

**Japan Industries Association of Radiological Systems Standards**

**JESRA X-0093<sup>-2005</sup>**

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**Quality Assurance (QA) Guideline for Medical Imaging  
Display Systems**

**Japan Industries Association of Radiological Systems**

Caution

1 Original document

This document is English version of JESRA X-0093 guideline. If any question raised, the original document shall be referred to.

2 Keyword definitions

Several keywords are used to differentiate between different levels of requirements and optionality, as follows:

- 2.1 shall: A keyword indicating a mandatory requirement.
- 2.2 should: A keyword indicating flexibility of choice with a strongly preferred alternative.
- 2.3 may: A keyword indicating flexibility of choice with no implied preference.

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## Preface

The quality assurance of medical imaging display systems (hereafter display systems) is recognized as an important issue, and concerned organizations in the individual countries have compiled standards for acceptance tests and constancy tests. However, the generation of standards preceded everything else, and methodical investigation about how the standards should be followed has been generally insufficient. In addition, because the standards have been compiled at overseas institutions' initiatives, the standards do not perfectly match the organizations and customs of Japanese medical institutions.

The guidelines presented in this document have been compiled so that Japanese medical institutions can follow smoothly; the standards and guidelines generated by foreign institutions have been reflected as necessary. The guidelines have an appendix that allows medical institutions to implement test methods without referring to other standards. Some other appendixes show generated test patterns and formats of standard reports, so that the quality assurance of display systems will be widely recognized.

## 1. Scope and Purpose

### 1.1 Scope

The following guidelines for the quality of display systems are applied to color and monochrome display systems that are used for monochrome image display and image reading at medical institutions. It is desirable for medical institutions to use display systems managed under the guidelines when performing image diagnosis. The guidelines cover only the evaluation methods and standards of display systems. For clinical applications, refer to the guidelines for handling digital images issued by Japan Radiological Society.

### 1.2 Purpose

The purpose of the following guidelines is to keep or improve the precision of image reading through quality assurance activities for display systems.

## 2. Reference Standards and Guidelines

### 2.1 Reference Standards

JIS Z 4752-1

Quality maintenance evaluation and routine testing methods in medical imaging departments-Part1:  
General aspects (in Japanese)

IEC 61223-1:1993

Evaluation and routine testing in medical imaging departments-Part1: General aspects

JIS Z 4752-2-5

Quality maintenance evaluation and routine testing methods in medical imaging  
departments-Part2-5: constancy tests - imaging display devices (in Japanese)

IEC 61223-2-5:1994

Evaluation and routine testing in medical departments - Part 2-5: Constancy tests-imaging display  
devices

DIN6868-57

Image Quality Assurance in X-Ray Diagnosis – Part 5-7: Acceptance testing for image display

devices

Digital Imaging and Communications in Medicine (DICOM)

Part14: Grayscale Standard Display Function

## 2.2 Reference Guidelines

AAPM TG18:2004 Public Draft v10.0

American Association of Physicists in Medicine, Task Group 18

Assessment of Display Performance for Medical Imaging System

TG18 Citation:

Samei E, Badano A, Chakraborty D, Compton K, Cornelius C, Corrigan K, Flynn MJ, Hemminger B, Hangiandreou N, Johnson J, Moxley M, Pavlicek W, Roehrig H, Rutz L, Shepard J, Uzenoff R, Wang J, and Willis C. Assessment of Display Performance for Medical Imaging Systems. Draft Report of the American Association of Physicists in Medicine (AAPM) Task Group 18, Version 10.0, August 2004

Guidelines for handling digital images, Version 1.1, June 2002

The Electron Information Committee of the Japan Radiological Society (in Japanese)

## 3. Terminology and Definitions

GSDF (Grayscale Standard Display Function)

This function is also referred to as the Barten curve from the name of the person who verified the function. DICOM Part 14 shows the GSDF's table for the function of the Just Noticeable Difference (JND) indices and luminance. The function is characterized by the uniform contrast resolution in the range from low to high luminance.

I/F (InterFace)

In a broad sense it designates a part of an apparatus or device to which another machine or device is connected for communication and/or control; it often refers to a connection part between a computer and a peripheral device. When used in the following guidelines, it means a connection part between a display system and another type of apparatus.

JND indices (Just Noticeable Difference indices)

The JND indices represents changes in input relative to changes of luminance levels in JND steps on the Grayscale Standard Display Function (GSDF).

LUT (Look Up Table)

An abbreviation for Look Up Table that designates the conversion table of digital pixel values.

p value

An input value for the standard display system whose output presents GSDF characteristics.

SI vendor (System Integration vendor)

This stands for a system integration vendor producing and supplying medical systems.

Aspect ratio, Aspect ratio of X/Y

The proportion of the display's width and its height. General 2M and 3M display systems of a horizontal type have an aspect ratio of 4:3 (for a vertical type, 3:4), and general 1M and 5M display systems of a horizontal type have an aspect ratio of 5:4 (for a vertical type, 4:5).

## Artifact

Any problematic phenomenon that should not be present. The types of phenomenon include pixel error, flicker, crosstalk, video characteristics (ghost and ringing), and color characteristics (convergence and landing characteristics).

## Interlaced display

Method in which a single screen display is generated through two sets of line drawings, whereby the pixel clock is reduced. Because this method utilizes the residual-image characteristics of the human eye, it can cause such problems as appearance of flicker or the intervals between odd and even lines may not have a ratio of 1:1. The method in which a single screen display is generated through one set of line drawing is called a non-interlaced or progressive.

## Acceptance test

A test having the objective of checking whether a purchased apparatus satisfies the required specifications. This test is usually conducted before such apparatus is installed and operated. However, the test is conducted also after the installation and operation if repair or adjustment affecting the characteristics is required or if environmental conditions change.

## Edge

The borderline of circumference of TG18-QC and TG18-UNL80 patterns.

## Overshoot

A phenomenon presenting an excessive output relative to input of square waves in an electric circuit. This problem makes white appear enhanced at the borderline between black and white on a display screen.

## Color artifact

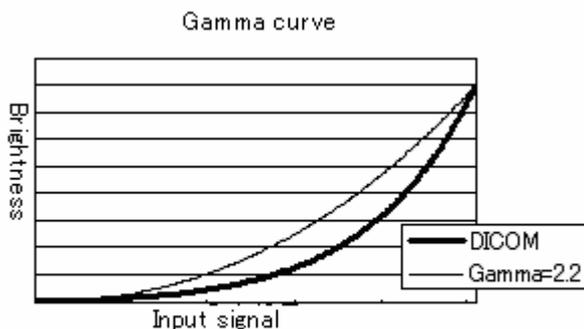
An artifact representing color characteristics. This often refers to color shift resulted from misconvergence or mislanding on a CRT display.

## Gamma, Gamma characteristics

The relationship between input signals and actual display luminance; this is represented by a characteristics curve.

## Gamma curve

A curve representing gamma characteristics. An example of a gamma curve is given below:



#### Crosstalk

A phenomenon caused when signals interfere with a different electric circuit. On an LCD, driving signals interfere with a panel circuit which is not currently driven, generating shadows along characters and lines.

#### Ghost

A false image generated through reflection mainly attributable to circuit and cable factors; multiple images often result.

#### Maximum luminance

Luminance produced when the maximum value of input signals is input.

#### Shadow

A phenomenon generating shadows along characters and lines at parts presenting contrast changes.

#### Horizontal / vertical crosshatch line

Grid pattern lines resulted from cross of multiple parallel horizontal and vertical lines equally spaced.

