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

Part 3:
Visual display requirements

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

Partie 3: Exigences relatives aux écrans de visualisation

Reference number
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Contents

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Annexes

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 9241-3 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Sub-Committee SC 4, *Signals and controls*.

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*
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— *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.

Introduction

Task performance as well as the comfort of people in office work systems is affected by the presentation of information on the visual display terminal (VDT) and by the visual conditions at the workplace.

The satisfaction of individual human requirements is highly application-dependent. The recommendations and requirements defined here are based on established ergonomics principles, as described in ISO 6385.

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

Part 3:
Visual display requirements

1 Scope

This part of ISO 9241 establishes image quality requirements for the design and evaluation of single- and multi-colour VDTs. The requirements are stated as performance specifications, and the evaluations provide test methods and conformance measurements. It should be noted that, at present, the recommendations are based on Latin, Cyrillic, and Greek origin alphabetic characters, and Arabic numerals.

Other factors that affect performance and comfort are coding, format, and the style of presentation of information. With the exception of their visual aspects, they are not covered by this part of ISO 9241.

This part of ISO 9241 applies to the ergonomic design of electronic displays for office tasks. Office tasks include such activities as data entry, text processing, and interactive inquiry, but do not include recommendations for other specific applications such as computer-aided design or process control.

It is planned to issue recommendations on such applications separately.

2 Definitions

For the purposes of this part of ISO 9241, the following definitions apply.

2.1 angle of view: The angle between the line-of-sight angle and the line orthogonal to the surface of the display at the point where the line-of-sight intersects the image surface of the display.

2.2 anti-aliased font: Alphanumeric characters in which a technique has been utilized to smooth character edges.

2.3 between-character spacing: The distance between horizontally adjacent characters at their nearest point.

2.4 between-line spacing: The distance between vertically adjacent characters at their nearest point.

2.5 between-word spacing: The horizontal distance between adjacent words at their nearest point.

2.6 blink coding: Information presented by temporal luminance variations in images.

2.7 character format: The number of horizontal and vertical elements in the matrix used to form a single character.

2.8 character height: The distance between the top and bottom edges of a non-accented capital letter.

2.9 character size uniformity: The constancy in size of a particular character presented at different locations on the screen.

2.10 character width: The horizontal distance between the edges at the widest part of a capital letter (excluding serifs).

2.11 character width-to-height ratio: The ratio of character width to character height.

2.12 design viewing distance: The distance or range of distances (specified by the supplier) between the screen and the operator's eyes for which the images on the display meet the requirements of this part of ISO 9241, such as character size, raster modulation, fill factor, spatial instability (jitter) and temporal instability (flicker).

2.13 diacritic: A modifying mark near or through a character indicating a phonetic value different from that given the unmarked character.

2.14 display luminance: The luminance of the radiation emitted and reflected from the screen corresponding to the luminance of character symbols for bright images on a darker background, and the luminance of the background for dark images on a brighter background.

2.15 fill factor: The fraction of the total area geometrically available to a pixel that can be altered to display information.

2.16 image polarity: The relationship between background brightness and image brightness. The presentation of brighter images on a darker background is designated negative polarity, and darker images on a brighter background is designated positive polarity.

2.17 legibility: The visual properties of a character or symbol that determine the ease with which it can be recognized.

2.18 line-of-sight: The line connecting the point of fixation and the centre of the pupil.

2.19 linearity: The uniformity of the raster such that rows or columns appear straight and continuous.

2.20 luminance balance: The ratio between the luminances of the displayed image and its adjacent surround, or sequentially viewed surfaces.

2.21 luminance coding: Information presented by temporally independent differences in image luminances.

2.22 luminance contrast: The relationship between the higher (L_H) and lower (L_L) luminances that define the feature to be detected, expressed as either contrast modulation (C_m) defined as:

$$C_m = \frac{(L_H - L_L)}{(L_H + L_L)}$$

or contrast ratio (CR), defined as:

$$CR = \frac{L_H}{L_L}$$

2.23 luminance uniformity: The constancy in luminance between areas on the display that are intended to have the same luminance.

2.24 orthogonality: The appearance of geometric alignment or perpendicularity of rows and columns to each other.

2.25 pixel: The smallest addressable element of a display. In a multicolour display, the smallest addressable element capable of producing the full colour range.

2.26 raster modulation: The relative spatial variation in maximum to minimum luminance when all pixels are switched on.

2.27 readability: The characteristics of text which allow groups of characters to be easily discriminated, recognized, and interpreted.

2.28 spatial instability; jitter: The perception of unintended spatial variations in images.

2.29 stroke width: The edge-to-edge distance of a character stroke; for a multiple-pixel stroke, the exterior edge-to-edge width of the character stroke.

2.30 temporal instability; flicker: The perception of unintended temporal variations in luminance.

3 Guiding principles

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

Design elements often interact such that optimising one degrades another. For example, for CRT displays there is a trade-off between character brightness and sharpness. Trade-offs should be made to achieve an acceptable balance.

A good work system should meet the needs of the individual. In a specific situation, this can be accomplished by custom design or by providing appropriate adjustability.

For viewing efficiency and comfort in office environments, the image quality should be significantly above the threshold values for the individual stimuli. The recommendations of this part of ISO 9241 take this into account.

4 Performance requirements

The objective of this part of ISO 9241 is to specify requirements for VDTs, compliance with which ensures that the VDTs are legible, readable and comfortable in use. (See clause 7 for compliance with this part of ISO 9241 and clause 2 for definitions.)

5 Design requirements and recommendations

5.1 Design viewing distance

For usual office tasks, the design viewing distance shall be no less than 400 mm.

For certain applications (e.g. soft key labels on touch screens) the minimum design viewing distance may be reduced to 300 mm.

Workstation parameters are the subject of ISO 9241-5. However, the workstation design should allow the display to be used within the design viewing distance. Preferably, if the task requires a significant amount of reading for context, the workstation design should permit the display to be used at a distance where the character height subtends approximately 20′ to 22′. Figure 1 gives a guide to the relationship between character height and viewing distance for character heights between approximately 2,0 mm and 5,0 mm.

The viewing distance requirement (and other requirements of this part of ISO 9241) are based on Latin, Cyrillic and Greek origin alphabetic characters and Arabic numerals. When the visual requirements for legibility and readability of more complex character sets, especially ideographic characters, are more fully understood, this part of ISO 9241 will be amended to include them.

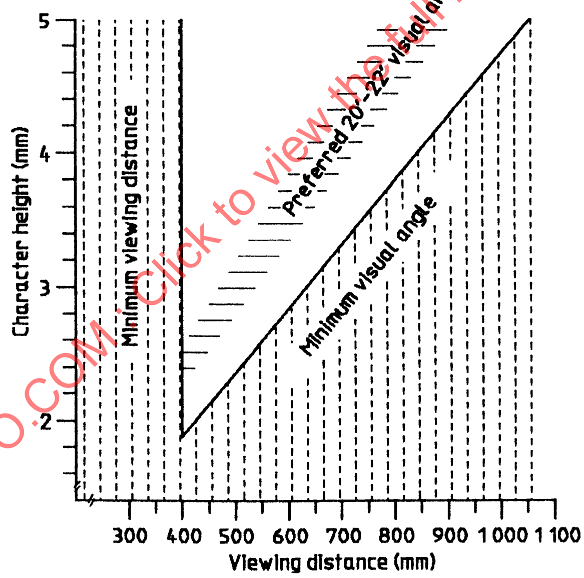


Figure 1 — Relationship between design viewing distance and character height

5.2 Line-of-sight angle

It shall be possible to position the display so that those areas of it to be viewed continuously can be viewed with a line-of-sight angle between horizontal and 60° below the horizontal (see figure 2). This requirement applies to the entire workstation.

5.3 Angle of view

A display should be legible from any angle of view up to at least 40° from the normal to the surface of the display, measured in any plane. If this is not the case, the manufacturer shall specify the restricted angle of view, and the display shall be easy to reposition to an orientation in which it is legible (see figure 3).

5.4 Character height

Character heights subtending from 20′ to 22′ are preferred for most tasks. The minimum character height shall be 16′.

For applications where readability is incidental to the task, smaller characters may be used (e.g. for footnotes, superscripts, subscripts).

5.5 Stroke width

The stroke width shall be within the range of 1/6 to 1/12 of character height.

NOTE 1 In general, the wider stroke widths are preferred for a positive image polarity, and the narrower stroke widths for a negative image polarity.

