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Ergonomics of human-system interaction —

Part 303: Requirements for electronic visual displays

Ergonomie de l'interaction homme-système —

Partie 303: Exigences relatives aux écrans de visualisation électroniques

Reference number
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Foreword

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

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

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

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

ISO 9241-303 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

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

— terms and definitions related to electronic visual displays have been transferred to, and collected in, ISO 9241-302;

— while the areas previously covered in ISO 9241 and by ISO 13406 remain essentially unchanged, test methods and requirements have been updated to account for advances in science and technology;

— all generic ergonomic requirements have been incorporated into ISO 9241-303;

— the application of those requirements to different display technologies, application areas and environmental conditions — including test methods and pass/fail criteria — is specified in ISO 9241-307.

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

— *Part 1: General introduction*

— *Part 2: Guidance on task requirements*

— *Part 4: Keyboard requirements*

— *Part 5: Workstation layout and postural requirements*

— *Part 6: Guidance on the work environment*

— *Part 9: Requirements for non-keyboard input devices*

— *Part 11: Guidance on usability*

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

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

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

For the other parts under preparation, see Annex A.

Introduction

This part of ISO 9241 addresses a large range of technologies, tasks and environments.

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

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

Ergonomics of human-system interaction —

Part 303: Requirements for electronic visual displays

1 Scope

This part of ISO 9241 establishes image-quality requirements, as well as providing guidelines, for electronic visual displays. These are given in the form of generic — independent of technology, task and environment — performance specifications and recommendations that will ensure effective and comfortable viewing conditions for users with normal or adjusted-to-normal eyesight.

This part of ISO 9241 does not address issues of accessibility for people with disabilities. However, it does take into account aspects of the eyesight of older people and could be of value to people dealing with issues of visual impairment in certain cases: the specification of essential characteristics for normal viewing can be used to gauge the severity of different visual abnormalities so that appropriate solutions can be identified.

NOTE In addition to the Bibliography, Annex F gives a selected bibliography of documents addressing the needs of people with disabilities, including people with poor, deteriorating or no eyesight.

2 Normative references

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

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

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

3 Terms and definitions

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

4 Guiding principles

For a satisfying human–display interaction, a number of different requirements have to be met at the same time in an appropriate balance. For the purposes of this part of ISO 9241, these requirements have been grouped into the following eight major areas:

- viewing conditions;
- luminance;
- special physical environments;
- visual artefacts;
- legibility and readability;
- legibility of information coding;
- legibility of graphics;
- fidelity.

NOTE For the attractivity of the image on the visual display, see Annex B.

5 Ergonomic requirements and recommendations

5.1 Viewing conditions

5.1.1 General

Many tasks require that the information presented on an electronic visual display be acted upon. Viewing the display such that this information can be taken up quickly, without error and with little effort, is thus highly important. A number of viewing conditions that are necessary, though not sufficient of themselves, can be specified for achieving fast, error-free and near-effortless viewing. These pertain to the design viewing distance and direction and to the needed gaze and head tilt angles of the viewer.

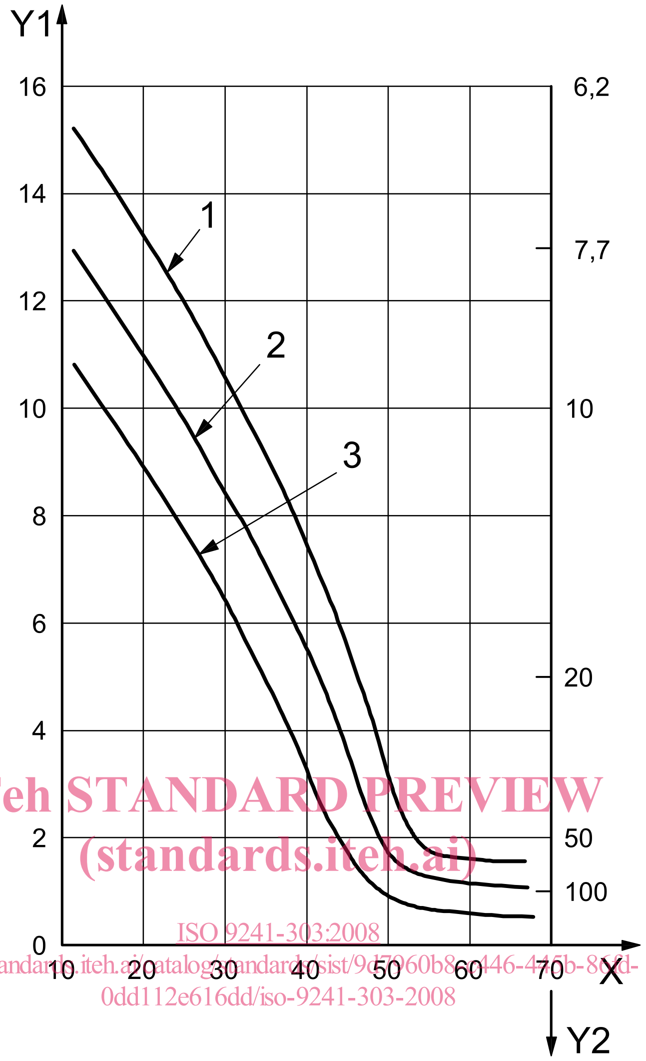
It is known that viewing distance and line-of-sight angle (gaze angle) need to be compatible with the user's vergence and accommodation capability and his or her capability to focus on short distances.