#### Scoring scale

Cx images generated by spuriously deteriorating the focus characteristics present at the center of the TG18-QC test pattern, step by step (12 steps, -2 to 9); this is used as the reference.

#### Correlated

When one of multiple measuring instruments in use is designated for reference, correlated means compensated by the error factor for the measuring instrument relative to the reference measuring instrument.

#### Nyquist frequency

The maximum frequency used when lines of a screen display are drawn.

#### Video artifact

An artifact caused by video signals such as ghost or shadow.

#### Constancy test

A test aimed at maintaining the characteristics of the apparatus in use within the permissible range. In this test the specified items regarding the initial characteristics of an apparatus that underwent an acceptance test are used as the reference, and the apparatus is periodically checked against the reference to ensure that the apparatus operates within the acceptable range. The test should be conducted by the actual user.

#### Flicker

A fluctuating image on a display screen. A display screen is refreshed several tens of times per second. In particular a CRT display causes flicker when the frequency of screen refreshing (vertical scanning frequency) is too low. Flicker appears different from person to person.

#### Misconvergence

A phenomenon on a color CRT such as blurred characters and color image blurring resulted from the fact that three electron beams (red, blue, and green) are not correctly sent to the fluorescent screen (are not focused on a single point on the fluorescent screen) because of the assembly variance of the deflection yoke and electron gun. This phenomenon can also be caused by changes in the installation

environment (i.e. influence by magnetism).

#### Mislanding

A phenomenon whereby an electron beam of any color on a color CRT does not reach an appropriate fluorescent substance but lands upon an adjacent fluorescent substance, causing an incorrect color to be emitted; this happens because of physical shift between the shadow mask (aperture grill) and the fluorescent substances or because the incident angle of the beam relative the shadow mask has shifted. When a perfectly white image is displayed, this phenomenon causes the luminance of the white portion to be nonuniform or in a worst case causes some white part to be colored.

#### 4. Management Grade Classification

Display systems that have been managed shall be classified into the following two categories:

Table 1 Display system management grade

Management grade	Maximum luminance $L_{\max}(\text{cd}/\text{m}^2)$	Luminance ratio $L_{\max}/L_{\min}$	Contrast response $\kappa\delta(\%)$
1	$\geq 170$	$\geq 250$	$\leq \pm 15$
2	$\geq 100$	$\geq 100$	$\leq \pm 30$

#### 5. Operation Framework

##### 5.1 Frameworks of Medical Institutions

The framework of a medical institution should be structured according to JIS Z 4752-1 and IEC 61223-1.

It is desirable to establish a Quality Assurance Committee (tentatively so named) within a medical institution upon the request of the head of the medical institution and causes the committee to carry out works concerning overall quality maintenance activities. Ideally, works relating to quality assurance should be carried out on the authority and responsibility of the Quality Assurance Committee (tentatively so named).

The Quality Assurance Committee (tentatively so named) should appoint a display system quality administrator.

##### 5.2 Display System Quality Administrator

A display system quality administrator should carry out works including the generation of procedures concerning quality maintenance, training of test administrators, storage of records, evaluation of results, and making improvements.

It is desirable for the display system quality administrator to be fully informed of acceptance and constancy tests.

##### 5.3 Regarding Outsourcing

Some of the works concerning the quality assurance of display systems may be carried out by organizations outside the medical institution.

## 6. Test Methods and Reference Values

In order to assure the display system's stable display capability needed for diagnosis, the display system must undergo acceptance and constancy tests. The records of the tests must be kept for the specified period. The outline and details of these tests are described in section 6 and appendix 1 respectively, so that the tests will be thoroughly understood.

### 6.1 Acceptance Tests

#### 6.1.1 Test conditions and timing

The display system quality administrator should conduct the acceptance tests and generate a report about the test results. In a case where the reproducibility of the evaluation data on the display system<sup>1</sup> has been confirmed<sup>2</sup>, the display system quality administrator may omit the acceptance test by checking and approving the display system's shipment test report presented by the system supplier. In order to prevent variations attributable to image reading environments and to maintain the reproducibility of test results, acceptance tests at medical institutions and shipments tests by system suppliers shall be conducted in an environment not exposed to ambient light.

#### 6.1.2 Preparation

The acceptance tests should be conducted according to the preparation procedure; for details, see section 1 in appendix 1.

#### 6.1.3 Check items and judgment criteria

The outline is shown in table 2, and the details are given in section 2 to 10 in appendix 1.

#### 6.1.4 Keeping test results

Acceptance test result reports should be kept for the period specified by the medical institution; a sample report is given in table 4.

### 6.2 Constancy Test

#### 6.2.1 Test conditions and timing

The constancy tests should be conducted on the responsibility of the display system quality administrator.

Visual check for the constancy tests shall be performed under ordinary ambient light. Measurement shall be performed in an environment free from ambient light in order to prevent variations attributable to image reading environments and to maintain the reproducibility of test results.

The constancy tests comprise the following three items, (1) to (3).

##### (1) Generation of reference values

The initial values for the constancy tests should be measured using the client terminal and luminance meter actually used at the medical institution at the earliest possible time after the display system has been installed; a "correlated" luminance meter also can be used. The initial values then should be compared with the shipment test data to check the grade and be used as the reference for constancy tests.

##### (2) Overall evaluation tests on each usage day

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<sup>1</sup> The range of display systems is defined in section 2 in appendix 4.

<sup>2</sup> Application examples are given in section 3 in appendix 4

The overall evaluation test on each usage day should be conducted by a user who is designated by the display system quality administrator. The test shall be implemented under ambient light conditions actually used for image reading as preparation for using the display system.

### (3) Periodical tests

Periodical constancy tests should be conducted under the same (or nearly the same) environment as when the reference values are generated. For medical CRT display systems, tests should be implemented every three months at least; for medical LCD display systems, every six months at least. For medical LCD display systems containing a luminance stabilizing circuit, tests may be implemented once a year.

#### 6.2.2 Preparation

The constancy tests should be conducted according to the preparation procedure; for details, see section 1 in appendix 1.

#### 6.2.3 Check items and judgment criteria

The outline is shown in table 3, and the details are given in section 2 to 9 in appendix 1.

#### 6.2.4 Procedures to be adopted when the test is not passed

When a constancy test is not passed, repeat the test. If the system still does not meet the judgment criteria, perform calibration<sup>3</sup> and then conduct the test once again. If the calibration does not allow the system to meet the criteria, contact the display system quality administrator and take appropriate procedures.

#### 6.2.5 Keeping test results

The results of constancy tests should be concluded as a constancy test result report and kept for three years following the last test; sample reports are as shown in tables 5 and 6.

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<sup>3</sup> The details are given in section 4 in appendix 4.

