
**Ergonomic requirements for office work
with visual display terminals (VDTs) —**

Part 7:
Requirements for display with reflections

*Exigences ergonomiques pour travail de bureau avec terminaux à écrans
de visualisation (TEV) —*

Partie 7: Exigences d'affichage concernant les réflexions



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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.

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.

International Standard ISO 9241-7 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human system interaction*.

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 3: Visual display requirements
- Part 4: Keyboard requirements
- Part 5: Workstation layout and postural requirements
- Part 6: Environmental requirements
- Part 7: Requirements for display with reflections
- Part 8: Requirements for displayed colours
- Part 9: Requirements for non-keyboard input devices
- Part 10: Dialogue principles
- 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*

Annexes A, B, C and D of this part of ISO 9241 are for information only.

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Introduction

Visual display terminals (VDTs) are subject to reflections of environmental luminance and illuminance from the display device surfaces. Under some conditions, the reflections become disturbing to the user and affect both comfort and task performance. The objective of this part of ISO 9241 is to maintain usable and acceptable VDT image quality in luminous environments that can cause reflections from the screen.

The document is intended for evaluators and users of VDTs. It is intended to be used with ISO 8995, ISO 9241-3, ISO 9241-6 and ISO 9241-8 to provide guidance for the visual ergonomics of the VDT workplace. Compliance with this part of ISO 9241 is dependent on the hardware characteristics of the VDT, except for polarity that can be application-dependent.

This part of ISO 9241 contains requirements and methods for measurement of the image quality of VDTs used in luminous environments that can cause specular and diffuse reflections from the screen. ISO 9241-3 and ISO 9241-8 contain requirements that deal with luminance and luminance ratios for VDT images measured under conditions that exclude specular reflections. These parts of ISO 9241 interact with this part of ISO 9241. VDTs that meet the interacting requirements and recommendations of ISO 9241-3 and ISO 9241-8 do not necessarily meet those of this part ISO 9241 and vice versa.

ISO 9241-6 and ISO 8995 contain specific recommendations concerning design of the workplace luminous environment to minimize sources of glare. The luminous environment conditions used to determine compliance with this part of ISO 9241 are drawn from, or are consistent with recommendations and requirements of these International Standards. The luminous environment values used to determine compliance to this part of ISO 9241 do not constitute specific recommendations or requirements for workplace lighting.

The burden of a visually acceptable VDT workplace is a tradeoff between the display hardware and the VDT environment. To acknowledge that tradeoff, compliance with this part of ISO 9241 has been developed in three classes, each with rules for decision based on environmental assumptions.

Although the decision rules are not expected to be exactly duplicated in the workplace environment, they do correspond approximately to general types of workplace environment to which VDTs are expected to be suitable:

Class	Environment
-------	-------------

- | | |
|-----|---|
| I | suitable for general office use |
| II | suitable for most, but not all, office environments |
| III | requiring a specially controlled luminous environment for use |

An alternative test method is provided for VDTs whose characteristics preclude use of the quantitative test method.

NOTE — ISO 13406 extends the definitions, requirements, and test method of this part of ISO 9241 for flat panels whose colour and/or luminance contrast is strongly dependent on the direction from which they are viewed, and whose reflection characteristics can vary with the logical state of the screen.

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Ergonomic requirements for office work with visual display terminals (VDTs) —

Part 7:

Requirements for display with reflections

1 Scope

This part of ISO 9241

- establishes image quality requirements for VDTs used in luminous environments that may cause reflections from the screen. The requirements are stated as performance or design specifications, and test methods are provided.
- applies to the ergonomic design of direct-view electronic displays for office tasks, including such activities as data entry, text processing and interactive inquiry. Office tasks are performed indoors, without exposure to direct sunlight. The recommendations can possibly be appropriate for other tasks, including process control, graphic design and computer-aided design, but their applicability has not been established.
- applies to monochrome and multicolour displays. The following displays and similar types are excluded from the scope of this part of ISO 9241: multi-user projection displays, transparent displays and virtual image displays.
- applies to VDTs for which its test method is suitable. The test method is limited to VDTs whose colour and/or luminance contrast does not vary strongly as a function of the viewing direction, and whose reflection properties do not vary as a function of the logical state of the screen. The test method is suitable for emissive VDT technologies, such as cathode ray tubes, and some flat panels.

NOTE — VDTs using display devices for which the test method of this part of ISO 9241 is not suitable (for example, liquid crystal displays) are directed to ISO 13406-2.

2 Normative references

The following standards contain provisions which, through reference in the text, constitute provisions of this part of ISO 9241. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9241 are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 9241-3:1992, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 3: Visual display requirements*.

ISO 9241-8:1997, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 8: Requirements for displayed colours*.

CIE 17.4: 1989, *International Lighting Vocabulary*.

3 Definitions and symbols

3.1 Definitions

For purposes of this part of ISO 9241, the definitions given in ISO 9241-3 (except in 3.1.5) and the following definitions apply.

3.1.1 dark room: Room in which the only sources of light are the VDT under test and the prescribed sources of luminance or illuminance.

3.1.2 extended source of luminance: Area of uniform luminance, $L_{A(EXT)}$ with a width or diameter of at least 15° measured from the VDT screen centre.

3.1.3 luminance coefficient (at a surface element, in a given direction, under specified conditions of illumination) [q_v , q]: Quotient of the luminance of the surface element in the given direction by the illuminance of the medium. [see IEC (50) 845-04-71].

NOTE — It is expressed per steradian.

3.1.4 luminance factor (at a surface element of a non-self-radiating medium, in a given direction, under specified conditions of illumination) (β_v , β): Ratio of the luminance of the surface element in the given direction to that of a perfect reflecting or transmitting diffuser identically illuminated [based on IEC (50) 845-04-69 unit: 1] (unit: 1).

3.1.5 luminance ratio: Ratio between a higher and a lower area-average luminance, in which each luminance in the ratio is the sum of emitted and reflected luminance components, with one or more components common to both the numerator and the denominator.

NOTE — To reduce potential confusion, the terms *contrast* and *luminance contrast* are avoided in this part of ISO 9241. The luminance ratios of this part of ISO 9241 do not correspond to the luminance contrast within and between character details of ISO 9241-3.

3.1.6 negative polarity: Condition in which the foreground luminance L_F is the highest luminance level of the display, and the background luminance, L_B is the lowest luminance level of the display.

3.1.7 positive polarity: Condition in which the foreground luminance L_F is the lowest luminance level of the display, and the background luminance, L_B is the highest luminance level of the display.

3.1.8 reflectometer value: Value measured using the test method of this part of ISO 9241 for the diffuse luminance coefficient, R_D (an estimate of q) and the specular reflection factor, R_S (an estimate of β).

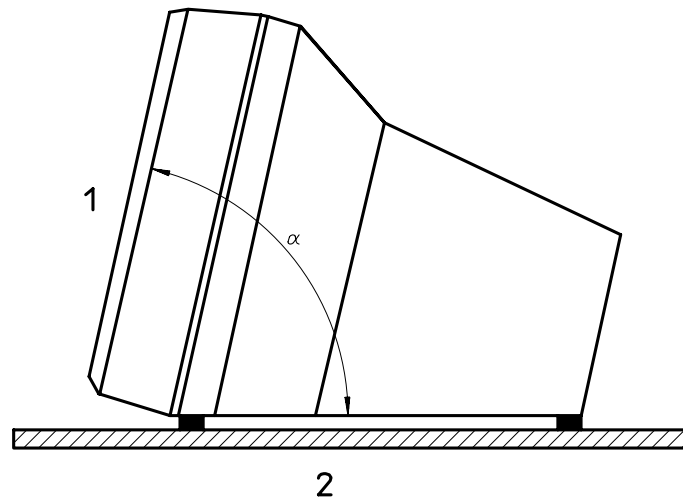
NOTE — The measured reflectometer value depends on the geometric characteristics of the test method, on the illuminant, on the spectral sensitivity of the detector (even when equipped with filters), and on the reference standard used.

[Adapted from CIE 50(845): 1987].

3.1.9 screen tilt angle, α : Angle formed by the intersection of the plane tangent to the centre of the display and the horizontal plane.

NOTES

- 1 This is identical to the angle A in 6.1.2 of ISO 9241-3:1992.
- 2 Figure 1 shows the intended angle.
- 3 Screen tilt angle is expressed in degrees.

**Key**

- 1 Viewing side
- 2 Horizontal support surface

Figure 1 — Screen tilt angle

3.1.10 small source of luminance: Area with a diameter of 1° (measured from the screen) of uniform luminance ($L_{A(SML)}$), to be used in the measurement of specular reflections from screens with diffusing treatments.

3.2 Symbols**3.2.1 Primary symbols**

The primary symbols used in this part of ISO 9241 are shown below. See figure 2.

