TCO’03 Displays

Flat Panel Displays

Ver. 3.0

19 October 2005

Contents TCO'03 FPD

Introduction

TCO (The Swedish Confederation of Professional Employees) has, since the end of the 1980s, been involved in influencing the development of IT equipment, particularly Visual Display Units (VDUs), in a more user-friendly direction. Since 1998 this work has been carried out by TCO Development, a wholly-owned TCO subsidiary company.

With the collective knowledge and experience of the 1.3 million office workers associated with the confederation, TCO Development has developed requirements and test methods for IT equipment used in offices. These definitive quality and environmental requirements have pointed the way for the rapid pace of development in this characteristically international branch.

The TCO certification system is a challenge for those manufacturers who have decided to adapt information technology to meet the needs of professionals, the work environment and nature, while at the same time accepting high quality requirements as a possibility rather than a burden.

The first TCO labelling program, TCO'92, was launched in 1992, and has since been succeeded by TCO'95 and TCO'99. Each new generation of labelling has seen the requirements extended and tightened, in pace with progress in technical innovation and development. Nevertheless, there has been a constant focus on the professional users and their demands on the tools they use in their work.

The publication of this TCO'03 Flat Panel Displays document marks the fourth generation of TCO labelling of displays. We have chosen to retain the same areas as in the previous labelling programs but tightened a number of the requirements. These are mainly concerned with the area of visual ergonomics, where there have been rapid technical developments in recent years. TCO Development welcomes comments on these requirements and suggestions for future updates.

Changes in version 3.0

In TCO'03 Displays version 3.0, the Energy requirements are harmonised with Energy Star Program Requirements for Computer Monitors, Tier 2 for sleep mode, off mode and on mode as predicted on the release of version 2.0. The requirement will become valid January 1st, 2006.

The requirement on front frame reflectance is removed in this version. The reason for this is partly the results obtained in the perceptual study called FFC (Front Frame Characteristics), which confirmed that gloss is the most important parameter and that the effect of diffuse reflectance depends to a large extent on other factors, such as individual preference and the environment surrounding the display. Read more about this in "TCO Development's updated position on front frame reflectance", which is available from TCO Development upon request.

It is important to put the individual product requirements for displays into a functional context. We have therefore published "The Advisor" on our website, which provides advice on purchase and use of computer displays, for example on high contrasts within the visual field.

In this version the ecological requirements are adapted to the EU directives Restriction of certain Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE). The requirements will become valid July 1st, 2006.

Some minor changes of requirements due to interpretations that have previously been communicated are also included.

A separate document "Summary of changes in TCO'03 Displays version 3.0 compared to version 2.0" can also be found at TCO Development's website www.tcodevelopment.com.

Stockholm October 19th 2005

TCO Development

SE-114 94 Stockholm, Sweden

Fax: +46 (0)8 782 92 07

E-mail: development@tco.se

Jan Rudling
Managing Director

Helena Nordin
Development Manager

A Criteria

A.1 General information

This document contains requirements, test methods and references for Flat Panel Displays, which are herein referred to as "FPD" throughout.

Many of the requirements in this document are the same as those contained in TCO'03 CRT Displays, and these requirements have the same numbering in the two documents. The contents of the two documents follow the same numbering sequence; to separate the technology-unique requirements some numbers are omitted from one of the documents. In this document the requirements for VDUs of CRT type are omitted, namely: A.2.2.1, A.2.3.3., A.2.4.2, A.2.7.1, A.2.7.2 and A.4.1.

A.1.1 TCO Document

Background
It is desirable that the purchaser of a product that has been certified in accordance with *TCO'03 Displays* receives information concerning the quality and capabilities of the product. This information is based on the viewpoint from the user's perspective that TCO Development represents.

Applicability
All FPDs.

References
The contract between TCO Development and the applicant company.

Mandate:

A TCO Document written in English shall accompany the product, describing why these particular requirements have been chosen for the products within the program of TCO'03 Displays, and what is expected to be achieved by them. The document may be provided as an electronic file. The text can be obtained from TCO Development.

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled. The document shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.2 Visual ergonomics FPD

Today computer displays are common work tools for users in different types of professions. Good visual ergonomics is a very important aspect of quality that can also have a direct effect on the health and comfort of the user.

Hence in developing requirements for visual ergonomics the health effects of various parameters have been taken into account, as well as other features that characterise good quality displays.

TCO Development used three main ways to determine the suitable level for each requirement and the test methods for the visual ergonomics part of the TCO labelling program. One is based on acceptable visual levels determined by scientific research. The second is based on statistics from tests carried out in accordance with TCO, ISO, MPR II regulations and from special VDU tests. The third way is based on manufacturers' knowledge and experience, which is invaluable. Manufacturers, consumer groups and other organisations with interests in the visual ergonomics field have contributed with a great deal of valuable information and ideas through discussions.

The expression Flat Panel Display (FPD) in this document primarily means Visual Display Units (VDUs) of LCD type. However, the measuring procedures can in many cases be applied to other types of flat panels with fixed positions of the pixels. VDUs of OLED type may need other requirements and test methods. Flat panels of CRT type should be tested according to TCO'03 CRT Displays.

Plans for updating

We are looking into the possibility to extend the gloss requirement to be valid also for the active surface of the panel, but at the time of writing we have not yet been able to establish the levels. In the future we aim to set a level for gloss of the active surface of the panel.

A.2.1 Pixel array characteristics

A.2.1.1 Pixel array requirements

Background
Image quality is negatively affected by a low fill factor, visible "jaggies", poor rendering of details, etc. All of these parameters are related to the pixel array of the display. For pixel array characteristics, it is important to take the viewing distance into account.

Definition
A pixel is the smallest addressable imaging element of the FPD capable of reproducing a full range of luminance and colours.

The pixel array is the number of pixels in the horizontal direction by the number of pixels in the vertical direction that the display can present.

Applicability
All FPDs.

Test procedure
See B.2.1.1.

References
Please see reference 2, 36 and 44.

Mandate:

The FPD shall have a pixel density ≥ 30 pixels/degree.

For the most common display formats the mandates are:

Display format	Horizontal pixels	Vertical pixels
5:4:3	896	679
18.36:16:9	972	557
6.4:5:4	875	706

For "wide format displays" or other special FPD formats the pixel density shall be calculated. The horizontal to vertical resolution ratio shall be as close as possible to the width to height ratio of the display.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.3 Luminance characteristics

A.2.3.1 Luminance level

Background
It shall be possible to set a sufficiently high luminance level with respect to the ambient lighting in order to present a comfortable viewing situation and to avoid eyestrain. Poor luminance can lead to low contrast and consequently affect legibility and colour discrimination and by that cause misinterpretations. It shall be possible to set the luminance level according to the lighting conditions of the surroundings.

Definition
The luminance at a point on a surface and in a given direction is the quotient of the luminous intensity in the given direction of an infinitesimal element of the surface containing the point under consideration, to the orthogonal projected area of the surface element on a plane perpendicular to the given direction.

The unit of luminance is cd/m^2.

Applicability
All FPDs.

Test procedure
See B.2.3.1.

References
Please see reference 1, 2, 18, 21, 27, 31, 36 and 44.

Mandate:

The maximum luminance of the FPD shall be ≥ 150 cd/m2.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.3.2 Luminance uniformity

Background
Image quality is badly affected by non-uniform luminance. When poor luminance uniformity is visible, it can locally affect the contrast and consequently the legibility of information on the display. The areas of deviating luminance can have different sizes and cause varying border sharpness.

Definition
Luminance uniformity is the capacity of the FPD to maintain the same luminance level over the whole active screen area. The luminance uniformity is defined as the ratio of maximum to minimum luminance within the fully active screen area.

Applicability
All FPDs.

Test procedure
See B.2.3.2.

References
Please see reference 1, 2, 16, 18, 21, 22, 27, 32, 33, 36 and 44.

Mandate:

Luminance variation across the active screen, L_{max} : L_{min} shall be ≤ 1.5:1 at test luminance settings.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.3.4 Luminance uniformity - angular-dependence

Background

The luminance of an FPD is angular-dependent , i.e. that screen luminance decreases when the FPD is viewed slightly from the side. This can have a negative effect on contrast and can affect the legibility of the screen, especially if two or more users are looking at the screen from different viewing angles or from different heights.

Definition

Luminance uniformity – angular dependence, is the capacity of the FPD to maintain luminance level independently of the viewing direction. The angular-dependent luminance uniformity is defined as the ratio of maximum luminance to minimum luminance in the specified measurement areas.

Applicability

All FPDs.

Test procedure

See B.2.3.4.

References

Please see reference 1, 16, 22, 27, 31, 32 and 33.

Mandate:

1) **For pivot FPDs and for nonpivot FPDs in landscape mode and in the horizontal direction, the mean value of the L_{max} to L_{min} ratios at ±30° shall be ≤ 1.7.**
2) **For nonpivot FPDs in landscape mode and in the vertical direction, the value of the L_{max} to L_{min} ratio at +15° shall be ≤ 1.7.**
3) **For pivot FPDs in portrait mode in the horizontal direction the largest ratio value of L_{max} to L_{min} at ± 15° shall be ≤ 1.7.**

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.4 Luminance contrast characteristics

A.2.4.1 Luminance contrast – characters

Background
The degree of contrast is important for legibility and for distinguishing one character from another.

Definition
Luminance contrast – characters is the capacity of the FDP to maintain a high luminance difference between a bright background and dark characters or parts of characters over the whole active area.

Luminance contrast – characters is expressed as the ratio of the L_{max} to L_{min} difference over the sum of L_{max} and L_{min}, according to Michaelson's formula. It is measured at two different angles.

Applicability
All FDPs.

Test procedure
See B.2.4.1.

References
Please see reference 2, 16, 19, 22, 23, 27, 32 and 44.

Mandate:

The FPD shall have a luminance contrast ≥ 0.7 measured orthogonally to the screen.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.4.2 Luminance contrast – angular dependence

Background

For FPDs the luminance and consequently the contrast on the display is angular-dependent. The luminance variations can influence both the bright white and the dark areas of the screen, causing a change in contrast. This can have a negative effect on the legibility of the screen, especially when two or more users are looking at the screen from different viewing angles or from different heights.

Definition

Luminance contrast – angular dependence, is the capability of the FPD to maintain the same contrast regardless of the direction from which the screen is viewed. Luminance contrast – angular dependence, is expressed as the ratio of the L_{max} to L_{min} difference over the sum of L_{max} and L_{min}, according to Michaelson's formula. It is measured at two different angles.

Applicability

All FPDs.

Test procedure

See B.2.4.2.

References

Please see reference 2, 16, 19, 23, 28 and 33.

Mandate:

For FPDs in landscape mode, the luminance contrast-angular dependence shall be ≥ 0.8 at ± 30° horizontally from the viewing direction.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.5 Front frame reflection characteristics

A.2.5.1 Front frame reflectance

The requirement has been deleted.

A.2.5.2 Front frame gloss

Background

Front frame gloss influences visual comfort and legibility by drawing attention away from the task at hand. The higher the gloss value the more likely it is that the surface will create irritating specular reflexes (mirror-like reflexes) from ambient lighting. If the gloss value is high enough, the problem of reflection images can occur. Also, the distinctness of the reflection influences its perceived impact.

The front frame shape can in some situations make a smooth frame act as a mirror and consequently increase the contrast between reflections and their background to a level that is far beyond the values that can be accepted by a user.

We are looking into the possibility to extend the gloss requirement to be valid also for the active surface of the panel, but at the time of writing we not yet been able to establish the levels. In the future we aim to set a level for gloss of the active surface of the panel.

Definition

Gloss is a measure of how a light beam, physically described as luminous flux, is scattered at the surface when incident against that surface. Gloss is a function of the directional reflectance properties of a surface.

Applicability

All FPDs.

Test procedure

See B.2.5.2.

References

Please see reference 5, 6, 7 and 37.

Mandate:

The gloss value G(60°) shall be 30 gloss units or less.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.6 Screen colour characteristics

A.2.6.1 Correlated colour temperature, CCT, variation

Background
Most FPDs are today equipped with a number of pre-set correlated colour temperature settings. This makes it possible to more accurately evaluate the colour of an image on the FPD compared to real scenes or prints.

Physical measurements of colour stimuli can only give an indication of the colour appearance in a practical situation. The colour of the frame, the spectral composition of the lighting, the colour of various areas in the visual field, and the complexity of brightness variations in the visual field all influence the colour appearance of an FPD image.

Normal daylight has a correlated colour temperature in the range 5000 – 10000 K.

Definition
The correlated colour temperature is a measure of the perceived screen colour expressed in kelvin (K).

Applicability
All FPDs.

Test procedure
See B.2.6.1.

References
Please see reference 2, 3, 4, 8-12, 14, 15, 17, 24, 25, 26, 28, 30, 34, 36 and 38.

Mandate:

The FPD shall have at least two predefined possibilities for pre-set correlated colour temperatures and one possibility for the user to adjust the CCT (total of three settings).

Each pre-set correlated colour temperature shall have a colour difference $\Delta u'v' \leq 0.01$ when compared to CIE u' and v' chromaticity co-ordinates for corresponding correlated colour temperatures.

The following information shall be submitted:

Declaration from the manufacturer and a test report from a test laboratory approved by TCO Development.

A.2.6.2 Colour uniformity

Background

The human visual system is very sensitive to changes in colour hue in white and grey areas. Since the white or grey colour hues are the background on which most colours are judged, the white or grey areas are the reference colours on the screen.

Patches of colour variation on an active white or grey screen could reduce the contrast locally, be disturbing and affect the legibility, colour rendering and colour differentiation.

Definition

The colour uniformity of an FPD is the capability to maintain the same colour in any part of the screen.

Applicability

All FPDs.

Test procedure

See B.2.6.2.

References

Please see reference 2, 8, 14, 15, 23, 25, 29, 35, 36 and 38.

Mandate:

$\Delta u'v' \leq 0.01$ for the maximum colour deviation between measured active areas on the screen that are intended to maintain the same colour.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.6.3 RGB settings

Background

Accurate colour rendering is important when realistic colour images or colour presentations are presented on the FPD screen. Poor colour rendering can lead to poor legibility and misinterpretation. The u' and v' chromaticity co-ordinates of the primary colours red (R), green (G) and blue (B) of the screen shall aim at values given in international IEC, EBU and ITU standards. The u' and v' chromaticity co-ordinates of the primary colours R, G and B form a triangle in the CIE 1976 uniform chromaticity scale diagram. The larger the area of the triangle, the wider the range of colours the screen is capable of presenting.

Definition

The colour characteristics of an FPD are based on the visual appearance of the FPD primary colour stimuli, the R, G, B-stimuli.

Applicability

All FPD s.

Test procedure

See B.2.6.3.

References

Please see reference 3, 4, 8-15, 17, 25, 26, 28, 30, 34, 36 and 38.

Mandate:

The minimum colour triangle shall have the following coordinates:

	Red		Green		Blue	
Co-ordinate	**u'**	**v'**	**u'**	**v'**	**u'**	**v'**
Requirement	**≥ 0.411**	**≥ 0.503**	**≤ 0.140**	**≥ 0.548**	**≥ 0.150**	**≤ 0.224**

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.6.4 Colour uniformity – angular dependence

Background

The human visual system is very sensitive to changes in colour hue in white and grey areas. Since the white or grey colour hues are the background on which most colours are judged, the white or grey areas are the reference colours on the screen. Angular-dependent colour variations on an active white or grey screen could be disturbing and affect legibility, colour rendering and colour differentiation.

Definition

The colour uniformity – angular dependence of an FPD is the capability of the screen to maintain constant colour over the screen surface depending of the direction from which the screen is viewed.

Applicability

All FPDs.

Test procedure

See B.2.6.4.

References

Please see reference 2, 8, 14, 15, 23, 25, 29 and 35.

Mandate:

For an FPD in landscape mode, the Δu'v' between areas on the left side and the right side of the screen when it is positioned at+30° and at -30° horizontally to the screen normal shall be ≤ 0.025.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.2.6.5 Colour greyscale linearity

Background

A well-tuned colour greyscale is the basis for good colour rendering on the screen. This is measured via steps in a greyscale on the screen. Each greyscale step shall have similar colour hues in order to simplify colour interpretation and to avoid confusion for the user, only the luminance shall vary.

Definition

Colour greyscale linearity is the capability of the screen to maintain the same u',v' co-ordinates of a greyscale pattern at all greyscale levels, i.e. only the luminance shall change from one greyscale step to the next.

Applicability

All FPDs.

Test procedure

See B.2.6.5.

References

Please see reference 2, 8, 14, 15, 23, 25, 29 and 35.

Mandate:

The greyscale steps to be used are 255, 225, 195, 165, 135 and 105, and each should be measured in the centre of the screen. The maximum difference in either u'or v' identifies those steps where Δu'v' should be calculated. The Δu'v' shall be ≤ 0.02.

The following information shall be submitted:

A test report from a test laboratory approved by TCO Development.

A.3 Work load Ergonomics

Work load ergonomics concerns the adaptation of tasks, tools, the work place and the rest of the physical environment in order to meet and optimize the users' needs for a good work environment.

Computer equipment is, just as much as furniture, lighting and other office equipment, an important part of the modern office work environment. TCO Development wants to contribute to the development of FPDs with good user characteristics, on the basis of work load ergonomics. This thereby enhances the possibility for users to be able to have good quality FPDs so that the best possible conditions for physical variation are created in the work environment.

It is important for FPDs to offer users the possibility of variation between different work postures. An aesthetically appealing design must not restrict the work load ergonomics function.

As a further complement and support for users, ergonomic user instructions are available in "the Advisor" on TCO Development's webpage http://www.tcodevelopment.com.

Plans for updating – future requirements

In pace with the rapid development of displays there is a need for updating the work load ergonomics requirements in order to create the best possible working environment.

Characteristics that might be included in future requirements are the shape of the frame, display size, display format. Other characteristics such as adjustment controls, their design, position and feedback, symbols as well as cable characteristics will also be taken into consideration.

A.3.1 Vertical tilt

Background
It is a benefit to be able to tilt the FPD in the vertical plane. This offers the possibility to tilt the FPD back in order to place the top of the FPD slightly farther away from the eyes than the bottom. This is beneficial for the possibility of work posture alteration and flexibility, particularly for neck comfort, but also to obtain and utilise the best visual ergonomics of the FPD.

Applicability
All FPDs.

References
Please see references 39-48.

Mandate:

It shall be possible to easily tilt the FPD in the vertical plane to the extent of 20 degrees or more.

The following information shall be submitted:

A written guarantee that the FPD meets the above mandate. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand name and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.3.2 Vertical height adjustment

Background
It is important to position the display so that it can be viewed within a line of sight angle between horizontal and 60 degrees below the horizontal. The height adjustment system should allow positioning of the top of the display at, or slightly below, the seated eye height of the average male or average female range of operators when the FPD is placed on a standard height (750 mm) table. A height adjustment function, especially the lowering of the FPD down towards the work top surface, is beneficial for the possibility of work posture flexibility to be able to get the best visual ergonomics of the FPD.

Applicability
All FPDs.

References
Please see references 39-49.

Definition
Work top surface: the surface where the FPD is positioned.

Mandate:

The FPD shall meet *one* of these three mandates:

1. **The FPD shall have a height adjustment function as a standard feature.**
2. **The FPD shall have a mounting interface applicable to the VESA mounting interface standard.**
3. **The manufacturer or a third party shall provide the accessories necessary to achieve the height adjustment function. Information of where the accessories can be purchased and how they are to be installed shall be provided to the customer in the user's manual.**

The following information shall be submitted:

If mandate 3 is met a copy of the information in the user's manual shall be included.

A written guarantee that the FPD meets one of the above mandates. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.4 Emissions

The amount of electrical equipment in our work places is increasing tremendously, with a concomitant increase in the presence of electrical and magnetic fields. Users of IT equipment now have several nearby field sources placed on work surfaces that are constantly in use. The degree of exposure of users working with this equipment is increasing. The permanent relationship of the body to certain field sources, such as visual distance from displays, mobile telephone location next to the ear and the proximity of lighting needed for the work are realities that exacerbate this development.

When the first TCO label was introduced in 1992 one of the main interests was the requirements for electrical and magnetic fields. Still the scientists and experts are divided around the question if they can cause any damage to the humans.

