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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This second edition cancels and replaces the first edition (ISO 9241-306:2008), which has been technically revised. The main changes compared to the previous edition are as follows:

— cathode ray tubes (CRT) displays have been added to a new informative Annex E;

— definitions of five chromatic text charts for elementary or device hue output have been added to Annex D.

A list of all parts in the ISO 9241 series can be found on the ISO website.

Introduction

This document is part of the ISO 9241 series which establishes 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 facilitates its revision and amendment, as ongoing technological development enables new forms of display interaction.

This document 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 can be reduced over time. The lighting conditions under which a display is used also often 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 can 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 give 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 met. 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 document do not, in most cases, require expensive measuring equipment and can generally 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 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 is performed to determine how it can be made to meet them. In cases involving the application software, it can be necessary to contact the software developers of the application product in order to ascertain possible corrective action. In cases involving 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, it can be necessary to make arrangements with the relevant interested parties in order to ascertain appropriate actions and their feasibility. For details, see Annex B.

The ISO 9241 series 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 the ISO 9241 series 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 series, (Ergonomics of human-system interaction) reflects these changes and aligns the series with the overall title and scope of Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*. The revised series 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 document 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 documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 9241-303:2011, *Ergonomics of human-system interaction — Part 303: Requirements 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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Preparation for assessment

4.1 Cleaning

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

4.2 Set-up

The visual display shall be physically prepared for assessment. Drive the visual display with the following parameters:

— resolution: use the native resolution or the resolution recommended by the manufacturer;

— in case of CRT, see Annex E;

— image size: adjust to a specified size.

NOTE 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).

a) Physical b) Reduced

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

4.3 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.

NOTE For some technologies, a specific warm-up sequence is sometimes recommended. For example, Electronic Paper Displays (EPD) can recommend that the test pattern be refreshed three times before taking measurements.

4.4 Control settings of the visual display

The manufacturer should deliver the visual display with a factory setting that helps the user to use the visual display in an ergonomic and efficient way within the intended context of use. If available, the user should follow the recommendations given by the manufacturer for the setup conditions.

Addressed controls are the brightness control, the contrast control and the gamma adjustment.

For visual displays that permit grey scale rendering, use the output of the 16-step equally spaced grey scale of test chart AE06 with samples between black and white, see Figure D.2.

In the intended environment, perform a visual check of the following display output properties:

1) The lowest two black levels should just be discriminated.

2) The lightest two white levels should just be discriminated.

3) All grey levels should be distinguishable.

4) The visual display should have an appropriate brightness level.

To achieve these conditions, apply the factory settings and recommendations of the display manufacturer for the setup conditions. If available, use the controls of the visual display to meet the above display output properties.

In a dark room, the 16-step grey scale should be approximately visually equally spaced, if the gamma is adjusted according to IEC 61966-2-1. For any ergonomic output in a non-dark environment, it is intended that the grey scale is approximately equally space. If this output setup stage is reached for the dark environment, then the reflection of the ambient light on the display surface changes the visual equal spacing. The changes increase with increasing ambient reflections on the screen. In the worst case, about 5 dark grey steps may not be distinguishable.

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, in particular character legibility (see Table 1) and in certain cases 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 ≥300 mm (see ISO 9241-303). The optimum viewing distance for desktop office work in a seated position is about 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 desktop 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. Typical applications are to be found in control rooms. Figure 2 shows the relation between viewing angle, application width and viewing distance.

Table 1 — Optimum and maximum viewing distances for character legibility

Character height mm	Viewing distance of generally accepted legibility cm	Maximum viewing distance cm
1,4	—	30
2	33	43
3	49	65
4	66	86
4,6	75	99
9,2	150	197
18,3	300	394

NOTE 1 The maximum viewing distance is based on character height of 16′ of arc. 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;

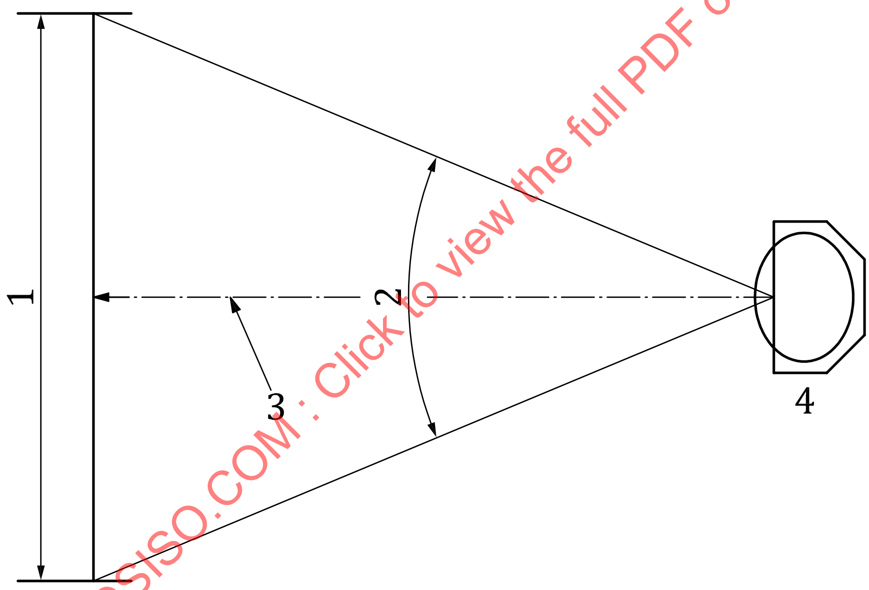
— acceptable range ≈ ±100 % for some users.

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) cm	Minimum viewing distance in order to avoid head movement cm
16	30
21	40
30	56
40	75
50	94
60	112
150	280
300	560

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, *W*

2 viewing angle (±15°)

3 viewing distance, *D*

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 9241-303:2011, 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 in the centre of the visual display. Use:

a) full screen white at maximum grey level;

b) a white box at maximum grey level with a size of 4 % of the active display area, as per Formula (1).

$$A = H_{\text{view}} / 5 \times W_{\text{view}} / 5 \quad (1)$$

where

A is the active display area;

H_{view} is the height of the active display area, measured in meters;

W_{view} is the width of the active display area, measured in meters.

Place the luminance meter perpendicular to the display surface on the target. Verify that the measurement area of the luminance meter is smaller than the target.

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

In case of interest, e.g. for determination of the lowest and highest luminance, repeat the measurement in measurement locations as defined by ISO 9241-307 for the individual technology.

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 can 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 9241-303:2011, 5.3.2.

5.3.2 Wind and rain

See ISO 9241-303:2011, 5.3.3.

5.3.3 Excessive temperatures

See ISO 9241-303:2011, 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 Formula (2):

$$L_{NU} = 100\,\% \left(\frac{L_{max} - L_{min}}{L_{max}} \right) \quad (2)$$

where

L_{NU} is the luminance non-uniformity;

L_{min} is the lowest luminance in cd/m^2;

L_{max} is the highest luminance in cd/m^2.

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 Formula (3):

$$C_{NU} = 100\ \% \left(\frac{C_{max} - C_{min}}{C_{max}} \right) \tag{3}$$

where

C_{NU} is the contrast non-uniformity;

C_{min} is the lowest contrast;

C_{max} is the highest contrast.

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 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)

See ISO 9241-303:2011, 5.4.7.

5.4.7 Spatial instability (jitter)

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 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	Depth of field of the eye False, unwanted (chromo)stereopsis
	Use black or dark grey foreground	Colour identification
Negative polarity, achromatic	Avoid blue as primary colour	Poor legibility. For text presentation, difficult to meet contrast requirements
	Use black or dark grey foreground	Colour identification
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

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

5.5.2 Image polarity

See ISO 9241-303:2011, 5.5.3.

5.5.3 Character height

5.5.3.1 Character height measured with comparator foil

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 Formula (4):

$$\alpha = 60 \times 2 \arctan\left(\frac{h_T}{2 \times D}\right) \approx \frac{3\,438 \times h_T}{D} \qquad (4)$$

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 3).

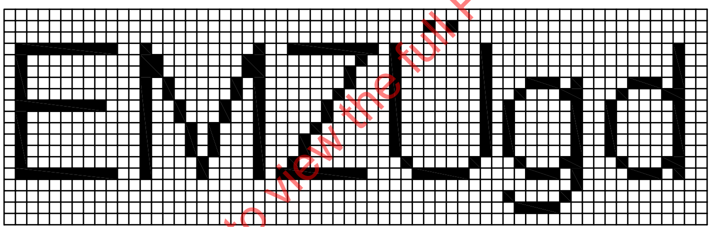


Figure 3 — Zoomed characters within a grid

Calculate the character height as a subtended visual angle, α, in minutes of arc, using Formula (5):

$$\alpha = 60 \times 2 \arctan\left(\frac{n \times s / p}{2 \times D}\right) \approx \frac{3\,438 \times n \times s / p}{D} \qquad (5)$$

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

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 9241-303:2011, 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 4.4.

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

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 9241-303:2011, 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 approximately 200 ms.

   NOTE 1 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 approximately 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 approximately 10 ms and 55 ms. This does not apply to all technologies, like sample-and-hold devices like electronic paper displays.

   NOTE 2 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.

NOTE In case of new pixel structures, and sub-pixel rendering methods are introduced, it is difficult to simply judge the spatial resolution by determining the number of pixel. The spatial resolution can be visually evaluated by rendering different spatial frequency test patterns.

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 is 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

The annex presents an overview of the structure of ISO 9241 (see Table A.1). For an up-to-date overview of its structure, subject areas and the current status of both published and projected parts, please refer to: https://www.iso.org/obp.

The structure reflects the numbering of the original ISO 9241 series; for example, displays were originally Part 3 and are now the 300 series. In each section, the “hundred” is an introduction to the section; for example, Part 100 gives an introduction to the software-ergonomics parts.

Table A.1 — Structure of ISO 9241 Ergonomics of human–system interaction

Part	Title
1	Introduction
2	Job design
11	Hardware and software usability
20	Accessibility and human–system interaction
21–99	Reserved numbers
100	Software ergonomics
200	Human–system interaction processes
300	Displays and display-related hardware
400	Physical input devices — Ergonomics principles
500	Workplace ergonomics
600	Environment ergonomics
700	Control rooms
900	Tactile and haptic interactions

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 9241-303:2011, 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 9241-303:2011, 5.3.2.
5.3.2	Wind and rain			X	See ISO 9241-303:2011, 5.3.3.
5.3.3	Excessive temperatures			X	See ISO 9241-303:2011, 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.
5.4.8	Moiré effects	X	X		

Table B.1 *(continued)*

Subclause	Title	Items (mainly) related to			Remark
		display itself	application software	physical environmental conditions	
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 9241-303:2011, 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		
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).

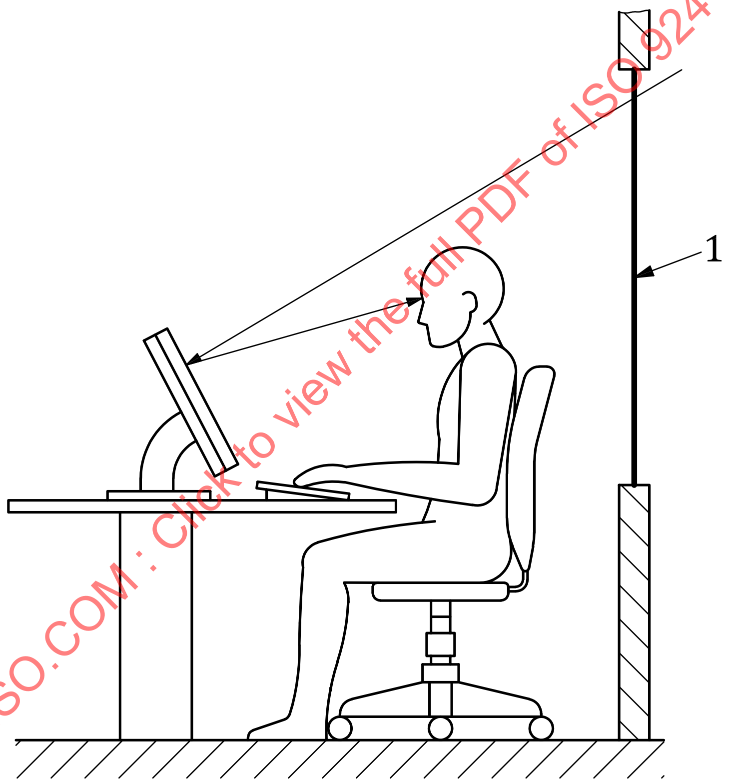
Table B.1 *(continued)*

Subclause	Title	Items (mainly) related to			Remark
		display itself	application software	physical environmental conditions	
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

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

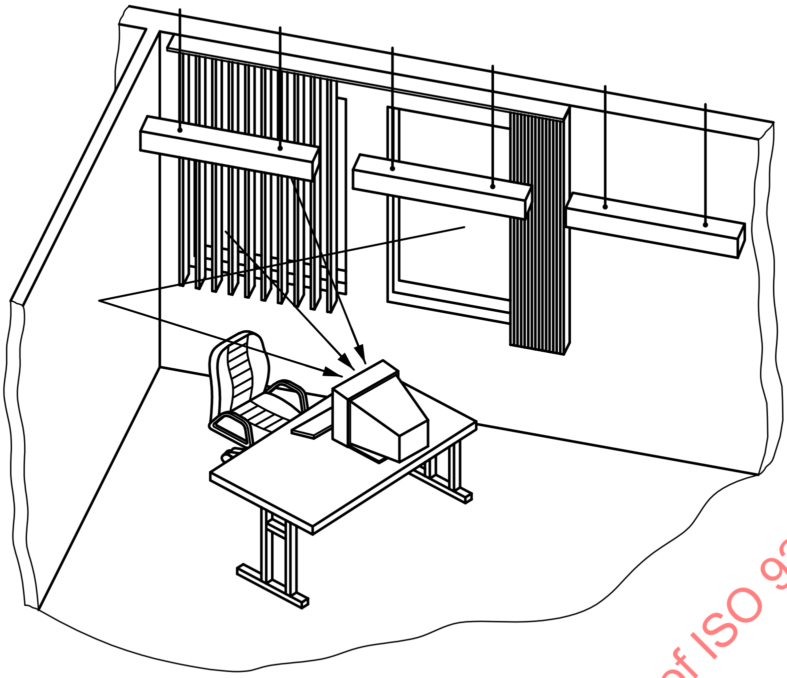
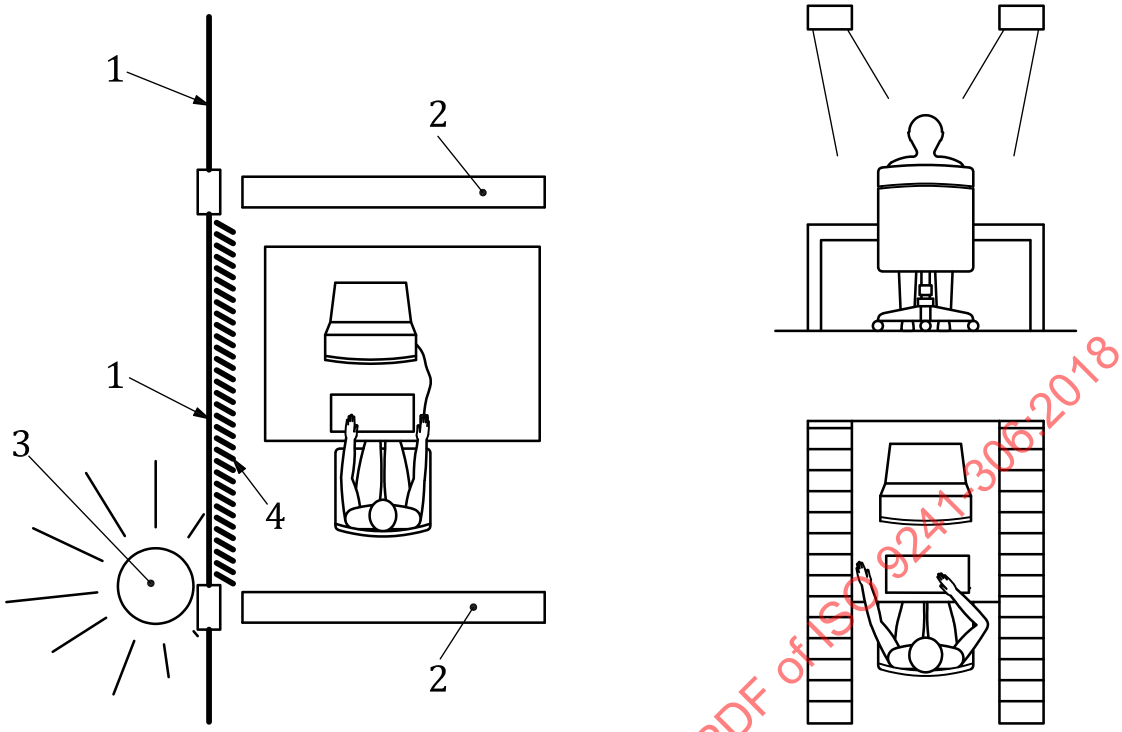


