BS EN 62563-1:2010

BSI Standards Publication

Medical electrical equipment — Medical image display systems

Part 1: Evaluation methods

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National foreword

This British Standard is the UK implementation of EN 62563-1:2010. It is identical to IEC 62563-1:2009.

The UK participation in its preparation was entrusted by Technical Committee CH/62, Electrical Equipment in Medical Practice, to Subcommittee CH/62/2, Diagnostic imaging equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Appareils électromédicaux - Systèmes d'imagerie médicale - Partie 1: Méthodes d'évaluation (CEI 62563-1:2009)

Medizinische elektrische Geräte - Medizinische Bildwiedergabesysteme - Teil 1: Bewertungsmethoden (IEC 62563-1:2009)

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Foreword

The text of document 62B/743/CDV, future edition 1 of IEC 62563-1, prepared by SC 62B, Diagnostic imaging equipment, of IEC TC 62, Electrical equipment in medical practice, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62563-1 on 2010-03-01.

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

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2010-12-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-03-01

In this standard, the following print types are used:

– requirements and definitions: roman type;
– informative material appearing outside of tables, such as notes, examples and references: in smaller type. Normative text of tables is also in a smaller type;
– TERMS DEFINED IN CLAUSE 3 OF THIS INTERNATIONAL STANDARD, OR AS NOTED: SMALL CAPITALS.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62563-1:2009 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

[1] ISO 9241-302 NOTE Harmonized as EN ISO 9241-302.

[19] IEC 61223-2-5 NOTE Harmonized as EN 61223-2-5.

[20] ISO 9241-303 NOTE Harmonized as EN ISO 9241-303.

[21] ISO 9241-305 NOTE Harmonized as EN ISO 9241-305.

[22] ISO 9241-307 NOTE Harmonized as EN ISO 9241-307.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC/TR 60788	2004	Medical electrical equipment - Glossary of defined terms	-	-
ISO 11664-1	2007	Colorimetry - Part 1: CIE standard colorimetric observers	-	-
CIE S010/E	2004	Photometry - The CIE system of physical photometry	-	-

CONTENTS

INTRODUCTION

This International Standard provides evaluation methods for testing IMAGE DISPLAY SYSTEMS used in MEDICAL ELECTRICAL EQUIPMENT and medical electrical systems for diagnostic imaging.

On site or after installation, two types of testing can be carried out. An acceptance test is carried out after a new IMAGE DISPLAY SYSTEM has been installed, or major modifications have been made to the existing IMAGE DISPLAY SYSTEM. Since an IMAGE DISPLAY SYSTEM may degrade over time, the constancy test is carried out by the user in a periodic cycle to verify that the performance is maintained for the intended use.

The standard describes various evaluation methods without dictating what particular tests shall be used for acceptance and/or constancy tests.

Rather, it is the intention of this standard to be a reference for other standards and guidelines specific to each modality or to be defined by national authorities who will refer to the evaluation methods of this standard and mention limiting values and frequencies for acceptance and constancy tests. Annex A shows sample reports of such a reference.

To maintain the homogeneity in the IEC standards for MEDICAL ELECTRICAL EQUIPMENT, IEC 61223-2-5, *Evaluation and routine testing in medical imaging departments – Part 2-5: Constancy tests – Image display devices* should be reviewed.

MEDICAL ELECTRICAL EQUIPMENT – MEDICAL IMAGE DISPLAY SYSTEMS –

Part 1: Evaluation methods

1 Scope

This part of IEC 62563 describes the evaluation methods for testing medical IMAGE DISPLAY SYSTEMS.

The scope of this International Standard is directed to practical tests that can be visually evaluated or measured using basic test equipment. More advanced or more quantitative measurements can be performed on these devices, but these are beyond the scope of this document.

This standard applies to medical IMAGE DISPLAY SYSTEMS, which can display monochrome image information in the form of greyscale values on colour and greyscale IMAGE DISPLAY SYSTEMS (e.g. CATHODE RAY TUBE (CRT) monitors, FLAT PANEL DISPLAYS, PROJECTION SYSTEM). This standard applies to medical IMAGE DISPLAY SYSTEMS used for diagnostic (interpretation of medical images toward rendering clinical diagnosis) or viewing (viewing medical images for medical purposes other than for providing a medical interpretation) purposes and therefore having specific requirements in terms of image quality. Head mounted IMAGE DISPLAY SYSTEMS and IMAGE DISPLAY SYSTEMS used for confirming positioning and for operation of the system are not covered by this standard.

It is not in the scope of this standard to define the requirements of acceptance and constancy tests nor the frequencies of constancy tests.

2 Normative references

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

IEC 60788:2004, *Medical electrical equipment – Glossary of defined terms*

ISO 11664-1:2007, *Colorimetry – Part 1: CIE standard colorimetric observers*

CIE S 010/E:2004 *Photometry – The CIE system of physical photometry*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purpose of this document, the terms and definitions given in IEC 60788:2004 and the following apply.

3.1.1
accuracy
closeness of agreement between a test result and the accepted reference value

[ISO 5725-1:1994, definition 3.6]

3.1.2
brightness
LUMINANCE as perceived by the human visual system

3.1.3
cathode ray tube
CRT
picture tube
component of an IMAGE DISPLAY SYSTEM in which images defined via electrical signals are visualized by means of an electron beam striking a phosphor

3.1.4
clinical reference image
specific medical image typical for the intended use of the IMAGE DISPLAY SYSTEM

NOTE The anatomical patterns reported in Annex C are examples of CLINICAL REFERENCE IMAGE.

3.1.5
clock artefact
artefact in form of distorted vertical bars or stripes, visible on the screens of fixed-pixel type IMAGE DISPLAY DEVICES (e.g. LCD), when the frequency of the internal dot clock is different from that of the incoming analogue signal

3.1.6
contrast
<IMAGE DISPLAY DEVICES> ratio of the difference of the LUMINANCE of two image areas, $L_1 - L_2$, divided by the average of the two LUMINANCE values:

$$\text{CONTRAST} = 2 \cdot (L_1 - L_2)/(L_1 + L_2)$$

3.1.7
digital driving level
DDL
digital value given as input to an IMAGE DISPLAY SYSTEM producing a LUMINANCE

3.1.8
display controller
electronic component of an IMAGE DISPLAY SYSTEM that provides the analogue or digital interface between the computer hardware and the IMAGE DISPLAY DEVICE

3.1.9
flat panel display
IMAGE DISPLAY DEVICE that is flat and thin

NOTE E.g. liquid crystal display (LCD), plasma display (PDP), field emission display (FED), surface-conduction electron-emitter display (SED), carbon-nano-tube display (CNT), organic light-emitting display (OLED).

3.1.10
flicker
perception of unintentional fluctuations of the LUMINANCE over time

3.1.11
greyscale standard display function
GSDF
mathematically defined mapping of input, DIGITAL DRIVING LEVEL (DDL) to LUMINANCE values based on the Barten model

[Source: DICOM PS 3.14:2007, see [2][1)]]

3.1.12
illuminance
measurement of the luminous flux incident on a surface per unit area (unit: Lux (lx), lx = lm/m^2)

3.1.13
image display device
monitor
specific hardware/medium used to display images presented through an analogue or digital interface

3.1.14
image display system
workstation consisting of an IMAGE DISPLAY DEVICE, DISPLAY CONTROLLER and computer hardware and software, capable of displaying images

3.1.15
luminance
ratio of luminous flux penetrating (impinging on) a surface area in a specified direction to the product of the irradiated solid angle and the projection of the surface area onto a plane perpendicular to the viewing direction (unit: candela per square meter (cd/m^2))

NOTE This definition has been derived from the term in DIN 5031-3:1982-03 [18] and is equivalent to the definition in the International Electrotechnical Vocabulary (IEV).

3.1.16
phase artefact
artefact in form of blurred edges of displayed objects (letters, lines, etc.), visible on the screens of fixed-pixel type IMAGE DISPLAY DEVICES (e.g. LCD), when the phase setting of the internal dot clock is different from that of the incoming analogue signal

3.1.17
precision
closeness of agreement between independent test results obtained under stipulated conditions

[ISO 5725-1:1994, definition 3.12]

3.1.18
projection system
large-screen IMAGE DISPLAY DEVICE which enlarges the small image generated on a plane by central projection to a second plane

3.1.19
resolution addressability ratio
RAR
measured pixel at 50 % point of LUMINANCE at peak or nominal rating expressed as a percentage of addressable space available

3.1.20
spatial resolution
measure of the ability of an IMAGE DISPLAY SYSTEM to distinguish spatial features of interest within an image

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1) Figures in square brackets refer to the Bibliography.

NOTE Systems designed with adequate SPATIAL RESOLUTION characteristics are necessary to assure that spatial details of interest are preserved when a medical image is displayed. Portraying image data on a IMAGE DISPLAY DEVICE with insufficient resolution will compromise the ACCURACY of the radiological interpretation.

3.1.21
test image
test pattern
image for testing or verifying the IMAGE DISPLAY SYSTEMS

3.1.22
veiling glare
enhancement of the LUMINANCE measurable on the IMAGE DISPLAY DEVICE caused by internal scatter processes

NOTE The value of the LUMINANCE enhancement is dependent on the illuminated portion of the image displayed.

3.1.23
window setting
display of a subset of the pixel values existing in the digital image

NOTE The WINDOW SETTING is determined by the window width and level (centre) and serves for CONTRAST enhancement.

3.2 Symbols

The symbols of physical parameters used in this standard are listed in Table 1. All measurements referred to in Table 1 are in the centre of the IMAGE DISPLAY DEVICE. Note that LUMINANCE may also be measured at other locations according to the methodologies described in this document.

Table 1 – Overview to the definitions of physical parameters

Abbreviation	Mathematically derived	Definition and explanation
L_{amb}		LUMINANCE generated by the ambient light on the surface of an IMAGE DISPLAY DEVICE when the IMAGE DISPLAY DEVICE is off.
L_{min}		Minimum LUMINANCE generated by a IMAGE DISPLAY DEVICE at DIGITAL DRIVING LEVEL (DDL) = 0 measured at the centre of the screen. It includes VEILING GLARE specific to TEST PATTERN used for measurement. It is measured with ambient light totally switched off (in the dark).
L_{max}		Maximum LUMINANCE generated by a IMAGE DISPLAY DEVICE at DIGITAL DRIVING LEVEL (DDL) = max measured at the centre of the screen. It includes VEILING GLARE specific to TEST PATTERN used for measurement. It is measured with ambient light totally switched off (in the dark).
L'_{min}	$L_{min} + L_{amb}$	LUMINANCE that will be perceived by the human eye at the centre of the screen at DIGITAL DRIVING LEVEL (DDL) = 0. It contains VEILING GLARE and L_{amb}
L'_{max}	$L_{max} + L_{amb}$	LUMINANCE produced by the IMAGE DISPLAY DEVICE at the maximum DIGITAL DRIVING LEVEL (DDL) measured at the centre of the screen. It contains VEILING GLARE and $L_{amb.}$
R_d		Diffuse reflection coefficient (provided by manufacturer with a specific measurement method, ideally following the methods described in Reference [10] using a CIE standard illuminant A and an aperture size 20 to 30 % larger than the diameter of the LUMINANCE meter).
r'	L'_{max}/L'_{min}	LUMINANCE ratio of an IMAGE DISPLAY DEVICE containing VEILING GLARE and ambient LUMINANCE.
E		ILLUMINANCE.
a	L_{amb}/L'_{min}	Safety factor.
$\Delta u'v'$	$((u_1'-u_2')^2 + (v_1'-v_2')^2)^{1/2}$	Maximum distance in u'-v' space.

3.3 Abbreviations

The following abbreviations are used in this standard.

CRT cathode ray tube
CT computed tomography
DDL digital driving level
DICOM digital imaging and communication in medicine
LCD liquid crystal display
MR magnetic resonance

4 General

In IMAGE DISPLAY SYSTEMS, every individual component can limit or reduce the image quality of the system. Therefore it is necessary to adopt suitable measures for quality monitoring. If IMAGE DISPLAY SYSTEMS are correctly adjusted and maintained, these devices can consistently generate similar images.

Simple test equipment is used (LUMINANCE meter, TEST IMAGES) with PRECISION appropriate for the purpose of a test. Before a test, all test equipment shall be checked for its functioning according to the manufacturer's specifications.

The manufacturer's data (e.g. requirements on operating voltage, humidity etc.) are required for the correct setting of the IMAGE DISPLAY SYSTEM and for correct installation. The manufacturer's data shall be enclosed with the technical documentation of the IMAGE DISPLAY SYSTEM.

The tests listed in this International Standard are a compilation of all the evaluation methods that may be used for testing an IMAGE DISPLAY SYSTEM. A subset of these test items or test methods may be selected and applied in any order depending on the intended purpose of the IMAGE DISPLAY SYSTEM.

For mobile systems, a fixed location for these tests shall be determined and used so that it is representative for the locations where such mobile systems may be used. Care should be taken to ensure that the ambient lighting in these areas can be adequately controlled.

5 Prerequisites

Prior to testing an IMAGE DISPLAY SYSTEM, the following shall be considered:

a) The testing of an IMAGE DISPLAY SYSTEM shall include the complete system including software, hardware and settings involved in image handling.
b) For all IMAGE DISPLAY SYSTEMS to be tested, all components including computer, IMAGE DISPLAY DEVICE, display card, display software, and software version shall be traceable.
c) The TEST IMAGES and the clinical images shall be presented in the same way on the IMAGE DISPLAY SYSTEM.
d) Before starting the tests, the front surface of the IMAGE DISPLAY DEVICE shall be cleaned according to the instructions for use.
e) It shall be ensured that no prior nominal settings have been changed.
f) Room lights, windows, viewing devices etc. shall not cause any disturbing reflections on the IMAGE DISPLAY DEVICE. Methods to prevent reflections are described in the standards ISO 9241-302, ISO 9241-303, ISO 9241-305 and ISO 9241-307.
g) The ambient lighting in the room shall be maintained at normally used conditions.

h) Before initiating a test, the IMAGE DISPLAY SYSTEM shall be installed and started up according to the manufacturer's recommendations; to ensure stable performance, the IMAGE DISPLAY DEVICE shall be switched on before the test for a period as specified by the manufacturer (e.g. 30 min). The IMAGE DISPLAY SYSTEM should be set to the desired display function. The GREYSCALE STANDARD DISPLAY FUNCTION (GSDF) is recommended and is a necessary prerequisite for some tests.

6 Equipment and tools

6.1 LUMINANCE meter

A LUMINANCE meter shall have the following specifications. The range of the LUMINANCE meter shall cover at least the range of LUMINANCE of the IMAGE DISPLAY SYSTEM with a PRECISION of at most 5 % (repeatability), and an ACCURACY of at most 10 %, with a calibration traceable to a primary standards laboratory. The manufacturer of the meter shall provide a clear calibration program. The aperture angle shall not exceed 5°. The relative spectral sensitivity shall correspond to the BRIGHTNESS CIE standard photopic spectral response (CIE S 010/E:2004). The influence of the photopic response shall be within the overall ±10 % ACCURACY described in this paragraph.