- E illuminance, expressed in lux (lx)
- L luminance, expressed in candela per square metre (cd/m^2)
- LR luminance ratio. (Unit: 1)
- R_D reflectometer value for the diffuse reflection characteristic of the screen, obtained following the procedure below. It is the ratio of diffusely reflected luminance of the screen to its illuminance, under the conditions specified by clause 7 of this part of ISO 9241 (see 3.1.8). It is expressed per steradian (sr^{-1}). The practical unit is candela per square metre per lux [$\text{cd}/(\text{m}^2 \cdot \text{lx})$].
- R_S reflectometer value for the specular and partially diffuse reflection characteristic of the screen, determined following the procedure of clause 7 of this part of ISO 9241. It is the ratio of specular and partially diffuse reflected luminance of a defined part of the reflected virtual image to the luminance the source of reflections under the prescribed conditions of measurement (see 3.1.8). (Unit: 1)

3.2.2 Subscripting convention

This part of ISO 9241 uses luminances whose total is made up of contributions from several identifiable components. Luminance is identified by the symbol L followed by subscripts showing its components. For example L_{FSD} represents a total luminance composed of contributions from the Foreground emitted luminance, the Specular reflected luminance, and the Diffuse reflected luminance. The principal subscripts are:

- B the emitted luminance from the display screen Background
- F the emitted luminance from the display screen Foreground
- D the Diffuse reflected component of a luminance.

S the Specular reflected component of a luminance.

A the luminance of an Area (whether extended or very small) that is the source of a specular reflection.

(0°) and (15°): the angle at which reflected and/or emitted luminances are measured, or the corresponding diffuse reflection factor or specular reflection coefficient applied. A measurement angle perpendicular or *normal* to the display screen surface is 0°. A measurement angle of 15° to the normal to the screen surface is 15°.

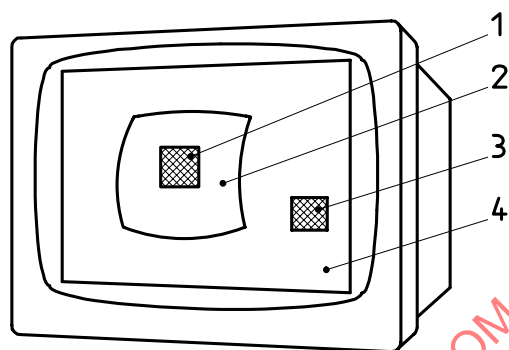
REF: the quantity is a reference value used in compliance calculations. Reference values are not intended to be reproduced during testing.

STD: the quantity is the calibrated value of a measurement standard.

Subscript modifiers:

(max): the maximum value of a quantity (usually the specular reflection source luminance $L_{A(max)}$) that will allow the VDT to just meet the requirements of this part of ISO 9241.

(EXT) and (SML): indicate specular reflected luminances and reflection characteristics determined using either an extended source or a small source of luminance. They are used only to modify the subscript S, as in $L_{S(F, SML, 15^\circ)}$, the specular reflected luminance of an area of the screen set to the foreground state, from a small source, measured at 15°.



Composite luminances:

1 L_{FSD} = Luminance of image Foreground + Specular reflection + Diffuse reflection

2 L_{BSD} = Luminance of image Background + Specular reflection + Diffuse reflection

3 L_{FD} = Luminance of image Foreground + Diffuse reflection

4 L_{BD} = Luminance of image Background + Diffuse reflection

Reflected luminances:

L_S = Luminance of Specular reflection = $R_S L_A$

R_S = Specular reflectometer value (from test method)

L_A = Luminance of an Area causing the specular reflection

L_D = Luminance of Diffusion reflection = $R_D E$

R_D = Diffuse reflectometer value (from test method)

E = ambient illuminance

Figure 2 — Screen luminances

3.2.3 Secondary symbols

L_F, L_B : The area-average emitted luminances of a patch of pixels in the centre of the screen. The emitted luminances are to be measured in the lowest and highest luminance levels of the display that are available for text or its background, under program control.

L_D, L_S : Reflected luminances used to decide compliance with this part of ISO 9241 are approximated by a calculation based on the reflectometer values of the VDT screen and assumed lighting environment conditions.

$L_D \approx R_D \cdot E$ is the diffuse reflection luminance

where

R_D is the reflectometer value for the diffuse reflection characteristic of the screen;

E is the illuminance incident in the plane of the screen.

$L_S \approx R_S \cdot L_A$ is the specular reflected luminance

where

R_S is the reflectometer value for the specular and partially diffuse reflection characteristic of the screen;

L_A is the luminance of a uniform, extended or small luminous source positioned at the specular angle from the point of measurement. The values of L_A used for compliance with this part of ISO 9241 are specified in clause 6.

Specular reflected luminances and reflection factors are subdivided into those resulting from an extended-source and a small-source of luminance.

$L_{S(EXT)}$, $L_{S(SML)}$: specular reflected luminances caused by extended and small sources, respectively.

$R_{S(EXT)}$, $R_{S(SML)}$: specular and partially diffuse reflectometer values of the screen caused by extended and small sources of luminance, respectively.

$LR_{BDS/FDS}$: luminance ratio of the screen image (foreground and background) with diffuse and specular reflections. It is the ratio between the higher and the lower area-average luminances of the image, when both specular and diffuse reflected luminances are superimposed on each. See figure 3. The definition of image luminance ratios is polarity-dependent.

$LR_{BDS/FDS}$ positive polarity:

$$LR_{BDS/FDS} \equiv \frac{L_B + L_D + L_S}{L_F + L_D + L_S}$$

Expanded,

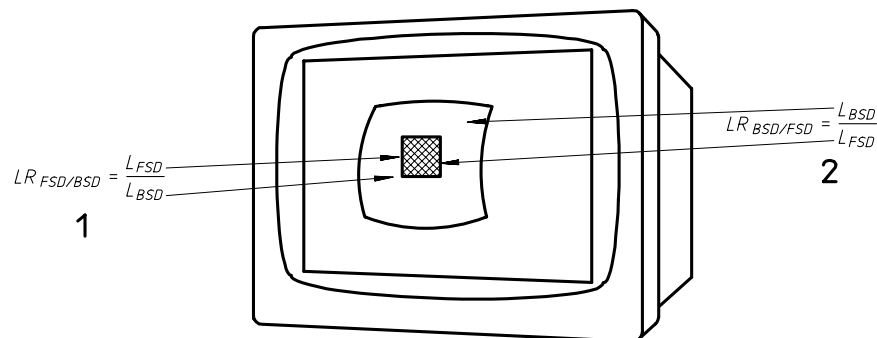
$$LR_{BDS/FDS} \equiv \frac{L_B + E \cdot R_D + L_A \cdot R_S}{L_F + E \cdot R_D + L_A \cdot R_S}$$

$(LR_{FDS/BDS})$ negative polarity:

$$LR_{FDS/BDS} \equiv \frac{L_F + L_D + L_S}{L_B + L_D + L_S}$$

Expanded,

$$LR_{FDS/BDS} \equiv \frac{L_F + E \cdot R_D + L_A \cdot R_S}{L_B + E \cdot R_D + L_A \cdot R_S}$$



1 in negative polarity

2 in positive polarity

Figure 3 — Image luminance ratio with both specular and diffuse reflections

$LR_{BDS/BD}$: specular reflection luminance ratio. It is the ratio between the luminance of an area of the screen set to the background state, with a specular reflection and diffuse reflection superimposed, and the luminance of the same area of the screen without the specular reflection. See figure 4. The definition is not polarity-dependent.

$$LR_{BDS/BD} \equiv \frac{L_B + L_{D(B)} + L_{S(B)}}{L_B + L_{D(B)}}$$

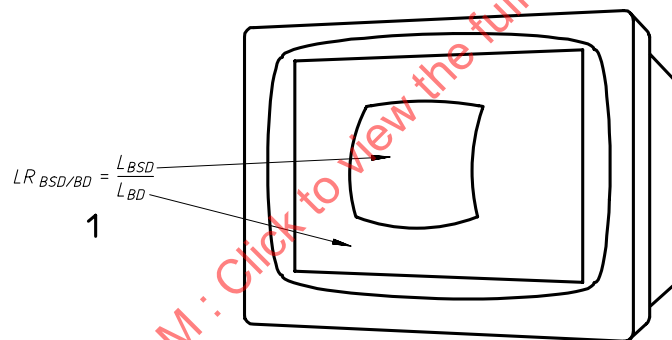
Expanded,

$$LR_{BDS/BD} \equiv \frac{L_B + E \cdot R_D + L_A \cdot R_S}{L_B + E \cdot R_D}$$

NOTES

1 Although mathematically the specular reflection luminance ratio is not polarity-dependent, practically and perceptually the polarity makes a very important difference. In negative polarity, the background is dark, causing much higher specular reflection luminance ratios. In positive polarity, the background is bright, which dramatically reduces the luminance ratio of specular reflections. This effect makes positive polarity VDTs far more resistant to the effects of reflections than negative polarity VDTs with the same highest and lowest luminance levels.

