INTERNATIONAL STANDARD

ISO 9241-8

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

Part 8
Requirements for displayed colours

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

Partie 8: Exigences relatives aux couleurs affichées

Reference number
ISO 9241-8:1997(E)

Contents

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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 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 of an International Standard requires approval by at least 75% of the member bodies casting a vote.

International Standard ISO 9241-8 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Sub-committee 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: Display requirements with reflections*
- *Part 8: Requirements for displayed colours*
- *Part 9: Requirements for nonkeyboard 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 and C of this part of ISO 9241 are for information only.

Introduction

The purpose of this part of ISO 9241 is to prescribe basic specifications for colours on computer display terminals to ensure their visibility, identification and discrimination.

The specifications in this part address colour images (visual "stimuli"), their appearance (visual "perception") and identification (colour "naming"). The specifications thus address both the perceptual components of colour (such as detection of saturation and lightness) and some cognitive components (such as naming of specific colours). Other cognitive components will be addressed in ISO 9241-12.

The ability to detect, identify and discriminate colours on display terminals determines the usefulness of colour in the perception and interpretation of the computer-generated image. Colour perception of displayed images depends on a number of factors such as:

- hardware and software components of the *display* system,
- physical characteristics of the display *image,*
- the ability of the *viewer* to perceive the colours,
- the lighting in the viewing *environment.*

The primary characteristics of these factors (that is display, image, viewer and environment) that affect colour appearance are shown in table 1.

Table 1 - Examples of factors affecting colour appearance

Source	**Factor affecting colour appearance**
Display	Luminance
	Spectral distribution and range
	Phosphor type
	Screen treatment for reflection control
	Resolution
Image	Adjacent colours
	Size
	Spatial frequency content
Viewer	State of visual adaptation
	Colour-perception ability
Room	Illumination level
	Colour temperature of the illumination

Colour interpretation depends on the ability of the viewer to associate a colour with a specific meaning, function, or action. It is thus important that colours assigned to images on displays be carefully chosen to achieve intended effects or convey intended meaning. However, the appearance of colours may vary among different suppliers' displays. For example, the blue on one display may appear darker and more purple than on another, and red may appear more orange.

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

Part 8:
Requirements for displayed colours

1 Scope

This part of ISO 9241 describes minimum ergonomic requirements and recommendations to be applied to colours assigned to text and graphic applications and images in which colours are discretely assigned. The specifications in this part thus exclude photorealistic images and graphics.

This part of ISO 9241 applies to both hardware and software for visual display terminals, because both these sources control the presentation and appearance of colour on the display screen.

The specifications, measurements and test procedures described in this part of ISO 9241 are for displays that produce colour images and are intended to be independent of display technologies unless otherwise specified.

The specifications in this part of ISO 9241 are for images on computer displays that meet minimum requirements for users with normal colour vision. Displays conforming to this part will be suboptimal for persons with colour vision deficiencies.

This part of ISO 9241 is complementary to ISO 9241-3. The tasks and conditions of use in this part are similar to those described in ISO 9241-3, unless otherwise specified. This part of ISO 9241 is not intended to be a specification on colour coding.

Although the primary users of this part of ISO 9241 are intended to be hardware and software user-interface designers and manufacturers, it will also be useful to those persons responsible for procuring colour displays and those evaluating the use of colour in the user-interface of the computer system.

2 Normative references

The following standards contain provisions which, through reference in this 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 editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 9241-5:—1), *Ergonomic requirements for office tasks with visual display terminals* (VDTs) – *Part 5: Workplace requirements.*

3 Definitions

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

3.1 achromatic (perceived) colour:
(1) <perceptual sense> Perceived colour devoid of hue.

The colour names white, gray and black are commonly used or, for transmitting objects, colourless and neutral.

(2) <psychophysical sense> See achromatic stimulus 845-03-06. [CIE 17.4 / IEC 50, 845-02-26]

3.2 adaptation (visual): Process by which the state of the visual system is modified by previous and present exposure to stimuli that may have various luminances, spectral distributions and angular subtenses. [CIE 17.4 / IEC 50, 845-02-07]

3.3 additive mixing: Stimulation that combines on the retina the actions of various colour stimuli in such a manner that they cannot be perceived individually. [CIE 17.4 / IEC 50, 845-03-15]

3.4 brightness: Attribute of a visual sensation according to which an area appears to emit more or less light. [CIE 17.4 / IEC 50, 845-02-28]

3.5 chroma: Chromaticness, or colourfulness, of an area judged as a proportion of the brightness of a similarly illuminated area that appears white or highly transmitting. [CIE 17.4 / IEC 50, 845-02-42]

3.6 chromaticity: Property of a colour stimulus defined by its chromaticity coordinates, or by its dominant or complementary wavelength and purity taken together. [CIE 17.4 / IEC 50, 845-03-34]

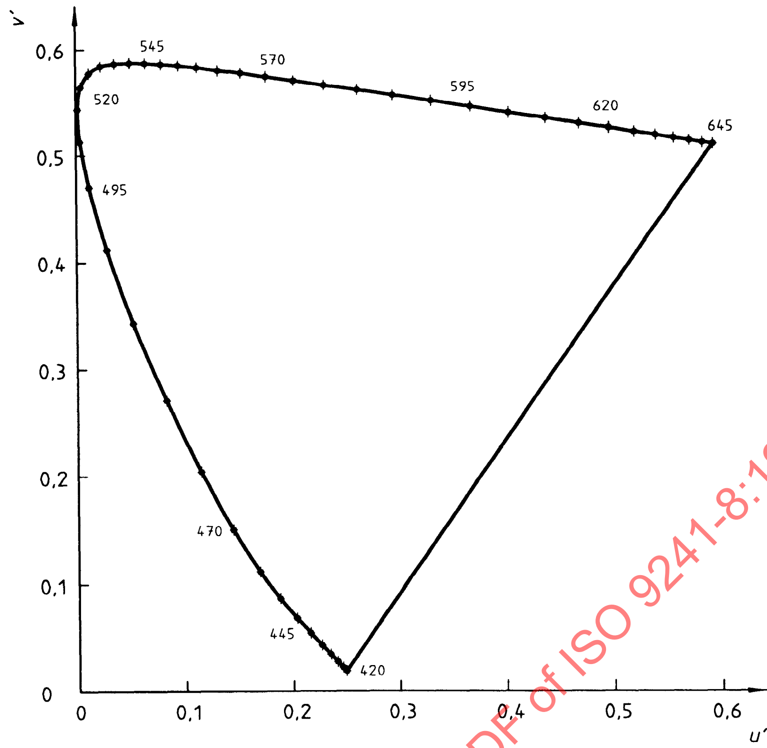
3.7 chromaticity coordinates: Ratio of each of a set of three tristimulus values relative to their sum. [CIE 17.4 / IEC 50, 845-03-33]

NOTES
1 As the sum of the three chromaticity coordinates equals one, two of them are sufficient to define a chromaticity.
2 In the CIE standard colorimetric systems, the chromaticity coordinates are represented by the symbols x, y, z and x_{10}, y_{10}, and z_{10}.