Table 2 Check items and judgment criteria for acceptance tests

Judgment method	Category	Test pattern , measuring instrument	Judgment criteria		Check item Formula   Unit	Test No. <sup>6</sup>
			Grade 1	Grade 2		
Spec	Specifications		$\geq 1k \times 1k$		Resolution   pixel	
Visual check	Overall evaluation	TG18-QC [SMPTE] <sup>7</sup>	The patches' luminance differences among 16 (11) steps should be clearly recognized. 5% and 95% patches should be visible.			2
		Reference clinical image	The judgment-use positions on the reference clinical image should be visible without any problem <sup>8</sup> .			
	Grayscale	TG18-QC [8-bit grayscale at least]	Smooth, stable and continuous display should be presented.			3
	Geometric distortion: CRT only	TG18-QC [SMPTE]	The entire screen should allow visual check and provide linearity. The aspect ratio of the width and height should be appropriate.			4
	Resolution: CRT only	TG18-QC [SMPTE]	$0 \leq Cx \leq 4$ Nyquist lines should be visible.		Cx score   --- <sup>11</sup>	5
	Artifact	TG18-UNL80 [Entirely white] TG18-QC [SMPTE]	Artifacts should not be present.		Flicker	6
Crosstalk Video artifact						
Color artifact: CRT only						
Measurement	Luminance uniformity	TG18-UNL80 [Entirely white] Luminance meter	$\leq 30$		$\{(L_{max}-L_{min})/(L_{max}+L_{min})\} * 200$   %	7
	Contrast response		$\leq \pm 15$	$\leq \pm 30$	K $\delta$ of 18 points   %	8
	Maximum luminance	TG18-LN [Equivalent pattern] Luminance meter	$\geq 170$	$\geq 100$	Lmax   cd/m <sup>2</sup>	9
			Between multiple displays <sup>10</sup>		$\{(L_{max1}-L_{max2})/L_{max2}\} * 100$   %	
	Luminance ratio		$\geq 250$	$\geq 100$	Lmax/Lmin   ---	
Chromaticity	TG18-UNL80 [Entirely white] Colorimeter	Inside the screen $\leq 0.01$	--- <sup>11</sup>		$\{(u'_1-u'_2)^2+(v'_1-v'_2)^2\}^{1/2}$   ---	10
		Between multiple displays <sup>10</sup> $\leq 0.01$			$\{(u'_m1-u'_m2)^2+(v'_m1-v'_m2)^2\}^{1/2}$   ---	

Table 3 Check items and judgment criteria for constancy tests

1. Items to be checked on each usage day prior to use and their judgment criteria

Judgment method	Category	Test pattern, measuring instrument	Judgment criteria		Check item Formula   Unit	Test No. <sup>6</sup>
			Grade 1	Grade 2		
Visual check	Overall evaluation	TG18-QC [SMPTE] <sup>7</sup>	The patches' luminance differences among 16 (11) steps should be clearly recognized. 5% and 95% patches should be visible.			2
		Reference clinical image	The judgment-use positions on the reference clinical image should be visible without any problem <sup>8</sup>			

2. Items to be checked every three months for CRT display systems, and every six or twelve months for LCD display systems, and their judgment criteria

Judgment method	Category	Test pattern, measuring instrument	Judgment criteria		Check item Formula   Unit	Test No. <sup>6</sup>
			Grade 1	Grade 2		
Visual check	Overall evaluation	TG18-QC [SMPTE] <sup>7</sup>	The patches' luminance differences among 16 (11) steps should be clearly recognized. 5% and 95% patches should be visible.			2
		Reference clinical image	The judgment-use positions on the reference clinical image should be visible without any problem <sup>8</sup>			
	Grayscale	TG18-QC [8-bit grayscale at least]	Smooth, stable and continuous display should be presented.			3
	Geometric distortion: CRT only	TG18-QC [SMPTE]	The entire screen should allow visual check and provide linearity. The aspect ratio of the width and height should be appropriate.			4
	Resolution: CRT only	TG18-QC [SMPTE]	$0 \leq Cx \leq 4$ Nyquist lines should be visible.		Cx score   --- <sup>11</sup>	5
	Artifact	TG18-UNL80 [Entirely white]	Artifacts should not be present.		Flicker	6
		TG18-QC [SMPTE]			Crosstalk	
				Video artifact		
				Color artifact: CRT only		
Luminance uniformity	TG18-UNL80 [Entirely white]	Excessive nonuniformity should be absent.			7	
Measurement	Contrast response		$\leq \pm 15$	$\leq \pm 30$	K $\delta$ of 18 points   %	8
	Maximum luminance	TG18-LN [Substitute pattern] Luminance meter	$\geq 170$	$\geq 100$	Lmax   cd/m <sup>2</sup>	9
			Luminance deviation $\leq \pm 10$		$\{(L_{max_n} - L_{max_0}) / L_{max_0}\} * 100$   %	
			Between multiple displays $\leq 10$		$\{(L_{max_1} - L_{max_2}) / L_{max_2}\} * 100$   %	
Luminance ratio		$\geq 250$	$\geq 100$	Lmax/Lmin   ---		
Illuminance (value for reference)				Screen vertical illuminance   lux		

Annotations common to tables 2 and 3.

- <sup>6</sup> Test No designate section numbers in appendix 1, “Acceptance and Constancy Tests for Display Systems.”
- <sup>7</sup> The content of [ ] shows an alternate test method to be used when TG18 test patterns cannot be displayed; no evaluation of Cx patterns.
- <sup>8</sup> The reference values for the window width and window level of the display software should be determined at the medical institution.
- <sup>9</sup> The meanings of Lmax and Lmin differ among test items. For details, refer to the relevant sections in appendix 1.
- <sup>10</sup> Deviation shall be calculated using the shipment test data of multiple displays of the same type for the use with the same client in the finally-installed situation.
- <sup>11</sup> --- designates that no test and unit is provided.

## Appendix 1. Acceptance and Constancy Tests for Display Systems

## 1. Preparation

## 1.1 Instruments

## (1) Luminance meter

Using a telescopic-type luminance meter, measure the luminance at the center of the screen (or the center of the specified area). If using a near-range luminance meter or any type of luminance sensor, correlate it with a telescopic-type luminance meter before using it. If measuring the luminance of a position outside the center, correlate it with the center.

## (2) Illuminance meter

Using an illuminance meter or a correlated sensor, measure the illuminance in the direction of normal lines at the center of the front of the display system. If measuring the illuminate of a position outside the center, correlate it with the center.

## (3) Colorimeter

The colorimeter should be capable of measuring in  $u'$  and  $v'$  chromaticity units. It does not matter whether the colorimeter is of a telescopic or near-range as long as it can measure the chromaticity of the center of the specified area. If using a meter in  $x$  and  $y$  chromaticity units, convert measured values using the following formula:  $u'=4x/(-2x+12y+3)$ ,  $v'=9y/(-2x+12y+3)$ .

## (4) Reference meter

If using more than one meter, specify one of them as the reference meter and correlate other meters with it. It is desirable to calibrate the reference meter at the specified periodic intervals.

## (5) Other equipment

Prepare a magnifying glass.

## 1.2 Test Patterns

The following four test patterns should be used. The actual test patterns and check points are shown in appendix 2. Each pattern shall be displayed on the entire screen with an appropriate aspect ratio.

TG18-QC pattern [SMPTE pattern]

TG18-LN 01 to 18 patterns

TG18-UNL80 pattern [Entirely white display]

Reference clinical images

If the above patterns cannot be prepared, patterns inside [ ] may be used instead.

## 1.3 Preparation and Precautions for Tests

## (1) Prepare the result data of acceptance test and constancy tests.

## (2) Prepare the required instruments and test patterns.

## (3) Turn on the power to the display system about 30 minutes before evaluation in order to stabilize its electronic components. Condensation occurs when the image display is quickly moved from a cold to a warm and humid place. Note that it is not desirable to turn on the display system when condensation is present.

## (4) Calibration

Perform calibration at the time of the acceptance test if necessary. Calibration here means

precisely setting such parameters as the luminance of the display system, gamma, and chromaticity, using a sensor. The details of calibration are given in appendix 4.