2 In negative polarity the specular reflection is the same polarity as the information displayed on the screen. This leads to some apparent perceptual competition between the reflection and the useful image. To maintain acceptable image quality, it is necessary to maintain the image luminance ratio $LR_{FDS/BDS}$ substantially greater than that of the specular reflection ratio $LR_{BDS/BD}$.



1 In either polarity.

Figure 4 — Luminance ratio of the specular reflection against the screen background

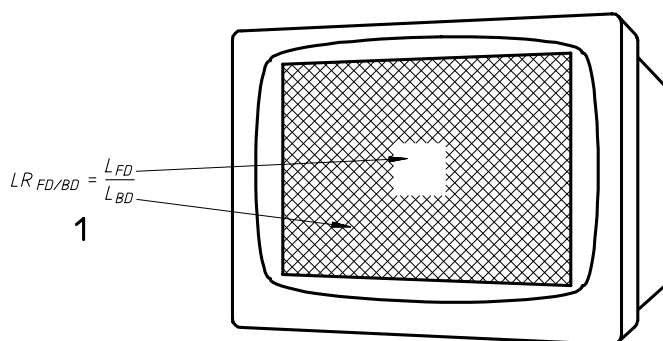
$LR_{FD/BD}$: luminance ratio of the screen foreground and background with diffuse reflected luminance only. It is the ratio between the higher and the lower area-average luminances of the image, when diffuse reflected luminance is superimposed on each. See figure 5. The maximum acceptable specular reflection luminance ratio is related to the luminance ratio of the image without specular reflection, in negative polarity. The definition is polarity-dependent. Only the definition in negative polarity is used for this part of ISO 9241.

Negative polarity

$$LR_{FD/BD} \equiv \frac{L_F + L_D}{L_B + L_D}$$

Expanded,

$$LR_{FD/BD} \equiv \frac{L_F + E \cdot R_D}{L_B + E \cdot R_D}$$



1 In negative polarity.

Figure 5 — Luminance ratio of the image with diffuse reflection only

4 Guiding principles

The work system is an integrated whole, which includes the visual display work station, environment, task structure, organizational concerns, and sociological factors. The characteristics of a visual display terminal must be considered in relation to the other elements of the work system and not as a collection of isolated visual requirements.

This part of ISO 9241 makes recommendations concerning image quality. The image quality of a visual display work station should be adequate to meet task demands, and acceptable to the user, in a normal actual work environment. Design characteristics of the workstation, such as luminance, polarity, screen reflectances and screen reflection control treatments, influence its ability to maintain its image quality and acceptability when viewed in varying lighting environments.

NOTE — There are tradeoffs between the design characteristics. For example, positive polarity reduces the contrast of specular reflections against the screen background. An exclusively positive polarity display possibly requires less reflection control treatment of the screen surface than an otherwise identical display that uses negative polarity. Design characteristics, such as reflectance, should be considered as they affect the overall image quality, and not individually.

It is the common responsibility of all parties concerned with the production, installation and use of the VDT, the workplace and the working room to obtain a good match between the VDT and its environment.

5 Performance objectives

The objective of this part of ISO 9241 is that VDTs be legible and comfortable in use. (See clause 8 for compliance with this part of ISO 9241.)

6 Requirements

6.1 Image luminance ratio with reflections

The luminance ratio of the image, including superimposed specular and diffuse reflected luminances, shall be equal to or greater than 3.

In positive polarity, $LR_{BDS/FDS} \geq 3$.

In negative polarity, $LR_{FDS/BDS} \geq 3$.

NOTE — These requirements are based on legibility (see annex D, references [10], [11] and [12]).

6.2 Specular reflection luminance ratio

The luminance ratio $LR_{BDS/BD}$ of a specular reflection against the screen background should be low.

The perceptibility and acceptability of the specular reflection against the screen background are modified by the polarity of the screen.

On screens that use positive polarity predominantly, the luminance ratio $LR_{BDS/BD}$ of the specular reflection and the bright screen background shall satisfy the relation:

$$LR_{BDS/BD} \leq 1,25$$

On screens that use negative polarity (dark background) predominantly, the luminance ratio $LR_{BDS/BD}$ of the specular reflection on the dark screen background shall satisfy the relation:

$$LR_{BDS/BD} \leq 1,2 + \frac{LR_{FD/BD}}{15}$$

On screens that use both polarities, the requirements for both positive and negative polarities shall be met.

NOTE — These requirements are based on user acceptance (see annex D, references [10], [11] and [12]).

6.3 Reflection control method and effect on image quality

The VDT shall meet the requirements of relevant clauses of ISO 9241-3 and ISO 9241-8 with its reflection control treatment, device, or method in place.

6.4 Reference luminous environment

For purposes of determining compliance with this part of ISO 9241, the following luminous environment values shall be used in the required calculations.

6.4.1 Reference illuminance

The screen angle, α , shall be declared by the supplier of the VDT under test. The reference illuminance E_{REF} for compliance determination shall be:

$$E_{REF} = 250 + 250 \cos(\alpha) \text{ lx.}$$

6.4.2 Reference luminance of the source of specular reflections

From the standpoint of establishing the general type of environment suitable for its use, each VDT shall meet the requirements of this part of ISO 9241 under Class I or Class II or Class III test conditions, choosing the reference luminance $L_{A(REF)}$ of the source of specular reflections from table 1.

Table 1 — Test conditions for compliance classes I, II and III

Class	Requirement
I	$L_{A(REF, EXT)} = 200 \text{ cd/m}^2$ AND $L_{A(REF, SML)} = 2000 \text{ cd/m}^2$
II	$L_{A(REF, SML)} = 200 \text{ cd/m}^2$ OR $L_{A(REF, SML)} = 2000 \text{ cd/m}^2$
III	$L_{A(REF, EXT)} = 125 \text{ cd/m}^2$ OR $L_{A(REF, SML)} = 200 \text{ cd/m}^2$

7 Measurements and calculations

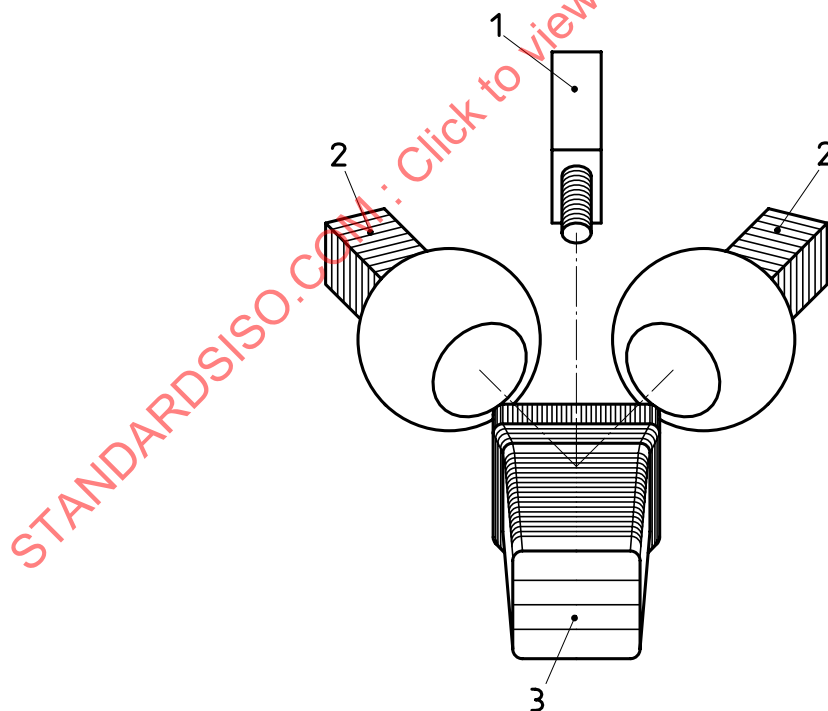
This clause provides the method for measurements and calculations related to image quality with reflections, and is to be used in conjunction with clauses 3 and 6 of this part of ISO 9241.

Regardless of the test requirements for the intended class of compliance, testing of each VDT screen should be conducted using both the extended and small sources of luminance.

7.1 General

See figure 6 for overall test equipment setup.

- a) At 0° (perpendicular to the VDT screen), determine the diffuse reflectometer factor R_D (approximating the diffuse reflection coefficient η).
- b) At 15° incidence to the VDT screen:
 - Measure the foreground and background emitted luminances L_F and L_B (in both polarities if appropriate).
 - Determine the small-source and/or extended-source specular reflectometer value(s) R_S (approximating the specular reflection factor, β).
- c) Determine the VDT's compliance with the requirements of this part of ISO 9241:
 - Calculate the luminance ratios defined in clause 3 of this part of ISO 9241, using the measured screen luminances, the diffuse and specular reflectometer factors, and the reference illuminance and luminance(s) of 6.4.
 - Determine if compliance with the requirements of clause 6 is achieved.