For near range LUMINANCE meters, a predefined angle and distance of measurement result in a defined measurement field size. During a measurement, the area to be measured shall be displayed by a field (or patch) that is significantly bigger than the defined measurement field size.

A LUMINANCE meter can be integrated into the IMAGE DISPLAY SYSTEM or be a stand-alone device.

6.2 ILLUMINANCE meter

An ILLUMINANCE meter may be required for testing IMAGE DISPLAY SYSTEMS with a range of 1 to 1 000 lux with an ACCURACY of at most 10 % and a PRECISION of at most 5 % (repeatability). The device calibration shall be traceable to a primary standards laboratory and shall have a clear calibration program. It shall have a uniform response to a Lambertian light source.

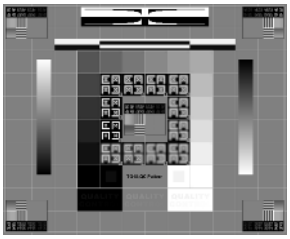
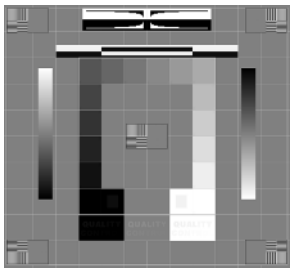
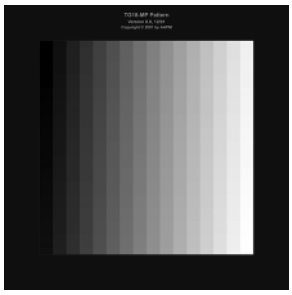
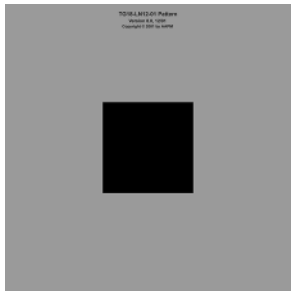
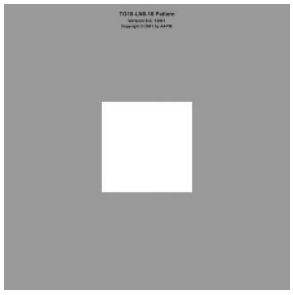
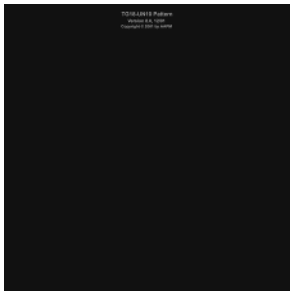
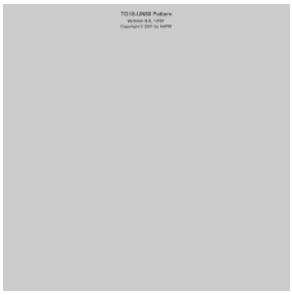
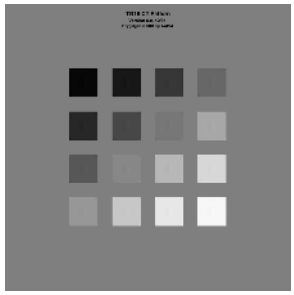
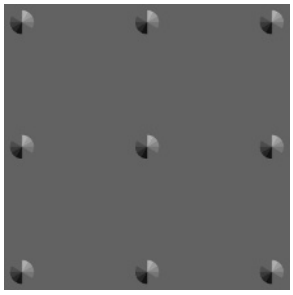
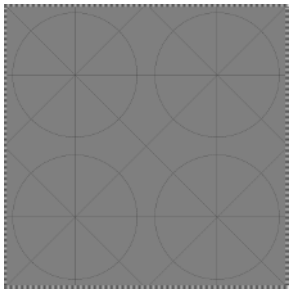
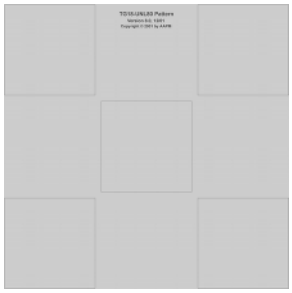
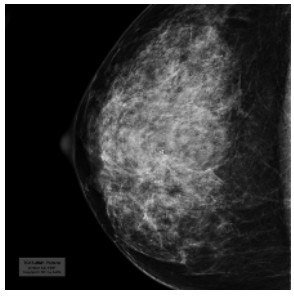
In measurement method B, C and D (described in Annex B), the ILLUMINANCE meter is ideally located at the centre of the screen facing outward. Side locations will also be acceptable as long as they provide similar measured values.

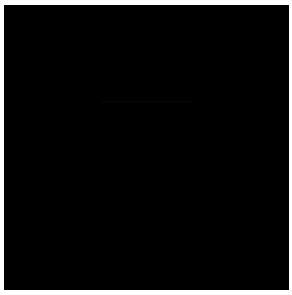
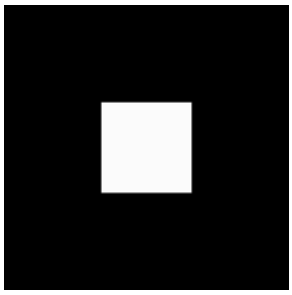
6.3 Colour meter

A colour meter may be required for testing IMAGE DISPLAY SYSTEMS. The meter shall be able to evaluate the CIE-specified (ISO11664-1:2007) colour coordinate with better than ±0,004 ACCURACY in the u',v' space (0,007 in the x,y space) for a standard illuminant, within the LUMINANCE range of the IMAGE DISPLAY SYSTEM. The device calibration shall be traceable to a primary measurement standard and shall have a clear calibration program.

6.4 TEST PATTERNS

Table 2 – TEST PATTERNS used for display testing

 TG18-QC for overall testing CATHODE RAY TUBE (CRT and LCD)	 OIQ for overall testing (LCD)	 TG18-MP for LUMINANCE resolution	 TG18-LN8-01 for LUMINANCE
 TG18-LN8-18 for LUMINANCE	 TG18-UN10 for LUMINANCE uniformity	 TG18-UN80 for LUMINANCE uniformity	 TG18-CT for LUMINANCE response
 ANG for angular response	 GD for geometrical properties	 TG18-UNL80 for LUMINANCE uniformity	 TG18-GVN for VEILING GLARE
 TG18-GV for VEILING GLARE	 TG18-CH as example chest radiograph	 TG18-KN as example extremity radiograph	 TG18-MM1 as example mammogram

 TG18-MM2 as example mammogram	 BN01 for LUMINANCE (LCD)	 BN18 for LUMINANCE (LCD)	

A subset of these examples or elements from these examples may be used to form composite TEST PATTERNS depending on the intended use of each modality being tested (see Annex C for more information).

7 Evaluation methods

7.1 General

This clause describes a number of evaluation methods (tests) that can be used for testing medical IMAGE DISPLAY SYSTEMS. The number and order of these evaluation methods are not mandatory; a modality standard can refer to a subset of these tests in any order with a preference for limiting values and evaluation criteria.

7.2 Evaluation method table overview

Table 3 shows an overview of all evaluation methods described in this standard. Not all of these tests may be required or be appropriate for a specific IMAGE DISPLAY SYSTEM. A subset of test items or test methods to be performed can be chosen from these lists that are relevant to a particular IMAGE DISPLAY SYSTEM. These tests can be performed in any appropriate order.

Table 3 – List of the evaluation methods that can be used for testing medical IMAGE DISPLAY SYSTEMS

Evaluation method	Equipment, tools
Visual evaluation methods	
Overall image quality evaluation – Verify overall performance.	TG18-QC TEST PATTERN
Greyscale resolution evaluation – Verify sufficient greyscale resolution based on 8- and 10-bit markers	TG18-MP TEST PATTERN
LUMINANCE response evaluation (more complete solution than overall image quality evaluation)	TG18-CT TEST PATTERN
LUMINANCE uniformity evaluation – Look for non-uniformities	TG18-UN80 TEST PATTERN
Chromaticity evaluation – Verify colour uniformity	TG18-UN80 TEST PATTERN
Pixel faults evaluation – Look for dark (TG18-UN80) and bright (TG18-UN10) pixel defects	TG18-UN10 and TG18-UN80 TEST PATTERN
VEILING GLARE evaluation – Look for low CONTRAST objects on 2 TEST PATTERNS	TG18-GVN and TG18-GV TEST PATTERN, mask
Geometrical image evaluation – Verify geometry, phase/clock correction, clipping	GD TEST PATTERN, ruler (CATHODE RAY TUBE (CRT) only)
Angular viewing evaluation – Verify viewing angle	ANG TEST PATTERN
Clinical evaluation	Clinical TEST PATTERNS (examples see TG18-CH, TG18-KN, TG18-MM1 and TG18-MM2)
Quantitative evaluation methods	
Basic LUMINANCE evaluation	LUMINANCE meter, ILLUMINANCE meter
Basic LUMINANCE evaluation without ambient light	LUMINANCE meter
LUMINANCE response evaluation The GREYSCALE STANDARD DISPLAY FUNCTION (GSDF) is prerequisite for this test	LUMINANCE meter, ILLUMINANCE meter
LUMINANCE evaluation of multiple displays	LUMINANCE meter
Chromaticity evaluation	Colour meter
Chromaticity evaluation of multiple displays	Colour meter
LUMINANCE uniformity evaluation	LUMINANCE meter
Viewing angle evaluation	(Provided by manufacturer)

7.3 Visual evaluation methods

7.3.1 General

All visual tests shall be performed from the customary viewing distance unless specified differently.

7.3.2 Overall image quality evaluation

The elements in the TG18-QC TEST IMAGE may be used to assess the overall performance of IMAGE DISPLAY SYSTEMS as described in Figure 1.

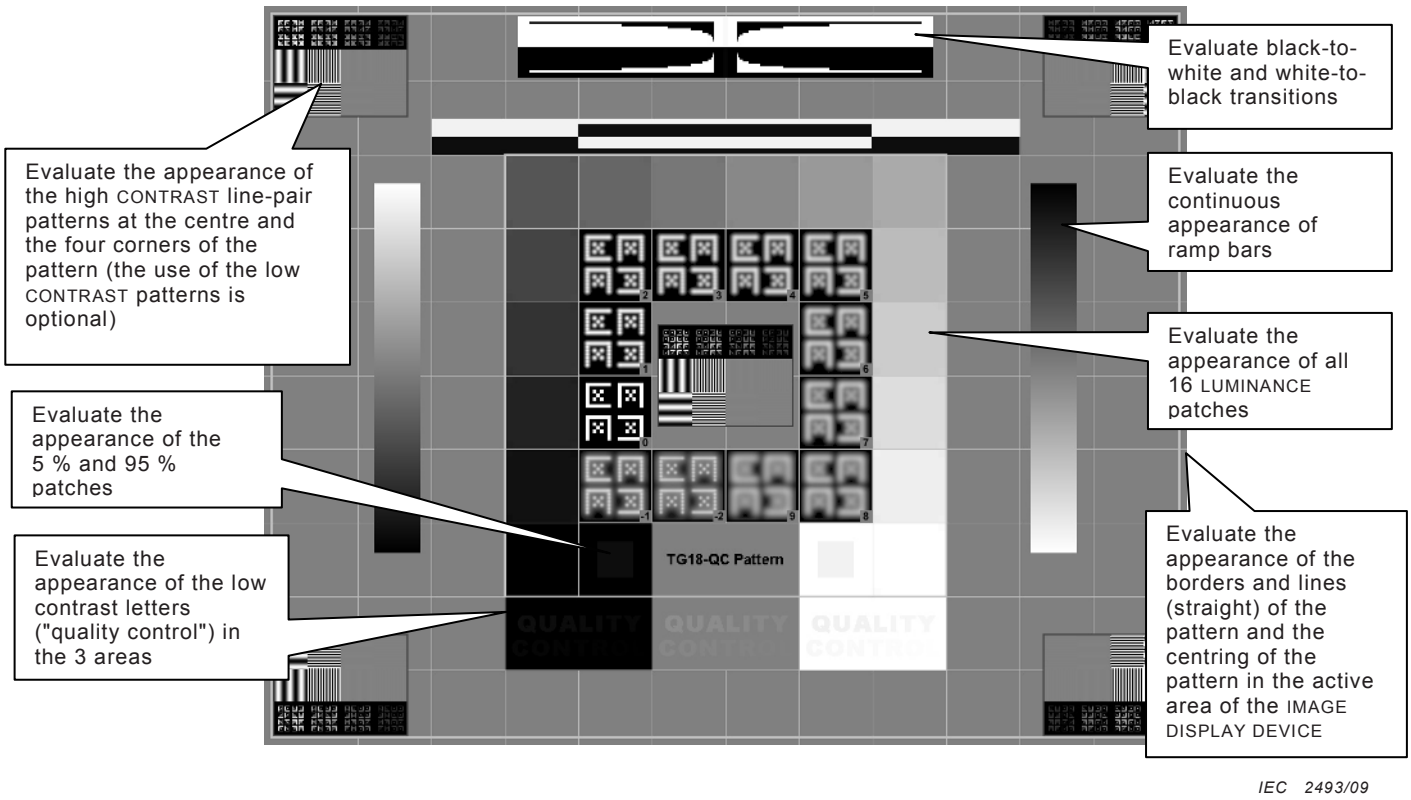


Figure 1 – Overall image quality evaluation using the TG18-QC TEST PATTERN

For CATHODE RAY TUBES (CRT) the SPATIAL RESOLUTION shall be included: Evaluate the CX patterns at the centre and corners of the pattern and grade them compared to the reference score (see Annex C).

As an alternative, the OIQ (overall image quality) TEST IMAGE may be used to assess overall performance of LCDs as described in Figure 2.