Figure C.2 — Disturbing light sources — Bright surfaces reflecting on screen



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)

Definition and application of test charts for display output linearization for eight different ambient light reflections at office work places

D.1 Introduction, applications and changes compared to the previous edition

In Annex D of the previous edition, one achromatic test chart of ISO/IEC 15775 was used for the output. For eight different ambient light reflections a *simulation file* with eight pages showed different output properties. The output of the simulation file served as a training tool for users. It showed the appearance changes by the output of eight different pages. Now five chromatic test charts are added which can be useful depending on the user application.

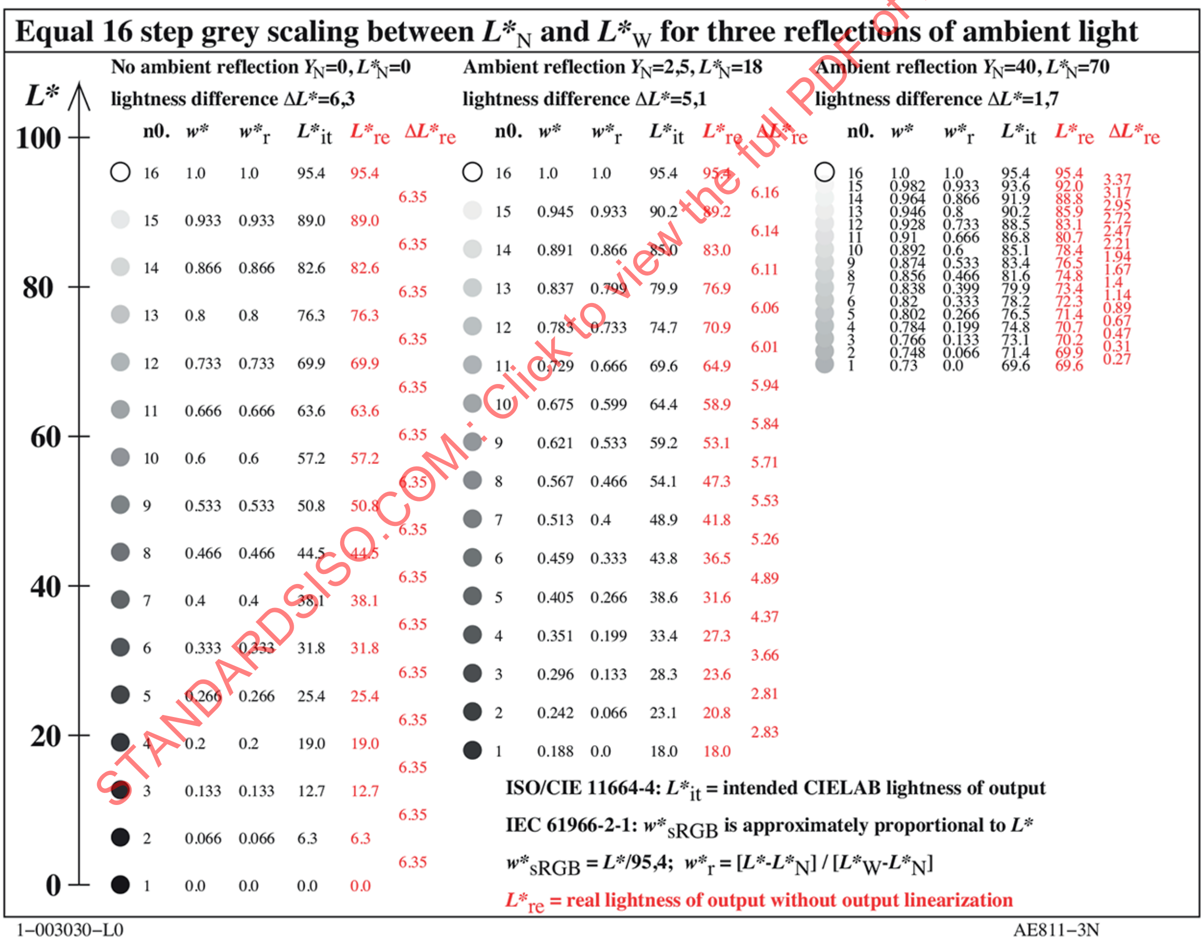


Figure D.1 — Equal 16 step grey series by output of the test chart AE06 according to this document

Figure D.1 illustrates a common problem for emissive displays under ambient illumination. The viewed luminance is the sum of the luminance of the emissive part and the luminance of the ambient reflection on the display. The ambient reflection produces a fixed dark grey step or offset. In a dark room, there is no ambient reflections, and the lightness offset is zero (L^*_N = 0). But when there is some illumination on the display, the lightness offset increases. Figure D.1 illustrates examples where L^*_N = 18 (which is regarded as the standard case), and where L^*_N = 70 is considered a worst case. It is the ergonomic goal that the grey series between any L^*_N and the maximum white lightness (L^*_W) are always equally spaced in the output.

Figure D.1 shows three cases, each with 16 step grey scales between three different any L^*_N and the maximum white lightness L^*_W . Following ISO/IEC 11664-4, the three darkest colours of the three cases have the CIELAB lightness L^*_N=0 (no reflection), 18 (standard reflection), and 70 (large reflection) in the viewing situation. The lightness of white is equal for the three cases, having the value L^*_W = 95,4. This value is the CIE lightness of the standard offset paper under the CIE measuring geometry 45/0 degree and the CIE standard illuminant D65, see ISO/IEC 15775. In colorimetry, the relative lightness l^*_r is defined by Formula (D.1):

$$l^*_r = (L^* - L^*_N) \,/\, (L^*_W - L^*_N) \qquad \text{(D.1)}$$

For image technology, the *sRGB* standard IEC 61966-2-1 defines for grey colours three equal values rgb^*_{sRGB}. One can call this visual attribute the “relative whiteness” with the value 0 for the darkest grey in the series and the value 1 for white [see Formula (D.2)].

$$l^*_r = w^*_r \qquad \text{(D.2)}$$

For the equally spaced input data $w^* = r^* = g^* = b^*$ the standard IEC 61966-2-1 shall produce equally spaced relative output series in relative lightness. The *sRGB* standard realizes that for surface colours. For display colours it is realized *only without* any reflection of the ambient light. In this ideal case, the standard IEC 61966-2-1 produces the equally spaced (intended) lightness L^*_{it} for equally spaced input values w^* *or* w^*_r, see Figure D.1.

This IEC goal matches in this ideal case the goal of ergonomics. However, if the *sRGB* standard is applied for any reflection of the ambient light, the relative lightness l^*_r is no longer proportional to the input value w^*_r. In the worst case, about 5 dark grey steps of the 16 grey steps are not distinguishable. The lightness differences ΔL^*_{re} of the real output vary between 0,27 and 3,37 in the last column of Figure D.1. Five steps have a lightness difference below the threshold (ΔL^*_{re} = 1). Therefore the *sRGB* standard fails for a basic goal of ergonomics to produce an equally spaced grey series with the intended lightness difference ΔL^*_{it} = 1,7 [=(95,4-70)/15], see Figure D.1 in the last column.

At work places using emissive displays, there is usually a reflection equal or larger than L^*_N = 2,5. This corresponds to about 18 % of the lightness scale. This reflection decreases the ideal lightness difference of ΔL^* = 6,3 to ΔL^* = 5,1. According to Figure D.1, a further decrease to ΔL^* = 1,7 is expected for an ambient reflection of Y_N = 40. This can happen for projector displays and LCD displays with reflection from strong daylight. Therefore, it is expected that readability decreases by a similar amount. It is the goal of ergonomics to optimize the readability and not to lose contrast. This is possible with an output linearization method. It is critical that in applications ranging from material science to medicine that the contrast information is preserved. It is desirable that the 16 grey steps are visible at any of the eight luminance contrast steps 288:1 (C_{Y8}) towards the standard contrast step 36:1 (C_{Y5}) to the low contrast step 2,25:1 (C_{Y1}), which is defined in Table D.4.

One can study further the grey discrimination in Figure D.8 without and with output linearization. More information about a similar change for 16 step colour series is given in Figure D.9. The colour gamut reduces by a factor 9 (=3 × 3) for the contrast step C_{Y1} compared to the standard contrast step C_{Y5}. However, the 16 grey and colour steps can still be visible if output linearization is used.

For the usual emissive displays, the *sRGB* colour space is only able to match the ergonomic goal without any ambient reflection. However, this can happen only in a dark room. Even in this case, a black sample on the screen is illuminated by some stray light, for example of the white parts of the display. The case where there are no reflections is not a standard ergonomic situation.

For reflective displays, for example electronic paper displays, the *sRGB* standard produces the intended lightness L^*_{it} which is equally spaced for equally spaced input values. For reflective displays and surface colours, the contrast does not depend on the ambient illumination.

In the previous edition, a software tool was described that takes the real display output of the standard file (according to this document and ISO/IEC 15775) and linearizes the output of the whole computer or external (projector) display for the given ambient lighting environment of the office work place. This software tool for output linearization produces 16 equally spaced grey samples for any common ambient light reflection at the office work place. The method is called output linearization because it produces 16 equally spaced grey steps for 16 equally spaced *rgb*-data in the file between 0 and 1. The equally spaced output is defined as the ergonomic viewing condition for the given ambient light reflection on the screen viewed by the user. After output linearization, usually all greys can be distinguished and there is no loss of information.

The viewed luminance of Black and White is not changed by this software tool. However, for equal visual spacing between the given Black and White, different exponential functions are necessary. The exponent changes between the exponent 1/2,4 (for large luminance differences and a high luminance ratio 288:1 between White and Black), and the exponent 1/1,1 for small luminance differences or a low luminance ratio 2:1 between White and Black. A software tool allows the necessary change of the exponent which is known as a “gamma change” of the output.

Most computer displays now produce a colour output based on *rgb*-data in the file. Therefore, two standard colour files of ISO/IEC 15775 and ISO/IEC TR 24705 are added. They include 16 step series between device Black and six device colours Red, Green, Blue, Cyan, Magenta, and Yellow, and an ISO/IEC-image. However, the scales between White and the six colours are missing. It is appropriate to add these scales and the device-independent elementary colours. Annex D recommends different chromatic test charts, with advantages and disadvantages depending on the application.

Similarly to the 2008 edition, the following clauses present the information in the following parts:

— D.2 — Definition of six test charts of this document for elementary or device hue output

— D.3 — Definition of eight contrast steps for elementary or device hue output

— D.4 — Output simulation for six test charts of this document and for eight contrast steps

— D.5 — Software tool for output linearization of the six original test files

— D.6 — Test reports by visual inspection of outputs in the central and frame area

— D.7 — Colour output of an example *sRGB* printer device and *rgb** devices

Clause D.7 includes additional information about the device-independent hue output and advantages and disadvantages of the *sRGB* output according to IEC 61966-2-1 and the *rgb** output. The *rgb** output produces a device-independent hue output and an equally spaced output for 5, 9 and 16 step colour scales.

D.2 Definition of six test charts of this document for elementary or device hue output

D.2.1 Definition of six test charts for elementary hue output

The ambient light reflections on the screens of computer and projector displays change the luminance contrast, for example between white W and Black N. This report considers 8 luminance contrast steps C_{Y1} to C_{Y8} between 288:1 and 2:1. The last (worst) case can happen in offices with significant daylight reflection on the screen, but is usually only for projector screens illuminated by daylight and the projector. The standard contrast case 36:1 (with the tristimulus values Y_W = 88,6 and Y_N = 2,5) is adopted from standard offset colours according to ISO/IEC 15775 and taken as a reference.

Depending on the application and the preference of the user, six test charts are proposed. One achromatic test chart AE06 and two chromatic test charts AE17 and AE27 of ISO/IEC 15775 are recommended. In addition, a test chart AE36 is used and two modifications AE46 and AE56. The equal spacing of the 16 step or 9 step colour series can be evaluated with five of the six test chart. Additional evaluations can be appropriate depending on applications. For example, a test of the device-independent elementary hue output and of the equal hue spacing can be conducted with the test chart AE056. All six test charts are shown in Figures D.2 to D.7.

NOTE The first four test charts in the ISO Standard Maintenance Portal (http://standards.iso.org/iso/9241/306/ed-2/index.html) are modified versions of the test charts in [6] and [9] for eight display reflections.

The test charts AE46 and AE56 are since 2009 public test charts on a TUB server, see for example http://standards.iso.org/iso/9241/306/ed-2/GE20/index.html.

The test charts of References [5], [6] and [9] have been used as the starting point for this document.