Key

- 1 Spot photometer
- 2 Extended luminance source
- 3 VDT under test

Figure 6 — Basic apparatus arrangement

7.2 Apparatus

The following equipment is required to complete this measurement procedure:

7.2.1 Spot photometer

See figure 7 for terms used in setting photometer requirements.

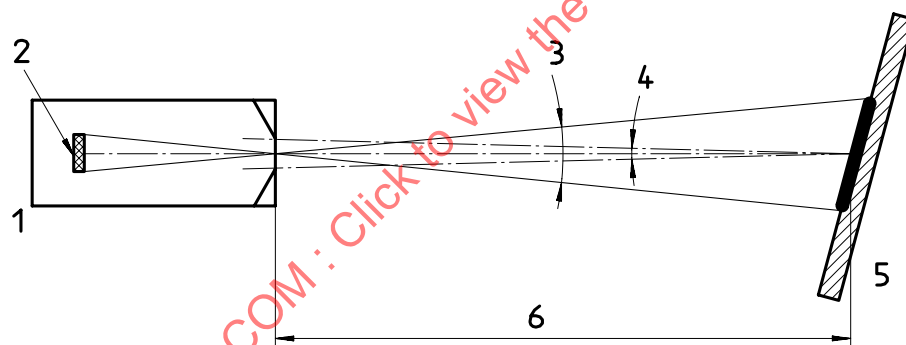
- For measurements using extended specular reflection sources, the field of view (FOV) should be 1° to 2° and the working distance should exceed 500 mm.

NOTE 1 The important factor in the measurement is that the FOV and working distance jointly determine a spot size on the screen that is both smaller than the size of the luminous patch measured and sufficiently large that aperture factors (from the screen structure on the order of 0,03°) are minimal.

- For measurements using the small source of specular reflections, a photometer with a round field of view of 0,3° or less shall be used, and the working distance shall be 500 mm ± 50 mm. The spot photometer, at working distance of 500 mm should have an acceptance cone of < 1. The acceptance cone shall be specified.

The values of the acceptance cone, the field of view and the working distance shall be reported.

NOTE 2 The magnification of the overall (source-screen-photometer) optical system is critical to the relationship of the virtual image of the small source to the photometer field of view. The field of view must be smaller than the virtual image. The data correlating user responses to reflections and small-source measurements are valid for the specified measurement geometry only.



Key

- | | |
|--|--|
| 1 Photometer | 4 Acceptance cone: Angle formed by the entrance pupil of the instrument and the working distance |
| 2 Photosensitive element | 5 Specimen |
| 3 Field of view: Angular extent of the considered object formed in the final image of the instrument | 6 Working distance range: Distance between the front lens of the meter and the considered object over which the meter can focus. |

Figure 7 — Terms used in setting photometer requirements

7.2.2 Calibrated diffuse reflectance standard, at least 20 mm in diameter with a diffuse reflection coefficient of q_{STD} .

NOTE — Diffuse reflection standards are typically calibrated in terms of their diffuse reflectance, ρ_{STD} . This is converted to q_{STD} as follows:

$$q_{STD} = \frac{\rho_{STD}}{\pi}$$

7.2.3 Sources

7.2.3.1 Two extended sources of approximately uniform luminance

The aperture of each source shall subtend at least 15° (30° preferred) at a working distance of at least 500 mm from the centre of the screen of the device under test. The luminance of the source should exceed 2000 cd/m^2 . The luminance should be uniform ($\pm 5\%$ over the central 80% diameter $\pm 1\%$ at a single point) and be stable to $\pm 1\%$ over the duration of the test. The colour temperature of the source should be recorded. The device should incorporate a shutter so that the luminance can be occluded without moving the device from its position in the apparatus.

NOTE — Commercial sources are available. (Integrating spheres with apertures $\geq 150 \text{ mm}$ are suitable).

7.2.3.2 A small source of approximately uniform ($\pm 5\%$ over the central 80% diameter, $\pm 1\%$ at a single point over the duration of the test), which can be obtained by adding an aperture to one of the extended sources. The source aperture shall be round and its diameter shall subtend 1° ($0,9^\circ$ to $1,1^\circ$ acceptable range) measured from the centre of the screen of the device under test.

NOTE — The recommended small source consists of an aperture (approximately 9 mm diameter) placed in front of one of the extended sources. If the extended sources are not sufficiently luminous ($>2000 \text{ cd/m}^2$ recommended), a different diffuse light source should be used. If a source other than one of the extended sources is used, its spectral distribution should approximately match that of the extended sources.

7.2.4 Mechanical apparatus, measuring and setting angles between parts of the test components.

7.3 Test procedure

7.3.1 General

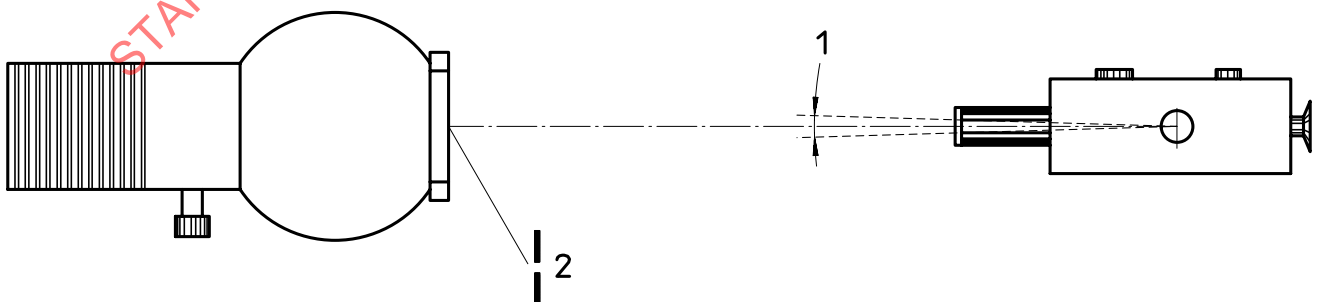
All measurements shall be made in a room that is dark except for the VDT screen itself and the luminance sources used for measurement. Illuminance at the screen from stray sources shall be less than 5 lux, and should be less than 1 lux.

For measurements of screen luminances, a consistent photometer-to-screen distance should be used. The photometer should be focussed on the active surface of the VDT screen. For the small-source specular reflection measurement, the photometer should be optically refocussed to provide the sharpest view of the reflected virtual image of the small source.

7.3.2 Source luminance measurements

7.3.2.1 Extended-source luminance

Measure the luminance $L_{A(\text{EXT})}$ of the central portion of one of the extended-area uniform light sources. See figure 8.



Key

- 1 Photometer aperture smaller than source aperture
- 2 9 mm aperture (1° at 500 mm) (optional small-source)

Figure 8 — Source luminance measurement

7.3.2.2 Small-source luminance

Measure the luminance $L_{A(SML)}$ of the small luminance source. For this measurement, the photometer should be focussed on the aperture, and not on the interior surface, of the source. See figure 8.

7.3.3 Measurements perpendicular (0°) to the VDT screen (diffuse reflectometer constant)

Arrange the VDT, the extended-area sources and the photometer for measurements perpendicular to the screen centre. See figure 9.

Switch off the VDT power.

Open the shutters of both luminance sources. Measure the diffusely reflected luminance $L_{D(0^\circ)}$.

Place the diffuse reflectance standard at the measurement location. Measure $L_{D(STD, 0^\circ)}$.