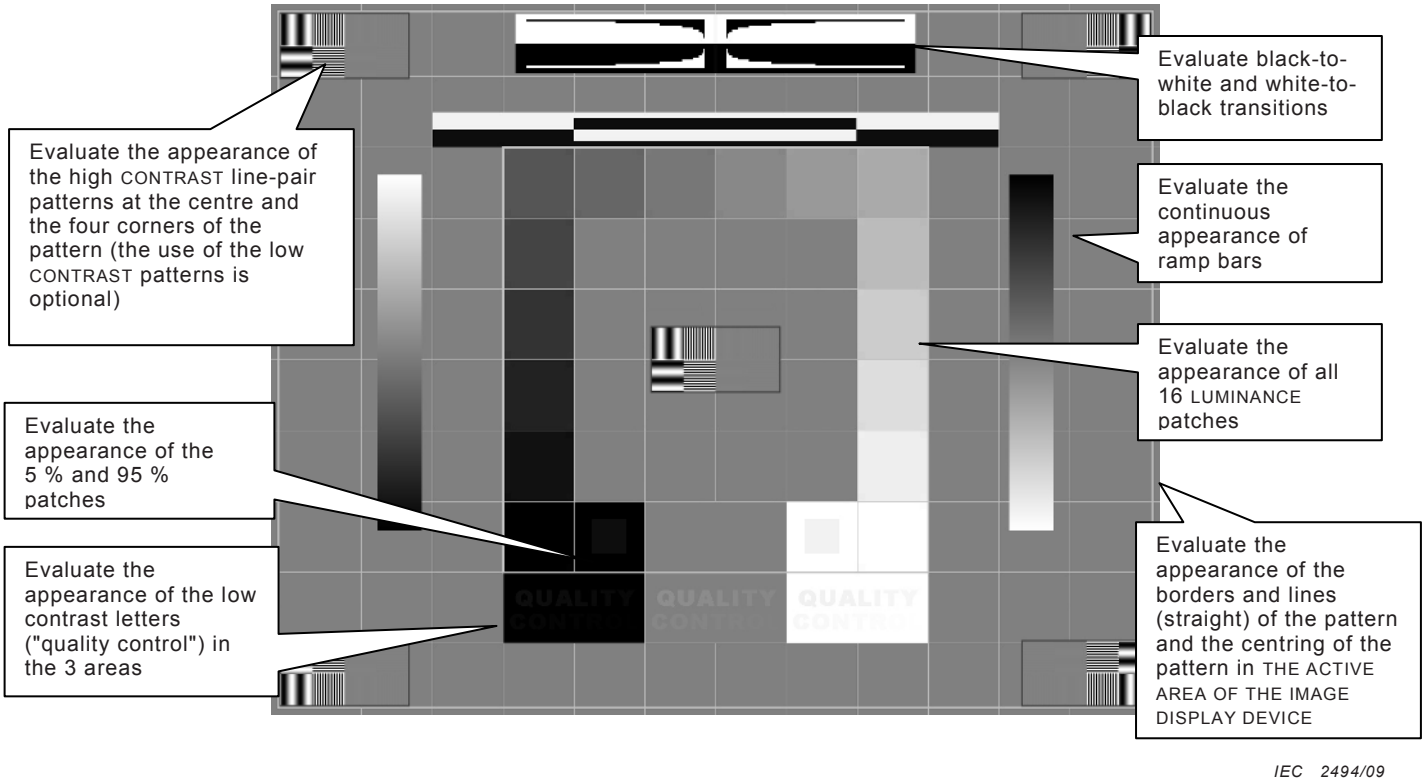


Figure 2 – Overall image quality evaluation using the TG18-OIQ TEST PATTERN

During this test, also evaluate the overall appearance of the TEST PATTERN. Look for sufficient SPATIAL RESOLUTION details, possible FLICKER, cross-talk, noise and video artefacts. Note that a TEST PATTERN specifically designed to evaluate each of these items may also be used.

For the overall image quality evaluation the SMPTE TEST PATTERN can also be used with similar criteria.

NOTE While not yet considered to be crucial for general display performance characteristics of medical displays, dynamic display performance (also called temporal response) might be important for certain medical applications. Other relevant documents may be consulted for applicable procedures to test the dynamic performance of medical displays [15].

7.3.3 Greyscale resolution evaluation

The greyscale resolution of the IMAGE DISPLAY DEVICE shall be evaluated using the TG18-MP TEST PATTERN as described in Figure 3. It might be good to magnify the pattern about 200 % when doing the test.

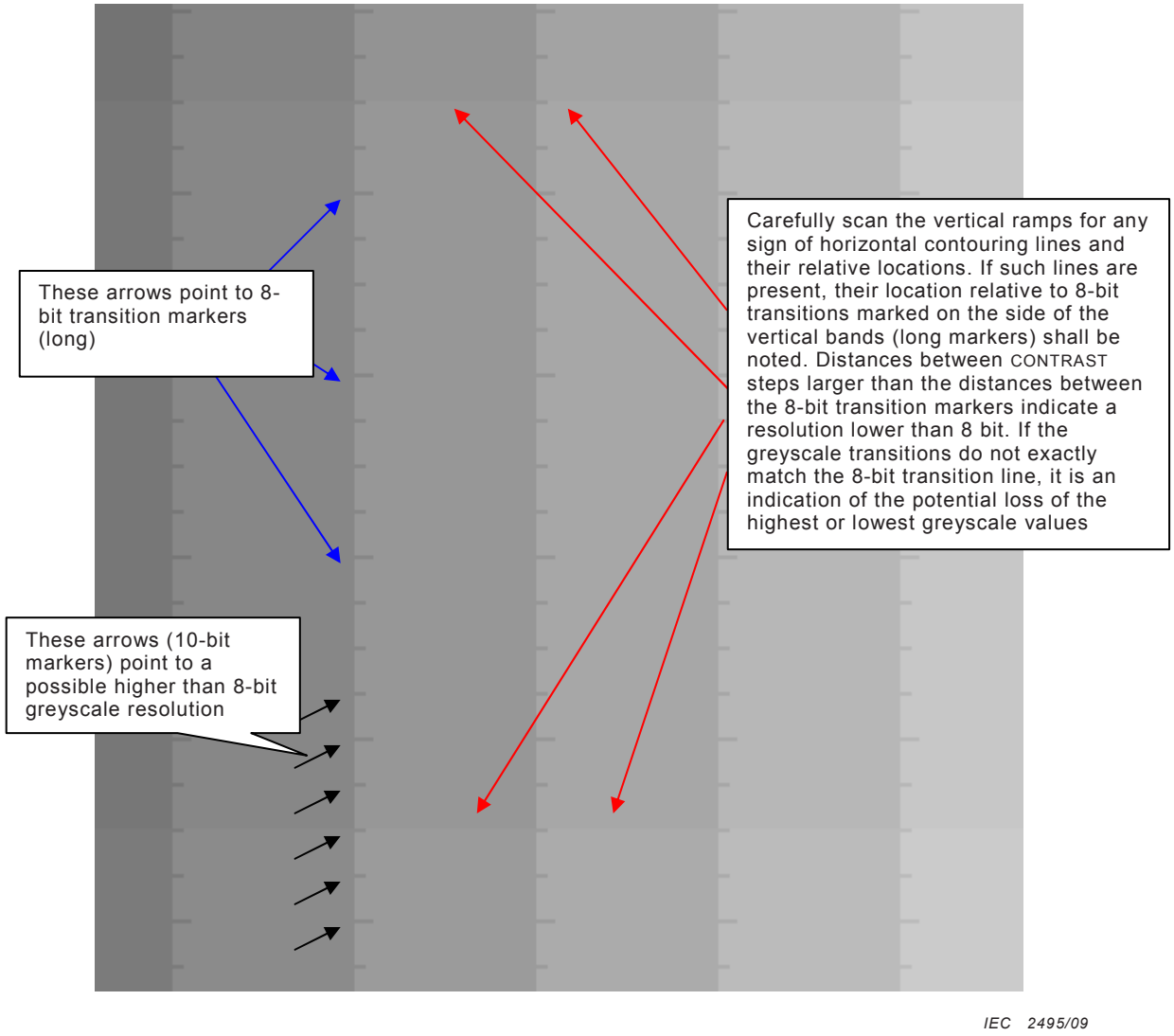


Figure 3 – Magnified view of TG18-MP TEST PATTERN showing the 8-bit and 10-bit markers

7.3.4 LUMINANCE response evaluation

The LUMINANCE response of the IMAGE DISPLAY DEVICE can be evaluated using the TG18-QC TEST PATTERN as part of the overall image quality evaluation (7.3.2). However using the TG18-CT TEST PATTERN is a more complete solution for a visual LUMINANCE response evaluation, as described in Figure 4.

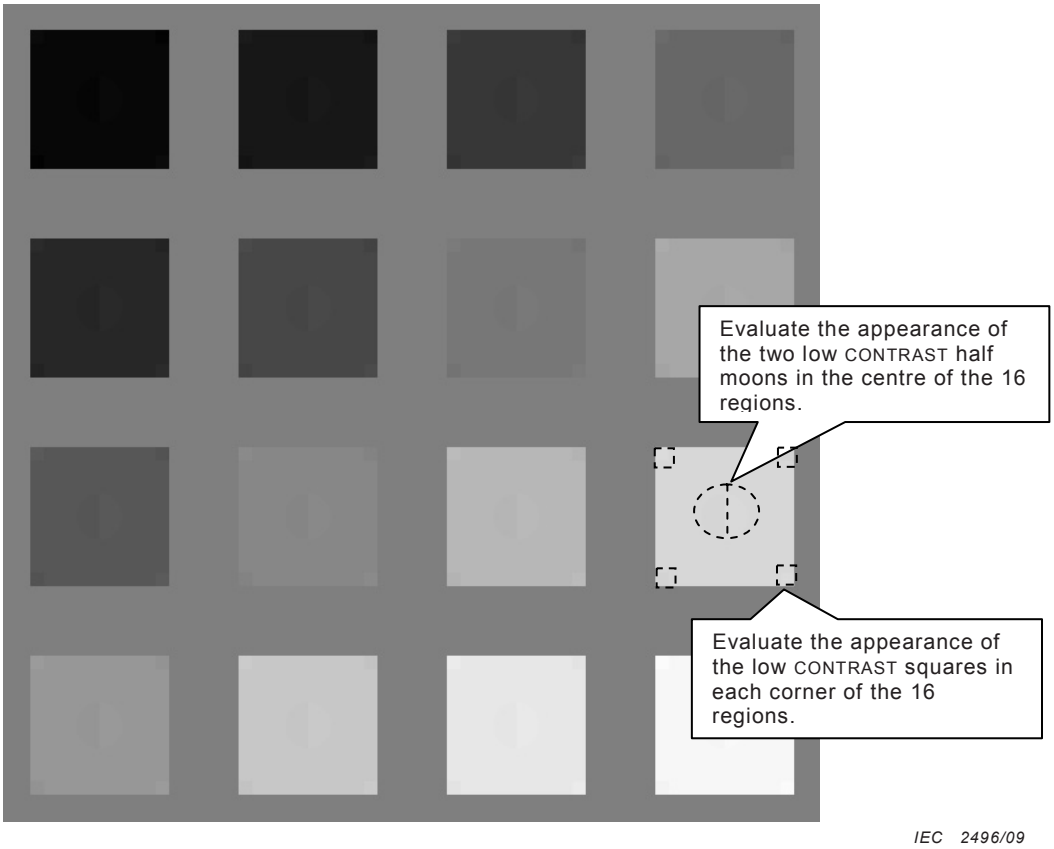


Figure 4 – A close-up of the TG18-CT TEST PATTERN

7.3.5 LUMINANCE uniformity evaluation

Verify the TG18-UN80 TEST PATTERN and look for gross non-uniformities from the centre to the edges. Typical CATHODE RAY TUBES (CRT) show symmetrical non-uniformities and LCDs are associated with non-symmetrical ones. Since the human visual system is generally not sensitive to very low spatial frequencies, gradual non-uniformity extending over the full display surface is not a problem unless the variation is very pronounced. Smaller scale non-uniformities that have dimensions in the order of 1 cm are of more significance and should not be visible when viewing a uniform TEST PATTERN. Non-uniformities of smaller dimension are classified as noise (evaluated in 7.3.2).

7.3.6 Chromaticity evaluation

The visual assessment of chromaticity is performed using the TG18-UN80 TEST PATTERN. Verify the colour uniformity of the displayed pattern across the screen.

The test can also be performed on multiple IMAGE DISPLAY DEVICES of the same type associated with a particular IMAGE DISPLAY SYSTEM. Check perceivable colour differences amongst different IMAGE DISPLAY DEVICES of a system.

7.3.7 Pixel faults evaluation

Pixel faults are evaluated by displaying the TEST PATTERNS TG18-UN10 and TG18-UN80. The number of defects shall be counted. The fault type shall be identified by using a magnifying glass according to the error type definitions below.

Type A fault: sub-pixel (an addressable part of a greyscale pixel or one of the base colour parts of a colour pixel) is stuck at high state - count bright sub-pixels in TG18-UN10.

Type B fault: sub-pixel is stuck at low state - count dark sub-pixels in TG18-UN80.

Type C fault: abnormal sub-pixel not of type A or B - count in TG18-UN10 and TG18-UN80 (e.g. stuck at intermediate state, blinking sub-pixel).

Cluster: Two or more sub-pixels with faults within a block of 5 × 5 pixels.

The types above or similar types would also apply to other point artefacts such as scratches, dust, and point defects in analogue IMAGE DISPLAY SYSTEMS such as CATHODE RAY TUBES (CRT).

7.3.8 VEILING GLARE evaluation

This test only applies to CATHODE RAY TUBES (CRT) and some FLAT PANEL DISPLAYS with thick protective covers. The visual assessment of VEILING GLARE can be accomplished using the TG18-GV and TG18-GVN TEST PATTERNS.

The observer shall discern the appearance of the low CONTRAST objects in sequential viewing of the TG18-GV and TG18-GVN patterns with the bright region masked (Figure 5).

The mask shall be made of black, non-transparent, light-absorbing, and non-reflective material (for instance, black paper).

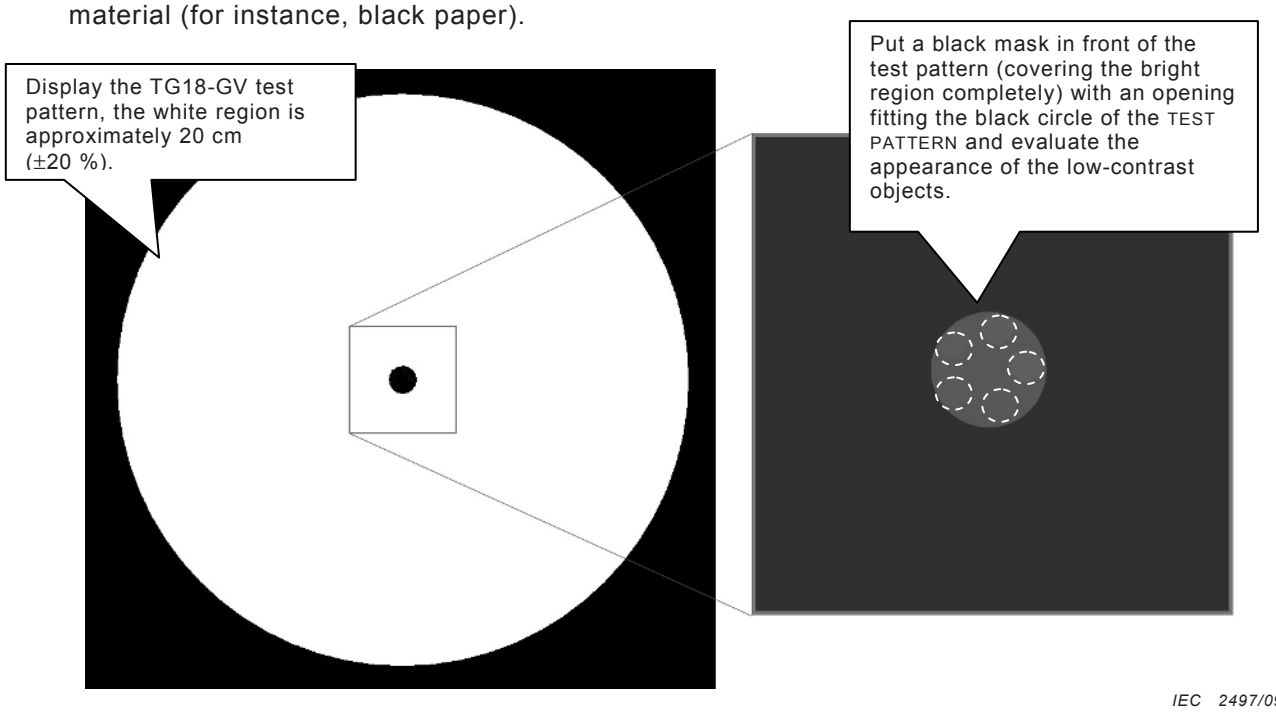


Figure 5 – The TG18-GV TEST PATTERN is displayed (left), a close-up of the centre of the TEST PATTERN when covered with a mask (right)

7.3.9 Geometrical image evaluation

The TG18-QC TEST PATTERN is used for the geometrical image evaluation as part of the overall image quality evaluation (7.3.2). However using the geometric distortion TEST PATTERN (GD pattern) is a more complete solution for this evaluation (Figure 6).