3.8 chromaticity diagram: Plane diagram in which points specified by chromaticity coordinates represent the chromaticities of colour stimuli. [CIE 17.4 / IEC 50, 845-03-35]

NOTE –In the CIE standard colorimetric systems, *y* is normally plotted as ordinate and *x* as abscissa, to obtain an *x, y* chromaticity diagram (see figure 1 and 3.10).

1) To be published.



NOTE – The numbers along the curve are the wavelengths of light, in nanometres.

Figure 1 — CIE 1976 uniform-chromaticity-scale diagram; CIE 1976 UCS diagram

3.9 chromostereopsis: Phenomenon in which two visual objects that differ in dominant wavelength and/or brightness appear to be at different distances from the viewer.

3.10 CIE 1976 uniform-chromaticity-scale diagram; CIE 1976 UCS diagram: Uniform-chromaticity-scale diagram produced by plotting in rectangular coordinates v' against u', quantities defined by the equations (1):

$$(1) \quad \begin{cases} u' = \dfrac{4X}{X+15Y+3Z} = \dfrac{4x}{-2x+12y+3} \\ v' = \dfrac{9Y}{X+15Y+3Z} = \dfrac{9y}{-2x+12y+3} \end{cases}$$

X, Y, Z are the tristimulus values in the CIE 1931 or 1964 standard colorimetric systems, and x, y are the corresponding chromaticity coordinates of the colour stimulus considered. [CIE 17.4 / IEC 50, 845-03-53].

NOTE – This diagram is a modification of and supersedes, the CIE 1960 UCS diagram in which v was plotted against u in rectangular coordinates. The relationships between the two pairs of coordinates are:

$u' = u$; $v' = 1,5v$

3.11 CIE L*u*v* colour space; CIELUV colour space:

Three-dimensional, approximately uniform colour space produced by plotting in rectangular coordinates L^*, u^*, v^* quantities defined by the equations (2):

$$(2) \quad \begin{cases} L^* = 116(Y/Y_n)^{\frac{1}{3}} - 16; \quad Y/Y_n > 0{,}008\ 856 \\ u^* = 13L^*(u' - u'_n) \\ v^* = 13L^*(v' - v'_n) \end{cases}$$

Y, u', v' describe the colour stimulus considered and Y_n, u'_n, v'_n describe a specified white achromatic stimulus. (See CIE 15.2) [CIE 17.4 / IEC 50, 845-03-54]

NOTE – Approximate correlates of CIE 1976 u, v lightness, CIE 1976 u, v saturation, CIE 1976 u, v chroma and CIE 1976 u, v hue may be calculated as follows:

$$\text{CIE 1976 } \textit{lightness } L^* = 116(Y/Y_n)^{\frac{1}{3}} - 16; \qquad Y/Y_n > 0{,}008\,856$$

$$\text{CIE 1976 } \textit{v, u saturation } s_{uv} = 13\left[(u'-u'_n)^2 + (v'-v'_n)^2\right]^{\frac{1}{2}}$$

$$\text{CIE 1976, } \textit{v, u chroma } C^*_{uv} = \left[u^{*2} + v^{*2}\right]^{\frac{1}{2}} = L^* s_{uv}$$

$$\text{CIE 1976 } \textit{v,u hue-angle } h_{uv} = \arctan\left[(v'-v'_n)/(u'-u'_n)\right] = \arctan(v^*/u^*)$$

3.12 CIE 1976 L*u*v* colour difference: CIELUV colour difference: Difference between two colour stimuli, defined as the Euclidean distance between the points representing them in the L^* u^* v^* space and calculated as equation (3): (See CIE 15.2) [CIE 17.4 / IEC 50, 845-03-55]

$$(3) \qquad \Delta E^*_{uv} = \left[(\Delta L^*)^2 + (\Delta u^*)^2 + (\Delta v^*)^2\right]^{\frac{1}{2}}$$

NOTE – The CIE u, v hue-difference may be calculated as follows:

$$\Delta H^*_{uv} = \left[(\Delta E^*_{uv})^2 - (\Delta L^*)^2 - (\Delta C^*_{uv})^2\right]^{\frac{1}{2}}$$

3.13 CIE standard illuminants: Illuminants A, B, C, D_{65} and other illuminants D, defined by the CIE in terms of relative spectral power distributions. (See CIE 15.2) [CIE 17.4 / IEC 50, 845-03-12]

NOTE – These illuminants are intended to represent:
- A, Planckian radiator at a temperature of about 2856 K;
- B, direct solar radiation (obsolete);
- C, average daylight (obsolete);
- D_{65}, daylight including the ultraviolet region.

3.14 colour detection: Perception of the presence of a colour on a visually noisy background.

3.15 colour discrimination: Detection of colour difference between visual stimuli.

3.16 colour identification: Perception signified by the ability to name a colour.

3.17 colour interpretation: Association of a particular colour to a meaning or function.

3.18 colour temperature: Temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus. It is expressed in kelvins. [CIE 17.4 / IEC 50, 845-03-49]

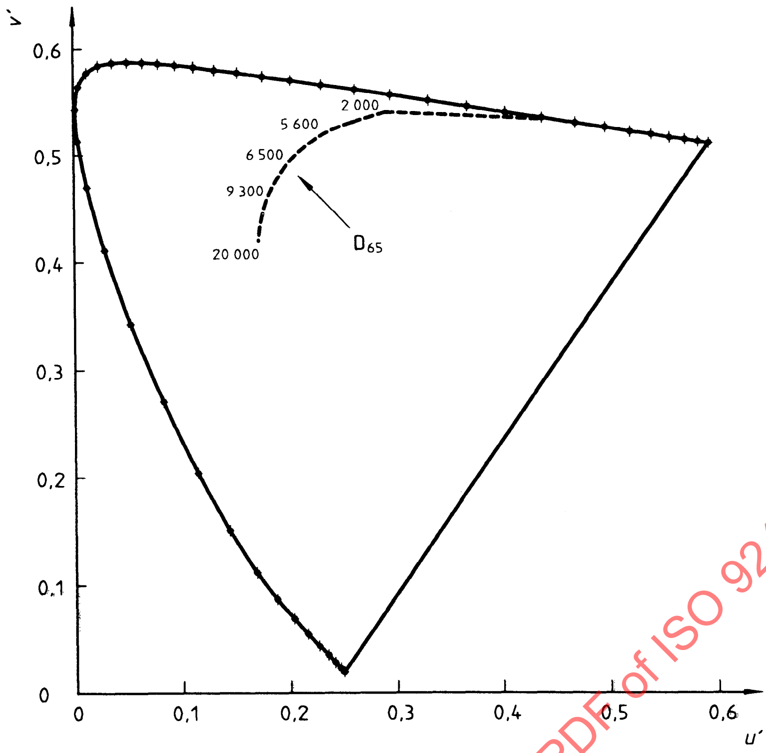


Figure 2 — Location of CIE illuminant D_{65} and colour temperatures on a 1976 CIE UCS diagram

3.19 chromaticity uniformity difference: A distance in the CIE 1976 UCS diagram.

$$\Delta u'v' \equiv \sqrt{\left(u_1' - u_2'\right)^2 + \left(v_1' - v_2'\right)^2}$$

where

u_1', v_1' and u_2', v_2'

are the coordinates of the same colour displayed at sites 1 and 2.