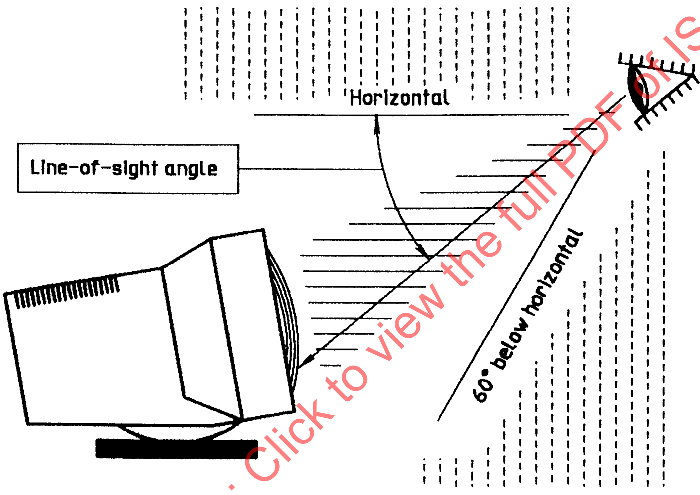


Figure 2 — Line-of-sight angle

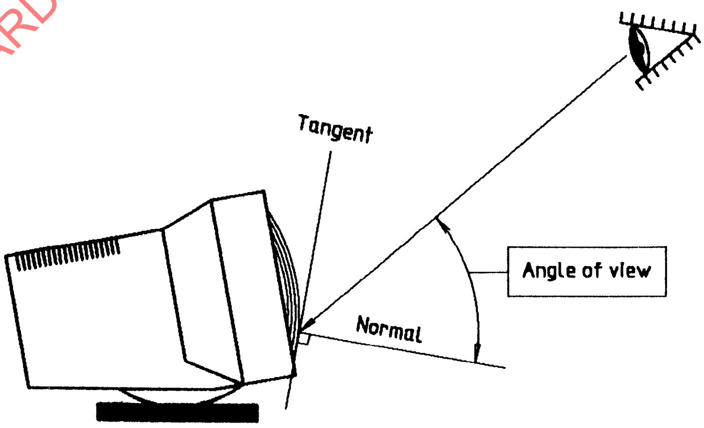


Figure 3 — Angle of view

5.6 Character width-to-height ratio

A width-to-height ratio between 0,7:1 and 0,9:1 is recommended for optimum legibility and readability. However, for other considerations (e.g. line length, proportional spacing) the ratio shall be between 0,5:1 and 1:1.

5.7 Raster modulation and fill factor

5.7.1 Raster modulation

For a CRT having a pixel density of less than 30 pixels per degree (perpendicular to the raster, at the design viewing distance), the luminance modulation in the direction perpendicular to adjacent raster lines shall not exceed $C_m = 0,4$ for monochrome displays, and $C_m = 0,7$ for multi-colour displays when all pixels are in their "on" state.

NOTE 2 For better legibility it is recommended that C_m should not exceed 0,2 for either type of display.

5.7.2 Fill factor

For non-CRT matrix displays having a pixel density of less than 30 pixels per degree at the design viewing distance, the fill factor shall be at least 0,3.

5.8 Character format

A 5 pixels by 7 pixels (width × height) character matrix shall be the minimum used for numeric and upper-case-only presentations.

A 7 pixels by 9 pixels (width × height) character matrix shall be the minimum used for tasks that require continuous reading for context, or where individual alphabetic character legibility is important for the task, such as proofreading.

The character matrix shall be increased upward by at least two pixels if diacritics are used. If lower case is used, the character matrix shall be increased downward by at least two pixels, to accommodate the descenders of the lower case letters (see figure 4).

For higher density character matrices, the number of pixels used for diacritics should follow conventional designs for printed text.

A 4 pixels by 5 pixels (width × height) character matrix shall be the minimum used for subscripts and superscripts, and for numerators and denominators of fractions that are displayed in a single character position. It may also be used for alphanumeric information not related to the operator's task, such as copyright information.

For non-dot-matrix techniques, equivalent character shapes should be achieved.

5.9 Character size uniformity

The height and width of a specific character of a specific character font shall not vary by more than ± 5 % of the character height (see 6.6.1) of that character set, regardless of where it is presented on the display surface.

5.10 Between-character spacing

For character fonts without serifs, the between-character spacing shall be a minimum of one stroke width or one pixel (see figure 5). If characters have serifs, the between-character spacing shall be a minimum of one pixel between the serifs of adjacent characters.

5.11 Between-word spacing

A minimum of one character width (capital "N" for proportional spacing) shall be used between words.

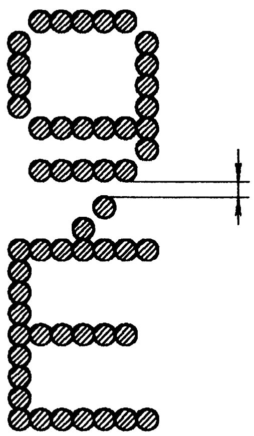


Figure 4 — Between-line spacing

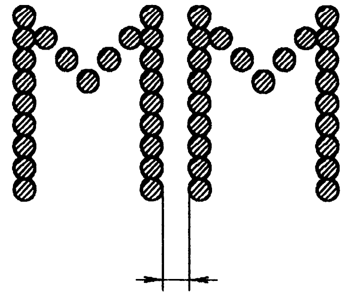


Figure 5 — Between-character spacing

5.12 Between-line spacing

A minimum of one pixel shall be used for spacing between lines of text. This area may not contain parts of characters or diacritics, but may contain underscores (see figure 4).

5.13 Linearity

See figure 6. The following two conditions shall be fulfilled.

a) For different rows or columns, the difference of length shall not exceed 2 % of the length of that row or column.

b) The horizontal displacement of a symbol position relative to the symbol positions directly above and below it shall not vary by more than 5 % of the character width. The vertical displacement of a symbol position, relative to the symbol positions to the right and left of it, shall not vary by more than 5 % of the character height.

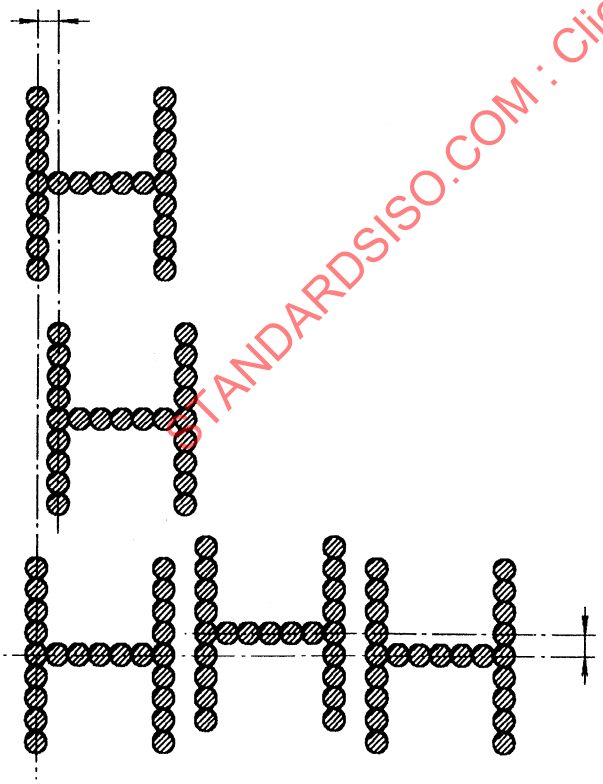


Figure 6 — Linearity

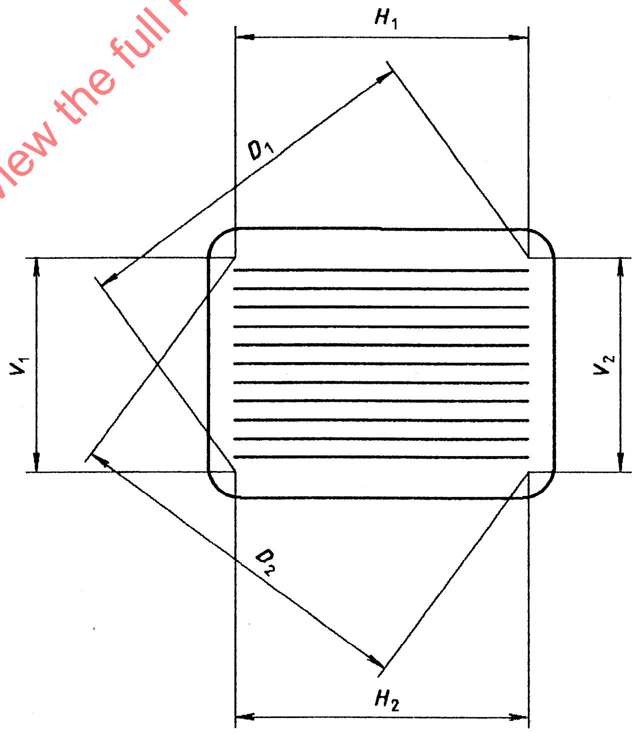
5.14 Orthogonality

See figure 7. The addressable area of the display shall be rectangular, and the following conditions shall be fulfilled.

a) The ratio of the difference in length between the horizontal edges, $|H_1 - H_2|$, and their mean length, $0,5(H_1 + H_2)$, shall not exceed 0,02.

b) The ratio of the difference in length between the vertical edges, $|V_1 - V_2|$, and their mean length, $0,5(V_1 + V_2)$, shall not exceed 0,02.

c) The ratio of the difference in length between the diagonals, $|D_1 - D_2|$, and their mean length, $0,5(D_1 + D_2)$, shall not exceed 0,04 times the ratio of the mean length of the shorter edges (i.e. vertical or horizontal depending on orientation) to the mean length of the longer edges (i.e. horizontal or vertical).



Horizontal: $\dfrac{|H_1 - H_2|}{0,5\,(H_1 + H_2)}$

Vertical: $\dfrac{|V_1 - V_2|}{0,5\,(V_1 + V_2)}$

Diagonal: $\dfrac{|D_1 - D_2|}{0,5\,(D_1 + D_2)}$

Figure 7 — Orthogonality

5.15 Display luminance

From a perspective of the limits of visual acuity, the display shall be capable of a display luminance of at least 35 cd/m². For displays to which the provisions of 5.7.2 (fill factor) apply, this shall be achievable with the peak luminance of the display. If luminance coding is used, 35 cd/m² specifies the minimum for the lower luminance.