- (5) It is essential to generate reference values for constancy tests and conduct constancy tests in a finally-installed environment. The placement of the display system and the condition of illumination shall have been finalized, and the client terminal and luminance meter actually used at the medical institution shall be used for the tests; a “correlated” luminance meter also can be used. The display system shall have been placed so that direct light from overhead illumination, sunlight, or viewing box shall not be present at a usual image reading position at the front of the display system under usual ambient conditions.
- (6) For a CRT display system, check if it is affected by magnetic fields. Using the TG18-QC (or SMPTE) pattern, check if ambient magnetic fields cause image distortion, fluctuation, or color shift.
- (7) A LCD display system has angler dependence characteristics. When visually checking a LCD display system, view the image on the screen from the front.
- (8) Before conducting the test, clean the screen so that it is free from dust and dirt. When cleaning the screen, follow the procedure presented by the system supplier.

## 2. Overall Evaluation Tests (Visual Evaluation)

Before starting individual tests, make the screen display the test patterns and reference clinical images and check the overall image quality of the display system. Normally perform evaluation using the TG18-QC pattern; if this pattern cannot be prepared, the SMPTE pattern may be used instead. It is desirable to also use the reference clinical images no matter which pattern is used.

### 2.1 Overall Evaluation Test Using the TG18-QC Pattern

- Check items
  - (1) Differences in luminance among 16-step patches
  - (2) Recognition of 5% and 95% patches
- Judgment criteria
  - (1) Differences in luminance should be clearly recognizable.
  - (2) Visual recognition should be possible.

### 2.2 Overall Evaluation Test Using the SMPTE Pattern

- Check items
  - (1) Differences in luminance among 11-step patches
  - (2) Recognition of 5% and 95% patches
- Judgment criteria
  - (1) Differences in luminance should be clearly recognizable.
  - (2) Visual recognition should be possible.

### 2.3 Overall Evaluation Tests Using Reference Clinical Images

Ideally the medical institution should prepare clinical images suitable for each modality. If the medical institution cannot itself prepare reference images, it is recommended to use the test images shown in “1) Guidelines for handling digital images” listed under the bibliography.

- Check items  
Check how nodules to be recognized appear on reference clinical images.
- Judgment criteria  
Points for judgment should be visible without problems.

### 3. Grayscale Test (Visual Evaluation)

- Check items  
Make the screen display the TG18-QC pattern (or another 8 bit or higher grayscale) and check that the grayscale bars are continuous.
- Judgment criteria  
Smooth, even and continuous display should be presented.

### 4. Geometric Distortion (Visual Evaluation): CRT Display Systems Only

- Check items  
Visually check geometric distortion using the TG18-QC (or SMPTE) test pattern. Make the pattern cover the entire display area. Visually check the linearity of the pattern over the entire display area and at the borderlines of the pattern's periphery.
- Judgment criteria  
The pattern should not present a significant geometric distortion, and the entire pattern should be displayed. The pattern should be displayed with an appropriate aspect ratio, and each grid should be square. Each line should be straight and present an appropriate linearity; it should not be curved or winding. Extreme barrel or pincushion distortion should not be present; presence of minimal barrel or pincushion distortion is not a problem.

### 5. Resolution Test (Visual Evaluation): CRT Display Systems Only

- Check items  
Visually check how the Cx pattern included in the TG18-QC test pattern appears. It is important to check that image pixels match display pixels one for one. A digitally enlarged display does not allow its actual resolution to be evaluated. With the TG18-QC and magnifying glass, check the Cx patterns displayed at the center and four corners of the screen, and perform evaluation using the appropriate scoring scale where the clearest reference pattern is 0, and the least clearest reference pattern is 9. In addition, check if lines are visible for the horizontal and vertical line pair patterns at the Nyquist frequency on the TG18-QC and SMPTE patterns.
- Judgment criteria  
The result of the Cx evaluation should be between 0 and 4 (clearer than score 4). The horizontal and vertical line pair patterns at the Nyquist frequency should be recognizable at all positions and in every direction.

### 6. Artifact test (Visual Evaluation): For Color Artifact Test, CRT Display Systems Only

- Check items

(1) Flicker

Visually check the artifact using the TG18-UN80 test pattern (or entirely white display).

(2) Crosstalk

Visually check the crosstalk element of the TG18-QC test pattern (or low contrast line pattern of the SMPTE pattern).

(3) Video artifact

Visually check the white-to-black and black-to-white signal change of the TG18-QC (or SMPTE) test pattern.

(4) Color artifact

Visually check the crosshatch lines and background of the TG-18-QC (or SMPTE) pattern.

- Judgment criteria

(1) Flicker

No flicker should be visible; this test does not apply to display system with an interlace display technique.

(2) Crosstalk

Crosstalk elements should be properly displayed; the low contrast lines of the SMPTE pattern should be properly displayed.

(3) Video artifact

There should be no extreme tailing, overshoot, shadow or ghosting.

(4) Color artifact

Horizontal and vertical crosshatch lines should not present significant misconvergence. The pattern background should not present a significant mislanding.

## 7. Luminance Uniformity Test

### 7.1 Acceptance Test Evaluation (Quantitative Evaluation)

- Check items

Using a calibrated luminance meter and the TG18-UNL80 pattern (or entirely white display), measure the luminance of the center of each of the displayed five patches; when using the entirely white display, the measurement points should be the same as for the TG18-UNL80 pattern. The following formula allows the luminance deviation of the display pattern to be obtained.

$$Formula = \frac{(Lmax - Lmin)}{(Lmax + Lmin)} * 200$$

where Lmax is the maximum luminance value among the measured five points,

and; Lmin is the minimum luminance value among the measured five points.

- Judgment criteria

The luminance deviation shall be within 30%.

### 7.2 Constancy Test Evaluation (Visual Evaluation)

- Check items

Use the TG18-UNL80 test pattern (or entirely white display) to visually check the luminance uniformity of the display system. Visually check the uniformity of the displayed pattern.

- Judgment criteria

The pattern should not present a significant non-uniformity from the center to the edges.

## 8. Contrast Response Tests (Quantitative Evaluation)

### - Check items

Using a calibrated luminance meter and the TG18-LN test pattern (or a correlated luminance meter or a substitute pattern), measure the luminance inside the test area for 18-step digital drive levels.

### - Judgment criteria

Using the measured luminance values and the DICOM 3.14 standard luminance response curve, calculate the contrast response relative to the JND indices.<sup>4</sup> For grade 1 display systems, the calculated contrast response values shall be within  $\pm 15\%$  of the standard values at all measurement points; for grade 2 display systems, within  $\pm 30\%$ .

## 9. Maximum luminance and luminance Ratio Tests

### 9.1 Acceptance Tests (Quantitative Evaluation)

#### - Check items

Using a calibrated luminance meter and the TG18-LN test pattern (or a correlated luminance meter or a substitute pattern), measure the maximum luminance (white luminance,  $L_{max}$ ) and the minimum luminance (black luminance,  $L_{min}$ ) and calculate the luminance ratio ( $L_{max}/L_{min}$ ).

The following formula allows the calculation of the deviation of the maximum luminance among multiple displays of the same type for the use with the same client. For the acceptance tests, the deviation value shall be calculated using the shipment test data of the targeted display system. For the constancy tests, calculation shall be performed using the values measured in the finally-installed situation.

$$Formula = \{(L_{max_1} - L_{max_2}) / L_{max_2}\} * 100$$

where  $L_{max_1}$  is the maximum luminance of the display system presenting the maximum luminance, and;  $L_{max_2}$  is the maximum luminance of the display system presenting the minimum luminance.

