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Ergonomics of human-system interaction —

Part 306: Field assessment methods for electronic visual displays

Ergonomie de l'interaction homme-système —

Partie 306: Méthodes d'appréciation sur le terrain des écrans de visualisation électroniques

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Foreword

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

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

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

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

ISO 9241-306 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

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

— *Part 1: General introduction*

— *Part 2: Guidance on task requirements*

— *Part 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 is one of a group of standards in the ISO 9241 series that establish requirements for the ergonomic design of electronic visual displays. At the same time, this “300” subseries replaces either partially or fully certain previously published parts of ISO 9241 as well as several other International Standards (see the Forewords of the respective parts for the details).

— An introduction to the subseries is given by ISO 9241-300.

— 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 — are specified in ISO 9241-307.

— Methods for performing formal display measurements to determine display characteristics and verify technical specifications (tests that can be very costly and time-consuming and that are normally performed under rigorous test conditions with a new device) are given in ISO 9241-305 and ISO 9241-307.

— In addition, guidance on the design of SED (surface-conduction electron-emitter displays) and OLED (organic light-emitting diode) displays is given in ISO/TR 9241-308 and ISO/TR 9241-309.

The overall modular structure of the subseries will facilitate its revision and amendment, as ongoing technological development enables new forms of display interaction.

This part of ISO 9241 is concerned with ergonomic workplace assessment and is aimed at providing a means of assessing whether or not the visual ergonomic requirements specified in ISO 9241-303 are satisfied within a specified task setting. The intention is not necessarily to produce a perfect display with optimum visual characteristics, but rather to ensure that the needed qualities to perform the visual task satisfactorily are indeed present.

During the lifetime of a display, the context in which it is used can often vary; “ageing” normally takes place as the display is used and, as a result, the performance of the display may be reduced over time. The lighting conditions under which a display is used often also vary.

In actual VDT workstation use, the main ergonomic concerns are the visual task being performed and the input devices being used to accomplish the task.

There are several factors that make the performance of a visual task using a VDT different from that in many other non-VDT or paper tasks. These factors are related to the positioning of the various elements needed for performing the visual task.

The ergonomic goal is to be able to read the information on the display comfortably, easily, accurately and quickly (where necessary) — as when a paper “hardcopy” placed on the work desk is read.

One consideration is what might be called the *positional sensitivity* of the screen. If positioned poorly, displays are susceptible to external light sources: these can be reflected back to the viewer and can contribute to reduced legibility of the information on the screen. In more compelling environments, these light sources can give rise to glare. They can come from either natural light from windows or from artificial lighting systems such as overhead mounted luminaries in offices.

Given the size and dimensions of most displays, a display is typically oriented in a vertical rather than horizontal position. This orientation and position of the information to be read is considerably different than that when a book or paper placed on the desk is read. The line of sight from the eye to the visual task is raised up to 45°, giving rise to a quite different visual background, often with a varying luminous background arising from walls and other objects in the environment. These factors can affect the working posture of a user trying to compensate between the line of sight angle to the display needed to be maintained and the distance to the visual task.

These and other considerations demonstrate that the positioning of a display is much more important than the mere positioning of paper or other hardcopy reading materials. They gives rise to the need to be able to adjust the display for orientation and height and to have the flexibility to set up the workstation equipment so that the needs of a specific user can be realized. The combination of display, lighting environment and workstation equipment are the basics for an ergonomically well-designed workplace.

Unlike most visual task materials, displays are intended to be used for several years. Many other kinds of work materials are used only once or a few times, or are renewed or refreshed when visibility is too low or possibly too uncertain (e.g. safety instructions or warnings), or else simply remain unchanged over time.

The display assessment methods presented in this part of ISO 9241 do not, in most cases, require expensive measuring equipment and will in general be able to be carried out easily in a working field environment. In conducting these assessments, it ought to be possible to determine whether a problem is related to

a) the display itself (or the display in combination with the graphic adapter),

b) the application software, or

c) physical environmental conditions.

In cases involving a), the display, it is beneficial that the workstation set-up be reviewed to determine whether it meets the supplier’s recommendations; if it does not, another assessment will need to be performed to determine how it can be made to meet them. In cases involving b), the application software, it might be necessary to contact the software developers of the application product in order to ascertain possible corrective action. In cases involving c), conditions in the physical environment, simple re-orientations or the repositioning of the workstation and/or display can be a satisfactory solution; whereas, in more complex situations, arrangements might need to be made with the relevant interested parties in order to ascertain appropriate actions and their feasibility. For details, see Annex B.

ISO 9241 was originally developed as a 17-part International Standard on the ergonomics requirements for office work with visual display terminals. As part of the standards review process, a major restructuring of ISO 9241 was agreed to broaden its scope, to incorporate other relevant standards and to make it more usable. The general title of the revised ISO 9241, *Ergonomics of human-system interaction*, reflects these changes and aligns the standard with the overall title and scope of Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*. The revised multipart standard is structured as a 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 306:
Field assessment methods for electronic visual displays

1 Scope

This part of ISO 9241 establishes optical, geometrical and visual inspection methods for the assessment of a display in various contexts of use according to ISO 9241-303.

2 Normative references

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

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

ISO 9241-303:2008, *Ergonomics of human-system interaction — Part 303: Requirements for electronic visual displays*

ISO 9241-305, *Ergonomics of human-system interaction — Part 305: Optical laboratory test methods for electronic visual displays*

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

3 Terms and definitions

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

4 Preparation for assessment

4.1 Cathode ray tube (CRT) displays

4.1.1 Display warm-up

Allow sufficient time (at least 20 min) for the display luminance to stabilize.

4.1.2 Degaussing

If a monitor has a built-in degaussing device, activate it.

4.1.3 Cleaning

Ensure that the front glass of the display is clean; otherwise, clean it according to the manufacturer's instructions.

4.1.4 Contrast and brightness control settings

Adapt display contrast and brightness using contrast and brightness screen controllers according to the environmental lighting conditions, as follows:

— use a pattern that contains areas of different grey scale values from white to black;

— set both contrast and brightness to maximum (100 %);

— in a dark environment, reduce brightness until the darkest pattern area is displayed completely black — the difference between the darkest and the next lighter area should be distinguishable;

— set the contrast so that the brightness of the white area is at the maximum while the difference between the white and the next darker area is distinguishable;

— in a non-dark environment, set the brightness to a value where all grey levels are distinguishable.

4.1.5 Image size

Use factory or default setting if available. Otherwise, adjust to a specified size.

4.2 Liquid crystal displays (LCD)

The flat panel display shall be physically prepared for assessment.

4.2.1 Display warm-up

Allow sufficient time (at least 20 min) for the display luminance to stabilize. When indicated by the manufacturer, it shall be warmed up for the specified time.

4.2.2 Cleaning

Ensure that the display is clean; otherwise, clean it according to the manufacturer's instructions.

4.2.3 Contrast and brightness control settings

Adapt display brightness and contrast (if controllers are available) according to the environmental lighting conditions, as follows:

— use a pattern that contains areas of different grey scale values from white to black;

— set both contrast and brightness to maximum (100 %);

— set contrast to a value where all grey levels are distinguishable;

— display the content of a typical application and set brightness to a level appropriate to the lighting conditions.

4.2.4 Resolution

Use the factory-recommended (*physical*) resolution. Changing this native resolution to another can cause a degradation of the display image quality and character presentation, due to imperfect pixel interpolation (see Figure 1).

physical reduced

Figure 1 — Comparison of letters displayed with physical and reduced resolutions

5 Assessment methods

5.1 Viewing conditions

5.1.1 Design viewing distance

The optimum distance between the visual display and the user's eyes depends on various factors, and in particular character legibility (see Table 1) and the possibility of viewing a full application without head movement (see Table 2). The design viewing distance, i.e. the distance specified by the manufacturer of the display is set to $\geqslant$ 300 mm (see ISO 9241-303). The optimum viewing distance for office work in a seated position is 600 mm. However, individual users tend to prefer settings between 400 mm and 750 mm. Viewing distances in this range for most people require character heights that subtend between 20′ to 22′ of arc (see ISO 9241-303).

Check whether the display is used within the specified viewing distance, D. Measure the distance from the user's eyes to the centre of the screen with a ruler. For office work, the normal range is 400 mm to 750 mm: if the chosen distance is outside of this range, verify that there is not an underlying problem, such as bad image quality, incorrect font size or an uncorrected vision problem.

If the visual task requires that the entire application, i.e. its page or line width, is viewed at a glance, i.e. without head movements, the *minimum* viewing distances from Table 2 are recommended. They result from the maximum horizontal viewing angle of ± 15° with respect to the normal on the screen surface, which allows such viewing at a glance and depends on screen size. Figure 2 shows the relation between viewing angle, application width and viewing distance.

Table 1 — Maximum and optimum viewing distances for character legibility

Character height mm	**Maximum viewing distance for some users** cm	**Viewing distance of generally accepted legibility** cm
1,2	41	20
2	69	33
3	103	49
4	138	65
4,6	158	75

NOTE 1 The maximum viewing distance is based on character height of 10′ of arc and is usable only by a small number of users. Generally accepted legibility, i.e. one that is well accepted by most users, is calculated based on 21′ of arc. The optimum character height for task performance is a compromise between the legibility goal and the goal of “surveying at a glance” — presenting all information related to the same context on the same screen.

NOTE 2 The simplified rule of thumb for character legibility is: for optimum legibility, viewing distance ≈ 165 × character height:

— acceptable range ≈ ± 30 % for most users;

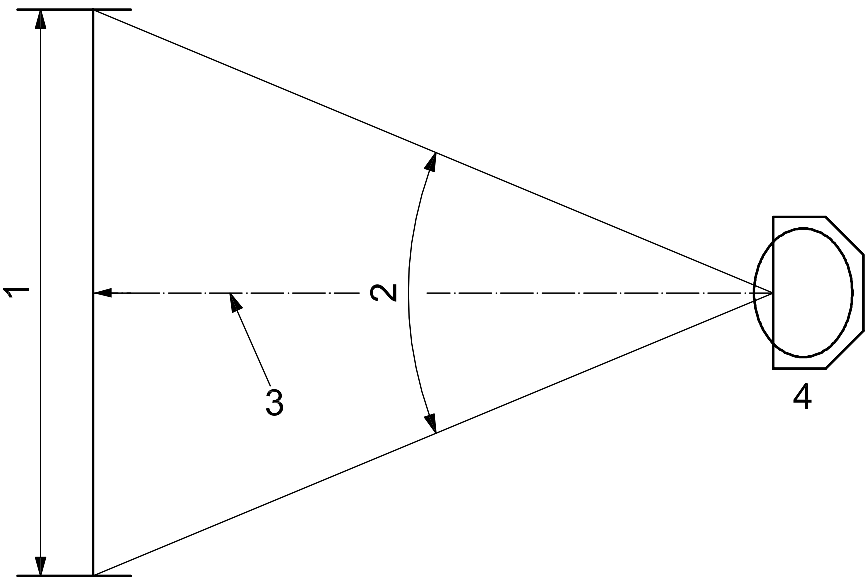
— acceptable range ≈ ± 100 % for some users.

Table 2 — The smallest viewing distance at which the full application width can be used without need for head movement

Width of the application (or page or line) mm	**Minimum viewing distance in order to avoid head movement** cm
215	40
250	47
300	56
350	65
400	75

NOTE 1 The relationship is based on the ± 15° requirement illustrated by Figure 2.

NOTE 2 In the field, it can be convenient to use the following approximation as a rule of thumb: viewing distance ⩾ 1,9 × application width.



Key

1 screen width
2 viewing angle (± 15°)
3 viewing distance
4 viewing location

Figure 2 — Viewing distance and viewing angle

5.1.2 Design viewing direction

If the display is a flat panel, check that it is used for the specified viewing direction class according to ISO 9241-303 and ISO 9241-307.

5.1.3 Gaze and head tilt angles

Verify that the work station and the visual display allow the user to view the screen with a gaze angle from 0° to 45° and a head tilt angle from 0° to 20°, using a device for measuring angles such as protractor or goniometer.

5.1.4 Virtual images

See ISO 9241-303:2008, Annex E.

5.2 Luminance

5.2.1 Illuminance

Measure the screen illuminance using a lux meter. Place the lux meter's sensor directly in the centre of the screen at the same tilt angle as applied by the user. Check that no shadows are falling onto the sensor.

Verify that the measured illuminance corresponds to the value specified by the supplier.

5.2.2 Display luminance

Measure the area luminance with a luminance meter: first, for white pattern on black background and, second, for black pattern on white background. Place the meter perpendicular to the display surface on the target. The target area shall be at least 100 % larger than the measurement area of the luminance meter.

For CRT, the luminance meter should be placed at measurement locations as shown in Figure 3. The pattern is the following:

— at the centre;

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

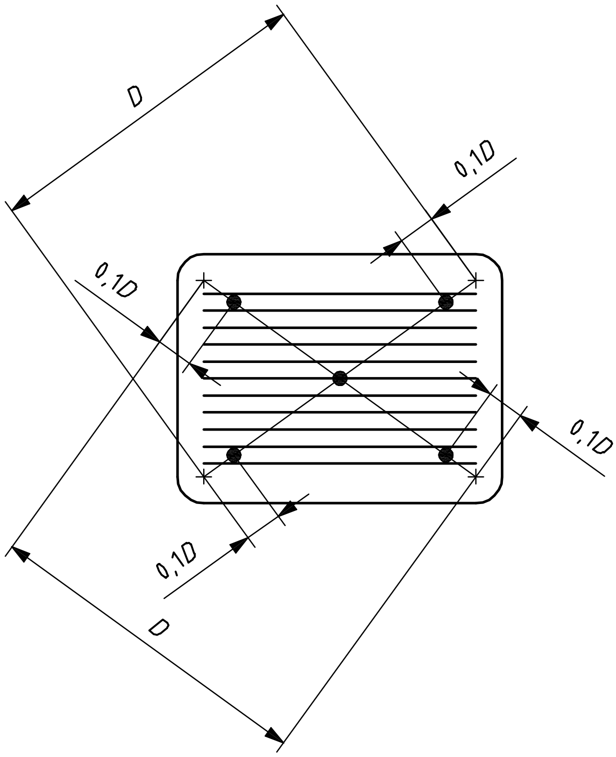
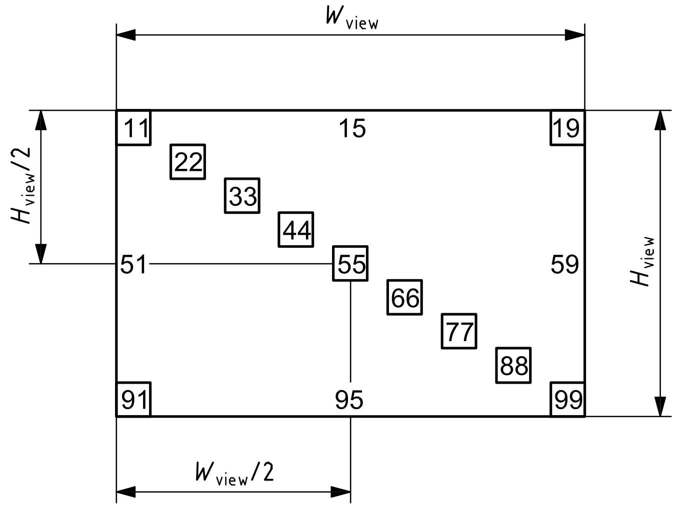


Figure 3 — Measurement locations — CRT

Verify that the measured luminance values are in accordance with ISO 9241-307.