The amount of fields surrounding us is increasing so still the criteria in the standard are more then than relevant. We are also convinced that the amount of fields that surrounds us in the office environment do not contribute to the well fare being of the office workers.

A.4.2 Alternating electric fields

Background

Electrical alternating fields are created between objects that have different levels of electrical potential which change over time. When the potential changes in a periodic manner, an electrical alternating field is set up, with a field strength and a frequency. A display contains many sources of electrical alternating fields. The field characteristics depend on the actual electrical potential difference and the distance from the FPD.

Display users are often concerned about a possible health risk arising from electrical alternating fields generated by equipment. Quite a large number of users also report various kinds of symptom that cannot completely be attributed to the influence of other factors in the work environment or to medical reasons.

The mandatory requirements are based on the ambition to reduce the electrical alternating fields to such a low level as not to burden the work environment with unnecessary factors. The mandatory requirements shall not be regarded as hygienic limit values.

Applicability

All FPDs.

Test procedure

See B.4.2.

References

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Mandate:

Band I: 5 Hz to 2 kHz, ≤ 10 V/m, measured at 30 cm and at 50 cm in front of the FPD.

Band II: 2 kHz to 400 kHz, ≤ 1.0 V/m measured at 50 cm around the FPD and at 30 cm in front of the FPD.

The following information shall be submitted:

A copy of a test report from a test laboratory approved by TCO Development.

A.4.3 Alternating magnetic fields

Background

Magnetic alternating fields are created when an electrical alternating current flows through a conductor. Like other electrical equipment, displays are surrounded by magnetic alternating fields. These magnetic alternating fields are generated by different parts of the display, e.g. power supply unit, voltage inverters and other electrical circuits. The field strength depends on the actual electric current and on the distance from the FPD.

Certain display users are concerned about a possible health risk arising from magnetic alternating fields generated by equipment. Quite a large number of users also report various kinds of symptom that cannot completely be attributed to the influence of other factors in the work environment or to medical reasons.

The obligatory requirements are based on the ambition to reduce the magnetic alternating fields to such a low level as not to burden the work environment with unnecessary factors. The obligatory requirements shall not be regarded as hygienic limit values.

Applicability

All FPDs.

Test procedure

See B.4.3.

References

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Mandate:

Band I: 5 Hz to 2 kHz, ≤ 200 nT, measured at 30 cm in front of the FPD and at 50 cm around the FPD.

Band II: 2 kHz to 400 kHz, ≤ 25 nT measured at 50 cm around the FPD.

The following information shall be submitted:

A copy of a test report from a test laboratory approved by TCO Development.

A.4.4 Noise

FPDs equipped with fans and ”all-in-one computers” shall fulfil the requirements regarding noise found in the latest version of the labelling document for Desktop computers. This document can be found on the TCO Development home page (www.tcodevelopment.com). (At the time of writing the latest version is TCO’05 Desktop computers 1.0.)

A.5 Electrical safety

A.5.1 Electrical safety

Background

Electrical safety concerns the electrical design of apparatus with respect to its electrical insulation and other arrangements that are intended to prevent accidents resulting from contact with live components, and the risk of fire or explosion as a result of electrical flash-over due to inadequate or faulty electrical insulation.

Applicability

All FPDs with built-in power supplies as well as any separate power supply intended to be used together with the FPD.

References

Please see reference 50.

Mandate:

The FPD shall be certified according to EN/IEC 60 950.

The following information shall be submitted:

A CB certificate or a national certificate from a CB member (NCB) shall be submitted.

A.6 Ecology

The TCO Development labelling requirements have a unique integrated balance of indoor and outdoor environmental issues. A good workplace environment shall not be gained at the expense of environmental problems in the surroundings we all share. We call our demand on outdoor environmental criteria “ecological requirements”.

The vision and business idea of TCO Development were inspired by Agenda 21, the Rio conference action plan for sustainable development. The basis of our work is described in Chapter 29 of Agenda 21.

The requirements that are present in this document are those that are in terms of the environment relevant to the product group, commercially attainable and can be checked in a suitable way.

When choosing which environmental aspects are to be included, TCO Development in the first place bases its selection on international references, and secondly on those which are European or national.

The Ecological requirements cover environmental management system in production, potential harmful substances in the product and aspects that support material recycling.

Plans for updating

Areas which are not at present included in the requirements are under continual review by TCO Development. Legislation which can affect the product group is also being followed continuously.

In future updates of the labelling documents requirements on mercury free lamps in FPDs, maximum levels of chemical emissions from various plastics and chemical substances that are included in FPDs might be added. TCO Development is also investigating the possibility of shifting towards a principle whereby requirements are defined for environmental characteristics instead of the current system of prohibiting various chemical substances or groups of substances. It is important to facilitate recycling, but requirements regarding recycling are also quite complex to handle. TCO Development will continue to build knowledge of how to set and achieve stricter requirements in this field.

A.6.0 Product description

Background
The aim of this front page is to provide a brief description of the product that is to be reviewed for compliance with the ecological requirements of Section A.6.

Applicability
All FPDs and the peripherals supplied with them.

Mandate:

A product declaration shall be provided for the FPD.

The following information shall be submitted:

1. **The following table, completed where applicable.**
2. **A copy of the marking plate for the display.**

The information submitted shall be signed by the responsible person at the applicant company.

Display	
Manufacturer	
Brand name	
Type/Model name	
Screen size in inch	

Panels	
Manufacturer	
Type/Model name	
Brand name	
Technology	

Peripherals	
Type of product	
Manufacturer	
Brand name	
Type/Model name	

We hereby guarantee that the above mandate is fulfilled.

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.1 Environmental management system certification

Background
A certified environmental management system is proof that the company shows concern for the environment and has chosen to work in a systematic way with constant improvement of the environmental performance of the company and its products in focus. A certified environmental management system includes external independent revisions.

Definitions
Manufacturing plant is the site where the final assembly of the product is taking place.

Applicability
The company or companies which manufacture the FPD.

References
Please see references 52 and 64.

Mandate:

Each *manufacturing plant* must be certified in accordance with ISO 14001, or EMAS registered. If the product is manufactured by a third party, it is this company that shall be certified or registered.

The following information shall be submitted:

1. **A document showing the names and addresses of the manufacturing plants.**
2. **Copies of the ISO 14001 certificates or EMAS registrations.**
3. **A written guarantee that the certificate(s)/registration(s) are valid.**

The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.2 Environmental hazards

A.6.2.1 Cadmium (Cd), mercury (Hg), and hexavalent chromium (Cr^{VI})

Background

The effects of mercury and cadmium on human health and the natural environment have been very thoroughly documented since the mid-1950s.

In an EU Directive, both mercury and cadmium shall be phased out in electrical and electronic equipment, no later than by July 1st, 2006.

The UN/ECE Convention on Long-range Transboundary Air Pollution (CLRTAP) was extended in June 1998 by a Heavy Metals Protocol that included cadmium pollutants and products containing levels of mercury.

Applicability

FPDs and the peripheral equipment supplied with them.

References

Please see references 51, 57, and 69.

Mandate:

Until July 1st, 2006:

The FPD and peripheral equipment shall not contain cadmium and mercury. The requirement applies to components, parts, and raw materials in all assemblies and sub-assemblies of the product. The listed parts are found in the TCO'03 Guidelines.

Exempted are mercury lamps in background lighting systems.

The limit value for listed parts is 2 ppm for mercury and 5 ppm for cadmium.

From July 1st, 2006:

The FPD and peripheral equipment shall not contain cadmium, mercury and hexavalent chromium. The requirement applies to components, parts, and raw materials in all assemblies and sub-assemblies of the product.

Exempted are mercury lamps in background lighting systems. Other exemptions are to be found in the TCO'03 Guidelines and are in accordance with EU Directive 2002/95/EC (RoHS).

The limit values for mercury and hexavalent chromium is 0.1 % by weight and for cadmium 0.01 % by weight in homogeneous materials. For batteries please see TCO'03 Guidelines.

The following information shall be submitted:

A written guarantee that the mandate above is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.2.2 Lead (Pb)

Background
Lead is a well known hazardous element. Lead has a very well documented negative health effect and is subject to restrictions in many countries and for different kind of uses.

In an EU Directive, lead shall be phased out in electrical and electronic equipment, no later than by July 1st, 2006.

UNEP has defined lead as one of the substances that requires regulation on a global level with a binding convention.

Applicability
FPDs and the peripheral equipment supplied with them.

References
Please see references 51, 54, 57 and 69.

Mandate:

The FPD and peripheral equipment shall not contain lead. The requirement applies to components, parts, and raw materials in all assemblies and sub-assemblies of the product.

Until July 1st 2006:
***Printed wiring boards*, electronic components, and solder are exempted.**

The limit value for listed parts is 50 ppm.

From July 1st 2006:
Exemptions that are valid from July 1st 2006 are to be found in TCO'03 Guidelines and are in accordance with EU Directive 2002/95/EC (RoHS).

The limit value for lead is 0.1 % by weight in homogeneous materials. For batteries please see TCO'03 Guidelines.

The following information shall be submitted:

A written guarantee that the mandate above is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.2.3 Flame retarding agents containing bromine and chlorine

Background

The general requirements and discussion in respect of bromine and chlorine flame retardants and the phasing out of this group concern about 75 substances. Two families within the bromine flame retardants group have been identified in particular as environmentally harmful. These are PBB and PBDE.

Chlorine and bromine flame retardants used are often persistent and can bioaccumulate in living organisms, and have been detected in flora and fauna.

A series of international elimination activities in respect of chlorine and bromine flame retardants is currently in progress within the EU, OECD, North Sea Conference, OSPAR (the Commission for the Protection of the Marine Environment of the North-East Atlantic) and HELCOM (the Baltic Marine Environment Protection Commission).

Applicability

All FPDs and the peripheral equipment supplied with them.

References

Please see references 53, 55, 59, 61, 65, 66, and 69.

Mandate:

Until 1st July, 2006:

1. **Plastic parts weighing more than 25 grams shall not contain flame retardants that contain bromine or chlorine. The requirement applies to plastic parts in all assemblies and sub-assemblies of the product.**

The limit value for flame retardants which contain bromine or chlorine is 0.5 percent by weight of the plastic part.

From 1st July, 2006:

1. **Plastic parts weighing more than 25 grams shall not contain flame retardants that contain bromine or chlorine. The requirement applies to plastic parts in all assemblies and sub-assemblies of the product.**
2. **The FPD and peripheral equipment shall not contain PBB and PBDE (listed in the TCO'03 Guidelines). The requirements applies to components, parts and raw materials in all assemblies and sub-assemblies of the product.**

The limit values for flame retardants is 0.1 % by weight in homogeneous materials.

Exemptions are to be found in the TCO'03 Guidelines.

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.2.4 Information regarding flame retarding agents

Background

The spread of synthetic chemical substances in various products is a global and very widespread environmental problem. Knowledge in respect of the different health and environmental characteristics of these substances is very limited. In order to be able to apply the correct type of measures, good basic information is required.

Applicability

All FPDs and the peripheral equipment supplied with them.

References

Please see references 56, 58, and 60.

Mandate:

The material specifications shall be provided for plastic parts and PWB laminates that weigh more than 25 grams and which have flame retardant concentrations above 0.5 percent by weight.

The following information shall be submitted:

The table below shall be completed and signed by the responsible person at the applicant company. Manufacturers of plastic materials who consider such information confidential may submit the information to a test laboratory approved by TCO Development.

Plastic part name	Weight in grams	Type of plastic	Plastic brand name	Plastic model name	Flame retardant type	Flame retardant CAS #	Plastic label code

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.2.5 Plastics with chlorine and bromine as part of the polymer

Background

PVC is by far the most common halogen containing plastic. There are however other plastics that contain chlorine or bromine in the plastic itself. As the requirement concerning permissible flame retardants tightens, the risk increases that halogenated plastics will become more common. TCO Development sees a future environmental risk with such development.

PVC is a much-debated plastic that can pose environmental problems in most parts of its life cycle. The magnitude of the environmental problems related with PVC differs depending on the environmental status of a particular manufacturing facility and the uses of additives. At present there are very limited possibilities to distinguish between harmful and less harmful production facilities for PVC.

Applicability

All FPDs and the peripheral equipment supplied with them.

References

Please see references 57 and 67.

Mandate:

Plastic parts that weigh more than 25 grams shall not contain chlorine or bromine as a part of the polymer.

Laminates for printed wiring boards, PWBs and all kinds of cable insulation are exempted.

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.3 Preparation for recycling

A.6.3.1 Material coding of plastics

Background

Within the EU the problem of electronic waste has been a major issue for many years. The EU has now brought out a set of rules for dealing with environmental questions related to electronic items in waste. There are large volumes of FPDs all over the world. Recycling and the handling of harmful substances is therefore an important environmental area.

Applicability

All FPDs and the peripheral equipment supplied with them.

References

Please see references 57, 62, 63, and 68.

Mandate:

Plastic parts that weigh more than 25 grams shall be material-coded in accordance with ISO 11469 and ISO 1043-1, -2, -3, -4. Such parts shall be listed in the table at Section A.6.2.4.

Exempted are laminates for printed wiring boards, PWBs.

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.3.2 Design for recycling – Mercury lamps

Background

During the dismantling and recycling of FPDs it is the mercury in the lamps that presents one of the greatest environmental problem. By setting the requirement that the lamps must be easily detached and dealt with separately, the process of material reclamation of the rest of the display is facilitated.

Applicability

All FPDs which contain mercury lamps for background lighting systems.

Mandate:

- **Connections to be separated during the disassembly of FPD must be easy to take apart in order to not damage the mercury lamps. This means that gluing and welding must not be used to bond parts and make removal of the lamps complicated.**
- **The total amount of mercury in the lamps shall be declared in the table below.**

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled together with:

- **An adequate description of the method by means of which the lamps shall be removed. The description shall be signed by the responsible person at the applicant company.**
- **The mercury lamp suppliers, the lamp ID code, the average, maximum and minimum amount of mercury in each lamp, the total number of lamps, the panel ID code, panel technology and the manufacturer shall be declared. A written declaration shall be signed by the responsible person at the applicant company.**

Display brand name:.....

Display type/model name:.....

FPD size: .....

Panel manufacturer:.....

Panel identification code: .....

Panel technology .....

Number of lamps:.....

Mercury lamp supplier:	Lamp ID code:	Average mg Hg/lamp:	Max. mg Hg/lamp:	Min. mg Hg/lamp:

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.3.3 Variety of plastics

Background
Recycling of used electronic products is an important environmental issue. Material recycling and reuse are the best options from an environmental point of view. Therefore TCO Development presents requirements that facilitate material recycling.

Applicability
All FPDs and the peripheral equipment supplied with them.

Definitions
Types of plastic materials (using the abbreviation terms, symbols and concepts for plastics in ISO 1043 Part 1, 2, 3, and 4) are:

- Basic polymers
- Mixtures of polymers
- Basic polymers with flame retardants
- Mixtures of polymers with flame retardants

Product units are:

- Display case and foot
- LCD panel in FPDs
- Peripherals

References
Please see reference 62.

Mandate:

No more than two different *types of plastic materials* are accepted for parts weighing more than 100 grams in each *product unit*.

The light guide in FPD panels are exempted.

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.3.4 Metallization of plastic housing and metal parts

Background
Recycling of used electronic products is an important environmental issue. Material recycling and reuse are the best options from an environmental point of view. Therefore TCO Development presents requirements that facilitate material recycling.

Definition
Metallization is a surface deposition process whereby a metallic layer is applied to the surface of a completed shaped plastic part. Examples of metallization processes are chemical coating and ion vapour deposition.

Applicability
All FPDs.

Mandate:

1. **There shall be no internal or external *metallization* of the FPD outer plastic casing and foot.**
2. **Moulded-in or glued metal parts are not accepted.**

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.6.3.5 Recycling information for customers

Background
Within the EU the problem of electronic waste has been a major issue for many years. EU has decided upon a legislation for dealing with electronics waste and several European countries have already imposed legislation for product take-back and recycling. There are huge volumes of FPDs in the world and it is very important to get these products into a closed loop to avoid the entry of harmful substances into the environment.

Definition
Environmentally acceptable recycling methods are:

- Product and component reuse.
- Material recycling with secured handling of hazardous chemicals and heavy metals.
- Pollution-controlled energy recovery of parts of the FPD.
- The recycling company or companies shall work in compliance with the Basle Convention when exporting FPDs or parts of FPDs.

Placement in landfills of whole products is not acceptable.

Applicability
All FPDs and the peripheral equipment supplied with them.

References
Please see reference 68.

Mandate:

The brand name holder (or his representative, associated company or affiliate) shall inform its customers in the user's manual of the possibility to dispose of the FPD by *environmentally acceptable recycling*. The information shall be made available to customers in the various geographical markets in the following way:

Until July 1st, 2006:

1. **For FPDs sold in Europe:**
   In at least three European countries where the FPD is sold.
2. **For FPDs sold in Asia:**
   In at least one Asian country where the FPD is sold.
3. **For FPDs sold in America (North and South):**
   In at least one country or one state in the USA where the FPD is sold.

From July 1st, 2006:

1. **For FPDs sold in Europe: In the countries within the European Union where the FPD is sold and where the EU directive 2002/96/EC (WEEE) is applicable.**
2. **For FPDs sold in Asia:**
   In at least one Asian country where the FPD is sold.
3. **For FPDs sold in America (North and South):**
   In at least one country or one state in the USA where the FPD is sold.

The following information shall be submitted:

A written guarantee that the above mandate is fulfilled. The guarantee shall be signed by the responsible person at the applicant company.

A copy of the description of the customer information. If this is provided in local language, a translation into English shall be submitted as well.

We hereby guarantee that the above mandate is fulfilled.

……..
Product brand and model name

.....	.....
Signature	Name and title in block capitals
.....	.....
Date	Company

A.7 Energy

There are both indoor and outdoor environmental aspects that concern energy consumption of displays. Most of the electrical energy consumed by an FPD is converted into heat energy which warms up the surrounding room. If the room must be cooled down, more energy is needed.

An important global environmental goal is to reduce energy consumption to counteract the current trend for global warming.

A.7.1 Energy consumption

Background
This requirement and test method has been harmonized with Energy Star's requirements on FPDs and includes requirements for *on mode*, *sleep mode*, and *off mode*.

Definitions
On Mode
The FPD is connected to a power source and produces an image.

Sleep Mode
The reduced power state that the FPD enters after receiving instructions from a computer or via other functions.

Off Mode
The lowest power consumption mode which cannot be switched off by the user and that may persist for an indefinite time when an FPD is connected to the main electricity supply. Off mode is the power state when the FPD is connected to a power source, produces no images and is waiting to be switched to the On Mode by a direct signal from a user/computer (e.g., user pushes power switch).

Applicability
FPDs.

Test procedure
See B.7.1.

References
Please see references 70-74.

Mandate:

The FPD shall meet the following requirement levels for maximum power consumption:

Until January 1, 2006:

FPD	*Sleep mode*	*Off mode*	*On mode*
Maximum power consumption	≤ 4 W	≤ 2 W	Shall be declared

From January 1, 2006:

FPD	*Sleep mode*	*Off mode*	*On mode**
Maximum power consumption	≤ 2 W	≤ 1 W	• if X < 1 megapixel, then Y = 23 • if X > 1 megapixel, then Y = 28X

***(X is the number of megapixels, Y is the energy consumption in watts)**

The following information shall be submitted:

An energy declaration sheet, showing power consumption in active mode, sleep mode and off mode together with display-specific data, from a test laboratory approved by TCO Development shall be submitted.

Energy declaration sheets

Brand name holder / manufacturer	
FPD model number	
FPD panel type	
Diagonal screen size in inches	
Aspect ratio	
Screen resolution	
Max. no. of pixels for declared screen size	
Luminance level	
Voltage level and frequency used	
No of lamps in background lightning	

FPD	*On mode*	*Sleep mode*	*Off mode*
Measured power consumption in watts			

There shall be a description, from the user's point of view, of how the FPD is brought into its energy mode(s) and how this is indicated on the FPD. The description shall be signed by the responsible person at the applicant company and submitted by the responsible person at the applicant company.

R References

International standard organisations referred to in the reference list below and their home pages.