5.1.2 Design viewing distance

The design viewing distance is dependent on the task and on the electronic visual display and shall not be less than 300 mm, being the typical minimum comfortable viewing distance, or *near point*, for normal (emmetropic) eyes of adults. There is a physiologically determined relationship between the near point and the age of the user, shown in Figure 1, and between the near point and the luminance level; however, there is a large variance in this relation.

Shorter viewing distances, of between 200 mm and 300 mm, can be observed in children and (very) young adults, enabling them to see details (e.g. parts of characters) smaller than those that they could see at greater distances, provided that aspects such as display luminance, contrast and the sharpness are high enough. However, most adults as well as older people position their displays at a larger viewing distance, typically 300 mm and more.

For larger visual displays, such as those used in office tasks, the preferred viewing distance is longer — typically 400 mm to 750 mm. At this distance, the accommodative strain to the eyes is less than at shorter viewing distances; moreover, there is larger freedom of movement at larger viewing distances. For presentation tasks or projection, the preferred viewing distance is still larger (typically 2 m to 10 m).



Key

X age, in years

Y1 accommodation span, dioptres

Y2 near point of accommodation, centimetres

1 maximum

2 mean

3 minimum

Figure 1 — Accommodation span and near point in relation to age of user

5.1.3 Design viewing direction

For normal use in which the user moves his or her head, a display shall be legible from any angle of inclination up to at least 40° from the normal to the surface of the display, measured in any plane.

Depending on the task, other limit values are possible. For example, for tasks requiring privacy, such as display use in crowded environments, the display should be only legible to a maximum angle of inclination between 15° and 20°.

EXAMPLE People in wheelchairs wishing to withdraw cash from an automatic teller machine in privacy are obliged to read the ATM display from a fairly low viewpoint. Their requirements can be met by a display that is only legible to a maximum angle of inclination between 15° and 20° in the horizontal plane, but downwards to a larger angle, of at least 40°, in the vertical plane.

NOTE Some display technologies exhibit anisotropic optical properties, which means that the luminance, contrast and colour vary with viewing direction.

5.1.4 Gaze and head tilt angles

For a typical working environment with an approximately vertical position of the upper body, the work place and the visual display should permit the user to view the screen with a gaze angle from 0° to 40° and a head-tilt angle of from 0° to 25°.

NOTE These angle values can require the tilt of the display to be adjustable, so that perpendicular view can be obtained. In addition, the height (above floor level) of the display might have to be adjustable.

5.1.5 Displays for virtual images

The ergonomics of displays for virtual images are considered in Annex E, covering the ergonomics characteristics of binocular non-see-through displays and gives recommended values.

5.2 Luminance

5.2.1 General

In order for information symbols on a visual display screen to be visible, sufficient contrast with their background is necessary. Both symbols and screen background therefore need to be of a certain, different luminance and/or colour.

In most cases, there is a luminous environment to the screen that contributes to its luminance and colour; therefore, the contrast on the screen is changed by the luminous environment (for reflective displays such as paper, contrast on the display screen is even caused by the luminous environment). Since the environment's luminosity generally cannot be controlled by the user, it is necessary to provide means of adjusting display luminance to obtain a proper luminance balance over a range of work environments.

5.2.2 Illuminance

The supplier shall specify the design screen illuminance, E_S.

NOTE If the application uses colours, their chromaticity coordinates, u',v', may change as a result of the colour of the design screen illumination.

5.2.3 Display luminance

In the ambient illumination for which the display is designed, the display luminance shall exceed the minimum value for obtaining a sufficient recognizability of the displayed information over the design viewing range and the intended lifetime of the visual display unit. Under night-time conditions, it should not be so high as to annihilate dark adaptation of the user's eyes.