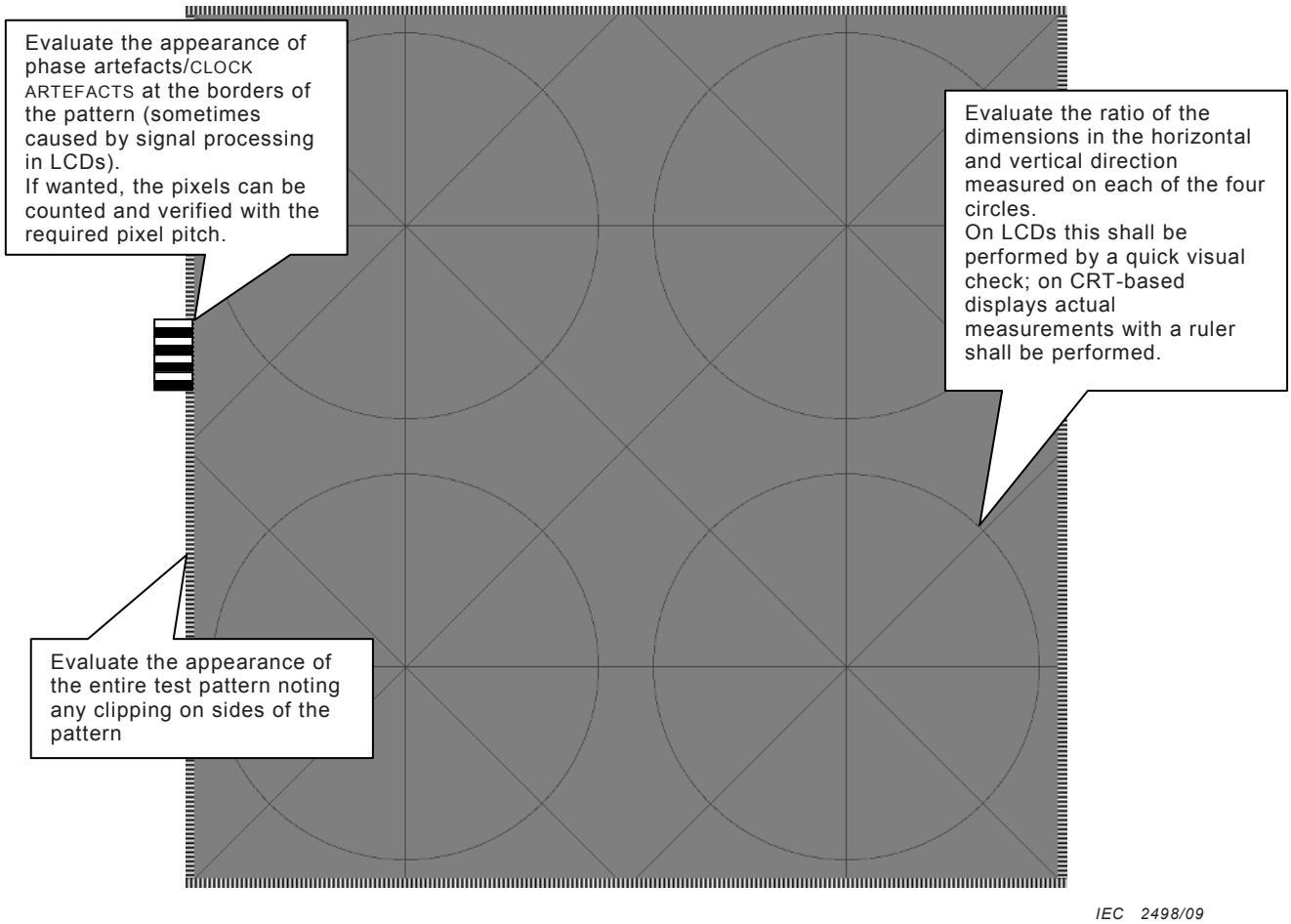


Figure 6 – Geometrical evaluation using the GD pattern

7.3.10 Angular viewing evaluation

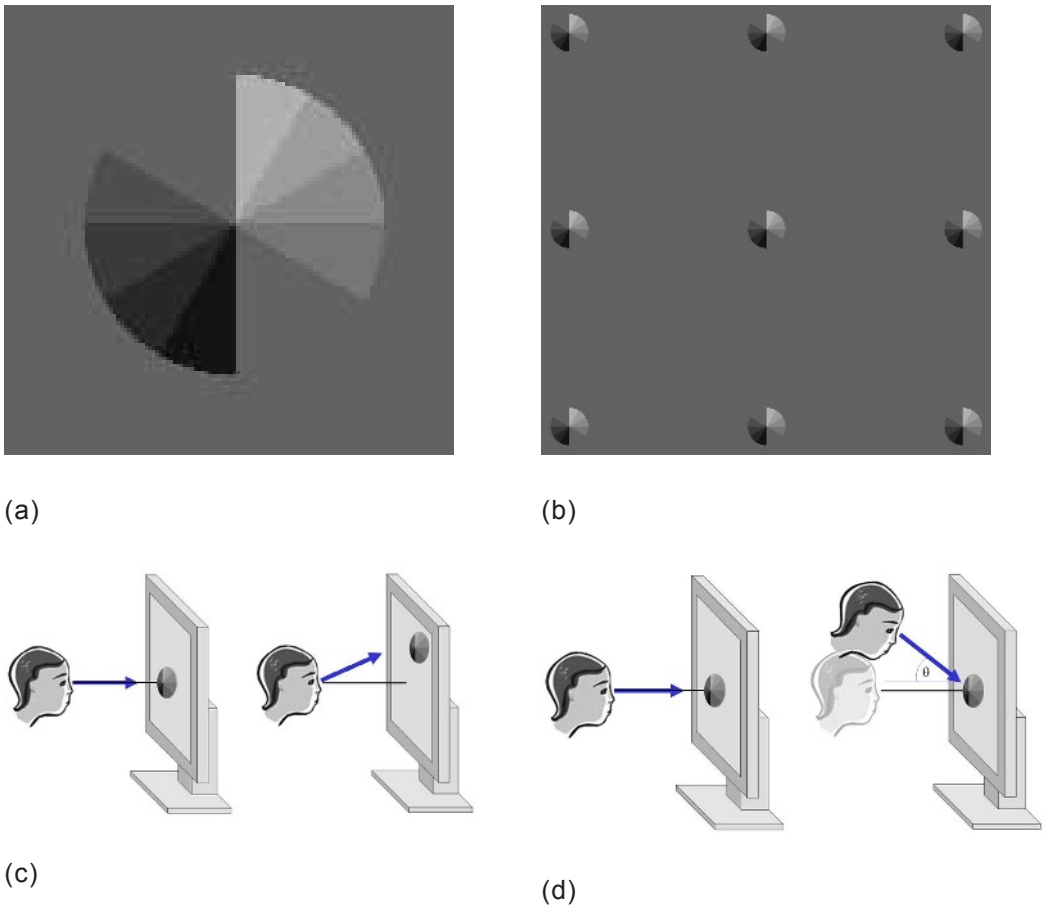
The characterization may be performed visually using methods described in the following paragraphs.

The TEST PATTERN used in the visual study, depicted in Figure 7a, consists of nine equally spaced circles in a 3 by 3 array and is fully described in Annex C.

The reading procedure can be done in two ways: (1) fixed observer, and (2) moving observer. In the case of fixed observer (option 1), the procedure requires viewing the pattern with the centre of the middle circle lined up with the centre point between the eyes at the normal viewing distance. The reader is then asked how many edges or transition lines between the slices are visible in the circle located at the centre of the screen. The inspection is then repeated for the circles at the eight other locations (top-centre, top-left, top-right, centre-left, centre-right, bottom-left, bottom-centre, and bottom-right). The reported score (S) is calculated by computing the ratio of the number of lines seen in an off-normal target (average of all non-centre scores) to the number of lines seen in the centre target. Both numbers are always between 0 and 10.

In the case of a moving observer (option 2), the procedure requires reading only the target in the centre of the pattern at perpendicular viewing, and then determining the maximum angle in off-normal directions (for example, in the horizontal and vertical directions) that provides a similar (or equal) score to that obtained in the perpendicular viewing direction.

An alternative, modified method with the same or similar TEST PATTERN in which the tester accommodates the viewing direction to be representative of conditions of use might be employed if a scientific evaluation demonstrates that the method is robust and sensitive to the expected or typical changes of LUMINANCE and CONTRAST with angle of view.



(a) Single target

(b) Full ANG TEST PATTERN

(c) Diagram showing reading procedure for option 1; with fixed position for observer

(d) Diagram showing reading procedure for option 2; with moving observer

Figure 7 – Visual evaluation of viewing angle response

7.3.11 Clinical evaluation

CLINICAL REFERENCE IMAGES or anatomical images as those reported in Annex C may be used for this test. The images shall be evaluated in terms of their clinical efficacy.

7.4 Quantitative evaluation methods

7.4.1 Basic LUMINANCE evaluation

The LUMINANCE ratio r' (= L'_{max}/L'_{min}) shall be evaluated for the IMAGE DISPLAY DEVICE.

Measure the values L'_{min}, L'_{max} and L_{amb} using one of the measurement methods described in Annex B.

For a given minimum required LUMINANCE ratio the corresponding maximum value of L'_{min} can be determined by:

L'_{max}/r'

Evaluating the safety factor "*a*":

$a = L_{amb}/L'_{min}$ where L_{amb} = ILLUMINANCE $E * R_d$ and $0 < a < 1$

The accommodation of ambient ILLUMINANCE can be accomplished in one of two ways depending on the environment and the LUMINANCE ratio range of the IMAGE DISPLAY DEVICE. For example, a safety factor equal or less than 0,4 implies a L_{min} of at least 1,5 times L_{amb}. However, in cases in which the implementation of this rule might negatively impact the desired LUMINANCE ratio (e.g. certain modality displays), the safety factor may have a value close to unity (1) provided that the desired display function (e.g. GREYSCALE STANDARD DISPLAY FUNCTION (GSDF)) calibration of the IMAGE DISPLAY DEVICE takes the ranges of the ILLUMINANCE in the environment into consideration.

The following relationship between L_{min} and L_{amb} can be useful:

$$L_{min} = L_{amb}\left(\frac{1}{a} - 1\right)$$

Optionally in this test the L_{max} can be evaluated against a target value as

$\Delta L_{max} = (L_{max} - L_{target})/L_{target}$

where L_{target} is the target LUMINANCE at maximum DIGITAL DRIVING LEVEL (DDL) being the IMAGE DISPLAY DEVICE vendor default value or the value used during calibration.

In addition, L_{max} can be evaluated and compared to a minimum required value to be defined by modality-specific or national organization standards.

7.4.2 Basic LUMINANCE evaluation without ambient light

This evaluation method should be used only for establishing the IMAGE DISPLAY SYSTEM basic LUMINANCE response without considering ambient lighting conditions.

This method should not be used if the IMAGE DISPLAY SYSTEM is calibrated to GSDF taking ambient light conditions into account.

The LUMINANCE ratio r (= L_{max}/L_{min}) shall be evaluated for the IMAGE DISPLAY DEVICE.

Measure the values L_{min}, L_{max} using one of the measurement methods described in Annex B.

Optionally in this test the L_{max} can be evaluated against a target value as

$\Delta L_{max} = (L_{max} - L_{target})/L_{target}$

where L_{target} is the target LUMINANCE at maximum DIGITAL DRIVING LEVEL (DDL) being the IMAGE DISPLAY DEVICE vendor default value or the value used during calibration.

In addition, L_{max} can be evaluated and compared to a minimum required value to be defined by modality-specific or national organization standards.

7.4.3 LUMINANCE response evaluation

The GREYSCALE STANDARD DISPLAY FUNCTION (GSDF) is a prerequisite for this test. Using a calibrated LUMINANCE meter and the TG18-LN TEST PATTERNS, the LUMINANCE L in the test region shall be measured for all 18 DIGITAL DRIVING LEVEL (DDL) P-values, $L(P)$, by the measurement methods described in Annex B.

The IMAGE DISPLAY SYSTEM shall be calibrated to the GREYSCALE STANDARD DISPLAY FUNCTION (GSDF). If the value of L_{amb} cannot be determined because of some practical reason, the value of L_{amb} (or $E * R_d$) used during the calibration shall be used for the LUMINANCE response evaluation. If the purpose is to evaluate the IMAGE DISPLAY SYSTEM response independently of ambient light conditions then this method is still valid with L_{amb} set to zero. However the GREYSCALE STANDARD DISPLAY FUNCTION (GSDF) as referred in [2] clearly quotes: "The GREYSCALE STANDARD DISPLAY FUNCTION explicitly includes the effects of the diffused ambient ILLUMINANCE".

The measured values shall be related to the GREYSCALE STANDARD DISPLAY FUNCTION (GSDF). First, they shall be transformed to just noticeable difference indices (*J*-values) based on the characteristics of the human visual system (*J*-values versus LUMINANCE). The *J*-values for the measured L'_{min} and L'_{max}, J_{min} and J_{max} shall be identified. The intermediate *J*-values shall then be evenly spaced within the range of J_{min} to J_{max}, ΔJ, and linearly related to the actual *P*-values used, *P*, as

$$J_i = J_{min} + \frac{P_i \Delta J}{\Delta P}$$

where *P* is the digital input to the system, ΔP is the range of digital input values from P_{min} to P_{max}, and i refers to the index of the 18 TEST IMAGES used for this test.

CONTRAST response is than calculated using the slope of the LUMINANCE response. The slopes based on measured values δ_i (measured CONTRAST) and GREYSCALE STANDARD DISPLAY FUNCTION (GSDF) values δ_i^d (target CONTRAST for the GREYSCALE STANDARD DISPLAY FUNCTION (GSDF) are calculated as

$$\delta_i = \frac{2(L'_i - L'_{i-1})}{(L'_i + L'_{i-1}) \cdot (J_i - J_{i-1})}$$

$$\delta_i{}^d = \frac{2(L'_i{}^d - L'_{i-1}{}^d)}{(L'_i{}^d + L'^d_{i-1}) \cdot (J_i - J_{i-1})}$$

where L'_i is the luminance value at index i, and $L'_i{}^d$ is the corresponding target luminance value according to GREYSCALE STANDARD DISPLAY FUNCTION (GSDF).

δ_i and δ_i^d are plotted against $0{,}5(J_i + J_{i-1})$ (the average of the *J* values that relate to the LUMINANCE measurements).