#### - Judgment criteria

The  $L_{max}$  shall be  $170 \text{ cd/m}^2$  or higher for grade 1 display systems and  $100 \text{ cd/m}^2$  or higher for grade 2 display systems.

The luminance ratio shall be 250 or higher for grade 1 display systems and 100 or higher for grade 2 display systems.

The maximum luminance deviation among multiple displays of the same type shall be within 10%.

### 9.2 Constancy Tests (Quantitative Evaluation)

#### - Check items

Besides the acceptance tests, check the deviation from the reference value of the maximum luminance.

$$Formula = \{(L_{max_n} - L_{max_0}) / L_{max_0}\} * 100$$

---

<sup>4</sup> The details are given in section 5 in appendix 4.

where  $L_{max_n}$  is the maximum luminance obtained through a periodic constancy test,  
and;  $L_{max_0}$  is the maximum luminance of the reference value for a periodic constancy test.

- Judgment criteria

The deviation shall be within  $\pm 10\%$  from the reference value.

10. Chromaticity Deviation Tests (Quantitative Evaluation): Grade 1 Display Systems Only

- Check items

Using a calibrated colorimeter and the TG18-UNL80 pattern (or entirely white display), measure the chromaticity ( $u'$ ,  $v'$ ) of the center of each of the displayed five patches; when using the entirely white display, the measurement points should be the same as for the TG18-UNL80 pattern. Use the following formula to calculate the chromaticity deviation between the measured points and perform judgment using the maximum value.

$$Formula = \{(u'_1 - u'_2)^2 + (v'_1 - v'_2)^2\}^{1/2}$$

where  $u'_1$  and  $v'_1$  are the  $u'$  and  $v'$  values of measurement point 1,  
and;  $u'_2$  and  $v'_2$  are the  $u'$  and  $v'$  value of measurement point 2.

With the mean value of the five points set to ( $u'm$ ,  $v'm$ ), the following formula allows the calculation of the chromaticity deviation between multiple displays of the same type, using the shipment test data of the targeted display systems. Perform judgment according to the maximum value.

$$Formula = \{(u'm_1 - u'm_2)^2 + (v'm_1 - v'm_2)^2\}^{1/2}$$

where  $u'm_1$  and  $v'm_1$  are the  $u'm$  and  $v'm$  value of display system 1,  
and;  $u'm_2$  and  $v'm_2$  the  $u'm$  and  $v'm$  value of display system 2.

- Judgment criteria

The chromaticity deviation shall be 0.01 or less.

The chromaticity deviation between multiple displays shall be 0.01 or less.

Appendix 2. Standard Test Patterns and Reference Clinical Images

1. TG18-QC Test Pattern

This pattern should be used for comprehensive judgment.

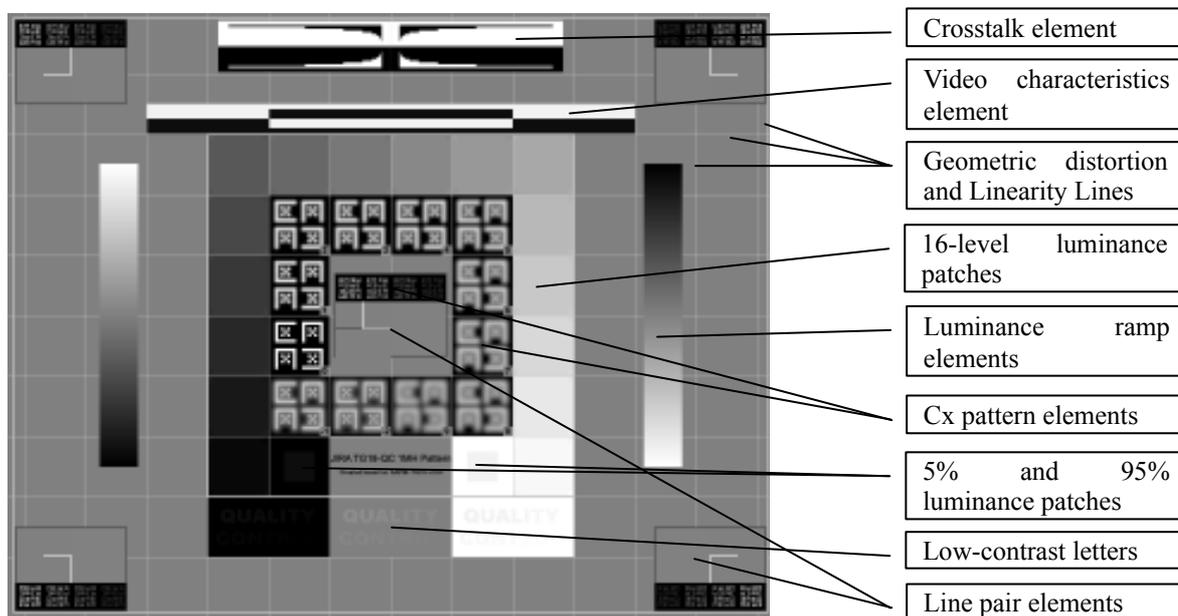


Figure 1 JIRA TG18-QC pattern

2. TG18-LN8-nn Pattern

This pattern should be used for luminance measurement. This pattern has 18 different versions (01 to 18) with p values divided at even intervals. It has been specified that the area of the patch to be measured is 10% of the entire area, and the luminance of the background is 20% of the maximum luminance.

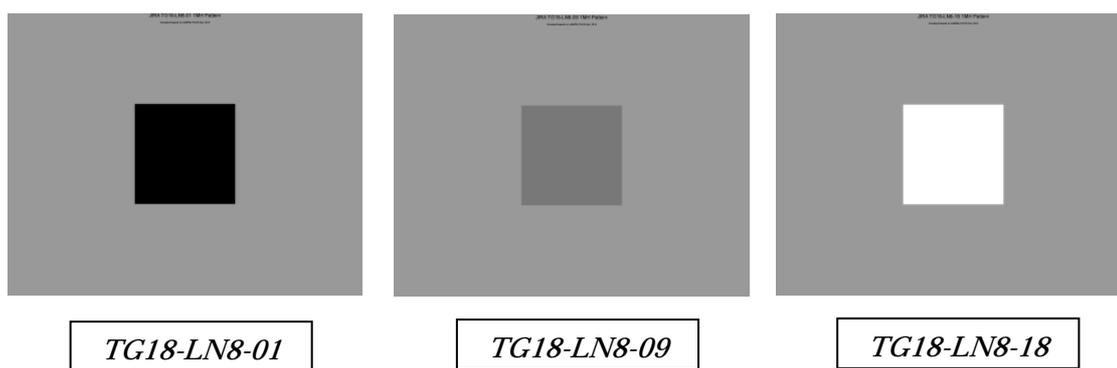


Figure 2 JIRA TG18-LN8 01 to 18 patterns

### 3. TG18-UNL80 pattern

This pattern should be used to measure the uniformity of the luminance and chromaticity. Measurement should be performed at the center of the five patches located at the center and four corners of the display area: five positions in all. It has been specified that the area of each patch to be measured is 10% of the entire area, and the luminance is 80% of the maximum digital drive level.



Figure 3 JIRA TG18-UNL80 pattern

### 4. SMPTE Test Pattern

This pattern may alternatively be used for comprehensive judgment.

