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Information technology — Office equipment — Measurement of image quality attributes for hardcopy output — Monochrome text and graphic images

Technologies de l'information — Équipement de bureau — Mesurage des attributs de qualité d'image pour copies papier — Texte monochrome et images graphiques

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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

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

In other circumstances, particularly when there is an urgent market requirement for such documents, the joint technical committee may decide to publish an ISO/IEC Technical Specification (ISO/IEC TS), which represents an agreement between the members of the joint technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/IEC TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/IEC TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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

ISO/IEC TS 24790 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 28, *Office equipment*.

~~This first edition of ISO/IEC TS 24790 cancels and replaces the first edition of ISO/IEC 13660:2001, which has been technically revised.~~

This corrected version of ISO/IEC TS 24790 cancels the above sentence that states that ISO/IEC TS 24790 cancels and replaces ISO/IEC 13660:2001.

Introduction

This Technical Specification is designed to help a quality control engineer evaluate the image quality of prints from office imaging systems.

In traditional imaging systems (such as ink-on-paper printing), an image is evaluated by comparison to an original or master version of that image. In many electronic imaging systems, however, the image is created digitally within the system. There is no hardcopy master and so there can be no evaluation by comparison in the ordinary way.

Often, those who operate electronic imaging systems ensure good image quality by controlling the imaging process. They use test targets and reference images to evaluate the performance of the system.

If it is not possible to control image quality by controlling the imaging process and if no test target or reference image is available, we can rely only on direct evaluation of properties of the image itself.

To perform intrinsic evaluations of image quality, we must consider the nature of an image that is output. An image is some organization of information in space. We assume that these signals have some purpose or are making some attempt at communication. Good image quality means that the image is legible (the organization and information can be interpreted) and that it has a pleasing appearance.

Our goals in developing this Technical Specification were to compile a list of image attributes that (taken together) correlate to human perception of print quality and to develop measurement methods for these attributes that can be automated and carried out on a simple system.

Legibility and appearance have several aspects:

- Detail can be detected easily.
- Image elements are well isolated from the background.
- The image has a minimum of gross defects.
- The imaging system has good geometric fidelity.

Not all these factors can be covered by evaluation of intrinsic, quantitative image quality attributes. Many of them have a large psychological or cultural component that is difficult to evaluate.

A print made with large optical reduction or one that is out of focus might still have excellent edge quality (and be totally lacking in gross defects, banding, noise, etc.) and yet be illegible. This could occur primarily because of the high process gamma (contrast) that is characteristic of many xerographic processes. Thus, the process can produce apparently sharp edges in spite of the loss in resolution. Without a resolution target of some kind, the extent of the resolution loss, and hence legibility, may not be known.

The purpose of this Technical Specification is to present a set of objective, measurable attributes that give some correlation to the perceived quality of an image to a human observer at a standard viewing distance. The standard will allow a user of printed material to sort samples into several groups, from excellent to bad.

The attributes and methods for their assessment are based on several assumptions:

- The image represents an attempt at communication.
- There is uniformity within identifiable image elements.

· Character images, symbols, and graphic elements are regular (that is, they are intended to be identical when they have multiple, similar occurrences).

· Samples with extreme gross defects have been screened out.

This Technical Specification applies to monochrome images made up of text, graphics, and other image objects with two tone levels of a single colour (typically black image on white paper) or halftones, images with more nominal gray levels. This Technical Specification does not cover continuous tone images, colour images, and so on.

Image quality measurement can be thought of as divided into diagnostic (high resolution), and visual scale (low resolution) procedures. Diagnostic measurements typically use precision test targets and instrumentation and are key to much engineering work. The present procedure, by contrast, is limited to phenomena visible to the naked eye and does not permit test patterns.

The working group has taken the approach of selecting simple and (in our judgment) effective metrics, rather than attempting to prove that our method of doing a given job will always be the most exact.

How will this Technical Specification actually be implemented? A complete evaluation system has four components: an image capture device, evaluation software, application-specific quality standards and sampling plan. The end user may choose to develop all these parts himself or he may choose to purchase one or more components from a commercial supplier.

Any equipment capable of gathering data appropriate to these measurements is understood to have a complex instrument function. Rather than attempting to explore the relationship among these instrument functions, the working group has defined reference images, and target values for them. If these target values are achieved by an instrument, calibration will be acceptably good.

This is not an attempt to break new ground in image science. It is an attempt to provide suppliers and customers for copies / prints with a practical and objective way to communicate about basic image quality parameters.

ISO/IEC 13660 was developed and standardized by the point of view described above. ISO/IEC 13660 is currently the only available systematic image quality attribute measurement standard. ISO/IEC 13660 has had a great influence on related industries and image quality measurement instruments based on ISO/IEC 13660 are already marketed. However, due to the limited development time, it was standardized with many issues unresolved, and therefore ISO/IEC 13660 has not been adopted as widely as expected. The main issues are listed as following.