The values for δ_i shall not deviate from δ_i^d beyond a certain threshold criterion. Figure 8 shows an example of the measured LUMINANCE for 18 display levels, plotted in relation to the target LUMINANCE response, which in this case happens to be the GREYSCALE STANDARD DISPLAY FUNCTION (GSDF). Figure 9 shows the CONTRAST response associated with the data shown in Figure 8.

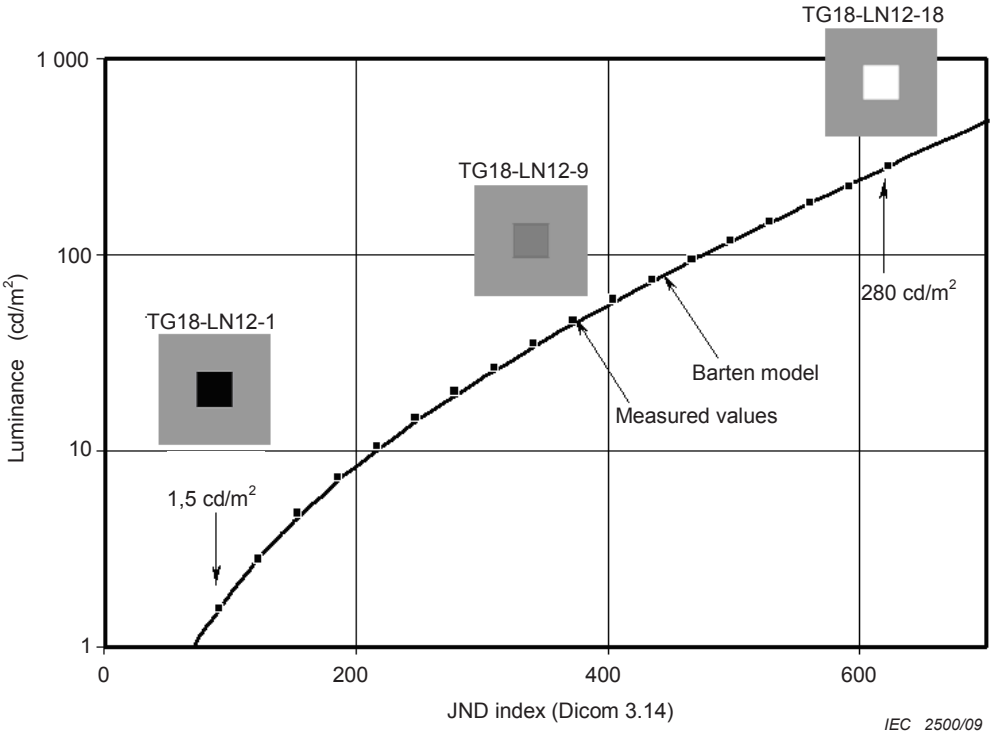


Figure 8 – Example of the measured LUMINANCE in relation to the standard LUMINANCE response function according to GREYSCALE STANDARD DISPLAY FUNCTION (GSDF)

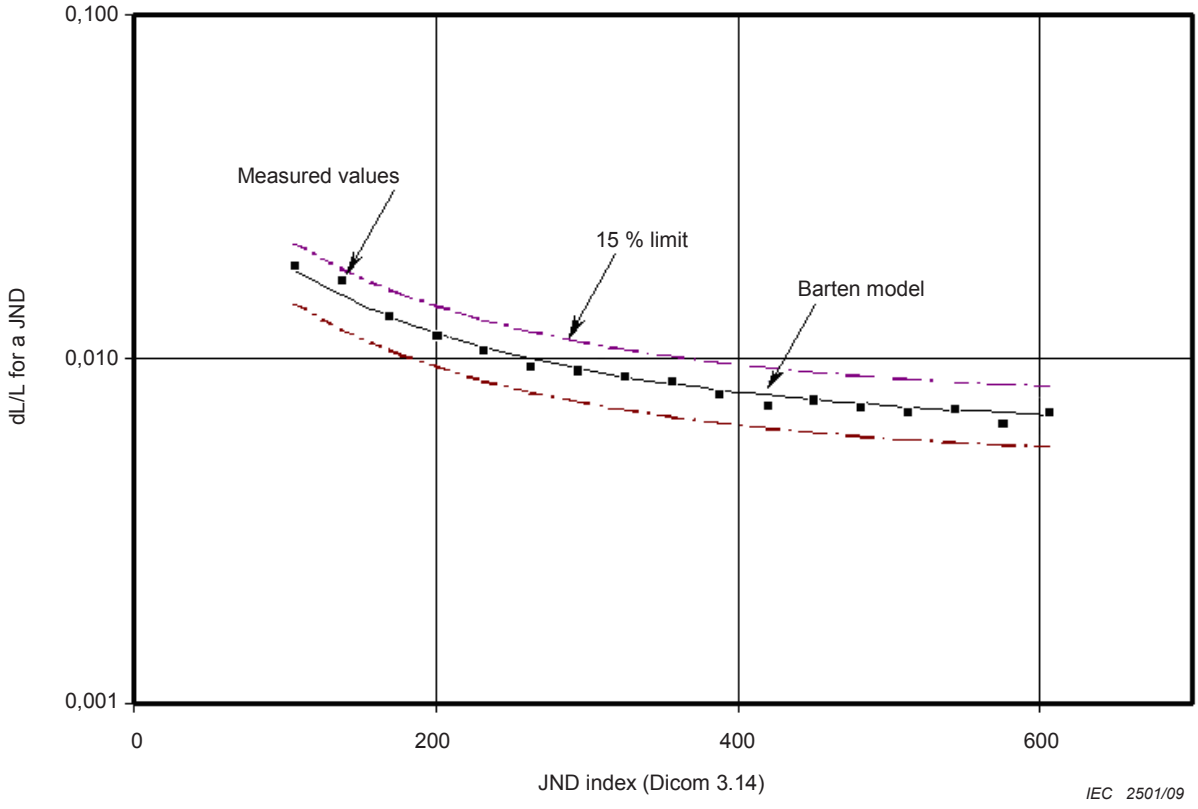


Figure 9 – An example of the CONTRAST response computed from 18 grey levels as related to the expected CONTRAST response associated with the DICOM 3.14 [2] standard LUMINANCE response with a given tolerance limit (e.g. 15 %) [10]

7.4.4 LUMINANCE evaluation of multiple displays

If multiple image displays devices are associated with the same IMAGE DISPLAY SYSTEM, the white LUMINANCE values as measured in the basic LUMINANCE evaluation (7.4.1) of all IMAGE DISPLAY DEVICES shall be compared. The values to be compared are L'_{max} or L_{max}. Also all measurement methods A, B, C and D (Annex B) can be used for these measurements. The maximum LUMINANCE deviation is calculated as a percent difference between the highest and lowest LUMINANCE values relative to their average value, $100 \cdot (L_{highest} - L_{lowest})/L_{lowest}$.

7.4.5 Chromaticity evaluation

Display the TG18-UNL80 TEST PATTERN on the IMAGE DISPLAY DEVICES. Using a colour meter, measure the (u',v') colour coordinates at the centre and at the four corners of the screen and compute the distance $\Delta u'v'$, as the maximum distance in u'-v' space between any possible pairs of (u',v') points using the following formula:

$$\Delta u'v' = ((u_1'-u_2')^2 + (v_1'-v_2')^2)^{1/2}$$

If a colour meter outputs its values in x,y coordinate, those can be converted to u',v' using the following conversion formulas:

$$u' = 4x/(-2x + 12y + 3)$$

$$v' = 9y/(-2x + 12y + 3)$$

7.4.6 Chromaticity evaluation of multiple displays

If multiple IMAGE DISPLAY DEVICES are associated with the same IMAGE DISPLAY SYSTEM the (u', v') chromaticity in the centre of every IMAGE DISPLAY DEVICE shall be compared. These central measurements can also be retrieved from the chromaticity evaluation of each IMAGE DISPLAY DEVICE (7.4.5). Compute the distance $\Delta u'v'$, as the maximum distance in u'-v' space between any possible pair of central measurements as

$$\Delta u'v' = ((u_1'-u_2')^2 + (v_1'-v_2')^2)^{1/2}$$

If this distance $\Delta u'v'$, is calculated to more than two IMAGE DISPLAY DEVICES, the two with the biggest deviation in (u',v') distance shall be used.

Optionally (in order to keep consistency with other standards), an averaged (u', v') chromaticity coordinate of 5-location measurements in each IMAGE DISPLAY DEVICE described in 7.4.5 can be used instead of the central measurement. Compute the distance $\Delta u'v'$ as the maximum distance in u'-v' space between any possible pair of the averaged coordinates using the same formula above.

7.4.7 LUMINANCE uniformity evaluation

Measure the LUMINANCE at five locations on the faceplate of the IMAGE DISPLAY DEVICE (centre and four corners) using the TG18-UNL80 TEST PATTERN and techniques A or B in Annex B. The maximum LUMINANCE deviation is calculated as a percent difference between the highest and lowest LUMINANCE values relative to their average value,

$$200 \times (L_{highest} - L_{lowest})/(L_{highest} + L_{lowest}).$$

7.4.8 Viewing angle evaluation

The quantitative viewing angle evaluation of the IMAGE DISPLAY DEVICE may be performed by the manufacturer according to the “viewing-cone thresholds” method proposed in reference [15].

The manufacturer may provide this information to the user at acceptance testing. This test is performed as a type test, where typical values for an IMAGE DISPLAY DEVICE model are given.

NOTE 1 A possible setup for a quantitative assessment of the viewing angle response is: arrange the LUMINANCE meter to measure the LUMINANCE and chromaticity at the IMAGE DISPLAY DEVICE centre from the normal direction; use a goniometric positioning device such as a rotating platter or motorized positioning system to assure an accurate angular alignment between the LUMINANCE meter and the screen normal for incremental increases in off-normal viewing directions (use a 5° maximum increment size for inclination and a 10° maximum increment for azimuth).

NOTE 2 The viewing angle should be evaluated using the degree of contrast ratio degradation in % from the on-axis direction [10].

Annex A
(informative)

Sample test reports

This annex provides several sample test reports, as follows:

– Table A.1: Acceptance test of a diagnostic display;
– Table A.2: Constancy test of a diagnostic display;
– Table A.3: Acceptance test of a monochrome reviewing display;
– Table A.4: Constancy test of a monochrome reviewing display;
– Table A.5: Acceptance test of a colour reviewing display;
– Table A.6: Constancy test of a colour reviewing display.

Table A.1 – Acceptance test sample report of a diagnostic display

General
Date of test: Jan 23 2007
Test performed by: John
Facility: St. John's facility, Jonathan Street 55, John's City, John's Country
Location: Radiology, Reading Room 4, Workstation Rad44
Display: Brand Monochrome LCD, Type 3MP Portrait, S/N 983300444 (first display of dual head)
Application: Diagnostic, multi-modality (RX,CT, MR) workstation

Evaluation method	**Equipment, tools**	**Requirement**	**Conclusion**
		Test result	
Global test result:			OK
Visual evaluations			
Overall image quality evaluation – Verify overall performance	TG18-QC TEST PATTERN	All appearances OK and no defects found No	OK
Greyscale resolution evaluation – Verify sufficient greyscale resolution based on 8- and 10-bit markers	TG18-MP TEST PATTERN	> 8 Bit Resolution matches the 8-bit markers	OK
LUMINANCE response evaluation (more complete solution than the corresponding evaluation within overall image quality evaluation)	TG18-CT TEST PATTERN	All squares and half moons are visible Yes	OK
LUMINANCE uniformity evaluation – Look for non-uniformities	TG18-UN80 TEST PATTERN	No visual non-uniformities detected No	OK
Chromaticity evaluation – Verify colour uniformity	TG18-UN80 TEST PATTERN	No visual non-uniformities on colour detected None	OK

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Pixel faults evaluation – Look for dark (TG18-UN80) and bright (TG18-UN10) pixel defects	TG18-UN10 and TG18-UN80 TEST PATTERN	type A: <=1 type B: <=1 type C: <=2 None in the same cluster	OK
		Detected pixel faults: 0 type A (<=1), 1 type B (<=1), 1 type C (<=2), none in the same cluster	
Angular viewing evaluation – Verify viewing angle	ANG TEST PATTERN	SCORE: >= 0,9	OK
		Centre score: 10 Top-left score: 8 Top-centre score: 10 Top-right score: 9 Centre-right score: 10 Bottom-right score: 9 Bottom-centre score: 10 Bottom-left score: 8 Centre-left score: 10 SCORE: 9,25/10	
Clinical evaluation	Clinical TEST PATTERNS TG18-CH, TG-18-KN	Clinical images appear OK	OK
		Yes	
Quantitative evaluations			
Basic LUMINANCE evaluation	LUMINANCE meter	L_{max} deviation < ±5 % of 500 cd/m^2 r' > 250 a < 0,4 L_{max} > 170 cd/m^2	OK
		Measured with method A (B.2.1) L'_{max} = 504,97 cd/m^2 L'_{min} = 1,28 cd/m^2 L_{amb} = 0,5 cd/m^2 L_{max} = 504,47 cd/m^2 r'= 394 a= 0,39	

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
LUMINANCE response evaluation	LUMINANCE meter	Max. deviation < 15 %	OK
		Measured with method A (B.2.1) L'(LN01) = 1,58 cd/m^2 L'(LN02) = 3,16 cd/m^2 L'(LN03) = 5,48 cd/m^2 L'(LN04) = 8,7 cd/m^2 L'(LN05) = 12,9 cd/m^2 L'(LN06) = 18,8 cd/m^2 L'(LN07) = 26,4 cd/m^2 L'(LN08) = 36,4 cd/m^2 L'(LN09) = 48,9 cd/m^2 L'(LN10) = 65,5 cd/m^2 L'(LN11) = 86,2 cd/m^2 L'(LN12) = 112,7 cd/m^2 L'(LN13) = 144,8 cd/m^2 L'(LN14) = 186,7 cd/m^2 L'(LN15) = 240,2 cd/m^2 L'(LN16) = 309,8 cd/m^2 L'(LN17) = 395,5 cd/m^2 L'(LN18) = 504,9 cd/m^2 Max. deviation = 5,10 %	
LUMINANCE evaluation of multiple displays	LUMINANCE meter	Deviation < 10 %	OK
		Measured with method A (B.2.1) L'_{max} = 504,97 cd/m^2 L'_{max} = 493,65 cd/m^2 Deviation = 2,27 %	

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Chromaticity evaluation	Colour meter	Max. deviation < 0,02	OK
		Measured with method B (B.2.2) Top-left *u*' = 0,2025 *v*' = 0,4699 Top-right *u'* = 0,2051 *v*' = 0,4688 Centre *u*' = 0,2024 *v*' = 0,4680 Bottom-right *u*' = 0,2052 *v*' = 0,4695 Bottom-left *u*' = 2009 *v*' = 0,4706 Max. deviation = 0,0046	
Chromaticity evaluation of multiple displays	Colour meter	Deviation < 0,02	OK
		Measured with method B (B.2.2) Centre *u*' = 0,2024 *v*' = 0,4680 Other display: Centre *u*' = 0,2046 *v*' = 0,4699 Deviation = 0,0029	
LUMINANCE uniformity evaluation	LUMINANCE meter	Max. deviation < 30 %	OK
		Measured with method B (B.2.2) Top-left *L* = 191,5 cd/m^2 Top-right *L* = 176,4 cd/m^2 Centre *L* = 197,2 cd/m^2 Bottom-right *L* = 202,5 cd/m^2 Bottom-left L = 195,8 cd/m^2 Max. deviation = 13,8 %	