For LCD, the measurement locations should be as shown in Figure 4. Determine the lowest and highest luminance.

Verify that the measured luminance values are in accordance with ISO 9241-307.



Key

H_{view} visible display height

W_{view} visible display width

Figure 4 — Measurement locations — LCD

5.2.3 Luminance balance and glare

Measure the luminance of the display (e.g. full screen white), of a frequently viewed task area (e.g. a document on the desk) and of a selected surround (e.g. a room wall). Calculate the luminance ratio between the screen and the frequently viewed area. Perform the same calculation for the luminance ratio between the screen and selected surround. Verify that the ratios are in accordance with the value range specified in ISO 9241-303.

A possible method of controlling the avoidance of glare is to check whether the surface of the housing is matte or glossy. Glossy surfaces may produce glare; the gloss value can be measured with a gloss meter or gloss reference samples.

5.2.4 Luminance adjustment

Verify that the luminance of the display and the contrast between characters and character background on the display are adjustable by the user to the ambient environmental conditions of the workplace.

5.3 Special physical environments

5.3.1 Vibration

See ISO 9241-303:2008, 5.3.2.

5.3.2 Wind and rain

See ISO 9241-303:2008, 5.3.3.

5.3.3 Excessive temperatures

See ISO 9241-303:2008, 5.3.4.

5.4 Visual artefacts

5.4.1 Luminance non-uniformity

Estimate the luminance non-uniformity by sequentially viewing different areas on the screen to determine the degree of non-uniformity. If it is determined that a noticeable amount of luminance non-uniformity is present, then the measurement of luminance with a luminance meter is recommended.

The measurement locations are the positions on the screen with the lowest and highest luminance (see 5.2.2). Determine the luminance non-uniform ratio using Equation (1):

$$\text{non-uniformity} = 100\ \% \left(\frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{max}}} \right) \quad (1)$$

Verify that the luminance uniformity value is according to ISO 9241-307.

5.4.2 Colour non-uniformity

Display the full screen with only one colour and estimate the colour non-uniformity by sequentially viewing different areas on the screen. Repeat with different colours.

The subjective impression of colour is not only determined by the colour itself (chromaticity) but also by the luminance. For applications requiring exact colour distinction, use a colorimeter or a spectrophotometer. For further details, see ISO 9241-305.

5.4.3 Contrast non-uniformity

Calculate the contrast non-uniformity from the values measured in 5.2.2 using Equation (2):

$$\text{non-uniformity} = 100\ \% \left(\frac{C_{\text{max}} - C_{\text{min}}}{C_{\text{max}}} \right) \quad (2)$$

5.4.4 Geometric distortions

Disturbing changes of character form or character location due to image stability or geometry faults should not occur. Such geometrical faults can be ascertained, for example, by placing a rectangular sheet of paper on the horizontal or vertical lines in the intended area of the display.

Most of these faults can be corrected using the screen display controls.

5.4.5 Pixel faults

5.4.5.1 Pixel/subpixel stuck on

These pixels/subpixels will always appear as bright on a black background. Use a black screen to observe.

5.4.5.2 Pixel/subpixel stuck dim

These pixels/subpixels can appear as grey, independent of white or black background. To observe, first use a white and then a black screen.

5.4.5.3 Pixel/subpixel stuck off

These pixels/subpixels always appear as dark on a white screen. Use a white screen to observe.

NOTE For a complete analysis, refer to Reference [7]. To determine the pixel fault class, see ISO 9241-307.

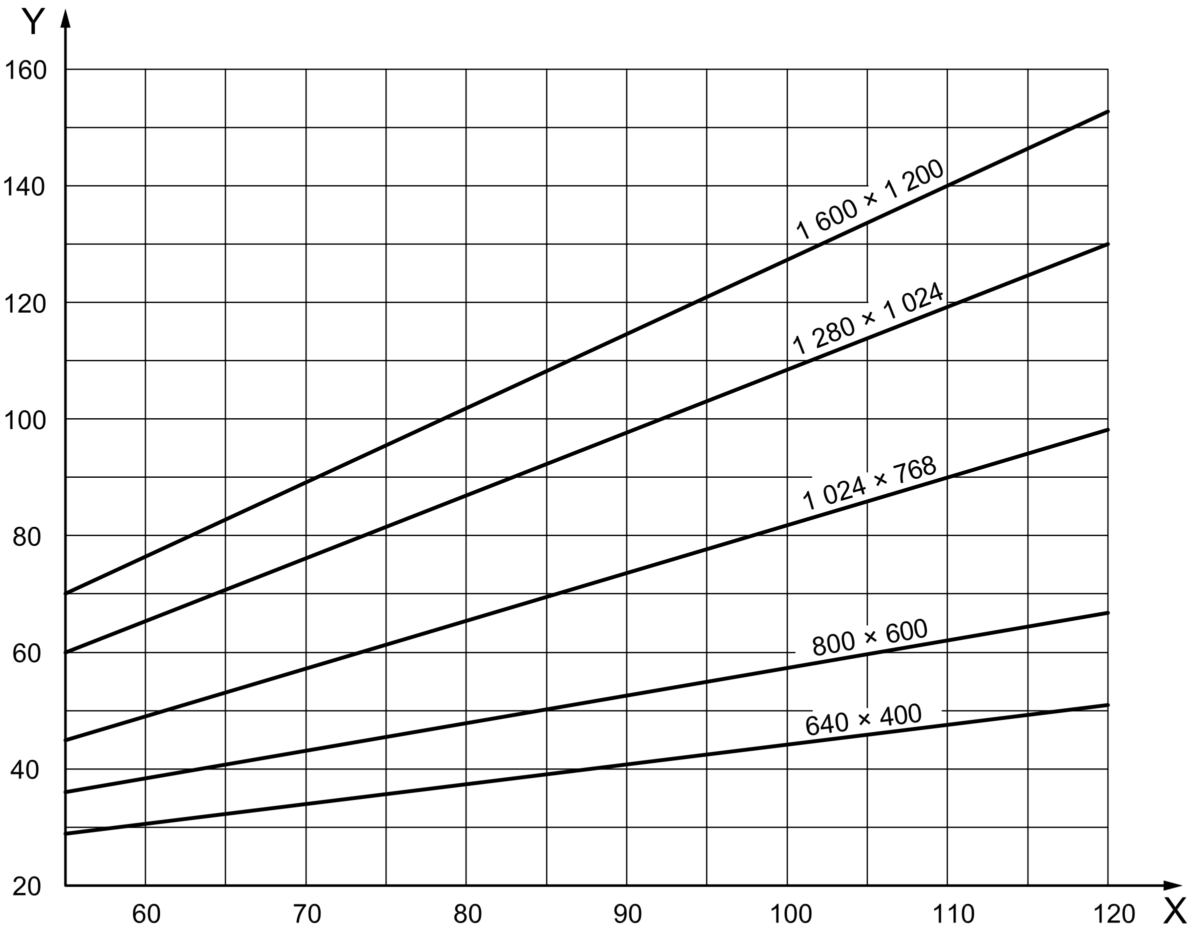
5.4.6 Temporal instability (flicker)

For CRT screens, flicker-free perception mainly depends on the interplay between the following factors:

- technical factors such as image refresh rate, image formation, resolution, phosphor persistence, average display luminance and the size of the display area;
- the individual operator's visual capabilities.

For CRT screens in positive polarity, use Figure 5 (which shows relationship between refresh rate, resolution and horizontal frequency) to determine the combinations needed to achieve a flicker-free screen. The recommended refresh rate is 100 Hz.

If the refresh rate is set to a value lower than 85 Hz, change it to a higher one if technically possible (depends on line frequencies of the monitor and properties of the graphic card).



Key

X refresh rate, Hz

Y horizontal frequency, kHz

Figure 5 — Correlation between refresh rate, horizontal frequency and resolution

The higher the needed refresh rate and resolution, the higher the horizontal frequency has to be, e.g. a horizontal frequency of 70 kHz is required in order to display image with refresh rate of 85 Hz and a resolution of 1024 × 768.

An alternative method for determining the presence of flicker is the following.

a) Adjust the display to present a white background (positive polarity).

b) Adjust the brightness and the contrast to the maximum.

c) Focus on a point about 30° to the left or to the right of the display; ensure that the display can be seen in the peripheral part of vision.

d) If the screen is not flicker free, flicker will be seen in the peripheral part of vision. In this case, check the refresh rate setting and adjust it to a higher level, if possible.

For display technologies such as LCD, electrical luminescence and plasma displays, other technical factors can be decisive for a flicker-free perception.

5.4.7 Spatial instability (jitter)

Jitter can be caused by either the display itself (internal) or by external electromagnetic fields (e.g. power line of railway, transformer, external power supply of IT equipment).

For LCD technology, jitter cannot be caused by external electromagnetic fields.

A strong jitter can be simply observed by the user without a measurement device. Jitter measurements can be performed using a magnifying glass with a built-in scale.

For measurement methods, see ISO 9241-305.

5.4.8 Moiré effects

Moiré effects can be detected by visual inspection or appropriate monitor test programs.

Some visual displays have a built-in correction function that should be used to eliminate Moiré effects.

5.4.9 Other instabilities

Other instabilities such as swim, drift, crosstalk or shadows on objects or characters can be detected by visual inspection. See ISO 9241-303.

5.4.10 Unwanted reflections

Disturbing reflections can be determined by visual inspection. Annex C gives guidelines for avoiding reflections.

Displays are divided according to their anti-reflection capabilities, separated, for positive and negative polarity, into three classes, see Table 3.

Table 3 — Reflection class of screen

Reflection class	Environment
I	Suitable for general office use
II	Suitable for most, but not all office environments
III	Requiring a specially controlled luminous environment

To determine if the display is suitable for the intended use in the given environment, check the data sheet or ask the vendor for reflection class.

For a typical office environment, positive polarity is recommended because unavoidable reflections have a less disturbing effect compared to negative polarity.

5.4.11 Unintended depth effects

Review the application for the presence of spectrally extreme colours in accordance with Table 4.

Table 4 — Spectrally extreme colours

Image background	Requirement/recommendation	Consideration/reference
Positive polarity, achromatic	Preferred for most tasks	See ISO 9241-303.
Positive polarity, chromatic	Avoid blue on red as primary colour Use black or dark grey foreground	Depth of field of the eye. False, unwanted (chromo)stereopsis. Colour identification.
Negative polarity, achromatic	Avoid blue as primary colour Avoid red as primary colour	Poor legibility. For text presentation, difficult to meet contrast requirements. About 8 % of users have reduced red-green discrimination.
Negative polarity, chromatic	Avoid red on blue as primary colour	Depth of field of the eye. False, unwanted (chromo)stereopsis

Spectrally extreme colours (extreme blue, extreme red) that produce depth effects (chromostereopsis) shall not be presented for images to be continuously viewed or read.

5.5 Legibility and readability

5.5.1 Luminance contrast

5.5.1.1 CRT — Inner contrast on characters or objects having non-discrete, non-uniform small area luminance distribution

This assessment can only be made using a scanning or imaging photometer with appropriate aperture. For further details, see ISO 9241-305.

5.5.1.2 LCD — Area luminance contrast of flat panel displays

Measure the area luminance with a luminance meter. Follow the procedure as specified in 5.2.2.

5.5.2 Image polarity

See ISO 9241-303:2008, 5.5.3.

5.5.3 Character height

5.5.3.1 Character height measured with comparator foil — LCD and CRT

Use a plastic foil with targets of different known height or a magnifier with a scale. Place the foil/magnifier on the screen. Compare the targets on the foil with the character height on the screen or measure the character height with a magnifier. Calculate the character height as a subtended visual angle, α, in minutes of arc, using Equation (3):

$$\alpha = 60 \times 2 \arctan\left(\frac{h_\mathrm{T}}{2 \times D}\right) \approx \frac{3438 \times h_\mathrm{T}}{D} \qquad (3)$$

where

h_T is the target height, in millimetres;

D is the viewing distance, in millimetres.

5.5.3.2 Character size determined from pixel count and screen height

Count the number of pixels, n, in the height of the character.

Use a pixel-oriented character program, often included in operating systems (see Figure 6).

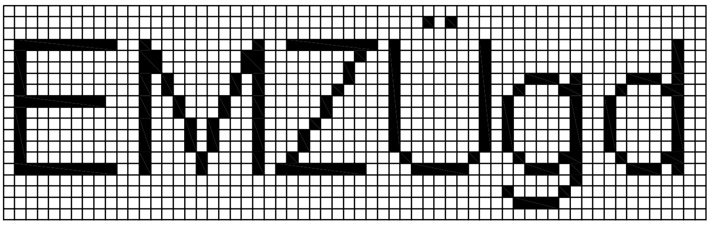


Figure 6 — Zoomed characters within a grid

Calculate the character height as a subtended visual angle, α, in minutes of arc, using Equation (4):

$$\alpha = 60 \times 2 \arctan\left(\frac{n \times s/p}{2 \times D}\right) \approx \frac{3438 \times n \times s/p}{D} \qquad (4)$$

where

D is the viewing distance, in millimetres;

n is the number of pixels in the height of the character;

p is the screen height, in pixels;

s is the screen height, in millimetres.

The screen size (height and width) is defined by the manufacturer in the user's manual or technical specification (such as a data sheet). For CRT displays, ensure that the screen size used is the same as that specified by the manufacturer; if not, change the screen size accordingly.