- ASTM, American Society for Testing and Materials, http://www.astm.org/
- CIE, Commission Internationale de l'Eclairage, International Commission on Illumination, www.cie.co.at/cie/
- DIN, Deutsches Institut für Normung e. V., www2.din.de
- EBU, European Broadcasting Union, http://www.ebu.ch/tech_info.html
- IEC, International Electrotechnical Commission, www.iec.ch
- ISO, International Organization for Standardization, http://www.iso.org/
- ITU, International Telcommunication Union www.itu.int/home/index.html
- SMTPE, Society of Motion Picture Television Engineers, www.smtpe.org
- VESA, Video Electronics Standards Association, www.vesa.org

1. CIE Publication 69 (1987), Methods of characterizing illuminance meters and luminance meters: performance characteristics and specifications.
2. Flat Panel Display Measurements Standard, (FPDM), Version 2.0, VESA - Video Electronics Standards Association Display Metrology Committee. June 1, 2001, CA 95035, Milpitas.
3. http://www.w3.org/Graphics/Color/sRGB.html
4. SMPTE RP 145-1994: SMPTE C Color Monitor Colorimetry
5. ASTM gloss standard D523.
6. ISO2813:1994 Paints and varnishes - Determination of specular gloss of non-metallic paint films at 20 degrees, 60 degrees and 85 degrees. International Organisation of Standardisation, 1994.
7. DIN 67 530.
8. CIE Publication 15.2 (1986), Colorimetry, p. 11, p.27-28 and p. 53-54, table 1.3).
9. IEC 61966-2-1 (1999-10) Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management - Default RGB colour space – sRGB.
10. ITU-R Recommendation BT.470-6: Conventional television systems.
11. ITU-R Recommendation BT.709-5: Parameter values for the HDTV standards for production and international programme exchange
12. E.B.U. Standard for chromaticity tolerances for studio monitors Tech. 3213-E August 1975.
13. SMPTE 170M-1999 Television - Composite Analog Video Signal - NTSC for Studio Applications.
14. Hunt, R.W.G. Measuring colour. 3rd edition (1998), Kingsley-Upon-Thames: Fountain Press.
15. ISO TC130 WD 12646 p. 5 Section 4.7 Chromaticity and luminance of the white and black points and tracking.

16. ISO 3664:1999, Viewing conditions for graphic technology and photography, p. 9 Uniformity of screen luminance.
17. ISO 3664:1999, Viewing conditions for graphic technology and photography, p. 5, 4.2.4 Surround and backing for reflection viewing, Note 1 p. 8.
18. ISO 3664:1999. Viewing conditions for graphic technology and photography, p. 10 Monitor luminance.
19. Barten, P.G.J., (1999) Contrast sensitivity of the human eye and its effects on image quality, SPIE Optical Engineering Press
20. Barten, P.G.J., (1999) Contrast sensitivity of the human eye and its effects on image quality, SPIE Optical Engineering Press p. 105 - 106.
21. Barten, P.G.J., (1999) Contrast sensitivity of the human eye and its effects on image quality, SPIE Optical Engineering Press p. 179.
22. Barten, P.G.J., (1999) Contrast sensitivity of the human eye and its effects on image quality, SPIE Optical Engineering Press p. 179 - 181.
23. Kokoschka S. (1986). Visibility aspects of VDUs in terms of contrast and luminance. Behaviour and information technology. vol.5, No. 4, pp 309-333.
24. Schenkman, B., and Kjelldahl, L. (1999). Preferred colour temperature on a colour screen. Displays, 20, 73 - 81.
25. Roberts, A., Eng, B., (1995) "A method for the calculation of tolerances for display primary chromaticity coordinates" Research and development Department, Technical Resources, The British Broadcasting Corporation.
26. www.srgb.com
27. Wyszecki, G., Stiles, W.S., (1982) Color Science: Concepts and methods, quantitative data and formula, Second Edition, John Wiley & Sons, Inc. Chapter 7, Visual thresholds, pp 567-569.
28. Wyszecki, G., Stiles, W.S., (1982) Color Science: Concepts and methods, quantitative data and formula, Second Edition, John Wiley & Sons, Inc. Chapter 7, Visual thresholds, pp 574-575.
29. Le Grand, Y. (1957). Light, colour and vision. Chapman and Hall, pp 278-279.
30. Le Grand, Y. (1957). Light, colour and vision. Chapman and Hall.
31. Le Grand, Y. (1957). Light, colour and vision. Chapman and Hall, p. 119
32. Le Grand, Y. (1957). Light, colour and vision. Chapman and Hall, Chapter 11, Luminance difference thresholds, p. 261.
33. Le Grand, Y. (1957). Light, colour and vision. Chapman and Hall, Chapter 11, Luminance difference thresholds.
34. Le Grand, Y. (1957). Light, colour and vision. Chapman and Hall, Chapter 12, Colour difference thresholds p. 279.
35. Fairchild M. D. (1995), "Considering the surround in device-independent color imaging". www.cis.rit.edu/people/faculty/fairchild/PDFs/Bart.pdf
36. ISO 13406-2 Ergonomic requirements for work with visual displays based on flat panels - Part 2: Ergonomic requirements for flat panel displays. International Organisation of Standardisation.
37. ISO 9241-7 Ergonomic requirements for office work with visual display terminals (VDTs) - Part 7: Requirements for display with reflections. International Organisation of Standardisation.

38. ISO 9241-8 Ergonomic requirements for office work with visual display terminals (VDTs) - Part 8: Requirements for displayed colours. International Organisation of Standardisation.
39. ASF, the Swedish Environment Authority´s Provisions and General Recommendations 1998:5
40. DIN 33402
41. EC Directive 90/270/EEC EU Directive 90/270/EEC Minimum safety and health requirements for work with display screen equipment.
42. ISO 11226 Ergonomics -- Evaluation of static working postures
43. ISO 13406-2 Ergonomic requirements for work with visual displays based on flat panels - Part 2: Ergonomic requirements for flat panel displays. International Organisation of Standardisation.
44. ISO 9241-3 Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 3: Visual display requirements. International Organisation of Standardisation, 1992
45. ISO 9241-5 Ergonomic requirements for office work with visual display terminals (VDTs) - Part 5: Workstation layout and postural requirements. International Organisation of Standardisation.
46. Nymans, Berns, Gelin 1995, research report "Do AM-LCD monitors offer better ergonomic solutions than CRTs?"
47. Statshälsan 1990, User recommendations from the Swedish Foundation of Occupational Health for State Employees, report "Man, Monitor and Work Environment"
48. UK Department of Trade and Industry, Consumer Safety Unit, Adult data DTI/Pub 45/3k/01/00/NP
49. VESA Flat Panel Monitor, Physical Mounting Interface Standard (FPMPMI), version 2.0, Revision 3, March 1, or VESA Flat Display Mounting Interface Standard, (FDMI) Version 1 October 28, 2002 which replaces and supersedes FPMPMI.
50. EN 60950 (IEC 60950). Safety of information technology equipment including business equipment.
51. CLRTAP; the UN/ECE Convention on Long-range Transboundary Air Pollution: "The 1998 Aarhus Protocol on Heavy Metals"
52. EMAS EU regulation no 761/2001 concerning the voluntary participation of industrial companies in the Union's environmental control and review structure.
53. Esbjerg declaration – 4th North Sea Conference 1995
54. EU Directive 91/157/EEC on batteries and accumulators containing certain dangerous substances
55. EU Directive (76/769/EEC) on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations
56. EU Directive 2001/58/EC amending for the second time Directive 91/155/EEC
57. EU Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment

58. EU Directive 91/155/EEC defining and laying down the detailed arrangements for the system of specific information relating to dangerous preparations in implementation of Article 10 of Directive 88/379/EEC
59. EU Directive 93/793/EEC on the evaluation and control of the risks of existing substances
60. Proposal for an EU Directive 2003/0256-0257. Regulation concerning Registration, Evaluation, Authorisation and Restriction of Chemials (REACH)
61. HELCOM article 5, annex I
62. ISO 1043-1, -2, -3, -4 Plastics - Symbols and abbreviated terms
63. ISO 11469 Plastics - Generic identification and marking of plastics products
64. ISO 14001 Environmental management systems - Specification with guidance for use
65. OSPAR Strategy with regard to Hazardous Substances (1998-16)
66. Risk Reduction Monograph no. 3 (OECD Environment Monograph series no 102)
67. The EU Green Paper "Environmental questions concerning PVC" KOM (2000) 469
68. EU Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)
69. TCO'03 Guidelines, available at http://www.tcodevelopment.com
70. Energy Star Program Requirements for Computer Monitors – Version 4.0 http://www.energystar.gov
71. VESA FPDM Standard 2.0
72. VESA Standard: Display Specifications and Measurements Procedures, Ver. 1.0, rev. 1.0 Section 8.1.3
73. VESA Video Signal Standard (VSIS), Version 1.0, Rev 2.0, December 2002
74. IEC 62301 Household electrical appliances – Measurement of standby power. Clause 4.3.1. International Electrotechnical Commission (IEC), 2005

B Test Methods

The following definitions, test conditions, requested specifications from clients, and other information apply for test methods described in this document.

Test results are valid only for the presentation form(s) and configuration(s) tested.

B.1 General test conditions

B.1.1 Definition of a test object

- Test objects covered by this document are visual display units of LCD type, henceforth called Flat Panel Displays, FDPs.
- A test object is defined as the FPD or the FPD plus necessary equipment in order to generate a test image. Any accessory, such as a graphic card or a character generator that can affect the test result can be considered part of the test object if the client so specifies.
- A test object with all necessary information for its operation shall be delivered to the test laboratory in test ready condition including any required accessories. All necessary information about how to operate and adjust the test object shall be provided.
- If the test object is a terminal, the client shall provide appropriate technical devices, manuals and other information to facilitate the necessary presentation.
- The performance of the test object shall in all aspects be fully in accordance with the performance of the final product.
- The client shall inform the test laboratory if any anti-aliasing is used for the FPD. The anti-aliasing can arbitrarily influence the results, making the test laboratories question the results and therefore causing delays.

B.1.2 Required test object information

- The client shall specify the name(s), type designation(s) and manufacturer for all different parts of the test object.
- The client shall specify if a particular graphic card shall be used for testing (see B.1.3).
- The client shall specify the default correlated colour temperature (CCT) of the FPD for testing. Recommended default CCTs are 9300 K or 6500 K but the CCT can be anywhere between 5000 K and 10000 K. If screen colours are given as reddish, bluish or any other colour indication instead of a CCT, the screen shall still have a CCT between 5000 K and 10000 K. The default CCT is the CCT that is set when the user presses the recall function of the display

on the On Screen Display (OSD) set-up. Sometimes this setting is called ”Factory setting”. If the display does not have a recall function, the Auto setting function is pressed and that CCT is used. An Auto setting is mandatory.
Note: Usually the display has an additional OSD menu that is accessible only by the factory or by authorised people. The term in the user OSD should be “Default setting” and the term in the factory-only OSD should be “Factory setting”.

- All tests shall be performed at the default CCT. It is therefore possible that other CCTs do not have the same performance as the tested one. Only the CCT testing will be performed at other values than the default CCT.
- The client shall specify the pixel array of the FPD and the vertical and horizontal frequencies for testing.

B.1.3 Graphic card (Video adapter)

- The client shall specify if a particular graphic card shall be used for testing. In this case the graphic card shall be representative of the common use of the FPD, for example included in the motherboard of associated equipment. Non-standard graphic cards shall not be accepted for testing, unless they are for a special purpose relevant for the product and sold together with it. If the client does not specify a graphic card, a high quality standard graphic card from the testing laboratory shall be used. This shall be reported in the test report and the client shall be informed. The graphic card shall be easily commercially available or supplied with the screen and be of recent model, in order to give the tested combination a more general validity and to give any user of the FPD the possibility of purchasing the same graphic card as used in the testing. The most recent versions of graphic cards and drivers are recommended.
- A character generator shall only be used to operate the FPD if it is not possible to use a standard graphic card. This is because a character generator is not representative of the usual way an FPD is run.
- The graphic card used for testing shall not be used for more than the test object during the test, if not stated by the client.
- The computer or similar devices used to run the test object in the test shall not use any unnecessary software or hardware that could influence the test.

B.1.4 Conditions for the equipment under test

- The FPD being tested shall be physically prepared for testing and shall be warmed up until it is fully stabilised.
- The FPD screen surface shall be clean when tested.
- The FPD shall be tested under nominal conditions of input voltage, current, etc.

B.1.5 FPD alignment for testing

The FPD screen front shall be aligned vertically with the possibility to rotate the screen ±30° around a vertical axis through the centre-point of the screen front. It shall also be possible to tilt the screen backwards 15° around a horizontal axis through the same centre-point.

B.1.6 Instruments used for testing

All instruments used for testing of FPDs shall be of good quality and carry a recent test certificate from a certified testing laboratory. Necessary instrument calibration shall be done before tests are carried out.

B.1.7 Settings of the FPD

- Section B.2.0 specifies the settings FPD controls shall have during testing.
- The standard controls of the FPD shall be used to configure and adjust the screen, e.g. brightness, contrast, correlated colour temperature.
- An external control unit that is not a standard part of the FPD is not allowed.
- The colour depth shall be 24 bits (8 bits per colour channel) or more.
- In Windows/Display Properties/Settings/Advanced the Windows “Small fonts” option shall be used.
- In Windows/Display Properties/Appearance the “Windows standard” colour scheme option shall be used.
- The FPD shall have an auto setting possibility that gives an acceptable image quality. This means that at least 12 of the steps in the 18-step greyscale shall be distinguishable. If this condition is not fulfilled, the FPD is not eligible for TCO certification.

B.1.8 Test image/test character

- All test images can be found on the home page of TCO Development, www.tcodevelopment.com.
- The default testing 12 point Arial font and 100% “zoom/magnification” shall be used. The latest version of MS Windows is the default user interface.
- The default testing polarity is positive polarity (black characters on a white background).
- Another possibility is to use a testing program that shall consist of software commonly used in office and home computer work. The word processor should be able to produce the text and graphics required for the test procedures.

- All parts of the tests for a test object shall be conducted using the same font, character size, correlated colour temperature, resolution, operating system and other settings of the FPD controls etc., unless otherwise stated in the test procedure.
- The FPD shall be tested in accordance with pixel array requirements as specified in A.2.1.1.
- All testing, if not otherwise stated, for visual ergonomics, emissions etc, shall be performed using the same basic settings.

B.1.9 Making an 80% image loading test image

The test image in Figure B.1.9.1, referred to as the TCO default test image, has an 80 % image loading with the luminance 125 cd/m^2. It shall be used for testing unless otherwise specified:

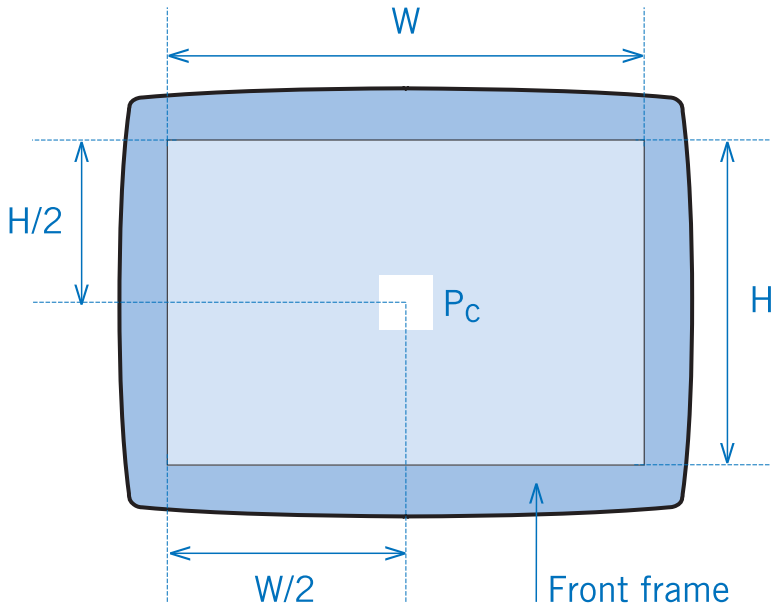

Figure B.1.9.1. The TCO default test image.

Where:

- The background colour shall be set to RGB 204, 204, 204 (i.e. equal to 80 % image loading).
- An active white square at the centre of the screen shall be 40 mm × 40 mm in size and have an RGB setting of 255, 255, 255.
- The luminance of the FPD shall be adjusted to produce a screen luminance of 125 cd/m^2, called the test luminance. If the adjustments do not allow a precise test luminance setting a setting as close as possible to 125 cd/m^2 and within the region 125-135 cd/m^2 is acceptable. To achieve this proceed as follows.

Use the TCO default test image with an 18-step grey scale pattern (see Figure B.1.9.2) presented on the screen at the default CCT setting. The controls of brightness and contrast shall be adjusted to get the best visual performance of the pattern at the test luminance level. This is usually achieved by first pressing the auto adjustment screen button to get the default setting of brightness and contrast. The contrast shall be left at the default setting. The brightness control shall then be adjusted to fine tune the screen luminance to 125 cd/m^2. If it is not possible to achieve the test luminance by this procedure it is suitable to start from a 50% contrast setting and then adjust the brightness. Sometimes there is also a possibility for backlight adjustment which shall not be used unless specified by the manufacturer. The main importance is to get the 18-step grey scale pattern optimised at the test luminance level. If the greyscale quality is not acceptable it can be improved by changing the contrast setting.

The settings of the brightness, contrast and backlight shall be kept for all test measurements. However, the image loading may vary depending on the content of the test image.

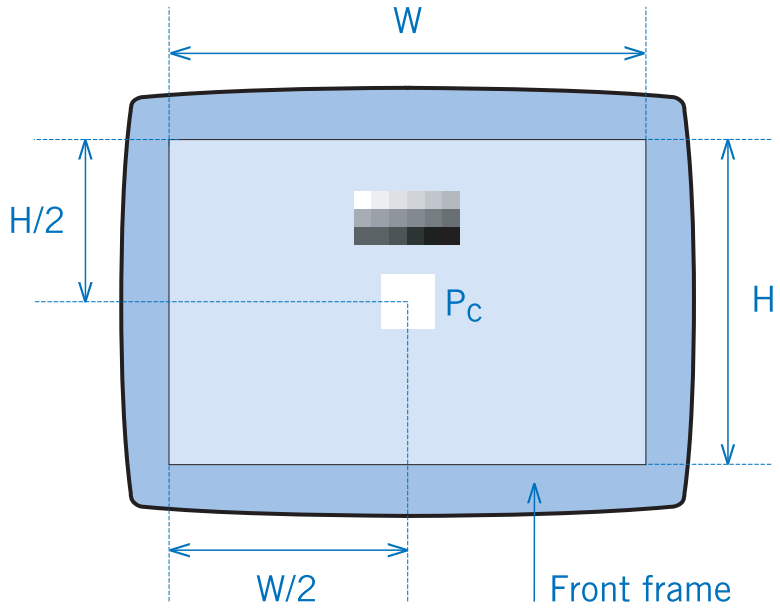

Figure B.1.9.2. The TCO default test image shown with an 18-step greyscale inserted above the white square at the centre of the FPD screen.

- An 18-step greyscale, which shall be used to optimise the image quality of the display, shall be presented just above the white square in the TCO default test image as shown in Figure B.1.9.2. The greyscale shall range from RGB 255, 255, 255 to RGB 000, 000, 000, The total size of the scale shall be approximately 40 mm × 80 mm and positioned close the screen centre.
- The greyscale shall range from RGB 255, 255, 255 to RGB 000, 000, 000. The 18-step grey scale shall consist of squares with grey levels 255, 240, 225,

210, 195, 180, 165, 150, 135, 120, 105, 90, 75, 60, 45, 30, 15 and 0. The squares shall have no line boarders.

- The 18-step grey scale may be accomplished by using the drawing mode in MS Word and making 18 squares with fillings of the different grey levels and putting them together to form a greyscale as shown in Figure B.1.9.2.

The TCO default test image as well as instructions for making the 80% image loading can be found on the TCO Development home page (www.tcodevelopment.com).

The grey scale shall be used to optimise the image quality of the display.

For FPDs the grey scale will not affect the luminance setting of the display since FPDs are not sensitive to image loading.

B.1.10 Test report

The test results are valid only for the presentation form(s) and configuration(s) tested.