1. The test chart and methods for measurement system conformance are only specified for some of character and line attributes. For large area graphic image attributes, neither test charts nor methods are specified. Eight items of image quality attribute for character and line image and six items of image quality attribute for large area graphic image are defined, and each measuring method is specified. Of the 14 image quality attributes, the conformance test method, the conformance test chart, and the targeted value for measurement apparatus conformance are specified for only four of the character and line image quality attributes, leaving 10 of the image quality attributes with no conformance specifications

2. Physical measures (line width, voids) and psychophysical factors (darkness, graininess, etc.) are intermingled, and are all defined as image quality attributes

3. The goal values for measurement system conformance are available for only four of character and line attributes. And the allowances are very large.

4. When one measures the character and line image quality attributes according to ISO/IEC 13660, the resulting values have large variation and they do not correspond well with subjective evaluations.

The Japanese WG4 which took charge of ISO/IEC 13660 within the SC28 committee of Japan pointed out these issues, and a NWIP to revise the ISO/IEC 13660 was proposed in January, 2006. Five participating nations were secured at the NWIP vote, and the NWIP was approved. The project to develop ISO/IEC NP

24790 (Information Technology 3 Office Equipment — Measurement of image quality attributes for hardcopy output — Monochrome text and graphic images) was started in July, 2006.

The ISO/IEC 24790 project added the following content to ISO/IEC 13660 to resolve the issues which ISO/IEC 13660 had and to improve the measurement accuracy.

1. Banding which is a common image quality defect of the hard copy output in a printer or a copying machine is added as one of the image quality attributes of a large area graphic image.

2. Conformance test charts and the goal values for measurement system qualification are specified to three character and line image attributes and seven large area graphic image attributes.

3. The fundamental resolution of the scanner for measurement was increased from 600 spi to 1200 spi to reduce the measurement variation.

4. Nearly all of the image quality attributes defined in ISO/IEC 13660 have been redefined in ISO/IEC 24790 to eliminate intermingling physical measures and psychophysical factors.

5. In order to improve the correspondence between image quality attributes and subjective evaluations, an image quality attribute verification experiment was conducted on seven items of image quality attributes to select prediction algorithms for image quality attributes that have the highest correlation with subjective evaluation. The verification experiment was conducted by five countries including Japan, U.S.A, China, South Korea, and the Netherlands.

Verification of the goal values specified in this Technical Specification is under development.

Information technology — Office equipment — Measurement of image quality attributes for hardcopy output — Monochrome text and graphic images

1 Scope

This Technical Specification specifies device-independent image quality attributes, measurement methods, and analytical procedures to describe the quality of output images from hardcopy devices. This Technical Specification is applicable to human-readable monochrome documents produced from printers and copiers.

The attributes, methods and procedures rely on measurable properties of printed text and graphic images. Special targets or reference images are not required, but image elements must meet some minimal requirements, e.g. on size or number present, in order to be useful for adequate measurements. The Technical Specification is not applicable to images on media other than hardcopy (e.g. images on a VDT) or to images that are intended to be machine readable only (e.g. bar codes).

2 Normative references

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

ISO 5-1:2009, *Photography and graphic technology — Density measurements — Part 1: Geometry and functional notation*

ISO 5-3:2009, *Photography and graphic technology — Density measurements — Part 3: Spectral conditions*

ISO 5-4:2009, *Photography and graphic technology — Density measurements — Part 4: Geometric conditions for reflection density*

ISO 2470-1:2009, *Paper, board and pulps — Measurement of diffuse blue reflectance factor — Part 1: Indoor daylight conditions (ISO brightness)*

ISO 14524:2009, *Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs)*

ISO 21550:2004, *Photography — Electronic scanners for photographic images — Dynamic range measurements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
background area
region outside the edge of any image element

3.2
background darkness
appearance of shade in background area due to presence of unintended colourant particles that cannot be resolved as individual marks

3.3
background extraneous mark
colourant particle or agglomeration of colourant particles in the background area that is visible at a viewing distance of 25cm - 40cm with the unaided eye

3.4
banding
appearance of one dimensional bands within an area that should be homogeneous

3.5
blurriness
appearance of being hazy or indistinct in outline, a noticeable transition of darkness from line element to background substrate whose transition width is zero, if the edge is ideally sharp

3.6
boundary
contour by reflectance threshold

3.7
character darkness
appearance of blackness of a line or character image

3.8
character surround area
region runs from the outer edge of the character image or other image element out 500 micrometres

3.9
character surround area haze
colourant particles or agglomerations of colourant particles within a character surround area that are visible but not resolvable as distinct marks

3.10
character surround area extraneous mark
colourant particle or agglomeration of colourant particles within a character surround area that is visible at a viewing distance of 25cm - 40cm with the unaided eye as a distinct mark

3.11
edge threshold
level in the reflectance gradient profile of an edge that is at 40% of the transition from the minimum reflectance factor (R_{min}) to the maximum reflectance factor (R_{max}) as: $R_{40} = R_{min} + 40\% (R_{max} - R_{min})$

3.12
fill
appearance of homogeneity of darkness within the boundary of a line segment, character image, or other glyph image

3.13
graininess
appearance of unintended microscopic but visible aperiodic fluctuations of lightness (microscopic means: variations with spatial frequencies greater than about 0,4 cy/mm)

3.14
graphic image
images except a character and a symbol

3.15
image area
region inside portion of inner boundary

3.16
image element
single, evidently intentional, object not connected to other objects