5.5.3.3 Screen height

For CRT, place a ruler on the screen and measure the screen height. Ensure that the eyes are perpendicular to the screen while measuring. Repeat the measurement and calculate the average value of the screen height, s.

5.5.4 Text size constancy

Perform a visual inspection.

5.5.5 Character stroke width

Use a comparator foil or a magnifier with a scale to determine the character stroke width. Place the foil/magnifier on the character on the screen. Ensure that the eyes are perpendicular to the screen while measuring.

5.5.6 Character width-to-height ratio

Use a comparator foil or a magnifier with a scale to determine the character width and height. Calculate the ratio.

As an alternate procedure, use the method specified in 5.5.3.2 for determining the character width and height. Calculate the ratio.

5.5.7 Character format

Count the number of pixels in the height and width of the selected character. Use the procedure specified in 5.5.3.2.

5.5.8 Between-character spacing

Use a comparator foil with a scale to measure the spacing between characters. For further consideration, refer to ISO 9241-303:2008, 5.5.9.

As an alternate procedure, use the method specified in 5.5.3.2 for determining the space between two characters. Count the space in pixels.

5.5.9 Between-word spacing

Use a comparator foil with a scale to measure the spacing between words.

As an alternate procedure, use the method described in 5.5.3.2 for determining the space between two words. Count the pixels in the spacing between the two words.

5.5.10 Between-line spacing

Use a comparator foil with a scale to measure the spacing between lines.

As an alternate procedure, use the method described in 5.5.3.2 for determining the space between the characters in two adjacent lines of text. Count the pixels in the spacing between the two adjacent lines.

5.6 Legibility of information coding

5.6.1 Luminance coding

Perform a visual inspection. Determine the discernability of the luminance code.

5.6.2 Absolute luminance coding

Perform a visual inspection. Determine the discernability of the luminance code.

5.6.3 Blink coding

If possible, use a stop watch. Start the watch and count a number of “blinks” (e.g. 10 cycles). Stop the watch. Calculate the blink frequency by dividing the number of cycles by the time.

For readability, determine if the blinking text can be read in one cycle.

5.6.4 Colour coding

Perform a visual inspection.

5.6.5 Geometrical coding

Perform a visual inspection to detect geometrical coding distortions.

5.7 Legibility of graphics

5.7.1 Monochrome and multicolour object size

Measure the height and the width of the image. Calculate the subtended visual angle taking into account the viewing distance. For the measurement procedures, see 5.5.3.1.

5.7.2 Contrast for object legibility

Perform a visual inspection to determine the discernability of the object.

5.7.3 Grey and colour considerations for graphics

Verify that an application offers a default set of colours and a grey scale. Perform a visual inspection. Determine whether each used colour pair can be discriminated. For text, alphanumerics and symbols used in reading tasks, see 5.4.11.

Determine whether all grey-scale levels can be distinguished. If not, adjust the display according to 4.1.4 or 4.2.3 for CRT or LCD, respectively.

For further information, see Annex D.

5.7.4 Background and surround 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.

Perform a visual inspection.

5.7.5 Number of colours

5.7.5.1 General

Count the number of colours on the display and compare it with the requirements for the type of application.

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 minimized. For accurate identification, the default colour set(s) should consist of no more than 11 colours for each set.

5.7.5.2 Visual search for colour images

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

5.7.5.3 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.

5.8 Fidelity

A new methodology for assessing colour and grey scale is under development. See Annex D.

5.8.1 Grey scale and gamma

Perform a visual inspection and an output linearization procedure. See Annex D.

5.8.2 Rendering of moving images

Perform a visual inspection and ensure there are no disturbing effects on the application. Verify that no blurred or “jerky” images appear in the application.

To render moving images properly, a display needs temporal fidelity. This temporal fidelity is influenced by rise time, hold time (time between end of rise time and beginning of fall time), fall time and sampling frequency.

The requirements relating to rise time, hold time and fall time specified in ISO 9241-303:2008, 5.8.4, apply.

5.8.3 Colour misconvergence

Misconvergence can be observed by the appearance of colour fringes or double images along the edges of an image.

5.8.4 Image formation time (IFT)

Perform a visual inspection. Depending on the task, the following applies.

a) Still and quasi-static images

If noticeable loss of contrast is observed during key entry, scrolling, animation, and blink coding, the IFT shall be larger than approx. 200 ms.

NOTE Pointing devices with rapid cursor positioning can be used only with special techniques.

If applications using scrolling, animation and pointing devices lose detectable contrast, the IFT shall be between approx. 55 ms and 200 ms.

Blink coding from 0,33 Hz to 5 Hz shall be operable.

If the contrast is stable for most applications, the IFT shall be between approx 10 ms and 55 ms.

NOTE Motion artefacts can be distracting.

b) Moving images

If motion artefacts become undetectable for all moving images, the IFT shall be less than 3 ms.

5.8.5 Spatial resolution

Perform a visual inspection.

Resolution of the display should enable a satisfying reproduction of the original image. The minimum resolution of the display, in pixels, should be (horizontal × vertical) as follows:

— VGA (video graphics array), ⩾ 640 × 480;

— PAL (phase alternating line), 768 × 576;

— NTSC (national television system committee), 720 × 480.

6 Other considerations

6.1 Isotropic surface

Luminance is measured from the position of the user's head, i.e. usually not perpendicularly to the screen. The size of the measurement spot is 1° of subtended angle. The size of the spot is defined as the subtended visual angle from the location of the user's head. Depending on the characteristics of the luminance meter, the test engineer shall be at the location of the head, farther away or closer, in order to obtain a spot size, in millimetres, that corresponds to the desired subtended angle.

EXAMPLE If the desired subtended angle is 1° and the actual viewing distance is 60 cm, then the same result will be obtained with the following two measurement set-ups:

— measurement at 60 cm distance using a spot luminance meter with a spot size subtending 1°;

— measurement at 20 cm distance using a spot luminance meter with a spot size subtending 3°.

6.2 Anisotropic surfaces

This measurement is identical to that according to 5.2.2 but with one addition: the angular aperture of the luminance meter shall be in the range 0,5° to 2°.

Luminance meters with other angular apertures shall not be used because, if used, the anisotropy of the display would cause false luminance readings. This means that a large number of commercially available luminance meters are unsuitable for testing of workplaces where, for example, LCD monitors are used.

6.3 Viewing angle range

Verify that the user can read the entire display and that sufficient legibility for the task is maintained even when moving the head or turning/tilting the display to avoid disturbing reflections.

6.4 Adjustability

Verify that the display can be tilted and turned enough to give a good viewing angle and to avoid disturbing reflections.

6.5 Controllability

Verify that power switch, brightness, contrast and other controls needed daily are accessible from the working position.

6.6 Luminous environment

Luminance balance, illumination level and countermeasures against glare from sunlight and luminaries usually require daily operation (e.g. on/off switches and operation of horizontal blinds). Verify that the controls are easily accessible and operable.

Annex A
(informative)

Overview of the ISO 9241 series

This annex presents an overview of ISO 9241: its structure, subject areas and the current status of both published and projected parts, at the time of publication of this part of ISO 9241. For the latest information on the series, see: http://isotc.iso.org/livelink/livelink?func=ll&objId=651393&objAction=browse&sort=name.

Part no.	Subject/title	Current status
1	General introduction	International Standard (intended to be replaced by ISO/TR 9241-1 and ISO 9241-130)
2	Guidance on task requirements	International Standard
3	Visual display requirements	Replaced by the ISO 9241 “300” subseries
4	Keyboard requirements	International Standard (intended to be replaced by the ISO 9241 “400” subseries)
5	Workstation layout and postural requirements	International Standard (intended to be replaced by ISO 9241-500)
6	Guidance on the work environment	International Standard (intended to be replaced by ISO 9241-600)
7	Requirements for display with reflections	Replaced by the ISO 9241 “300” subseries
8	Requirements for displayed colours	Replaced by the ISO 9241 “300” subseries
9	Requirements for non-keyboard input devices	International Standard (intended to be replaced by the ISO 9241 “400” subseries)
11	Guidance on usability	International Standard
12	Presentation of information	International Standard (intended to be replaced by ISO 9241-111 and ISO 9241-141)
13	User guidance	International Standard (intended to be replaced by ISO 9241-124)
14	Menu dialogues	International Standard (intended to be replaced by ISO 9241-131)
15	Command dialogues	International Standard (intended to be replaced by ISO 9241-132)

Part no.	Subject/title	Current status
16	Direct-manipulation dialogues	International Standard (intended to be replaced by ISO 9241-133)
17	Form filling dialogues	International Standard (intended to be replaced by ISO 9241-134)
20	Accessibility guidelines for information/communication technology (ICT) equipment and services	International Standard
Introduction		
100	Introduction to software ergonomics	Planned
General principles and framework		
110	Dialogue principles	International Standard
111	Presentation principles	Planned to partially revise and replace ISO 9241-12
112	Multimedia principles	Planned to revise and replace ISO 14915-1
113	GUI and control principles	Planned
Presentation and support to users		
121	Presentation of information	Planned
122	Media selection and combination	Planned to revise and replace ISO 14915-3
123	Navigation	Planned to partially revise and replace ISO 14915-2
124	User guidance	Planned to revise and replace ISO 9241-13
129	Guidance on software individualization	Planned
Dialogue techniques		
130	Selection and combination of dialogue techniques	Planned to incorporate and replace ISO 9241-1:1997/Amd 1:2001
131	Menu dialogues	Planned to replace ISO 9241-14
132	Command dialogues	Planned to replace ISO 9241-15
133	Direct-manipulation dialogues	Planned to replace ISO 9241-16
134	Form-based dialogues	Planned to replace ISO 9241-17
135	Natural language dialogues	Planned
Interface control components		
141	Controlling groups of information (including windows)	Planned to partially replace 9241-12
142	Lists	Planned
143	Media controls	Planned to partially revise and replace ISO 14915-2

Part no.	Subject/title	Current status
Domain-specific guidance		
151	Guidance on World Wide Web user interfaces	International Standard
152	Interpersonal communication	Planned
153	Virtual reality	Planned
Accessibility		
171	Guidance on software accessibility	International Standard
Human-centred design		
200	Introduction to human-centred design standards	Planned
210	Human-centred design of interactive systems	Planned to revise and replace ISO 13407
Process reference models		
220	Human-centred lifecycle processes	Planned to revise and replace ISO/PAS 18152
Methods		
230	Human-centred design methods	Planned to revise and replace ISO/TR 16982
Ergonomic requirements and measurement techniques for electronic visual displays		
300	Introduction to electronic visual display requirements	International Standard
302	Terminology for electronic visual displays	International Standard
303	Requirements for electronic visual displays	International Standard
304	User performance test methods for electronic visual displays	International Standard
305	Optical laboratory test methods for electronic visual displays	International Standard
306	Field assessment methods for electronic visual displays	International Standard
307	Analysis and compliance test methods for electronic visual displays	International Standard
308	Surface conduction electron-emitter displays (SED)	Technical Report
309	Organic light-emitting diode (OLED) displays	Technical Report

Part no.	Subject/title	Current status
Physical input devices		
400	Principles and requirements for physical input devices	International Standard
410	Design criteria for physical input devices	International Standard
411	Laboratory test and evaluation methods for the design of physical input devices	Planned
420	Selection procedures for physical input devices	Under preparation
421	Workplace test and evaluation methods for the use of physical input devices	Planned
Workstation		
500	Workstation layout and postural requirements	Planned to revise and replace ISO 9241-5
Work environment		
600	Guidance on the work environment	Planned to revise and replace ISO 9241-6
Application domains		
710	Introduction to ergonomic design of control centres	Planned
711	Principles for the design of control centres	Planned to revise and replace ISO 11064-1
712	Principles for the arrangement of control suites	Planned to revise and replace ISO 11064-2
713	Control room layout	Planned to revise and replace ISO 11064-3
714	Layout and dimensions of control centre workstations	Planned to revise and replace ISO 11064-4
715	Control centre displays and controls	Planned to revise and replace ISO 11064-5
716	Control room environmental requirements	Planned to revise and replace ISO 11064-6
717	Principles for the evaluation of control centres	Planned to revise and replace ISO 11064-7
Tactile and haptic interactions		
900	Introduction to tactile and haptic interactions	Planned
910	Framework for tactile and haptic interactions	Planned
920	Guidance on tactile and haptic interactions	Under preparation
930	Haptic and tactile interactions in multimodal environments	Planned
940	Evaluation of tactile and haptic interactions	Planned
971	Haptic and tactile interfaces to publicly available devices	Planned

Annex B
(informative)

Influences on ergonomics parameters of visual displays

See Table B.1 for a summary.

Table B.1 — Items having influence on the ergonomic parameters of visual displays

Subclause	Title	Items (mainly) related to			Remark
		display itself	application software	physical environmental conditions	
5.1	**Viewing conditions**				
5.1.1	Design viewing distance	X			
5.1.2	Design viewing direction	X			
5.1.3	Gaze and head tilt angles	X		X	
5.1.4	Virtual images				See ISO 9241-303:2008, Annex E.
5.2	**Luminance**				
5.2.1	Illuminance	X		X	
5.2.2	Display luminance	X		X	
5.2.3	Luminance balance and glare	X		X	
5.2.4	Luminance adjustment	X		X	
5.3	**Special physical environments**				
5.3.1	Vibration			X	See ISO 9241-303:2008, 5.3.2.
5.3.2	Wind and rain			X	See ISO 9241-303:2008, 5.3.3.
5.3.3	Excessive temperatures			X	See ISO 9241-303:2008, 5.3.4.
5.4	**Visual artefacts**				
5.4.1	Luminance non-uniformity	X			
5.4.2	Colour non-uniformity	X			
5.4.3	Contrast non-uniformity	X			
5.4.4	Geometric distortions	X		(X)	External electromagnetic fields can influence CRT displays.
5.4.5	Pixel faults	X			
5.4.6	Temporal instability (flicker)	X		(X)	
5.4.7	Spatial instability (jitter)	X		(X)	External electromagnetic fields can influence CRT displays.