Calculate

$$R_D = q_{(STD)} \cdot \frac{L_{D(0^\circ)}}{L_{D(STD, 0^\circ)}}$$

Dimension in millimetres

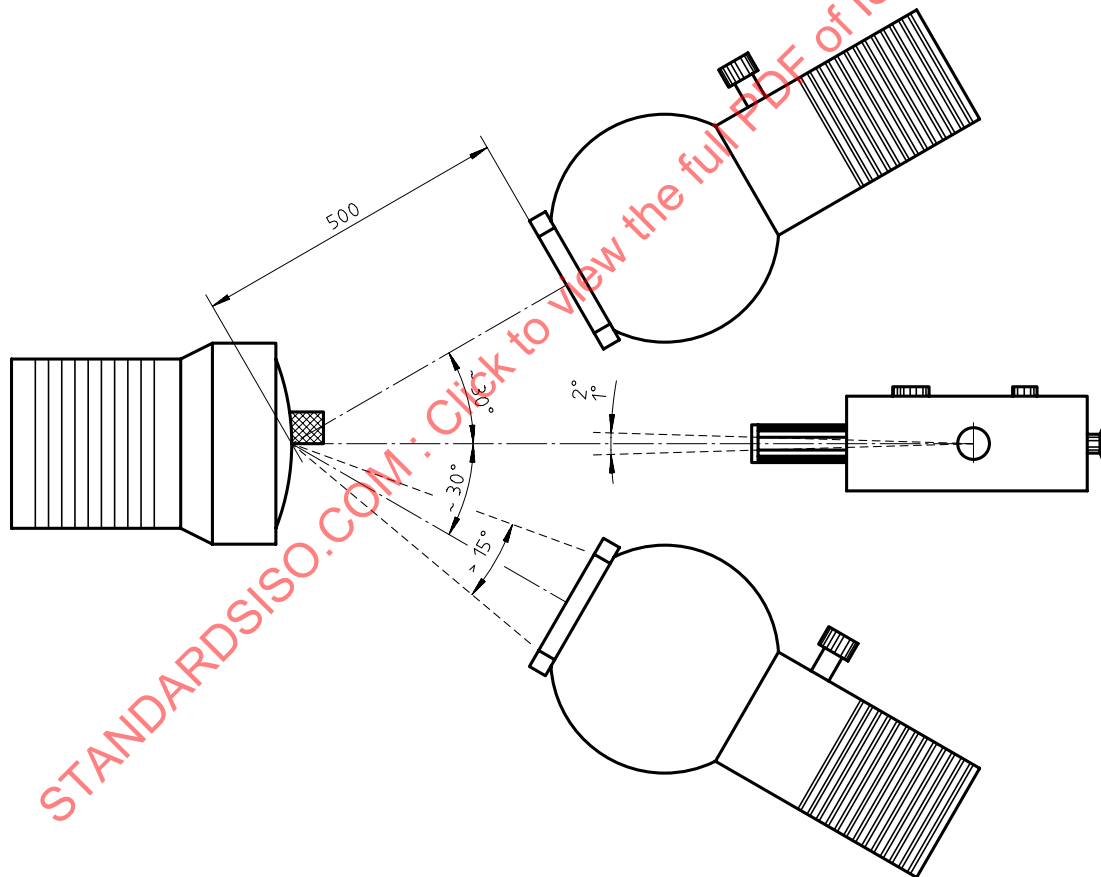
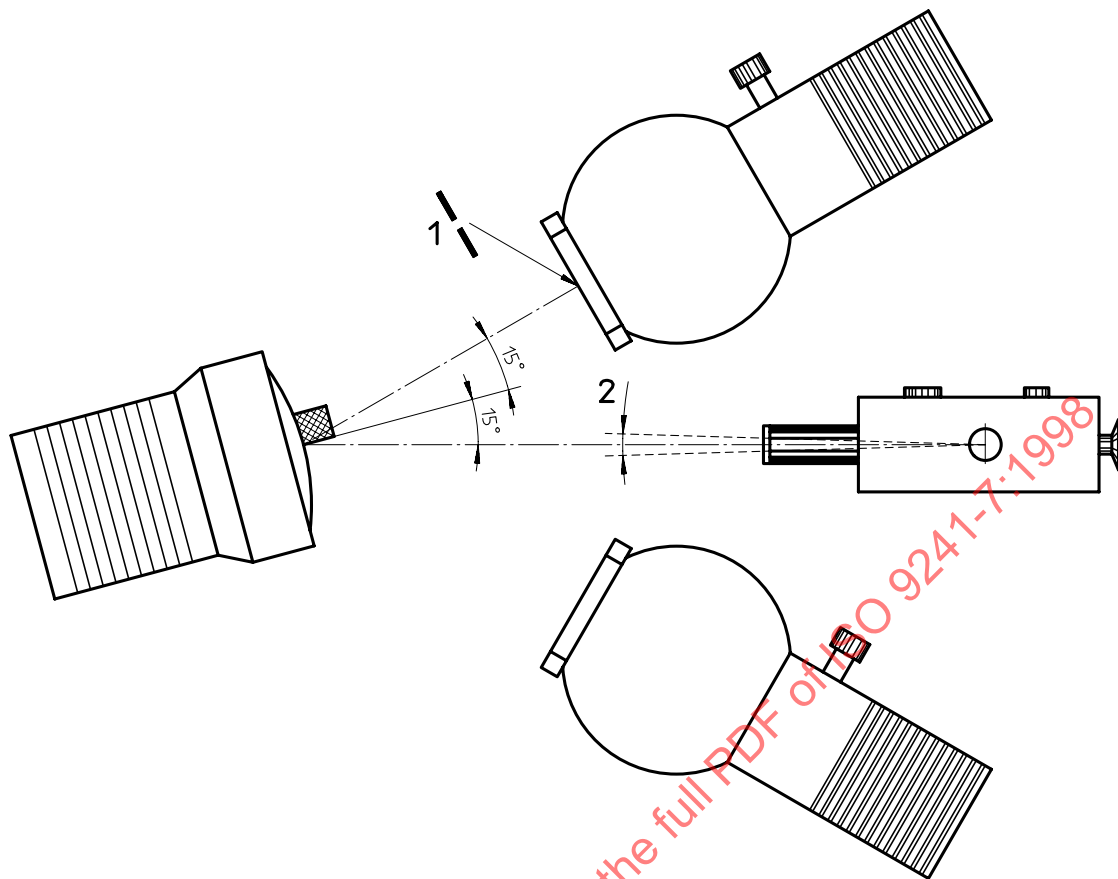


Figure 9 — Measurements perpendicular to the screen

7.3.4 Measurements at 15° to the VDT screen (specular reflectometer constant)

7.3.4.1 Emitted luminances at 15°

Close the shutters of both luminance sources. Rotate the VDT under test 15° around the measurement point (the centre of its screen). See figure 10 for the configuration, but both sources are occluded by the shutters.



Key

- 1 9 mm aperture (1° at 500 mm - small source)
- 2 1° to 2° (extended source)
< 0,3° (small source)

Figure 10 — Measurements at 15° to the screen

NOTE — The centre of rotation of VDT swivel and tilt mechanisms is usually well behind the screen surface. VDT swivel and tilt mechanisms are not recommended as the means to rotate the VDT for this procedure. Any integral swivel and tilt mechanism should be locked or removed during the entire measurement procedure, to prevent inadvertent changes in screen tilt.

Switch on the VDT power. Allow 20 min warm-up.

For each supported polarity:

- a) Set the VDT screen to the foreground and background logical states so that an array of foreground pixels approximately 50 mm square is displayed in the centre of the screen, with the rest of the screen in the background state. Figure 3 shows a positive polarity image, figure 5 a negative polarity image. The highest luminance level of the display duplicates the settings used to measure display luminance for 5.15, ISO 9241-3:1992. The lowest luminance level of the display is the lowest foreground or background luminance available under program control using the same control settings.
- b) Measure $L_{F(15^\circ)}$ and $L_{B(15^\circ)}$.

Maintain separate records of positive polarity and negative polarity measurements.

NOTE — The emitted luminance of a patch of pixels in a given level can depend on characteristics (for example, CRT beam current) related to the level of all other pixels on the screen. Foreground and background luminances are not simply exchanged between positive and negative polarity. They are measured separately in each polarity in which the VDT is, in order to demonstrate compliance with this part of ISO 9241.

7.3.4.2 Extended-source reflection measurements at 15°

See figure 10.

Switch off the VDT power and open the shutter of the appropriate luminance source.

Measure $L_{DS(EXT, 15^\circ)}$.

Place the diffuse reflectance standard at the measurement location.

Measure $L_{D(STD, 15^\circ)}$.

Calculate

$$R_{S(EXT)} = \frac{(L_{DS(EXT, 15^\circ)} \cdot L_{D(STD, 0^\circ)}) - (L_{D(0^\circ)} \cdot L_{D(STD, 15^\circ)})}{L_{A(EXT)} \cdot L_{D(STD, 0^\circ)}}.$$

7.3.4.3 Small-source reflection measurements at 15°

See figure 10. Position the small source of specular reflections at an angle of 15° from the centre of the screen, and at such a distance that its aperture subtends 1° measured from that point. Place a spot photometer with a 0,3° or smaller aperture about 500 mm from the screen centre, and aligned on the specular angle (15°) from the small source of specular reflections. Adjust the source, screen, and/or photometer so that the virtual image reflected from the screen is centred on the photometer aperture, and so that any multiple reflections from the screen first and subsequent optical surfaces are superimposed. Adjust the photometer so the virtual image is best focussed. (It can help to moisten the screen to make the image clearer, provided the screen can be cleaned prior to making the actual measurement.)

NOTE — The reflected virtual image of the specular reflection source does not lie in the same plane as the VDT screen. The image of the VDT screen under test is intentionally defocussed while making this measurement. This eliminates aperture factor of the screen structure over a very small measurement area as a consideration in uncertainty of measurement. However, it imposes the additional assumptions that the photometer response is linear for area-average luminances, whether or not the peak luminances within that area are clearly imaged, and that the portions of the luminous area that are correctly imaged in the plane of the screen (the diffuse components) are sufficiently large that all blur circles from the edges fall well outside the aperture of the photometer.

Measure $L_{DS(SML, 15^\circ)}$.