NOTE 3 Operators often prefer substantially higher display luminance levels (e.g. 100 cd/m²), particularly in conditions of high ambient illuminance.

5.16 Luminance contrast

The minimum luminance contrast of character details, within or between characters, that are relevant for legibility, shall be

$C_m = 0{,}5$ (contrast modulation)

or

$CR = 3{:}1$ (contrast ratio)

5.17 Luminance balance

The ratio of area average luminances of task areas that are frequently viewed in sequence (e.g. screen, document, etc.) should be lower than 10:1. For a stationary visual field, a significantly higher ratio of space average luminances between the task area and its surrounds (e.g. display housing, room walls, etc.) should not have any adverse effect. However, a luminance ratio of 100:1 between those two areas would be expected to produce a small but significant drop in performance.

5.18 Glare

Glare should be avoided. Additional glare reduction or contrast enhancement techniques, if used, shall not cause the display to violate the requirements of 5.15 (Display luminance) and 5.16 (Luminance contrast). ISO 9241-7 will give further requirements.

5.19 Image polarity

Either dark characters on a brighter background (positive image polarity), or bright characters on a darker background (negative image polarity) are acceptable provided the requirements of this part of ISO 9241 are met.

Users vary in their preferences for image polarity. If a display provides switchable image polarity, it shall meet the requirements of this part of ISO 9241 for each image polarity.

There are advantages for each image polarity. For example,

a) with positive polarity, specular reflections are less perceptible, edges appear sharper, and luminance balance is easier to obtain;

b) with negative polarity, flicker is less perceptible, legibility is superior for individuals with anomalous low acuity vision, and characters are possibly perceived to be larger than they actually are.

5.20 Luminance uniformity

For an intended uniform luminance, the variation in area average display luminance from the centre of the display to the edge of any portion thereof shall not exceed a ratio of 1,7:1.

The variation of the peak luminance of character elements (dots or strokes) shall not exceed a ratio of 1,5:1 within a character.

NOTE 4 This requirement does not apply to anti-aliased fonts or to multicoloured displays.

5.21 Luminance coding

Areas coded by luminance only shall differ in display luminance with respect to each other by a ratio of at least 1,5:1.

5.22 Blink coding

Where blink coding is used solely to attract attention, a single blink frequency of 1 Hz to 5 Hz with a duty cycle of 50 %, is recommended. Where readability is required during blinking, a single blink rate of 1/3 Hz to 1 Hz with a duty cycle of 70 %, is recommended. It should be possible to switch off the blinking of the cursor.

5.23 Temporal instability (flicker)

The image shall be free of flicker to at least 90 % of the user population.

NOTE 5 Methods of predicting and measuring flicker are still under development. Annexes A and B provide the current status of these tests. When final test methods are developed, they will be provided as an addendum to this part of ISO 9241.

5.24 Spatial instability (jitter)

The image shall appear to be stable. This can be accomplished by insuring that the peak-to-peak variation in the geometric location of picture elements does not exceed 0,000 2 mm per mm of design viewing distance for the frequency range of 0,5 Hz to 30 Hz.

5.25 Screen image colour

The image on a multicolour VDT shall comply with the relevant requirements of this part of ISO 9241. However, display colour is sufficiently complex to justify its treatment in detail; accordingly, ISO 9241-8 will deal with colour.

6 Measurement conditions and conventions

6.1 Measurement conditions

6.1.1 Equipment under test

The display unit being tested shall be physically prepared for testing. The VDT shall be oriented in the compass direction in which the measurements will be taken. It shall be warmed up for at least 20 min. It shall be tested under nominal conditions of input voltage, current, etc. After switching on, any integral manual degaussing device shall be activated.

6.1.2 Lighting conditions

To determine if the display meets the requirements of this part of ISO 9241, calculated reflected luminance levels shall be added algebraically to emitted luminance levels measured under dark room conditions.

For emissive displays, photometric measurements shall either be taken under dark room conditions, or, if the measurements are taken in a lighted room, they shall be converted to values equivalent to those that would have been taken under dark room conditions.

If dark room conditions cannot be obtained for luminance measurements, equivalent measurements under lighted room conditions may be substituted, using the following procedure.

a) Measure the VDT screen reflectance using either diffuse light (specular reflection excluded), or light incident from 45°.

b) Calculate the reflected luminance of the VDT screen under the assumed ambient light level.

c) Measure the actual reflected luminance of the VDT screen under the lighted-room conditions.

d) Correct the measured reflected luminance value to the calculated reflected luminance value for all subsequent measurements.

The other required measurements of this part of ISO 9241 shall then be carried out under the illuminance used for the first measurement (light-room conditions).

Light required for a measurement shall be supplied from a test fixture or from a standard reflectance measuring device appropriate for use on thick translucent materials with multiple reflecting interfaces. Incident light shall be either diffuse or from 45°. Reflected luminance levels shall be calculated, based on an assumed ambient light level, as if measured at the centre of the display, of $(250 + 250 \cos A)$ lx, where A is the angle formed by the intersection of the plane tangent to the centre of the display and the horizontal plane.

For non-emissive displays, the ambient illumination shall be either diffuse (preferred) or incident from 45°. The illuminance level required to obtain a reflected luminance level of 35 cd/m^2 shall be calculated, and included in the compliance report.

6.2 Photometric measurement requirements

A photometer (or equivalent instrument) integrates luminance over a finite measuring field and a finite time. The photometer shall have a sufficiently long time constant of integration that the measurements are not affected by the pulsation of the light emitted by most VDTs. The photometer measuring field shall be appropriate for the measurement being made. The photometer shall be positioned accurately. Luminance measurements shall be made with a photometer aligned parallel to the normal to the VDT screen at the centre.

For performance and characterization of illuminance meters and luminance meters, see CIE Publication 69.

6.2.1 Microphotometric luminance measurement

6.2.1.1 Photometer requirements

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 5.7 can be applied, a spot aperture shall be used.

For pixels of discontinuous luminance distribution (especially multi-colour shadow-mask CRTs), a photometer with a slit aperture or an equivalent instrument shall be used. The length of the slit shall be at least 4 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.

6.2.1.2 Luminance profile

A luminance profile (luminance versus relative position) of the defined feature, character, group of characters, or equivalent test object, shall be obtained by scanning the measuring field of the photometer perpendicular to the long axis of the features to be measured (see figures 8 to 10 and also figures 12 to 16).

The luminance profile shall be continuous. For pixels of discontinuous luminance distribution, the luminance profile shall be reconstructed by either:

a) plotting the measured luminance profile and connecting the peaks of luminance measurements from phosphor dots of a single colour with straight lines (see figure 8); or

b) applying a numerical low-pass (smoothing) algorithm to the peaks of the profile.

NOTE 6 Numerical procedures that fit a Gaussian distribution to the measured peaks should be used only with extreme caution. Most measurements required by this part of ISO 9241 require measurement of features more than one pixel wide. Such features are not Gaussian in their luminance profiles, if they are adequately resolved by the display.

The following correction, L_{COR}, (for shadow mask and photometer aperture effects) should be applied to the measured luminance profile:

$$L_{COR} = L_{1-M} \times \frac{L_{W-A}}{L_{1-P}}$$

$$L_{TOT} = L_{COR} + L_{REF}$$

where

L_{1-P} is the average peak luminance of the profile measured, with all pixels "on" in the colour used for the measurement. The profile is made in the direction specified for the measurement;

L_{1-M} is the measured luminance profile (in the colour used for measurement);

L_{W-A} is the area average luminance of white, or the colour used to set display luminance (see 6.3);

L_{REF} is the reflected luminance (see 6.1);

L_{TOT} is the total luminance (at a particular point).

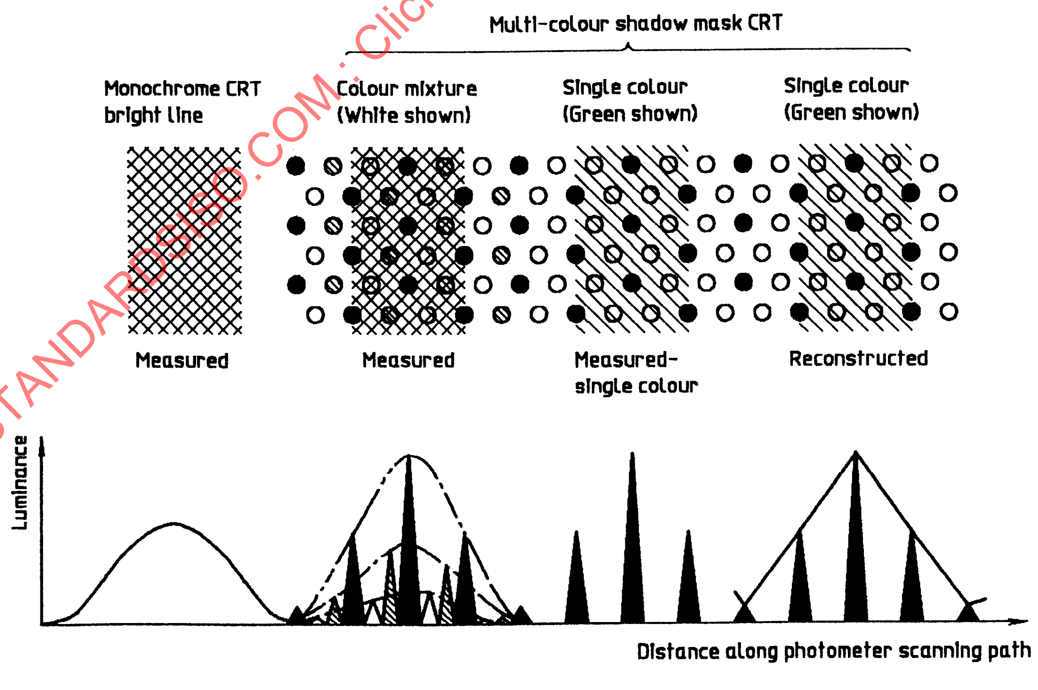


Figure 8 — Measured and reconstructed luminance profiles

The following procedure may be used to determine the required luminances at each measurement location, and should be carried out in a dark room.

c) At the measurement location, set an area of pixels to the logical state used to measure display luminance (see 6.3).

d) Measure the area average luminance, L_{W-A}.

e) If a single colour (e.g. green) is used for the measurement, change the pixels to that colour. With a slit aperture, measure the luminance profile in the direction required by the measurement. From the profile, determine the average peak luminance, L_{1-P}.

f) Change to the required character, test object, or pixel pattern, still in the same single colour. Determine the luminance profile, L_{1-M}.

g) Calculate the corrected luminance, L_{COR}, and the total luminance, L_{TOT}.