3.17
inner boundary
contour of points of an image element where edge gradient profiles cross a reflectance level that is at 10% of the transition from the minimum reflectance factor (R_{min}) to the maximum reflectance factor (R_{max}) as: $R_{10} = R_{min} + 10\% (R_{max} - R_{min})$

3.18
large area darkness
appearance of blackness of a large area graphic image element

3.19
large area
image area of graphical element or background that has a minimum size of 12.7 mm in both dimensions (equivalent to 600 pixels when sampling resolution is 1200 spi)

3.20
line image
line at least 1 mm long

3.21
line image density
average optical density within the R_{25} boundary

NOTE The average optical density should be converted from average reflectance factor

3.22
line width
average stroke width, where the stroke width is measured from edge to edge along a line normal to the center line of the image element

3.23
metric
measure of image quality attribute

3.24
monochrome image
image perceived as achromatic colour

3.25
mottle
measure of the appearance of unintended, aperiodic macroscopic fluctuations of lightness (macroscopic means: variations with spatial frequencies less than about 0,4 cy/mm)

3.26
optical density
negative logarithm to the base ten of the reflectance factor, measured using a 0/45-degree geometry, Illuminant A, and ISO visual density calibration as specified in ISO 5-1, 5-3 and 5-4 with an instrument using no polarization filters

3.27
outer boundary
contour of points of an image element where edge gradient profiles cross a reflectance level that is at 70% of the transition from the minimum reflectance factor (R_{min}) to the maximum reflectance factor (R_{max}) as: $R_{70} = R_{\text{min}} + 70\% \, (R_{\text{max}} - R_{\text{min}})$

3.28
raggedness
appearance of geometric distortion of an edge from its ideal position – an ideal edge should be absolutely straight along the length of the line

NOTE A ragged edge appears rough or wavy rather than smooth or straight.

3.29
reflectance factor
ratio of the reflected flux as measured to the reflected flux under the same geometrical and spectral conditions for an ideal 100% diffuse reflecting surface

3.30
R_{max}
maximum reflectance factor measured by a slit aperture in the background area, typically of the substrate

3.31
region of interest
ROI
area (inside defined boundaries) that the user wants to analyse

NOTE 1 ROI for character and line image attribute includes image element and background area.

NOTE 2 ROI for large area graphic image attribute is within image area.

NOTE 3 The difference between ROI for character and line image and large area graphic image is shown in Annex D.

3.32
R_{min}
minimum reflectance factor measured by a slit aperture in the image element, typically of the image

3.33
spots per inch
spi
spots per 25,4 millimetres

3.34
reflectance threshold
level in the reflectance gradient profile of an edge that is at some specified percentage of the transition from the minimum reflectance factor (R_{min}) to the maximum reflectance factor (R_{max}) as: $R_p = R_{\text{min}} + p\% \, (R_{\text{max}} - R_{\text{min}})$

3.35
void
visible hole or gap within a solid image area that is large enough to be individually distinguished at a viewing distance of 25cm - 40cm

4 Report of results and sampling scheme

4.1 Report of results

4.1.1 Test identification information

The report shall include the date of the measurements, the identity of the test operator, lot identifications, etc.

4.1.2 Instrument system

The report shall include a description of the instrument system used, noting any of the specifications (see Clause **6**) that are emulated or deviated from in any way.

4.1.3 Conformance

Report the results of the conformance tests, Instrument, specs, Instrument OECF, Instrument dynamic range, Large area attributes:(7) large area darkness, background darkness, graininess, mottle, background extraneous mark, void, banding, Character and line attributes:(7) line width, character darkness, blurriness, raggedness, fill, character suround area extraneous mark, character surround area haze. (See Clause **6** and **Annex B**.)

4.1.4 Sampling scheme

The report shall include a complete description of the sampling scheme (**4.3**) used to select the pages and images.

4.1.5 Results

For each attribute, the report shall include the number of samples per page and the mean, standard deviation, and range of the results for each page and for the entire lot.

ORIGINATOR Test Description Date of Report Test Operator	XYZ Printing Company Results of March 15, 2012 print set April 2, 2012 RJC
INSTRUMENTATION Type Measurement and analysis software Instrument OECF compensation software Instrument dynamic range measurement software	XYZ Optical Company, Model XXX 1200 dpi flatbed scanner ISO 24790 ANALYZER by ABC Inc. Auto OECF by ABC Inc. Auto DR by ABC Inc.
CONFORMANCE TESTS Density Measurements Spatial Measurements Line Attributes Measurements Graininess & Mottle Measurements SAMPLING SCHEME	 within the tolerance within the tolerance within the tolerance within the tolerance Random Sampling
LARGE AREA IMAGE ATTRIBUTES *large area darkness* *background darkness* *graininess* *mottle* *background extraneous mark*	*# of samples/page* *Mean* *Std*

void *banding* *CHARACTER AND LINE ATTRIBUTES* *line width* *character darkness* *...blurriness* *raggedness* *fill* *character surround area extraneous mark* *character surround area haze*	 *# of samples/page Mean Std*

Figure 1 — Sample report of an evaluation

4.2 Sampling of pages

The pages chosen shall be taken from a homogeneous lot. They shall all (as far as can be determined) be on the same substrate, produced with the same process, and be of the same age.