Either

a) calculate $R_{S(SML)}$ as

$$R_{S(SML)} = \frac{L_{DS(SML, 15^\circ)}}{L_{A(SML)}}$$

or

b) if the small specular reflection source is sufficiently luminous that the diffuse reflected luminance from the screen cannot be neglected, place the diffuse reflectance standard at the measurement location, measure $L_{D(STD, 15^\circ)}$, and calculate

$$R_{S(SML)} = \frac{(L_{DS(SML, 15^\circ)} \cdot L_{D(STD, 0^\circ)}) - (L_{D(0^\circ)} \cdot L_{D(STD, 15^\circ)})}{L_{A(SML)} \cdot L_{D(STD, 0^\circ)}}$$

7.4 Compliance report calculation

7.4.1 General

Compliance with this part of ISO 9241 is determined by comparing the calculated image luminance ratio and specular reflection luminance ratio to their required values, at the screen illuminance and specular reflection source

luminance specified in clause 6. The formulas for the requirements and the calculated luminance ratios are fully expanded below.

The formulas for determining and reporting compliance are polarity-dependent. If compliance is to be established in both polarities, the separately measured and calculated quantities for each polarity should be used in the appropriate formulas.

7.4.2 Compliance determination

7.4.2.1 Image luminance ratio

The requirement is polarity-dependent.

a) Positive polarity

$$LR_{BDS/FDS} \equiv \frac{L_B + L_D + L_S}{L_F + L_D + L_S} \geq 3$$

Expanded,

$$LR_{BDS/FDS} \equiv \frac{L_B + E_{REF} \cdot R_D + L_{A(REF)} \cdot R_S}{L_F + E_{REF} \cdot R_D + L_{A(REF)} \cdot R_S} \geq 3$$

b) Negative polarity

$$LR_{FDS/BDS} \equiv \frac{L_F + L_D + L_S}{L_B + L_D + L_S} \geq 3$$

Expanded,

$$LR_{FDS/BDS} \equiv \frac{L_F + E_{REF} \cdot R_D + L_{A(REF)} \cdot R_S}{L_B + E_{REF} \cdot R_D + L_{A(REF)} \cdot R_S} \geq 3$$

7.4.2.2 Specular reflection luminance ratio

The requirements are polarity-dependent.

a) Positive polarity

$$LR_{BDS/BD} \leq 1,25$$

Expanded,

$$LR_{BDS/BD} \equiv \frac{L_B + E_{REF} \cdot R_D + L_{A(REF)} \cdot R_S}{L_B + E_{REF} \cdot R_D} \leq 1,25$$

b) Negative polarity

$$LR_{BDS/BD} \leq 1,2 + \frac{LR_{FD/BD}}{15}$$

Expanded,

$$LR_{BDS/BD} \equiv \frac{L_B + E_{REF} \cdot R_D + L_{A(REF)} \cdot R_S}{L_B + E_{REF} \cdot R_D} \leq 1,2 + \frac{L_F + E_{REF} \cdot R_D}{15(L_B + E_{REF} \cdot R_D)}$$

7.5 Uncertainty of measurement

It is the goal of the test method that fixed bias errors (including instrument calibration) and random measurement variables, exclusive of violations of the test assumptions, should cause an uncertainty of no more than $\pm 10\%$ of each required value.

Measurement results shall be determined using the best-estimate values, without confidence intervals or allowed measurement tolerances, except that results may be rounded to three significant figures.

8 Compliance

8.1 Compliance with this part of ISO 9241 can be achieved by either:

a) meeting all requirements of clause 6 using the measurement methods of clause 7;

or

b) obtaining a positive result using an alternative test method and associated requirements specified in an amendment to this part of ISO 9241.

Either method demonstrates a compliance class.

Class	Environment
I	suitable for general office use
II	suitable for most, but not all, office environments
III	requiring a specially controlled luminous environment for use

NOTES

1 The alternative test method will become a normative amendment to this part of ISO 9241 when it has been proven. Annex A contains an informative proposed method. Before the normative amendment is published, only compliance route a) is available.

2 The test method is intended for VDTs for which clause 6 cannot be applied completely. One example is non-CRT displays.

Compliance shall be determined using the default parameters, e.g. character set(s), colour(s), configuration(s), system options and operator settings.

Compliance with this part of ISO 9241 can depend on hardware and software (polarity) and workstation elements. Although each element is shown by its supplier to comply individually, the parties using any given combination of such elements are responsible for compliance of that configuration.

8.2 The compliance report shall include the following information:

a) supplier's details (name and address, type numbers, etc.);

b) all details of equipment relevant to the test, including its settings and configuration, fixed and software driven characteristics, test conditions and test results;

c) conditions of use;

d) all relevant details of the test results and instruments:

- compliance class achieved
- for compliance class II or III, whether the extended or small source was used
- all relevant test results (for example, R_D , R_S , L_B , L_F , etc.) for extended and small-source tests
- all relevant calculation results (for example, $L_{FBDS/FDS}$, etc.)
- type of reflection control used

- all relevant data about the luminance sources (for example, spectral characterization, etc.)
 - all relevant data about the photometer used (for example, aperture, field of view, working distance, spectral sensitivity, etc.)
- e) if compliance route 8.1 b) is used (after it becomes available), all relevant details of the criteria used for the selection of the test subjects and their relevant characteristics.

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Annex A (informative)

Alternative test method

A.1 General

Since ISO 9241-3 was published, work toward a normative visual performance method has been underway. The decision was made in ISO 9241-8 to withdraw the proposed colour discrimination alternative test method and await the completion of the ISO 9241-3 addendum, because of published problems with the draft proposal and the conviction that most of the ISO 9241-3 test could be moved without change into ISO 9241-8. It is possible that users of this part of ISO 9241 would be best served by a similar strategy here. The proposed method here is based on different research (see annex D, [14] and [15]). The test configuration here is likely to be valid in either approach.

Annex A represents the current state of development of an alternative route to compliance with this part of ISO 9241. It has not been validated. The following test method is provided for information only. Testing organizations are encouraged to report their experience with the method or modifications of the draft normative method being circulated as an amendment to ISO 9241-3.

This test format was chosen for several reasons.

- Use of standard optotypes allows fairly clear interpretation of legibility test results.
- The basic legibility threshold determination uses established clinical and research vision testing methodology, which does not require further validation.
- There is good support for the correlation between visual threshold distance and visual task performance and comfort at normal (supra-threshold) viewing distances.
- The threshold distance method yields reliable data relevant to relative image quality more quickly and efficiently than a strictly performance-based task performed at normal reading distance.

Note that the essence of this test method is that each VDT (reference and test) is compared with itself under standardized reflection conditions. This is critical, as it is not well established that this test method allows direct comparisons between different VDTs with substantially different image characteristics.

This test method assesses the reduction in legibility of a VDT screen with reflections, relative to the legibility of the same screen without reflections. Two VDT screens are used: a test VDT that requires use of this test method, and a reference VDT that meets all quantitative requirements and passes the quantitative test method of ISO 9241-3, and passes the quantitative requirements for a particular Class (I, II, or III) of this part of ISO 9241. Two test conditions are used for each VDT screen. The independent variable is the amount of ambient illumination and luminance at the specular angle in two measurement cases. The dependent variable is the legibility distance LD from the test participant's eye to the VDT screen for 50% correct identification of letters and words. The result is a decision whether the test VDT image withstands the contrast reduction and interference produced by conditions that produce reflections, at least as well as a conventional VDT of a particular Compliance Class (I, II, or III). If the result is successful, compliance with this part of ISO 9241 will be claimed in the same compliance class as the reference display used for testing.

A.2 Principle

Reading speed and visual comfort are highly correlated with the relative legibility of words and letters on various displays. (See annex D, [14] and [15]) Relative legibility distance (RLD) with reflections can be assessed by determining the eye-to-screen distance at threshold for a test condition with reflections, relative to the threshold distance for a reference condition that is similar, but lacks reflections. The RLD of a VDT requiring use of this test method should not be less than the RLD of a reference VDT that meets all the quantitative test requirements of ISO 9241-3 and this part of ISO 9241.

$$RLR \equiv \frac{RLD_{TST}}{RLD_{REF}} \geq 1$$

where

$$RLD_{TST} \equiv \frac{LD_{TSTw}}{LD_{TSTw/o}}$$

LD_{TSTw} is the legibility distance under test conditions with reflections;

$LD_{TSTw/o}$ is the legibility distance under test conditions without reflections;

$$RLD_{REF} \equiv \frac{LD_{REFw}}{LD_{REFw/o}}$$

LD_{REFw} is the legibility distance under reference conditions with reflections;

$LD_{REFw/o}$ is the legibility distance under reference conditions without reflections.