6.2.1.3 Statistical analysis

On multi-colour shadow-mask CRTs, the measured luminance profile depends on many factors including the phase and size of the electron beam relative to the mask pitch. Considerable variation is expected between measurements. Since the outcome of a single measurement is probabilistic, statistical analysis can be required for interpretation. Reported values shall be the mean of not less than four measurements at different locations near the defined measurement point. For multi-colour shadow-mask CRTs, a reported value within ± 10 % of the required value shall be acceptable.

6.2.1.4 Test objects

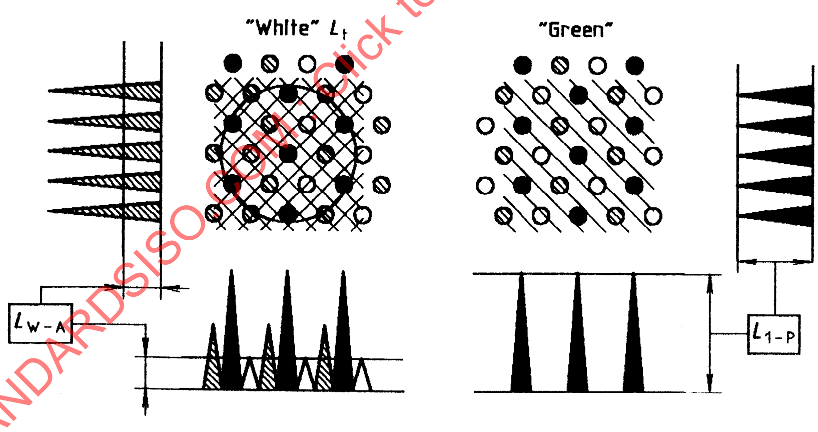
Measurements may be carried out on special test objects or on the character or other pattern on which the measurement is defined (see figures 12, 13 and 15, for example). Test objects, if used, shall have the following characteristics:

a) The test object shall consist of parallel vertical or horizontal lines of pixels.

b) Each line of pixels shall be at least 10 % longer than the length of the slit aperture of the photometer.

c) Each pixel in a line shall be in the same logical state.

d) The logical state of the pixels in successive lines shall be the same as those along the photometer path defined for the measurement.



NOTES

1 Vertical and horizontal peak luminances are not equal.

2 The luminance values are used to correct the measured luminance profile to the measured display luminance.

Figure 9 — Luminance values on shadow-mask multi-colour CRTs

EXAMPLE — A test object may be used to measure luminance contrast. One measurement is defined on a lower case "e" (see figure 16). If a vertical path through the inner loop finds one pixel "on", the next pixel "off", and the next pixel "on", then the equivalent test object consists of at least three horizontal lines in an "on-off-on" pattern. The pattern may repeat ("on-off-on-off-on...") for convenience in replicating the measurement.

NOTE 7 Test objects for determination of character size and between-character spacings may be blocks of pixels, with the inner pixels in any state.

6.2.2 Display luminance measurements

The effective measuring field diameter of the photometer or special display-measuring device should be about half the character width.

6.2.3 Area average luminance measurements

The effective measuring field of the photometer should cover approximately 1 % or more of the active area of the display surface.

6.3 Display luminance setting

A single display luminance and colour setting shall be used for all measurements, tests, and calculations required by this part of ISO 9241, except where the requirements of 6.2.1.3 apply. The default luminance setting shall be used for displays with system selectable luminance settings. Displays that have operator selectable luminance settings shall be set to at least 35 cd/m^2. See 6.2.2 and 6.6.8 for measurement.

NOTE 8 Although the minimum test luminance is 35 cd/m^2, no maximum is established. A realistic setting for actual use should be selected.

6.4 Measurement locations

Five standard measurement locations are defined (see figure 11). The locations are the following:

a) at the centre (that is, at the intersection of the two diagonals of the addressable area);

b) at the locations on the diagonals that are 10 % of the diagonal length in from the corners of the addressable area of the display.

NOTE 9 For requirements of this part of ISO 9241 that apply anywhere on the screen, and for requirements that specify only a worst case at any of the five standard locations, only the values at the centre of the screen and at the worst location(s) need to be reported.

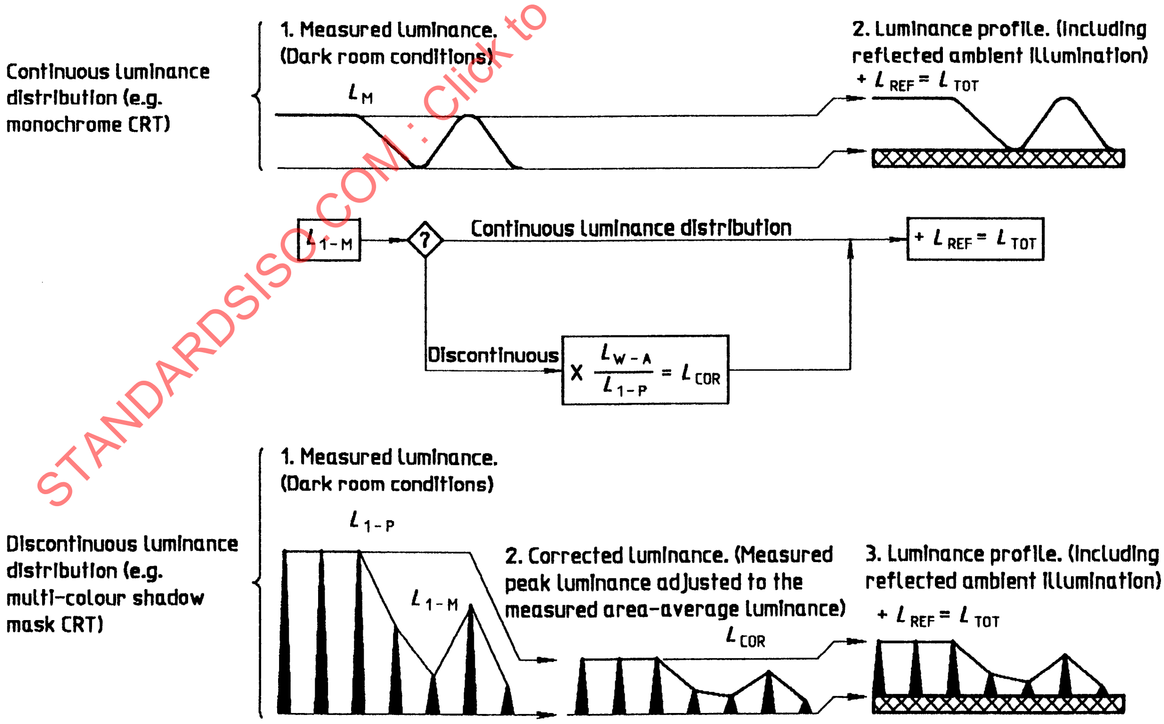


Figure 10 — Luminance profiles for measured, corrected, and total luminance

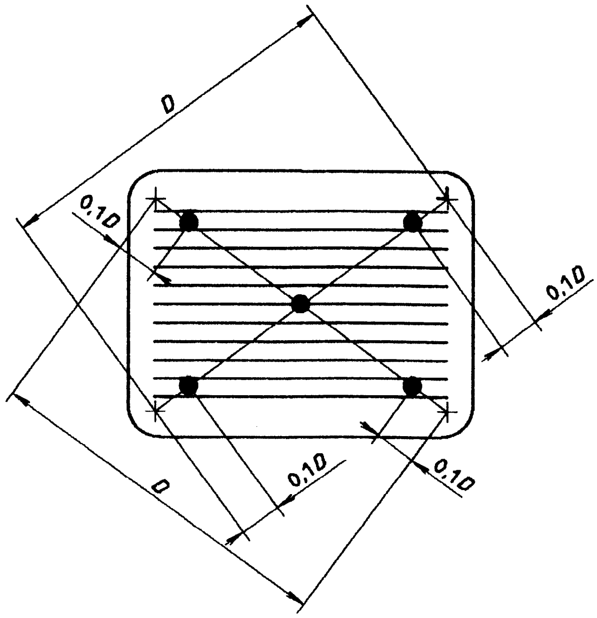


Figure 11 — Standard measurement locations

6.5 Screen distances

Screen distances for all measurements shall be measured parallel to the plane tangent to the centre of the screen.