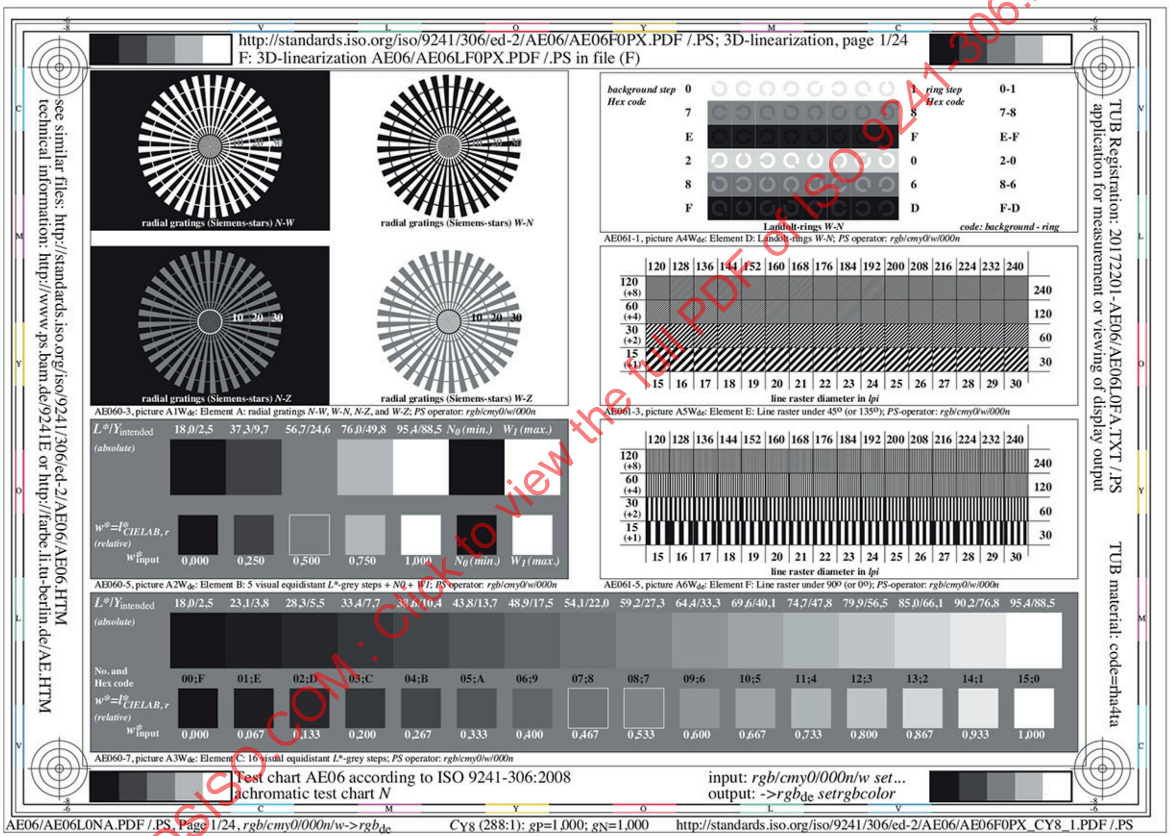


Figure D.2 — Achromatic test chart AE06 according to ISO 9241-306:2008

Figure D.2 shows the achromatic test chart AE06 according to this document. This test chart is identical to the test charts No. 3 according to ISO/IEC 15775.

Figures D.3 to D.6 show 5 additional chromatic test charts. Depending on the application, at least the use of the achromatic and one of five chromatic test charts is recommended.

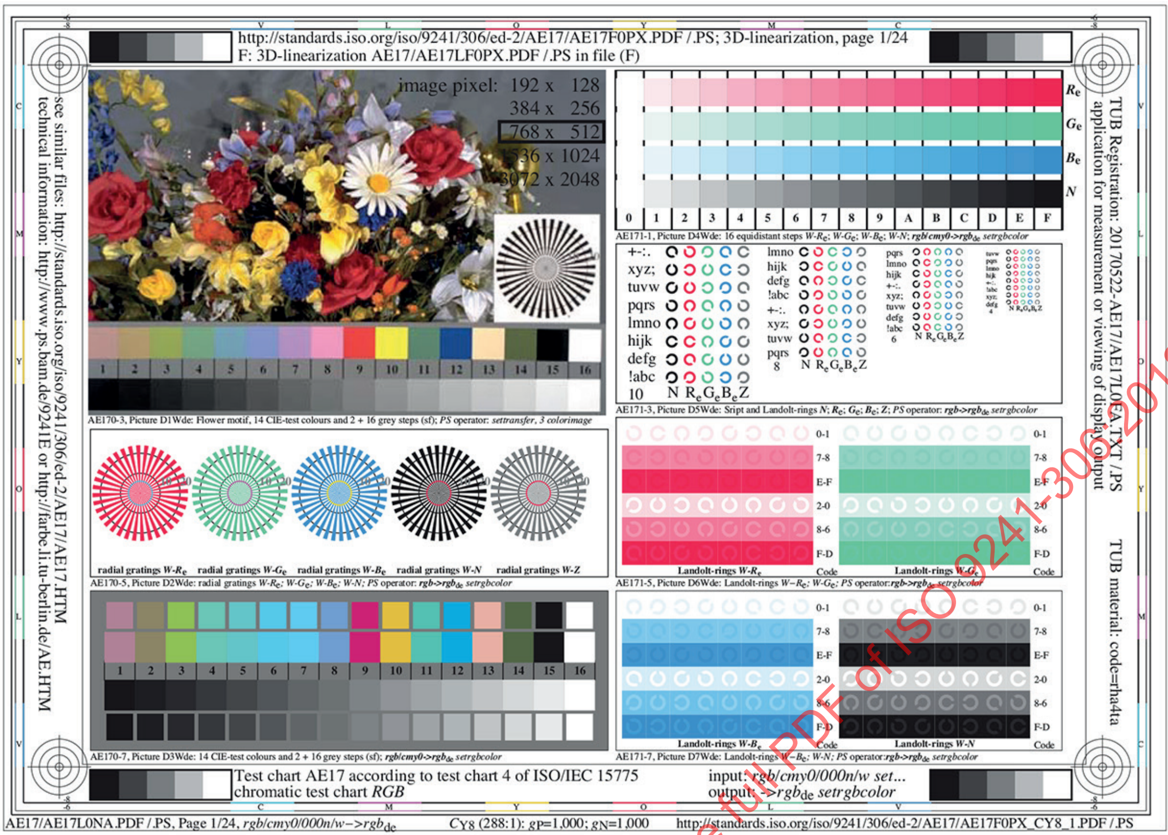


Figure D.3 — Chromatic test chart AE17 according to Test chart 4 from ISO/IEC 15775

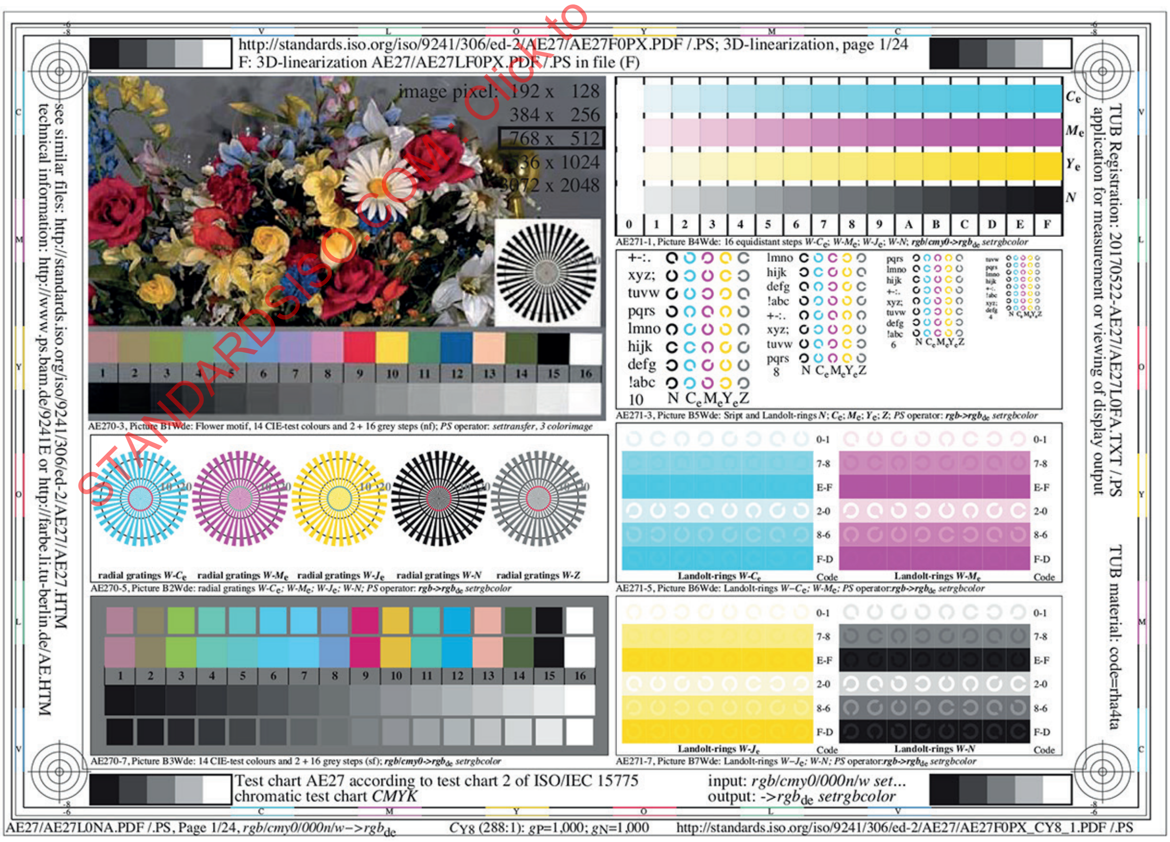


Figure D.4 — Chromatic test chart AE27 according to Test chart 2 from ISO/IEC 15775

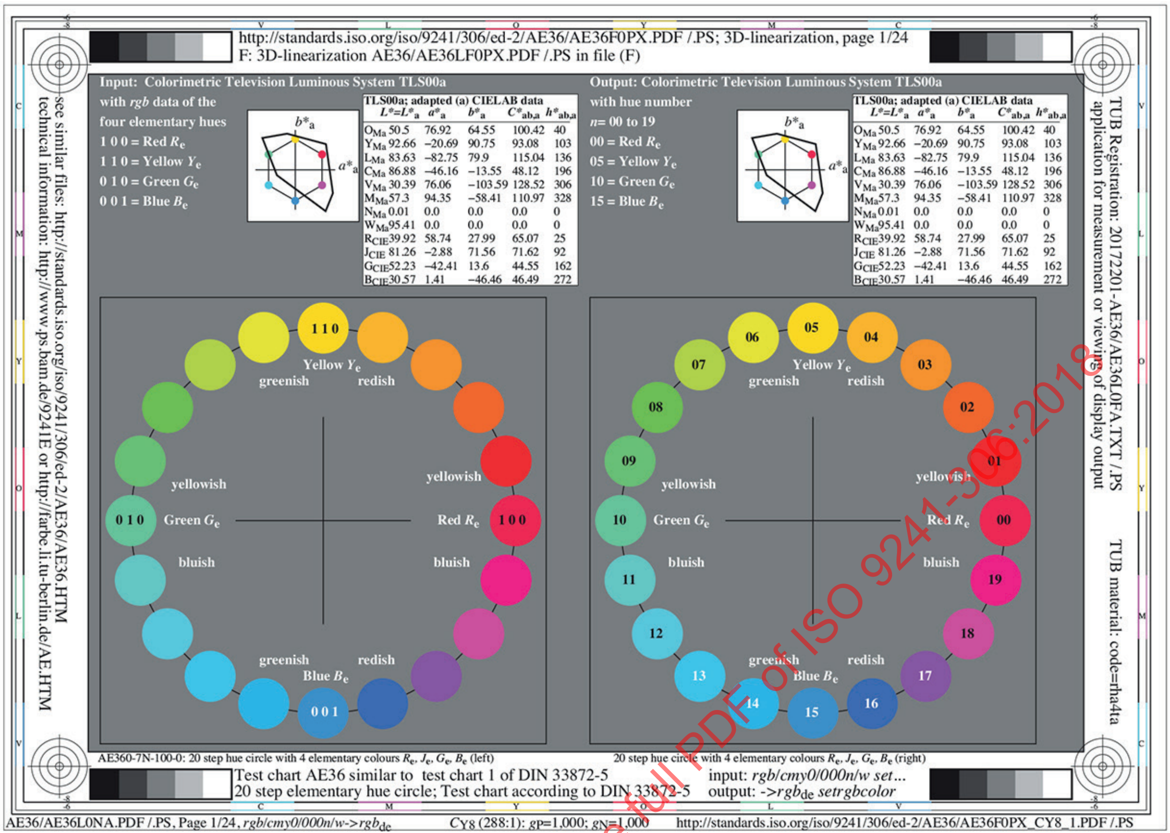


Figure D.5 — Chromatic test chart AE36 according to DIN 33872-5

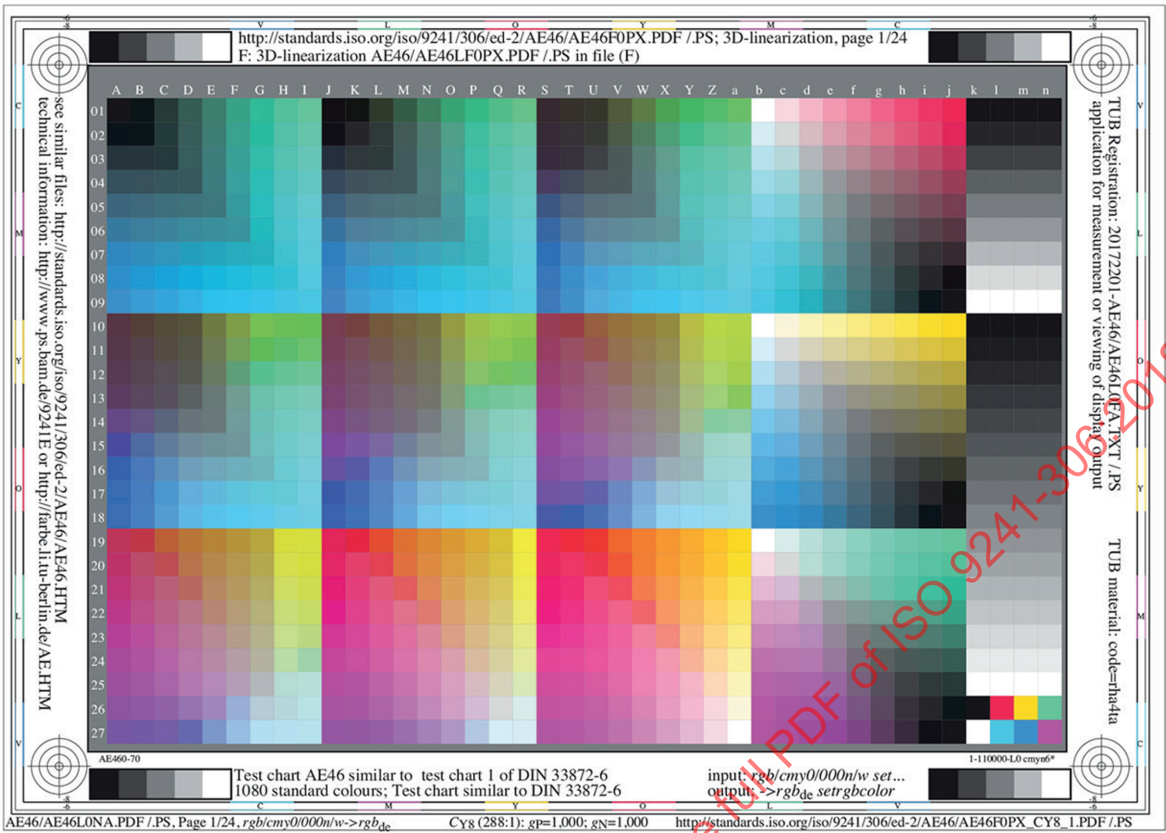


Figure D.6 — Chromatic test chart AE46 with similar parts compared to the test chart 1 from DIN 33872-6

Within the columns b to i the test chart AE56 shows colours in three basic hue planes which are identical to the colours in the three basic hue planes in the lines 10 to 18 of DIN 33872-6**.** The 729 (= 9 × 9 × 9) colours in the columns A to a and the rows 01 to 27 have nine equally spaced *rgb* data in the file between 0 and 1 and can be used for a visual test of the regular spacing of the output. One can find in the offset print of Reference [11] the content of the test chart AE46, and in addition prints of the content of the test charts AE06, and AE17.