The manufacturer, brand name, model type and serial number, if available, shall be stated in the test report.

The mode(s) (i. e. horizontal and vertical scan frequency and resolution) used during the test shall be stated in the test report.

The supply voltage and frequency used during the test shall be stated in the test report together with the type of FPD panel, type of AC adapter, definition of whether the FPD is of pivot type or not and whether it is CLASS I or CLASS II.

The uncertainty for each given measurement result shall be stated in the test report.

B.2 Visual ergonomics

B.2.0 General test conditions for visual ergonomics

B.2.0.1 Basic test requirements

As described in section B.1.
For all tests, the FPD screen shall be clean.

B.2.0.2 Photometric laboratory general requirements

Photometric measurements shall be performed under darkroom conditions. This means that measurement data shall in no way be affected by direct light from sources or light reflected from interiors, equipment, clothes etc.

The laboratory shall have a routine for the control of the stray-light level at the FPD screen.

B.2.0.3 Power supply and test room climate requirements for testing

- AC mains voltage* 230 VAC RMS, tolerance ≤ 1 %
- AC mains frequency* 50 Hz, tolerance ≤ 2 %
- Test room temperature 23±3 ºC
- Humidity 20-75 % RH (non condensing)

_____

* – or other voltage and frequency combination specified by the client.

B.2.0.4 Photometric and spectrometric measurements

Several instruments are to be used when carrying out measurements for visual ergonomics. All instrument shall be recently calibrated and carry a calibration certificate from a certified testing laboratory.

The following instrument types are to be used for testing:

- **Gloss meter**. An instrument for measuring gloss as a function of the directionally selective reflecting properties of a material at angles near to and including the direction giving specular reflection.
- **Luminance meter**. A luminance meter shall have a sufficiently good V_λ-sensitivity (Requirements for luminance meters are covered by CIE Publication 69 (1987). Luminance meters of CIE Class L(aboratory) with a combined performance characteristic ≤3 % shall be used.) and integrate luminance over a finite measuring field during a finite time. The meter shall be equipped with adjustable optics and always be focused on the measured area. The luminance meter must incorporate a sufficiently long time constant of integration in order to ensure averaging of the pulsation of the light emitted by FPDs.

The luminance meter measuring field shall be one degree for all measurements, except for the micro-photometric luminance measurements, see below.

An automated instrument using collimating optics may be used for testing although the measurement area will differ somewhat from the area covered by the luminance meter. When the luminance measurement in this case is done at a shorter distance than 1.5 × the screen diagonal (D) because of instrumental constraints, the laboratory shall verify that the results are equal to those done at 1.5 × D.

- **Micro-photometer**. Micro-photometric registration of the luminance distribution of test patterns shall be performed with an array photo detector device capable of resolving structures of ≤ 0.02 mm. A scanning device shall not be used because it is sensitive to jitter and other variations that may occur during a scanning.
- **Reflectometer**. An instrument designed for the measurement of reflectance shall be used.
- **Spectro-radiometer**. An instrument for the measurement of radiant flux as a function of wavelength shall be used. A spectro-radiometer for the measurement of light and colour is normally equipped with a microprocessor that makes it possible to obtain luminance and colour co-ordinates directly from raw measurement data. A spectro-radiometer can replace the luminance meter when suitable.

B.2.0.5 Measurement distance

Luminance and colour measurements shall be carried out through a point, simulating the eye position of the operator, at a distance of 1.5 × D from the centre-point of the FPD screen. The centre of the front lens of the luminance meter shall never be closer to the screen centre point than 500 mm.

B.2.0.6 Stray light

Stray light may cause errors which can negatively affect measurement of luminance and chromaticity coordinates. It is therefore necessary to make an evaluation of stray light influence for the different measurement procedures described in this document.

If it is verified that stray light affect the measurement result it is necessary to take actions to eliminate the source of error. Two possible ways to solve the problem are to equip the luminance meter with a well designed screening attachment or to use a black screening sheet at the FPD surface.

B.2.0.7 Overall uncertainty

The overall uncertainty of the test laboratory shall be calculated for each measurement procedure in this document and presented in the test report.

B.2.1 Pixel array characteristics

B.2.1.1 Pixel array requirements

B.2.1.1.1 Preparation of the FPD for testing

No specific preparation of the FPD is needed.

B.2.1.1.2 Equipment

Calculator and display manual or similar information about the pixel array of the display.

B.2.1.1.3 Test method

The maximum pixel array and frequencies of the display are found in the manual or similar information from the manufacturer.

B.2.1.1.4 Test evaluation

The FPD shall have a pixel density ≥ 30 pixels/degree.

For “wide-screens” or other special FPD sizes the requirement level shall be calculated.

B.2.1.1.4 Overall uncertainty

Uncertainty is not applicable in this case. Product data information is sufficient.

B.2.3 Luminance characteristics

B.2.3.1 Luminance level

B.2.3.1.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- The TCO default test image with an 18-step greyscale as shown in Figure B.2.3.1 shall be used for luminance level measurement.

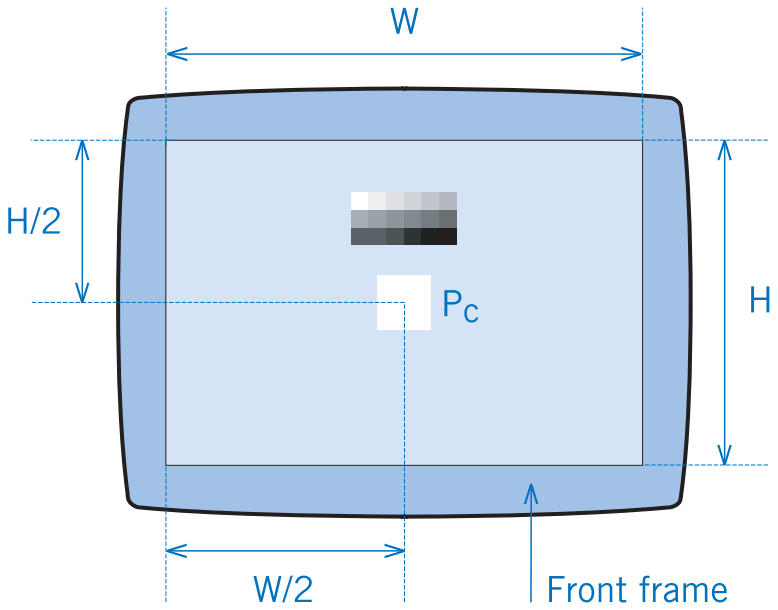

Figure B.2.3.1. TCO default test image with the 18-step greyscale inserted (identical to Figure B.1.9.2).

- The FPD shall be adjusted to the default CCT.
- The measurement position P_C shall be at the centre of a 40 mm × 40 mm square without line boarders, having an RGB setting of 255, 255, 255, and positioned at the centre of the screen.
- To achieve the maximum luminance proceed as follows:
  Use the TCO default test image with an 18-step grey scale pattern presented on the screen at default CCT setting and the controls of brightness and contrast shall be adjusted to maximum. If the image quality of the display becomes unacceptable (see B.2.0.6), the controls shall be adjusted to lower values to find the setting where the highest possible screen luminance with an acceptable image quality is found. It is advisable to start the adjustment at the default contrast setting and to adjust the brightness.

B.2.3.1.2 Equipment

Luminance meter.

B.2.3.1.3 Test method

The luminance at the centre of the white test area shall be measured with the luminance meter directed orthogonally to the test area as described in B.2.0.5.

B.2.3.1.4 Test evaluation

The measured luminance is the required value. The luminance shall be reported with no decimal places.

(The mandate, according to clause A.2.3.1, is the following:

The maximum luminance of the FPD shall be ≥150 cd/m^2).

B.2.3.1.5 Overall uncertainty

≤ ± 10 % in luminance.

See B.2.0.7.

B.2.3.2 Luminance uniformity

B.2.3.2.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- The entire active area of the screen shall be white and the FPD colour setting shall be RGB 255, 255, 255.

B.2.3.2.2 Equipment:

Luminance meter.

B.2.3.2.3 Test method:

The luminance uniformity shall first be evaluated visually by the technician in order to find the darkest and the brightest areas. The most applicable of the following luminance uniformity tests shall then be performed.

- Measure the luminance in the darkest and brightest areas that were visually identified. Then, in addition to this, measure the luminance at each corner position as shown in Figure B.2.3.2.1.
- If no dark or bright areas are identified, measure the luminance at each corner position as shown in Figure B.2.3.2.1.
- An alternative measurement procedure is to use a scanning spectro-radiometer aimed orthogonally to the FPD screen plane to measure the luminance over the entire screen surface. A suitable measurement point density is roughly one per 10 cm^2. A one degree measuring angle corresponds to a measuring area with a diameter of 8.73 mm at 500 mm viewing distance, which is about 1.75 % of the screen diagonal.

The conditions for luminance measurement in the corner positions are illustrated in Figure B.2.3.2.1.

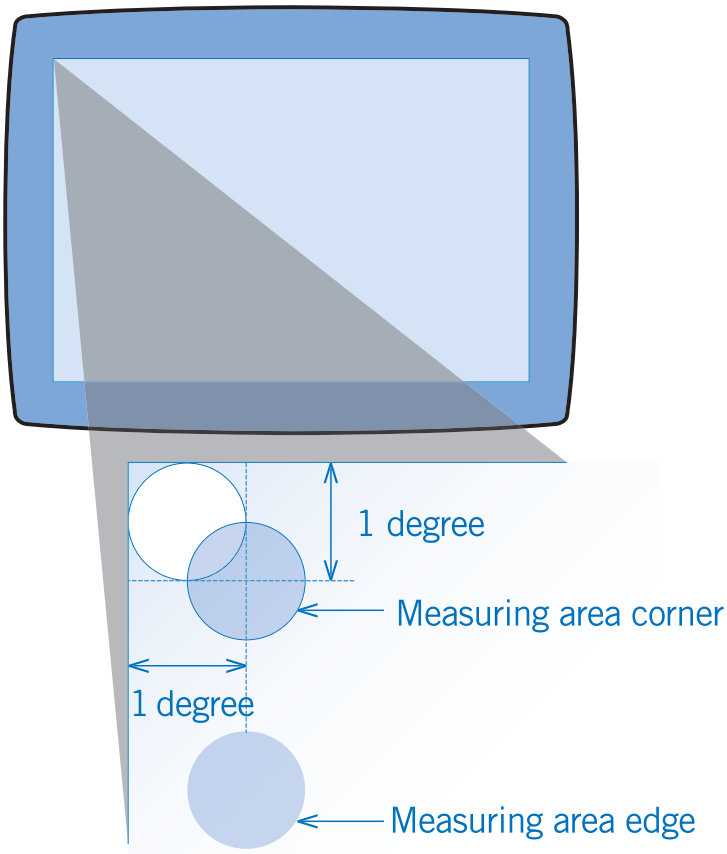

Figure B.2.3.2.1. Corner positions for the measurement of luminance and colour uniformity. A one degree measuring angle corresponds to a measurement area with a 0.0175 × D diameter at a 1.5 × D measuring distance. If an instrument with collimating optics is used it shall be aimed at the centre point of the measuring area as shown in the figure.

B.2.3.2.4 Test evaluation

The luminance uniformity shall be reported as the ratio between the highest and the lowest measured luminance values.

The result shall be presented to 2 decimal places.

(The mandate, according to clause A.2.3.2, is the following:
Luminance variation across the active screen, L_{max}:L_{min} shall be ≤1.5:1 at test luminance settings).

B.2.3.2.5 Overall uncertainty

≤ ± 10 % in luminance.

≤ ± 0.1 unit in luminance uniformity.

See B.2.0.7.

B.2.3.4 Luminance uniformity – angular dependence

B.2.3.4.1 Preparation for the FPD testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- Luminance values shall be measured at five different positions on the screen as shown in Figure B.2.3.4.1. Each measurement position shall consist of white RGB 255, 255, 255 squares sized 40 mm × 40 mm without line boarders.
- The screen background shall be RGB 204, 204, 204.
- The luminance meter shall be positioned and directed orthogonally to the screen centre-point as described in B.2.0.5.

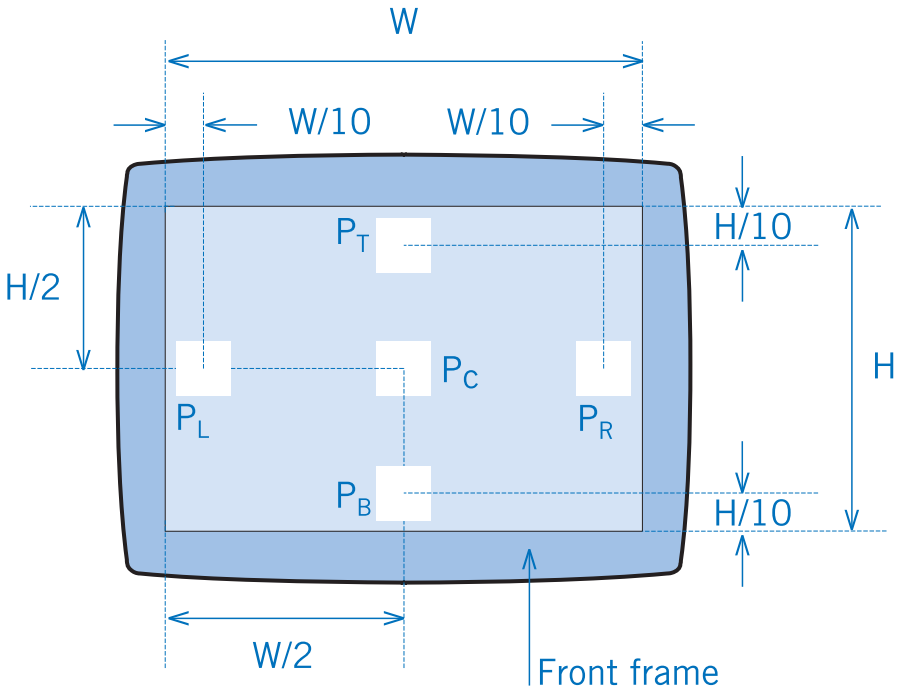

Figure B.2.3.4.1. Measurement positions for angular dependent luminance uniformity.

B.2.3.4.2 Equipment

Luminance meter.

B.2.3.4.3 Test method

1. The luminance meter shall always be directed towards a measurement point and rotated around a fixed vertical axis as described in B.2.0.5.
2. With the FPD in the vertical start position (0/0 = no rotation/no tilt) the luminance meter shall first be turned towards positions P_L and P_R, shown in Figure B.2.3.4.1, and focused. The luminances at these positions ($L_{PL/0/0}$ and $L_{PR/0/0}$ respectively) shall be recorded. This measurement shall only be used for laboratory reference.

3. The screen shall then be rotated +30 degrees around a vertical axis through the screen centre-point and the luminances at positions P_L, P_R, ($L_{PL/+30/0}$ and $L_{PR/+30/0}$ respectively) shall be recorded. See Figure B.2.3.4.2.
4. The screen shall then be rotated -30 degrees around the vertical axis through the screen centre-point and the luminances at positions P_L and P_R ($L_{PL/-30/0}$ and $L_{PR/-30/0}$ respectively) shall be recorded. See Figure B.2.3.4.2.
5. For non-pivot screens the screen shall then be tilted +15 degrees backwards around a horizontal axis through the screen centre-point and the luminances at positions P_T and P_B ($L_{PT/0/+15}$ and $L_{PB/0/+15}$ respectively) shall be recorded. See Figure B.2.3.4.3.
6. Pivot screens shall be measured in both the usual landscape mode and in the portrait mode.
7. For the pivot screen landscape mode the test method will be the same as described above for non-pivot screens in vertical position (3 and 4).
8. With the pivot screen in the portrait mode and only with respect to rotation around the vertical axis, the rotation around the vertical axis shall in this case only be ± 15° and the measurements at positions P_T and P_B ($L_{PT/+15/0}$ and $L_{PB/-15/0}$ respectively) shall be recorded.
9. The measurements to be carried out are summarised in Table B.2.3.4.1.

Table B.2.3.4.1.

Reference above Note no.	Mode	Screen rotation	Screen tilt	Measuring points used			
				P_L	P_R	P_T	P_B
2.	Non pivot/pivot Without rotation For reference only	0°	0°	X	X		
3. **4.**	Non pivot/Landscape Non pivot/Landscape	+30° -30°	0° 0°	X X	X X		
5.	Non pivot/Landscape/tilt	0°	+15°			X	X
3. **4.**	Pivot/Landscape Pivot/Landscape	+30° -30°	0° 0°	X X	X X		
8. **8.**	Pivot/Portrait Pivot/Portrait	+15° -15°	0° 0°			X X	X X

Note:
In the pivot/portrait mode P_T (top) and P_B (bottom) are equivalent to P_R and P_L in Figure B.2.3.4.1.

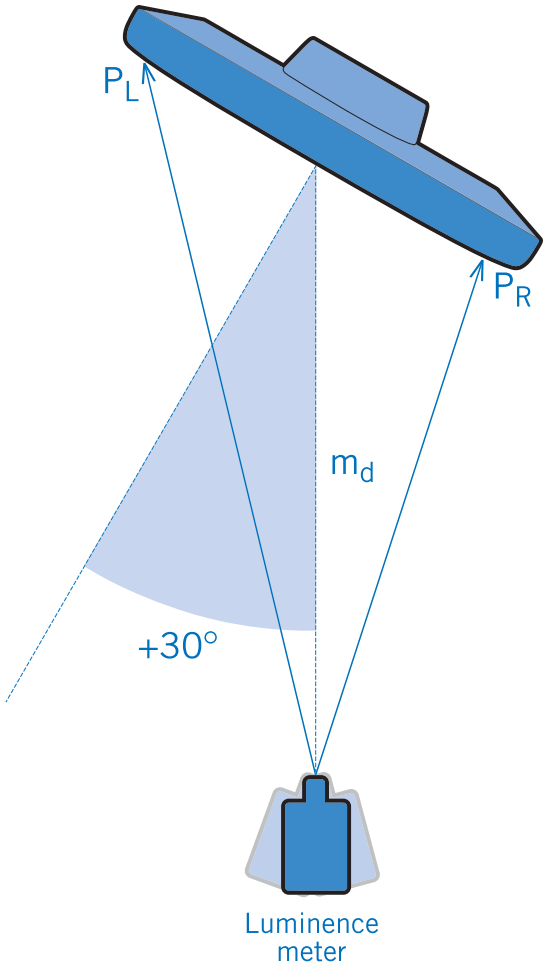

Figure B.2.3.4.2. Top view of test set-up when the screen is rotated ±30 degrees. The + rotation is defined clockwise.

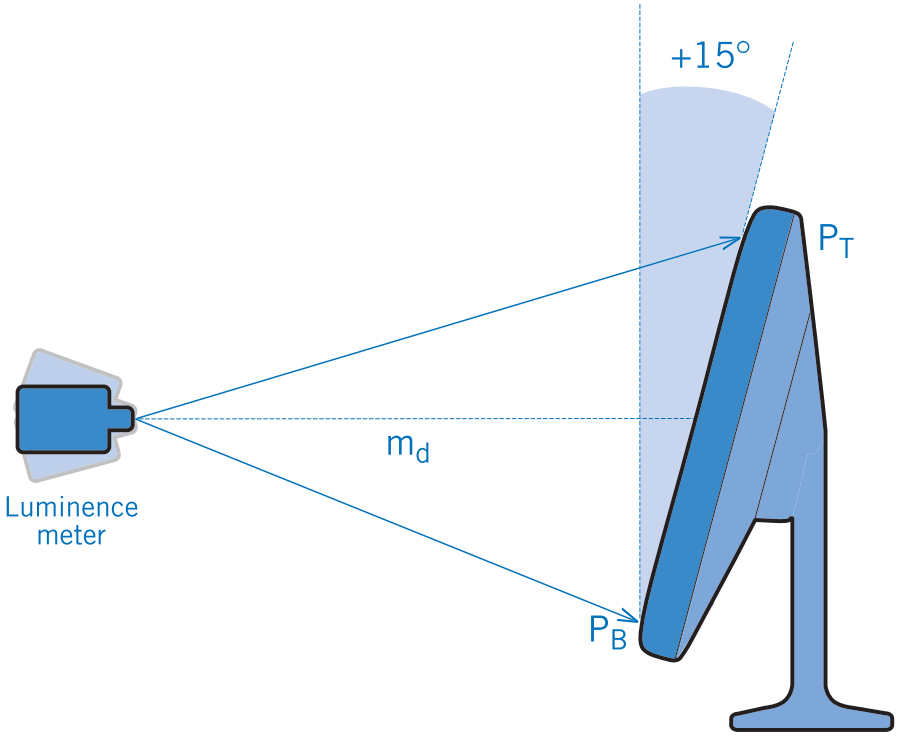

Figure B.2.3.4.3. Side view of the test set-up (for testing non-pivot screens only) when the screen is tilted 15 degrees backwards.