Table A.2 – Constancy test sample report of a diagnostic display

General
Date of test: Apr 23 2007 (QUARTERLY TEST)
Test performed by: John
Facility: St. John's facility, Jonathan Street 55, John's City, John's Country
Location: Radiology, Reading Room 4, Workstation Rad44
Display: Brand Monochrome LCD, Type 3MP Portrait, S/N 983300444 (first head of dual head)
Application: Diagnostic, multi-modality (RX,CT, MR) workstation

Evaluation method	**Equipment, tools**	**Requirement**	**Conclusion**
		Test result	
Global test result:			OK
Visual evaluations			
Overall image quality evaluation	TG18-QC TEST PATTERN	All appearances OK and no defects found	OK
– Verify overall performance		No	
LUMINANCE uniformity evaluation	TG18-UN80 TEST PATTERN	No visual non-uniformities detected	OK
– Look for non-uniformities		No	
Clinical evaluation	Clinical TEST PATTERNS TG18-CH, TG-18-KN	Clinical images appear OK	OK
		Yes	

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Quantitative evaluations			
Basic LUMINANCE evaluation	LUMINANCE meter, ILLUMINANCE meter	$r' > 250$ $a < 0,4$	OK
		Measured with method C (B.2.3) L_{max} = 520,9 cd/m^2 L_{min} = 0,64 cd/m^2 E = 24 lux Rd = 0,017 L_{amb} = 0,408 cd/m^2 r'= 497 a= 0,389	
LUMINANCE response evaluation	LUMINANCE meter, ILLUMINANCE meter	Max. deviation < 15 %	OK
		Measured with method C (B.2.3) L(LN01) = 0,64 cd/m^2 L(LN02) = 2,03 cd/m^2 L(LN03) = 4,17 cd/m^2 L(LN04) = 7,11 cd/m^2 L(LN05) = 11,12 cd/m^2 L(LN06) = 16,75 cd/m^2 L(LN07) = 24,07 cd/m^2 L(LN08) = 33,67 cd/m^2 L(LN09) = 46,24 cd/m^2 L(LN10) = 63,12 cd/m^2 L(LN11) = 83,94 cd/m^2 L(LN12) = 110,6 cd/m^2 L(LN13) = 144,9 cd/m^2 L(LN14) = 190,1 cd/m^2 L(LN15) = 246,3 cd/m^2 L(LN16) = 317,8 cd/m^2 L(LN17) = 406,4 cd/m^2 L(LN18) = 520,9 cd/m^2 Max. deviation = 8,10 %	

Table A.3 – Acceptance test sample report of a monochrome reviewing display

General
Date of test: Feb 14 2007
Test performed by: John
Facility: St. John's facility, Jonathan Street 55, John's City, John's Country
Location: East Wing, Room 405, Workstation WS_405_1
Display: Brand Monochrome LCD, Type 2MP Portrait, S/N 44829922 (first display of dual head)
Application: Reviewing, multi-modality (CT, MR) workstation

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Global test result:			OK
Visual evaluations			
Overall image quality evaluation – Verify overall performance	TG18-QC TEST PATTERN	All appearances OK and no defects found No	OK
Greyscale resolution evaluation – Verify sufficient greyscale resolution based on 8- and 10-bit markers	TG18-MP TEST PATTERN	> 8 bit Resolution matches the 8-bit markers	OK
LUMINANCE response evaluation (more complete solution than the corresponding evaluation within overall image quality evaluation)	TG18-CT TEST PATTERN	All squares and half moons are visible Yes	OK
LUMINANCE uniformity evaluation – Look for non-uniformities	TG18-UN80 TEST PATTERN	No visual non-uniformities detected No	OK
Chromaticity evaluation – Verify colour uniformity	TG18-UN80 TEST PATTERN	No visual non-uniformities on colour detected No	OK
Angular viewing evaluation – Verify viewing angle	ANG TEST PATTERN	SCORE >= 0,75 Centre score: 10 Top-left score: 8 Top-centre score: 9 Top-right score: 8 Centre-right score: 10 Bottom-right score: 8 Bottom-centre score: 10 Bottom-left score: 9 Centre-left score: 8 SCORE: 8,75/10	OK
Clinical evaluation	Clinical TEST PATTERNS TG18-CH, TG-18-KN	Clinical images appear OK Yes	OK

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Quantitative evaluations			
Basic LUMINANCE evaluation	LUMINANCE meter Manufacturer X Instrument Y – S/N 98832	L_{max} deviation < ±10 % of 400 cd/m^2 r' > 100	OK
		Measured with method A (B.2.1) L'_{max} = 418,2 cd/m^2 L'_{min} = 2,01 cd/m^2 L_{amb} = 1,5 cd/m^2 r' = 208 a = 0,746	
LUMINANCE response evaluation	LUMINANCE meter Manufacturer X Instrument Y – S/N 98832	Max. deviation < 30 %	OK
		Measured with method A (B.2.1) L'(LN01) = 2,012 cd/m^2 L'(LN02) = 3,324 cd/m^2 L'(LN03) = 5,236 cd/m^2 L'(LN04) = 7,488 cd/m^2 L'(LN05) = 10,396 cd/m^2 L'(LN06) = 14,9 cd/m^2 L'(LN07) = 20,756 cd/m^2 L'(LN08) = 28,436 cd/m^2 L'(LN09) = 38,492 cd/m^2 L'(LN10) = 51,996 cd/m^2 L'(LN11) = 68,652 cd/m^2 L'(LN12) = 89,98 cd/m^2 L'(LN13) = 117,42 cd/m^2 L'(LN14) = 153,58 cd/m^2 L'(LN15) = 198,54 cd/m^2 L'(LN16) = 255,74 cd/m^2 L'(LN17) = 326,62 cd/m^2 L'(LN18) = 418,22 cd/m^2 Max. deviation = 14,72 %	
LUMINANCE evaluation of multiple displays	LUMINANCE meter Manufacturer X Instrument Y – S/N 98832	Deviation < 10 %	OK
		Measured with method A (B.2.1) L'_{max} = 418,2 cd/m^2 L'_{max} = 389 cd/m^2 Deviation = 7,2 %	

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
LUMINANCE uniformity evaluation	LUMINANCE meter Manufacturer X Instrument Y – S/N 98832	Max. deviation < 30 %	OK
		Measured with method B (B.2.2) Top-left L = 144 cd/m^2 Top-right L = 159,1 cd/m^2 Centre L = 149,8 cd/m^2 Bottom-right L = 168,2 cd/m^2 Bottom-left L = 153,7 cd/m^2 Max. deviation = 15,5 %	

Table A.4 – Constancy test sample report of a monochrome reviewing display

General
Date of test: Aug 23 2007 (TWICE A YEAR TEST)
Test performed by: John
Facility: St. John's facility, Jonathan Street 55, John's City, John's Country
Location: East Wing, Room 405, Workstation WS_405_1
Display: Brand Monochrome LCD, Type 2MP Portrait, S/N 44829923 (second display of dual head)
Application: Reviewing, multi-modality (CT, MR) workstation

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Global test result:			OK
Visual evaluations			
Overall image quality evaluation – Verify overall performance	TG18-QC TEST PATTERN	All appearances OK and no defects found	OK
		No	
LUMINANCE uniformity evaluation – Look for non-uniformities	TG18-UN80 TEST PATTERN	No visual non-uniformities detected	OK
		No	
Clinical evaluation	Clinical TEST PATTERNS TG18-CH, TG-18-KN	Clinical images appear OK	OK
		Yes	
Quantitative evaluations			
Basic LUMINANCE evaluation	LUMINANCE meter, ILLUMINANCE meter	r' > 100	OK
		Measured with method C (B.2.3) L_{max} = 430,6 cd/m^2 L_{min} = 0,6 cd/m^2 E = 53 lux Rd = 0,025 L_{amb} = 1,325 cd/m^2 r' = 224 a = 0,688	

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
LUMINANCE response evaluation	LUMINANCE meter, ILLUMINANCE meter	Max. deviation < 30 %	OK
		Measured with method B (B.2.3) L(LN01) = 0,6 cd/m^2 L(LN02) = 1,9 cd/m^2 L(LN03) = 4 cd/m^2 L(LN04) = 7 cd/m^2 L(LN05) = 11 cd/m^2 L(LN06) = 16,1 cd/m^2 L(LN07) = 23 cd/m^2 L(LN08) = 31,9 cd/m^2 L(LN09) = 42,8 cd/m^2 L(LN10) = 57,4 cd/m^2 L(LN11) = 75,6 cd/m^2 L(LN12) = 97,7 cd/m^2 L(LN13) = 127 cd/m^2 L(LN14) = 163,1 cd/m^2 L(LN15) = 209,7 cd/m^2 L(LN16) = 266,6 cd/m^2 L(LN17) = 340,1 cd/m^2 L(LN18) = 430,6 cd/m^2 Max. deviation = 11,6 %	

Table A.5 – Acceptance test sample report of a colour reviewing display

General
Date of test: Mar 21 2007
Test performed by: John
Facility: St. John's facility, Jonathan Street 55, John's City, John's Country
Location: West Wing, Room 1109, Workstation WS_1109_4
Display: Brand Colour LCD, Type 2MP Landscape, S/N 56698221 (first display of dual head)
Application: Reviewing workstation

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Global test result:			OK
Visual evaluations			
Overall image quality evaluation – Verify overall performance	TG18-QC TEST PATTERN	All appearances OK and no defects found No	OK
Greyscale resolution evaluation – Verify sufficient greyscale resolution based on 8- and 10-bit markers	TG18-MP TEST PATTERN	> 8 bit Resolution matches the 8-bit markers	OK
LUMINANCE response evaluation (more complete solution than the corresponding evaluation within overall image quality evaluation)	TG18-CT TEST PATTERN	All squares and half moons are visible Yes	OK
LUMINANCE uniformity evaluation – Look for non-uniformities	TG18-UN80 TEST PATTERN	No visual non-uniformities detected No	OK
Chromaticity evaluation – Verify colour uniformity	TG18-UN80 TEST PATTERN	No visual non-uniformities on colour detected No	OK
Clinical evaluation	Clinical TEST PATTERNS TG18-CH, TG-18-KN	Clinical images appear OK Yes	OK
Quantitative evaluations			
Basic LUMINANCE evaluation	LUMINANCE meter	L_{max} deviation < ±10 % of 300 cd/m^2 r' > 100 Measured with method A (B.2.1) L'_{max} = 285 cd/m^2 L'_{min} = 1,95 cd/m^2 L_{amb} = 1,2 cd/m^2 L_{max} = 283,8 cd/m^2 r' = 146 a = 0,615	OK

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
LUMINANCE response evaluation	LUMINANCE meter	Max. deviation < 30 %	OK
		Measured with method A (B.2.1)	
		L'(LN01) = 1,95 cd/m^2	
		L'(LN02) = 3,15 cd/m^2	
		L'(LN03) = 4,8 cd/m^2	
		L'(LN04) = 7,1 cd/m^2	
		L'(LN05) = 9,85 cd/m^2	
		L'(LN06) = 14,05 cd/m^2	
		L'(LN07) = 18,68 cd/m^2	
		L'(LN08) = 24,66 cd/m^2	
		L'(LN09) = 31,99 cd/m^2	
		L'(LN10) = 40,87 cd/m^2	
		L'(LN11) = 51,4 cd/m^2	
		L'(LN12) = 65 cd/m^2	
		L'(LN13) = 83,8 cd/m^2	
		L'(LN14) = 108,3 cd/m^2	
		L'(LN15) = 139 cd/m^2	
		L'(LN16) = 177,9 cd/m^2	
		L'(LN17) = 224 cd/m^2	
		L'(LN18) = 285 cd/m^2	
		Max. deviation = 13,62 %	
LUMINANCE evaluation of multiple displays	LUMINANCE meter	Deviation < 10 %	OK
		Measured with method A (B.2.1)	
		L'_{max} = 285 cd/m^2	
		L'_{max} = 306 cd/m^2	
		Deviation = 7,1 %	
LUMINANCE uniformity evaluation	LUMINANCE meter	Max. deviation < 30 %	OK
		Measured with method B (B.2.2)	
		Top-left L = 95,3 cd/m^2	
		Top-right L = 90,8 cd/m^2	
		Centre L = 110,6 cd/m^2	
		Bottom-right L= 101,1 cd/m^2	
		Bottom-left L = 112 cd/m^2	
		Max. deviation = 20,9 %	

Table A.6 – Constancy test sample report of a colour reviewing display

General
Date of test: Jul 23 2007 (QUARTERLY)
Test performed by: John
Facility: St. John's facility, Jonathan Street 55, John's City, John's Country
Location: West Wing, Room 1109, Workstation WS_1109_4
Display: Brand Colour LCD, Type 2MP Landscape, S/N 56698221 (first display of dual head)
Application: Reviewing workstation

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
Global test result:			OK
Visual evaluations			
Overall image quality evaluation – Verify overall performance	TG18-QC TEST PATTERN	All appearances OK and no defects found No	OK
LUMINANCE uniformity evaluation – Look for non-uniformities	TG18-UN80 TEST PATTERN	No visual non-uniformities detected No	OK
Clinical evaluation	Clinical TEST PATTERNS TG18-CH, TG-18-KN	Clinical images appear OK Yes	OK
Quantitative evaluations			
Basic LUMINANCE evaluation	LUMINANCE meter, ILLUMINANCE meter	$r' > 100$ Measured with method B (B.2.2) L_{max} = 280,3 cd/m^2 L_{min} = 0,7 cd/m^2 E = 45 lux Rd = 0,029 L_{amb} = 1,305 cd/m^2 r' = 140 a = 0,651	OK

Evaluation method	Equipment, tools	Requirement	Conclusion
		Test result	
LUMINANCE response evaluation	LUMINANCE meter, ILLUMINANCE meter	Max. deviation < 30 %	OK
		Measured with method B (B.2.2)	
		L(LN01) = 0,7 cd/m^2	
		L(LN02) = 1,92 cd/m^2	
		L(LN03) = 3,48 cd/m^2	
		L(LN04) = 5,56 cd/m^2	
		L(LN05) = 8,06 cd/m^2	
		L(LN06) = 11,85 cd/m^2	
		L(LN07) = 16,55 cd/m^2	
		L(LN08) = 22,84 cd/m^2	
		L(LN09) = 29,65 cd/m^2	
		L(LN10) = 37,2 cd/m^2	
		L(LN11) = 49,1 cd/m^2	
		L(LN12) = 63,7 cd/m^2	
		L(LN13) = 82,5 cd/m^2	
		L(LN14) = 107 cd/m^2	
		L(LN15) = 137,7 cd/m^2	
		L(LN16) = 176,6 cd/m^2	
		L(LN17) = 225,5 cd/m^2	
		L(LN18) = 280,3 cd/m^2	
		Max. deviation = 14,76 %	

Annex B
(informative)

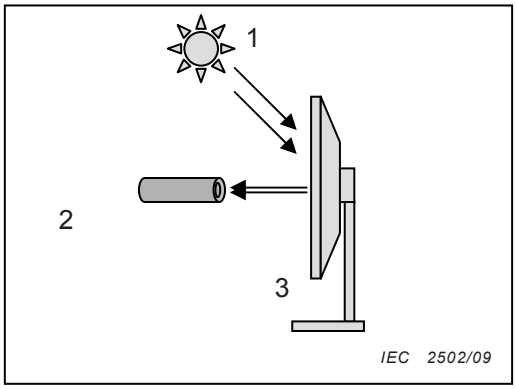
LUMINANCE measurement methods

B.1 General

This annex describes the methods to be used for the measurement of the LUMINANCE response of the IMAGE DISPLAY SYSTEM. All of the methods employ instruments that should be compliant to the specifications of Clause 6. Unless specified otherwise the measurements should be performed at the centre of the screen. However, since LUMINANCE measurements are time-consuming and thus expensive, current technologies enable automation of these measurements by using integrated LUMINANCE meters.