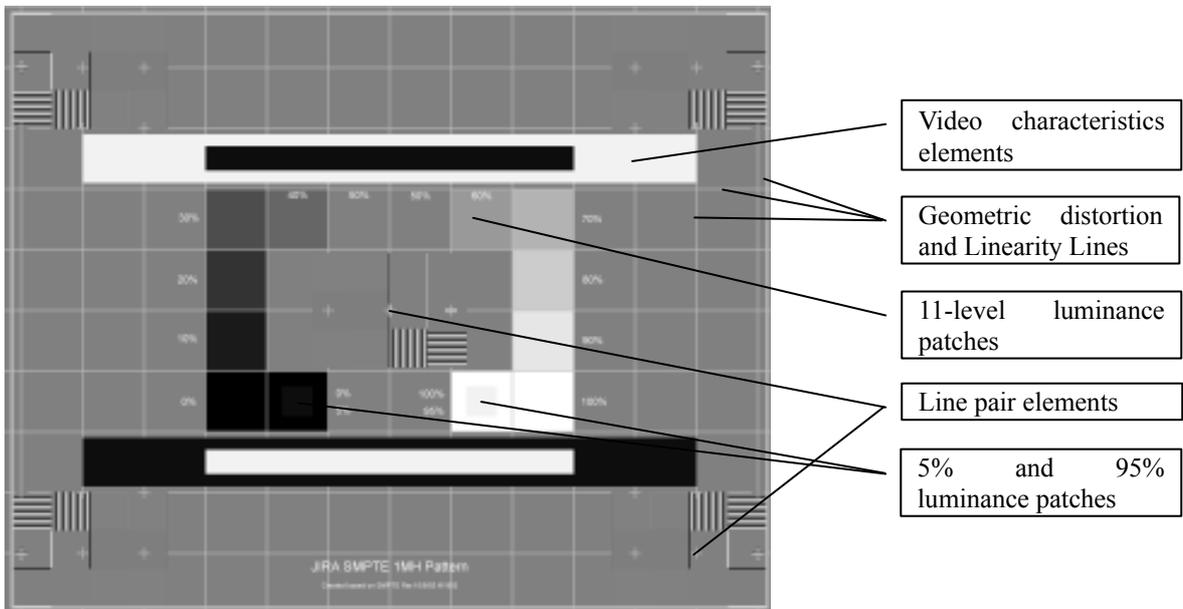
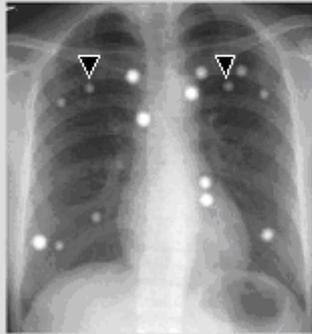


Figure4 SMPTE pattern

5. Reference Clinical Images

### Reference Clinical Image

If the arrowed nodules are not recognized, it means that the luminance of the display system has deteriorated or the viewing conditions have become inappropriate for diagnostic tasks.



Ishigaki T, Kodera Y et al. ECR, March 2 - 6, Vienna, 2001

*Figure5 Reference clinical image*

Appendix 3. Standard Reports

Table 4 Acceptance test result report (sample)

Institution	JIRA hospital		Approved by	Conducted by	
Department	Radiology		Taro JIRA	Jiro JIRA	
Model name	xxx-xxx				
Sr.No.	0001				
Test date	2/21/2005				
Judgment method	Category	Judgment criteria		Check item Formula   Unit	Judgment
		Grade 1	Grade 2		
Spec	Specifications	$\geq 1k \times 1k$		Resolution   pixel	OK
Visual check	Overall evaluation	The patches' luminance differences among 16 (11) steps should be clearly recognized. 5% and 95% patches should be visible. The judgment-use positions on the reference clinical image should be visible without any problem.			OK
	Grayscale	Smooth, stable and continuous display should be presented.			OK
	Geometric distortion: CRT only	The entire screen should allow visual check and provide linearity. The aspect ratio of the width and height should be appropriate.			---
	Resolution: CRT only	$0 \leq Cx \leq 4$ Nyquist lines should be visible.		Cx score   ---	---
	Artifact	Artifacts should not be present.		Flicker Crosstalk Video artifact Color artifact: CRT only	OK
Measurement	Luminance uniformity	$\leq 30$		$\{(L_{max}-L_{min})/(L_{max}+L_{min})\} * 200$   %	Measured value
	Contrast response	$\leq \pm 15$	$\leq \pm 30$	$K\delta$ of 18 points   %	Measured value
	Maximum luminance	$\geq 170$	$\geq 100$	$L_{max}$   $cd/m^2$	Measured value
		Between multiple displays $\leq 10$		$\{(L_{max1}-L_{max2})/L_{max2}\} * 100$   %	Calculated value <sup>5</sup>
	Luminance ratio	$\geq 250$	$\geq 100$	$L_{max}/L_{min}$   ---	Measured value
	Chromaticity	Inside the screen $\leq 0.01$			$\{(u'_1-u'_2)^2+(v'_1-v'_2)^2\}^{1/2}$   ---
Mean value inside screen at the time of shipment		---			u'm: measured value v'm: measured value
Between multiple displays $\leq 0.01$				$\{(u'_m1-u'_m2)^2+(v'_m1-v'_m2)^2\}^{1/2}$   ---	Calculated value <sup>5</sup>

<sup>5</sup> Deviation shall be calculated using the shipment test data of multiple display systems of the same type for the use with the same client in the finally- installed situation.

Table 5 Constancy test result report for each usage day (sample)

1. Items to be checked on each usage day prior to use and their judgment criteria

Institution	JIRA hospital					Approved by	Conducted by
Department	Radiology					Taro JIRA	Jiro JIRA
Model name	xxx-xxx						
Sr.No.	0001						
Test month	March 2005						
Judgment method	Category	Category	Judgment criteria				
			Grade 1		Grade 2		
Visual check	Overall evaluation	Overall evaluation	The patches' luminance differences among 16 (11) steps should be clearly recognized. 5% and 95% patches should be visible. The judgment-use positions on the reference clinical image should be visible without any problem.				
Sun	Mon	Tue	Wed	Thu	Fri	Sat	
---	---	---	1/3 ✓	2/3 ✓	3/3 ✓	4/3 ✓	
---	6/3 ✓	7/3 ✓	8/3 ✓	9/3 ✓	10/3 ✓	11/3 ✓	
---	13/3 ✓	14/3 ✓	15/3 ✓	16/3 ✓	17/3 ✓	---	
---	20/3 ✓	21/3 ✓	22/3 ✓	23/3 ✓	24/3 ✓	---	
---	27/3 ✓	28/3 ✓	29/3 ✓	30/3 ✓	31/3 ✓	---	

Table 6 Periodic constancy test result report (sample)

2. Items to be checked every three months (for CRT display systems), or every six or twelve months (for LCD display systems), and their judgment criteria