B.2.3.4.4 Test evaluation

The luminance uniformity for angular dependence shall be calculated as follows.

For each separate measurement pair presented in Table B.2.3.4.1 a ratio between the two measured luminances shall be calculated. This ratio, or its inverse if it has a higher value, shall be reported as the requested L_{max} to L_{min} luminance uniformity.

The result shall be presented to 2 decimal places.

(The mandate, according to clause A.2.3.4 is the following:

1) For pivot FPDs and for nonpivot FPDs in landscape mode and in the horizontal direction, the mean value of the L_{max} to L_{min} ratios at ±30° shall be ≤ 1.7.
2) For nonpivot FPDs in landscape mode and in the vertical direction, the value of the L_{max} to L_{min} ratio at +15° shall be ≤ 1.7.
3) For pivot FPDs in portrait mode in the horizontal direction the largest ratio value of L_{max} to L_{min} at ± 15° shall be ≤ 1.7).

B.2.3.4.5 Overall uncertainty

≤ ± 10 % in luminance.

≤ ± 0.3° in rotation angle.

≤ ± 0.1 unit in luminance uniformity.

See B.2.0.7.

B.2.4 Luminance contrast characteristics

B.2.4.1 Luminance contrast – characters

B.2.4.1.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- A micro-photometer for luminance measurement shall be aligned orthogonally to the FPD screen.
- The test image shall be filled with rows of the regular capital letter "H" in 12 point Arial font.
- The brightness and contrast shall be set as for the TCO default test image at the test luminance.

B.2.4.1.2 Equipment

A micro-luminance meter such as an array photodetector capable of measuring luminance on structures ≤ 0.02 mm. Measurement requirements are given in clause B.2.0.2.

B.2.4.1.3 Test method

- By visual evaluation of the standard test measurement position the technician shall search for and locate visual stripes, or patches, that clearly influence the contrast of characters or even parts of characters. Once the patches are visually identified as having significantly lower contrast they shall be geometrically referenced from the upper left corner of the active image and measured, see below. If one position is found that does not fulfil the mandate, there is no need to make further measurements.
- With a micro-luminance meter or a luminance scanner the luminance signal of and around a vertical stroke of a capital H of 12 point Arial font shall be measured. The optical axis of the luminance meter shall be aligned with the normal of the screen surface at the measuring point. The misalignment between the screen surface normal and the optical axis of the luminance meter shall be less than 0.3°.
- The height (h) of the measuring windows shall be 1/3 of the actual height (H) of the character "H". The window shall be positioned symmetrically between the horizontal stroke and the lower ending of the vertical stroke (see Figure B.2.4.1.1).

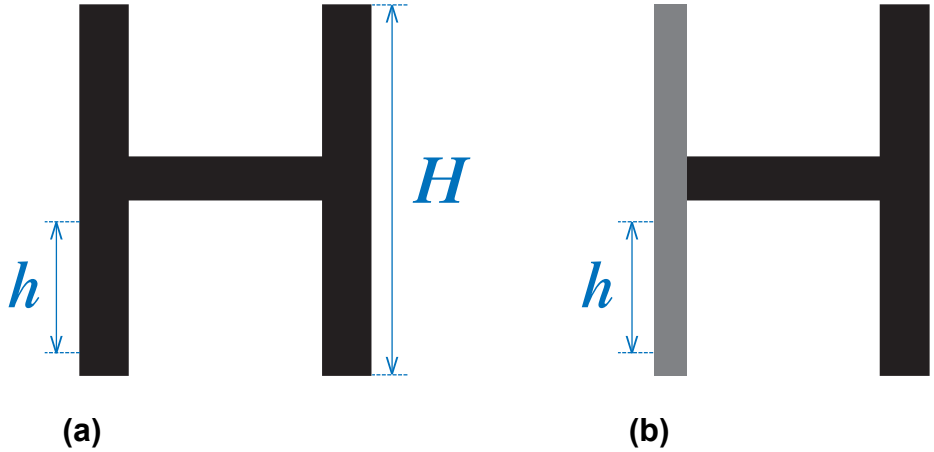

Figure B.2.4.1.1. Example of one capital "H" with (a) good contrast and one with (b) low contrast due to a paler and thinner left vertical stroke. The measuring window having height *h* shall be positioned symmetrically between the horizontal stroke and the lower ending of the vertical stroke of the H.

- The physical width of each measuring window or the matrix element shall be less or equal to 1/8 of the pixel size, but not more than 0.02 mm (cf. Figure B.2.4.1.2).

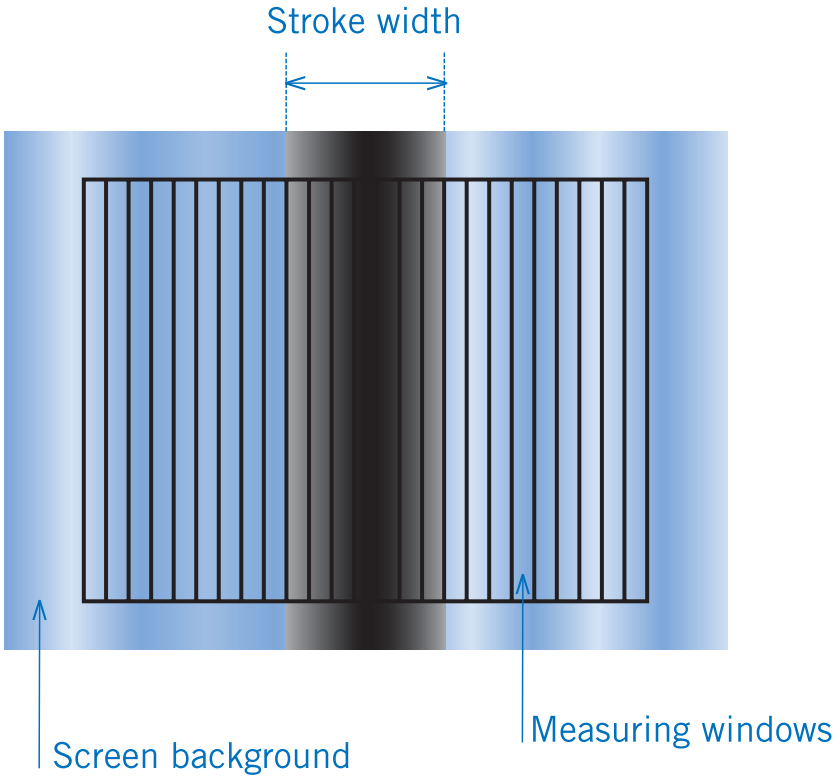

Figure B.2.4.1.2. Magnification of of the vertical stroke in Figure B.2.4.1.1(a) showing a number of sampling windows.

- The basic luminance signal scanned from left to right in Figure B.2.4.1.2 could for example be as shown in Figure B.2.4.1.3.

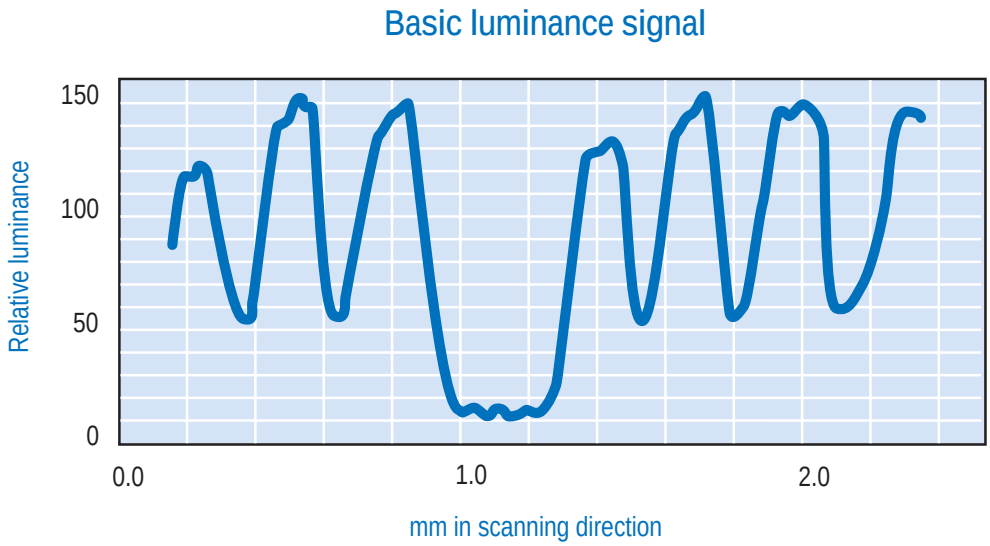

Figure B.2.4.1.3. Example of a basic luminance signal of a vertical stroke of H.

B.2.4.1.4 Test evaluation

- The basic luminance signal received from the micro-luminance meter depends on the resolution (sampling window size) of the sensor and the pixel size of the display. It is likely that the sampling window size differs between laboratories depending on photometer brand.
- The luminance contrast C shall be calculated using the formula

$$C = \frac{L_{max} - L_{min}}{L_{max} + L_{min}}$$

with the maximum and minimum luminances determined as described below.

- The photometer produces a basic luminance signal which can be filtered to a resolution of either 1 or 4 minutes of arc. These filtered signals shall be used for the calculation of C.
- To find the L_{min} proceed as follows: The basic luminance signal shall be filtered to correspond to the 1 minute of arc resolution of the human visual system. This is equal to a sampling window size of 0.145 mm at 500 mm viewing distance. The filtering shall be done by applying a moving average to the basic input data. For example, the 1 minute of arc filtering applied to the luminance signal in Figure B.2.4.1.3 gives the signal in Figure B.2.4.1.4.

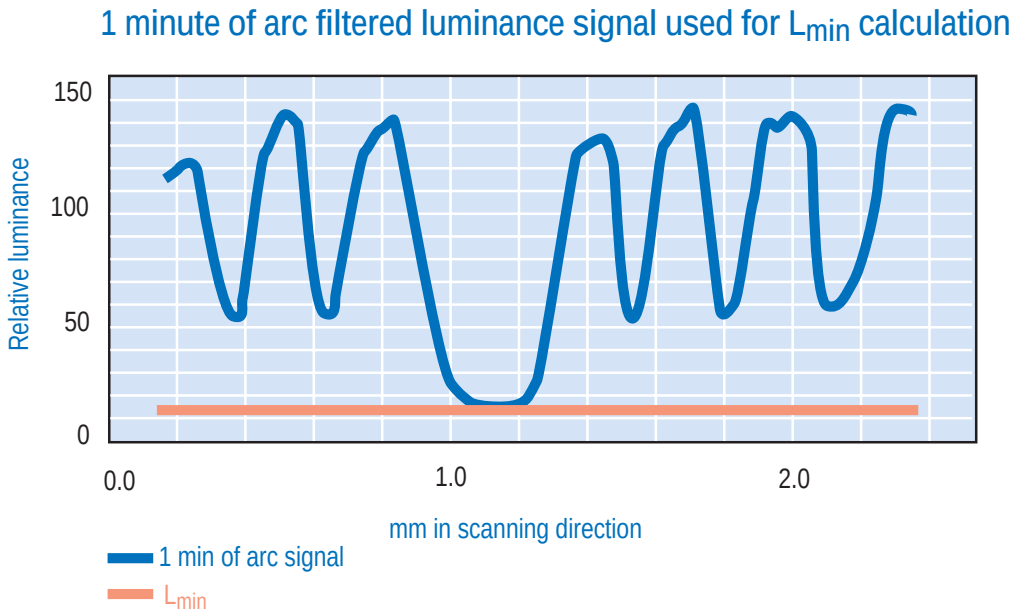

Figure B.2.4.1.4. The luminance signal filtered to 1 minute of arc and showing L_{min}.

- The lowest relative luminance in the vertical stroke in the 1 minute of arc signal is L_{min}.
  (In the example of Figure B.2.4.1.4, the L_{min} value is 14 cd/m²).
- To find the L_{max} proceed as follows: The 4 minute of arc signal filtering shall be obtained by applying a moving average to the 1 minute of arc signal. This corresponds to a more comfortable viewing condition. The filtered luminance signal is shown in Figure B.2.4.1.5.

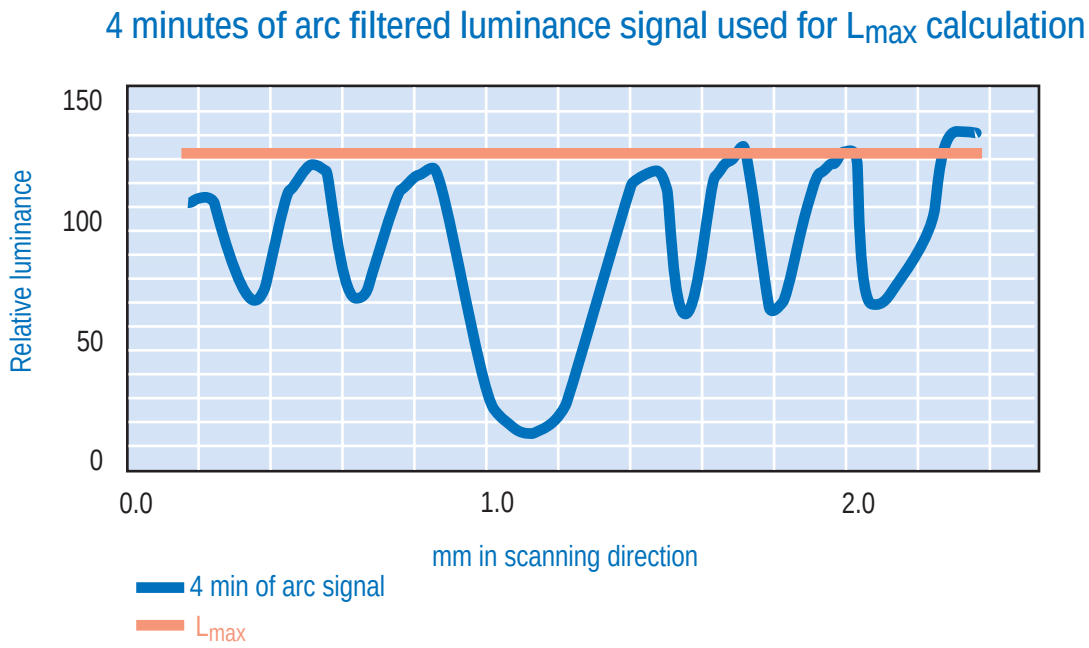

Figure B.2.4.1.5. The 1 minute of arc luminance signal filtered to 4 minutes of arc and showing L_{max}.

- The maximum luminances may be different on the two sides of the H stroke. Select the lower one as L_{max}.

  (In the example of Figures B.2.4.1.4 and B.2.3.1.5 the luminance is lower on the left side than the right side and thus

  L_{max} = 127 cd/m^2. With L_{min} =14 cd/m^2 the contrast is C=(127-14)/(127+14)= 0.80).

  The lowest luminance contrast found shall be reported.

  The result shall be presented to 2 decimal places.

  (The mandate, according to clause A.2.4.1, is the following:
  The FPD shall have a luminance contrast ≥0.7 measured orthogonally to the screen.)

B.2.4.1.5 Overall uncertainty

≤ ± 0.05 in contrast.

See B.2.0.7.

B.2.4.2 Luminance contrast – angular dependence

B.2.4.2.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- Luminance contrast shall be measured at the centre of the screen. The measurement position shall consist of an active white (RGB 255, 255, 255)

square with size 40 mm × 40 mm and a non-active black square of identical size. The two squares shall be positioned on top of each other and centred on the screen as seen in Figure B.2.4.2.1. When the white square is measured the black one is hidden behind the white and vice versa.

- The luminance meter shall be positioned and directed orthogonally to the screen centre-point as described in B.2.0.5.

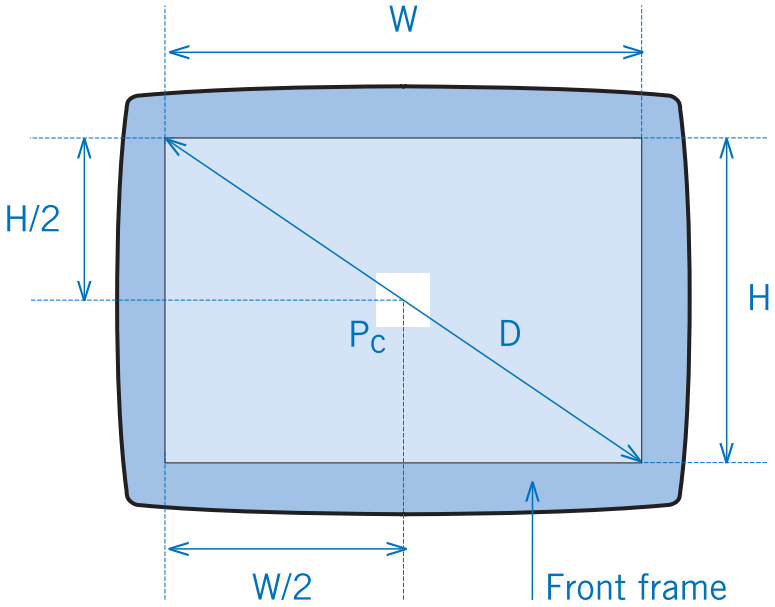

Figure B.2.4.2.1. Measurement position for luminance contrast.

B.2.4.2.2 Equipment

Luminance meter.

B.2.4.2.3 Test method

- Luminance contrast shall be measured at the centre of the screen.
- The luminance meter shall be directed towards the centres of the white and black squares and the luminances L_W and L_B shall be measured. This is not a required measurement but it is advisable to carry out this measurement for laboratory reference use.
- The FPD shall then be rotated around a vertical axis through the screen front centre, changing the azimuth angle to + 30°. The luminances L_{W+30} and L_{B+30} at the centres of the white and black squares shall be recorded.
- Finally the azimuth angle of the screen shall be changed to -30°and the new measurements $L_{W/-30}$ and $L_{B/-30}$ taken.

B.2.4.2.4 Test evaluation

The luminance contrast values C_0, C_{+30} and C_{-30} shall be calculated using the formula

$$C = \frac{L_W - L_B}{L_W + L_B}$$

C_0 shall only be used as a laboratory reference.

Of C_{+30} and $C_{-30,}$ only the lowest value shall be reported as the luminance contrast.

(The mandate, according to clause A.2.4.2, is the following:
For FPDs in landscape mode, the luminance contrast-angular dependence shall be ≥ 0.8 at ± 30º horizontally from the viewing direction.).

B.2.4.2.5 Overall uncertainty

≤ ± 10% in luminance.

≤ ± 0.05 in contrast.

See B.2.0.7.

B.2.5 Front frame reflection characteristics

B.2.5.2 Front frame gloss

B.2.5.2.1 Preparation of the FPD for testing

- No special preparation of the FPD is needed.
- FPD frame surfaces to be tested shall be clean.
- A gloss measurement instrument needs an absolutely flat surface to function properly.
- If the front frame of the FPD is curved, a measurement could be made elsewhere on the housing, provided that the measured surface microstructure, texture and colour are the same as the surface of the front frame.
- If no absolutely flat test surface can be found on the screen frame, the manufacturer can also supply a flat piece of material with optical properties fully equivalent to the front frame material.

B.2.5.1.2 Equipment

A gloss meter in accordance with ISO2813, ASTM D 523 or DIN 67 530, and a calibrated reference standard.

The measurement of gloss shall be made using an instrument with an incident light beam angle of 60° to the normal of the measured surface.

B.2.5.1.3 Test method

Measurement of gloss shall be made at several locations on the front frame of the FPD. Logos, brand names, type marks, control buttons and other small markings are excluded from the measurements and the requirements.