3.20 complementary wavelength (of a colour stimulus) (λ_c): Wavelength of the monochromatic stimulus that, when additively mixed in suitable proportions with the colour stimulus considered, matches the specified achromatic stimulus. (CIE 17.4 / IEC 50, 845-03-45)

3.21 convergence: The exact intersection of electron beams of a colour CRT at a specific point on the plane of its phosphor screen. See figure 3.

Misconvergence is the departure from convergence. See figure 4.

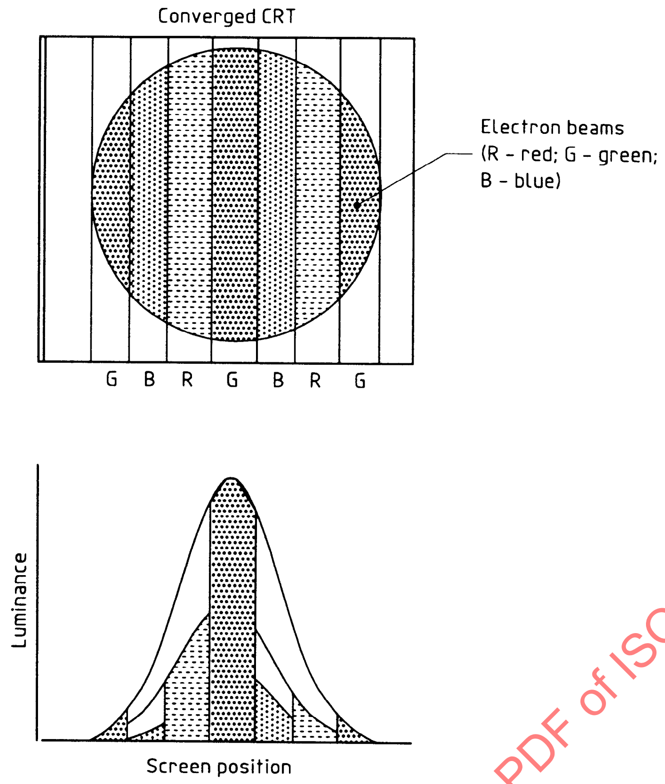


Figure 3 – CRT converged R,G,B electron beams

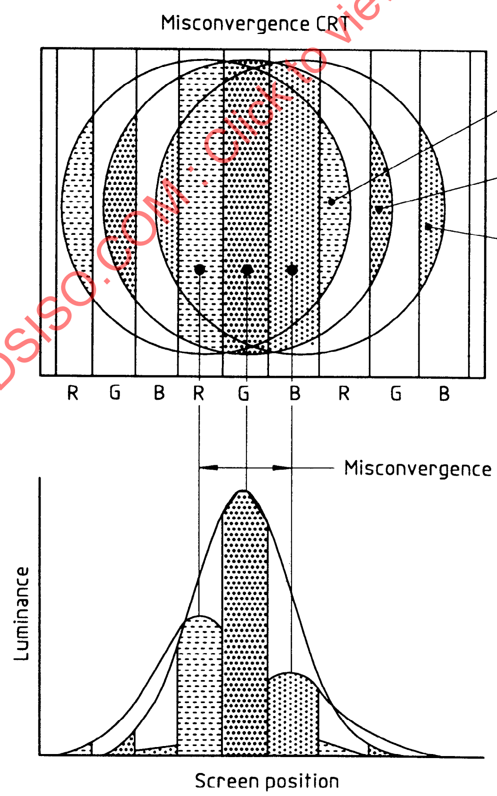


Figure 4 – CRT misconverged R,G,B electron beams

3.22 default colour set: Predetermined group of colours assigned by the software application or operating system.

3.23 defective colour vision: Anomaly of vision in which there is a reduced ability to discriminate some or all colours. [CIE 17.4 / IEC 50, 845-02-13]

3.24 depth-of-field: Range of visual focus of images from the distance at which all images are in focus.

3.25 design viewing distance: Distance, or range of distances, between the screen and the operator's eyes for which the display is designed to be viewed (see ISO 9241-3:1992, 2.12).

3.26 dominant wavelength: Wavelength of the monochromatic stimulus that, when additively mixed in suitable proportions with the specified achromatic stimulus, matches the colour stimulus considered.

NOTE – In the case of purple stimuli, the dominant wavelength is replaced by the complementary wavelength. [CIE 17.4 / IEC 50, 845-03-44]

3.27 hue: Attribute of a visual sensation, according to which an area appears to be similar to one of the perceived colours red, yellow, green or blue, or a combination of two of them. [CIE 17.4 / IEC 50, 845-02-35]

3.28 just-noticeable difference: Perceptual unit which specifies the amount of least physical change of an image at which the difference can be detected.

3.29 lightness: Brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting. [CIE 17.4 / IEC 50, 845-02-31]

3.30 luminance contrast: Ratio between the higher (L_H) and lower (L_L) luminances that define the feature to be detected and measured by contrast modulation, calculated by:

$$C_m \equiv \frac{L_H - L_L}{L_H + L_L}$$

or contrast ratio (CR), defined as:

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

[ISO 9241-3:1992, 2.22]

3.31 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. It is expressed in reciprocal steradians (sr^{-1}) [IEC 50, 845-04-71]

3.32 colorimetric purity, p_c: Quantity defined by the relation

$$p_c = \frac{L_d}{(L_n + L_d)}$$

where L_d and L_n are the respective luminances of a monochromatic stimulus and of a specified achromatic stimulus that match the colour stimulus considered in an additive mixture. [CIE 17.4 / IEC 50, 845-03-47]

3.33 reference white: Specified white achromatic stimulus Y_n, u'_n, v'_n.

3.34 saturated colour: Colour with a colorimetric purity of one (1).