Annex D presents a treatise on basic concepts of contrast and luminance in visual perception. Equation (D.11) defines the minimum value of bright parts of a display taking into account the luminances of the dark parts and of diffuse and specular reflections on the display surface.

EXAMPLE For an office application having 500 lx illuminance (horizontally) of white paper with a reflectance of 80 % and positive display polarity, it is often recommended that the display luminance be in the range of 100 cd/m^2 to 150 cd/m^2.

5.2.4 Luminance balance and glare

The area average luminance of task areas that are frequently viewed in sequence while using the display (paper document, screen, etc.) should be between 0,1L and 10L, where L is the average luminance of the whole screen in the application used on the display in the design viewing direction. For a stationary visual field, a higher ratio of space average luminances between the task area and its surrounds (for instance, room walls), up to 1:10, has no adverse effect.

The design of the visual display screen and surrounding area of the product housing shall not contribute to disturbing glare by the environmental lighting. This holds especially for prolonged viewing in work environments.

NOTE 1 Glare is defined by CIE (845-02-52; glare) as: “condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or too extreme contrasts” (Reference [22]). Disturbing glare thus is a condition of vision in which there is a disturbing degree of visual discomfort or/and a noticeable reduction in the ability to see details or objects.

NOTE 2 Matt surfaces typically do not produce glare, whereas gloss surfaces can, depending on design aspects such as shape, colour, size and environmental lighting conditions. There are, however, cases where gloss is advantageous. For printed paper and some mobile displays, such as reflective colour displays, gloss is necessary for obtaining high colour fidelity, whereas the occurrence of disturbing glare can be avoided by changing the orientation of the paper or mobile display with respect to the environmental light source.

NOTE 3 For prolonged viewing in work environments, the aim is to harmonize the visual display screen and surrounding area of the product housing with their environment and its lighting according to ISO/IEC 8995-1 and ISO 9241-6.

5.2.5 Luminance adjustment

For emissive displays, the luminance of the background and/or the contrast between the characters and their background shall be easily adjustable by the user. The emissive display shall be easily adjustable to ambient conditions over the range of luminances that can occur in the particular work environment.

5.3 Special physical environments

5.3.1 General

The following guidelines should be taken into consideration in the design of a display wherever it is expected that the display will be subjected to one or more of the environmental conditions described in 5.3.2 to 5.3.4.

5.3.2 Vibration

Vibration of the display with respect to the head and therefore the eyes (or *vice versa*) is an annoying effect that can even reduce visual performance, because

- vibration hampers eye movement control during reading by making it more difficult to determine the target of saccades, and causing image movement during a fixation pause, in which the centre of the visual field needs to be recognized,
- the contrast of small details is reduced because the zones along a border will have the average luminance of both sides of the border, and
- the rapid alternation of light and dark in an area of the visual field can create flicker effects.

The severity of these effects depends on the frequency and amplitude of the vibration. Frequencies above 0,5 Hz of the display are disturbing when their amplitude is more than a threshold value. Also, frequencies of the head above 6 Hz are disturbing when the amplitude is more than a threshold value. Such frequencies and amplitudes should therefore be avoided — for example, by embedding the display in appropriate damping material.

5.3.3 Wind and rain

Strong winds can cause vibrations of objects such as visual displays that are sufficiently exposed.

Rain drops falling on a display screen will distort the displayed image, to the point where text becomes illegible.

Visual displays that may be used outdoors should therefore be mechanically shielded from such weather effects.

5.3.4 Excessive temperatures

When operation of display devices is required in environments where temperatures are approaching 0 °C or + 40 °C, users should take equipment and personal precautions to ensure that they are able to complete their tasks satisfactorily and safely. Excessive temperatures will adversely affect the performance of most display devices, as well as the associated electronic circuitry and therefore affect user performance on the task. Consult the manufacturer's product specifications to find out the recommended operating range of temperatures for the device. If the environmental conditions are close to or beyond the recommended limits, the display device and the associated electronic circuitry may have to be heated or cooled to a temperature level within the manufacturer's specified range in order to ensure proper operation of the device(s).

5.4 Visual artefacts

5.4.1 General

Ideally, an electronic visual display will show only intended, high-quality information, in the form of text, graphics or images. However, display technology is usually not ideal, and reflected images of the outside world as well as unintended images due to visual perception phenomena cause *visual artefacts*, i.e. information competing with the intended information for the viewer's attention.

5.4.2 Luminance non-uniformity

For an intended uniform display luminance, the luminance non-uniformity, either step-wise or smooth, in ambient illumination shall not exceed the threshold for reduced visual performance, with a maximum of 1,7:1.