Testing begins with the viewing distance sufficiently close that identification is 90% or more correct. The viewing distance is increased by equal logarithmic steps of 0,1 diopter (or less, long viewing distances require greater resolution) until identification is 10% or less correct. Standard methods (probability paper, regression analysis, etc.) are used to determine the viewing distance at which 50% correct identification is achieved. The eye-to-screen distance for each test position should be known within ± 5 mm, but may contain a small offset from use of a fixed eye reference, such as a head-restraint reference mark.

Testing is monocular, using the test subject's preferred eye. The other eye is occluded.

Test stimuli are groups of five unrelated letters from the set used in the Bailey-Lovie visual acuity chart (D, E, F, H, N, P, R, U, V, Z) in random order without replacement. Stimuli are presented sequentially in the centre of the VDT screen, and are accompanied by an audible cue tone. In the character rows above and below the test stimulus, there are similar groups of five random characters drawn from the same set:

```

D R F E V
Z N U P D      ← test row
H U Z V F

```

Test participants should respond, following the cue tone, with the identities of the five letters in the central row. At least two test stimuli (10 characters) should be presented at each viewing distance. Responses are scored as correct or incorrect, by character position. That is, a report of a character present in the test row, but reported in the wrong position, is incorrect. Responses are recorded as the number of correct responses over the total number of correct responses possible.

A.3 Test conditions

There are four test conditions, shown in table A.1

Table A.1 — Test conditions

Condition	Display	Screen
1	Test	With reflections
2	Test	No reflections
3	Reference	With reflections
4	Reference	No reflections

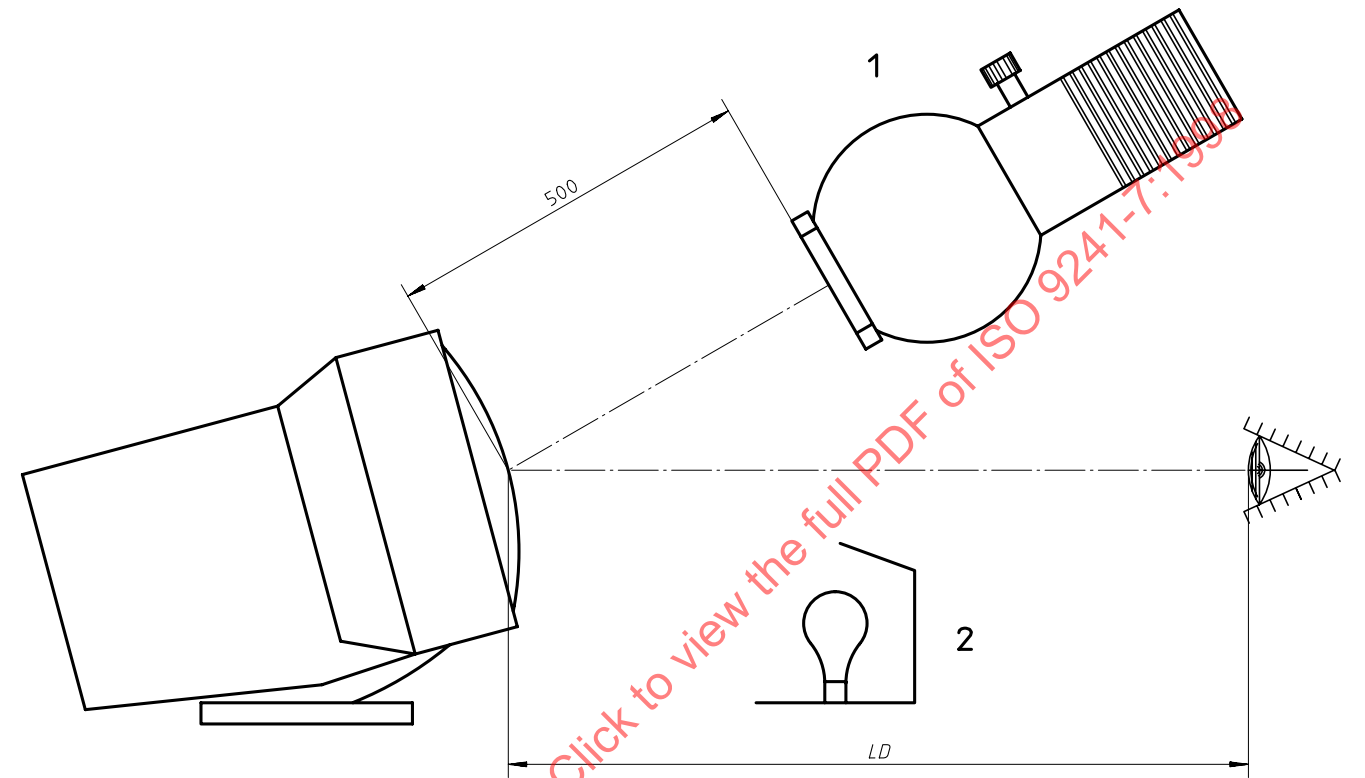
VDTs used for testing:

The reference display is one that has passed the quantitative test methods of ISO 9241-3 and the quantitative test method of this part of ISO 9241 under the conditions for the compliance class sought. See table 1.

The test display is one for which the quantitative test method of this part of ISO 9241 has been found unsuitable.

The screen conditions are given in tables A.2 and A.3. See figure A.1.

Dimension in millimetres



- Key
- 1 Specular reflection source
 - 2 Auxiliary screen illumination source

Figure A.1 — Physical setup for visual performance test

Table A.2 — Screen conditions — Luminance

Screen condition	Luminance source			
	Aperture 15° to 16°		Aperture 1° to 2°	
	Class I or II	Class III	Class I or II	Class III
With reflections	200 cd/m ²	125 cd/m ²	2000 cd/m ²	200 cd/m ²
Without reflections	Less than 12 cd/m ²		Less than 12 cd/m ²	

Luminance magnitudes should be set to ± 10%.

Table A.3 — Screen conditions — Illuminance

Screen condition	Illuminance
With reflections	$E_{\text{REF}} = 250 + 250 \cos(\alpha) \text{ lx}$
Without reflections	Less than 50 lx.

Illuminance magnitudes should be set to $\pm 10\%$.

The screen angle, α , should be specified by the supplier and the same value used for both the reference and test displays.

For reflective displays, E_{REF} should be specified by the supplier and used in both screen conditions.

Physical setup (see figure A.1):

- centre of VDT screen is at eye level;
- VDT screen is tilted back $90^\circ - \alpha$ (screen angle $\alpha = 75^\circ$ is illustrated);
- a small or extended source of specular reflections meeting the requirements of clauses 3, 6 and 7 of this part of ISO 9241 is located 500 mm from the screen, and at the specular angle above the centre of the VDT. Test conditions “reflections” and “without reflections” are set according to tables A.2 and A.3;
- an auxiliary source of screen illuminance is positioned to avoid specular reflections.

A.4 Test room and environment

Testing is done in an environment that approximates that used for clinical visual acuity testing. Except as noted below, the test environment should meet the environmental requirements and recommendations of ISO 9241-6.

- Test room general illumination $\leq 50 \text{ lx}$.
- Test room surfaces at or near the specular angle from the centre of the VDT screen have luminances $\leq 12 \text{ cd/m}^2$.
- Test room surfaces within 45° of the test participant have luminances $\leq 12 \text{ cd/m}^2$. ($\leq 1/3$ minimum display luminance for ISO 9241-3, to insure that luminance adaptation of the test participant is determined primarily by the VDT)
- Either the VDT and its associated luminance and illuminance sources, or the test participant, should be capable of controlled horizontal movement along the eye-to-screen axis. The eye-to-screen reference distance LD should be known or measured, to $\pm 5 \text{ mm}$. Following movement to a new test distance, head position should be stable within $LD \pm 5 \text{ mm}$ while performing the character recognition task. This movement shall maintain the specular reflection centred on the test stimulus location on the VDT screen.

A.5 Test criterion

Following collection of data, RLR (See A.1.1) is calculated for each test participant.

The mean value of RLR over all test participants is calculated and compared to the criterion:

$$\overline{RLR} \equiv \frac{RLD_{\text{TST}}}{RLD_{\text{REF}}} \geq 1$$

Annex B (informative)

Graphical report format

B.1 General

Compliance with this part of ISO 9241 is established under specific conditions. It is possible, given the reflection properties and emitted luminances determined in the test method, to calculate the range of luminous environment conditions over which the requirements would be just-met. These data can be presented graphically, and can be useful in predicting the match between a VDT and its environment.

NOTE — The graphical report does not establish compliance, and does not replace the compliance report.

B.2 Graphical report

The graphical report shows the values of the specular reflection source $L_{A(max)}$ at or below which the VDT meets the requirements, as a function of the screen illuminance E over the range 0 to 1500 lux. The value $L_{A(max)}$ is limited both by the image luminance ratio requirement and by the specular reflection luminance ratio requirement. The lower of the two possible values applies.