Figure D.7 — Chromatic test chart AE56 with similar parts compared to test chart 1 from DIN 33872-6

Within the columns A to I, the test chart AE56 shows colours in three basic hue planes which are identical to the colours in the three basic hue planes in lines 10 to 18 of DIN 33872-6. In addition, the colours in nine intermediate hue planes are shown. Colours in intermediate hue planes are also used in DIN 33872-2. However, the test chart AE56 uses 9 step colour scales and DIN 33872-2 uses 5 and 16 step colours scales.

There are similar changes to all test charts by the screen reflections of the ambient light. Depending on the starting properties of the screen colours and the “starting gamma”, the output can be very different. The spacing of the achromatic 16 step scales, the elementary hue output, and the spacing of the 16 step colour circle are main evaluations. All evaluations are possible by the human visual system at the work place without any measurement equipment and for eight steps of screen reflections. The ISO committee TC159/SC4/WG2 defined in 2007 wishes for the output of hue and scaling by the following statements:

Table D.1 — Conclusion of ISO TC159/ SC4/WG2 for a device-independent *RGB colour space**

Conclusion 31/2007 ISO TC159/SC4/WG2
Ergonomics - Visual Display Requirements

ISO TC159/SC4/WG2 realizes that the colour spaces CIELAB and CIELUV of ***CIE Division 1*** will soon become ISO/CIE standards. In applications we use these CIE colour spaces and *device-dependent* relative RGB colour spaces. For users of visual display systems a *device-independent* RGB colour space is useful. This produces via software the elementary hues Red, Green and Blue for the RGB data 100, 010 and 001 and equally spaced output in CIE colour spaces for equally spaced RGB input. We recommend that ***CIE Division 1*** study the colorimetric definition of such a space, which can be used in visual display applications.

Remark: We have realized that an example colour space of this type is published in CIE X030:2006, p. 139-144.

AE700−1N

Table D.1 shows a Conclusion of the ISO committee TC 159/SC 4/WG 2 “Visual Display Requirements”, being a request for the definition of the elementary hues by CIE Division 1 *Vision and Colour*. (CIE Division 1 is the appropriate body to study the colour problems and to produce guidance.) A star (*) was added in Reference [12] to indicate equal spacing in CIELAB[10] with the coordinates *L**, *b**, and *b**.

Table D.2 — Elementary hue angles h_{ab} according to the standard series DIN 33872-1 to -6:2010

Elementary colour and CIE illuminant		CIELAB data, CIE tristimulus values and CIE chromaticity for the CIE standard illuminants D65 and D50 and the 2 degree observer									
CIE-test colour	Illuminant	L^*	a^*	b^*	C^*_{ab}	h_{ab}	X	Y	Z	x	y
09, Red ***R***	D65	40,04	58,98	28,32	65,43	25,7	20,64	11,27	4,34	0,5693	0,3110
10, Yellow ***Y***		81,30	-2,99	71,82	71,89	92,4	54,89	59,01	12,02	0,4359	0,4686
11, Green ***G***		52,27	-42,40	13,64	44,54	162,2	12,15	20,38	15,34	0,2538	0,4258
12, Blue ***B***		30,52	1,21	-46,35	46,37	271,5	6,24	6,45	27,59	0,1550	0,1601
09, Red ***R***	D50	41,88	62,00	31,82	69,69	27,2	23,31	12,42	3,24	0,5982	0,3188
10, Yellow ***Y***		81,97	1,81	71,59	71,61	88,5	58,84	60,24	9,50	0,4576	0,4685
11, Green ***G***		51,62	-41,12	11,52	42,70	164,4	12,10	19,81	11,95	0,2759	0,4515
12, Blue ***B***		29,20	-5,28	-49,34	49,62	263,9	5,25	5,92	21,25	0,1621	0,1825

AE780-1

Table D.2 includes colorimetric data of the four CIE-test colours no. 09 to 12 according to the CIE Publication 13.3[14] for colour rendering. In 13.3, these four test colours are called “strong” Red, Yellow, Green and Blue. Table D.2 is identical to Table 7 of the “Colorimetric supplement for DIN 33872-1 to -6”. This paper shows in Table 5 and 6 on page 32 and the corresponding text, why the four hue angles of the CIE-test colours no. 09 to 12 are used in DIN 33872-5 as the hue angles of the four elementary colours Red R_e, Yellow Y_e, Green G_e, and Blue B_e. The four elementary hue angles h_{ab} = 26, 92, 162, and 272 appear in the output of the DIN-test chart according to DIN 33872-5 and in the ISO-test chart AE36 of Annex D.

D.3 Definition of eight contrast steps for elementary or device hue output

The standard IEC 61966-2-1 defines the tristimulus values of the screen without any ambient reflections. This property is unusual in applications. There are large changes of the colours and the colour gamut by the ambient reflections. In addition, the equal spacing of 16 step scales is destroyed and some of the 16 steps are indistinguishable in some applications.

Table D.3 — CIE data according to IEC 61966-2-1

Basic television colour or mixture colour for D65 CIE data for Y_W=100	chromaticity		tristimulus values (*Y=100,00 for white D65*)			Standard CIELAB data LAB^*_d (*L*=100,00 for white; L*=0,00 for black*)				
	x_d	y_d	X_d	Y_d	Z_d	L^*_d	a^*_d	b^*_d	$C^*_{ab,d}$	$h_{ab,d}$
three additive mixture colours: television colours according to ITU-R BT.709-3										
C_d cyan (cyan blue)	0,225	0,329	53,91	78,74	106.97	91,11	-48,08	-14,12	48,12	196
M_d magenta (magenta red)	0,321	0,154	59,29	28,48	96,99	60,32	98,23	-60,82	110,97	328
Y_d yellow	0,419	0,505	77,00	92,78	13,85	97,14	-21,56	94,48	93,07	103
three additive basic colours: television colours according to ITU-R BT.709-3										
R_d Red (orange red)	0,640	0,330	41,24	21,26	1,93	53,24	80,08	67,20	100,42	40
G_d Green (leaf green)	0,300	0,600	35,76	71,52	11,92	87,74	-86,18	83,18	115,04	136
B_d Blue (violet blue)	0,150	0,060	18,05	7,22	95,05	32,30	79,19	-107,85	128,52	306
achromatic colours:										
W -	-	-	-	-	-	-	-	-	-	-
W1 (white monitor, 100%)	0,313	0,329	95,05	100,00	108,90	100,00	0,00	0,00	0,00	0
N (black monitor, 0,00%)	0,313	0,329	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0
N0 -	-	-	-	-	-	-	-	-	-	-

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Table D.3 includes the basic and calculated data by CIE colorimetry for the CIE standard illuminant D65. The chromaticity data and the tristimulus value Y of the three sRGB device primaries are given in IEC 61966-2-1. For the tristimulus value of White, it is valid $Y_W = Y_{Rd} + Y_{Gd} + Y_{Bd} = 100$.

NOTE For similar table data for the normalization $Y_W = 88,59$ instead of $Y_W = 100$ and for eight contrast steps see http://standards.iso.org/iso/9241/306/ed-2/AE80L0NP.PDF.

All data assume no reflection on the screen. This can happen in a dark room. However, even in this case there is a contrast reduction by stray light of the visual system (which increases with the age of the observers) and stray light within the screen surface. Therefore, in practical cases the tristimulus value Y_N of Black is never zero. The contrast ratio $Y_W/Y_N = 100 / 0,35 = 288$ can be reached in an ideal case and is assumed in the Tables D.4 to D.6. Instead of $Y_W = 100$ ($L^*_W = 100$) in Table D.3, the following Tables D.4 to D.6 include for White the tristimulus value $Y_W = 88,9$ ($L^*_W = 95,4$). ISO/IEC 15775 uses these data for the standard offset paper. For comparison of printed and display colours it is essential to use the same normalization. Therefore, it is appropriate to use the normalization according to ISO/IEC 15775 in this Annex D, which is different compared to the normalization of IEC 61966-2-1 in Table D.3.

Table D.4 — Contrast steps C_{Y1} to C_{Y8} and luminances for offset paper and data projector displays

Contrast step C_{Yi} (i=1 to 8), CIE tristimulus values Y_W and Y_N according to ISO 9241–306 1)					
Contrast step C_{Yi} and Y -ratio (i=1 .. 8)	**CIE tristi-mulus value; ratio $Y_W : Y_N$ White W and Black N**	**CIE tristi-mulus value; range Y_{N1} ... Y_{N2}**	**Paper (S) lumi-nance 2); ratio [cd/m²] $L_{WS} : L_{NS}$**	**Display (E) lumi-nance 2); ratio [cd/m²] $L_{WE} : L_{NE}$**	**application and colour mode at work place; illuminance on display 500 lux or 250/125/62 lux**
C_{Y8} 288:1	88,9 : 0,31	0,00 ... <0,46	142 : 142/288	142*36 : 018	display, only 062 lux
C_{Y7} 144:1	88,9 : 0,62	0,46 ... <0,93	142 : 142/144	142*36 : 035	display, only 125 lux
C_{Y6} 72:1	88,9 : 1,25	0,93 ... <1,87	142 : 142/72	142*36 : 071	display, only 250 lux
C_{Y5} 36:1	**88,9 : 2,50**	**1,87 ... <3,75**	**142 : 142/36**	**142*36 : 142**	**display and surface**
C_{Y4} 18:1	88,9 : 5,00	3,75 ... <7,50	142 : 142/18	142*18 : 142	display and surface
C_{Y3} 9:1	88,9 : 10,0	7,50 ... <15,0	142 : 142/09	142*09 : 142	display and surface
C_{Y2} 4,5:1	88,9 : 20,0	15,0 ... <30,0	142 : 142/4,5	142*4,5 : 142	display and surface
C_{Y1} 2,25:1 3)	88,9 : 40,0	30,0 ... <60,0	142 : 142/2,25	142*2,25 : 142	display and surface

1) The example is intended for data projectors (P). The standard contrast step (bold) L_{WP}=142*36 cd/m² is hard to reach.
2) 500 lux corresponds to the viewing luminance L_v=142 cd/m² for the standard offset paper (S) with the tristimulus value Y_W=88,9.
3) For the contrast C_Y=2:1 the viewing luminances of both the black in the projection and the white standard offset paper are equal (!). Visual fatigue caused by the adaptation luminance ratio 36:1 of the black at the screen and the black at the paper shall be reduced. If for example a grey screen with the CIE tristimulus value Y_Z = 22,2 (=0,25*88.9) is used the contrast step C_{Yi} remains constant. Then the luminance ratio of all colours at the screen and the paper has reduced to 9:1. This reduces visual fatigue.

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Table D.4 shows in the first column the contrast steps C_{Y1} to C_{Y8}. According to ISO/IEC 15775 for offset print on standard offset paper, the **standard** contrast step C_{Y5} is reached (see bold line). The standard output has the contrast value 36:1, which corresponds to the tristimulus value ratio $Y_W:Y_N = 88,6:2,5$ of White and Black. The offset **standard** contrast step C_{Y5} is accepted as a high-quality contrast. The silky matte black of offset print has for the CIE 45/0 measuring and viewing geometry the luminance reflection 2,5 % reflection ($Y_N = 2,5$). Usually all matte blacks of surface colours have a luminance reflection near 4 %, so usually the contrast step can be one step lower.

In offices and at many work places the illuminance is 500 lux, see Reference [13].

The illuminance 500 lux produces the luminance 142 cd/m² for the white offset paper with the tristimulus value 88,6. Therefore the printed offset black has the luminance 142 cd/m² divided by 36, which is about 4 cd/m².

In Table D.4, it is assumed that the illuminance 500 lux produces the luminance 142 cd/m² on a white projection screen similar to offset paper. Then, for example, a data projector must produce a 36 times greater luminance to reach the standard contrast step C_{Y5} of offset paper. Data projectors do not usually reach these luminance values on the projection screen. Therefore, the visual change as function of contrast step needs to be considered. The illuminance on the projection screen can, for example, be reduced to 62 lux instead of 500 lux in order to reach the larger contrast step by utilizing window shutters.

More information about the eight contrast steps for displays is given below.

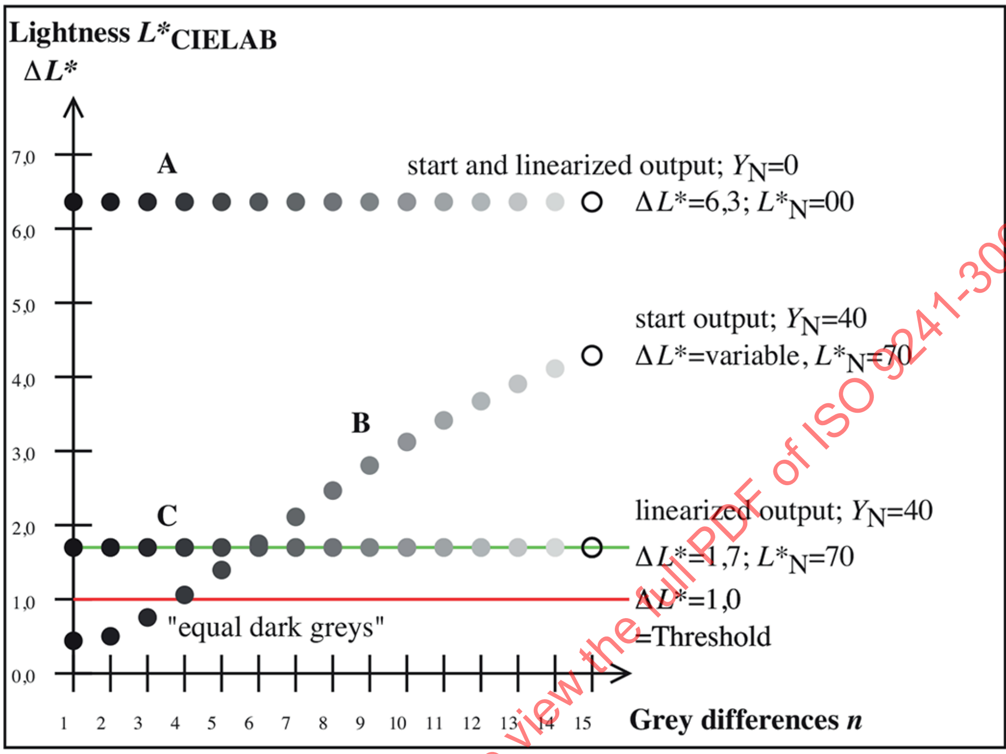

Figure D.8 — Change of 15 sample differences for the tristimulus values Y_N = 0,3 and 40.