Institution	JIRA hospital		Approved by	Conducted by	
Department	Radiology		Taro JIRA	Jiro JIRA	
Model name	xxx-xxx				
Sr.No.	0001				
Test date	2/24/2006				
Judgment method	Category	Judgment criteria		Check item Formula   Unit	Judgment
		Grade 1	Grade 2		
Visual check	Overall evaluation	The patches luminance differences among 16 (11) steps should be clearly recognized. 5% and 95% patches should be visible. The judgment-use positions on the reference clinical image should be visible without any problem			OK
	Grayscale	Smooth, stable and continuous display should be presented.			OK
	Geometric distortion: CRT only	The entire screen should allow visual check and provide linearity. The aspect ratio of the width and height should be appropriate.			-
	Resolution: CRT only	$0 \leq Cx \leq 4$ Nyquist lines should be visible.		Cx score   ---	-
	Artifact	Artifacts should not be present.		Flicker Crosstalk Video artifact Color artifact: CRT only	OK
	Luminance uniformity	Excessive non-uniformity should be absent.			OK
	Measurement	Contrast response	$\leq \pm 15$	$\leq \pm 30$	$K\delta$ of 18 points   %
Maximum luminance		$\geq 170$	$\geq 100$	$L_{max}$   $cd/m^2$	Measured value
Reference value $L_{max_0}$ :		Luminance deviation $\leq \pm 10$		$\{(L_{max_n} - L_{max_0}) / L_{max_0}\} * 100$   %	Measured value
Measured value $cd/m^2$		Between multiple displays $\leq 10$		$\{(L_{max_1} - L_{max_2}) / L_{max_2}\} * 100$   %	Measured value
Luminance ratio		$\geq 250$	$\geq 100$	$L_{max} / L_{min}$   ---	Measured value
Illuminance (value for ref.)				Screen vertical Illuminance   lux	Measured value

## Appendix 4. Explanation

### 1. Purpose and Intent of Enactment (Especially Concerning Consistency with JIS Standards)

Section 1 details the description of the preface.

The existing standard for the constancy tests of display systems has been presented in JIS Z 4752-2-5 “Quality maintenance evaluation and routine testing methods in medical imaging departments-Part2-5: constancy tests - imaging display devices.” This standard has been generated through translation of IEC 61223-2-5:1994 “Evaluation and routine testing in medical departments-Part2-5: Constancy tests-imaging display devices” enacted in 1994. The standard was drawn up when LCD display systems, which are widely used at present were unavailable in the market. In addition, no Japan Industrial Standard’s (JIS) standard exists for acceptance tests.

The IEC is currently working for enactment of IEC61223-3-6 “Evaluation and routine testing in medical imaging departments Part 3-6: Acceptance Tests-Imaging Display systems” that covers acceptance and constancy tests. However, the JIS standard based on this standard will not be enacted soon enough; a considerable time will be needed to complete the process. Because of an increasing quantity of diagnosis with display systems also in Japan, there is an urgent need to conclude the management standards for display systems

In addition, because Japanese and overseas medical institutions differ in systems and image reading environments, applying standards and guidelines generated for foreign institutions to Japanese institutions can cause operational problems.

For the above reasons, this guideline have been concluded with domestic situations taken into account, based on both the IEC61223-3-6 standard to be newly enacted and the AAPM TG18 guideline that underlie the IEC61223-3-6 standard. The IEC61223-3-6 standard and AAPM TG18 guideline are still in process of drafting. If changes are made to reflected in those guidelines, this guideline as on JESRAX-0093<sup>-2005</sup> will be revised as necessary.

### 2. The Range of Display Systems

Section 2 defines the range of display systems mentioned in 6.1 Acceptance Test and 6.2 Constancy Test. The display systems referred in this guideline are systems that can display the GSDF curve.

- (1) If a medical display contains the LUT and can set the GSDF curve of itself, the display system consists of only the medical display.
- (2) If a video board that contains the LUT allows the GSDF curve to be set, the display system consists of the medical display and video board.
- (3) If the GSDF curve cannot be set without using viewer’s functions, the display system consists of the medical display, video board, and display software. Because the settings of the viewer are daily changed, the viewer should be preset with a point for setting the GSDF curve, and tests should be conducted with the preset status recalled.

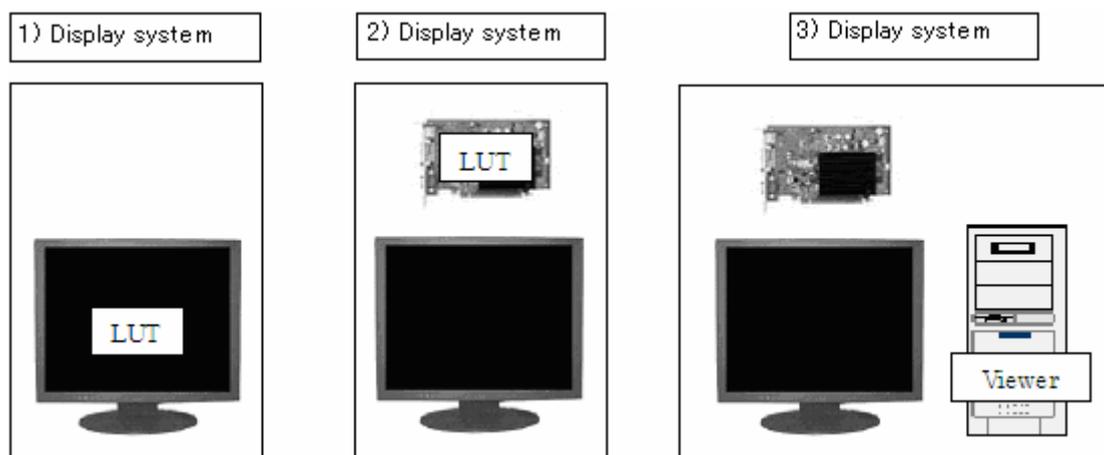


Figure 6 Three different display system configurations

### 3. When Shipment Test Data can be Used as Acceptance Test Data

Section 3 describes the conditions that the shipment test report provided with a display system by a supplier can be used as acceptance test data as mentioned in 6.1 Acceptance Test.

- (1) The SI vendor shall prepare shipment test data of the display system defined in section 2 in Appendix 4.
- (2) The video board and medical display shall be connected through a digital interface.

If the above conditions are satisfied, shipment test data can be used as acceptance test data.

If the conditions are not met, the medical institution is required to conduct an acceptance test.

Example: An intended display system consists of a medical display, video board, and viewer software to make the LUT available, but all of them are purchased separately.

### 4. Calibration

Section 4 defines the calibration mentioned in section 1.3 in appendix 1, and describes the concrete implementation methods.

Calibration here means precisely setting the maximum or minimum luminance, gamma curves, and chromaticity of display systems, using sensors. It is desirable for display systems to be calibrated at the time of installation.

Pattern locations for tests should conform to those recommended in DICOM 3.14. That is, the test area which is 10% of the entire image area is located at the center of the screen, and the remaining area is uniform and presents 20% of the maximum luminance. When performing calibration with a sensor attached to a position outside the center of the screen, it is necessary to correlate with the calibration of the standard pattern.

Normally with a sensor attached to the screen of the display system, automatic setting is performed by the application software.

Figure 7 shows the typical calibration example.

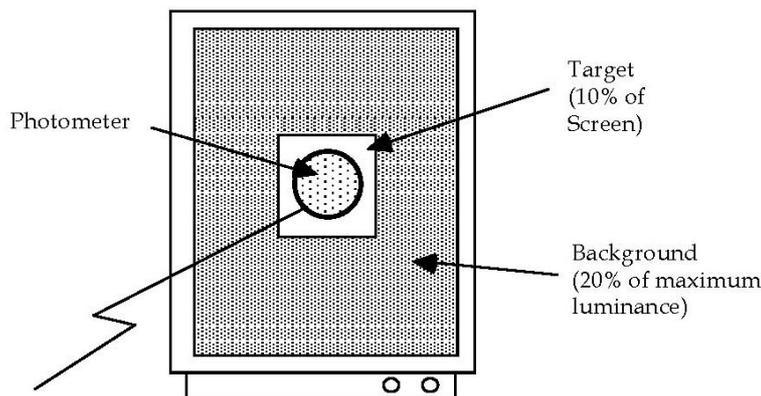


Figure 7 Test pattern and sensor placement example

## 5. Contrast Response

This section describes the calculation procedure for Contrast Response Test (Quantitative Evaluation) mentioned in section 8 in appendix 1.