Table B.1 (*continued*)

Subclause	Title	Items (mainly) related to			Remark
		display itself	application software	physical environmental conditions	
5.4.8	Moiré effects	X	X		
5.4.9	Other instabilities	X			
5.4.10	Unwanted reflections	X		X	
5.4.11	Unintended depth effects		X		
5.5	**Legibility and readability**				
5.5.1	Luminance contrast	X			
5.5.2	Image polarity		X		See ISO 9241-303:2008, 5.5.3.
5.5.3	Character height	X	X		
5.5.4	Text size constancy	X			
5.5.5	Character stroke width	X	X		
5.5.6	Character width-to-height ratio		X		
5.5.7	Character format		X		
5.5.8	Between-character spacing		X		
5.5.9	Between-word spacing		X		
5.5.10	Between-line spacing		X		
5.6	**Legibility of information coding**				
5.6.1	Luminance coding	(X)	X		Minimum contrast of display shall be high enough
5.6.2	Absolute luminance coding	X	X		
5.6.3	Blink coding	(X)	X		
5.6.4	Colour coding	(X)	X		Display shall be able to display (enough) colours
5.6.5	Geometrical coding		X		

Table B.1 (*continued*)

Subclause	Title	Items (mainly) related to			Remark/related requirement
		display itself	application software	physical environmental conditions	
5.7	**Legibility of graphics**				
5.7.1	Monochrome and multicolour object size		X		
5.7.2	Contrast for object legibility	(X)	X		Minimum contrast of display shall be high enough.
5.7.3	Grey and colour considerations for graphics	(X)	X		Display shall be able to display (enough) colours.
5.7.4	Background and surround image effects	(X)	X		Display shall be able to display (enough) colours.
5.7.5	Number of colours	(X)	X		Display shall be able to display (enough) colours.
5.8	**Fidelity**				
5.8.1	Grey scale and gamma	X	X	X	For recognition of 16 grey steps, the gamma value has to be adjusted concerning the lighting conditions (see Annex D).
5.8.2	Rendering of moving images	X			
5.8.3	Colour misconvergence	X			
5.8.4	Image formation time (ITF)	X			
5.8.5	Spatial resolution	X			
6	**Other considerations**				
6.1	Isotropic surfaces	X			
6.2	Anisotropic surfaces	X			
6.3	Viewing angle range	X			
6.4	Adjustability	X			
6.5	Controllability	X			
6.6	Luminous environment			X	

Annex C
(informative)

Unwanted reflections

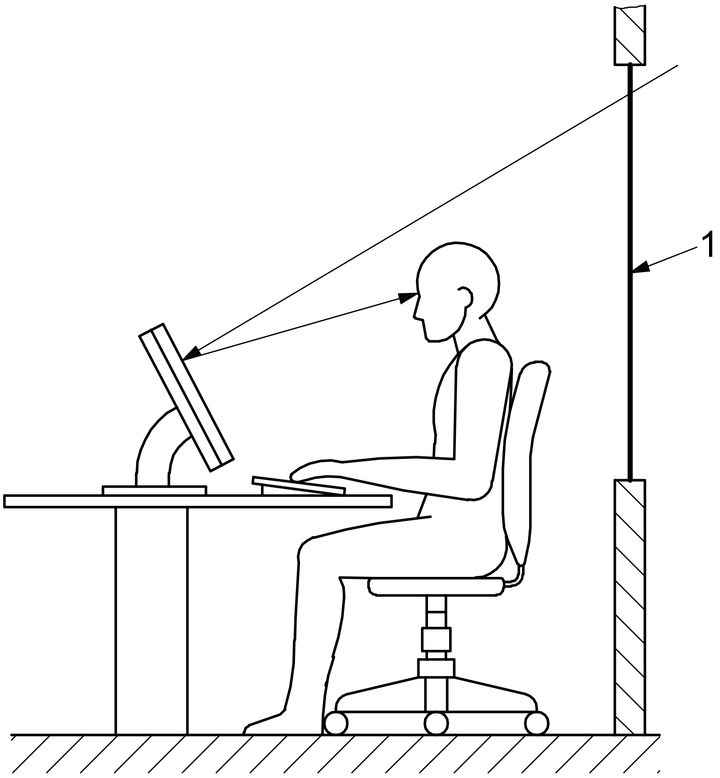
Screen surfaces are made of optical transparent material and reflect a part of the incidental light. This reflection is either directed, as specular reflections (e.g. on untreated screen surfaces), or scattered (e.g. on roughened screen surfaces). Work at visual display units is made more difficult by disturbing glare and reflections, since character contrast is decreased and, correspondingly, the recognizability of the characters is worsened. Furthermore, the user must pay more attention in order to clearly grasp the information on the screen. The clearer such reflections are, the more negative the effect they have on the user.

Table C.1 shows the maximum permitted luminance of disturbing light sources, depending on the reflection class of the screen for positive and/or negative polarity.

Table C.1 — Luminances of luminaries and bright surfaces (disturbing light sources), depending on reflection class of screen

Display polarity	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.
Reflection class (see 5.4.10)	I	I	I	II	II	II	II	III	III	III
Average luminance, $\bar{L}$, of disturbing light sources, cd/m^2	$\leqslant$ 1 000	$\leqslant$ 1 000	$\leqslant$ 1 000	$\leqslant$ 200	$\leqslant$ 1 000	$\leqslant$ 200	$\leqslant$ 1 000	$\leqslant$ 200	$\leqslant$ 200	$\leqslant$ 200

The workplace should be arranged in a direction of view that is parallel to the main window front and not directly at the windows. Windows close behind the user can cause reflections on the screen (see Figure C.1). Reflections on the screen caused by windows, luminaries or other surfaces with high luminance can also cause a decrease of contrast on the screen (Figure C.2). Arranging screens in front of windows or very bright surfaces can cause direct glare from too great luminance differences between the screen and the work environment (Figure C.3). In order to avoid this, the luminance of the disturbing light sources and quality of the screen should be adjusted so as to supplement one another.



Key

1 window

Figure C.1 — Glare from excessive brightness differences in field of view — Example: window

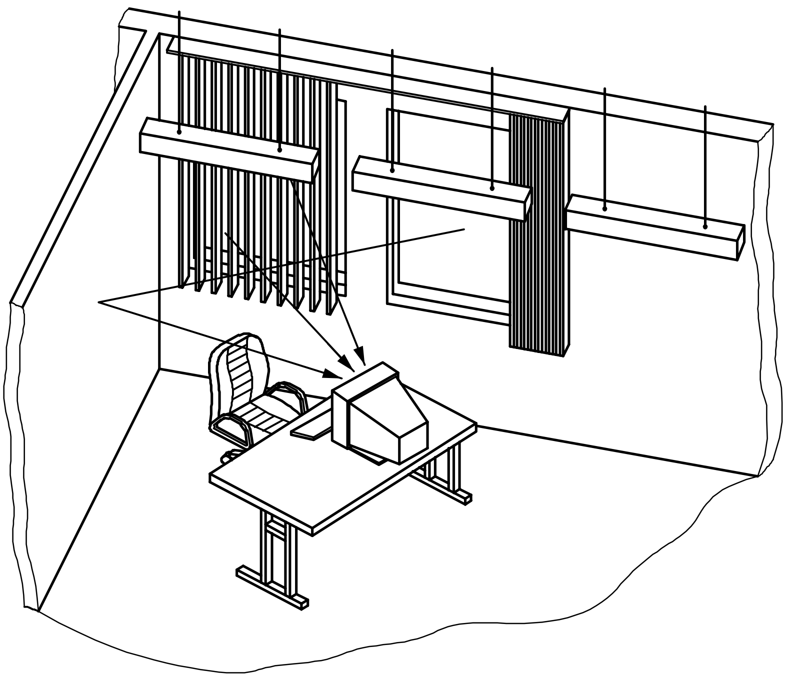
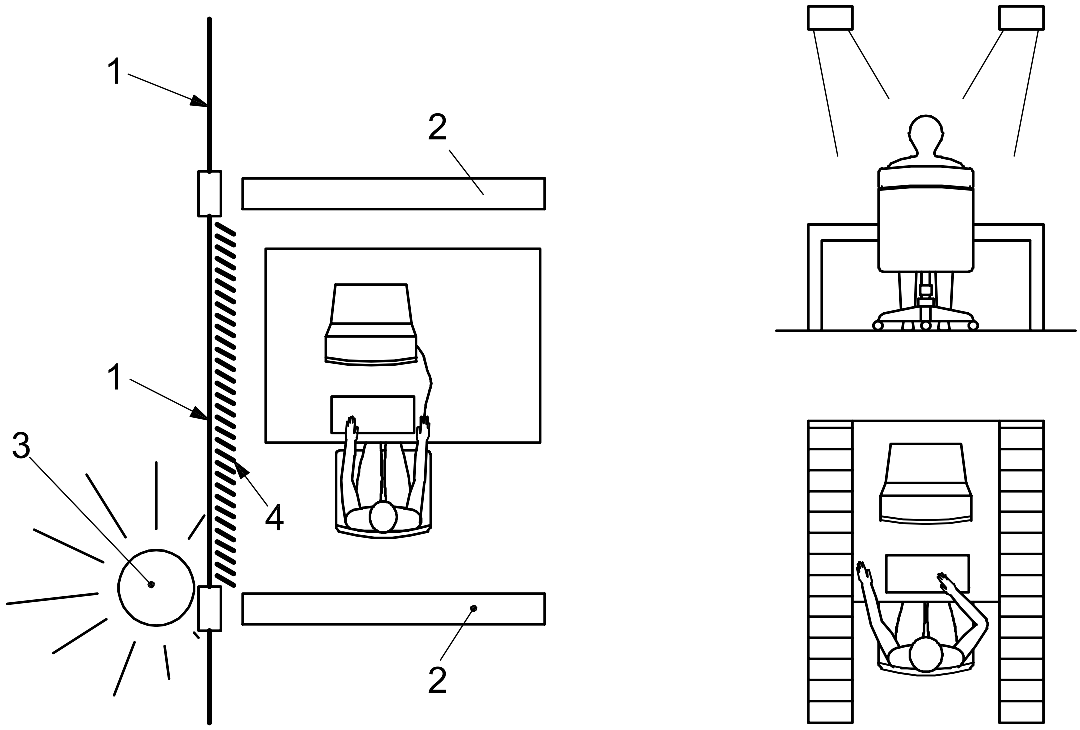


Figure C.2 — Disturbing light sources — Bright surfaces reflecting on screen



a) **Natural light**

b) **Artificial light (luminaries arranged at side, above workplace)**

Key

1 window

2 partition wall

3 sun

4 vertical blinds (example)

Figure C.3 — Reflection protection measures and arrangement of workstation towards lighting

High levels of luminance from daylight incidence can be restricted with curtains or blinds (e.g. vertical blinds) in the window area. The materials used for such light protection devices should allow an appropriate transparency (transmission) and have a reflectance adapted to the walls. Light protection devices should allow visual contact with the outside (Figure C.3).

If the reflection class of the display is unknown, then the user can estimate the display reflection in a simple way by observing unwanted images (such as of him or herself) on the screen.

Annex D
(informative)

Display output linearization and evaluation of achromatic ISO/IEC test chart output for eight different ambient light reflections at office work places

D.1 General

D.1.1 Terms and definitions

For the purposes of this annex, the terms and definitions given in ISO 22028-1 apply.

D.1.2 Linear input–output relationship for grey colours of ISO/IEC 15775 test charts

Depending on the application, a single set of colorimetric coordinates of many sets is used to define and describe grey colours. Three sets of colorimetric coordinates are given in the next figure. There is a basic user requirement for a linear relationship between the colorimetric coordinates and the visual colour output.

Table D.1 shows equivalent colorimetric coordinates for a five-step grey series between black, N, and white, W, for the offset reflective system, ORS18. The values in Table D.1 are taken from ISO/IEC TR 19797:2004, which defines a method for output linearization of a 16-step grey and colour series. The output can be measured and for the standard output, ORS18, the measurement data, LAB^*, are given. If the CIELAB L^* lightness data are used, then the calculated relative output lightness, l^*, data are identical to the input whiteness, w^*, data, which are used by the PostScript operator, *setgray*, in the digital file. In this case, the input–output relationship in a w^*–l^* diagram is a diagonal line which indicates a linear relationship between input and output. The output linearization method of ISO/IEC TR 19797 matches all these intentions, including equal output for the three equivalent colorimetric input coordinates.

Table D.1 — Equivalent colorimetric coordinates for device system, ORS18

Five steps of colour series black–white (N–W)	Colour space, coordinates and PostScript operator calculations according to ISO/IEC 15775						
Linear mixture between black and white in CIELAB colour space	CIELAB (absolute)			CIELAB relative			
	$L^*, a^*, b^* = LAB^*$ LAB^* setcolor			$lab^*l = w^*$ w^* setgray	$lab^*olv = rgb^*$ rgb^* setrgbcolor		
1,00 N + 0,00 W	18,01	0,50	–0,40	0,00	0,00	0,00	0,00
0,75 N + 0,25 W	37,75	0,10	0,80	0,25	0,25	0,25	0,25
0,50 N + 0,50 W	56,70	–0,10	2,10	0,50	0,50	0,50	0,50
0,25 N + 0,75 W	76,05	–0,50	–3,40	0,75	0,75	0,75	0,75
0,00 N + 1,00 W	95,41	–0,98	4,76	1,00	1,00	1,00	1,00
Colorimetric relationship pf LAB^*, w^*, rgb^* for the five-step scale: black–white							

NOTE Relative lightness, l^*, is calculated from the CIELAB lightness, L^*, of grey and L^*_{N} of black and L^*_{W} of white by Equation (D.1):

$$l^* = \left(L^* - L^*_{\mathrm{N}}\right) \Big/ \left(L^*_{\mathrm{W}} - L^*_{\mathrm{N}}\right) \qquad \text{(D.1)}$$

The input–output relationship is usually non-linear but can be made linear using the following method.

First, a file with 16 equally spaced device input coordinates, w, (without *) and the PS operator, w, *setgray,* produce an output. For the grey output colours the absolute lightness, L^*, data are measured and the relative output lightness, l^*, data calculated. Then, for equally spaced relative output lightness, l^*, a device-dependent mapping between w^* and w solves the problem. If the software transforms the 5 or 16 equally spaced digital w^* values in the file to the device-dependent w values, then the output is visually equally spaced and the intended equally spaced l^* output data are produced.

D.1.3 Linear input–output relation of non-linear sRGB space according to IEC 61966-2-1

IEC 61966-2-1 defines the relationships between different colour coordinates of the sRGB colour space, and CIEXYZ, and CIELAB. There are linear ($R_{\text{sRGB}} = r$) and non-linear ($R'_{\text{sRGB}} = r^*$) coordinates in IEC 61966-2-1. The linear coordinates *(rgb)* have a linear relationship to CIEXYZ and the non-linear coordinates *(rgb*)* have, for the achromatic colours, a linear relationship to the CIELAB lightness, L^*.