Figure D.8 shows the change of 15 sample differences for two different luminance reflections at the emissive or data projector display.

In a dark room, and for equal colour input values *r* = *g* = *b* of the *sRGB* colour space according to IEC 61966-2-1, the output produces equally spaced grey steps with a lightness difference of delta L^* = 6,3. Then the largest contrast step C_{Y8} is reached.

In Figure D.8, in an office with significant daylight, the ambient light reflection can produce the tristimulus value Y_N = 40 for Black *N*, and subsequently yield the lowest contrast step C_{Y1}. In this case, the illuminance of a data projector at the screen is about equal compared to the ambient illuminance. This scenario has four grey differences that are below the noticeable difference threshold (delta L^* = 1, *red* line in Figure D.8) and appear as black.

However, in Figure D.8, a *linearized output* produces 15 equal grey differences with delta L^*=2.3. Therefore, a 16 step equally spaced grey scale is visible again. However, the grey difference is by about a factor three smaller compared to the dark room condition.

In general, equally spaced grey and colour scales in a dark room are no longer equally spaced for increased display reflections produced by the ambient light. It can be shown by colorimetry that an appropriate “gamma change” produces the intended linearized output for any display reflection.

Table D.5 — Contrast steps, display and room illuminance and discriminable grey steps

Contrast step C_{Yi} (i=1 to 8), CIE tristimulus value Y_N, grey steps according to ISO 9241-306[1)]						
Contrast step C_{Yi} and Y-ratio (i=1 .. 8)	**CIE tristimulus value Y_N and CIE lightness L^*_N of black**	**total viewing display illuminance E_{P+R} [lux][3)]**	**measured projector (P) display illuminance E_P [lux][3)]**	**room light (R) display illuminance E_R [lux][3)]**	**grey steps without output linearisation $L^*=1$ amount a_n[2)]**	**grey steps with output linearisation $L^*=1$ amount a_l[2)]**
C_{Y8} **288:1**	0,31 / 1	80000+64000	143500	500	47 (max)	94 (max)
C_{Y7} **144:1**	0,62 / 6	40000+32000	61500	500	44	88
C_{Y6} **72:1**	1,25 / 11	20000+16000	35500	500	42	84
C_{Y5} **36:1**	**2,5 / 18**	**10000+8000**	**17500**	**500**	**38**	**77**
C_{Y4} **18:1**	5,0 / 27	5000+4000	8500	500	34	68
C_{Y3} **9:1**	10 / 38	2500+2000	4000	500	28	57
C_{Y2} **4,5:1**	20 / 52	1250+1000	1750	500	21	43
C_{Y1} **2,25:1**	40 / 70	625+500	625	500	12	25

1) The example is intended for data projectors (P). The standard contrast step (bold) C_{Y5} = 36:1 is hard to reach.
2) For the amount of discriminable colour steps use the equations: $c_n = a_n^3$ or $c_l = a_l^3$, for example $c_n = 4096$ for $a_n = 16$.
3) For the contrast C_Y=2:1 the viewing luminances of both the black in the projection and the white standard offset paper are equal (!).
Visual fatigue caused by the adaptation luminance ratio 36:1 of the black at the screen and the black at the paper shall be reduced.
If for example a grey screen with the CIE tristimulus value Y_Z = 22,2 (=0,25*88.9) is used the contrast step C_{Yi} remains constant.
Then the luminance ratio of all colours at the screen and the paper has reduced to 9:1. This reduces visual fatigue.

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For eight contrast steps, Table D.5 shows the example where the introduction of the room illuminance to the projector screen illuminancereduces the number of distinguishable grey steps a_n to between 12 <= a_n <= 47. The application of output linearization doubles the number of visible grey steps to 25 <= a_l <= 94.

Table D.5 shows the amount of distinguishable grey and colour steps with and without output linearization. The introduction of ambient reflections also reduces the colour gamut.

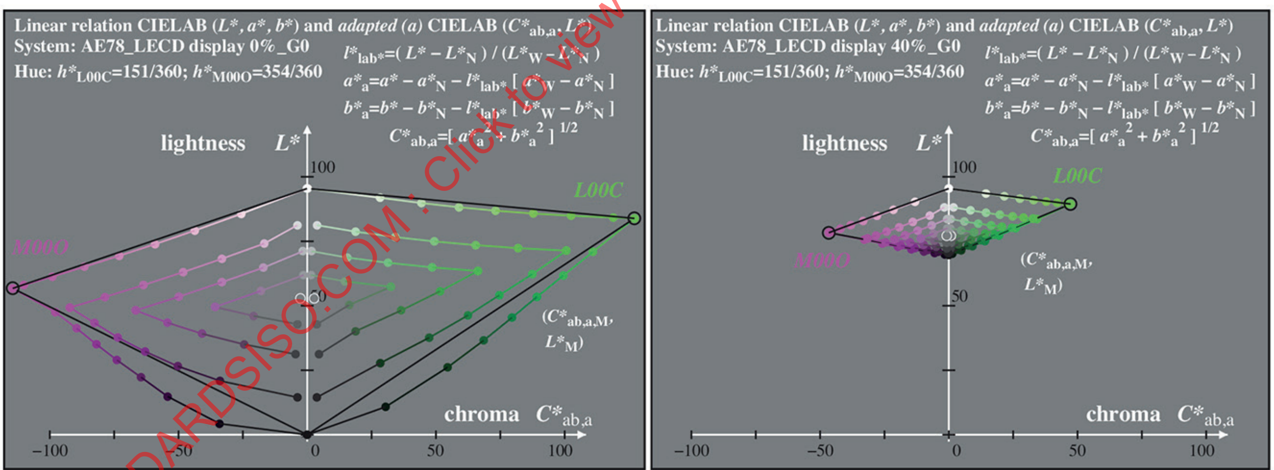

Figure D.9 — Change of 15 sample differences for the tristimulus values Y_N = 0,3 and 40

Figure D.9 shows the colour output of a real colour display with the tristimulus value of black Y_N = 0,3 *(left)* and Y_N = 40 (right), for a non-linearized colour spacing. The CIELAB values for lightness and chroma are reduced by a factor. Therefore, the colour gamut shrinks by a factor 9. The visual difference of the 9 steps decreases near black, compare Figure D.9 *(right).*

Table D.6 — Contrast steps C_{Y1} to C_{Y8} and gamma values for emissive and data projector displays

Contrast step C_{Yi} (i=1 to 8) and absolute and relative Gamma according to ISO 9241-306[1)]

Contrast step C_{Yi} and Y -ratio (i=1 .. 8)	**CIE tristimulus value; ratio $Y_W : Y_N$ White W and Black N**	**CIE tristimulus value; range Y_{N1} ... Y_{N2}**	**absolute Gamma** G_{Pk}(k=0 to 7) **for display (P) with G_{P0}=2,4**[2)] **G_{Pk}=2,4-0,18k**	**relative Gamma** g_{Pk}(k=0 to 7) **for display (P) with G_{P0}=2,4**[2)] **g_{Pk}=G_{Pk}/2,4**	**application and colour mode at work place; illuminance on display 500 lux or 250/125/62 lux**
C_{Y8} **288:1**	88,9 : 0,31	0,00 ... <0,46	G_{P0} = 2,40	g_{P0} = 1,000	display, only 062 lux
C_{Y7} **144:1**	88,9 : 0,62	0,46 ... <0,93	G_{P1} = 2,22	g_{P1} = 0,925	display, only 125 lux
C_{Y6} **72:1**	88,9 : 1,25	0,93 ... <1,87	G_{P2} = 2,04	g_{P2} = 0,850	display, only 250 lux
C_{Y5} **36:1**	**88,9 : 2,50**	**1,87 ... <3,75**	**G_{P3} = 1,86**	**g_{P3} = 0,775**	**display and surface**
C_{Y4} **18:1**	88,9 : 5,00	3,75 ... <7,50	G_{P4} = 1,68	g_{P4} = 0,700	display and surface
C_{Y3} **9:1**	88,9 : 10,0	7,50 ... <15,0	G_{P5} = 1,50	g_{P5} = 0,625	display and surface
C_{Y2} **4,5:1**	88,9 : 20,0	15,0 ... <30,0	G_{P6} = 1,32	g_{P6} = 0,550	display and surface
C_{Y1} **2,25:1**[3)]	88,9 : 40,0	30,0 ... <60,0	G_{P7} = 1,14	g_{P7} = 0,475	display and surface

1) The example is intended for data projectors (P) with G_{P0}=2,4. compare IEC 61966-2-1: G_{P0}=2,4.
2) The computer operating system *Apple* has used the value 1,8 until 2010. The change to 2,4 *(= Windows)* is in the wrong direction.
3) For the contrast C_Y=2:1 the viewing luminances of both the black in the projection and the white standard offset paper are equal (!).
Visual fatigue caused by the adaptation luminance ratio 36:1 of the black at the screen and the black at the paper shall be reduced.
If for example a grey screen with the CIE tristimulus value Y_Z = 22,2 (=0,25*88.9) is used the contrast step C_{Yi} remains constant.
Then the luminance ratio of all colours at the screen and the paper has reduced to 9:1. This reduces visual fatigue.

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The eight contrast steps of Table D.6 correspond to different absolute gamma values G_{Pk} (k = 0 to 7). The absolute gamma value G_{P0} = 2,4 is defined for the *rgb* data in the *sRGB* colour space (according to IEC 61966-2-1) with no screen reflection. The nonlinear data of the *sRGB* colour space, which can be named rgb_{sRGB} according to colorimetry, are defined by Formula (D.3):

$$r_{sRGB} = r^{(1/2,4)} \qquad g_{sRGB} = g^{(1/2,4)} \qquad b_{sRGB} = b^{(1/2,4)} \tag{D.3}$$

The value G_{P0} = 2,4 in the exponent is called the absolute gamma value. According to Table D.6, the value shall be G_{P0} = 1,86 for the **standard** viewing condition of the contrast step C_{Y5}. Therefore, in this case, the modified rgb_{sRGB} data are defined by Formula (D.4):

$$r_{sRGB} = r^{(1/1,86)} \qquad g_{sRGB} = g^{(1/1,86)} \qquad b_{sRGB} = g^{(1/1,86)} \tag{D.4}$$

It is assumed that the exponent G_{P0} = 2,4 of the *sRGB* colour space is used by the hardware-software workflow. In Table D.6, the relative gamma values g_{Pk} (k = 0 to 7) are defined as per Formula (D.5):

$$g_{Pk} = G_{Pk} / 2,4 \tag{D.5}$$

These values g_P are given at the bottom of any test chart. The graphs on page 3 (of any 24 page test chart file) show approximately the relative gamma values g_{Pk}. For example, the relative gamma value g_{P3} = 0,775 (= 1,86 / 2,4) changes the linearized output in a dark room (Y_N = 0,3) to a linearized output in the office room (Y_N = 2,5).

The former edition (2008) of this standard includes already a simulation of the output by eight screen reflections for the achromatic test chart of ISO/IEC 15775, and the output linearization of the whole display. The change of the relative gamma (g_{Pk}) (k = 0 to 7) of the achromatic and chromatic test charts is simulated in D.4.

D.4 Output simulation for six test charts of ISO 9241-306 and for eight contrast steps

D.4.1 File for simulation of output properties with 8 and 24 pages for eight contrast steps

For the six original test charts of Figures D.2 to D.7, the *output simulation* of this clause produces a change of the relative gamma (g_{Pk}), (P = positive, k = 0 to 7), see Table D.6. The *output linearization* needs an opponent change of the relative gamma g_{Nk} (N = negative, k = 0 to 7).

For any test chart of Figures D.2 to D.7, files for *output simulation* are available for the eight positive (P) relative gamma (g_{Pk}) and the eight negative (N) relative gamma g_{Nk}. The steering of the output is done by a PS Frame-File, which is identical for the six PS test files of this document. Two loops within the Frame-File allow to produce 8 output pages (for the parameters *xchart* = 0 to 7 and *pchart* = 0) or 24 output pages (for the parameters *xchart* = 0 to 7 and *pchart* = 0 to 2). The parameters *xchart* = 0 and *pchart* = 0 produce the original test chart without any *gamma* change.

The files for *output simulation* of the six test charts, ,8 pages, are available at: http://standards.iso.org/iso/9241/306/ed-2/AEi6/AEi6F0P0.PDF (i = 0 to 5).

The *output simulation* files of the six test charts, 24 pages, are available at http://standards.iso.org/iso/9241/306/ed-2/AEi6/AEi6F0PX.PDF (i = 0 to 5).

With increasing number pages, the output looks lighter and the steps near black get larger. Depending on the reflection of the screen, the 16 grey steps appear equally spaced for only one of the eight pages. It is the task of the observer to choose the one page out of the eight pages with approximately an equal spacing for the 16 steps.

This usually happens for one of the eight output pages of the above files. However, some devices with a starting relative gamma in the range $1 < g_{Nk} < 2$ (not in agreement with IEC 61966-2-1) can need the files for *output simulation* of the six test charts, 8 pages, which are available at http://standards.iso.org/iso/9241/306/ed-2/AEi6/AEi6F0N0.PDF (i = 0 to 5.

The *output simulation* files of the six test charts, 24 pages, are available at http://standards.iso.org/iso/9241/306/ed-2/AEi6/AEi6F0NX.PDF (i = 0 to 5).

D.4.2 Simulation of file outputs with properties and questions for eight contrast steps

Example outputs of the simulation files are shown below for the contrast steps C_{Y5} and C_{Y1}. For the output of the original files with the highest contrast step C_{Y8} (relative gamma g_P = 1), see Figures D.2 to D.7.