6.6 Specific measurements

6.6.1 Character size

Character height and width for a particular character font are the distance between the appropriate parallel edges of a non-accented capital letter (see figure 12). For the purposes of this part of ISO 9241, the capital letter "M" should preferably be used to define the character height and width. However, the capital letter "M" may be unsuitable for measurement of character height. Therefore, a test object (see 6.2.1.4), having the same number of pixels between its measured features as a capital letter "M", may be used for character height and width measurements. Character height and width shall be the mean dimensions of the character "M" or of the equivalent test object presented in the five test locations defined in 6.4 (see figure 12).

NOTE 10 The character edge is defined as extending to the 50 % point of luminance difference between the character and the background. The 50 % point is decided from the luminance profiles measured according to 6.2.1.

6.6.2 Character width-to-height ratio

The width-to-height ratio of a particular font is the ratio of the character width to the character height of a non-accented capital letter, measured in accordance with 6.6.1.

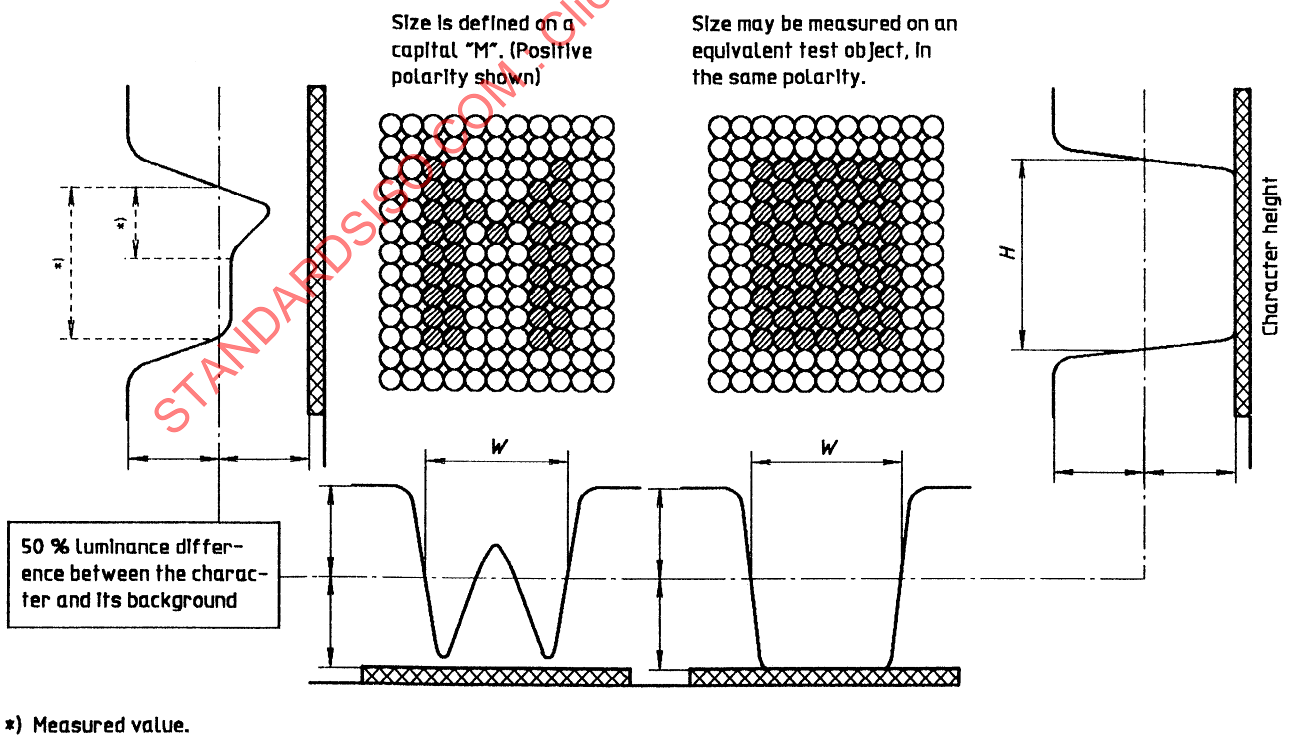


Figure 12 — Character height and width

6.6.3 Character stroke width

The stroke width of a character set is the distance between the 50 % contours of luminance difference between the body of a stroke used to define a character, and the background. The 50 % luminance difference contours are determined from the luminance profile measured according to 6.2.1. The distance shall be measured along lines that pass horizontally through the centre, or centres, of the pixels that define vertical strokes, and vertically through the centre, or centres, of pixels that define horizontal strokes. Serifs shall not be included in these measures. Stroke width for a character set will be the average stroke width for horizontal and vertical strokes presented in the five measurement locations defined in 6.4. The capital letter "M" shall be used to define vertical stroke width. The capital letter "H" shall be used to define horizontal stroke width (see figure 13).

6.6.4 Raster modulation

Raster modulation shall be measured by obtaining a luminance profile, in accordance with 6.2.1, along a line passing through adjacent raster lines (see figure 14). The raster modulation is the modulation between the mean of the maxima and the mean of the minima along the profile. For multi-colour displays, the profile should include at least nine lines.

6.6.5 Fill factor and peak display luminance

Fill factor shall be calculated by multiplying the height of a pixel by its width, and dividing by the area allocated to the pixel. Pixel size shall be decided by the 50 % luminance difference contours between the pixel and its background based on a luminance profile obtained in accordance with 6.2.1. Peak display luminance shall be measured as the peak luminance of the profile(s) used for determination of fill factor.

6.6.6 Character size uniformity

Character size, both height and width, shall be measured in accordance with 6.6.1 at the five measurement points defined in 6.4 at least. The capital letter "M" shall define the character size.

6.6.7 Between-character spacing

Between-character spacing is the minimum distance between horizontally adjacent characters at their nearest points. The between-character space shall be decided from the number of pixels between horizontally adjacent characters.

6.6.8 Display luminance

Display luminance shall be measured as the integrated luminance of a character position, when all pixels in that character position are in the state specified in accordance with 6.3. The photometer shall meet the requirements of 6.2.

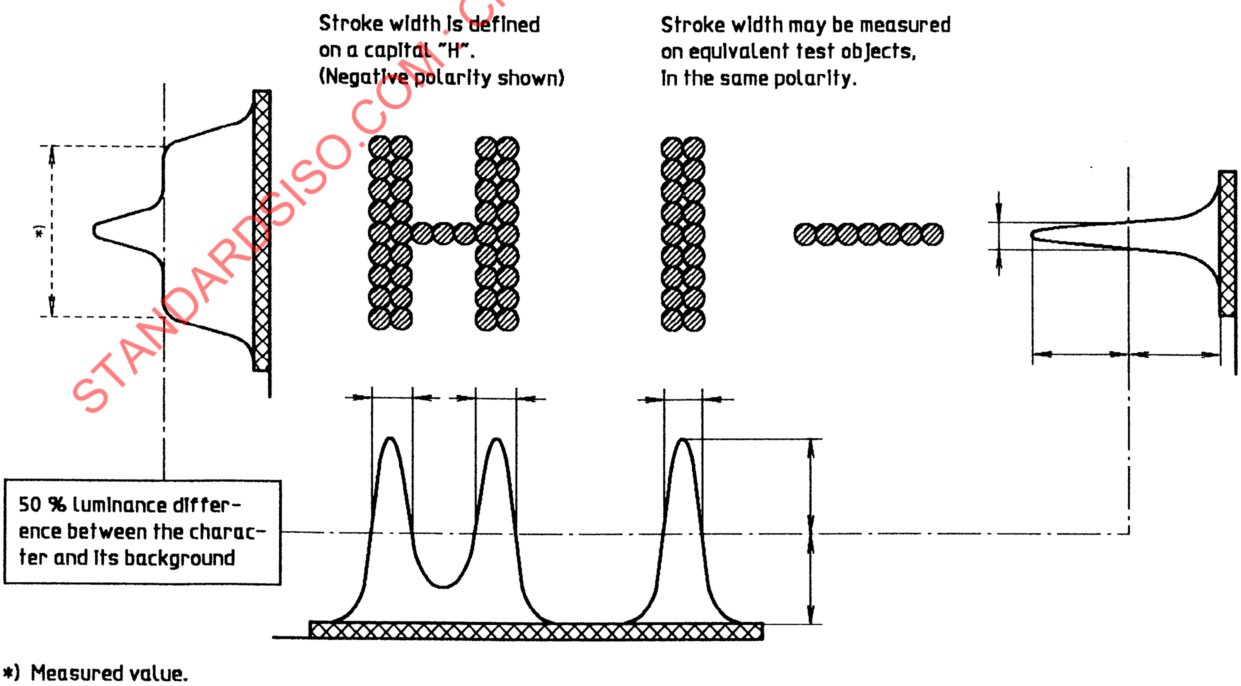


Figure 13 — Character stroke width

6.6.9 Luminance uniformity

6.6.9.1 Area average luminance

For area average luminance uniformity measurements, the entire display screen shall be filled with pixels set to the state specified by 6.3. Average display luminance shall be measured with a photometer meeting the requirements of 6.2.