The connection between linear and non-linear coordinates used in IEC 61966-2-1 is approximately:

$$R'_{\text{sRGB}} = \left(R_{\text{sRGB}}\right)^{1/2,4} \tag{D.2}$$

which, for the achromatic colours, is very similar to the following colorimetric equation ($0 \leqslant Y \leqslant 100$):

$$L^* = 100\left(Y/100\right)^{1/2,4} \tag{D.3}$$

which, in the range $1 \leqslant Y \leqslant 100$, is a good approximation for the CIELAB lightness, L^*, defined as:

$$L^* = 116\left(Y/100\right)^{1/3} - 16 \tag{D.4}$$

NOTE If Equations (D.2) and (D.3) are compared and the linear relationship between R_{sRGB} and Y used, then R'_{sRGB} must be linearly related to the CIELAB lightness, L^*, and the relative CIELAB lightness, l^*, as defined in Equation (D.1). All printer and nearly all monitor applications operate in the range $1 \leqslant Y \leqslant 100$, then, approximately:

$$l^* = L^* / 100 = \left(Y/100\right)^{1/2,4}$$

Different exponents or “gamma” values will be used in some figures later.

Therefore, at least in the range between black ($L^*_{\text{N}} = 8$, $l^*_{\text{N}} = 0$) and white ($L^*_{\text{W}} = 95$, $l^*_{\text{W}} = 1$), the RGB'_{sRGB} *(rgb*)* data have a linear relationship to the relative lightness, l^*, data. In application, therefore, the so-called sRGB devices have a linear input–output relationship between the RGB'_{sRGB} data in the file and the measured relative lightness, l^*, of the output.

NOTE White standard offset paper has a luminance reflectance of $Y = 88,6$ and not $Y = 100$. The Y values used in the equation of the sRGB space are usually normalized to the media white. According to ISO/IEC 15775 and ISO/IEC TR 24705, the CIELAB media white and media black define the relative lightness 1 and 0. Therefore, Equation (D.1) for relative lightness is the only correct colorimetric equation and thus the only one used in this annex. Colorimetric device coordinates with a linear relationship to the coordinates of CIELAB are called “star” (*) coordinates; others with a linear relationship to the coordinates of CIEXYZ are defined without the “*”.

D.1.4 Large change of the input–output relationship by display reflections of the ambient light

ISO/IEC TR 24705 includes tables for the grey and colour changes on displays caused by different ambient room light reflections on the monitor surface. For comparison of hardcopy (paper) and softcopy (monitor) output, a standard display according to ISO/IEC TR 24705 is normalized for black and white to the same lightness compared to the standard offset paper.

A white lightness, L^*_W = 95,4 (luminance factor Y_W = 88,6), and a black lightness, L^*_N = 18,01 (luminance factor Y_N = 2,51), are used. The luminance factor, Y_N = 2,51, is taken as standard ambient room light reflection on the monitor surface. For displays used in offices, a range between Y_N = 1 and Y_N = 10 is appropriate. The luminance of LCD monitors is in general higher compared to CRT monitors. Therefore, for equal room light luminance, LCD monitors have a lower room light reflection than CRT monitors.

D.1.5 Linearized output and input–output relationship by eight different display reflections of the ambient light

Tables for different room light reflections can be calculated between Y_N = 0 and Y_N = 40. For the standard ambient reflections, the luminance contrast between white and black is Y_W:Y_N = 88,6:2,5 = 37:1. The luminance contrast decreases from very high values if Y_N is near zero up to the value Y_W:Y_N = 88,6:40 ≈ 2:1 for about 40 % room light reflection. For good legibility of the display output, a luminance contrast of at least 3:1 is the minimum ergonomic requirement (see ISO 9241-303).

NOTE For data projectors used in daylight offices, the relation between projector and room luminance on the screen can reach the ratio 2:1. In this case, 16 grey steps can still be distinguished if the relative luminance on the screen is adjusted to the real lighting and viewing conditions.

Figures D.1 to D.6 show six output pages of a 16 page file that includes the calculations for eight room light reflections, see the following URL (16 pages, 1,7 MB):

http://www.ps.bam.de/ME15/10L/L15E00FP.PDF

The output of this file produces 16 pages for eight different luminance ratios between Y_W:Y_N = 88,6:0 and Y_W:Y_N = 88,6:40 ≈ 2:1.

The uneven pages (1, 3, ..., 13, 15) are intended to produce a linearized output of the ISO/IEC test chart according to ISO/IEC 15775.

The even pages (2, 4, ..., 14, 16) produce the input–output relationships and some tables defined in ISO/IEC 15775:1999, Annex G.

For a linearization method and a linearized display output of the achromatic ISO/IEC test chart no. 3, see the following URL (1 page, 100 kB), which forms the basis for the ISO test report of this part of ISO 9241.

http://www.ps.bam.de/ME16/10L/L16E00NP.PDF

The graphical elements and the methods for this evaluation are identical to the methods given in ISO/IEC 15775 and in ISO/IEC TR 24705 for monitor output.

For the test reports, Form A and Form B of this annex are necessary for the computer display and/or the external display.

A flowchart is given for all steps, including the linearization method and the two test reports.

Figure D.1 shows the ISO/IEC test chart no. 3 according to ISO/IEC 15775 for the high contrast range (Y_W : Y_N = 88,6:0,0, L^*_W:L^*_N = 95,4:0,0). Figure D.1 is produced by the output of the 16 page file on page no. 1.

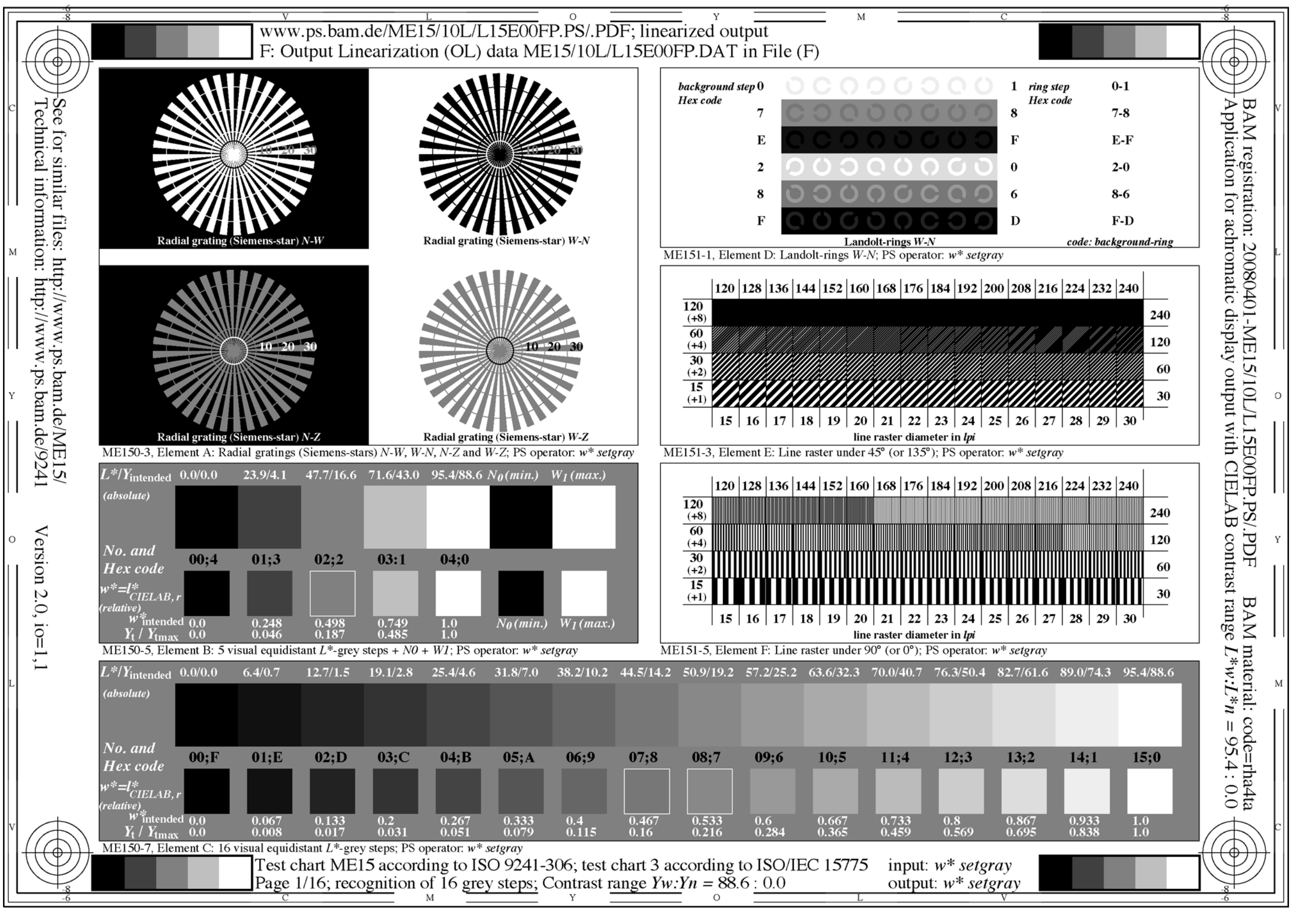


Figure D.1 — ISO/IEC test chart no. 3, according to ISO/IEC 15775, page no. 1, for high contrast range

Figure D.2 shows the linearized input–output relationship of a monitor system for the high contrast range (Y_W:Y_N = 88,6:0,0, L^*_W:L^*_N = 95,4:0,0).

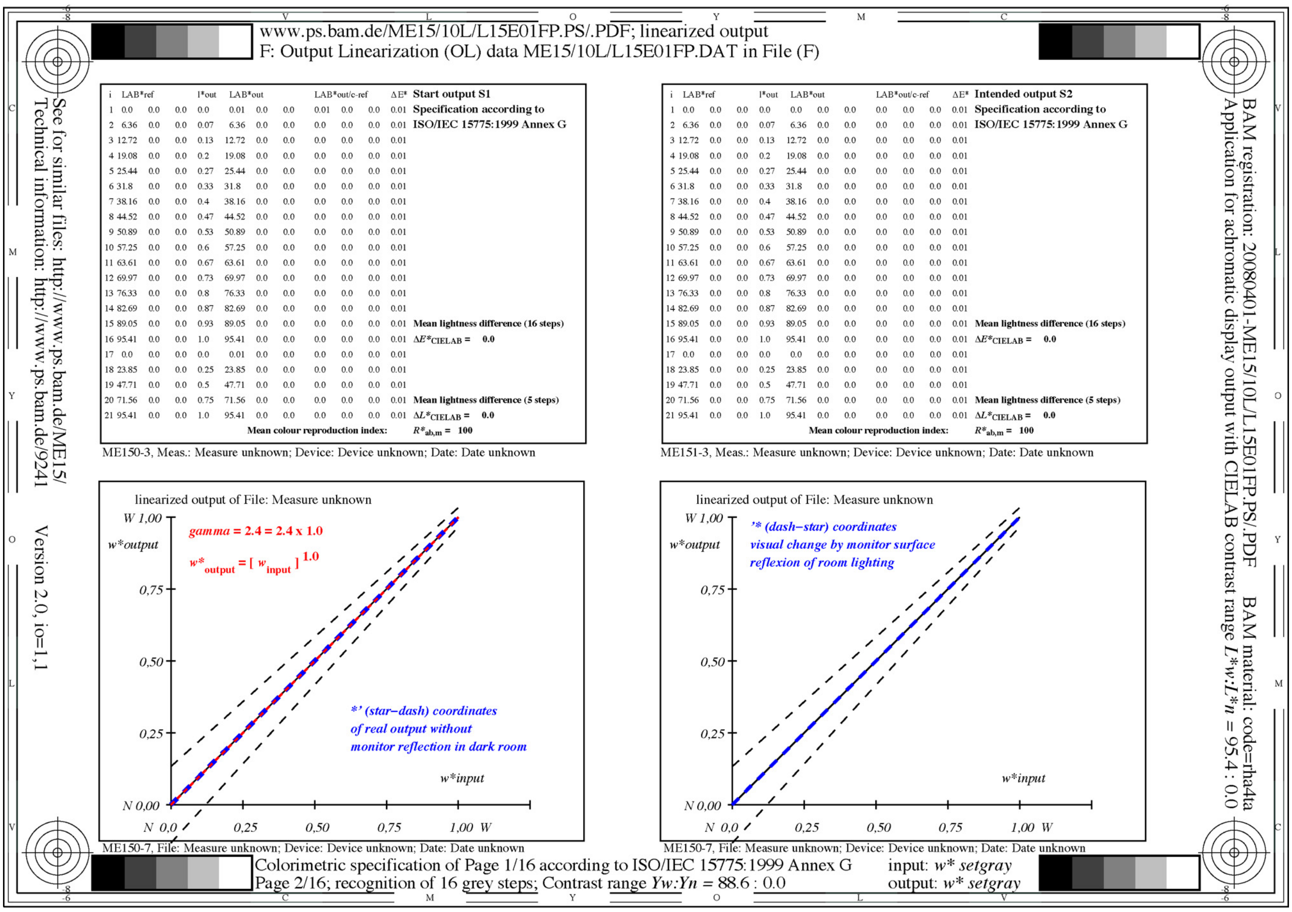


Figure D.2 — Linearized input–output relationship, page no. 2, for high contrast range

Figure D.2 is produced by the output of the 16 page file on page no. 2. The input values may be the equal three rgb values of the sRGB colour space (IEC 61966-2-1) and the output values, the relative CIELAB lightness, $l^* = \left(L^* - L^*_{\mathrm{N}}\right)/\left(L^*_{\mathrm{W}} - L^*_{\mathrm{N}}\right)$. The absolute CIELAB lightness, L^*, between the black lightness, L^*_{N}, and the white lightness, L^*_{W}, are given in the tables shown in Figure D.2. They are equally spaced between the value zero and the value 95,4, which is the standard normalization for both monitors and the white standard offset paper (cf. ISO/IEC 15775 and ISO/IEC TR 24705). In Figures D.3 and D.4 and Figures D.5 and D.6, the black lightness, L^*_{N}, changes from 0 to 18 and up to 70, respectively. This leads to large changes of the lightness and luminance contrast ratios.