The number of pages to be sampled depends on the user's optimal balance between risk and cost and on the uniformity of the process that produced the lot.

Any sampling scheme selected shall allow for the presence of pages with defects beyond the scope of this Technical Specification (such as physical damage to pages) and pages with defects which would be unacceptable to practically all observers. These pages should be evaluated separately.

4.3 Sampling of images

4.3.1 General

Three sampling schemes and the information required to specify them in the report of results are given below. Use one of these three schemes. The report shall contain enough specific information that the sampling scheme can be duplicated exactly.

4.3.2 Discretionary sampling

In discretionary sampling, a human operator intervenes to select features for analysis, based on some subjective criteria.

4.3.2.1 Procedure

1) For each attribute, establish decision rules for selecting regions.

   Example 1 "Select the 10 regions with the highest apparent mottle."

   Example 2 "Find the 3 lightest character images. Find the 3 darkest character images."

2) Visually inspect the page and select regions that meet the criteria.

3) Evaluate the attribute within each region selected.

4.3.2.2 Specification of sampling scheme

If this sampling method is selected, the report shall include:

1) all decision rules used

2) location of each region evaluated, for each attribute.

4.3.3 Random sampling

4.3.3.1 General

In random sampling, features are taken from a portion of the page that has been selected blindly to represent the whole page.

4.3.3.2 Procedure

1) Cover the page with a grid of uniform rectangular cells.

2) Select a cell at random (using any random or pseudorandom method that ensures that each cell has the same chance of being selected as any other).

3) If the attribute being evaluated does not apply to the cell, discard it and select a replacement.

4) Evaluate the attribute within the cell.

5) Sample cells until the desired accuracy is obtained.

4.3.3.3 Specification of sampling scheme

If this sampling method is used, the report shall include:

1) dimensions of the grid cells

2) method of placing grid on page

   a) location of origin

   b) orientation of axes

3) decision rule for deciding if attribute is applicable to cell

4) any other decision rules used

5) decision rule for deciding when to stop sampling

6) method of randomization in selection of grid cells

7) stratification, if any. (Stratification is dividing the grid into homogeneous sections and then selecting samples from each section according to a predetermined proportion of the total number of samples.)

4.3.4 Whole page sampling

In whole page sampling, features are extracted from throughout the page.

4.3.4.1 Procedure

Divide the page into the cells and measure each attribute (if present) in each cell.

4.3.4.2 Specification of sampling scheme

If this sampling method is selected, the report shall include:

1) dimensions of the grid cells

2) method of placing grid on page

   a) location of origin

   b) orientation axes

3) decision rule for deciding if attribute is applicable to cell

4) any other decision rules used.

5 Attributes and their measures

5.1 Schema of attributes

The next table gives an overview of the image quality attributes. They have been divided into 2 groups. The attributes in each group generally require similar assumptions and have similar or related measurement procedures.

Group of Attribute	Attribute	Clause
Large area graphic image attributes		
	large area darkness	**5.2.3**
	background darkness	**5.2.4**
	graininess	**5.2.5**
	mottle	**5.2.6**
	background extraneous mark	**5.2.7**
	void	**5.2.8**
	banding	**5.2.9**
Character and line image attributes		
	line width	**5.3.3**
	character darkness	**5.3.4**
	blurriness	**5.3.5**

raggedness	**5.3.6**
fill	**5.3.7**
character surround area extraneous mark	**5.3.8**
character surround area haze	**5.3.9**

5.2 Large area graphic image attributes

5.2.1 General

This clause contains measuring procedures for attributes characterizing areas larger than 161 mm^2 and with minimum dimension of 12,7 mm (Equivalent to 600 pixels when resolution is 1 200spi).

All measurements described in this clause shall be made under the conditions prescribed in Clause 6.

5.2.2 Large area R_{max} and R_{min}

In order to determine the inner boundary, the maximum reflectance factor (R_{max}) is determined by averaging the data measured in the area selected by the user as background area and the minimum reflectance factor (R_{min}) is determined by averaging the data measured in the area selected by the user as image area.Then, from R_{max} and R_{min}, R_{10} is computed and the inner boundary edge is determined.

5.2.3 Large area darkness

1) Find a region of interest (ROI) with a minimum dimension of 12,7 mm contained wholly within the inner boundary (R_{10}) of an image element.

2) Measure the optical reflectance factor $Y(x, y)$ wholly within the ROI.

3) Compute the average optical density of the ROI as the large area darkness using the following equation. The average optical density should be converted from the average reflectance factor.

$$\text{Large area darkness metric} = \log_{10}\left(\frac{1}{\frac{1}{n \times m}\sum_{y}\sum_{x} Y(x, y)}\right) \quad (1)$$

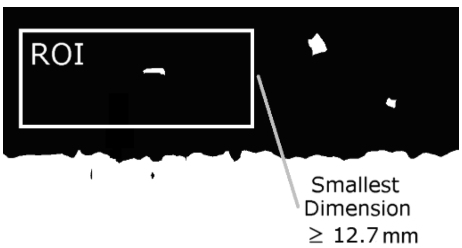


Figure 2 — Large area darkness

5.2.4 Background darkness

1) Find an ROI of a minimum dimension of 12,7 mm in the background area (with marks excluded) at least 500 micrometres away from the outer boundary of any image element.