5.4.3 Colour non-uniformity

Any non-uniformity of the colour shall not create competing information content when evaluated at three locations on the screen. The maximum chromaticity difference shall be in accordance with Table 1.

Table 1 — Maximum chromaticity difference

$\frac{D_{active}}{D_{design\ view}}$	**Chromaticity difference** $\Delta(u',v')$	
	Applications using colour per default colour set	**Any primary colour** [a]
< 0,75	0,02	0,02
⩾ 0,75	0,03	0,03

D_{active} diagonal of active area of screen

$D_{design\ view}$ design viewing distance

[a] The primary colours are the unmixed colours, usually red, green and blue.

Colour uniformity refers to how well the colour remains constant over the surface of the screen. Conversely, non-uniformity of colour characterizes the manner in which the colour changes over the surface of the screen. The non-uniformity of colours is best specified by the maximum colour difference (using some colour difference metric) between any two points on the screen. Several colour different metrics and coordinates are in use today, including CIELAB, CIELUV and CIE 1931 (x, y).

For the purposes of this part of ISO 9241, the metric, u',v' colour difference, is used.

5.4.4 Contrast uniformity

Contrast uniformity can be important if proper recognition or presentation of information depends critically on proper scene or pattern rendering. It is expressed as a percentage: contrast uniformity = 100 %(C_{min}/C_{max}), where C_{min} and C_{max} are the minimum and maximum contrast, respectively, of the sampled contrast set on the screen (see ISO 9241-305). The contrast uniformity should be as high as possible and, in general, be commensurate to the user's task.

NOTE There are three different forms of contrast non-uniformity:

— variation in area average luminance contrast from the centre of a display to the edge of any portion thereof;

— variation of the peak contrast of character elements (dots or strokes) at different locations of the screen;

— variation of the peak contrast of character elements (dots or strokes) within a character.

The threshold for visual detection of contrast non-uniformity is higher than the threshold for measurable difference in task performance. Both thresholds are dependent on the following factors:

— target size;

— contrast sensitivity of the user;

— task;

— luminance of the target, background and surrounds.

There are other ways of expressing contrast uniformity that may be found to be useful, for example, the ratio of the "intended contrast", such as that between text characters and their background, to the contrast that is due to the contrast non-uniformity.

One way to ascertain the impact of contrast non-uniformity is to use a user performance test method (see ISO 9241-304). Test persons representing a sample from the intended user population most likely to suffer performance reduction should be used. In the test, the contrast uniformity shall be intentionally varied over the screen.

5.4.5 Geometric distortions

For different rows or columns of text, the difference of length shall not exceed 1 % of the length of that column or row.

The horizontal displacement of a symbol position relative to the symbol positions directly above and below 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.

5.4.6 Screen and faceplate defects

The electronic display should be free of screen and faceplate defects.

Regularly addressed displays should be free of pixel faults[1]. If not, the supplier shall specify the number of defective pixels and/or subpixels.

Depending on the task of the user, screen and faceplate defects or pixel faults can be disturbing, resulting in reduced performance in reading speed and reading errors or to reduced appreciation of an image and visual discomfort. Or they can present wrong information in images and their information content, leading to misinterpretation of the displayed content. Aesthetic and attractivity aspects can affect the user's acceptance regarding the displayed content in case of faults as well.

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1) As defined in ISO 9241-302, "pixel fault" includes both defective pixels and *subpixels*.

Therefore, screen and faceplate defects or pixel faults have to be examined from the point of view of their relevance to

a) ergonomics performance, and

b) acceptance by the users, given their tasks.

If a regularly addressed display meets the ergonomics performance criteria for pixel faults, these faults will not reduce reading speed, increase number of reading errors or cause visual discomfort symptoms such as red, sore, itchy or watering eyes, headaches or aches and pains associated with poor posture.

If an electronic display meets the acceptance criteria for pixel faults in a specified fault class, these pixel faults will probably not cause misinterpretations or insufficient acceptance by the users, related to the intended tasks.

NOTE If an electronic display has pixel faults, their number is not the only important factor, but rather, this number in relation to the size of both pixels and display. Also of importance is the material being displayed, task of the user, position on the display screen of the defective pixel and/or subpixel, etc. The exact ergonomic performance requirement level is not defined in this part of ISO 9241. Therefore, a display in any of the fault classes (0, I, II, III, IV) can meet the ergonomics performance and visual discomfort requirement level, depending on the context of use. Research is continuing to elucidate these issues and will be taken into account in future amendments of this part of ISO 9241.