Figure D.3 shows the ISO/IEC-test chart no. 3 according to ISO/IEC 15775 for the medium contrast range ($Y_{\mathrm{W}} : Y_{\mathrm{N}}$ = 88,6 : 2,5, $L^*_{\mathrm{W}} : L^*_{\mathrm{N}}$ = 95,4 : 18,0). Figure D.3 is produced by the output of the 16 page file on page no. 7.

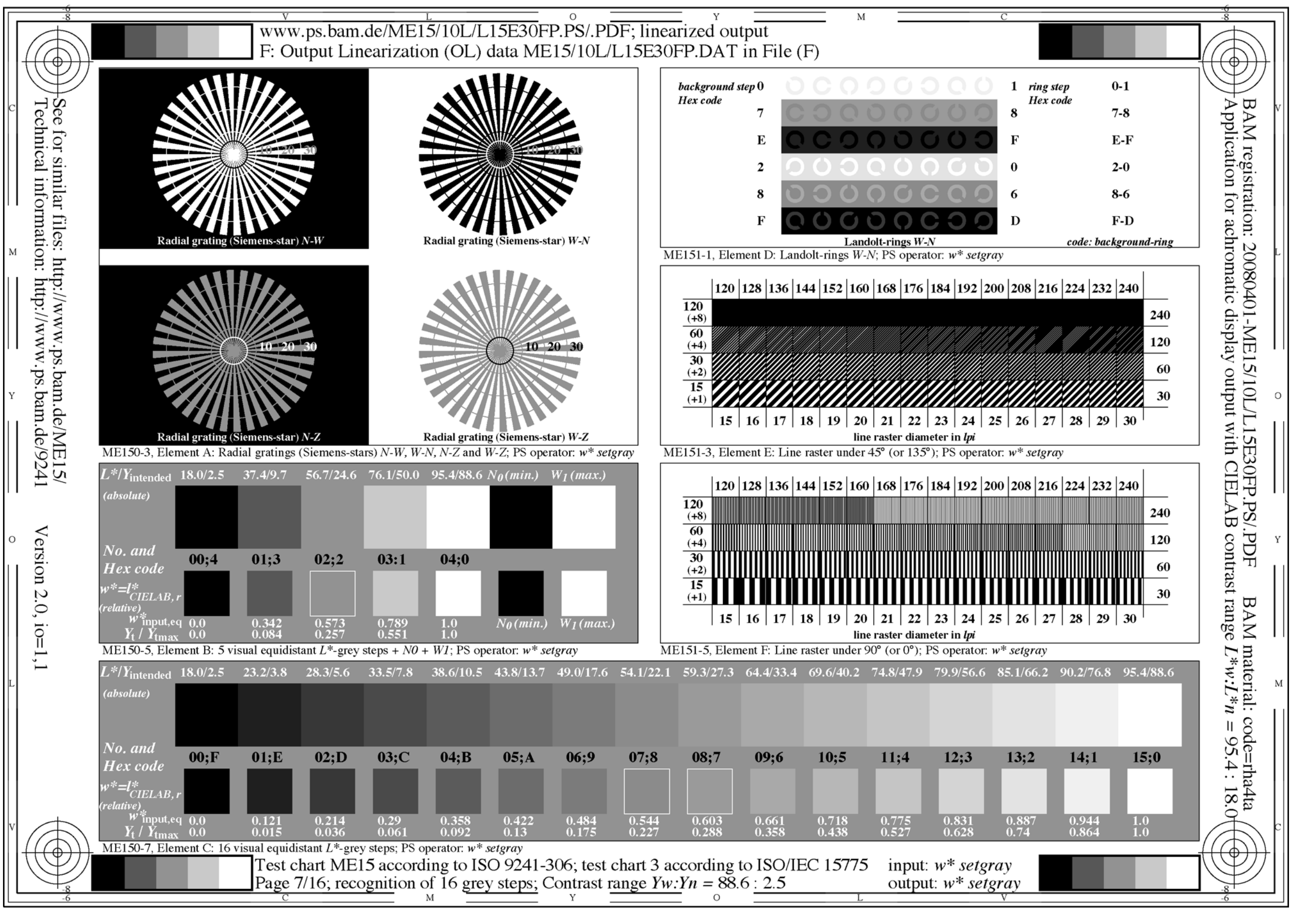


Figure D.3 — ISO/IEC test chart no. 3, according to ISO/IEC 15775, page no. 7, for medium contrast range

Figure D.4 shows the input–output relationship of a monitor system for the medium standard contrast range (Y_W:Y_N = 88,6:2,5, L^*_W:L^*_N = 95,4:18). Figure D.4 is produced by the output of the 16 page file on page no. 8. In the dark room, the output appears lighter (table and figure on left side of Figure D.4). The daylight reflection on the monitor surface creates the inverse input–output relationship. This finally leads to the equally spaced output values of the lightness L^* in the right top table shown in Figure D.4. Luminance measurements lead approximately to the same values. Without the monitor surface reflection, the output values, L^*_{out}, of the lightness are not equally spaced (compare left top table).

Figure D.5 shows the ISO/IEC test chart no. 3 according to ISO/IEC 15775 for the low contrast range (Y_W:Y_N = 88,6:40.6, L^*_W:L^*_N = 95,4:70,0), and is produced by the output of the 16 page file on page no. 15.

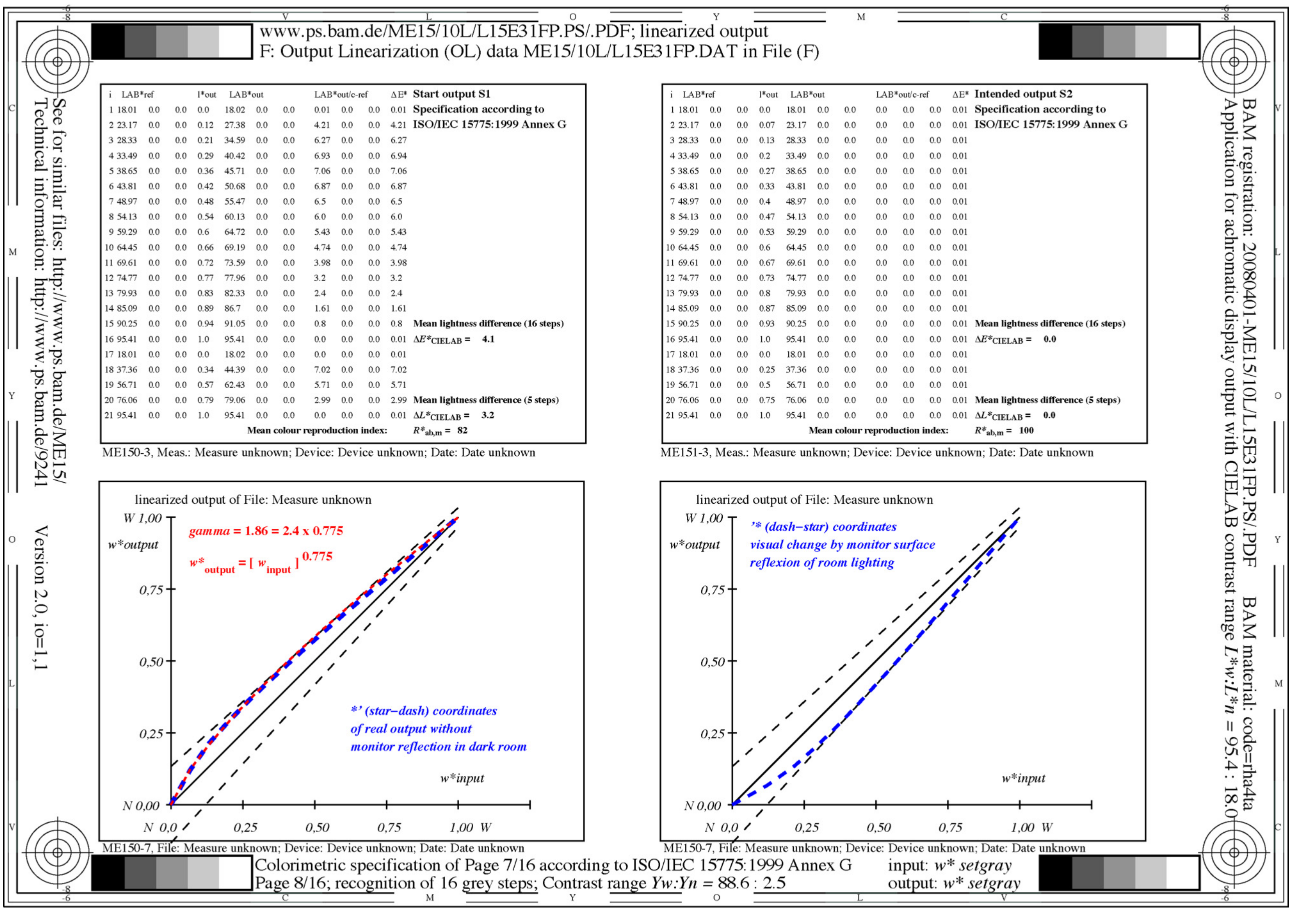


Figure D.4 — Input–output relationship, page no. 8, for standard medium contrast range

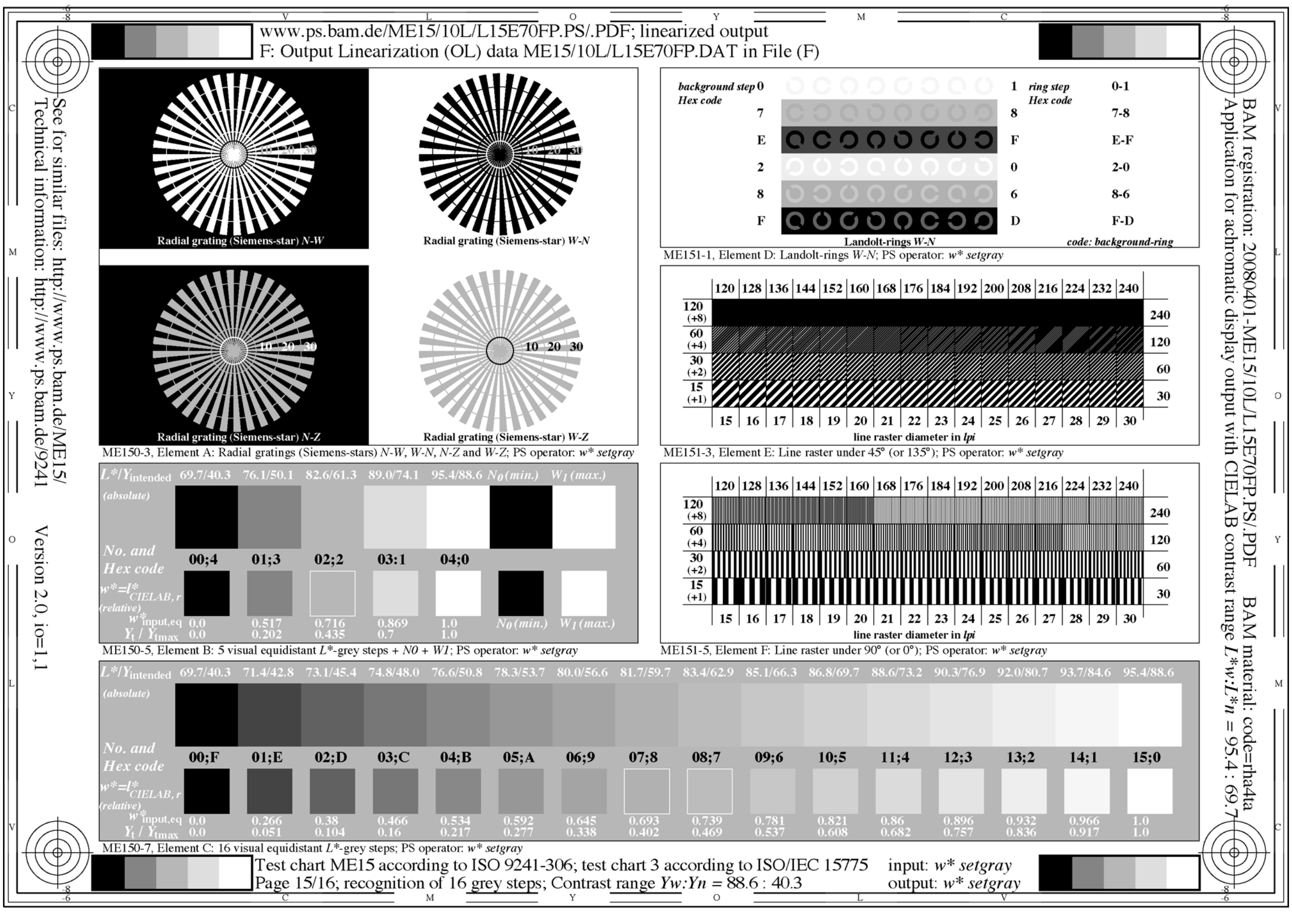


Figure D.5 — ISO/IEC test chart no. 3, according to ISO/IEC 15775, page no. 15, for low contrast range

Figure D.6 shows the input–output relationship of a monitor system for the low contrast range (Y_W:Y_N = 88,6:40, L^*_W:L^*_N = 95,4:70), and is produced by the output of the 16 page file on page no. 16. This low contrast range can appear on the projection screen if data projectors are used in the daylight office. The calculated medium lightness difference is equal in Figures D.4 and D.6 (value 4,1). In the low contrast range, there is a reduced lightness range, ΔL^* = 25, instead of the much larger lightness range, ΔL^* = 77, for the medium contrast range. If, in the dark room, the grey scale includes insufficient steps in the dark area, then it appears equally spaced in the daylight office for the luminance contrast ratio 2:1.