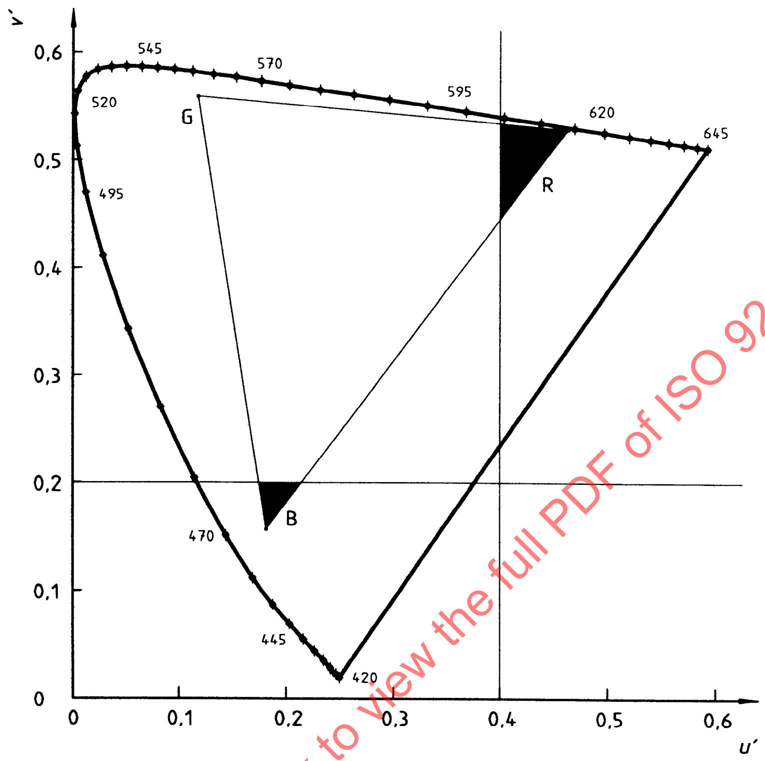
3.35 saturation: Chromaticness, or colourfulness, of an area judged in proportion to its brightness. [CIE 17.4 / IEC 50, 845-02-41]

3.36 simple graphics: Computer-generated graphs, charts, icons and pictures composed of lines or area-fill which are not continuous shades, photo-like in appearance or having few gray levels.

3.37 spectrum locus: Locus in a chromaticity diagram or colour space of the points that represent monochromatic stimuli throughout the spectrum.

3.38 spectrally extreme colours: Extreme blue (any colour with $v' < 0{,}2$) and extreme red (any colour with $u' > 0{,}4$).

The extreme regions are illustrated in figure 5.



NOTE – Filled-in areas show spectrally extreme colours of a cathode ray tube gamut (indicated by the triangular outline).

Figure 5 – Spectrally extreme colours

3.39 stereopsis: Binocular, visual perception of depth or three-dimensional space.

3.40 tritanopia, small-field: Normal reduction in colour discrimination for short-wavelength (perceived as blue) images of small angular subtense (approximately 20 minutes of arc or less) stimulating the central fovea of the eye.

3.41 tristimulus values: Amounts of the three reference stimuli, in a given trichromatic system, required to match the colour of the stimulus considered. [CIE 17.4 / IEC 50, 845-03-22]

3.42 uniform-chromaticity-scale (UCS) diagram: Two-dimensional diagram in which the coordinates are defined with the intention of making equal distances represent as nearly as possible equal steps of colour discrimination for colour stimuli of the same luminance throughout the diagram. [CIE 17.4 / IEC 50, 845-03-52]

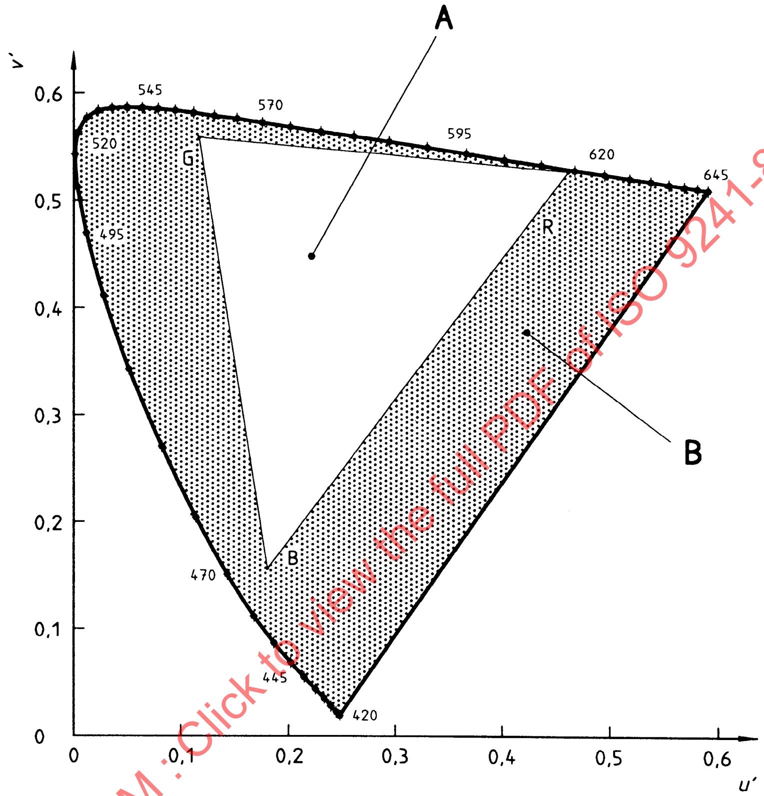
4 Guiding principles

Colour can enhance the visual and cognitive processing of information on display screens. For example, colour can help locate, classify, and associate images (i.e. show a relationship between information).

The application of colour to display images and their backgrounds should facilitate the correct perception, recognition and interpretation of images and information. Colour assignment should be consistent with human factor engineering (ergonomic) guidelines (see annex C) and accepted practice. The incorrect use of colour can reduce the perception of information displayed on the screen.

NOTES

1 It is not possible for a computer display to produce all the colours that can be perceived by the human visual system (see figure 6).



A CRT colour production

B Visible colour range

Figure 6 – Colour gamut of a CRT

The triangle superimposed on the 1976 CIE chromaticity diagram shows the limited range of chromaticities generated by a CRT compared to chromaticity visibly perceptible (cross-hatch).

2 Providing colours that accommodate viewers with colour vision deficiencies is important to computer applications where both colour identification and discrimination are critical.

Less than 0,1% of people are unable to perceive hue. However, approximately 8% of males and 0,5% of females are colour-vision deficient. The most frequently occurring colour deficiency is the inability to distinguish red, yellow and green; other colours easily confused by colour-vision deficients are cyan from white and blue from purple. Ensuring sufficient brightness differences between colours eliminates confusion between them. Thus, if a yellow has a high luminance value, a green has a medium luminance, and a red has a low luminance value, all users should be able to detect differences between them.

5 Visual performance objectives

The primary objective of presenting information in colour on a display screen is to enhance the user's ability to process information. This objective is obtained if colours can easily be detected, identified, and discriminated, and if the assignment of meaning to colour is appropriate to the task. Although colours can be used for aesthetic purposes, the selection of colours for this purpose should not impede visual performance and information processing.