6.6.9.2 Character element uniformity

Character element uniformity shall be measured as the luminance uniformity of the horizontal and vertical strokes of a capital letter "H" or an equivalent test object. The luminance uniformity shall be decided by the luminance profiles of the character strokes (see figure 15).

6.6.9.3 Luminance balance

For luminance balance measurements, the display screen should be filled with alternating capital letter "M" and "space" characters.

6.6.10 Between-word spacing

Between-word spacing is the minimum horizontal distance between adjacent words at their nearest points. The between-word spacing shall be decided from the number of pixels between adjacent words.

Serifs, if used, shall not be considered in determining between-word spacing.

6.6.11 Between-line spacing

Between-line spacing is the minimum distance between vertically adjacent characters at their nearest points. The between-line space shall be decided from the number of pixels between vertically adjacent characters.

6.6.12 Linearity

Linearity shall be determined with a travelling microscope or equivalent instrument. The microscope axis shall be aligned approximately parallel to the axis of the row or column to be measured. Character position shall be determined by visual or electronic comparison of analogous character features on adjacent characters.

6.6.13 Luminance contrast

The contrast of the image details that are to be seen as separate shall be used to measure luminance contrast. Two characters (or equivalent test objects) shall be used and each shall be measured in the five positions defined in 6.4 (see figure 16). The characters are the lower case "e" (for contrast between vertically adjacent character features) and "m" (for contrast between horizontally adjacent character features). The path of the photometer travel when measuring the contrasts of the details of the characters (or test objects with the same pixel pattern) is shown in figure 16. Contrast modulation shall be measured by obtaining a luminance profile, in accordance with 6.2.1, along the prescribed path. The contrast modulation is the modulation between the maximum and the minimum of the profile.

6.6.14 Spatial instability (jitter)

For displays with pixels having continuous luminance distributions only, jitter may be measured using a measuring microscope of at least 20 power. The movement is determined by visual alignment of the microscope cursor or comparator reticle with the extreme positions of the centroid or edge of a character or test object during the observation period.

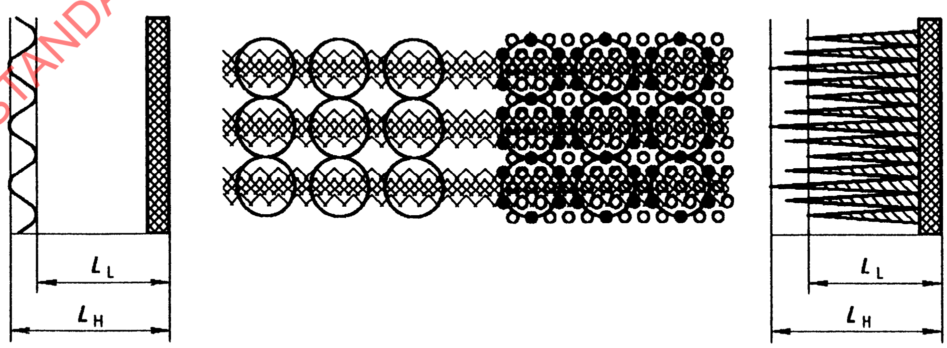


Figure 14 — Raster modulation (flat field)

For any display type, a special display-measuring device may be used. This device shall determine, on a scan-by-scan basis, the relative location of a character or test object. If a device is used that determines movement along the horizontal and vertical axes only, the extent of the jitter shall be defined as the square root of the sum of the squares of the maximum horizontal and vertical differences.

Observations shall extend for periods of at least 4 s. Measuring devices that sample scans shall accumulate a number of scans equivalent to at least 4 s of continuous observation.

6.6.15 Temporal instability (flicker)

Methods of predicting and measuring flicker are still under development. Annexes A and B provide the current status of these tests. When final test methods are developed, they will be provided as an addendum to this part of ISO 9241.

7 Compliance

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

a) meeting all mandatory requirements of clause 5;

or by

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

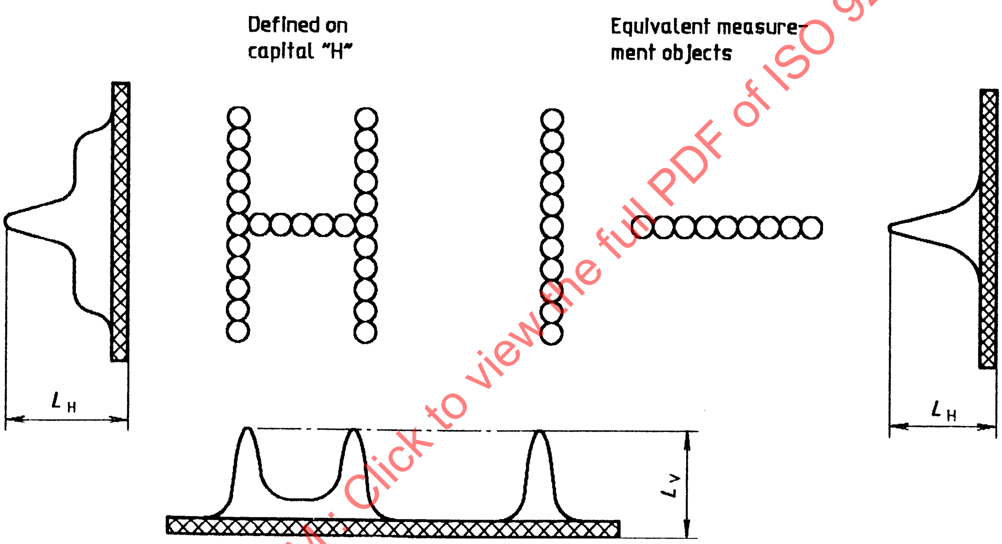


Figure 15 — Within-character luminance uniformity

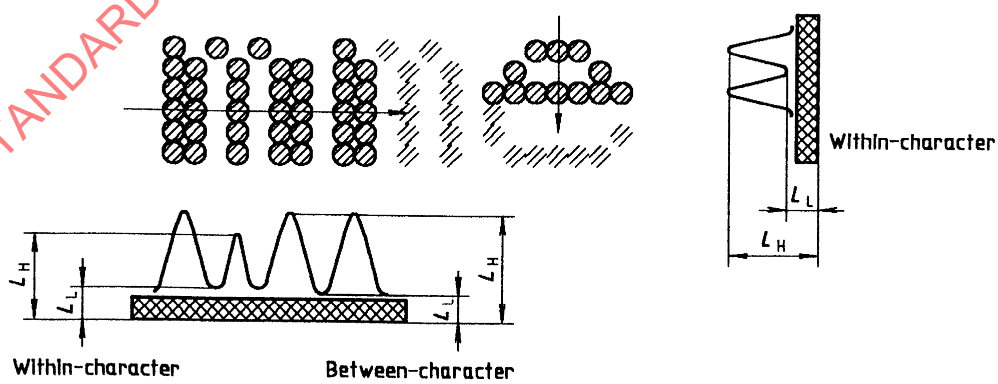


Figure 16 — Luminance contrast within and between characters

NOTES

11 The test method will become an addendum to this part of ISO 9241 when it has been proven. Annex C contains the current version. Before the addendum is published, only compliance route a) is available.

12 The test method is intended for VDTs for which clause 5 cannot be applied completely. One example is non-CRT displays.

Mandatory requirements are identified by the presence of the word "shall".

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, software and workstation elements and although each such element shall be shown by its supplier to comply individually, the parties using any given combination of such elements shall be responsible for compliance of that configuration.

7.2 The compliance report shall include the following minimum information:

a) suppliers details (name and address, type numbers, etc.);

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

c) conditions of use;

d) special requirements;

e) if compliance route 7.1 b) is used, full details of the criteria used for the selection of the test subjects and their relevant characteristics.

Annex A
(informative)

Analytical techniques for predicting screen flicker

Two analytical methods for predicting whether a VDT will appear to flicker to a stated percentage of the user population are described in this annex. In future editions of this part of ISO 9241, this is intended to be reduced to one method.

A.1 An analytical method for predicting screen flicker

A.1.1 General

This method is useful for evaluating displays during design and as a tool for selecting phosphors and refresh frequencies that will result in flicker-free displays. As a method of testing flicker-free compliance, the following shall be kept in mind.

a) The method allows one to predict whether a display will be flicker-free to 90 % of the user population given the phosphor persistence, refresh frequency and maximum display luminance.

b) The predictions are valid for positive polarity displays that vary in size (see table A.1). The predictions apply to the "worst case" display configuration in which every single pixel or scan line is illuminated. The method is, therefore, a conservative flicker test. If a VDT is flicker-free when every pixel or scan line is illuminated, then it will be flicker-free when approximately 85 % of the pixels are illuminated, as in character displays. It is not the case, however, that if a VDT appears to flicker in the extreme or worst configuration it will necessarily appear to flicker in the character configuration.

In light of the above, an empirical method of screen flicker assessment (see annex B) should be used as a compliance testing method whenever a display fails to comply using method A.1.

If a display is found to be flicker-free by either of the methods described in this annex, then an empirical assessment of flicker is not necessary. If, however, it predicts that the display will appear to flicker, then the empirical method of screen flicker assessment given in annex B, should be used as the flicker compliance test method. In other words, if a display is determined to be flicker-free by the methods of this annex, it will be considered to be flicker-free. If the display is determined to be flicker-free by the empirical method (although not flicker-free by the methods in this annex) it will also be considered to be flicker-free.