2) Measure the optical reflectance factor $Y(x,y)$ wholly within the ROI.

3) Compute the average optical density of the ROI as background darkness using the following equation. The average optical density should be converted from the average reflectance factor.

$$\text{Background darkness metric} = \log_{10}\left(\frac{1}{\frac{1}{n \times m}\sum_{y}\sum_{x} Y(x,y)}\right) \quad (2)$$

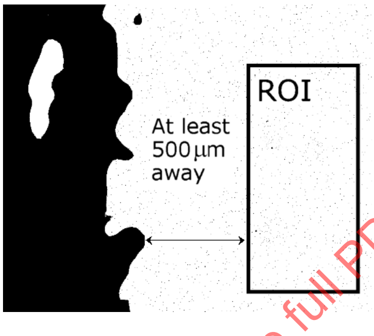


Figure 3 — Background Darkness

5.2.5 Graininess

5.2.5.1 Sampling for the graininess measurement

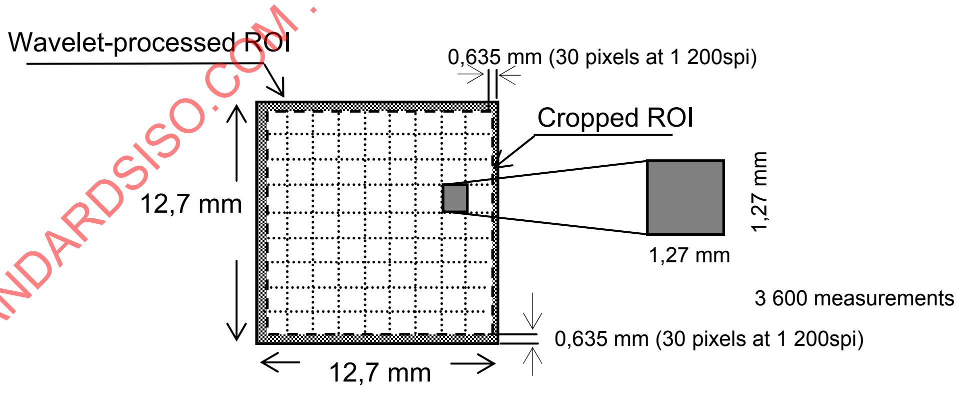


Figure 4 — ROI divided into tiles; a tile (with dimensions)

Find an ROI of a minimum dimension of at least 12,7 mm (600 pixels at 1 200 spi), contained wholly within the area. Apply the wavelet filtering to this ROI. Remove margins 0,635 mm (30 pixels at 1 200 spi) from each side of the wavelet-processed ROI to get a cropped ROI, as shown in Figure 4. Divide the cropped ROI into at least 81 (9 x 9) uniform, non-overlapping square tiles. The height and width of each tile is at least 1,27 mm (60 pixels at 1 200 spi).

Within each tile, make 3 600 (60 x 60 pixels) evenly-spaced, non-overlapping measurements of reflectance.

NOTE For a 1 200 spi detector system, the cropped ROI corresponds to a region of 291 600 (540 x 540) pixels divided into 81 (9 x 9) tiles of 3 600 (60 x 60) pixels each.

5.2.5.2 Graininess measurement

1) Find an ROI of a minimum dimension of at least 12,7 mm contained wholly within the inner boundary of an image element.

2) Measure the optical reflectance factor *R(x,y)*, *G(x,y)* and *B(x,y)* of 360 000 (600 x 600) pixels, using a red, green and blue filter, respectively. Pixels are evenly-*spaced, non*-overla*pping* elements within the ROI.

3) Convert into reflectance *Y* from scanner-RGB and compute *Y (x, y) by the following equation*.

$$Y(x,y) = 0.3R(x,y) + 0.5G(x,y) + 0.2B(x,y) \quad (3)$$

4) Apply the wavelet transform (Daubechies wavelets of order 16) to the 600 x 600 pixels ROI. Set the number of wavelet levels *n* = 6.

5) Zero all the detail components (horizontal, vertical, and diagonal) of the four highest-detail wavelet levels (scale levels 2, 3, 4, and 5). The frequency band of each wavelet level is shown in Table 1.

6) Zero the approximation component of the wavelet image. (This is the low-pass component at the lowest scale: level 0).

Table 1 — Frequency band of 6 wavelet levels

Scale level	Frequency Band (cy/mm)	
5	23.6220 – 11.8110	High frequencies to be removed
4	11.8110 – 5.9055	
3	5.9055 – 2.9526	
2	2.9526 – 1.4763	
1	1.4763 – 0.7382	Frequencies for Graininess
0	0.7382 – 0.3691	

7) Apply the inverse wavelet transform to get the filtered image *Y'(x,y)*.

8) Crop the filtered image, removing 0,635 mm (30 pixels) from each side (as shown in Figure 4).