The physical characteristics of images (such as size) impact the ability to identify and discriminate their colours. The effect of these physical characteristics on colour perception should be analyzed and considered when choosing colour for display screen images and their background. Colours and colour combinations that cause unintended visual effects should not be used.

6 Design requirements and recommendations

The discriminability of pairs of colours depends on differences in both chromaticity and luminance. The colour difference calculation requirements in this section are based on the colour space as defined by the CIE in 1976. See clause 3 and annex A for further information on CIE colour space and colour difference calculations.

6.1 Default colour set

When an application requires the user to discriminate or identify colours, it shall offer a default set of colours (see 6.9.1 regarding number) which meets the requirements of this part of ISO 9241. If the colour can be altered by the user, the default set of colours shall be retrievable and restorable.

6.2 Colour uniformity

For an intended uniform colour appearance, the chromaticity differences of a colour at different locations on the screen shall be as specified in table 2.

Table 2 – Colour uniformity

Diagonal of the active area in mm / Design viewing distance in mm	Maximum $\Delta u'v'$
< 0,75	0,02
≥ 0,75	0,03

NOTE – ΔE^*uv has not been used to calculate chromaticity uniformity because it only applies to immediately adjacent colours. The two categories in table 2 are based on the reduction in colour discrimination as colours are spatially separated.

6.3 Colour misconvergence

The level of misconvergence at any location on multicolour, shadow mask CRT screens shall not be greater than 3,4 minutes of arc and preferably should be less than 2,3 minutes of arc at the design viewing distance.

NOTES

1 The convergence of electron beams is a major component in the appearance, quality and resolution of a CRT image. Convergence is especially important when resolution is critical, such as when reading alphanumeric characters.

2 If the electron beams are not correctly aligned (that is, they are misconverged) on the phosphor triads, they cause the appearance of colour fringes or double images along the edges of an image. Since these fringes reduce image resolution, they can reduce user performance.

3 The lower value of misconvergence (that is, 2,3 minutes of arc) is noticeable, but not visually distracting.

4 As the distance between the viewer and the display decreases, the ability of the operator to detect misconvergence increases. Red-green beam misconvergence is the most perceivable of the beam combinations. For line width of 1 to 2 minutes of arc, as little as 0,5 minutes of arc of red-green beam misconvergence is detectable. Blue-green beam misconvergence, the least perceivable of the beam combinations, is detectable at slightly over 1,0 minutes of visual arc.

6.4 Character height and object size

6.4.1 Character strings and data fields

Where accurate colour identification of alphanumeric character strings and data entry fields is required, the character height shall subtend at least 20 minutes of arc at the design viewing distance.

6.4.2 Isolated images

Where accurate colour identification of an isolated image (e.g. a character or a symbol) is required, the image should subtend at least 30 minutes of arc at the design viewing distance, and preferably 45 minutes of arc.

6.4.3 Small images

The use of spectrally extreme blue ($v' < 0{,}2$) should be avoided for images subtending less than 2°.

NOTES

1 Multicolour displays produce not only luminance contrasts between the characters and the background, but also produce colour contrasts that improve total contrast threshold, legibility and readability of text and symbols.

2 Colour images composed of thin lines are often difficult to identify and discriminate, especially on light-emissive displays. Thus, the colours of individual characters composed of single strokes such as "1", "\", and "/" and symbols such as "(" and "<" are not accurately perceived unless they subtend at least 30 minutes of arc (enough area on the retina to stimulate accurate colour identification) at the design viewing distance. Colour pairs that are easily confused are those with a small hue angle difference such as red and orange, blue and purple, and green and cyan. These combinations are especially difficult to discriminate if they are very bright and of similar brightness, such as white and yellow. White-background emissive displays further reduce the discriminability of these colour pairs.

6.5 Colour differences

Colour pairs that are to be discriminated shall have values of $\Delta E^*_{uv} > 20$

NOTES

1 If viewers are to accurately discriminate colours, even a ΔE^*_{uv} significantly larger than 20 does not necessarily guarantee satisfactory perceptual performance because of the effects of adjacency and size on colour appearance.

2 The lightness difference, ΔL^*, the red-green difference, $\Delta u'$ and the yellow-blue difference, $\Delta v'$ metrics predict perception differently for different conditions. For example, for colour images widely separated, ΔL^* overestimates colour-difference perception. For small images, $\Delta v'$ overestimates colour-difference perception by a factor of 5 to 1 compared to $\Delta u'$.

3 Small images composed of colours from the blue-green region of the visible spectrum are very difficult to identify and discriminate because of small-field tritanopia. It is thus best to assign blue to large images (greater than 20) and avoid blue for small images (less than 20).

6.6 Contrast for symbol and character legibility

The luminance contrast of multicolour display images shall conform to ISO 9241-3:1992, 5.16.

NOTE – See 7.2.7 for the situations in which the methods in ISO 9241-3 apply.

6.7 Spectrally extreme colours

6.7.1 Negative polarity

For text, alphanumerics and symbols used in reading tasks that are presented in negative polarity:

— blue ($v' < 0{,}2$) on a dark background shall not be used;

NOTE – Blue ($v' < 0{,}2$) on a dark background (particularly black on CRTs) does not usually maintain the required luminance contrast specified in ISO 9241-3:1992, 5.16. In addition, if other colours are present, blue can sometimes exceed the depth-of-field of the eye.

— red ($u' > 0,4$) on a dark background should be avoided and shall not be used on a spectrally extreme blue ($v' < 0,2$) background.

6.7.2 Positive polarity

For text, alphanumerics and symbols used in reading tasks that are presented in positive polarity:

— spectrally extreme blue ($v' < 0,2$) shall not be used on a spectrally extreme red ($u' > 0,4$) background.

NOTE – Visual effects of spectrally extreme colours are more obvious at low ambient illuminance (for example, 250 lx or less).

6.7.3 Depth effects

Spectrally extreme colours that produce depth effects shall not be presented for images to be continuously viewed or read.

NOTE — The phenomenon is that two visual objects that differ in chroma (brightness and dominant wavelengths) appear to be at different distances from the viewer.

6.8 Background and surrounding image effects

To better discriminate and identify colours, systems and applications should use an achromatic background behind chromatic foreground image colours or achromatic foreground image colours on chromatic backgrounds.

NOTES

1 A dark achromatic background (such as black or dark gray) maximises visibility of the foreground colours on emissive displays.

2 Colours evaluated on an achromatic background best approximate chromatic differences predicted by the CIELUV metric.

3 Achromatic foreground colours such as white, black or dark gray preserve their intended colour appearance better than light or medium gray achromatic foreground colours on chromatic backgrounds. Medium achromatic values (such as light or medium gray) of thin images (such as normal-font alphanumeric characters and lines) typically appear as a desaturated value of the colour background; the same medium achromatic values in bold fonts and thick lines typically appear as a desaturated value of the complement of their background colour.