Gloss in different directions shall also be measured at the selected locations.

B.2.5.1.4 Test evaluation

The gloss results shall be presented in gloss units with no decimal places.

The highest recorded gloss value shall be reported.

(The mandate, according to clause A.2.5.2, is the following:
The gloss value $G(60^{o})$ shall be 30 gloss units or less).

B.2.5.1.5 Overall uncertainty

$\leq \pm 2$ gloss units.

See B.2.0.7.

B.2.6 Screen colour characteristics

B.2.6.1 Correlated colour temperature (CCT) variation

B.2.6.1.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- A TCO default test image, as shown in Figure B.2.6.1.1, shall be used for this measurement.

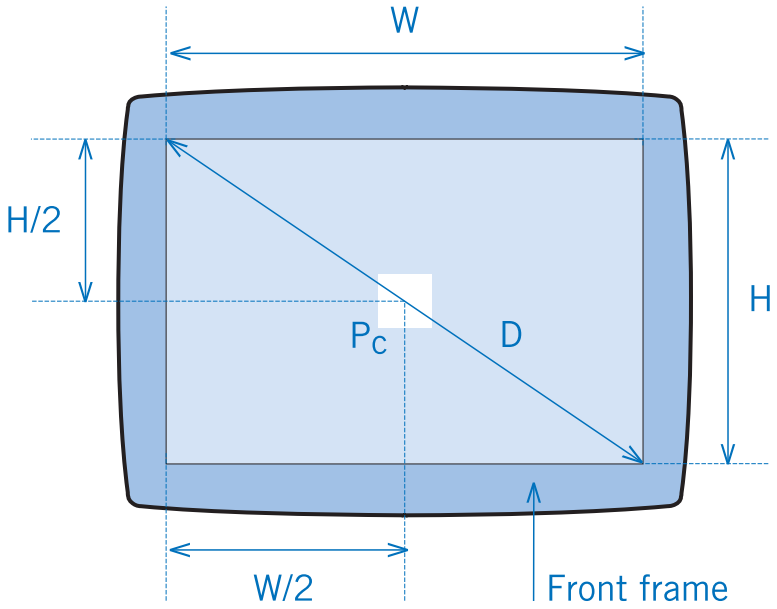

Figure B.2.6.1.1. The TCO default test image shall be used for CCT variation

- The FPD shall be adjusted to the default CCT.
- If no default CCT is given or available the colour temperature presented by the recall function (or equivalent function) in the OSD (On Screen Display) shall be used.
- The background FPD colour setting shall be RGB 204, 204, 204.
- The measurement position "P_C" shall be a 40 mm × 40 mm square positioned in the centre of the screen with an RGB setting of 255, 255, 255.

The following rules shall apply:

- Recommended default CCTs are 6500 K or 9300 K but the CCT can be anywhere between 5000K and 10000K.
- The minimum number of pre-set CCTs is two. The display shall also have a user setting.
- Only CCTs with exactly specified numerical values have to fulfil the requirements.
- CCTs lower than 5000 K shall not be tested.

- If screen colours are given not as CCTs but as reddish, bluish or any other colour indication these settings shall be tested and the u' and v' co-ordinates of the CIE 1976 uniform chromaticity scale diagram shall be reported in the test protocol.

B.2.6.1.2 Equipment

Spectro-radiometer capable of presenting CIE u' and v' chromaticity co-ordinates with at least three decimals.

B.2.6.1.3 Test method

The spectral properties at the centre of the test square shall be measured with a spectro-radiometer.

The spectral data shall then be processed, which is normally done directly in the instrument microprocessor, to give chromaticity co-ordinates. In this case the CIE co-ordinates u' and v' are needed for the test evaluation and are often presented directly by the spectro-radiometer used.

If the client has stated more than two pre-set CCTs preparation and testing shall be repeated for the additional CCTs.

B.2.6.1.4 Test evaluation

The measured u'_m and v'_m values of the screen for the pre-set CCT and the CIE reference chromaticity co-ordinates u'_{CCT} and v'_{CCT} values for the reported CCT shall be used to calculate the colour difference as follows:

$$\Delta u'v' = \sqrt{\left(u'_{CCT} - u'_m\right)^2 + \left(v'_{CCT} - v'_m\right)^2}$$

This calculation shall be done for all tested pre-set CCTs.

Most FPDs are delivered with two or more pre-set CCTs for a white screen. These pre-set CCTs are often one or more of the following; 9300 K, 7500 K, 6500 K, 5500 K and 5000 K. The CIE 1976 u' and v' reference chromaticity co-ordinates for the five mentioned CCTs are given in Table B.2.6.1.1.

Table B.2.6.1.1

CCT in K	u'_{CCT}	v'_{CCT}
9300	0.1888	0.4457
7500	0.1935	0.4586
6500	0.1978	0.4684
5500	0.2044	0.4808
5000	0.2091	0.4882

If default CCTs other than those given in Table B.2.6.1.1 are used in the test, u'_{CCT} and v'_{CCT} can be found by using CIE tabulated data or by using CIE formulae presented in CIE Publication 15.2 (1986), Colorimetry, p.11, p. 27-28 and p. 53-54, Table 1.3.

If the spectro-radiometer used only can produce CIE 1931 x and y chromaticity co-ordinates these can be transformed to u' and v' chromaticity co-ordinates by using the formulae in the CIE Publication 15.2 mentioned above.

The relevant CIE material – conversion formulae and tabulated data for u'_{CCT} and v'_{CCT} – can also be found on the TCO homepage, www.tcodevelopment.com. A computer program based on the given equations can be supplied by TCO.

The resulting colour difference calculation shall be presented to 3 decimal places.

(The mandate, according to clause A.2.6.1, is the following:
The FPD shall have at least two predefined possibilities for pre-set correlated colour temperatures and one possibility for the user to adjust the CCT (total of three settings).

Each pre-set correlated colour temperature shall have a colour difference $\Delta u'v' \leq 0.01$ when compared to CIE u' and v' chromaticity co-ordinates for corresponding correlated colour temperatures.)

B.2.6.1.5 Overall uncertainty

$\leq \pm 0.003$ in u' and v'.

See B.2.0.7.

B.2.6.2 Colour uniformity

B.2.6.2.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- The FPD colour setting shall be RGB 255, 255, 255.

B.2.6.2.2 Equipment

Spectro-radiometer with a capacity to present u' and v' co-ordinates with at least 3 decimals.

B.2.6.2.3 Test method

The colour uniformity shall first be evaluated visually by the technician in order to find those areas where the colour varies the most. The most applicable of the following colour uniformity test shall then be performed.

- Measure the chromaticity co-ordinates u' and v' in the visually most colour-deviating areas. Then, in addition to this, measure the chromaticity co-ordinates in the corner positions as shown in Figure B.2.3.2.1.
- If no areas can be identified where the colour varies, measure the chromaticity co-ordinates in corner the positions as shown in Figure B.2.3.2.1.
- An alternative measurement procedure is the following: Use a scanning spectro-radiometer aimed orthogonally to the FPD screen plane and measure chromaticity co-ordinates all over the screen surface. A suitable measurement point density is roughly one per $10cm^2$.

B.2.6.2.4 Test evaluation

$\Delta u'v'$ according to the CIE (1976) uniform chromaticity scale diagram shall be calculated for each measured position using the formula

$$\Delta u'v' = \sqrt{(u'_A - u'_B)^2 + (v'_A - v'_B)^2}$$

where A and B are the two points found to have the largest colour difference between them.

The largest difference in $\Delta u'v'$ value shall be reported.

The result shall be presented to 3 decimal places.

(The evaluation procedure is exemplified below

- Make a table of colour chromaticity values for each measured position

Measurement position no	u'	v'
1	0.190	0.447
2	0.186	0.441
3	0.186	0.437
–	–	–
–	–	–
n-1	0.185	0.434
n	0.186	0.432
Largest difference	0.005 in this example	0.015 in this example

- The largest u' difference, $\Delta u'$, is 0.005 (between 0.190 and 0.185) at measurement positions 1 and n-1.
- The largest v' difference, $\Delta v'$, is 0.015 (between 0.447 and 0.432) at measurement positions 1 and n.
- Since $\Delta v'$ (= 0.015) is much larger than $\Delta u'$ (= 0.005), the $\Delta v'$ value shall be used for the calculation of $\Delta u'v'$.
- The corresponding two pairs of u' and v' to be used for the calculation are thus the values found at position 1 and position n and thus become the values used for points A and B such that

  $u'_1 = u'_A = 0.190$ and $v'_1 = v'_A = 0.447$ for point A in this example

  and

  $u'_n = u'_B = 0.186$ and $v'_n = v'_B = 0.432$ for point B in this example

  Hence $\Delta u'v' = \sqrt{0.000016 + 0.000225} = 0.01552$, which shall be reported as 0.016.)

(The mandate, according to clause A.2.6.2 is the following:
$\Delta u'v' \leq 0.01$ for the maximum colour deviation between measured active areas on the screen that are intended to maintain the same colour.)

B.2.6.2.5 Overall uncertainty

$\leq \pm 0.003$ in u' and v'.

See B.2.0.7.

B.2.6.3 RGB settings

B.2.6.3.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- For RGB measurements, red, green and blue 40 mm × 40 mm squares shall consecutively be positioned in the centre of the screen surrounded by a grey area of 80% image loading.
- The RGB settings shall be the following:
  255, 000, 000 for red,
  000, 255, 000 for green,
  000, 000, 255 for blue.

B.2.6.3.2 Equipment

Spectro-radiometer with a capacity to present u' and v' co-ordinates with at least 3 decimals.

B.2.6.3.3 Test method

The instrument shall be directed orthogonally towards the different test square centres at the measurement distance described in B.2.0.5. The chromaticity co-ordinates of the red, green and blue squares shall be measured.

B.2.6.3.4 Test evaluation

The recorded chromaticity co-ordinates u' and v' for the red, green and blue squares shall be reported.

The u' and v' shall be presented to 3 decimal places.

(The mandate, according to clause A.2.6.3 is the following:
The minimum colour triangle shall have the following co-ordinates:

for red	$u' \geq 0.411$ and $v' \geq 0.503$
for green	$u' \leq 0.140$ and $v' \geq 0.548$
for blue	$u' \geq 0.150$ and $v' \leq 0.224$)

B.2.6.3.5 Overall uncertainty

$\leq \pm 0.003$ in u' and v' for red and green.

$\leq \pm 0.007$ in u' and v' for blue.

See B.2.0.7.

B.2.6.4 Colour uniformity – angular dependence

B.2.6.4.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- The screen background shall be RGB 204, 204, 204.
- Chromaticity co-ordinates u' and v' shall be measured at three different positions on the screen as shown in Figure B.2.6.4.1. Each measurement position shall consist of white RGB 255, 255, 255 squares sized 40 mm × 40 mm.
- The spectro-radiometer shall be positioned and directed orthogonally to the screen centre-point as described in B.2.0.5.

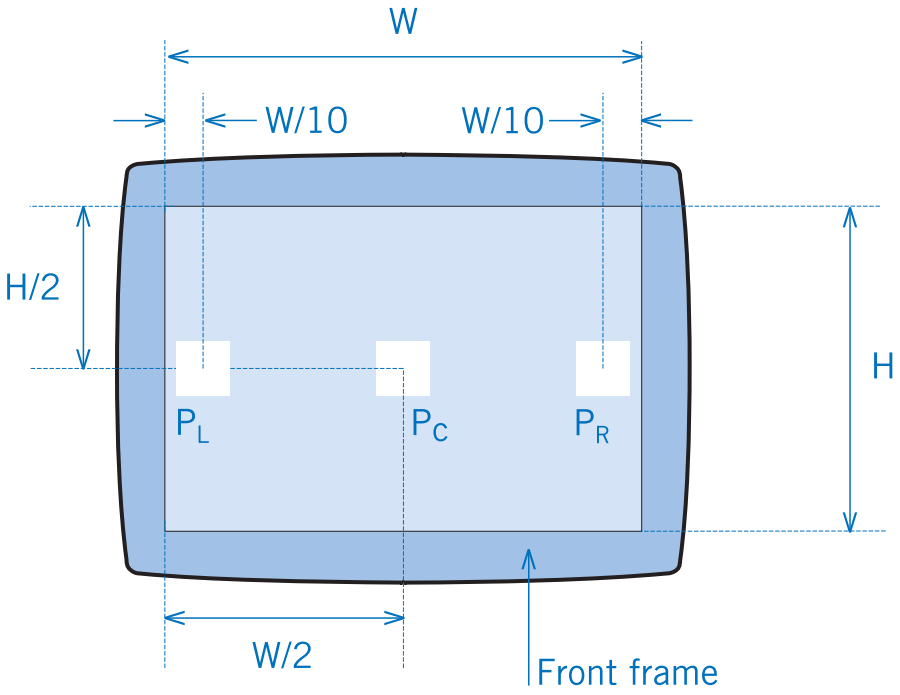

Figure B.2.6.4.1. Measurement positions for colour uniformity-angular dependence.

B.2.6.4.2 Equipment

Spectro-radiometer

B.2.6.4.3 Test method

- The spectro-radiometer shall always be directed towards a measurement position keeping the centre-point of its front lens at a fixed position.
- The spectro-radiometer shall be turned towards positions P_C, P_L and P_R and focused. The colour co-ordinates at positions P_C, P_L and P_R ($u'_{PC/0}$, $v'_{PC/0}$, $u'_{PL/0}$, $v'_{PL/0}$ and $u'_{PR/0}$, $v'_{PR/0}$ respectively) shall be recorded. Measurements at position PC shall only be used for laboratory reference.
- The screen shall then be rotated +30 degrees around a vertical axis through the screen centre-point and the chromaticity co-ordinates at positions P_L, P_R, ($u'_{PL/+30}$, $v'_{PL/+30}$ and $u'_{PR/+30}$, $v'_{PR/+30}$ respectively) shall be recorded.

- The screen shall finally be rotated -30 degrees around a vertical axis through the screen centre-point and the chromaticity co-ordinates at positions P_L, P_R, ($u'_{PL/-30}$, $v'_{PL/-30}$ and $u'_{PR/-30}$, $v'_{PR/-30}$ respectively) shall be recorded.
- Pivot screens shall only be measured in the usual landscape mode.

B.2.6.4.4 Test evaluation

Δu'v' according to the CIE (1976) uniform chromaticity scale diagram shall be calculated for each measured position using the formula

$$\Delta u'v' = \sqrt{(u'_A - u'_B)^2 + (v'_A - v'_B)^2}$$

where A and B are the two points found to have the largest colour difference between them.

The largest difference in Δu'v' value shall be reported

The result shall be presented to 3 decimal places.

(The evaluation procedure is exemplified below

- Make a table of chromaticity values for each measurement position and calculate Δu'v' for +30° for and -30°

Measurement position no	Example value u'	Example value v'
PL/+30	0.190	0.447
PR/+30	0.187	0.442
Difference at +30°	0.003	0.005
Δ u'v' at +30°	0.0059	
Measurement position no	**Example value u'**	**Example value v'**
PL/-30	0.182	0.436
PR/-30	0.189	0.432
Difference at -30°	0.007	0.004
Δ u'v' at -30°	0.0081	
Largest difference Δ u'v'	0.0081 in this example	

- The largest calculated Δu'v' difference is 0.0081 when the screen is rotated -30°. The test value to be reported is this value, reported to 3 decimal places, thus 0.008.

(The mandate, according to clause A.2.6.4 is the following:
For an FPD in landscape mode, the Δu'v' between areas on the left side and the right side of the screen when it is positioned at + 30° and at -30° horizontally to the screen normal shall be ≤ 0.025).

B.2.6.4.5 Overall uncertainty

≤ ± 10% in luminance.

≤ ± 0.003 units for u' and v'.

≤ ± 0.3° in rotation angle.

See B.2.0.7.

B.2.6.5 Colour greyscale linearity

B.2.6.5.1 Preparation of the FPD for testing

- All necessary preparations described in B.1 and B.2.0 shall be done.
- A test image consisting of a white screen with 100% image loading as background shall be used with a test pattern as shown in Figure B.2.6.5.1.
- Squares of 40 mm × 40 mm in size, filled with the following greyscale steps; 255, 225, 195, 165, 135, and 105, shall be arranged in the centre of the screen.

Figure B.2.6.5.1. A 6-step greyscale to be used for the measurement of colour greyscale linearity. Each square is 40 mm × 40 mm in size.

The greyscale can be found at the TCO homepage www.tcodevelopment.com

B.2.6.5.2 Equipment

Spectro-radiometer.

B.2.6.5.3 Test method

The first grey-step, i.e. having level 255, shall be moved (scrolled) into the centre of the screen and both the luminance and the u' and v' co-ordinates shall be measured. The next grey-step, having level 225, shall then be moved (scrolled) into the centre position and measured. The same procedure shall then be repeated for grey-steps 195, 165, 135 and 105.

B.2.6.5.4 Test evaluation

The evaluation task is to find the two grey scale steps that represent the pairs of u' and v' giving the largest colour difference in Δu'v' by use of the equation:

$$\Delta u'v' = \sqrt{(u'_A - u'_B)^2 + (v'_A - v'_B)^2}$$

where indices A and B are the two grey levels found to have the largest colour difference between them.

The largest difference in Δu'v' value shall be reported.

The result shall be presented to 3 decimal places.

The evaluation procedure is exemplified below

- Make a table of chromaticity values for each grey level.

Example value			
Grey level	Luminance cd/m2	u'	v'
255	124.8	0.190	0.447
225	90.4	0.186	0.441
195	61.2	0.186	0.437
165	40.1	0.185	0.435
135	25.2	0.185	0.434
105	15.8	0.186	0.432
Maximum difference		0.005 in this example	0.015 in this example

- The largest u' difference, $\Delta u'$, is 0.005 (between 0.190 and 0.185 at grey levels 255 and 165/135 respectively).

  The largest v' difference, $\Delta v'$, is 0.015 (between 0.447 and 0.432 at grey levels 255 and 105 respectively).

- Since $\Delta v'$, (= 0.015) is much larger than $\Delta u'$ (= 0.005), the $\Delta v'$ value shall be used for the calculation of $\Delta u'v'$.

  The corresponding two pairs of u' and v' to be used for the calculation are thus the values found at grey level 255 and grey level 105 and thus

  $u'_{255} = u'_A = 0.190$ and $v'_{255} = v'_A = 0.447$ for grey level A in this example

  $u'_{105} = u'_B = 0.186$ and $v'_{105} = v'_B = 0.432$ for grey level B in this example

  Hence $\Delta u'v' = \sqrt{0.000016 + 0.000225} = 0.01552$, which shall be reported as 0.016).

(The mandate, according to clause A.2.6.5, is the following:
The greyscale steps to be used are 255, 225, 195, 165, 135, and 105, and each should be measured in the centre of the screen. The maximum difference in either u' or v' identifies those steps where $\Delta u'v'$ should be calculated. The $\Delta u'v' \leq 0.02$).

B.2.6.5.5 Overall uncertainty

$\leq \pm$ 10% in luminance.

$\leq \pm$ 0.003 units for u' and v'.

See B.2.0.7.

B.4 Emissions

B.4.0 General test conditions for emissions

B.4.0.1 Basic test requirements

As described in section B.1.

For the test methods for emissions described in this document the following conditions apply:

- AC mains voltage* 230 VAC RMS, tolerance ≤ 1 %
- AC mains frequency* 50 Hz, tolerance ≤ 2 %

The equipment shall be connected to phase and neutral.

* – or other voltage and frequency combination specified by the client.

B.4.0.2 Conditions and set up for the test object

The tests shall be performed with the full screen size activated.

The FPD control settings shall be the same as for visual ergonomics. This means that 125 cd/m^2 for FPDs at an image loading of 80 % shall be used for the emission testing of alternating electric and magnetic fields. See section B.1.9 for details concerning this setting.

The FPD shall display a full screen of capital “H” pattern in dark/black letters on an illuminated background (positive polarity), see section B.1.8 for details concerning this setting.

Any pivot FPD that can be used in both normal landscape position and portrait position (turned 90°) shall have measurements taken in both positions. The worst case shall be reported.

Any FPD equipped with a height-adjustable stand shall have measurements taken in both the lowest and highest positions. Both measurements shall be done with the FPD positioned to the centre-centre point of the screen surface. The worst case shall be reported.