9) Divide the cropped image into non-overlapped tiles of uniform size. There must be at least 81 tiles, with at least 9 tiles vertically and at least 9 tiles horizontally. The area of each tile must be at least 1,27 mm x 1,27 mm (60 x 60 pixels each).

10) Compute the reflectance variance v_{ij} of each tile of i-th row and j-th column. (The equation (4) assumes a total of 60 x 60 = 3600 pixels per tile.)

$$v_{i,j} = \frac{1}{(60 * 60 - 1)} \sum_{i=1}^{60} \sum_{j=1}^{60} \left(Y'_{i,j}(x,y) - \bar{Y}'_{i,j} \right)^2 \quad (4)$$

11) Compute the graininess metric as the square root of the average of all tiles' variances using the equation (5). (The equation (5) assumes a total of 9 x 9 = 81 tiles, obtained after cropping a 600 x 600 wavelet-processed image into a 540 x 540 image.)

$$\text{Graininess metric} = \sqrt{\frac{1}{(9*9)}\sum_{i=1}^{9}\sum_{j=1}^{9} v_{i,j}} \tag{5}$$

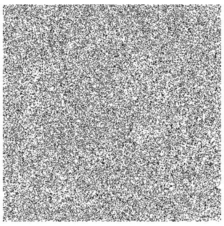


Figure 5 — Graininess

5.2.6 Mottle

5.2.6.1 Sampling for the mottle measurement

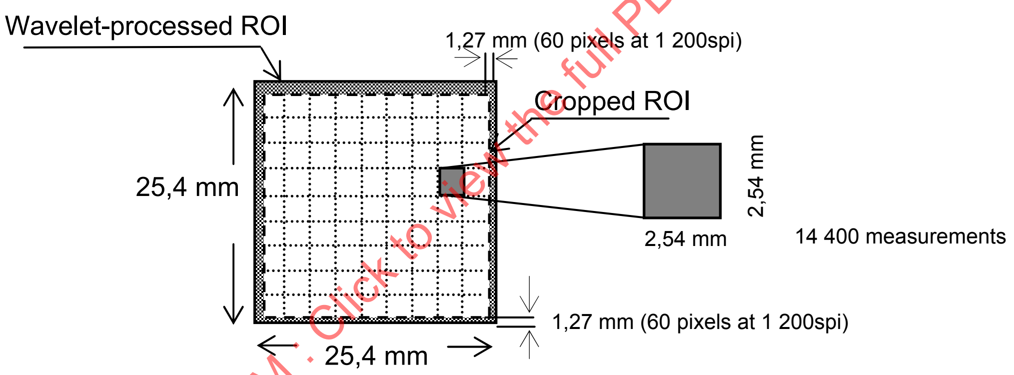


Figure 6 — ROI divided into tiles; a tile (with dimensions)

Find an ROI of a minimum dimension of at least 25,4 mm (1 200 pixels at 1 200 spi), contained wholly within the area. Apply the wavelet filtering to this ROI. Remove margins 1,27 mm (60 pixels at 1 200 spi) from each side of the wavelet-processed ROI to get a cropped ROI, as shown in Figure 6. Divide the cropped ROI into at least 81 (9 x 9) uniform, non-overlapping square tiles. The height and width of each tile is at least 2,54 mm (120 pixels at 1 200 spi).

Within each tile, make 14 400 (120 x 120 pixels) evenly-spaced, non-overlapping measurements of density.

NOTE For a 1 200 spi detector system, the cropped ROI corresponds to a region of 1 166 400 (1 080 x 1 080) pixels divided into 81 (9 x 9) tiles of 14 400 (120 x 120) pixels each.

5.2.6.2 Mottle measurement

1) Find an ROI of a minimum dimension of at least 25,4 mm contained wholly within the inner boundary of an image element.

2) Measure the optical reflectance factor *R(x,y)*, *G(x,y)* and *B(x,y)* of 1 440 000 (1 200 x 1 200) pixels, using a red, green and blue filter, respectively. Pixels are evenly-spaced, non-overlapping elements within the ROI.

3) Convert into reflectance *Y* from Scanner-RGB and compute *Y (x, y) by the following equation*.

$$Y(x,y) = 0.3R(x,y) + 0.5G(x,y) + 0.2B(x,y) \tag{6}$$

4) Apply the wavelet transform (Daubechies wavelets of order 16) to the 1 200 x 1 200 pixels ROI. Set the number of wavelet levels *n* = 9.

5) Zero all the details components (horizontal, vertical, and diagonal) of the six highest-detail wavelet levels (scale levels 3, 4, 5, 6, 7, and 8). The frequency band of each wavelet level is shown in Table 2.

6) Zero the approximation component of the wavelet image. (This is the low-pass component at the lowest scale: level 0).

7) Apply the inverse wavelet transform to get the filtered image *Y'(x,y).*

8) Crop the filtered image, removing 1,27 mm (60 pixels) from each side (as shown in Figure 6).

9) Divide the cropped image into non-overlapped tiles of uniform size. There must be at least 81 tiles, with at least 9 tiles vertically and at least 9 tiles horizontally. The area of each tile must be at least 2,54 mm x 2,54 mm (120 x 120 pixels each).