B.2 Measurement methods

B.2.1 Method A: Telescopic method



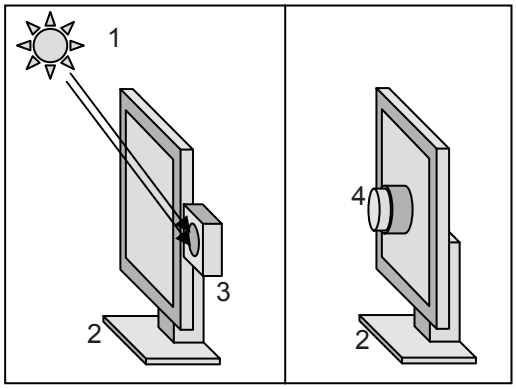
1 ambient light
2 telescopic LUMINANCE meter
3 display

Figure B.1 – Method A, telescopic method

Measurements are done with a telescopic LUMINANCE meter, as described in Figure B.1. A telescopic meter should enable the measurement of LUMINANCE including the ambient LUMINANCE. Those include LUMINANCE meters with telescopic viewfinders. For telescopic measurements, a predefined angle and distance of a measurement result in a defined measurement field size. The LUMINANCE measurement is only correct if this field size is significantly smaller than the corresponding square for the minimum or maximum LUMINANCE (L_{min} and L_{max}). If the LUMINANCE meter is equipped with an imaging lens, focusing onto the screen surface is necessary for the measurement of the LUMINANCE. In order to minimize the influence of flare on the low LUMINANCE measurements, the measurements should be made through a cone or baffle (covered with a black light-absorbing coating) to shield the instrument from the surround light.

Alternatively, to avoid the use of a cone or baffle with LCDs the TEST IMAGE may be BN01 to BN18 to reduce the error induced by the measuring instrument. For high-glare displays, e.g. CRTs, the use of these TEST IMAGES is not advised.

B.2.2 Method B: Near-range LUMINANCE meter in combination with ILLUMINANCE meter



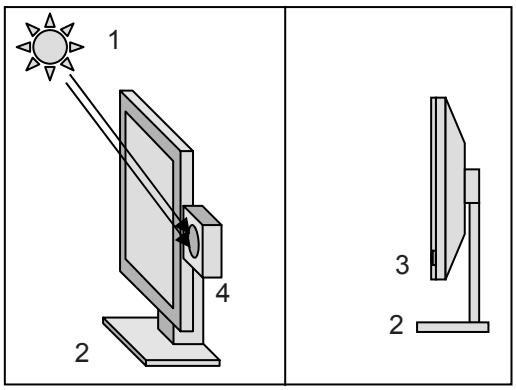
IEC 2503/09

1 ambient light
2 display
3 ILLUMINANCE meter
4 near range LUMINANCE meter

Figure B.2 – Method B, near-range LUMINANCE meter in combination with an ILLUMINANCE meter

A near range photometer will provide a measurement of LUMINANCE (L) without taking account of the ambient lighting (Figure B.2).Therefore it should be combined with an ILLUMINANCE measurement E for calculating L'. The near range LUMINANCE meter should comply with the specifications for LUMINANCE meters mentioned above. The ILLUMINANCE meter for procedure B is ideally located at the centre of the IMAGE DISPLAY DEVICE facing outward. The ILLUMINANCE E and the diffuse reflection coefficient R_d of the IMAGE DISPLAY DEVICE should be used to calculate L′ values ($L' = L + E \cdot R_d$) from the measurement results.

B.2.3 Method C: Frontal integrated LUMINANCE meter in combination with ILLUMINANCE meter



IEC 2504/09

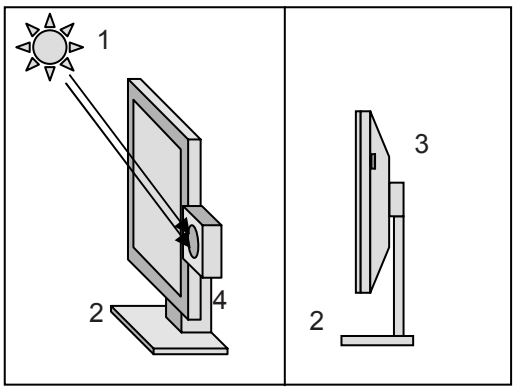
1 ambient light
2 display
3 frontal integrated LUMINANCE meter
4 ILLUMINANCE meter

Figure B.3 – Method C, frontal integrated LUMINANCE meter in combination with ILLUMINANCE meter

As indicated in Figure B.3, a measurement (L) can be performed with an integrated, frontal sensor. It is important that this measurement method highlights a front measurement since it is able to measure different LUMINANCE values displayed at the front of the panel, seeing what the user is observing. It should also be combined with an ILLUMINANCE meter enabling L' to be calculated as $L' = L + E \cdot R_d$.

If the integrated meter is located at the border of the screen, the measurement should represent the LUMINANCE in the most used area of the screen (front centre area). This is normally realized by a factory calibration of the integrated sensor.

B.2.4 Method D: Back integrated LUMINANCE meter in combination with ILLUMINANCE meter



1 ambient light
2 display
3 back integrated LUMINANCE meter
4 ILLUMINANCE meter

Figure B.4 – Method D, back integrated LUMINANCE meter in combination with ILLUMINANCE meter

As indicated in Figure B.4 a measurement can be performed with an integrated back sensor. This measurement method allows measuring the light source of the IMAGE DISPLAY DEVICE. It should be calibrated to provide L_{max} with a frontal sensor. This meter should only be used to measure the maximum white LUMINANCE of the IMAGE DISPLAY DEVICE. It should also be combined with an ILLUMINANCE meter for calculating L'.

B.3 Notes on measurement methods

The near-range meter used in method B and C should measure L values and be compliant with the specifications listed in Clause 6. These measurements should not include ambient light. Ambient light can for example be excluded by subtracting the corresponding value from every measurement, shielding the LUMINANCE meter or providing very low measurements (e.g. below 0,05 cd/m^2) when the display is switched off.

Each of the four measurement methods has advantages and disadvantages. For instance, method A will only give repeatable results if the environment and measurement conditions remain the same. Method C is known to be affected by changes of the LUMINANCE uniformity of the IMAGE DISPLAY DEVICE. If the LUMINANCE at the location of the integrated sensor changes in a different manner from the LUMINANCE in the centre of the screen, the measurement result will only reflect the LUMINANCE response in that area and not necessarily the LUMINANCE of the panel unless a correction is employed. On the other hand, methods A and B cannot be performed automatically and require human intervention. Method D, while being amenable to automation, has the disadvantage of measuring only the emission of the backlight and not the greyscale response of the IMAGE DISPLAY DEVICE.

Annex C
(informative)

Description of TEST PATTERNS

TEST IMAGES consist of the following:

a) technical TEST PATTERN generated digitally. The technical TEST IMAGES deliver a standard input signal for the test of the IMAGE DISPLAY SYSTEM;

b) clinical TEST IMAGE that is typical for the intended clinical application. The clinical TEST IMAGES are designated as CLINICAL REFERENCE IMAGES. Examples are shown in Table 2. Table C.4 summarizes the evaluation criteria for these examples.

For most patterns, it is essential to have a one-on-one relationship between the image pixels and the display pixels unless indicated otherwise in the test procedures in Clause 7. Patterns in DICOM or 16-bit TIFF formats should be displayed with a WINDOW SETTING and level setting to cover the range from 0 to 4 095 (WW = 4 096, WL = 2 048), except for the TG18-LN, where a WW of 4080 and WL of 2040 should be used. For 8-bit patterns, the displayed range should be from 0 to 255 (WW = 256, WL = 128).

Pixel dimensions, locations and pixel values of each TEST PATTERN/feature are described in C.1. Pixel dimension values and location values are for a matrix size of 1024×1024 and values within square brackets are for a matrix size of 2048×2048.

For matrix sizes other than 1024×1024 or 2048×2048, TEST PATTERNS and features should be scaled in principle so that the same pattern looks similar on the screens of various dimensions and matrix sizes. Those patterns and features are categorized into the following three groups based on the scaling requirement levels:

– MUST NOT SCALE: Scaling of CX patterns and line pairs (e.g. from 7×7 to 10×10, from “1 on, 1 off” to “2 on, 2 off”,) is prohibited.

– SHOULD SCALE: Scaling of patterns and features whose pixel dimension for a matrix size of 2048×2048 is indicated within a square bracket is recommended.

– MUST SCALE: Scaling of measurement areas of LN patterns, those of UNL patterns, white annulus of GV and GVN patterns and target circles of ANG patterns must be scaled to meet the requirements like “10 % of full area”, “20 cm” or “22 mm”.

If the targeted matrix size is not square like 1536×2048, a scaling factor should be calculated based on the pixel count of the short side (1536/1024 = 1,5). Example description of TG-18 QC pattern for a matrix size of 1536×2048 is also provided in Table C.5 and Figure C.1. It is just an example and the original 1024×1024 patterns can be used as it is except for the background of each pattern and the third category (must scale) above.

The location of corner elements must be specially taken care of if the targeted matrix size is not square. Measurement areas at the four corners of ULN patterns, 46×46 [92×92] CX patterns, 46×46 [92×92] line pairs at the four corners of QC pattern must be placed at the four corners of the targeted rectangles.

NOTE If the area (e.g. about 6 mm to 7 mm) on top and bottom of IMAGE DISPLAY DEVICES are protected and cannot be tested (e.g. by the imaging application and/or toolbars), the remaining matrix size should be used as a compromise.

Table C.1 – Description of multi-purpose TEST PATTERNS

TEST PATTERN/features	Pixel dimensions and location 1 k [2 k] size	Pixel values 8-bit [12-bit]
TG18-QC		
Background	1024 × 1024 [2048 × 2048]	128 [2048]
Crosshatch	Spacing: 102 × 102 [204 × 204] Width: 1 (CIE S 010/E:2004); 3 [3] around central region	191 [3071]
LUMINANCE patches: – 16 levels, equally spaced	102 × 102 [204 × 204]; clockwise increasing LUMINANCE in central region (see Table C.2)	8, 24, …, 248 [128, 384, …, 3968]
– Low CONTRAST corners	10 × 10 [20 × 20]; in corners of 16 uniform patches	+4 [64] in upper left-lower right −4 [64] in lower left-upper right
– Min/max levels	102 × 102 [204 × 204]; lower central region	0 [0] and 255 [4095]
– CONTRAST at min/max levels	51 × 51 [102 × 102]; centred in the minimum and maximum patch	Foreground / Background: Min: 13/0 [205/0] Max: 242/255 [3890/4095]
Line pairs (horizontal and vertical grilles)	46 × 46 [92 × 92]; 1 on, 1 off and 2 on, 2 off; at centre and four corners of pattern	High CONTRAST: 0,255 [0,4095] Low CONTRAST: 128,130 [2048,2088]
Cx patterns: – Measurement set	46 × 46 [92 × 92]; at centre and four corners of pattern	Background: 0 [0] Cx: 255, 191, 128, 64 [4095, 3071, 2048, 1024]
– Fiducial marker set, 12 levels of defocus	95 × 95 [190 × 190]; clockwise increasing underfocus; numbered -2, -1, 0, 1, … , 9 (see Table C.2 and Table C.3)	Maximum CONTRAST input; defocus determined by Kohm et al. (2001) [16]
LUMINANCE ramps	512 × 64 [1024 × 128] aligned vertically on left/right sides of the pattern. Number of lines at constant pixel value: 2 [4] for 8-bit, 1 [CIE S 010/E:2004] for 12-bit.	1k: 0, 1, …, 255 [0, 8, …, 4088] 2k: 0, 1, …, 255 [0, 4, …, 4092]
White/black windows – Outer windows – Inner windows	815 × 25 [1629 × 50]; above central region 407 × 25 [813 × 50]; above central region	13/242 [205/3890]
Crosstalk bars	576 × 86 [1152 × 172]; along top of pattern Bar lengths: 256, 128, … , 1 [512, 256, … , 1] Bar height: 3 [6] Central vertical bar 6 × 86 [12 × 172]	Maximum CONTRAST 0/255 [0/4095] -6 [-96] and +6 [+96] at the upper and lower portions
Low CONTRAST letters: “QUALITY CONTROL”	Bold capital letters, 23 [46] pixels high; in uniform background areas below central region	Backgrounds: 0, 128, 255 [0, 2048, 4 095]. Letters at +1 [16] for first letter, +2 [32] for second letter, etc. above background.
Border	Width: 3 [3]. Inset: 10 [20].	191 [3071]
OIQ		
Background	1024 × 1024 [2048 × 2048]	128 [2 048]
Crosshatch	Spacing: 102 × 102 [204 × 204] Width: 1 (CIE S 010/E:2004); 3 [3] around central region	191 [3 071]