The FPD must comply with the mandatory requirements without having to rely on an earth connection via the signal cable. In order to test an FPD without an earth connection via the power cable, a battery operated computer, with no connection to earth, can be used to operate the FPD.

If the FPD is connected to mains via a detachable mains cord, the measurement shall be performed with a non-shielded mains cord of normal type, (connected to earth for CLASS I device).

An FPD without an external power supply shall be connected to mains via the above mentioned power cable, which shall run from the point of its connection on the FPD and then horizontally straight to a point 0.4 m behind the screen surface.

The cable shall then from this point run downwards at least 1 m. – see figure B.4.0.2.1.

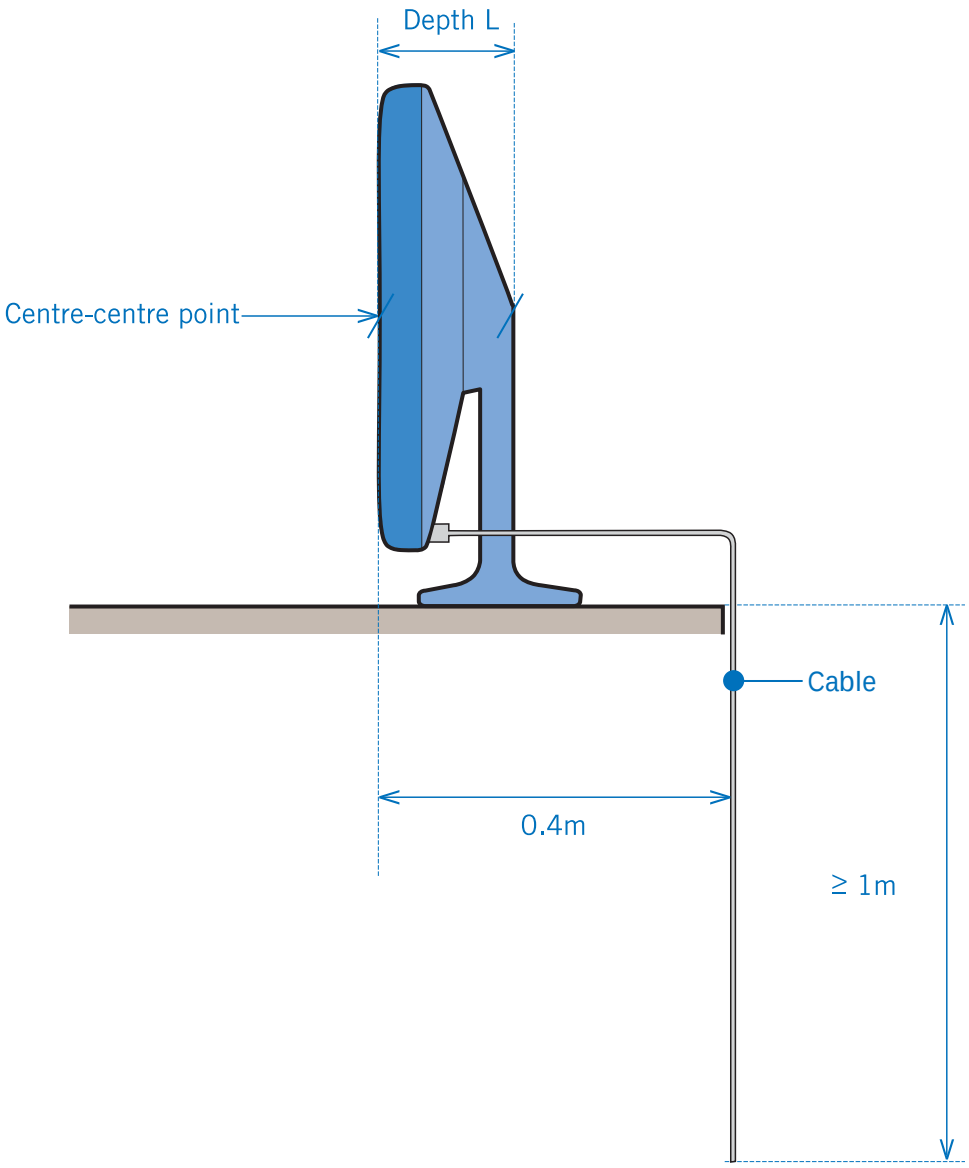

Figure B.4.0.2.1 FPD without external power supply unit.

If the FPD is provided with a fixed holder for the power and signal cables, to secure them together, then this holder is to be used during the test.

The external power supply unit, if any, will contribute to the electromagnetic fields around the FPD. Power supply units, which are connected via a primary cable to the outlet, shall be positioned centrally, directly behind the test sample, on the (turn)table, with the secondary side towards the FPD, see Figure B.4.0.2.2. The primary cable shall extend horizontally, on the (turn)table to a point 0.4 m behind the screen surface. The cable shall then, from this point run downwards at least 1 m. If the power supply can be positioned with different sides up, it shall be tested in all positions and the worst case shall be used.

The secondary cable of the power supply shall run the shortest distance from the point of its connection on the FPD to the secondary side of the power supply. The unused portion of the secondary cable, if any, shall be bundled together with the power supply unit. The bundle loops shall have a length equal to the longest dimension of the power supply. For supply units with dimensions less than 10 cm, a 10 cm bundle loop length shall be used.

For power supply units which are designed to be put directly in the outlet, without a primary cable, the secondary cable shall run vertically down to the (turn)table from the point of its connection on the FPD and then horizontally straight to a point 0.4 m behind the screen surface. The cable shall then, from this point, run downwards at least 1 m.

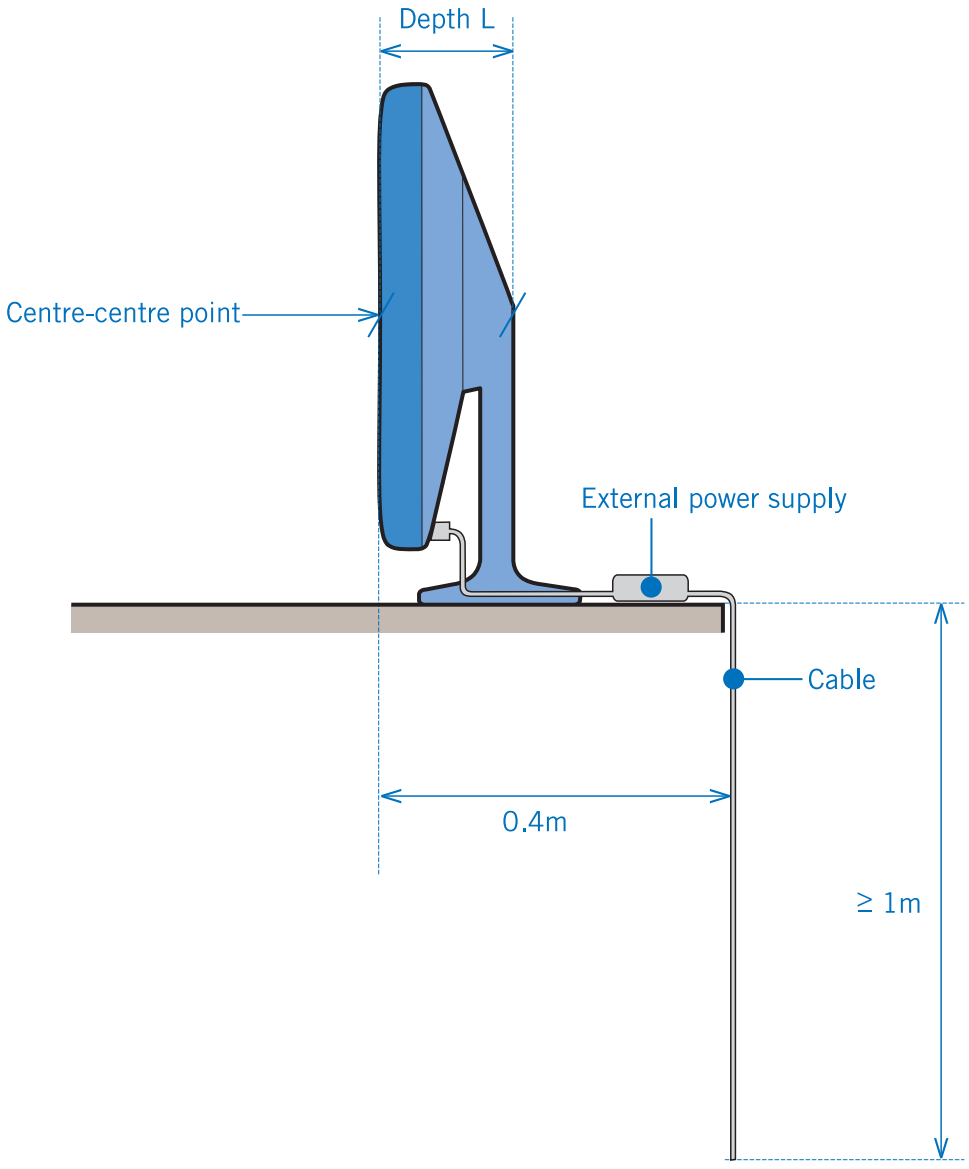

Figure B.4.0.2.2 FPD with external power supply units.

Note! For pivot FPDs and FPDs equipped with height-adjustable stands, the cable has to be adjusted for the different positions.

For measurements of alternating magnetic fields (B.4.3) the power cable may be positioned in another way, as the cable contributes a negligible amount to the magnetic field. However external power supplies must be correctly positioned, as they may give rise to magnetic fields.

If positioning according to the above rules is not possible, then the positioning of the supply unit and cables shall be described in the test report.

B.4.0.3 Emission measurement instruments

The instruments used for emission testing shall comply with the requirements and calibration procedures described below:

Alternating electric field meter

The alternating electrical field emission from the FPD under test shall be determined by measuring the displacement current passing a given surface of the measuring probe. The probe consists of a disc of double sided printed circuit board laminate with a diameter of 300 mm. On the front of the board the copper layer is removed in the annulus between radii 50 and 52 mm, see Figure B.4.0.3.1.

The copper foil surrounded by the annulus is the active measuring surface. It is connected to one input terminal of an operational amplifier, with capacitive feedback. The other input terminal of the operational amplifier, the copper ring outside the active surface, and the back of the board are connected to ground. The output voltage (U) from the probe (active surface with area (A)) is related to the incident electrical field, E, averaged over the active surface according to $U = \varepsilon \cdot E \cdot A/C$ where C is the capacitance in the feedback loop of the operational amplifier and ε is the permittivity for a vacuum.

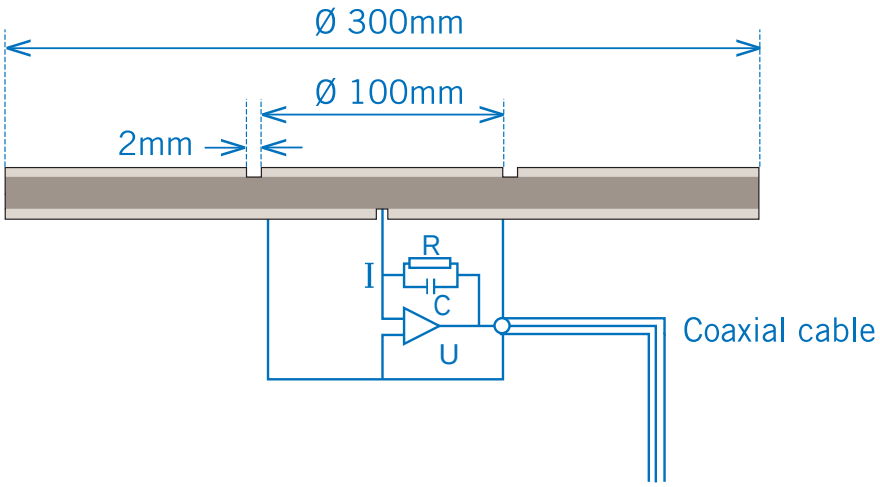

Figure B.4.0.3.1 Sketch and circuit principle of the Alternating electric field meter for alternating electrical field measurements. The feedback circuit of the operational amplifier is a capacitance C in parallel with a high value resistor R to ensure that there is no DC voltage across the plates of the capacitor C.

The specifications for the frequency response of the are given by the calibration procedure. The signals from the probe shall be filtered by high-pass and low-pass filters. The specification of the filters is given in Table B.4.0.3.1.

Table B.4.0.3.1 Filter specifications

Frequency Band I					
Frequency	<5 Hz	5 Hz	100 Hz	2 kHz	>2 kHz
Attenuation	>80 dB/decade	3 dB/decade	0 dB/decade	3 dB/decade	>40 dB/decade

Frequency Band II					
Frequency	<2 Hz	2 Hz	30 kHz	400 kHz	>400 kHz
Attenuation	>80 dB/decade	3 dB/decade	0 dB/decade	3 dB/decade	>40 dB/decade

After amplification and filtering the output voltage of the measuring probe shall be used to determine the r.m.s. value of the electric field strength in both frequency bands.

The measuring time shall be sufficiently long to enable measurements with an accuracy of ± 5 % at 50/60 Hz.

The measuring system shall be capable of measuring at least down to 2.0 V/m in band I and down to 0.20 V/m in band II.

The measuring probe shall be calibrated using a parallel plate capacitor (air dielectric) consisting of the measuring probe and a metal plate of at least 300 mm diameter. The distance between the surface of the probe and the plate shall be 30 mm.

The calibration shall be performed with sinusoidal fields at the amplitudes and frequencies specified in Table B.4.0.3.2.

Table B.4.0.3.2 Calibration frequencies and amplitudes

Frequencies		Amplitudes
Band I	50, 100, 500, 1000 Hz	10, 25 V/m
Band II	15, 30, 60, 120 kHz	1.0, 2.5, 10 V/m

Recorded values at these calibration points shall be within ± 5 % of the nominal value. Due to the nature of the specified filters the deviation shall be calculated at 1 kHz from 9.5 and 22.5 V/m and at 120 kHz from 0.95, 2.4 and 9.5 V/m.

Alternating magnetic field meter in band I and band II

The magnetic field shall be measured with two coil systems, one covering band I and the other band II. Each coil system shall consist of three mutually

perpendicular concentric circular coils each with an area of 0.01 m^2. The coils may depart from a circular shape where they intersect. The minimum inner diameter shall be 110 mm and the maximum outer diameter 116 mm. The measuring coils shall not be sensitive to electric fields.

The resonance frequency of each coil appropriately connected to cables and amplifiers shall be greater than 12 kHz for band I and greater than 2.5 MHz for band II. The resonances shall be suppressed by resistive loading of each coil.

Amplifiers and integrating networks to make the output voltage proportional to the magnetic flux density and independent of frequency shall follow each coil. The specifications in respect of the frequency response are given in the calibration procedure.

High-pass and low-pass filters shall filter the signals from the coil systems. The specifications of the filters are given in Table B.4.0.3.1.

After amplification, integration and filtering, the signals from the three coils in each coil set shall be used as input values for calculating the r.m.s. values of the amplitudes of the magnetic flux density vectors in both frequency bands. It is permissible to calculate the r.m.s. value for each of the coil signals and use the root of the squared sum of those r.m.s. values as the test result.

The measuring time shall be sufficiently long to enable measurement with an accuracy of ± 5 % at 50/60 Hz.

The alternating magnetic field meter in band I and band II shall be capable of measuring down to at least 40 nT in band I and down to 5.0 nT in band II.

The alternating magnetic field meter in band I and band II shall be calibrated using a Helmholtz-type calibration coil as shown in the Figure B.4.0.3.2. Calibration set-up. Calibration shall be performed with sinusoidal fields at the amplitudes and frequencies specified in Table B.4.0.3.3.

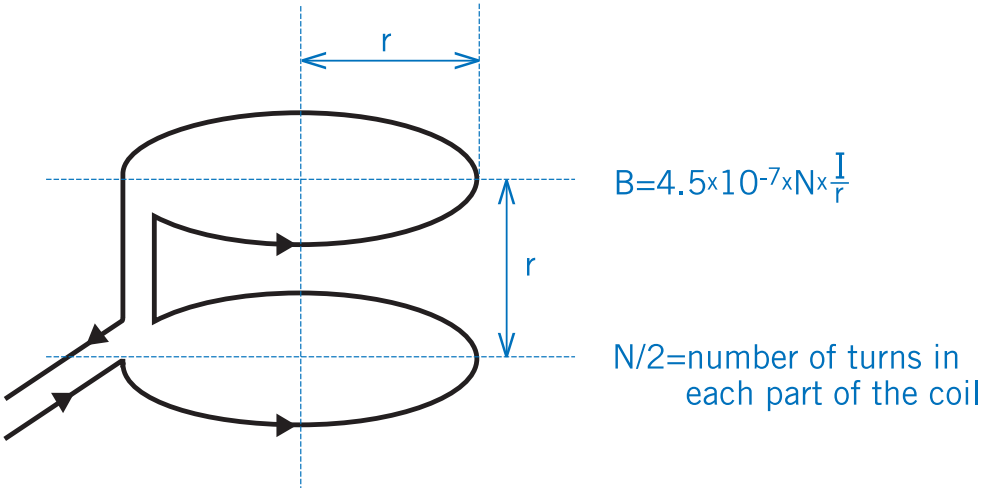

Figure B.4.0.3.2. Calibration using a Helmholtz-type calibration coil.

Table B.4.0.3.3 Calibration frequencies and amplitudes

Frequencies		Amplitudes
Band I	60, 100, 500, 1000 Hz	200, 2000 nT
Band II	15, 30, 60, 120 kHz	25, 250 nT

Recorded values for these calibrations shall not deviate more than ± 5 % from the nominal value. Due to the nature of the specified filters the deviation at 1 kHz shall be calculated from 180 nT and 1800 nT and at 120 kHz from 24 nT and 240 nT.

The calibration shall be performed for each of the three individual coils separately exposed, and for one situation where approximately the same flux density passes through all three coils.

B.4.2 Alternating electric fields

B.4.2.0 Test laboratory requirements

Background electric field strengths in the test laboratory, including disturbances transmitted by power lines and internally generated noise in the measuring system, shall together not exceed 2.0 V/m in band I and 0.20 V/m in band II.

The mains voltage to the FPD under test shall be within ± 3 % of its nominal value.

B.4.2.1 Preparation of the FPD for testing

All necessary preparations described in B.1 and B.4.0 shall be done.

An external optical filter may not be used in order to comply with the mandatory requirement.

B.4.2.2 Equipment

Alternating electric field meter

B.4.2.3 Test Method

The true r.m.s.-value of the amplitude of the electric field strength, at the surface of the measuring probe, is measured in front of the test object in band I and in four azimuths in band II. The frequency ranges are selected by means of filters in the measuring equipment.

The FPD shall be positioned such that the tangential plane, to the centre-centre point of the screen surface, is at a right angle to the horizontal plane. The distance between the centre-centre points of the screen surface and the back of the FPD, including an eventual part of a stand holder, along the normal to this tangential plane is called L, see Figure B.4.2.3.1.

The origin of the cylindrical co-ordinate system is chosen to be situated at a distance L/2 behind the screen surface on the normal to the tangential plane through the centre-centre point. The z-axis is chosen to be at a right angle to the horizontal plane. The angular reference direction is along the above mentioned normal in the direction pointing outwards from the screen. An angle (ϑ) is positive in the counter-clockwise direction.

Measurements shall be made at all points which have a minimum clearance of 0.25 m to the outer surface of the FPD and with co-ordinates according to:

$z = 0$

$r = (L/2 + 0.5)$ m (at the front also $(L/2 + 0.3)$ m)

$\vartheta = 0°$ for band I

$\vartheta = 0°$, 90°, 180° and 270° for band II

In case of less then 0.25 m clearance the instrument shall be moved out radial until 0.25 m clearance is achieved.

Distances are given in metres and angles in degrees. The co-ordinates are given for the centre of the measuring probe. The surface of the probe shall be perpendicular, within ± 5°, to the radial axis.