Expanded formulas for $L_{A(max)}$, as a function of E and based on the image luminance ratio and the specular reflection luminance ratio, are given below. The functions describe straight lines, so calculating only two points for each is sufficient, and plot the resulting lines graphically. The lines are then trimmed off above their intersection.

B.3 Definitions and formulas

B.3.1 Maximum specular reflection source luminance $L_{A(max)}$

The maximum specular reflection source luminance can be mathematically derived from the requirements of this part of ISO 9241. The graphical report shows the specular reflection source luminance $L_{A(max)}$ at or below which the requirements of this part of ISO 9241 are just met, for each illuminance E in the range 0 to 1500 lux. At lower illuminance, the maximum specular reflection luminance ratio $LR_{BDS/BD}$ limits $L_{A(max)}$. At higher illuminance, the minimum image luminance $LR_{FDS/BDS}$ or $LR_{BDS/FDS}$ limits $L_{A(max)}$.

B.3.2 Maximum specular reflection source luminance limited by $LR_{BDS/BD}$

The maximum specular reflection luminance ratios set by clause 6 for positive and negative polarity screens determine the corresponding maximum specular reflection source luminance, $L_{A(max, BDS/BD)}$, as a function of E . See figure B.1. In slope-intercept form:

a) Positive polarity

$$L_{A(max)}(E) = \left(\frac{R_D}{4R_S} \right) E + \frac{L_B}{4R_S}$$

b) Negative polarity

$$L_{A(max)}(E) = \left(\frac{4R_D}{15R_S} \right) E + \frac{(L_F + 3L_B)}{15R_S}$$

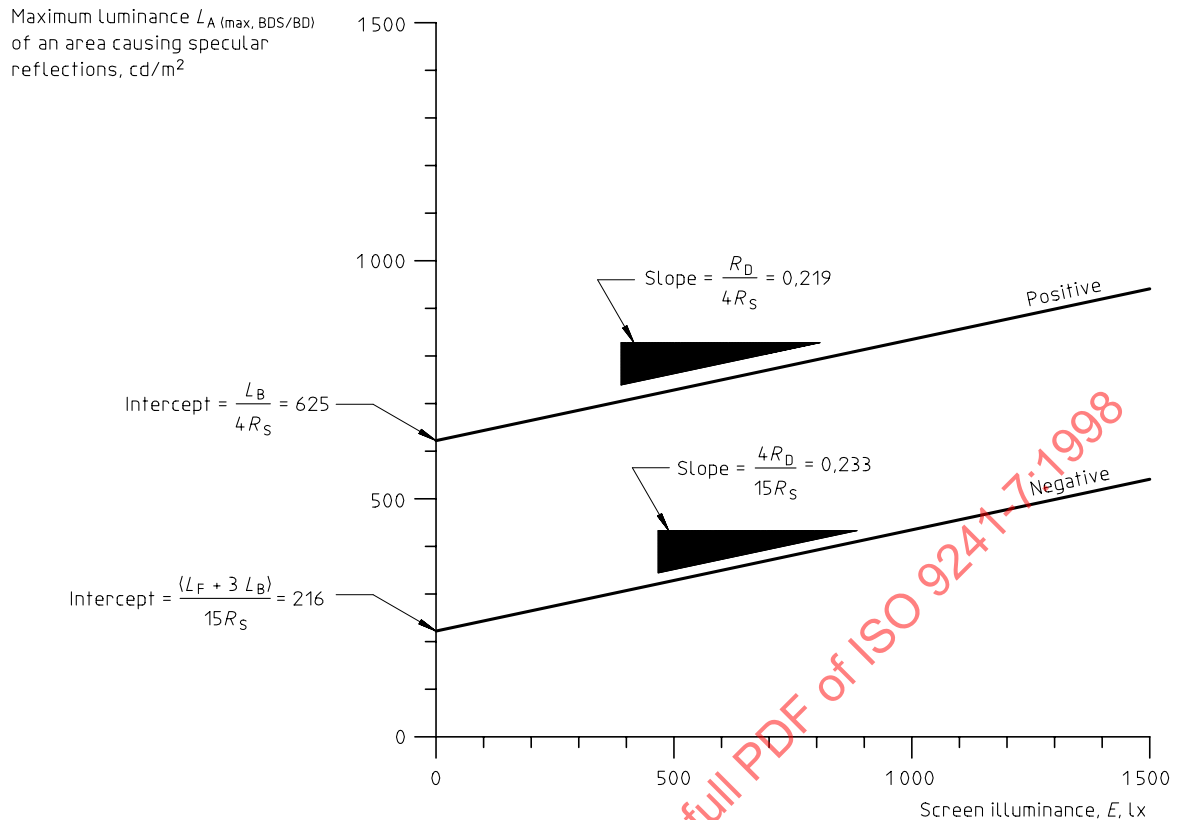


Figure B.1 — Specular reflection luminance ratio limited

B.3.3 Maximum specular reflection source luminance limited by $LR_{\text{BDS}/\text{FDS}}$ or $LR_{\text{FDS}/\text{BDS}}$

The minimum acceptable image luminance ratio set by clause 6 determines the corresponding maximum specular reflection source luminance, $L_{A(\max, \text{FDS}/\text{BDS})}$ or $L_{A(\max, \text{BDS}/\text{FDS})}$. See figure B.2. In slope-intercept form:

a) Positive polarity

$$L_{A(\max, \text{BSD}/\text{FSD})}(E) = - \frac{R_D}{R_S} \cdot E + \frac{(L_B - 3L_F)}{2R_S}$$

b) Negative polarity

$$L_{A(\max, \text{FSD}/\text{BSD})}(E) = - \frac{R_D}{R_S} \cdot E + \frac{(L_F - 3L_B)}{2R_S}$$

Maximum luminance L_A (max, BDS/FDS) or
 L_A (max, FDS/BDS) of an area causing
specular reflections, cd/m^2

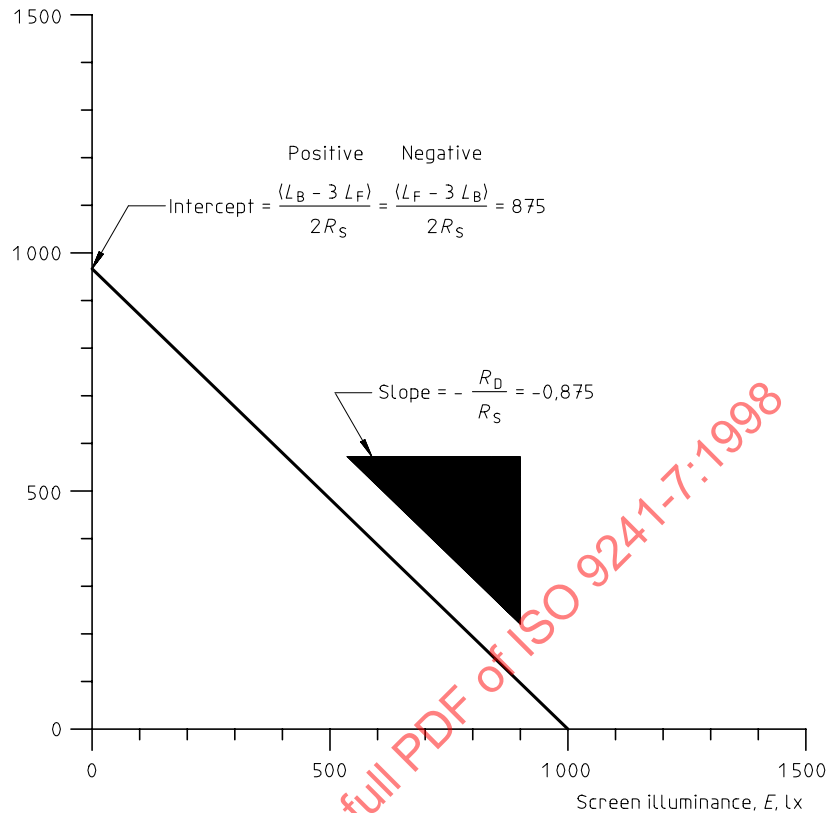


Figure B.2 — Luminance ratio reduction limited

B.4 Graphs

From the above formulas and data obtained in the test method of clause 7, graphs should be drawn of $L_A(\text{max, BDS/BD})$ and either $L_A(\text{max, FDS/BDS})$ or $L_A(\text{max, BDS/FDS})$ depending on polarity. The area below both graph lines is the region deemed satisfactory in the model. The graphed lines should be trimmed above their intersection. The resulting graph is the graphical report, see figure B.3.

In the figure examples, the following values have been assumed:

- the higher of $[L_F, L_B] = 100 \text{ cd/m}^2$;
- the lower of $[L_F, L_B] = 10 \text{ cd/m}^2$;
- $R_D = 0,035 \text{ 01}$ (11% diffuse reflectance);
- $R_S = 0,04$ (CRT glass, extended luminance source).

NOTE — The screen illuminance E is typically half the room illuminance.