TEST PATTERN/features	Pixel dimensions and location 1 k [2 k] size	Pixel values 8-bit [12-bit]
LUMINANCE patches: – 16 levels, equally spaced	102 × 102 [204 × 204]; clockwise increasing LUMINANCE in central region (see Table C.2)	8, 24, …, 248 [128, 384, …, 3968]
– Low CONTRAST corners	10 × 10 [20 × 20]; in corners of 16 uniform patches	+4 [64] in upper left-lower right −4 [64] in lower left-upper right
– Min/max levels	102 × 102 [204 × 204]; lower central region	0 [0] and 255 [4095]
– CONTRAST at min/max levels	51 × 51 [102 × 102]; centred in the minimum and maximum patch	Foreground / Background: Min: 13/0 [205/0] Max: 242/255 [3890/4095]
Line pairs (horizontal and vertical grilles)	46 × 46 [92 × 92]; 1 on, 1 off and -2 on, 2 off ; at centre and four corners of pattern	High CONTRAST: 0,255 [0,4095] Low CONTRAST: 128,130 [2 048,2088]
LUMINANCE ramps	512 × 64 [1024 × 128] aligned vertically on left/right sides of the pattern. Number of lines at constant pixel value: 2 [4] for 8-bit, 1 [CIE S 010/E:2004] for 12-bit.	1k: 0, 1, …, 255 [0, 8, …, 4088] 2k: 0, 1, …, 255 [0, 4, …, 4092]
White/black windows – Outer windows – Inner windows	815 × 25 [1629 × 50]; above central region 407 × 25 [813 × 50]; above central region	13/242 [205/3890]
Crosstalk bars	576 × 86 [1152 × 172]; along top of pattern Bar lengths: 256, 128, … , 1 [512, 256, … , 1] Bar height: 3 [6] Central vertical bar 6 × 86 [12 × 172]	Maximum CONTRAST 0/255 [0/4095] -6 [-96] and +6 [+96] at the upper and lower portions
Low CONTRAST letters: “QUALITY CONTROL”	Bold capital letters, 23 [46] pixels high; in uniform background areas below central region	Backgrounds: 0, 128, 255 [0, 2048, 4095]. Letters at +1 [16] for first letter, +2 [32] for second letter, etc. above background.
Border	Width: 3 [3]. Inset: 10 [20].	191 [3071]
TG18-MP		
Background	1 024 × 1 024	16 [256]
Vertical ramps	16 768 × 48 ramps	Each ramp: 48 [3] horizontal lines per pixel value
Border	770 × 770, pixel-wide bordering the ramp area	Pixel value = 32 [512]
Markers	1 × 3 and 1 × 5 markers for various bit transitions	4 1 × 3 markers per 8 bit transition [1 × 3 markers for 10 bit and 1 × 5 markers for 8 bit transitions] Pixel value = pixel value of the adjacent lines +16 [256] (left half) and -16 [256] (right half)
TG18-CT		
Background	1024 × 1024	128 [2048]
LUMINANCE patches: – 16 levels, equally spaced	102 × 102, separated by 51; ordered in 4 × 4 matrix, diagonal zig-zag increment, centred in pattern	8, 24, …, 248 [128, 384, …, 3 968]
– Low CONTRAST corners	10 × 10; in four corners of each LUMINANCE patch	+4 [64] in upper left-lower right −4 [64] in lower left-upper right

TEST PATTERN/features	Pixel dimensions and location 1 k [2 k] size	Pixel values 8-bit [12-bit]
– Low CONTRAST central disk (half moon)	Diameter: 34	±2 [32] + on right half, − on left half
TG18-LN{8,12}-nn		
Background	1024 × 1024 [2048 × 2048]	153 [2457] (~20 % of peak LUMINANCE)
LUMINANCE measurement areas: nn = 01 to 18	324 × 324 [648 × 648] (10 % of full area); centred in background	0, 15, … , 255 [0, 240, … , 4080]
TG18-UN{10,80}		
Background	1024 × 1024 [2048 × 2048]	26 [410] or 204 [3276]
TG18-UNL{10,80}		
Background	1024 × 1024 [2048 × 2048]	26 [410] or 204 [3276]
Borders of measurement areas	324 × 324 [2048 × 2048] (10 % of full area), 1 pixel wide; at centre and four corners of pattern.	128 [2048]
TG18-GV		
Background	1024 × 1024 [2048 × 2048]	0 [0]
White annulus	Inner, outer diametres: 1 cm (±20 %), 20 cm (±20 %). Centred in pattern.	255 [4095]
Low CONTRAST disks	Five disks, equally spaced inside inner radius of white annulus.	2, 4, 6, 8, 10 [32, 64, 96, 128, 160]
TG18-GVN		
Same as TG18-GV but without white annulus		
GD		
Background Lines	1024 × 1024 [2048 × 2048] 4 circles in 4 quadrants of the pattern with 224 pixel radius 6 diagonal lines connecting pattern corner and centres of the circles 4 axial lines connecting centres of the circles 10 pixel-wide, 2-pixel-on/2-pixel-off line pair patterns at the 4 edges of the pattern with line-pair perpendicular to the edge of the pattern.	128 [2048] Circumference 64 [1024] 64 [1 024] 64 [1 024] 0 [0] and 255 [4095]

TEST PATTERN/features	Pixel dimensions and location 1 k [2 k] size	Pixel values 8-bit [12-bit]
ANG		
Background Targets	1024 × 1024 [2048 × 2048] 9 equally spaced circles in a 3 by 3 array between 10 mm and 20 mm from the border. Each circle contains of 12 slices correlated to the hour increments on a clock, with no transition line (or edge) at the 5 or 11 positions. 8 slices are shaded with different grey levels, while 4 have a grey level equivalent to the background grey level. The pixel extension of the targets should have a physical size in the screen of approximately 22 mm (±10 %).[11]	10 [160] Starting from the 12 o'clock position in the clockwise direction, the grey levels of the slices are +4 [+64], +3 [+48], +2 [+32], +1 [+16], 0 [0], 0 [0], -4 [-64], -3 [-48], -2 [-32], -1 [-16], 0 [0], and 0 [0] with respect to the background level.
TG18-CH	PA chest TEST PATTERN (see Table 2) 2048 × 2048	12-bit range: 8 to 3944
TG18-KN	Knee TEST PATTERN (see Table 2) 2048 × 2048	12-bit range: 2 to 3902
TG18-MM1	Mammogram TEST PATTERN 1 (see Table 2) 2048 × 2048	12-bit range: 0 to 4095
TG18-MM2	Mammogram TEST PATTERN 2 (see Table 2) 2048 × 2048	12-bit range: 0 to 4095
BNnn		
Background	1024 × 1024 [2048 × 2048]	0 [0]
LUMINANCE measurement areas: nn = 01 to 18	324 × 324 [648 × 648] (10 % of full area); centred in background	0, 15, … , 255 [0, 240, … , 4080]

Table C.2 – TG18-QC pattern: LUMINANCE levels with 8-bit and [12-bit] pixel values and CX ratings

Level 6 88 [1408]	Level 7 104 [1664]	Level 8 120 [1920]	Level 9 136 [2176]	Level 10 152 [2432]	Level 11 168 [2688]
Level 5 72 [1152]	Cx 2	Cx 3	Cx 4	Cx 5	Level 12 184 [2944]
Level 4 56 [896]	Cx 1			Cx 6	Level 13 200 [3200]
Level 3 40 [40]	Cx 0			Cx 7	Level 14 216 [3456]
Level 2 24 [384]	Cx -1	Cx -2	Cx 9	Cx 8	Level 15 232 [3712]
Level 1 8 [128]	0/5 % 0/13 [0/205]			100/95 % 255/242 [4095/3890]	Level 16 248 [3968]

Table C.3 – The blurring characteristics of the CX reference set utilized in TG18-QC TEST PATTERNS [16]

Ref No.	Standard deviation of blurring in pixels	Corresponding RESOLUTION ADDRESSABILITY RATIO (RAR)
-2	0,35 σ1, 0,875 σ2 *	NA
-1	0,3 σ1, 0,99 σ2 *	NA
0	0	1 (perfect)
1	0,339	0,80
2	0,383	0,90
3	0,432	1,02
4	0,488	1,15
5	0,551	1,30
6	0,622	1,47
7	0,703	1,65
8	0,794	1,87
9	0,896	2,11

Profile = 0,85 $N(\sigma 1)$ + 0,15 $N(\sigma 2)$, where N is Gaussian distribution.

Table C.4 – Evaluation criteria for the examples of the CLINICAL REFERENCE IMAGES

Example image	Evaluation criteria
TG18-CH	Degree of difficulty for exam
	Overall CONTRAST
	Overall sharpness
	Symmetrical reproduction of the thorax, as shown by the central position of a spinous process between the medial ends of the clavicles
	Medial border of the scapulae
	Reproduction of the whole rib cage above the diaphragm
	Visually sharp reproduction of the vascular pattern of the lungs, particularly the peripheral vessels
	Sharp reproduction of the trachea and proximal bronchi
	Sharp reproduction of the borders of the heart and the aorta
	Sharp reproduction of the diaphragm
	Visibility of the retrocardiac lung and the mediastinum
	Visibility of the subdiaphragmatic features
	Visibility of the spine through the heart shadow
	Visibility of small details in the whole lung, including the retrocardiac areas
	Visibility of linear and reticular details out to the lung periphery
TG18-KN	Degree of difficulty for exam
	Overall CONTRAST
	Overall sharpness
	Reproduction of trabecular detail
	Reproduction of bony and soft tissue
TG18-MM1 and TG18-MM2	Degree of difficulty for exam
	Overall and BRIGHTNESS
	Overall sharpness (no blur)
	Sharp appearance of Cooper’s ligaments
	Structure of the clip and the presence of the gap at its apex (TG18-MM1 only)
	Appearance and visibility of subtle microcalcifications (TG18-MM1 only)
	Visibility of structures at the margins of the breast (TG18-MM1 only)

Table C.5 – Example description of TG-18 QC pattern for a matrix size of 1536 × 2048

TEST PATTERN/features	Pixel dimensions and location 1536 × 2048 size	Pixel values 8-bit [12-bit]
Background	1536 × 2048	128 [2048]
Crosshatch	Spacing: 154 × 154 Width: 1; 3 around central region	191 [3071]
LUMINANCE patches: – 16 levels, equally spaced	154 × 154; clockwise increasing LUMINANCE in central region (see Table C.2)	8, 24, …, 248 [128, 384, …, 3968]
– Low CONTRAST corners	15 × 15; in corners of 16 uniform patches	+4 [64] in upper left-lower right −4 [64] in lower left-upper right
– Min/max levels	154 × 154; lower central region	0 [0] and 255 [4095]
– CONTRAST at min/max levels	77 × 77; centred in min/max patches	Min: 0/13 [0/205] Max: 242/255 [3890/4095]
Line pairs (horizontal and vertical grilles)	69 × 69; 1 on, 1 off and 2 on, 2 off; at centre and four corners of pattern	High CONTRAST: 0,255 [0,4095] Low CONTRAST: 128,130 [2048,2088]
Cx patterns: – Measurement set	69 × 69; at centre and four corners of pattern	Background: 0 [0] Cx: 255, 191, 128, 64 [4095, 3071, 2048, 1024]
– Fiducial marker set, 12 levels of defocus	143 × 143; clockwise increasing underfocus; numbered -2, -1, 0, 1, … , 9 (see Table C.2 and Table C.3)	Maximum CONTRAST input; defocus determined by Kohm et al. (2001) [16]
LUMINANCE ramps	768 × 96 aligned vertically on left/right sides of the pattern. Number of lines at constant pixel value: 3 for 8-bit, 1 for 12-bit.	1k: 0, 1, …, 255 [0, 8, …, 4088] 2k: 0, 1, …, 255 [0, 4, …, 4092]
White/black windows – Outer windows – Inner windows	1223 × 38; above central region 611 × 25; above central region	13/242 [205/3890]
Crosstalk bars	864 × 130; along top of pattern Bar lengths: 384, 192, … , 1 Bar height: 5 Central vertical bar: 10 × 130	Maximum CONTRAST: 0/255 [0/4095] -6 [-96] and +6 [+96] at the upper and lower portions
Low CONTRAST letters: “QUALITY CONTROL”	Bold capital letters, 23 pixels high; in uniform background areas below central region	Backgrounds: 0, 128, 255 [0, 2048, 4095]. Letters at +1 [16] for first letter, +2 [32] for second letter, etc. above background.
Border	Width: 3. Inset: 15.	191 [3071]

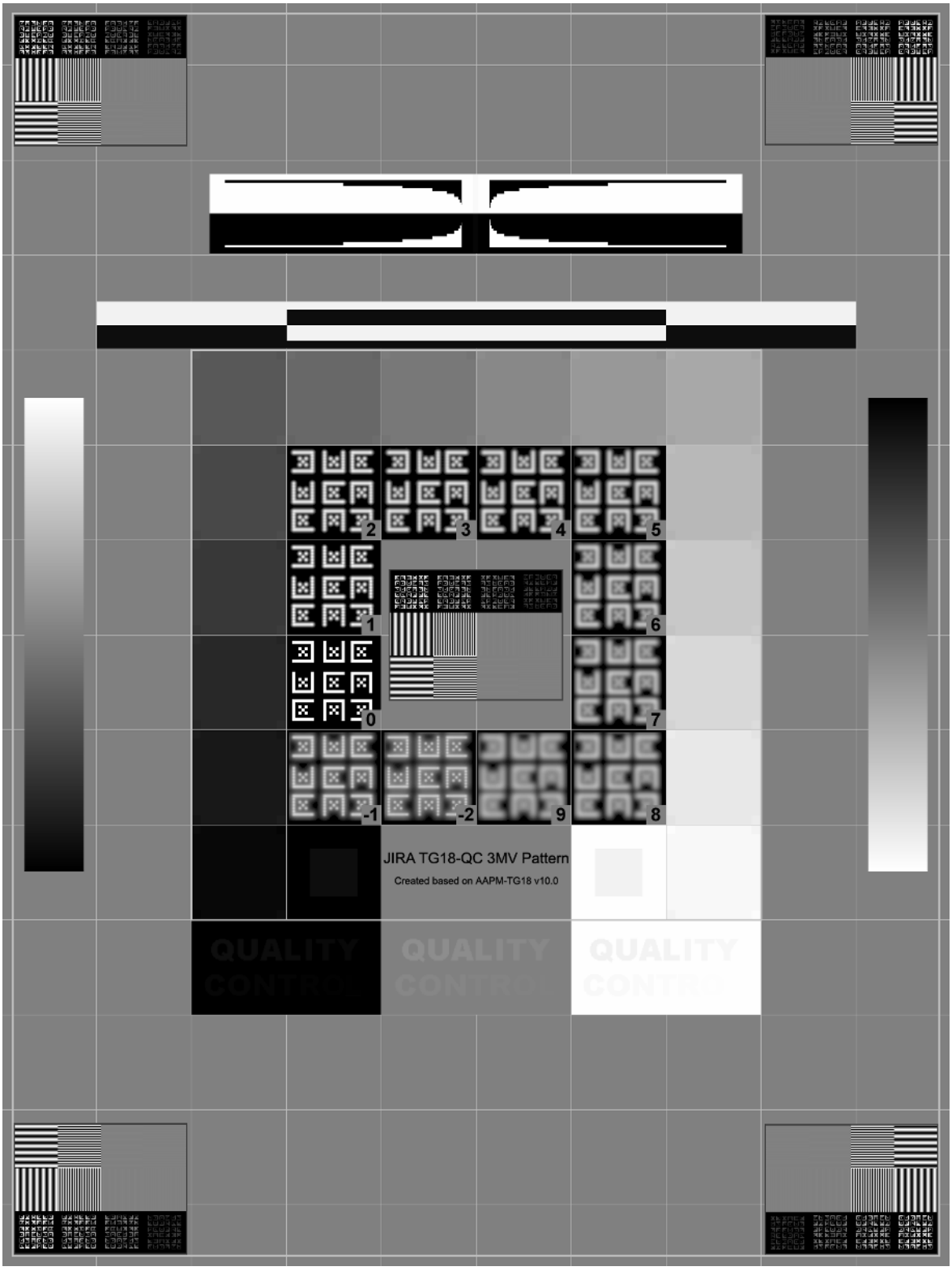


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Figure C.1 – Example of TG-18 QC pattern for a matrix size of 1536 × 2048

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Index of defined terms

NOTE The definitions used in this International Standard may be looked up at http://std.iec.ch/glossary.

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