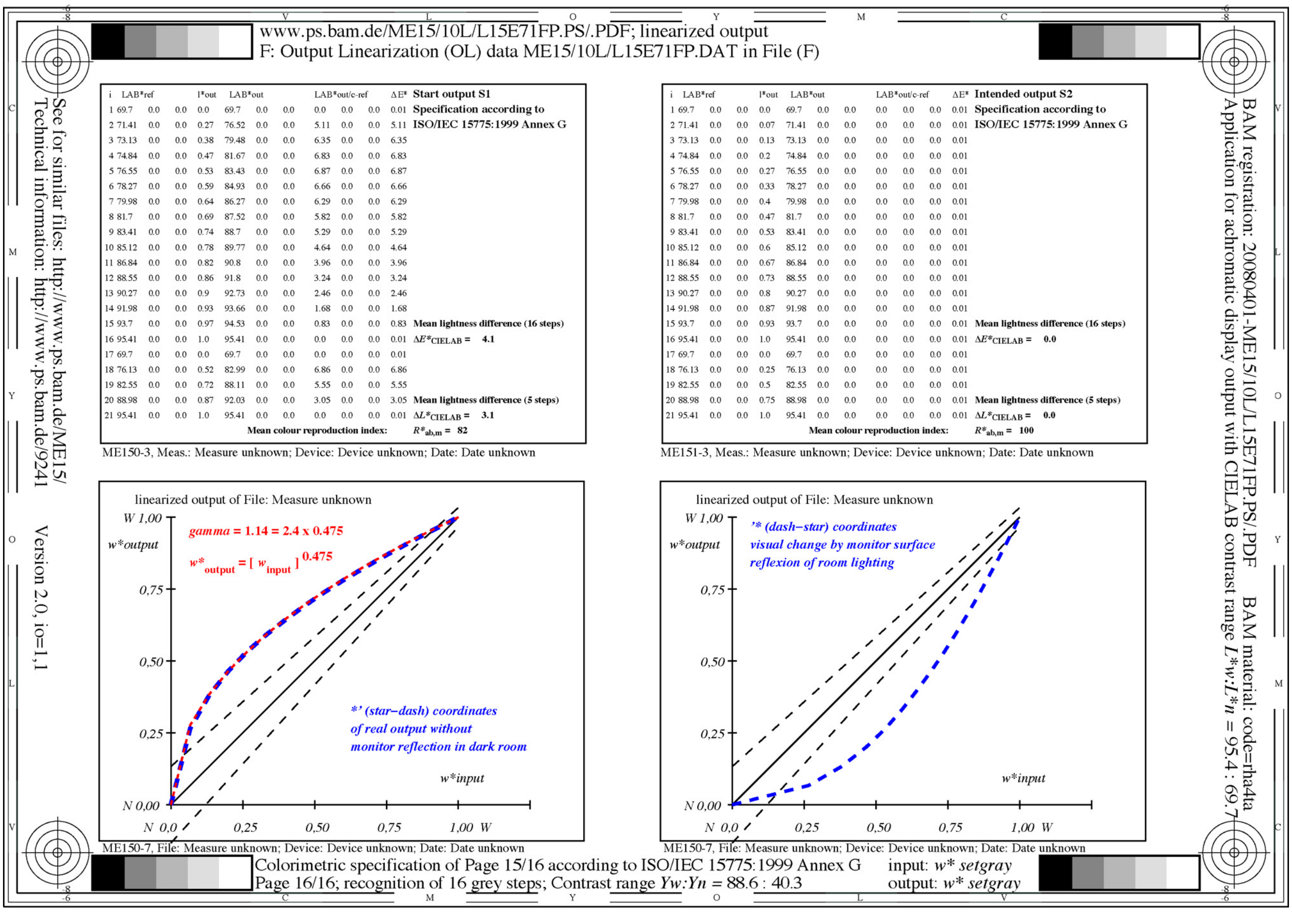


Figure D.6 — Input–output relationship, page no. 16, for the low contrast range

D.2 Output linearization with the standard achromatic ISO/IEC-test file

D.2.1 Inverse input–output relationship to consider the ambient light reflections

It is known by experience that more and more ambient light reflections decrease the recognition of the dark grey steps and the recognition of the Landolt rings in the dark area. The input–output relationship of this effect is shown in the right bottom graphs of Figures D.4 and D.6. For compensation, the input data are changed in the file. This inverse input–output relationship is shown in the left bottom graphs of Figures D.4 and D.6.

For the worst case, with the luminance ratio 2:1 between white and black, the discrimination disappears for about six of 16 steps in the dark area. This can produce security and safety problems. Therefore, it is necessary to use an output linearization method that always produces six equally spaced steps for any ambient light condition including the luminance ratio 2:1. A simple method is needed that allows testing if this goal is reached.

The grey output of Figure D.5 appears much too light in the dark grey area. The difference between black and the adjacent grey step appears too large. However, if, finally, 40 % ambient light reflections are produced on top of both as well as all other grey steps, then the 16 grey steps appear visually equally spaced.

It is therefore the task to produce for any output (not only the PDF output) the inverse input–output relationship for any ambient light condition (between a very large luminance ratio and the luminance ratio 2 : 1) on any computer operating system, including Windows[1] and Macintosh[2].

It must be realised that the output always depends not only on the ambient light conditions but also on hardware and software at the work place. Therefore, a solution for one particular work place may fail in another and the many changes of reflections between sunrise and sunset in an office could require several changes at the work place during daytime. Therefore, in application, simple and effective methods for naive users are necessary. A type of eight-step method shown in the 16 page file and its output examples in Figures D.1 to D.6 is appropriate to realized the effect. The question of how to implement the visual results by simple methods at the work place has high priority.

Additionally, the output of the ISO/IEC test chart is usually different at the computer display and at the external display, for example, a data projector output on a screen in the office illuminated by daylight.

D.2.2 View of ISO/IEC test file according to ISO/IEC 15775

Figure D.7 shows the ISO/IEC test chart no. 3 according to ISO/IEC 15775 for output linearization. In the file, the digital values for the 16 grey steps change between 0 and 1 in equal steps between 1/15, 2/15, and 14/15. The output of Figure D.7 is at least shown on the computer display and can be shown additionally on the external display. In both cases, it is intended for the display output that the 16 grey steps be equally visually spaced.

1) "Windows" is the trade name of a product supplied by Microsoft Corporation. This information is given for the convenience of users of this part of ISO 9241 and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

2) "Macintosh" is the trade name of a product supplied by Apple Inc. This information is given for the convenience of users of this part of ISO 9241 and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

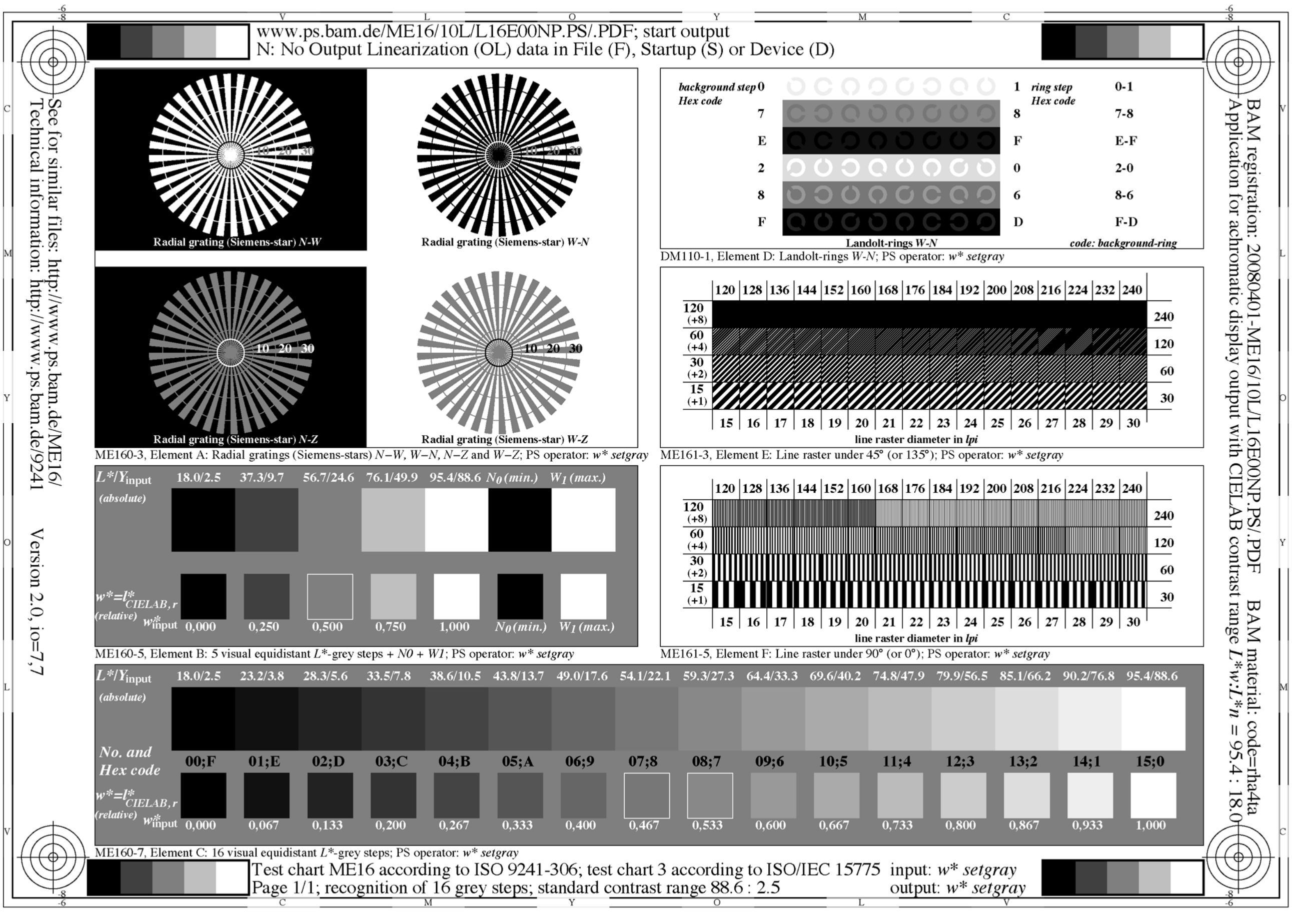


Figure D.7 — ISO/IEC test chart no. 3, according to ISO/IEC 15775, for output linearization

For practical applications, a quick change on both displays with two independent tools is necessary. On the computer system, Apple Macintosh, since Version X 10.4 a tool ("System preferences, Displays, Colour, Calibrate") exists that shows two windows for the two displays. Each window allows independent profiles to be created for both the computer display (e.g. an LCD display), and the external display (e.g. a VGA display).

There is a default profile for the computer display with a default gamma value of 1,8 for the Apple Macintosh. A user can change the gamma value and can store, for example, eight different "Profiles Colour LCD x" with x = 1,14; 1,32; ...; 2,22; 2,40.

NOTE The effective gamma values for the intended output are shown calculated in Figures D.4 and D.6. Some modifications of these gamma values and its range might be appropriate for different applications.

Figure D.8 shows eight gamma values used for eight different input–output profiles for the computer display. The option "Calibrate" of Figure D.8 has been used to create eight profiles with eight appropriate gamma values and names. The input–output relationships of these eight profiles are inverse compared to the input–output relationships of the ambient light reflections, Y_N = 0,0; 0,63; 1,25; 2,51; 5,02; 10,04; 20,08; 40,16, shown in the 16 page test file and in Figures D.2, D.4, and D.6.

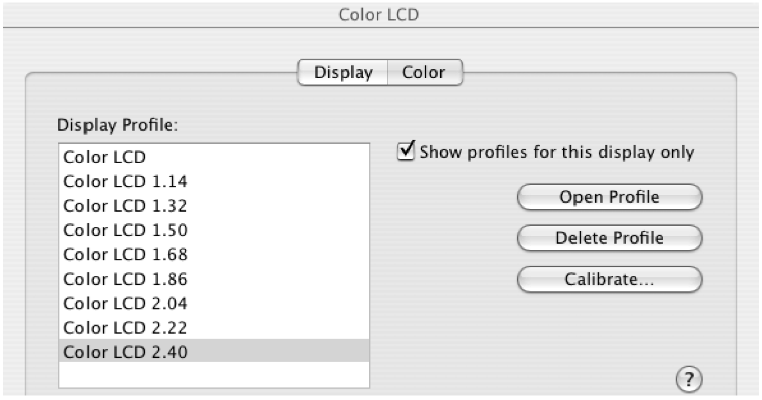


Figure D.8 — Eight gamma values that produce eight different input–output profiles for computer display

If the recommended ISO/IEC test chart (Figure D.7) is viewed on the computer display, then a step-by-step click on the eight different profiles changes the visual output of the test chart (and all applications). It takes a few seconds to choose the ISO/IEC test chart output with the intended 16 step grey scale, which is visually equally spaced for the computer display.

In some cases, additional external displays are at the workplace. If, for example, an external monitor or data projector is at the external display connector, then a second display tool is shown on the computer system Apple Macintosh Version X 10.4.

Figure D.9 shows eight “gamma” values which can be used to create eight different input–output profiles for the external display. The “gamma” value 1,80 is called the “native gamma” on the Apple Macintosh Version X 10.4 computer system.

There are “gamma” values in the range 1,00 to 3,50, but only the values in the range 1,75 to 3,50 have been useful for the intended linearized output. Larger modifications of the “gamma” values could be appropriate for different applications.

If the recommended ISO/IEC test chart is viewed on the external display, for example, on the data projector screen, then a step-by-step click on the eight different profiles changes the visual output of the test chart — and all other windows on the external screen (in this case, there is no change on the computer display). It takes a few seconds to choose the ISO/IEC test chart output with the intended 16 grey steps, which are visually equally spaced for the external display.

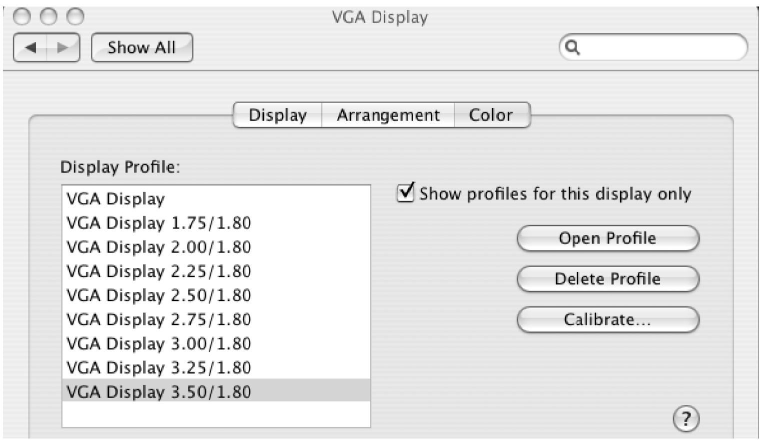


Figure D.9 — Eight “gamma” values that produce eight different input–output profiles for external display

A quick method exists for output linearization of both the computer display and the external display. For output linearization on both screens, it is essential for the visual control to have the ISO/IEC test chart on both screens.

These properties allow a linearized output to be produced from a workflow diagram.