6.9 Number of colours

6.9.1 Simultaneous colour presentation

The number of colours simultaneously presented on a display should be based on the performance requirements of the task. In general, the number of colours simultaneously presented should be minimised. For accurate identification, the default colour set(s) should consist of no more than eleven colours for each set.

6.9.2 Visual search for colour images

When a rapid visual search based on colour discrimination is required, no more than six colours should be used.

6.9.3 Colour interpretation from memory

If the meaning of each colour of a set of colours is to be recalled from memory, no more than six colours should be used. Software applications that require the meaning of each colour of a set of more than six colours to be recalled shall make the associated meaning of each colour accessible.

7 Measurement conditions and conventions

7.1 Measurement conditions

If not otherwise specified in this part of ISO 9241, the test method definitions and requirements of ISO 9241-3 shall apply (e.g. viewing distance).

7.1.1 Equipment under test

The visual display terminal being tested shall be physically prepared for testing. The VDT shall be oriented in the compass direction in which it will be measured, and 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.

If the equipment under test has user convergence-adjustment capability, the procedure to optimize the adjustment should be followed. If the equipment under test has user focus-adjustment capability, the procedure to optimize focus should be followed because of the significant interaction between focus and convergence.

The luminance of the foreground or background (whichever is brighter) shall be equal to the display luminance setting used to establish compliance with ISO 9241-3. This setting shall exceed 35 cd/m^2 in reference white and shall not be changed during testing.

The set X_n Y_n Z_n and the corresponding u'_n v'_n define the colour of the nominally white object-colour stimulus. See 3.33.

Examples of commonly specified reference whites are given in table 3.

Table 3 – Typical reference white points

Colour temperature K	u'_n	v'_n
5600	0,204	0,478
6500	0,198	0,468
9300	0,181	0,454

The supplier shall specify the reference white to be used in the photometric and colorimetric evaluations that follow. If the system offers user-selectable reference white, a single setting shall be used throughout testing.

7.1.2 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 and colorimetric measurements shall be taken under darkroom conditions. During data recording, the illuminance on the horizontal support surface shall not exceed 5 lx.

Light required for the measurement of the luminance coefficient 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 an angle of 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(α) lux, where α is the angle formed by the intersection of the plane tangent to the centre of the display and the horizontal plane.

NOTE – The screen tilt angle, α, is the angle "A" in ISO 9241-3:1992, 6.1.2. It is illustrated in figure 7.

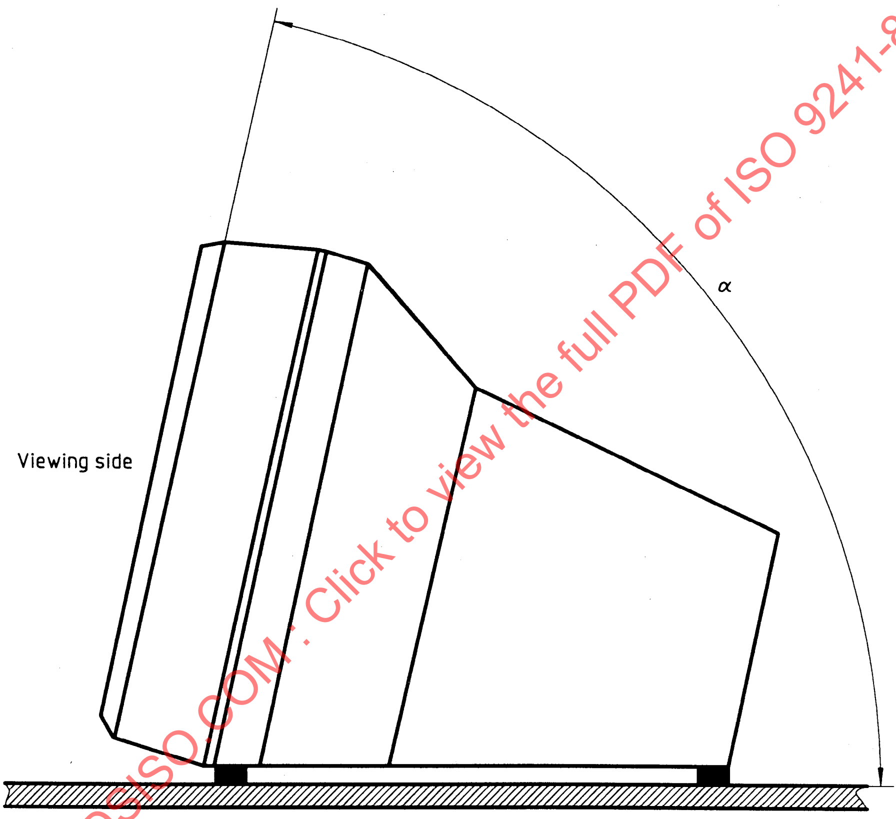


Figure 7 — Screen tilt angle

7.1.3 Measurement locations

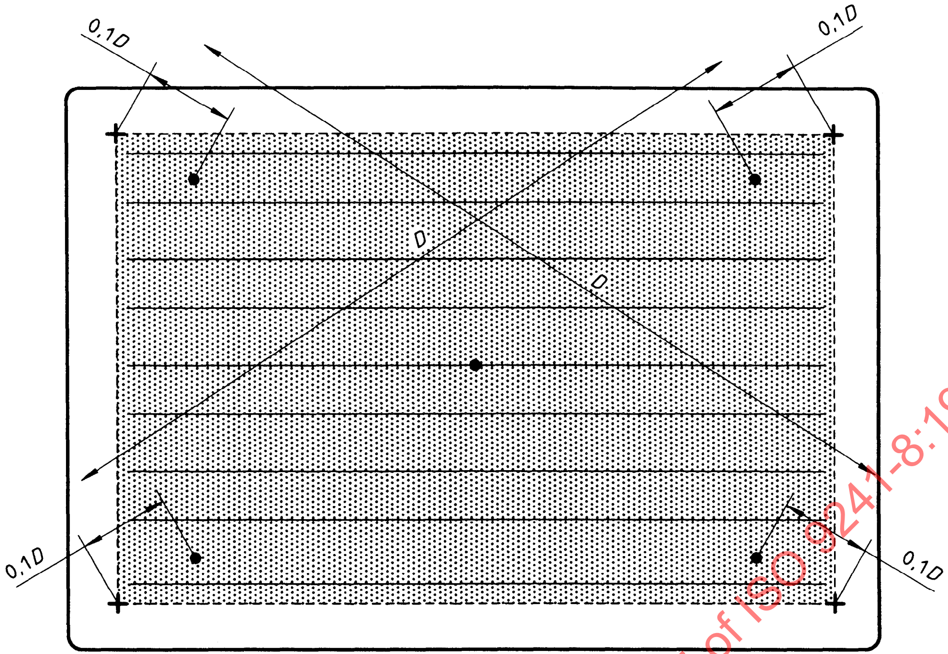


Figure 8 – Measurement locations

There are five standard measurement locations.