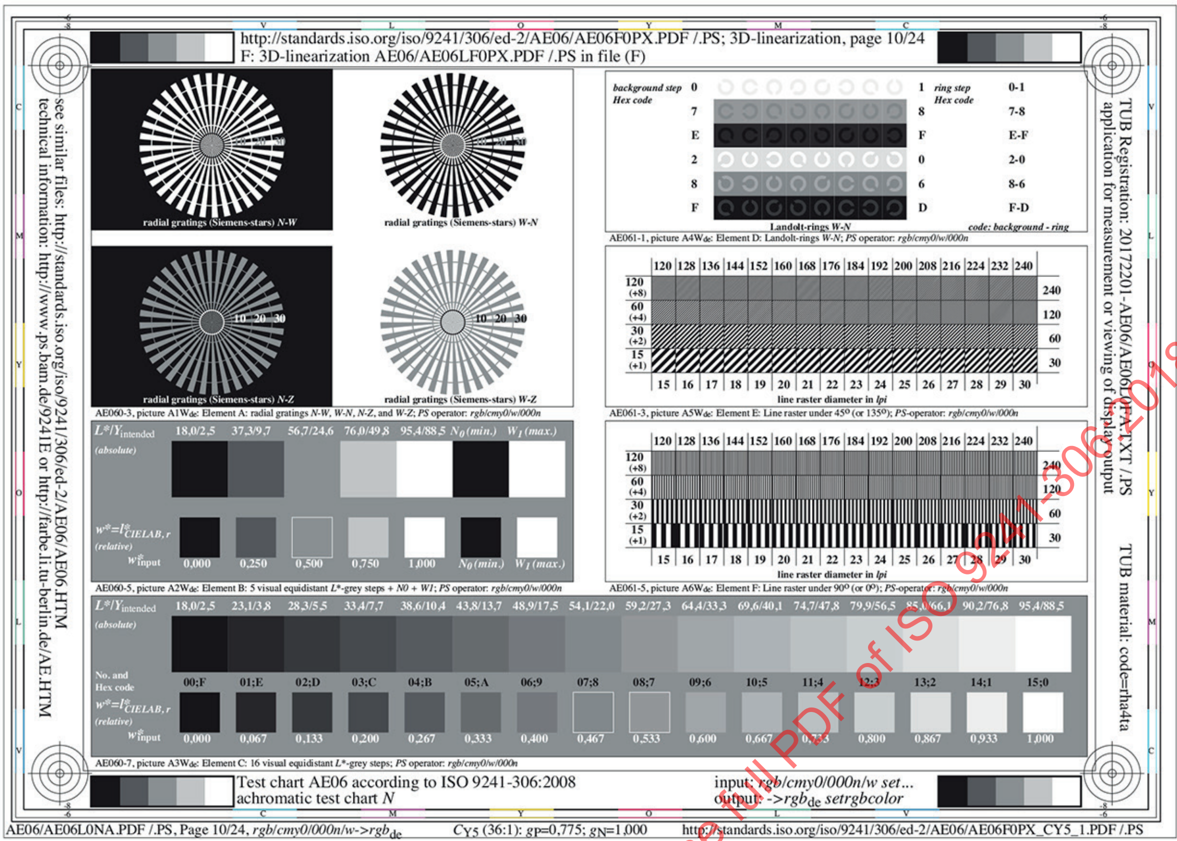


Figure D.10 — Achromatic output of test chart AE06 for contrast step C_{Y5} (g_P = 0,77)

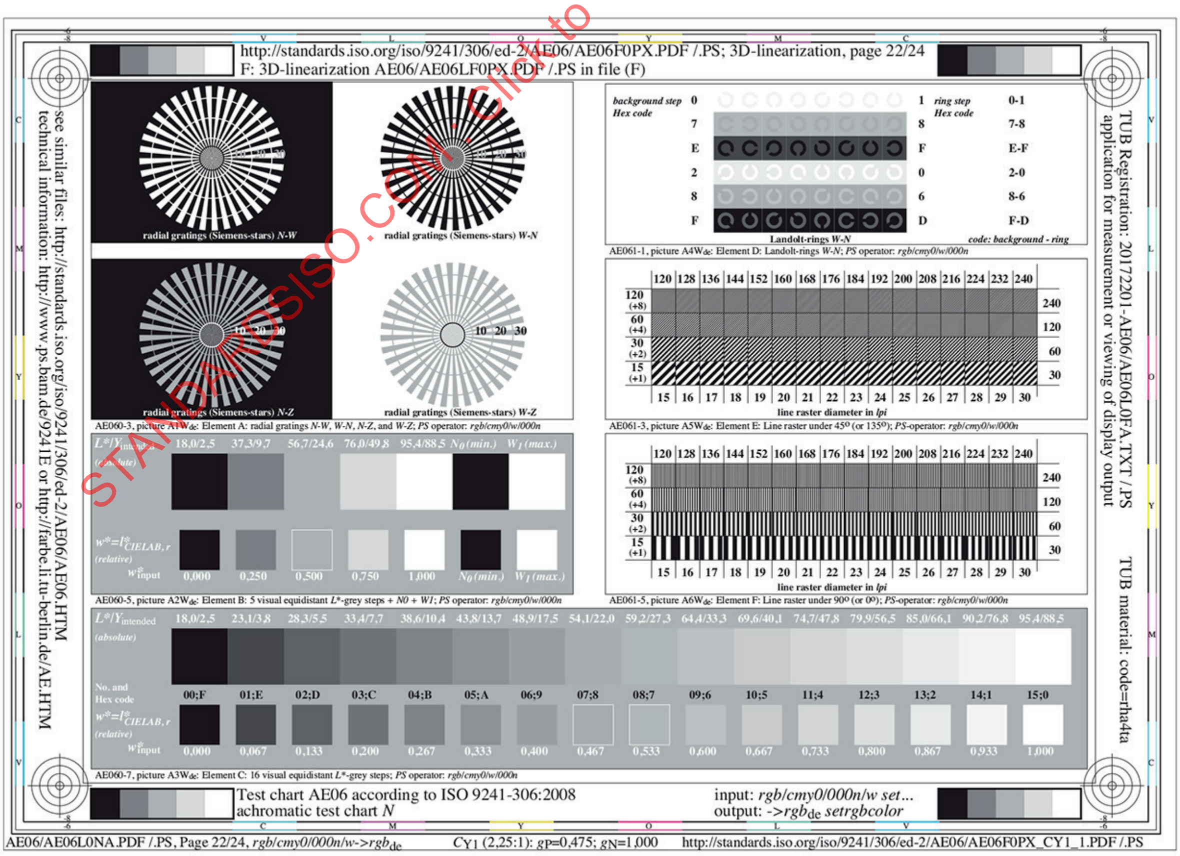


Figure D.11 — Achromatic output of test chart AE06 for contrast step C_{Y1} (g_P = 0,47)

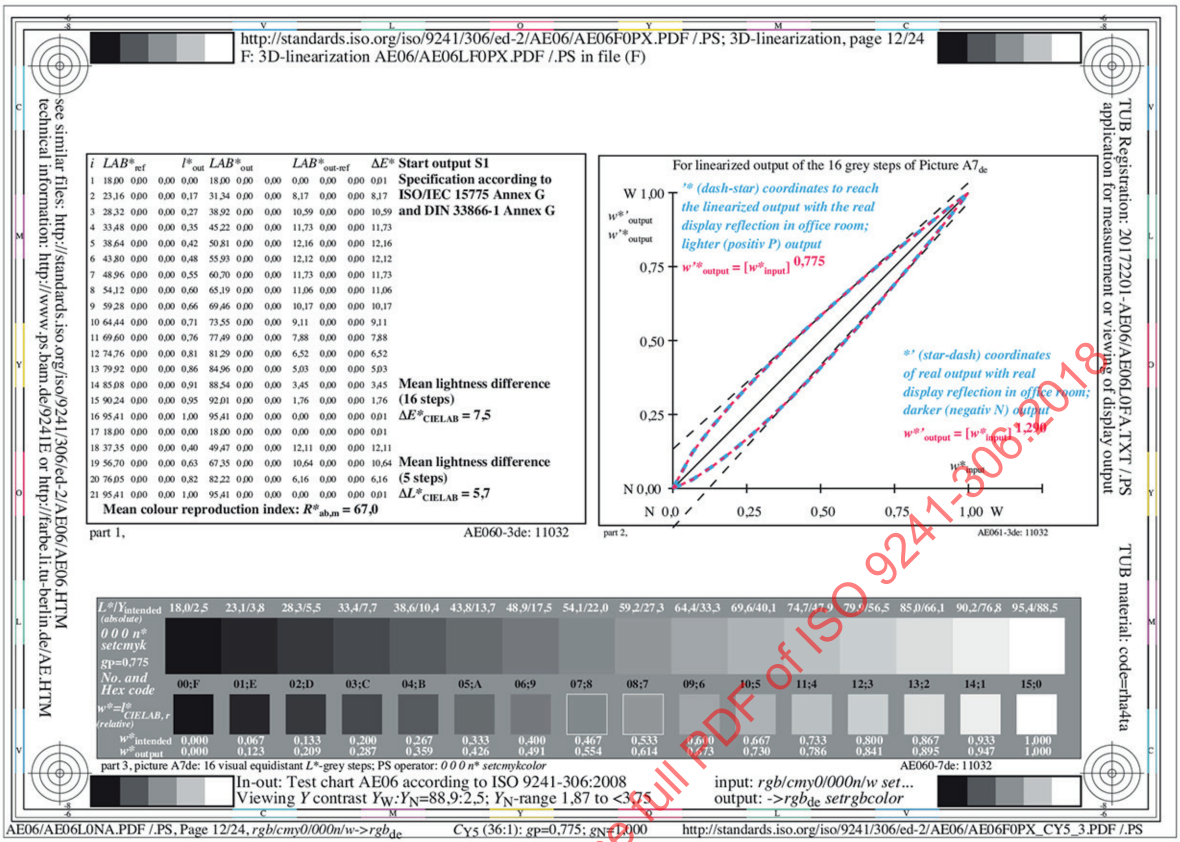


Figure D.12 — Input – output relation for output of achromatic test chart AE06 for contrast step C_{Y5}

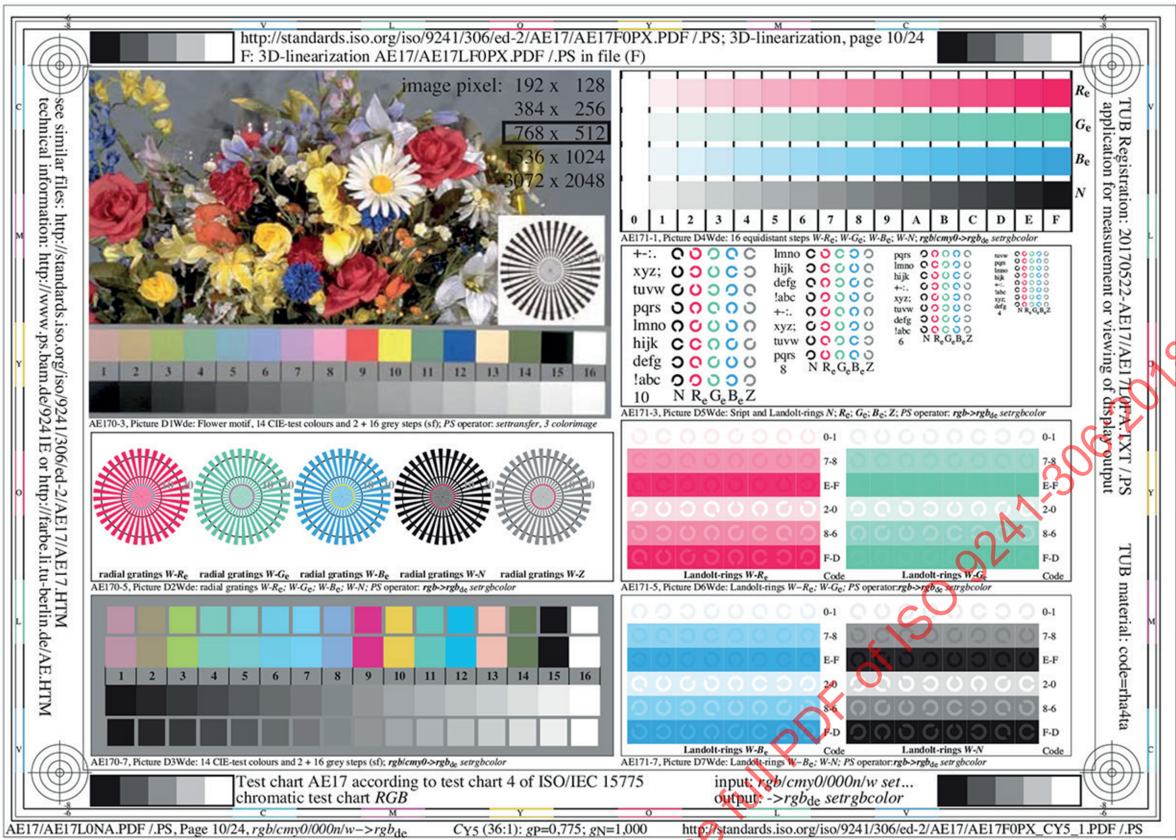


Figure D.13 — Chromatic output of test chart AE17 for contrast step C_{Y5} (g_P = 0,77)

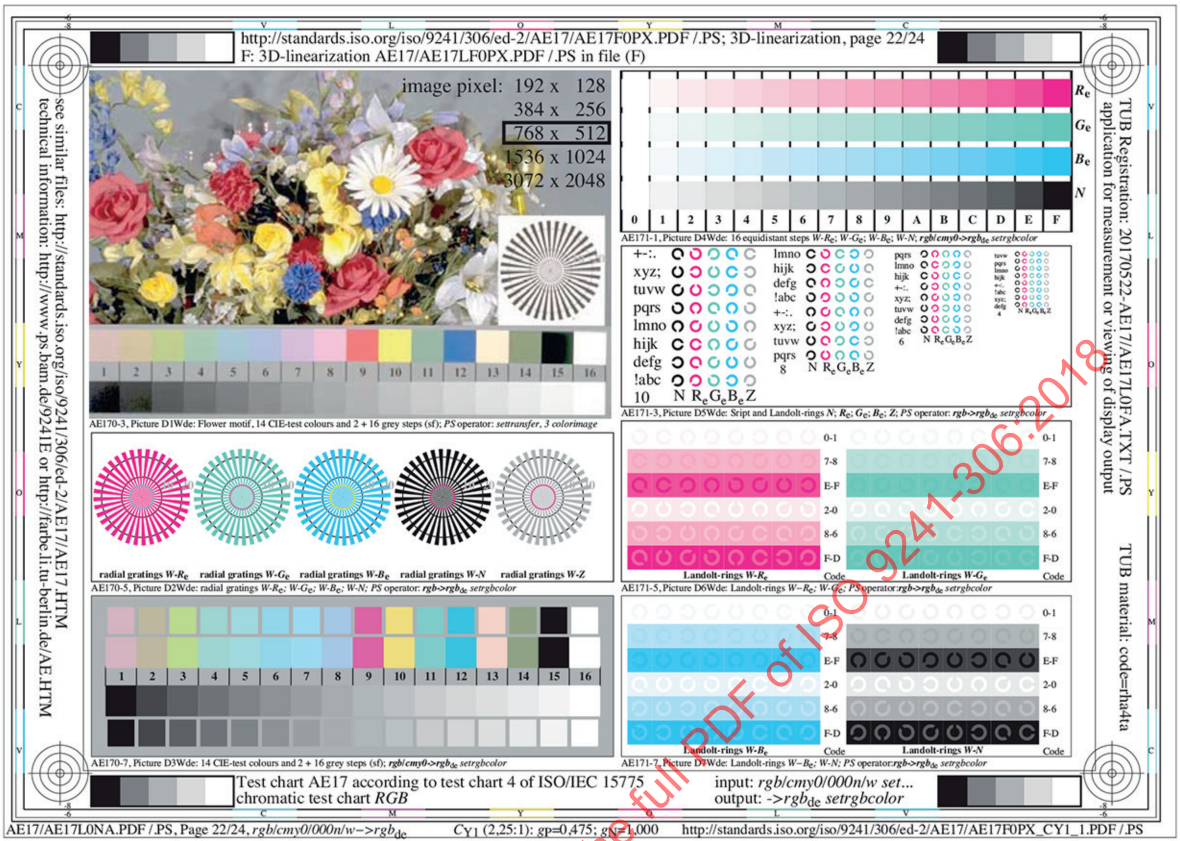


Figure D.14 — Chromatic output of test chart AE17 for contrast step C_{Y1} (g_P = 0,47)

NOTE 1 The radial gratings and other graphical elements are shown on a white background, which is the standard background of paper output. On a white background, the luminance contrast is low for yellow and high for blue. On a black background it is opposite, the luminance contrast is high for yellow and low for blue. There are other test charts with a black and grey background.