D.2.3 Complete workflow for output linearization and ISO/IEC test report data

The procedure for reaching the linearized output and the evaluation of this result is shown in Figure D.10, where workflow is used to produce a linearized output for the 16 grey steps. For both the computer and external displays (see the two paragraphs in Figure D.10, under “and/or external VGA display”), the standard ISO/IEC test chart file is used (see the URL given in the diagram).

D.3 Test reports for visual output at office work place

D.3.1 General

The test report for visual output at office work places is based on the test report of ISO/IEC test chart no. 3 according to ISO/IEC TR 24705. The one-page output of the achromatic ISO/IEC test chart file is used according to ISO/IEC 15775 and ISO/IEC TR 24705 (see Figure D.7).

D.3.2 Output linearization method and test report for computer and external displays

After output linearization according to the workflow shown in Figure D.10, at least one ISO test report according to ISO 9241-306 is necessary for the computer and/or the external display.

Fill out at least one of the following for the computer and/or the external display.

a) Test report, Form A, for the frame area (see D.3.3 and D.3.4).

NOTE Some additional data describe the test person, the test date and the software and operating system used.

b) Test report, Form B, for the image area (see D.3.5).

NOTE For the testing of line screens' reproduction, the resolution limit 60 lpi of ISO/IEC 15775 for printer output is reduced to 30 lpi for display output.

The output linearization method for the achromatic ISO/IEC-test chart for both the computer and the external display is shown here as an example on the Apple Macintosh X 10.4 computer system. Similar methods might be available on the Windows computer systems and others.

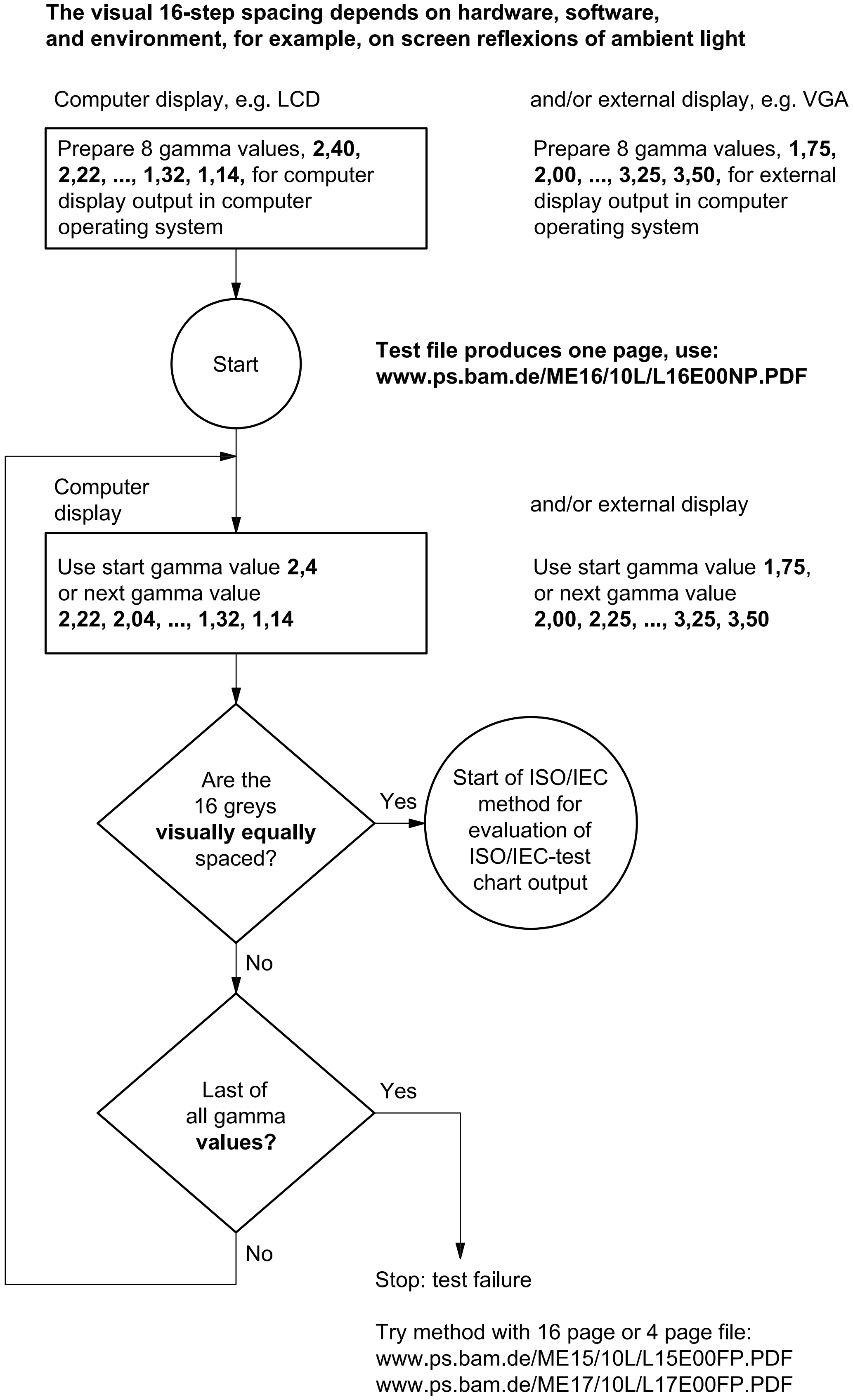


Figure D.10 — Workflow to produce a linearized output of the 16 grey steps and test report data

D.3.3 Form A — Visual output at office work places for frame area

Form A may be freely copied. For this test, the computer display output in the size 282 mm × 194 mm is recommended. For an external display output any output size is possible. ISO test chart ME16, according to this part of ISO 9241, is used before ISO/IEC test chart 3 (see Figure D.7) for this test.

Please fill out or mark by **(x):**

ISO test chart: e. g. Test chart 3 for colour devices (write text from frame area of ISO test chart)

Test of achromatic ISO/IEC test chart 3 for *computer* display ( ) or for *external* display ( ):

....

ISO/IEC BAM registration: e.g. 20050501-ME16/10L/ (write code from top right side) ....

ISO/IEC reference material: e.g. r(h/c)a4(r/t)(a/d) (write code from bottom right side) ....

File-name: e.g. L16E00NP.PDF (write code from top side) ....

Test person (e. g. name, first name): ....

Test date (e. g. 2009-09-01): ....

Computer operating system and version (e. g. Unix Build X.Y)[3]: ....

PDF Reader software and version for display output (e. g. Adobe Reader 7.0): ....

Display (computer or external) driver and “gamma value” of linearized output: ....

Remarks

The **output size** on the computer display should be adjusted to the original size (282 mm × 194 mm) for the inner thicker frame rectangle. The output size should be adjusted with an accuracy of ± 2 mm to this size by the software using a ruler.

The output size of the external display is different. For the test report the scaling factors (see below) or the corresponding output size of the computer display should be used.

Test of agreement of the four 5-step grey scales according to the grey scales in the frame region:

Are there clearly-seen differences between the four 5-step grey scales near the corners? Yes/No

If Yes: Indicate by **(x)** – only one **(x)** – which grey scale deviates most from the average of the four grey scales and mark if this is darker or lighter.

top left ( ) if **(x)**: is this darker ( ) or lighter ( )?

top right ( ) if **(x)**: is this darker ( ) or lighter ( )?

bottom left ( ) if **(x)**: is this darker ( ) or lighter ( )?

bottom right ( ) if **(x)**: is this darker ( ) or lighter ( )?

Test of the scaling factors using width and height of the inner rectangle in the frame region:

The width and height of the inner rectangle in the x and y directions, expressed in millimetres, of the reproduction (Δx_o and Δy_o, where o is output) is to be measured. The scaling factors (s_x and s_y) in the x and y directions shall be calculated. For this, three digits, in millimetres and with rounding such as in the example, are used (e. g. s_x = 1,01 and s_y = 0,98):

$s_x = \Delta x_o / \Delta x_r = \ldots$ mm / 282 mm $= \ldots$ $s_y = \Delta y_o / \Delta y_r = \ldots$ mm / 194 mm $= \ldots$

NOTE The width, Δx_r, and height, Δy_r, of the inner rectangle are defined in *PS*-file (or equivalent) as 282 mm in the x direction and 194 mm in the y direction.

3) “Unix” and “Adobe Reader” are examples of suitable products available commercially. This information is given for the convenience of users of this part of ISO 9241 and does not constitute an endorsement by ISO of these products.

D.3.4 Form A — Visual interpretation of ISO/IEC test chart 3 for computer or external display output

This form is similar to ISO/IEC TR 24705:2005, Form C, for the visual interpretation of the ISO/IEC test chart 3 reproduction for colour devices.

D.3.5 Test report Form B — Visual output at office work places for image area

Form B may be freely copied. For this test, the computer display output in the size 282 mm × 194 mm is recommended. For an external display output, any output size is possible. ISO test chart ME16, according to this part of ISO 9241, is used before ISO/IEC test chart 3 (see Figure D.7) for this test.

Please fill out or mark by **(x):**

ISO test chart: e. g. Test chart 3 for colour devices (write text from frame area of ISO test chart)

Test of achromatic ISO/IEC-test chart 3 for *computer* display (…) of for *external* display (…):

Test of the radial grating (Element A)

N–*W* radial grating:	Is the resolution diameter < 6 mm?	Yes/No
	Test with naked eye and ruler	resolution diameter: .... mm
W–*N* radial grating:	Is the resolution diameter < 6 mm?	Yes/No
	Test with naked eye and ruler	resolution diameter: .... mm
N–*Z* radial grating:	Is the resolution diameter < 6 mm?	Yes/No
	Test with naked eye and ruler	resolution diameter: .... mm
W–*Z* radial grating:	Is the resolution diameter < 6 mm?	Yes/No
	Test with naked eye and ruler	resolution diameter: .... mm

Test of 5 visually equally spaced L^*-grey steps (Element B)

Are all the 5-steps on the upper row distinguishable?	Yes/No
If No: How many steps can be distinguished?	of the given 5 steps: .... steps

Test of 16 visually equally spaced L^*-grey steps (Element C)

Are all the 16-steps on the upper row distinguishable?	Yes/No
If No: How many steps can be distinguished?	of the given 16 steps: .... steps

Test of the Landolt-rings *N*–*W* (Element D)

Is the recognition of gaps in the Landolt-rings > 50 % (5 of 8 at least)?

background–ring	
0–1	Yes/No
7–8	Yes/No
E–F	Yes/No
2–0	Yes/No
8–6	Yes/No
F–D	Yes/No

Test of the line raster under 45° (Element E)

Can equally spaced lines be seen?

Visual testing: equally spaced line raster from 15 lpi to 30 lpi can be seen	Yes/No
Test with a naked eye: Equally spaced line raster can be seen from 15 lpi:	to .... lpi

Test of the line raster under 90° (Element F)

Can equally spaced lines be seen?

Visual testing: equally spaced line raster from 15 lpi to 30 lpi can be seen	Yes/No
Test with a naked eye: equally spaced line raster can be seen from 15 lpi:	to .... lpi

D.3.6 Form B — Visual interpretation of ISO/IEC test chart 3 for computer or external display output

This form is similar to ISO/IEC TR 24705:2005, Form E, for the visual interpretation of the ISO/IEC test chart 3 reproduction for colour devices.

For the test of line rasters, the limit 60 lpi has been reduced to 30 lpi as most of the display output can only resolve up to 30 lpi.

D.4 Future chromatic output linearization based on measurement and visual data

For the colour printer output, a colour output linearization method is defined in ISO/IEC TR 19797, based on the CIELAB measurement data of a first printer output. The second output uses the measurement data and is linearized.

For achromatic monitor output, a visual method for achromatic output linearization has been developed — see the following URL (16 pages, 1,5 MB), which has the title *Visual efficiency for image output on colour monitors*:

http://www.ps.bam.de/VISE05.PDF

There is a first output of five step grey scales. The visual assessment data are used for the second linearized output.

For chromatic monitor output, a visual method for colour output linearization has been developed — see the following URL (8 pages, 1,0 MB):

http://www.ps.bam.de/ME18/10L/L18E00FP.PDF

There is a first output of five step colour scales. The visual assessment data are used for the second linearized output.

For colour display output that considers eight ambient light reflections, a solution can be based on lockup tables. For newer developments, see under “publications” at the following URL:

http://www.ps.bam.de

There could be tools developed for the direct input of, for example, 16 values of the “gamma curves” instead of one “gamma value”. “Gamma curves” are available under the option “Open Profile”, as shown in Figures D.8 and D.9 — see the URL (4 pages, 400 kB)

http://www.ps.bam.de/ME17/10L/L17E00FP.PDF

A four-page file allows the actual input–output relationship to be determined visually: by the assessment of five-step scales (compare pages 3 and 4 with the actual output spacing values 0,10; 0,30 and 0,75 instead of the equal spacing values 0,25; 0,50; 0,75). The calculated inverse input–output relationship on page 4, with 16 steps of the “gamma curve”, could replace the “gamma curve” in the “Open Profile” section. Tools exist in Windows for adjusting the “gamma curve”, but these methods might be too difficult for naive users.

There are other alternatives for output linearization. The 16 page file used here includes a linearization method in the *PS* file. This method can be applied to any *PS* file, if the *PostScript* linearization code is copied, for example, to the “Start-up folder” of the software *Adobe Acrobat Distiller*, which transforms *PS* to *PDF* files. The software uses this linearization code, which includes either visual or measurement output data of the display. This method is appropriate for any computer operating system. However, this method could also be too difficult for naive users.

Bibliography

[1] IEC 61966-2-1, *Multimedia systems and equipment — Colour measurement and management — Part 2-1: Colour management; Default RGB colour space; sRGB*

[2] ISO/IEC 15775:1999, *Information technology — Office machines — Method of specifying image reproduction of colour copying machines by analog test charts — Realisation and application*

[3] ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

[4] ISO/IEC TR 19797:2004, *Information technology — Office machines — Device output of 16 colour scales, output linearization method (LM) and specification of the reproduction properties*

[5] ISO 22028-1:2004, *Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange — Part 1: Architecture and requirements*

[6] ISO/IEC TR 24705, *Information technology — Office machines — Machines for colour image reproduction — Method of specifying image reproduction of colour devices by digital and analog test charts*

[7] *Flat Panel Display Measurements Standard*, Version 2.0, VESA, 2002 [4)]

[8] SP 2.1 (BGI 650), *Workstations and Office Workplaces Design Manual*, 2002, VBG Germany

4) US Video Electronics Standards Association

ICS 13.180; 35.180

Price based on 45 pages