1 The upper left corner along the diagonal and 10% in from the edge of the display.
2 The upper right corner along the diagonal and 10% in from the edge of the display.
3 The lower left corner along the diagonal and 10% in from the edge of the display.
4 The lower right corner along the diagonal and 10% in from the edge of the display.
5 The centre of the screen.

7.1.4 Environment

The room temperature shall be between 19 °C and 27 °C. The relative humidity shall be sufficiently low that no condensation forms. Temperature and humidity shall be recorded.

7.2 Measurements and evaluations

The measuring field of the luminance meter or colorimeter should be at least 10 pixels in diameter in 7.2.1 and 7.2.6. The target measured should be about twice the diameter of the measuring field, to avoid edge effects.

7.2.1 Reflectance factor measurement

The reflection factor is needed to complete the evaluations of 6.5 and 6.6. See 3.31.
Steps:

1 Illuminate an otherwise dark display screen with a standard illuminant (for example, D_{65} or F2).

2 Record the reflected luminance and chromaticity coordinates $Y_{\text{step 2}}$, u'_R, v'_R.

3 Under the same illuminance, place a reflectance standard with known q_{STD} in approximately the same position as the centre of the screen.

4 Record the reflected luminance from the reflectance standard, $Y_{\text{step 4}}$.

5 The luminance coefficient of the screen is given by the relation:

$$q = \frac{q_{STD} Y_{STEP\,2}}{Y_{STEP\,4}} = \frac{\rho_{STD} Y_{STEP\,2}}{\pi\, Y_{STEP\,4}}$$

where $Y_{step\,2}$ and $Y_{step\,4}$ are the luminances measured in steps 2 and 4 respectively. Reflectance standards are sometimes specified in diffuse reflectance, ρ. In that case, the right-hand expression may be used. (CIE 17.4, IEC 50(845), 845-04-62 defines diffuse reflectance).

7.2.2 Default colour-set evaluation

Determine whether the application requires the user to discriminate or identify colours. If so, verify that a default set of colours has been specified and means to display each member of the set exists. If the colours can be altered by the user, verify that the default set is retrievable and restorable.

7.2.3 Colour uniformity measurement

Measure u', v' of each primary colour, each 2-primary colour mixture and reference white, at each of the five standard measurement locations under dark-room conditions. For each colour, determine the maximum value of $\Delta u'v'$ for any two of the five measurement locations. See 3.19 for the calculation.

7.2.4 Colour misconvergence measurement

7.2.4.1 Test equipment

A misconvergence instrument should be used that simultaneously determines the centres of the red, green and blue electron beams from a white test pattern.

NOTE – Test instruments that sequentially measure the position of each beam understate misconvergence due to the effect of the space charge of one beam on the position of the others. In addition, these instruments confound misconvergence with jitter, which reduces measurement accuracy.

7.2.4.2 Measurement protocol

In order to determine the amount of misconvergence, the misconvergence of each of the three pairs (that is, red-blue, red-green and blue-green) of electron beams shall be determined at the five locations specified in 7.1.3. The largest value of the three pairs shall be recorded as the misconvergence at that site. The largest value of the 15 measurements shall be reported as the misconvergence.

A test pattern (a white grid of intersecting lines) shall be displayed in the five screen locations described in 7.1.3. The test pattern should consist of a line that is three pixels wide with the outside pixels at 0,5 times the luminance of the centre pixel as illustrated in figure 9. If this pattern cannot be displayed, a single pixel-line pattern, or a character approximation using the "plus" (+) character, may be used.

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

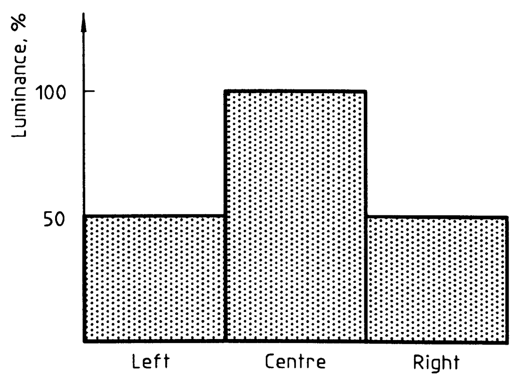


Figure 9 – Luminance ratio test pattern

The misconvergence of each colour pair (that is: red-green, blue-green and red-blue) at each of the five screen locations (see figure 10) should be measured following the instructions provided by the test instrument manufacturer. The distance (the root-mean-square of the horizontal and vertical distances) between the centre of each component beam should be determined with an accuracy of ± 0,05 mm.

The resulting data shall be compared to the requirements in table 4 for the design viewing distance.

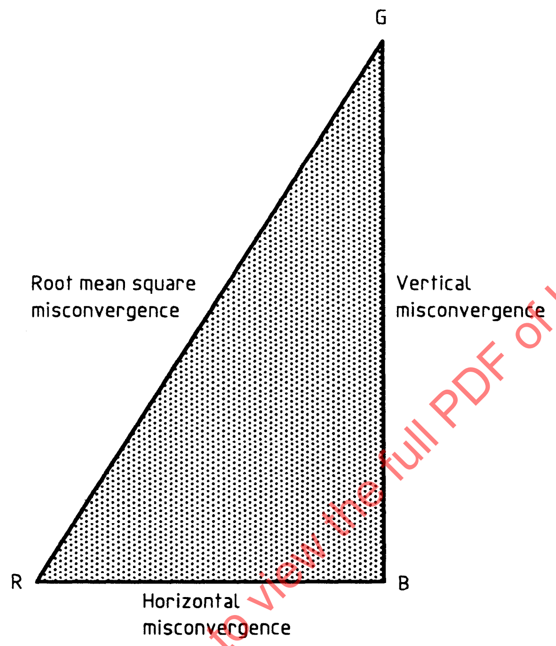


Figure 10 – Meaning of root-mean-square

Table 4 - Misconvergence requirements

Dimensions in millimetres

	Maximum misconvergence (root-mean-square)	
Design viewing distance	**Recommended**	**Required**
400	0,27	0,40
450	0,30	0,45
500	0,33	0,49
550	0,37	0,54
600	0,40	0,59
650	0,43	0,64
700	0,47	0,69
750	0,50	0,74
800	0,54	0,79

If the data show that the display is within ±10% of failing the requirement, the convergence shall be remeasured at locations at least two pixels, but not more than one character position, from the initial location that did not demonstrate compliance. Four remeasurements shall be made and resulting data shall be averaged. The resulting average shall be compared with the requirements in table 4 and the resulting success or failure reported.

NOTES

1 There are several methods that can be used to determine misconvergence, but there is no international consensus on one measurement technique. In addition, there are several engineering difficulties in obtaining this measurement.

2 One difficulty is that the pattern of the illuminated phosphor dots has no observable centre. Thus, the measurement instrument must determine the centre of the illumination of the phosphor dot.