For the output of the graphical elements with the colours Red, Green and Blue *(RGB)* and Black *(N)* of Figure D.14 and Figure D.3 on a black and grey background, see for example http://standards.iso.org/iso/9241/306/ed-2/OE56L0NP.PDF.

For the output of the colours Cyan, Magenta and Yellow *(CMY)* and Black *(N)* of Figure D.4 on a black and grey background, see for example http://standards.iso.org/iso/9241/306/ed-2/OE55L0NP.PDF.

D.4.3 Visual inspection for equally spaced output of eight screen reflections

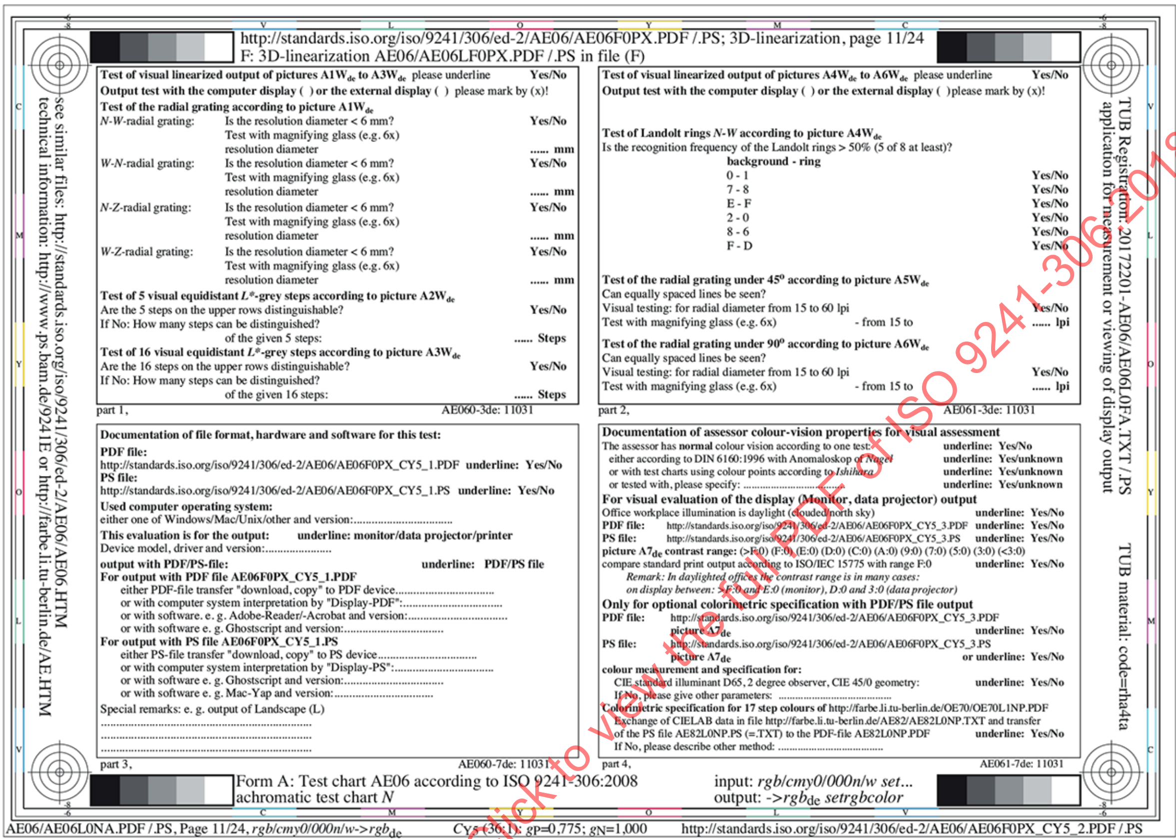
In many technical areas, for example in material science and X-ray technology, the method of *Visual Inspection* shows homogeneous or unexpected properties of the material. Within this annex, different test charts are appropriate to show the expected or unexpected properties of the screen output. There are many sources for the different output properties, including the file, colour coordinates in the file, the colour workflow, the colour output software, and the colour device primaries. *Visual Inspection* is an appropriate method to evaluate the different output properties. Visual inspection needs clearly defined visual criteria, for example:

1) Are the 9 step output colour series between Black N or White W and the four colours Red (R), Yellow (Y), Green (G), and Blue (B) approximately equally spaced?

2) Is the appearance of the output colours Red, Yellow, Green, and Blue approximately the elementary colours? For example, does Yellow appear neither reddish nor greenish?

Similar and additional questions, which are already known from ISO/IEC 15775, ISO/IEC TR 24705, and DIN 33872-1 to -6, are used in D.4.

Table D.7 — Form A: Questions for output of achromatic test chart AE06 for contrast step C_{Y5}


http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX.PDF /.PS; 3D-linearization, page 11/24
F: 3D-linearization AE06/AE06LF0PX.PDF /.PS in file (F)

Test of visual linearized output of pictures A1W$_{de}$ to A3W$_{de}$ please underline Yes/No
Output test with the computer display ( ) or the external display ( ) please mark by (x)!
Test of the radial grating according to picture A1W$_{de}$
N-W-radial grating: Is the resolution diameter < 6 mm? Yes/No
Test with magnifying glass (e.g. 6x)
resolution diameter ...... mm
W-N-radial grating: Is the resolution diameter < 6 mm? Yes/No
Test with magnifying glass (e.g. 6x)
resolution diameter ...... mm
N-Z-radial grating: Is the resolution diameter < 6 mm? Yes/No
Test with magnifying glass (e.g. 6x)
resolution diameter ...... mm
W-Z-radial grating: Is the resolution diameter < 6 mm? Yes/No
Test with magnifying glass (e.g. 6x)
resolution diameter ...... mm
Test of 5 visual equidistant *L-grey steps according to picture A2W$_{de}$**
Are the 5 steps on the upper rows distinguishable? Yes/No
If No: How many steps can be distinguished?
of the given 5 steps: ...... Steps
Test of 16 visual equidistant *L-grey steps according to picture A3W$_{de}$**
Are the 16 steps on the upper rows distinguishable? Yes/No
If No: How many steps can be distinguished?
of the given 16 steps: ...... Steps
part 1, AE060-3de: 11031

Test of visual linearized output of pictures A4W$_{de}$ to A6W$_{de}$ please underline Yes/No
Output test with the computer display ( ) or the external display ( )please mark by (x)!
Test of Landolt rings *N-W* according to picture A4W$_{de}$
Is the recognition frequency of 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 radial grating under 45° according to picture A5W$_{de}$
Can equally spaced lines be seen?
Visual testing: for radial diameter from 15 to 60 lpi Yes/No
Test with magnifying glass (e.g. 6x) - from 15 to ...... lpi
Test of the radial grating under 90° according to picture A6W$_{de}$
Can equally spaced lines be seen?
Visual testing: for radial diameter from 15 to 60 lpi Yes/No
Test with magnifying glass (e.g. 6x) - from 15 to ...... lpi
part 2, AE061-3de: 11031

Documentation of file format, hardware and software for this test:
PDF file:
http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX_CY5_1.PDF **underline: Yes/No**
PS file:
http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX_CY5_1.PS **underline: Yes/No**
Used computer operating system:
either one of Windows/Mac/Unix/other and version:................................
This evaluation is for the output: **underline: monitor/data projector/printer**
Device model, driver and version:.....................
output with PDF/PS-file: **underline: PDF/PS file**
For output with PDF file AE06F0PX_CY5_1.PDF
either PDF-file transfer "download, copy" to PDF device................................
or with computer system interpretation by "Display-PDF":................................
or with software. e. g. Adobe-Reader/-Acrobat and version:................................
or with software e. g. Ghostscript and version:................................
For output with PS file AE06F0PX_CY5_1.PS
either PS-file transfer "download, copy" to PS device................................
or with computer system interpretation by "Display-PS":................................
or with software e. g. Ghostscript and version:................................
or with software e. g. Mac-Yap and version:................................
Special remarks: e. g. output of Landscape (L)
....
....
....
part 3, AE060-7de: 11031

Documentation of assessor colour-vision properties for visual assessment
The assessor has **normal** colour vision according to one test: **underline: Yes/No**
either according to DIN 6160:1996 with Anomaloskop of *Nagel* **underline: Yes/unknown**
or with test charts using colour points according to *Ishihara* **underline: Yes/unknown**
or tested with, please specify: .... **underline: Yes/unknown**
For visual evaluation of the display (Monitor, data projector) output
Office workplace illumination is daylight (clouded/north sky) **underline: Yes/No**
PDF file: http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX_CY5_3.PDF **underline: Yes/No**
PS file: http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX_CY5_3.PS **underline: Yes/No**
picture A7$_{de}$ contrast range: (>F:0) (F:0) (E:0) (D:0) (C:0) (A:0) (9:0) (7:0) (5:0) (3:0) (<3:0)
compare standard print output according to ISO/IEC 15775 with range F:0 **underline: Yes/No**
Remark: In daylighted offices the contrast range is in many cases:
on display between: >F:0 and E:0 (monitor), D:0 and 3:0 (data projector)
Only for optional colorimetric specification with PDF/PS file output
PDF file: http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX_CY5_3.PDF
picture A7$_{de}$ **underline: Yes/No**
PS file: http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX_CY5_3.PS
picture A7$_{de}$ **or underline: Yes/No**
colour measurement and specification for:
CIE standard illuminant D65, 2 degree observer, CIE 45/0 geometry: **underline: Yes/No**
If No, please give other parameters: ....
Colorimetric specification for 17 step colours of http://farbe.li.tu-berlin.de/OE70/OE70L1NP.PDF
Exchange of CIELAB data in file http://farbe.li.tu-berlin.de/AE82/AE82L0NP.TXT and transfer
of the PS file AE82L0NP.PS (=.TXT) to the PDF-file AE82L0NP.PDF **underline: Yes/No**
If No, please describe other method: ....
part 4, AE061-7de: 11031

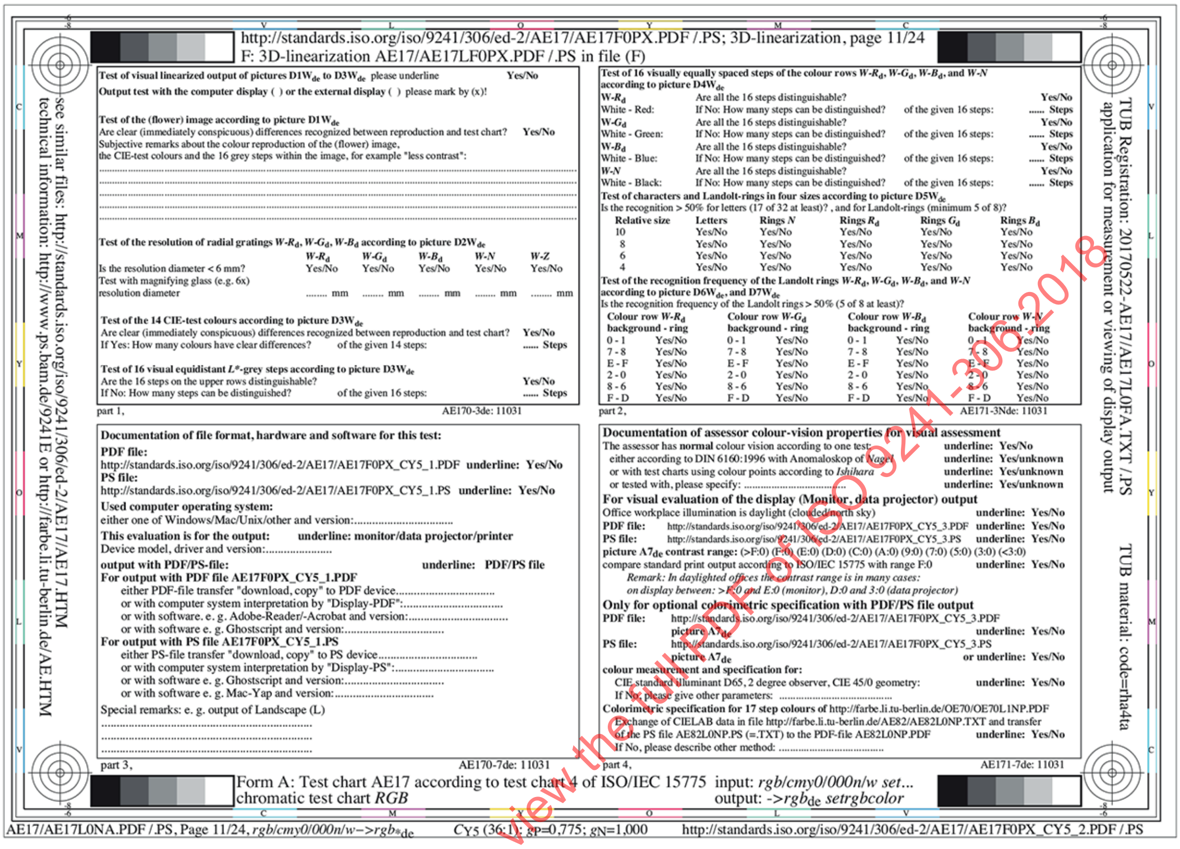
Form A: Test chart AE06 according to ISO 9241-306:2008
achromatic test chart *N*
input: *rgb/cmy0/000n/w set...*
output: *->rgb$_{de}$ setrgbcolor*

see similar files: http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06.HTM
technical information: http://www.ps.bam.de/9241E or http://farbe.li.tu-berlin.de/AE.HTM

TUB Registration: 20172201-AE06/AE06L0FA.TXT /.PS
application for measurement or viewing of display output
TUB material: code=rha4ta

AE06/AE06L0NA.PDF /.PS, Page 11/24, *rgb/cmy0/000n/w->rgb$_{de}$* C_{Y5} (36:1): g_P=0,775; g_N=1,000 http://standards.iso.org/iso/9241/306/ed-2/AE06/AE06F0PX_CY5_2.PDF /.PS

Table D.8 — Form A: Questions for output of the chromatic test chart AE17 for contrast step C_{Y5}



http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX.PDF /.PS; 3D-linearization, page 11/24
F: 3D-linearization AE17/AE17LF0PX.PDF /.PS in file (F)

see similar files: http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17.HTM
technical information: http://www.ps.bam.de/9241E or http://farbe.li.tu-berlin.de/AE.HTM

Test of visual linearized output of pictures D1W$_{de}$ to D3W$_{de}$ please underline Yes/No
Output test with the computer display ( ) or the external display ( ) please mark by (x)!

Test of the (flower) image according to picture D1W$_{de}$
Are clear (immediately conspicuous) differences recognized between reproduction and test chart? Yes/No
Subjective remarks about the colour reproduction of the (flower) image,
the CIE-test colours and the 16 grey steps within the image, for example "less contrast":
....
....
....
....
....