5.4.7 Temporal instability (flicker)

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

Flicker is the perception of unintended temporal variations in luminance on the display, in a frequency range of a few hertz up to the critical flicker frequency. These unintended temporal variations can affect the comfort and performance of the user. The critical flicker frequency (CFF) is an upper frequency above which flicker is no longer perceived by the user. The perception of flicker increases with increasing luminance and increasing screen size.

NOTE 1 The eye is more sensitive to flicker in the lateral visual field than in the central visual field.

NOTE 2 The critical frequency decreases with age (*between individuals* factor) and with fatigue (*within individuals* factor) and with duration of exposure.

5.4.8 Spatial instability (jitter)

The image shall be free of jitter in the intended display environment.

This can be accomplished by ensuring that the peak-to-peak variation in the geometric location of image elements does not exceed 0,000 1 mm per millimetre of design viewing distance for the frequency range of 0,5 Hz to 30 Hz.

5.4.9 Moiré effects

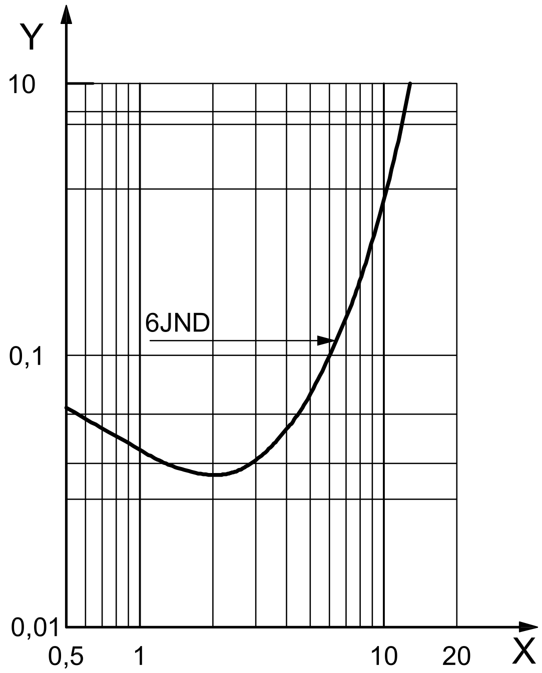
Moiré is a regular image superimposed on the intended image. Because the image is a structured pattern, it is often detected easily by users.

Moiré patterns are natural interference phenomena. They can appear as ripples, waves and intensity variations that are superimposed on the screen image.

For colour displays, moiré patterns, which resemble a periodic noise field overlying the screen image area, should not have more than 6 JND (just noticeable differences) (see ISO 9241-302) of modulation at their fundamental spatial frequency.

Moiré patterns with spatial frequency and modulation falling above the curve in Figure 2 are predicted to exceed 6 JND and therefore be clearly visible.

To minimize (decrease) the detection of moiré patterns by users, the fundamental spatial frequency and modulation of a colour display should be below the curve shown in Figure 2.



Key

X spatial frequency, cycles per degree

Y contrast

JND just noticeable difference

Figure 2 — Thresholds for visibility of moiré patterns

[From HFES 100 [1] (reprinted with permission)]

5.4.10 Other instabilities

Electronic visual displays can exhibit unintended spatial and temporal luminance variations such as “swim” or “crosstalk”. In addition to the requirements specified in 5.4.6, 5.4.7 and 5.4.8, those for proper ergonomics design criteria should be used to minimize other unintended spatial or temporal artefacts that exceed the threshold for visual detection.

It is important to first analyse the context of use to verify whether or not the threshold for detection is exceeded. There are many artefacts that are visible through, for example, a magnifying glass, but not at the actual viewing distance.

EXAMPLE Technically speaking, a display can exhibit jitter that is spatially so small that it cannot be detected with the naked eye at normal viewing distance. From an ergonomics point of view, the display is jitter-free when used at that viewing distance. This jitter, however, will still have an effect on contrast of thin lines. So the conclusion will be that the display has, from an ergonomics point of view, reduced contrast in thin lines, technically caused by jitter. It will depend on the degree of contrast reduction whether or not corrective action, i.e. reduce or eliminate the jitter, is necessary.

5.4.11 Unwanted reflections

Disturbing and/or unwanted reflections that reduce contrast shall be avoided. If necessary, the screen shall have antiglare and/or antireflection treatment. Unavoidable reflections shall be as small as possible.

Specular reflections of ambient light sources (luminaires, lamps, windows, etc.) on a display screen are unwanted reflections. They reduce the contrast and thus the legibility of displayed information. Often, they are the cause of glare, leading to discomfort or inability to recognize the information for the user. Depending on the kind of visual display terminal, reflections can be one of the following types or combinations thereof:

a) Lambertian (reflected luminance constant for all directions) — paper for photocopiers is a good example of a Lambertian reflector;