3 Some instruments fit a curve to the sampled measurements. The curve may be a spline or a best-fitting Gaussian. The beam centre is reported as the *peak location based on the fitted curve.* Other instruments find the centroid of the beam or use optical apparatus that contains a prism. The misconverged pixel is viewed through the apparatus and adjusted until the image is perfectly converged. The misconvergence is the *amount of adjustment required to converge the beams.*

7.2.5 Character height and object size measurement

Evaluate the appropriateness of image sizes using table 5. Character size is a requirement. The other two situations are recommendations.

Table 5 – Sizes of multicolour objects.

	Minimum size		Remarks
	Subtense angle	**Viewing distance relation**	
Character strings and data fields	20'	VD/172	Application requires accurate colour identification of alphanumeric character strings and data entry fields.
Isolated images	45'	VD/76	Application requires colour identification of an isolated image (e.g. a character or a symbol).
Small images	2°	VD/29	Application uses spectrally extreme blue ($v' < 0{,}2$) images.
NOTE VD is the design viewing distance specified by the supplier. See 3.25			

7.2.6 Colour difference measurement

Measure Y, u', v' for each default colour and the luminance coefficient, q, at the centre of the screen. If the reference white is not a default colour, also measure Y_n, u'_n, v'_n. From these measurements, calculate the lightness, L^*, and chroma plane values (u^*, v^*) for all the default colours. Include the effect of reflected light. Calculate ΔE^*_{uv} for all default colours.

The set of colours to be measured shall be displayed in the centre of the screen. Each colour image to be measured shall be larger than the aperture of the colorimeter. See the worked example in annex A.

Steps:

1 In the darkroom, measure the colour coordinates Y, u', v' for each default colour. If reference white is not a default colour, it shall be measured as well.

2 Correct the coordinates for each colour resulting in Y, u', v' for each default colour (and reference white, if it is not a default colour), using the results of 7.2.1.

3 Calculate L^*, u^*, v^* for each default colour (See 3.11 for the calculation details).

4 Calculate D(D-1)/2 $\Delta E^*_{uv}s$ for all possible pairs of "D" (default) colours. See 3.12.

5 Check that no ΔE^*_{uv} is less than 20.

Coordinate correction calculation for step 2:

$Y_R = qx[250 + 250\cos(\alpha)]$, expressed in candelas per square metre

where q, u'_R and v'_R were determined as in 7.2.1. The α is the specified screen tilt angle.

$$Y_{illuminated} = Y + Y_R$$

$$u'_{illuminated} = \frac{Yu'v'_R + v'u'_R Y_R}{Yv'_R + v'Y_R}$$

$$v'_{illuminated} = \frac{(Y + Y_R)v'v'_R}{Yv'_R + v'Y_R}$$

7.2.7 Contrast for symbol and character legibility measurement

Verify that the contrast modulation exceeds 0,5 or equivalently that the contrast ratio exceeds 3 (See *3.30*). If applicable use ISO 9241-3:1992, 6.2.1.2, for this measurement.

For the method of luminance contrast measurement in ISO 9241-3:1992, 6.2.1.2 to produce correct results, one of the following conditions shall apply:

a) Both the higher and lower luminances (L_H and L_L) are approximately the same chromaticity.

b) Either the higher or the lower luminance consists of reflected light only.

7.2.8 Evaluation of use of spectrally extreme colours

Review the application for conforming use of spectrally extreme colours in accordance with 6.7.1, 6.7.2 and 6.7.3.

7.2.9 Background and surrounding image effects

Review the application for consistency with the recommendation in 6.8.

7.2.10 Evaluation of number of colours

Review the application for consistency with the recommendations in 6.9.1 and 6.9.2. If the application requires colour interpretation from memory of more than 6 colours, verify that an on-screen or off-screen reference is available.

8 Compliance

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

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

or by

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

NOTES

1 The test method will form an amendment to this part of ISO 9241 when it has been approved. Annex B contains a status report. Until the 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 features and workstation elements. Although each 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.

8.2 The compliance report shall include at least the following information:

a) supplier's 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,

c) test conditions and test results;

d) conditions of use;

e) special requirements;

f) if compliance route 8.1 b) is used (when available), full details of the criteria used for the selection of the test subjects and their relevant characteristics.

Annex A
(informative)

Colour difference calculations

A.1 CIELUV colour space

The discriminability of pairs of colours depends on differences in both chromaticity and luminance. The colour difference calculation requirements in this section are based on the CIE 1976 L*u*v* (CIELUV) colour space (see 3.10, 3.11 and 3.12). This colour space is a three-dimensional, approximately uniform space produced by plotting colour values (L^*, u^*, v^*) in rectangular coordinates. This colour space model is derived from the weighted differences between the locations of colour in the space.

In this colour space, L^* (lightness) depends on the luminance of each colour and the luminance of reference white. The chroma plane (represented by u^* and v^*) is orthogonal to the lightness (L^*) dimension. The distance from the reference white to the image colour in this plane is called the chroma of the target. When a pair of image colours differ in the u^* dimension, their difference is predominantly red-green; when they differ in the v^* dimension, their difference is predominantly yellow-blue.

CIELUV does not combine sets of tristimulus values (that is X, Y, Z) into an accurate linear model for predicting psychophysical results on a display. A CIELUV threshold value separates pairs of colours that are predicted to be different (that is, their threshold is exceeded) from pairs of colours that may be perceptually confused (that is, their threshold is not exceeded). Since CIELUV in this application is not sufficiently linear, a difference of twice the threshold is not necessarily better than a difference close to the threshold. Thus, both colour pairs are predicted to be discriminable.

The colour difference parameter which attempts to represent the perceptual difference between two colour stimuli is ΔE^*_{uv} (see 3.12). This parameter is often inadequate for analysis of computer display stimuli because the science upon which the colour difference parameter is based assumes large visual targets (see table A.1).

The experimental conditions upon which the original CIE colorimetric system was based are shown in table A.1.

Table A.1 - CIE colorimetric test conditions

Elements	Values
Size of colour difference	1 to10 units
Field size	4° or more
Nature of surround	Uniform
Luminance of surround	100 cd/m^2 to 1000 cd/m^2
Chromaticity of the surround	Equal to CIE D - 5500 K to 7500 K
Luminance of the sample	5% to 500% of surround luminance
Dividing line	Approaching zero width
Observers	Perceptibility judges without acceptability bias

In principle, the CIELUV colour space can be applied either for the 2° CIE 1931 Standard Observer or for the 10° CIE 1964 Standard Observer. The colorimetric system used in this document is applicable to centrally-viewed fields of angular subtense between about 1° and about 4° (0,017 rad and 0,07 rad). See CIE 17.4, 845-03-28, IEC 50(845). For measurement, it is important that the test object is larger (2 times is common practice) than the colorimeter aperture. Applying results to objects smaller than 1° (such as single characters, lines, or symbols) can sometimes be misleading.