Test of the resolution of radial gratings *W-R*$_d$, *W-G*$_d$, *W-B*$_d$ according to picture D2W$_{de}$

	W-R$_d$	*W-G*$_d$	*W-B*$_d$	*W-N*	*W-Z*
Is the resolution diameter < 6 mm?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Test with magnifying glass (e.g. 6x) resolution diameter	.... mm	.... mm	.... mm	.... mm	.... mm

Test of the 14 CIE-test colours according to picture D3W$_{de}$
Are clear (immediately conspicuous) differences recognized between reproduction and test chart? Yes/No
If Yes: How many colours have clear differences? of the given 14 steps: ...... Steps

Test of 16 visual equidistant *L-grey steps according to picture D3W$_{de}$**
Are the 16 steps on the upper rows distinguishable? Yes/No
If No: How many steps can be distinguished? of the given 16 steps: ...... Steps

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Test of 16 visually equally spaced steps of the colour rows *W-R*$_d$, *W-G*$_d$, *W-B*$_d$, and *W-N* according to picture D4W$_{de}$

W-*R*$_d$	Are all the 16 steps distinguishable?		Yes/No
White - Red:	If No: How many steps can be distinguished?	of the given 16 steps:	...... Steps
W-*G*$_d$	Are all the 16 steps distinguishable?		Yes/No
White - Green:	If No: How many steps can be distinguished?	of the given 16 steps:	...... Steps
W-*B*$_d$	Are all the 16 steps distinguishable?		Yes/No
White - Blue:	If No: How many steps can be distinguished?	of the given 16 steps:	...... Steps
W-N	Are all the 16 steps distinguishable?		Yes/No
White - Black:	If No: How many steps can be distinguished?	of the given 16 steps:	...... Steps

Test of characters and Landolt-rings in four sizes according to picture D5W$_{de}$
Is the recognition > 50% for letters (17 of 32 at least)? , and for Landolt-rings (minimum 5 of 8)?

Relative size	Letters	Rings *N*	Rings *R*$_d$	Rings *G*$_d$	Rings *B*$_d$
10	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
8	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
6	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
4	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

Test of the recognition frequency of the Landolt rings *W-R*$_d$, *W-G*$_d$, *W-B*$_d$, and *W-N* according to picture D6W$_{de}$, and D7W$_{de}$
Is the recognition frequency of the Landolt rings > 50% (5 of 8 at least)?

Colour row *W-R*$_d$ background - ring		Colour row *W-G*$_d$ background - ring		Colour row *W-B*$_d$ background - ring		Colour row *W-N* background - ring	
0 - 1	Yes/No	0 - 1	Yes/No	0 - 1	Yes/No	0 - 1	Yes/No
7 - 8	Yes/No	7 - 8	Yes/No	7 - 8	Yes/No	7 - 8	Yes/No
E - F	Yes/No	E - F	Yes/No	E - F	Yes/No	E - F	Yes/No
2 - 0	Yes/No	2 - 0	Yes/No	2 - 0	Yes/No	2 - 0	Yes/No
8 - 6	Yes/No	8 - 6	Yes/No	8 - 6	Yes/No	8 - 6	Yes/No
F - D	Yes/No	F - D	Yes/No	F - D	Yes/No	F - D	Yes/No

part 2, AE171-3Nde: 11031

Documentation of file format, hardware and software for this test:
PDF file:
http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX_CY5_1.PDF **underline: Yes/No**
PS file:
http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX_CY5_1.PS **underline: Yes/No**
Used computer operating system:
either one of Windows/Mac/Unix/other and version:................................
This evaluation is for the output: **underline: monitor/data projector/printer**
Device model, driver and version:......................
output with PDF/PS-file: **underline: PDF/PS file**
For output with PDF file AE17F0PX_CY5_1.PDF
either PDF-file transfer "download, copy" to PDF device................................
or with computer system interpretation by "Display-PDF":................................
or with software. e. g. Adobe-Reader/-Acrobat and version:................................
or with software e. g. Ghostscript and version:................................
For output with PS file AE17F0PX_CY5_1.PS
either PS-file transfer "download, copy" to PS device................................
or with computer system interpretation by "Display-PS":................................
or with software e. g. Ghostscript and version:................................
or with software e. g. Mac-Yap and version:................................
Special remarks: e. g. output of Landscape (L)
....
....
....

part 3, AE170-7de: 11031

Documentation of assessor colour-vision properties for visual assessment
The assessor has **normal** colour vision according to one test: **underline: Yes/No**
either according to DIN 6160:1996 with Anomaloskop of *Nagel* **underline: Yes/unknown**
or with test charts using colour points according to *Ishihara* **underline: Yes/unknown**
or tested with, please specify: .... **underline: Yes/unknown**
For visual evaluation of the display (Monitor, data projector) output
Office workplace illumination is daylight (clouded/north sky) **underline: Yes/No**
PDF file: http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX_CY5_3.PDF **underline: Yes/No**
PS file: http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX_CY5_3.PS **underline: Yes/No**
picture A7$_{de}$ contrast range: (>F:0) (F:0) (E:0) (D:0) (C:0) (A:0) (9:0) (7:0) (5:0) (3:0) (<3:0)
compare standard print output according to ISO/IEC 15775 with range F:0 **underline: Yes/No**
Remark: In daylighted offices the contrast range is in many cases:
on display between: >F:0 and E:0 (monitor), D:0 and 3:0 (data projector)
Only for optional colorimetric specification with PDF/PS file output
PDF file: http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX_CY5_3.PDF
picture A7$_{de}$ **underline: Yes/No**
PS file: http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX_CY5_3.PS
picture A7$_{de}$ **or underline: Yes/No**
colour measurement and specification for:
CIE standard illuminant D65, 2 degree observer, CIE 45/0 geometry: **underline: Yes/No**
If No, please give other parameters: ....
Colorimetric specification for 17 step colours of http://farbe.li.tu-berlin.de/OE70/OE70L1NP.PDF
Exchange of CIELAB data in file http://farbe.li.tu-berlin.de/AE82/AE82L0NP.TXT and transfer
of the PS file AE82L0NP.PS (=.TXT) to the PDF-file AE82L0NP.PDF **underline: Yes/No**
If No, please describe other method: ....

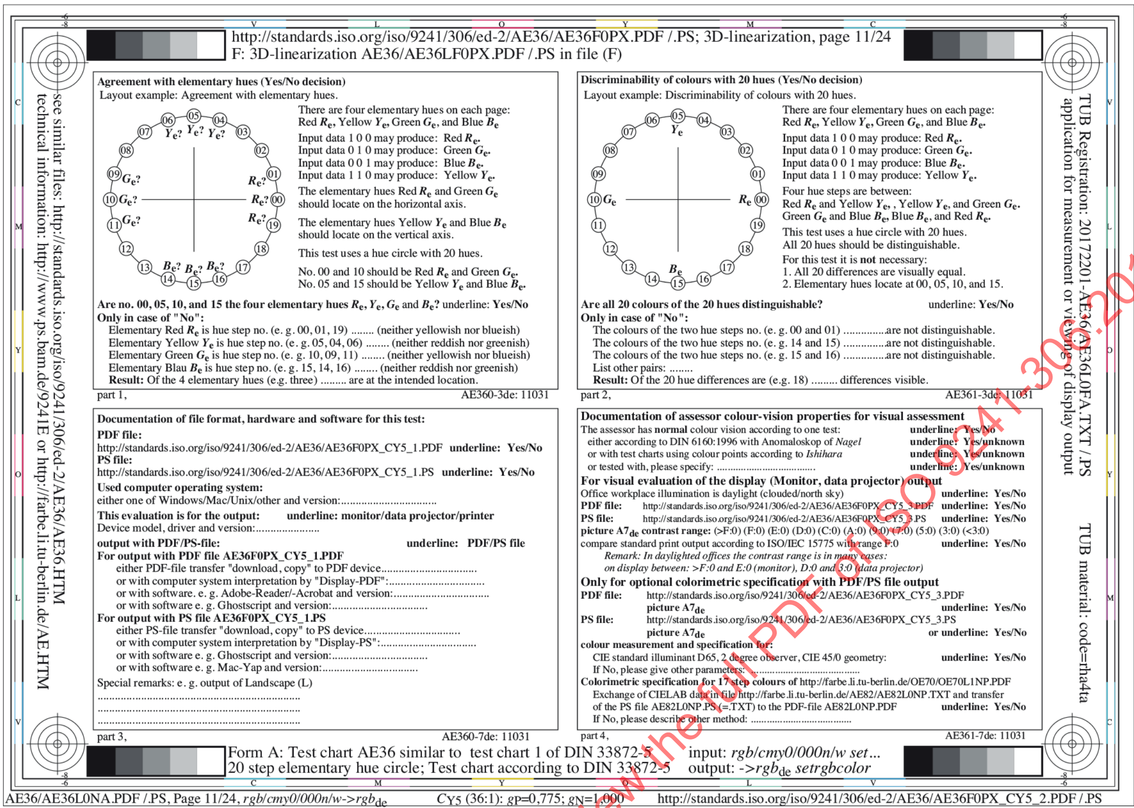
part 4, AE171-7de: 11031

TUB Registration: 20170522-AE17/AE17L0FA.TXT /.PS
application for measurement or viewing of display output
TUB material: code=rha4ta

Form A: Test chart AE17 according to test chart 4 of ISO/IEC 15775 input: *rgb/cmy0/000n/w set...*
chromatic test chart *RGB* output: *->rgb*$_{de}$ *setrgbcolor*

AE17/AE17L0NA.PDF /.PS, Page 11/24, *rgb/cmy0/000n/w->rgb*$_{*de}$ C_{Y5} (36:1): g_P=0,775; g_N=1,000 http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX_CY5_2.PDF /.PS

Table D.9 — Form A: Questions for output of the chromatic test chart AE36 for contrast step C_{Y5}



Many users like the *output simulation* for the eight viewing conditions by utilizing a file with 8 or 24 pages. Users can choose the one page with the most equally spaced output out of the many pages. By this method, users recognize the large improvement in equal spacing for a given ambient reflection. Users can appreciate the increased colour information in the linearized output. The chromatic test charts with output simulation consist of 24 pages (2,2 MB without an image or 10 MB with an image). The parameters I and j define different files with the 24 output pages

http://standards.iso.org/iso/9241/306/ed-2/AEij/AEijF0PX.PDF (i = 0 to 5, j = 6 or 9)

The parameters i = 0 to 5 define 6 test charts: j = 6 defines an *rgb** output, j = 9 defines an *sRGB* output. However, an *sRGB* output is only defined for C_{Y8}. The same parameters are used for the following 8 output pages.

http://standards.iso.org/iso/9241/306/ed-2/AEij/AEijF0P0.PDF (i = 0 to 5, j = 6 or 9)

The highest contrast step C_{Y8} is shown in Figure D.2. The contrast step C_{Y5} of Figure D.10 can show the best equally spaced output in offices. The contrast step C_{Y1} can show l large steps near black and small steps near white in Figure D.11. Table D.7 shows Form A, with the questions for the standard output (tristimulus value Y_N = 2,5).

The test chart file output shows the changes that are created by the eight luminance reflections on the display surface. For the example shown in Figure D.8, it was shown that the five darkest grey steps were indistinguishable. However, if a user chooses the appropriate relative gamma value for rendering the test charts, the differences of the dark grey steps are increased, become visible, and can be equally spaced. The file includes corrections by the eight relative gamma values g_{Pk} (k = 0 to 7) given in Table D.6.

The 24 pages of the chromatic test chart with output simulation include on: pages 1, 4, 7, ..., 22 the ISO/IEC-image, radial gratings, 16 step colour scales, and *Landolt*-Rings.

Pages 2, 5, 8, ..., 23 tables with questions for the visual evaluation or colorimetric specification of the output.

Pages 3, 6, 9, ..., 24 the 16 step grey scale output for the visual evaluation or colorimetric specification, and the standard input-output relationship according to ISO/IEC 15775.

The chromatic test chart with output simulation allows the user to choose the appropriate output for the ISO/IEC-image, and the four colour scales, at any work place by a visual evaluation or optional by a colorimetric specification.

Figures D.3, D.10 and D.11 show the content of the three pages no. 1, 10, and 22. The print of these figures, or the display output of the pages no. 1, 10, and 22 in a dark room, shows an increasing grey difference of the grey samples near black with the test chart AE46. An increasing colour difference appears near Black N and White W for the series White – Colour and Black – Colour.

With increasing tristimulus values of Black N between Y_N = 0 and Y_N = 40 of the display output at any workplace, only one of the pages 1, 4, 7, ..., 22 with the ISO/IEC-image and the four colour scales shows a visually appropriate (or the best) output with approximately equal spacing of the four colour series and the ISO/IEC-image.

However, with increasing tristimulus values of Black *N*, the colour gamut and the colour differences between the samples of the 16 step series decrease, compare Figure D.9. Therefore, the tristimulus value Y_N = 0,3 leads to the largest colour gamut and the largest colour differences, compare Figure D.9.

However, for the computer or data projector display output at any work place with an illuminance of 500 lux, the tristimulus value is at least Y_N = 2,5 and often much larger. For ergonomic reasons, working with at least 500 lux of illumination is preferred.

The Black *N* of standard offset print defines the **standard** tristimulus value Y_N = 2,5, compare bold line in Tables D.3 to D.5. Similarly, the White *W* of standard offset printing has the tristimulus value Y_W = 88,6. These two measured values lead to the visual CIE lightness data L^*_N = 18 and L^*_W = 95 for Black *N* and White *W*, compare Table D.3.

Instead of the large lightness range between L^*_N = 0 and L^*_W = 95 in a dark room, there is the standard lightness range between L^*_N = 18 and L^*_W = 95 in illuminated offices for both surface colours and display colours. Figure D.8 shows for the 16 grey steps the lightness difference delta L^* = 6,3. Therefore, in offices for offset print and for the **standard** display output the lightness difference is reduced by a factor 0,81 [= (95-18)/95] to ΔL^* = 5,1.

D.5 Questions for the visual evaluation and input-output relationship

For the standard *sRGB* display with no luminance reflection at the display, the grey colours have a linear relationship between the equal *rgb*-colour input data in the file and the CIELAB lightness L^* of the output. This is called a linear input-output relationship. Output linearization produces this property for the eight viewing conditions at work places, and for different luminance reflections on the display. Visual inspection decides, if equal visual spacing is reached.

The chromatic test chart with output simulation of this annex consists of 24 pages; see (12 MB, 24 pages): http://standards.iso.org/iso/9241/306/ed-2/AE17/AE17F0PX.PDF.

Pages 1, 4, 7, ..., 22 show the ISO/IEC-image, radial gratings, 16 step colour scales and *Landolt*-Rings.

Pages 2, 5, 8, ..., 23 show tables with questions for the visual evaluation or colorimetric specification of the output.

Pages 3, 6, 9, ..., 24 show the 16 step grey scale output for the visual evaluation or colorimetric specification, and the standard input-output relationship.

The chromatic test chart with output simulation allows to choose the appropriate output of both the ISO/IEC-image and the colour scales at any workplace by a visual evaluation or optional by a colorimetric specification.