In order to obtain the contrast response, measure the luminance inside the test area for 18-step drive levels using a calibrated luminance meter (or a correlated luminance meter) and the TG18-LN pattern (or substitute pattern). Transform the measured luminance values ( $L$ ) into JND indices ( $J$ ) using the following formula. The JND indices relative to the mean value are divided at even intervals within the JND range, so that linear relationships with  $p$  values are presented.

$$J(L) = 71.498068 + 94.593053 * \log_{10}(L) + 41.912053 * \log_{10}(L)^2 + 9.8247004 * \log_{10}(L)^3 \\ + 0.28175407 * \log_{10}(L)^4 - 1.1878455 * \log_{10}(L)^5 - 0.18014349 * \log_{10}(L)^6 \\ + 0.14710899 * \log_{10}(L)^7 - 0.017046845 * \log_{10}(L)^8$$

where  $L$  is the measured value.

Figure 8 shows an example plotted with the DICOM 3.14 standard luminance response curve after conversion from the luminance values measured on the following display system to JND indices: the display system that has a maximum luminance of  $280 \text{cd/m}^2$  and a minimum luminance of  $1.5 \text{cd/m}^2$ .

Next the measured data shall be converted into the contrast value  $(L_{n+1} - L_n) / \{(L_{n+1} + L_n) / 2\}$  that corresponds to JND indices  $(JND_{N+1} + JND_N) / 2$ . The contrast response at the individual points can be obtained by dividing the  $dL/L$  by the difference between the JND indices  $JND_{N+1} - JND_N$ .

Figure 9 shows how the contrast response to the data shown in figure 8 corresponds to the DICOM3.14 standard contrast response.

If manually performed, it takes a considerable time to complete the procedures from 18-step luminance measurement to contrast response calculation. Therefore in general auxiliary programs are used for automatic measurement and calculation.

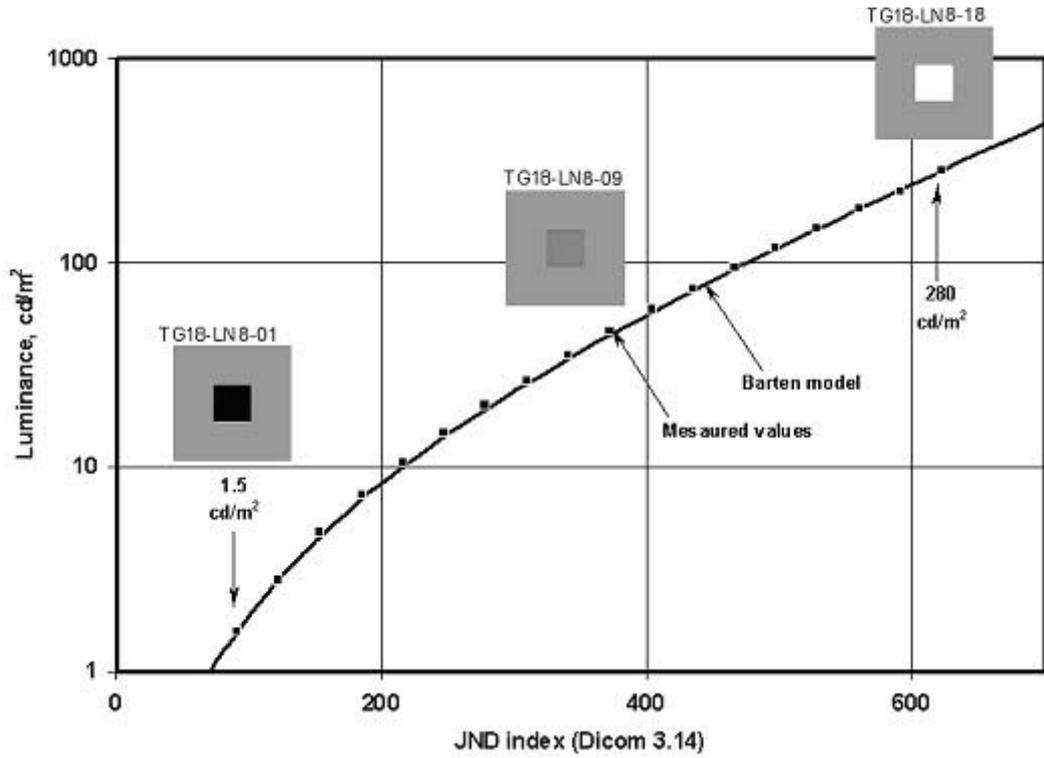


Figure 8 Example plotted by relating the luminance measurement values of 18-step display levels to the DICOM 3.14 standard luminance response

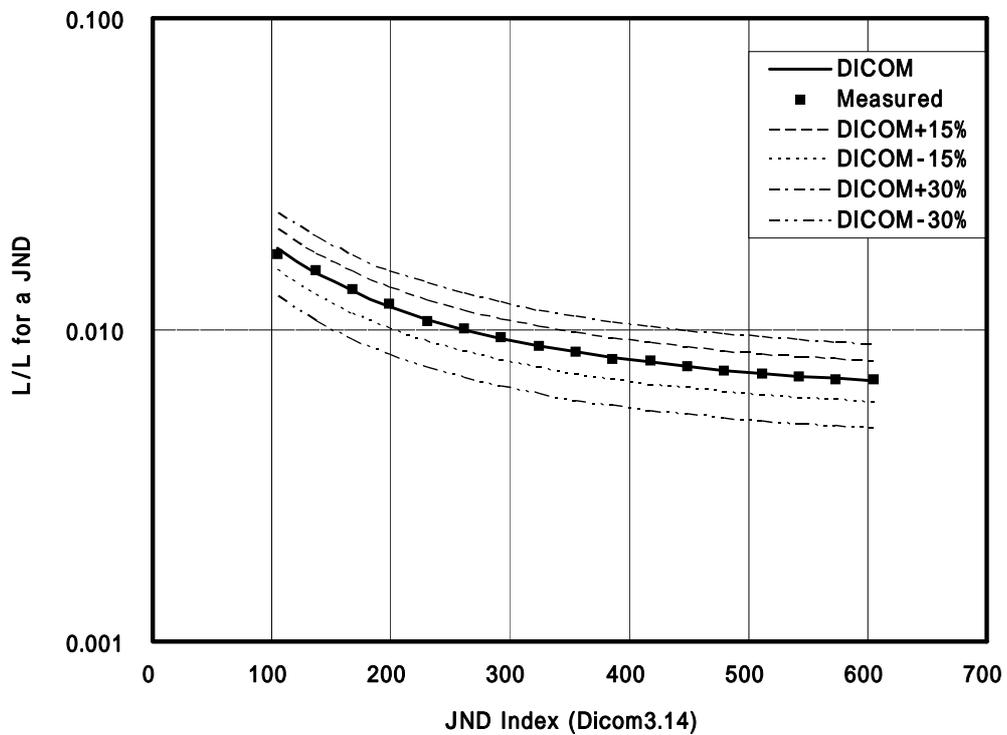


Figure 9 Example showing how the contrast response calculated from 18-step gray levels relate to the contrast expectation response relating to the DICOM3.14 standard contrast response

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