Table 2. Frequency band of 9 wavelet levels

Scale level	Frequency Band (cy/mm)	
8	23,6220 – 11,8110	High frequencies to be removed
7	11,8110 – 5,9055	
6	5,9055 – 2,9526	
5	2,9526 – 1,4763	
4	1,4763 – 0,7382	
3	0,7382 – 0,3691	
2	0,3691 – 0,1846	Frequencies for Mottle
1	0,1846 – 0,0923	
0	0,0923 – 0,0461	

10) Compute the reflectance variance v_{ij} of each tile of i-th row and j-th column. (The equation (7) assumes a total of 120 x 120 = 14 400 pixels per tile.)

$$v_{i,j} = \left(\frac{1}{(120 * 120 - 1)} \sum_{x=1}^{120} \sum_{y=1}^{120} Y'_{i,j}(x,y) - \bar{Y}' \right)^2 \tag{7}$$

11) Compute the mottle metric as the square root of the average of all tiles' variances. (The equation below assumes a total of 9 x 9 = 81 tiles, obtained after cropping a 1 200 x 1 200 wavelet-processed image into a 1 080 x 1 080 image.)

$$Mottle\ metric = \sqrt{\frac{1}{(9*9)}\sum_{i=1}^{9}\sum_{j=1}^{9} v_{i,j}} \tag{8}$$

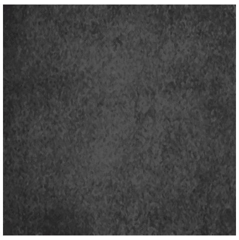


Figure 7 — Mottle

5.2.7 Background extraneous mark

1) Find an ROI of a minimum dimension of 12,7 mm in the background area (with marks included) at least 500 micrometres away from the outer boundary of any large area graphic image element.

2) Compute the edge threshold using maximum reflectance factor R_{max} and minimum reflectance factor R_{min}.

3) Compute the total area A_{EM} (in square micrometers) of all marks consisting of connected pixels (in one or more of 8 directions) with reflectance value below R_{40} that together have a minimum size of 7 850 μm^2, which is the size of a 100 micrometer diameter circle.

4) Report the results as a list of all marks and their areas along with the area of the ROI or as a summary. For a summary, report the total area of all the marks divided by the area of the ROI.

$$Extraneous\ mark\ metric = \frac{A_{EM}}{Area\ of\ the\ ROI} \tag{9}$$

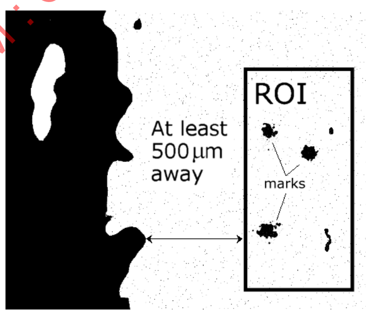


Figure 8 — Background extraneous mark

5.2.8 Void

1) Find an ROI of at least 161 mm^2 and a minimum dimension of 12,7 mm contained wholly within the inner boundary of any large area graphic image element within a nominally solid image area.

2) Compute the edge threshold (R_{40}) using the maximum reflectance factor R_{max} and minimum reflectance factor R_{min}.

3) Compute the total area A_V (in square micrometers) of all voids consisting of connected pixels (in one or more of 8 directions) with reflectance value above R_{40} that together have a minimum size of 7 850 μm^2, which is the size of a 100 micrometer diameter circle.

4) Report the results as a list of all voids and their areas along with the area of the ROI, or as a summary. For a summary, report the total area of all the voids divided by the area of the ROI as shown in the following equation.

$$Void\ metric = \frac{A_V}{Area\ of\ the\ ROI} \tag{10}$$

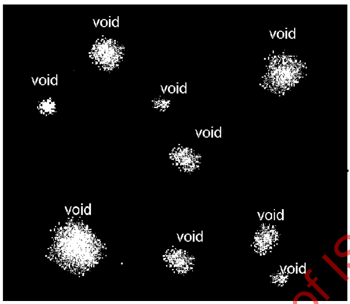


Figure 9 — Void

5.2.9 Banding

1) Find a nominally uniform ROI of at least 160 mm (x-direction) by 100 mm (y- direction), contained wholly within the inner boundary edge of an image element.

2) Measure the optical reflectance factors *R(x, y)*, *G(x, y)* and *B(x, y)* within the ROI at a minimum of 600 dpi using red, green and blue filters, such that *R*, *G*, and *B* represent sRGB color.

3) Calculate one-dimensional reflectance profiles *R(x)*, *G(x)*, and *B(x)* by averaging in the y-direction.

4) Convert the three reflectance profiles to a single CIE *Y(x)* profile, using the formula

$Y(x) = 0{,}2126 * R(x) + 0{,}7152 * G(x) + 0{,}0722 * B(x)$. (see <http://www.color.org/sRGB.xalter>). (11)

5) Calculate an *L** profile by converting *Y(x)* into *L*(x)*.

$$L^*(x) = 116\,(Y(x))^{1/3} - 16 \qquad Y(x) > 0{,}008856 \tag{12}$$

6) Calculate a modulated profile, *L'(x)*, by applying a band pass filter to *L*(x)* as follows.

$$L'(x) = FFT^{-1}\left\{ Q(f)\,FFT\left\{ L^*(x) \right\} \right\} \tag{13}$$

where *Q(f)* is a modulation function given by

$$Q(f) = 0{,}617 + 0{,}40 * \tan^{-1}(1{,}33 * \log(f / 0{,}074)), \tag{14}$$

where *f* is frequency in cycle per millimeter, and where *Q(f)* is set to zero for $f > 0{,}5$ c/mm.