A.1.2 Analytical method for predicting screen flicker

A.1.2.1 Principle

The method is based on the fact that it can be predicted whether people will detect flicker in a homogeneously-illuminated display or not from the amount of energy in the fundamental temporal frequency of the display [7, 9, 10, 13 to 15 and 17]. The first step in the method therefore, is to compute the amount of energy in the fundamental temporal frequency E_{obs}. This number is then compared to the amount of energy that people will detect as flicker, i.e., the predicted flicker threshold, E_{pred}.

If $E_{obs} < E_{pred}$ then we predict that people will not see flicker.

If $E_{obs} \geqslant E_{pred}$ then we predict that people will see flicker.

A.1.2.2 DC component

The amount of energy in the fundamental temporal frequency of a VDT can be calculated as follows:

a) Convert the screen luminance into units of retinal illuminance (trolands).

b) The mean screen luminance over time, L_t, in candelas per square metre, is the luminance of the display as determined in accordance with 6.1 and 6.3. L_t is the total luminance of the screen and it includes the luminance reflected from the screen as well as the luminance emitted by the display phosphors.

c) Turn the display off and measure the reflected luminance from the screen, L_r, in candelas per square metre.

d) Estimate the area of the observer's pupil in square millimetres. Pupil area, A, is a function of the adapting luminance. Use the formula below [6] to estimate the diameter of the pupil and hence calculate A.

$$d = 5 - 3 \tanh[0{,}4 \lg(3{,}183 L_t)]$$

e) The DC component of the temporally-varying retinal illuminance, expressed in trolands, is

$$DC = (L_t - L_r)A \qquad \ldots \text{(A.1)}$$

A.1.2.3 Amplitude coefficient

Calculate the amplitude coefficient of the fundamental frequency of the screen luminance.

The screen luminance is a series of pulses with exponentially decaying persistence, $e^{-t/\alpha}$. The amplitutude coefficient of the fundamental frequency of the time-varying screen luminance can be calculated using the formula [19]:

$$\text{Amp}(f) = \frac{2}{[1 + (2\pi \alpha f)^2]^{1/2}}$$

where

α is the time constant of the exponential describing the phosphor persistence, in seconds; and

f is the refresh frequency of the display, in hertz.

NOTE 13 α is the time required for the luminance of a phosphor to decay to 1/e of its initial value. However, the time constant ($TC_{10\,\%}$) is usually given as the time required for the luminance to decay to 10 % of its initial value. Phosphor $TC_{10\,\%}$ values can be converted to α values by the following relationship:

$$\alpha = TC_{10\,\%} \times \frac{\ln 1/e}{\ln 1/10} = 0{,}434\,3 \times TC_{10\,\%}$$

A.1.2.4 Energy at the fundamental frequency

Calculate the luminance modulation of the fundamental frequency, E_{obs}, by multiplying the DC component of the temporal screen variation by the amplitude coefficient of the fundamental frequency, Amp(f).

$$E_{obs} = DC \times \text{Amp}(f) \qquad \ldots \text{(A.2)}$$

A.1.2.5 Predictions

Having calculated the actual amount of energy in the fundamental temporal frequency of a display, E_{obs}, calculate the amount of energy that people will detect as flicker, E_{pred}.

$$E_{pred} = a\,e^{bf} \qquad \ldots \text{(A.3)}$$

where

f is the refresh frequency; and

a and b are constants that depend on the size of the display. Table A.1 lists the parameter values (a and b) for several different display sizes.

If $E_{obs} < E_{pred}$ then it predicts that people will not see flicker.

If $E_{obs} \geqslant E_{pred}$ then it predicts that people will see flicker.

Table A.1 — Flicker parameters for several display sizes

Size (°)	$CFF = m + n \ln(E_{obs})$		$E_{pred} = a\,e^{bf}$	
	m	n	a	b
10	14,6	6,999	0,127 6	0,142 4
30	13,837 6	8,31	0,191 9	0,120 1
50	8,31	9,73	0,507 6	0,100 4
70	6,783	10,034	0,53	0,099 2

NOTES

1 Display size, specified in degrees of visual angle, is calculated from

$$\text{Size} = 2 \arctan\left(\frac{D}{2V}\right)$$

where

D is the diagonal of the display, expressed in millimetres; and

V is the design viewing distance, expressed in millimetres.

The diameter of the active area of a typical CRT display ranges between 250 mm and 375 mm. Therefore, the size of a typical CRT display ranges between 28° and 41° of visual angle.

2 The parameter values m and n were derived by a linear regression of CFF on ln(E_{obs}). Conversely, the parameter values a and b were derived by a linear regression of ln(E_{obs}) on CFF. Ideally, if the linear regression equations accounted for 100 % of the variance, then $a = e^{-m/n}$ and $b = 1/n$, respectively.

The linear regressions, in fact, accounted for 95 % to 99 % of the variance. Therefore small differences occur between the empirical values of a and b and $e^{-m/n}$ and $1/n$ respectively.

Alternatively, given the screen luminance (DC), one can calculate E_{obs} (see equation A.2, above) and then the refresh rate that will appear to be flicker-free, CFF, using

$$CFF = m + n \ln(E_{obs}) \qquad \text{. . . (A.4)}$$

where m and n are parameter values that depend on the size of the display.

Table A.1 lists parameter values for several different display sizes.

A.1.3 Sample calculation

A.1.3.1 Display configuration

The display is a CRT with a 280 mm diagonal viewed from approximately 500 mm.

Therefore the display size is
2 arctan(280/2 × 500) = 30,75° visual angle.

The display luminance, L_1, is 100 cd/m^2 and the light reflected from the screen L_r is 10 cd/m^2. Finally, the phosphor (P4) decay constant, α, is $2,5 \times 10^{-5}$ s (which corresponds to a value of $TC_{10\ \%}$ of 6×10^{-5} s).

A.1.3.2 Calculations

Starting at step A.1.2.2 d), the following calculations are made:

a) Pupil diameter is

$$d = 5 - 3 \tanh[0,4 \lg(3,183 \times 100)]$$
$$= 2,713\ 789 \text{ mm}$$

b) Pupil area is

$$A = 3,141\ 59 \times \left(\frac{2,713\ 789}{2}\right)^2 = 5,784\ 2 \text{ mm}^2$$

c) The DC component is

$$DC = (100 - 10) \times 5,784\ 2 = 520,57 \text{ td}$$

d) The amplitude factor of the fundamental temporal frequency is

$$\text{Amp}(f) = \frac{2}{\left[1 + \left(2,5 \times 10^{-5} \times 6,283\ 2 \times f\right)^2\right]^{1/2}}$$

Therefore, when the refresh frequency, f, is 60 Hz, the amplitude factor is 1,999 91. When the refresh frequency, f, is 72 Hz, the amplitude factor is 1,999 87.

e) The luminance modulation of the 60 Hz display is

$$E_{obs} = 520,576 \times 1,999\ 9 = 1\ 041 \text{ td}$$

f) The luminance modulation required for a flicker-free 60 Hz display is

$$E_{pred} = a\ e^{bf} = 258,58 \text{ td}$$

where f = 60 Hz, a = 0,191 9, and b = 0,120 1. (See table A.1 for a and b parameters for a display subtending 30° of visual angle.)

g) Since $E_{obs} > E_{pred}$, the conclusion is that the 60 Hz display will appear to flicker.

h) The luminance modulation of the 72 Hz display is

$$E_{obs} = 520,576 \times 1,999\ 9 = 1\ 041 \text{ td}$$

and the luminance modulation required for a flicker-free 72 Hz display is

$$E_{pred} = 0,191\ 9 \times e^{0,120\ 1 \times 72} = 1\ 092,71 \text{ td}$$

Since $E_{obs} < E_{pred}$, the 72 Hz display will be flicker-free.

NOTE 14 If the calculations are carried out using a phosphor (P39) decay constant $\alpha = 3,040 \times 10^{-2}$ s, the 60 Hz display will be flicker-free.

A.2 An algorithm for predicting flicker in a visual display

A.2.1 Principle

In order to estimate whether a visual display will be flicker-free or not, an algorithm is used.

A.2.2 Compute the mean CFF for the display

This is estimated by the following equation:

$$\overline{CFF} = 34,9 + 17,6 \lg(L_1) \qquad \text{. . . (A.5)}$$

where L_1 stands for the display luminance in accordance with 6.3. Equation A.5 is based on psychophysical group mean data for a bright (positive polarity) screen with a fast phosphor (P31) subtending a visual angle of 70°. Thus the formula includes the requirement that the peripheral visual field should be flicker-free.

A.2.3 Estimate intersubject variability

The standard deviations for inter-individual differences, σ_{int}, are given in table A.2.

Table A.2 — Standard deviations and inter-individual differences

Mean screen luminance	(cd/m^2)	25	50	100	200	400
σ_{int}	(Hz)	5,71	5,28	5,78	6,93	8,29

A.2.4 Determine the percentile criterion

The distribution of subjects in *CFF* measurements is essentially Gaussian. Consequently, if the 95th percentile is used, implying that 95 % of the subjects will perceive the screen as flicker-free, it follows that the criterion corresponds to 1,65 σ_{int}.

A.2.5 Compute the standard value

Given the 95th percentile criterion the standard becomes

$$CFF_{STANDARD} = \overline{CFF} + 1{,}65\ \sigma_{int}$$

If the refresh rate is higher than $CFF_{STANDARD}$ the screen is considered flicker-free.