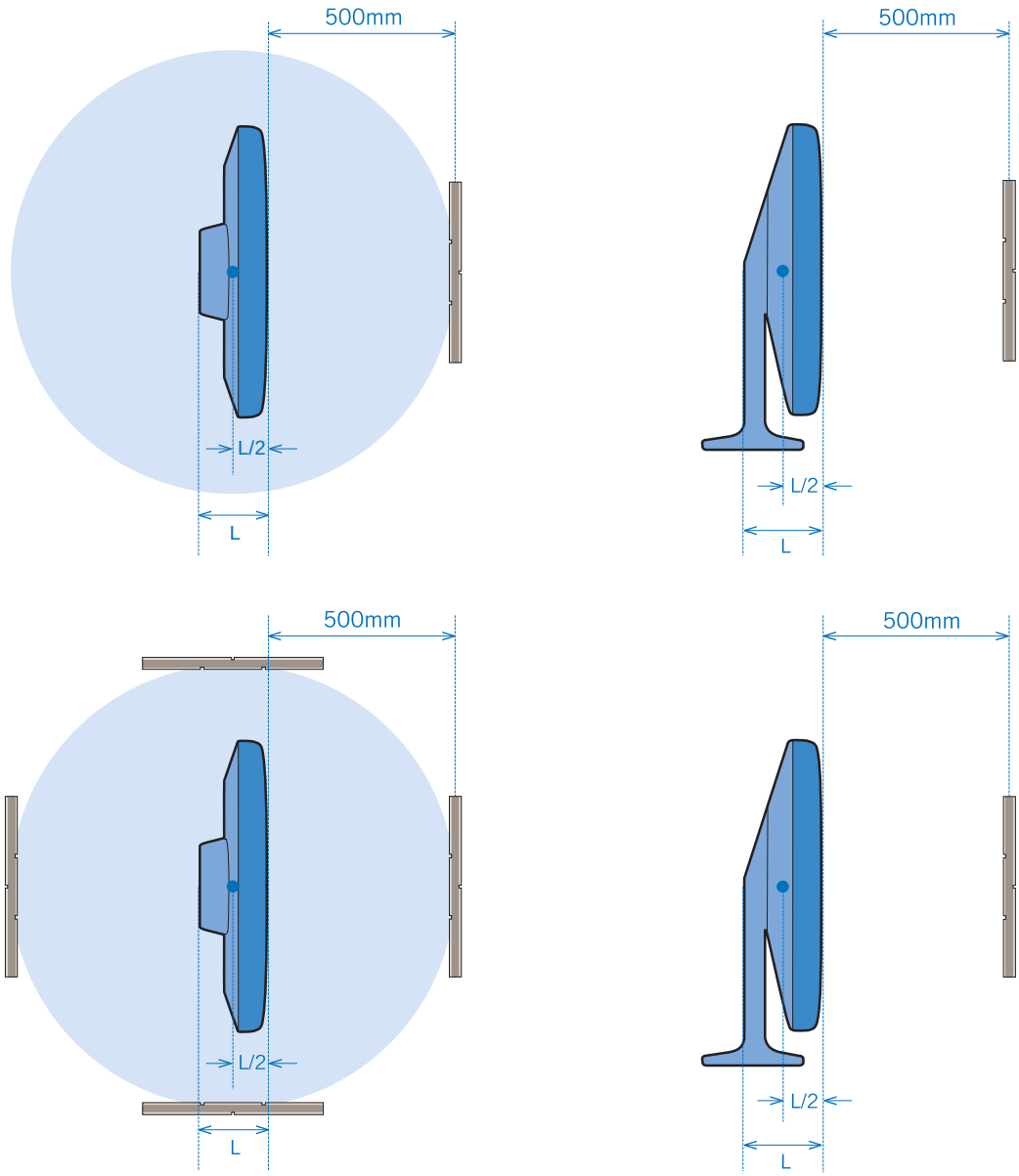

Figure B.4.2.3.1. Measurement geometry for band I (top) and band II (bottom).

The FPD under test and the measuring probe shall be positioned at least 1 m from all significant metallic structures and objects.

Additional units and connecting cables necessary for the operation of the FPD, which are not part of the test, shall be placed so far away from the measuring setup that the fields they emit do not influence the measurement. Shielding may be added to these units and cables, as long as the 1 m clearance is maintained.

The measuring probe shall be connected to ground. Any eventual cables running between the measuring probe and the measuring instrument, shall be positioned in such a way that they do not influence the measured value.

The power cable of the test object shall be connected to the phase and the neutral conductors of the mains power supply. If the mains power supply plug permits an

interchange of the live and neutral conductors, measurements shall be taken with the connection that gives the highest reading in band I.

B.4.2.4 Test evaluation

Results shall be presented as r.m.s. values of the alternating electric field expressed in volt per meter (V/m). For band I, results shall be presented as the measured values at 30 cm and 50 cm for normal and stand-by operations if they differ. For band II, the measured values in front of the FPD and the maximum value at rotation shall be presented for normal and stand-by operations if they differ.

If the measured values are less than 10.0 V/m in band I or less than 1.0 V/m in band II the result shall be reported as "< 10.0 V/m" or "≤1.0 V/m", respectively.

(The mandate according to clause A.4.2 is the following:

Band I: 5 Hz to 2 kHz, ≤ 10 V/m, measured at 30 cm and at 50 cm in front of the FPD.

Band II: 2 kHz to 400 kHz, ≤ 1.0 V/m measured at 50 cm around the FPD and at 30 cm in front of the FPD.)

B.4.2.5 Overall uncertainty

The test shall be performed in such a way that the total extended uncertainty in the test result will be less than ± (10 % of the reading + 1. 5 V/m) for band I and ± (10 % of the reading + 0. 1 V/m) for band II.

B.4.3 Alternating magnetic fields

B.4.3.0 Test laboratory requirements

Background magnetic fields in the test laboratory, including disturbances transmitted along the power line and internally generated noise in the measuring system, shall together not exceed 40 nT in band I and 5 nT in band II.

B.4.3.1 Preparation of the FPD for testing

All necessary preparations described in B.1 and B.4.0 shall be done.

B.4.3.2 Equipment

Alternating magnetic field meter in band I and band II

B.4.3.3 Method

The true r.m.s. value of the amplitude of the magnetic flux density vector is measured at 48 points on a cylindrical surface around the test object in the two frequency ranges, band I and band II. The frequency ranges are selected by specified filters in the alternating magnetic field meter.

The measuring geometry is illustrated in Figure B.4.3.3.1.The measurement points are mathematically defined in the following way.

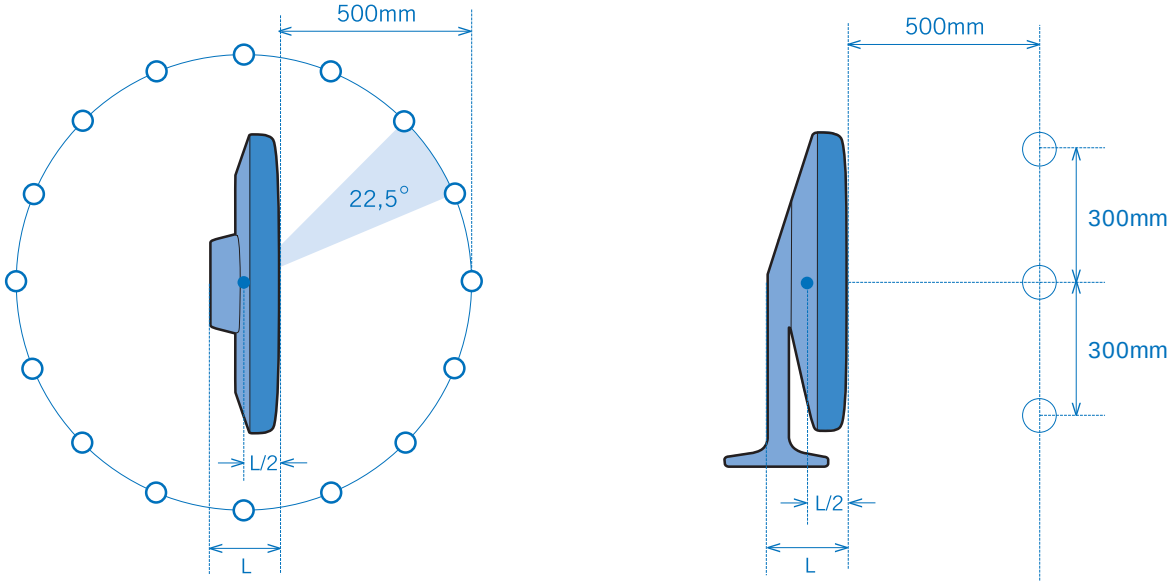

Figure B.4.3.3.1. Measurement geometry for the test object.

The FPD shall be positioned such that the tangential plane, to the centre-centre point of the screen surface, is at a right angle to the horizontal plane. The distance between the centre-centre points of the screen surface and the back of the FPD, including an eventual part of a stand holder, along the normal to this tangential plane is called L.

The origin of the cylindrical co-ordinate system is chosen to be situated at a distance L/2 behind the screen surface on the normal to the tangential plane through the centre-centre point. The z-axis is chosen to be at a right angle to the horizontal plane. The angular reference direction is along the above-mentioned

normal in the direction pointing outwards from the screen. An angle (ϑ) is positive in the counter-clockwise direction. Measurements shall be made at all points which have a minimum clearance of 0.25 m to the outer surface of the FPD and with co-ordinates according to:

z = - 0.3 m, z = 0 and z = + 0.3 m

r = (L/2 + 0.5) m (at the front also (L/2 + 0.3) m in band I)

ϑ= p 22.5° where p represents all integers in the range $1 \leq p \leq 15$.

In case of less then 0.25 m clearance the instrument shall be moved out radial until 0.25 m clearance is achieved.

Distances are given in metres and angles in degrees.

The measuring coils shall be stationary during the measurements.

For FPD luminance settings – see General test conditions for emissions.

The power cable of the test object shall be connected to the phase and the neutral conductors of the mains power supply. The FPD does not need to be measured with the phase and neutral interchanged in this case, as the magnetic fields are not influenced by such a change.

B.4.3.4 Test evaluation

Results shall be presented as r.m.s. values of the magnetic flux density expressed in nanotesla (nT) for the two frequency bands. The values in front of the FPD and the maximum value and its position shall be given both for normal and for standby operation if they differ. If measured values are less than 200 nT in band I or less than 10.0 nT in band II the result shall be reported as "< 200 nT" and "< 10.0 nT" respectively.

(The mandate according to clause A.4.3 is the following:

Band I: 5 Hz to 2 kHz, ≤ 200 nT, measured at 30 cm in front of the FPD and at 50 cm around the FPD.

Band II: 2 kHz to 400 kHz, ≤ 25 nT measured at 50 cm around the FPD.)

B.4.3.5 Overall uncertainty

The test shall be performed in such a way that the total extended uncertainty in the test result will be less than ± (10 % of the reading + 30 nT) for band I and ± (10 % of the reading + 1.5 nT) for band II.

Note

The uncertainties given are worst case limits. In many cases it will be possible to obtain better accuracy, especially in band II.

B.7 Energy

This test method is equivalent to the test method that Energy Star presented in the Program Requirement for Computer Monitors (Version 4.0). Differences are explained in notes which are marked by notes in square brackets [ ] in the text in this test method.

An important difference that does not relate to test methodology is that TCO Development requires tests performed at a test laboratory approved by TCO Development but only one single test object.

In this test method the Energy Star terminology "Computer Monitor" has in this test method been changed to "FPD", an abbreviation of "Flat Panel Displays".

B.7.0 General test conditions for Power measurements

B.7.0.1 Basic test requirements

As described in section B.1.1-B.1.8.

The FPD shall be warmed-up for a minimum of 20 minutes.

B.7.0.1.1 Definitions

On Mode/Active Power
The FPD is connected to a power source and produces an image.

Sleep Mode/Low Power
The reduced power state that the FPD enters after receiving instructions from a computer or via other functions.

Off Mode/Standby Power
The lowest power consumption mode which cannot be switched off by the user and that may persist for an indefinite time when an FPD is connected to the main electricity supply. Off mode is the power state when the FPD is connected to a power source, produces no images and is waiting to be switched to the On Mode by a direct signal from a user/computer.

Hard Off Mode
An operating condition where the product is still plugged into the mains, but has been disconnected from an external power source. This mode is usually engaged by the consumer via a "hard off switch". While in this mode, a product will not draw any electricity and will usually measure 0 watt when metered.

Disconnected
The product has been unplugged from the mains and is therefore disconnected from all external power sources.

B.7.0.2 Test laboratory general requirements

Dark room conditions: When performing light measurements, the FPD shall be located in a dark room condition. The FPD illuminance measurement, when the screen is switched off, must be 1.0 lux or less. Measurements should be made at a point perpendicular to the screen using a Luminance meter with the power to the FPD switched off. (Reference VESA FPDM Standard 2.0, Section 301-2H). [3]

B.7.0.3 Test conditions, general criteria

- AC mains voltage* 230 VAC RMS, tolerance ± 1 %
- AC mains frequency* 50 Hz, tolerance ± 0.5 Hz
- Line impedance 0.25 Ω
- Total harmonic distortion < 2%
- Test room temperature 23±3 ^{o}C [1]
- Humidity 20-75 % RH (non-condensing) [2]
- Refresh rate 60 Hz

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* – or other voltage and frequency combination specified by the client based on the market in which the FPD will be sold.

Notes

[1] Energy Star states 20±5 ^{o}C.

[2] Energy Star states 30-80 % RH.

[3] Energy Star uses an LMD, Light Measuring Device. TCO Development uses a luminance meter in the visual ergonomics section of this document to measure the luminance of the display.

B.7.0.4 Power measurements

Several instruments are to be used when carrying out measurements for power as well as the prerequisite luminance and illuminance levels. All instruments shall have been recently calibrated and bear a calibration certificate from a certified laboratory.

The following instrument types are to be used for testing:

- RMS power meter

The RMS power meter shall have a crest factor of at least five.

- Luminance meter [3]

A luminance meter shall have a sufficiently good V_{λ}-sensitivity (CIE class A with a combined performance characteristic of ≤5 %) and integrate luminance over a finite measuring field during a finite time. The meter shall be equipped with adjustable optics and always be focused on the measured area. The luminance

meter must incorporate a sufficiently long time constant of integration in order to ensure averaging of the pulsation of the light emitted by FPDs.

The luminance meter measuring field shall be one degree for all measurements, except for the micro-photometric luminance measurements, see below.

An automated instrument using collimating optics may be used for testing although the measurement area will differ somewhat from the area covered by the luminance meter.

Requirements for luminance meters are covered by CIE Publication 69 (1987).

If the luminance measurement for instrument design reasons is done at a shorter distance than 1.5 x diagonal, the laboratory shall verify that the results are equal to those done at 1.5 x diagonal.

B.7.0.5 Measurement stability

Measurements shall be taken after a stable wattage value has been obtained over a three-minute period. Values are considered to be stable when variations in wattage values are 1% or less for the duration of the three minute period.

B.7.1 Energy requirement

B.7.1.1 Preparation of the FPD for testing

The preparations include generation of a luminance test pattern and procedures**.**

- For FPDs a test pattern (VESA FPDM Standard 2.0, A112-2F, SET01K) shall be displayed that provides eight shades of grey from full blank (0 volt) to full white (0.7 volt)* Input signal levels shall conform to VESA Video Signal Standard (VSIS), Version 1.0, Rev 2.0, December 2002. With the brightness and contrast control at maximum, the technician shall check that, at a minimum, the white and near grey levels can be distinguished. If white and near white grey levels cannot be distinguished, then contrast shall be adjusted until they can be distinguished. The technician shall next display a test pattern (VESA FPDM Standard 2.0, A112-2H, L80) that provides a full white (0.7 volt) box that occupies 80% of the image. The technician shall then adjust the brightness controls until the white area of the screen provides at least 175 cd/m^2 of luminance, measured according to VESA FPDM Standard 2.0, Section 302-1. [If FPD maximum luminance is less than 175 cd/m^2 (e.g., 150), then the technician shall use the maximum luminance (e.g., 150) and include the value in the test documentation. Similarly, if FPD minimum luminance is greater than 175 cd/m^2 (e.g., 200), then the technician shall use the minimum luminance (e.g., 200) and include the value in the test documentation.] When light measurements, such as illuminance and luminance, need to be made a luminance meter shall be used with the FPD located in dark room conditions. The luminance meter shall be used to make measurements at the centre of, and perpendicular to the FPD screen at a distance of 1.5 x diagonal of the FPD screen size or following the procedure in section B.7.0.4, Luminance meters.[3]
- The FPD refresh rate shall be set to 60 Hz.

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* – For digital interface displays the following voltage levels corresponds to the brightness of the image:

0 volt (black) = a setting of 0,

0.1 volt (dark shade of grey analogue) = 36 digital grey and

0.7 volt (full white analogue) = 255 digital grey.

A digital signal generator should be used to perform the test measurements.

B.7.1.2 Equipment

- RMS power meter
- Luminance meter [3]

B.7.1.3 Test method

The following are the test steps for measuring the true power requirements of the FPD in On Mode/Active Power, Sleep Mode/Low Power and Off Mode/Standby Power. The FPD shall be tested using the analogue interface, except in those cases where one is not provided (i.e., digital interface displays, which are defined as only having a digital interface for purposes of this test method.)

On Mode/Active power

1. Connect the test sample to the outlet or power source and test equipment. For computer displays shipped with an external power supply, the external power supply (as opposed to a reference power supply) must be used in the test.
2. Power on all test equipment and properly adjust the power source voltage and frequency.
3. Check for normal operation of the test unit and leave all customer adjustments set to factory default settings.
4. Bring the test unit into On Mode/Active Power either by using the remote control device or by using the ON/OFF switch on the test unit cabinet. Allow the unit under test to reach operating temperature (approximately 20 minutes).
5. Set the proper display mode, see section B.7.1.1.
6. Provide dark room conditions, see section B.7.0.2.
7. Set size and luminance, see section B.7.1.1. Once luminance is set, dark room conditions are no longer needed.
8. Either verify that the wall outlet power is within specifications or adjust the AC power source output as described in B.7.0.3.
9. Set the power meter current range. The full-scale value selected multiplied by the crest factor rating (I peak/I rms) of the meter must be greater than the peak current reading from the oscilloscope.
10. Allow the readings on the power meters to stabilize and then take the true power reading in watts from the power meter. Measurements are considered stable if the wattage reading does not vary by more than 1% for the duration of the three-minute period.
11. Power consumption shall be recorded for: On Mode/Active Power, Sleep Mode/Low Power and Off Mode/Standby Power.
12. Record the test conditions and results for: On Mode/Active Power, Sleep Mode/Low Power and Off Mode/Standby Power.

Sleep Mode/Low power

1. At the conclusion of the On Mode/Active Power test, initiate the FPD's Sleep Mode/Low Power. The method of adjustment shall be documented along with the sequence of events required to reach the Sleep Mode/Low Power. Power on all test equipment and properly adjust operation range.
2. Allow the FPD to remain in Sleep Mode/Low Power until stable power readings are measured. Measurements are considered stable if the wattage reading does not vary by more than 1% for the duration of the three-minute period. The input sync signal check cycle shall be ignored when metering the model in Sleep Mode/Low Power.
3. Record the test conditions and results. The measurement time shall be sufficiently long to measure the correct average value (i.e., not peak or instantaneous power). If the device has different Sleep Modes that can be manually selected, the measurements should be taken with the device in the

mode that consumes most energy. If the modes are cycled through automatically, the measurement time should be long enough to obtain a true average that includes all modes.

Off Mode/Standby Power (Power switched off)

1. At the conclusion of the Sleep Mode/Low Power test, initiate the FPDs Off Mode/Standby Power. The method of adjustment shall be documented along with the sequence of events required to reach the Off Mode/Standby Power. Power on all test equipment and properly adjust operation range.
2. Allow the FPD to remain in Off Mode/Standby Power until stable power readings are measured. Measurements are considered stable if the wattage reading does not vary by more than 1% for the duration of the three-minute period. Manufacturers shall ignore the input sync signal check cycle when metering the model in Off Mode/Standby Power.

B.7.1.4 Test evaluation

Record the test conditions and test results as specified in section B.7.1.3.

B.7.1.5 Overall uncertainty

The uncertainty in the test results in the range:

- < 10 W shall be better than ± 5%
- 10-30 W shall be better than ± 2%
- >30 W shall be better than ± 1%