2\phi =$ apex angle

$w = R_2 - R_1 = (r_1 - r_2)/\cos\phi$

$C_1 = 2\pi\, r_1 = R_1\theta$

$C_2 = 2\pi\, r_2 = R_2\theta$

$R_1 = r_1/\cos\phi$

$R_2 = r_2/\cos\phi$

$\theta = 2\,\pi\cos\phi$

For $\phi = 45°$, $\cos\phi = \frac{1}{\sqrt{2}}$:

$R_1 = \sqrt{2} \times r_1$

$R_2 = \sqrt{2} \times r_2$

$\theta = \pi \times \sqrt{2}$

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.