EXAMPLE — For a display with mean luminance $= 100\ cd/m^2$ the $\overline{CFF}$ is 70,1 Hz. Since σ_{int} is 5,78 Hz, the $CFF_{STANDARD}$ becomes

$$70{,}1 + 1{,}65 \times 5{,}78 = 79{,}6\ Hz$$

NOTE 15 For slow phosphors (e.g. P39) preliminary data indicate that the limit should be set about 5 Hz lower.

Annex B
(informative)

Empirical method for assessing temporal and spatial instability (flicker and jitter) on screen

B.1 General

Subjects should be a sample representing the anticipated user population (those who perform office tasks as specified in clause 1) in terms of factors pertinent to the equipment being tested. At least twenty subjects should be used for the test.

When testing bright characters on a dark background, there should be as many characters displayed as the maximum occurring in normal operation.

B.2 Procedure

a) Adjust the ambient light to $(250 + 250 \cos A)$ lx as measured at the screen.

b) Fill the screen with characters.

c) Adjust the display luminance to the level specified in 6.3.

d) Position the screen at the design viewing distance from the observer.

e) Place the screen:

1) 30° into the observer's visual periphery;

and then

2) straight ahead of the observer.

B.3 Report

The display is reported as being free from flicker and jitter if it appears free from flicker and jitter to at least 90 % of the test subjects.

Annex C
(informative)

Comparative user performance test method

This test method is under consideration for its applicability as an alternative method of testing compliance for this part of ISO 9241. Testing organisations are requested to indicate their experience with this technique together with supporting documentation, in particular the statistical methods employed.

C.1 Principle

This test procedure is concerned with the detection and recognition of characters on the display. It is used to assess the effectiveness of the display in presenting alphanumeric characters to the user. Effective in this context means that the user is able to detect and recognize the image accurately, quickly, and without discomfort. User performance is specified in terms of the accuracy and speed achieved by the test subjects in the detection and recognition test and the discomfort experienced.

The user performance on a display, referred to as the test display, is compared to performance on a reference display known to meet the mandatory requirements of clause 5. The test is conducted in a simulated office environment using people with normal or appropriately-corrected vision. These and other test conditions are described below.

Each subject undergoes the test procedure twice, once for the test display and once for the reference display (the order of presentation being balanced across subjects).

The test programme should take due note of the manufacturer's guide for installation and use. The assessment should be carried out with the participation of a person trained in the assessment of human behaviour.

C.2 Test subjects

Subjects should be a sample representing the anticipated user population (those who perform office tasks as specified in the scope) in terms of factors pertinent to the equipment being tested. Guidance on how to estimate the number of subjects required is provided in C.10.

Subjects should be screened for visual ability including, for example, tests for vertical phoria, lateral phoria, colour normalcy and contrast sensitivity. Subjects should have near acuity not less than 0,5 (corrected if necessary) at the design viewing distance.

C.3 The displays

The test display should be a production or full-feature pre-production unit. It shall incorporate all anti-glare and reflection filters and treatments which will be in the production unit.

The reference display should be supplied or nominated by the supplier of the test display and shall meet all mandatory requirements in clause 5.

Both displays should be switched on in sufficient time to ensure that they are fully warmed up. The displays shall be labelled for identification purposes, e.g. "Display 1" and "Display 2". The test subjects should not be informed which is the test and which is the reference display.

C.4 Test workstation and environment

C.4.1 General requirements

The test should be conducted in an area which is free from distractions and external interference which could influence test results. The ambient conditions should be comfortable and unvarying throughout the test session.

C.4.2 Environment

The following conditions are important in determining the correct environment for the test. As these are test conditions, the requirements given below are intended to minimise extraneous variables that may influence task performance.

C.4.2.1 Noise

Background noise level during the test, measured at the subject's head position, should be below 55 dB(A).

C.4.2.2 Thermal environment

The test shall be carried out under the conditions given in table C.1.

Table C.1 — Thermal environment

Air temperature	19 °C to 26 °C
Relative humidity	40 % to 60 %
Air velocity	⩽ 0,15 m/s

C.4.2.3 Lighting

The test environment should be designed to simulate a working environment. The ambient illumination should be measured at the centre of the display on a plane tangent to it. The illumination should be a minimum of $(250 + 250 \cos A)$ lx where A is the angle formed by the intersection of the plane tangent to the centre of the display and a horizontal plane.

The symbol or background luminance (whichever is higher) of the reference display should be set in accordance with 6.3.

The ambient illumination should be designed to minimize glare. Noticeable specular reflections on the screen are to be avoided. The surfaces in the test room should have reflectances within the ranges shown in table C.2.

Table C.2 — Range of reflectance of surfaces in test room

Source	**Reflectance** %
Ceiling	70 to 80
Walls	30 to 50
Floor	10 to 30
Furniture	20 to 50

The test subjects should be light-adapted by being placed in the test room or an equivalently-lit room for 15 min prior to the test. The test subjects should be kept at this level of adaptation throughout the tests.

C.4.3 Workstation for the test

The displays and associated equipment (e.g., keyboard) should be supported by a work surface of appropriate size, height and finish (see ISO 9241-5). The viewing distance to the displays should be the design viewing distance (see 5.1) and the line-of-sight angle should be between 0° and 60° below the horizontal (see 5.2).

The subject should be seated in a chair which meets the requirements of ISO 9241-5.

C.5 Test material

The test material will be the character set associated with the 8-bit single-byte coded graphic character set as given in tables 1 to 3 concerning 8-bit VDTs in ISO/IEC 4873[1]. Each test will use the complete character set or a specified subset, e.g. ISO/IEC 646[2] for 7-bit VDTs. The same set should be used for both displays.

C.6 Familiarization with the test material

Before the test, it should be determined that the subjects are familiar with each of the characters in the test character set.

C.7 Procedure

The following procedure is suggested as a guide to the conduct of the test. The objective of the procedure is to conduct a test which is both accurate and reliable. Any variations from this suggested procedure should be directed at enhancing the accuracy and reliability of the test. The test procedures should be designed to be easy and to avoid loading the subjects unduly.

It should be emphasised that the object of the test is to compare the user performance of the two displays.

The subjects should be given the opportunity to adjust the test display (not the reference display) to their preferred level of brightness and contrast.

Test characters are to be displayed in blocks of three rows by five characters each. The middle row is the test row in order to take account of the influence of inter-line spacing. Each test character should be presented randomly in each test row at least twice during the course of the test.

1) ISO/IEC 4873:1991, *Information technology — ISO 8-bit code for information interchange — Structure and rules for implementation.*

2) ISO/IEC 646:1991, *Information technology — ISO 7-bit coded character set for information interchange.*

The centre of one test block should be located as close as is practical to each of the following five locations (see figure 11):

a) the upper left corner, along the diagonal, 10 % of the diagonal in from the corner;

b) the upper right corner, along the diagonal, 10 % of the diagonal in from the corner;

c) the centre of the screen;

d) the lower left corner, along the diagonal, 10 % of the diagonal in from the corner;

e) the lower right corner, along the diagonal, 10 % of the diagonal in from the corner.

Before the blocks are displayed, a visual or auditory start signal is presented to alert the subject. The five test blocks at the five locations are presented simultaneously 0,5 s after the termination of the signal and are displayed until they are completely identified by the test subject.

The test subject is instructed to identify the characters in the test row of each block, working from top left to bottom right. For guidance in performing the test, the subject should be informed about the importance of speed and accuracy.

The time from the appearance of the test blocks to the subject's response to the last letter of the last block should be recorded with an accuracy of 100 ms or better.

The next set of test blocks should be presented immediately after completion of the response to the preceding set.

NOTE 16 The test procedure permits any appropriate response method to be used (e.g. by keyboard). The important point is that identical procedures and measures are used for both the test and the reference displays.

C.8 Assessment of discomfort

C.8.1 Procedure

On completion of the test for the display viewed first, the subjects should be asked to assess its acceptability with respect to important characteristics of visual discomfort. For half the subjects, the display viewed first will be the test display, and for the other half the display viewed first will be the reference display. The subjects should not be informed which is the test and which is the reference display. The scales to be used and instructions to be given to the subjects are specified below.

After viewing the second display, the subjects should make a comparative assessment of acceptability relative to the display viewed first, on each of the scales. The scales to be used and the instructions to be given to the subjects are specified.

NOTE 17 The subjects use a continuous, pseudo-interval scale to rate the acceptability of the first display in order to record the maximum amount of information about each judgement. This information is then available for reference to the subject when the comparative judgement of the acceptability of the second display is made.

C.8.2 Scales to be used for the assessment of discomfort

The response sheet shown in figure C.1 should be given to each subject after completing the test for the first display, and again after completing the test for the second display.

C.8.3 Instructions to subjects

The following verbal instructions should be given to each subject to explain how responses are to be made:

a) Instructions for the display viewed first

"We would like you to indicate how you judge the display you have just used with respect to the characteristics shown on the sheet. For each characteristic, you should place a cross on the line to the left of the characteristic in the position corresponding to your judgement."

b) Instructions for the display viewed second

"We would like you to indicate how you judge the second display with respect to the characteristics shown on the sheet. For each characteristic, you should refer to your judgement of the first display which is indicated by the position of your earlier cross on the line. Then you should indicate whether you consider the second display to be worse, the same, or better by ticking the appropriate box."

C.8.4 Scoring

Where the display viewed second is the test display, the comparative judgements for the second display are scored by the experimenter as follows:

worse = − 1

same = 0

better = + 1