7) Separate the $L'(x)$ profile into three frequency channel profiles D_1, D_2, and D_3, using three Gaussian convolution kernels as follows:

$$G_i(x) = e^{-(x/w_i)^2}, \quad \text{with } w_1 = 50\text{mm}, w_2 = 5\text{mm}, w_3 = 0.5\text{mm} \tag{15}$$

$$\begin{cases} D_1(x) = G_1(x) * L(x)' \\ D_2(x) = G_2(x) * L(x)' - G_1(x) * L'(x) \\ D_3(x) = G_3(x) * L(x)' - G_2(x) * L'(x) \end{cases} \tag{16}$$

8) From each of the three profiles, discard the first 5 mm and last 5 mm (in order to avoid potential FFT artifacts). Then, for each of the three profiles D_1, D_2, and D_3, find local extrema $\{\delta_{ki}\}_{i=1}^{N_k}$, counting only local maxima that are above zero, and counting only local minima that are below zero. Here k=1, 2, 3 identifies the profile (D_1, D_2, or D_3), and i is an index corresponding to the local extrema on a given profile. Only the absolute value (not the sign) of the extrema is retained.

9) The local extrema defined in this way for each profile, are combined into a single list of extrema values, $\{\tilde{\delta}_i\}_{i=1}^{N}$ sorted by descending magnitude.

10) The local extrema are pooled using "tent-pole summation":

$$M = \sum_{i=1}^{N} \frac{\tilde{\delta}_i}{p^{i-1}}, \text{ with } \delta_i \geqq \delta_{i+1} \tag{17}$$

where p=2.

11) The banding metric is calculated as

$$\textit{Banding metric} = 3.66\sqrt{M} \tag{18}$$

Figure 10 — Banding

5.3 Character and line image attributes

5.3.1 General

This clause contains measuring procedures for attributes applicable to character images (and their near vicinity).

These attributes also apply to lines at least 1 mm long. In this case, the interior of the line is taken to be the interior of the line that falls within the ROI.

NOTE Blurriness, raggedness, and extraneous colourant in the character surround area are caused by similar processes and their effects are often confounded. This Technical Specification does not attempt to completely separate the effects in the proposed measurement methods, so (for example) the blur measurement may contain some component of raggedness or the raggedness measurement may contain some component of extraneous marks.

All measurements described in this clause shall be made under the conditions prescribed in Clause 6.

5.3.2 Character and line image Rmax and Rmin

In order to determine the edge threshold, first, the reflectance distribution of an image element and a background area are measured, and the maximum reflectance factor (R_{max}) and the minimum reflectance factor (R_{min}) are determined. In the reflectance measurement, the aperture size should be 0,2 - 0,3 mm in a direction parallel to the edge of image element and 0,01 - 0,03 mm in a perpendicular direction. Measurement scans three or more the places in horizontal and vertical direction for each image element, and calculates the average value. From R_{max} and R_{min}, R_{40} is computed and the edge threshold is determined.

5.3.3 Line width

1) Find an ROI that includes lines at least 1 mm long and background. The recommended width of the ROI is no less than (line width)+2 mm, the height no less than 5 mm.

2) Compute the edge threshold R_{40} using the maximum reflectance factor R_{max} and the minimum reflectance factor R_{min} within ROI.

3) Compute the distance from the right edge position to the left edge position along a line normal to the centre line of the image element.

4) Compute the average distance using the following equation by carrying out data sampling at equal intervals within the ROI.

$$\text{Line width metric} = \frac{1}{N}\sum_{K=1}^{N}\left|(\text{left edge threshold position}) - (\text{right edge threshold position})\right| \quad 19)$$

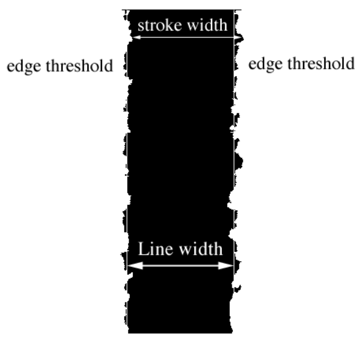


Figure 11 — Line width

5.3.4 Character darkness

1) Find an ROI that includes lines at least 1 mm long and background.
The recommended width of the ROI is no less than (line width) +2 mm, the height no less than 5 mm.

2) Compute the R_{25} boundary threshold using the maximum reflectance factor R_{max} and the minimum reflectance factor R_{min} within the ROI.

3) Compute the Line Image Density (*LID*) by averaging the density within the R_{25} boundary. The average optical density should be converted from the average reflectance factor.

4) Compute darkness by the following equation:

$$\text{Character darkness metric} = LID \times \sqrt{LW} \qquad (20)$$

where *LW* is the Line width specified in 5.3.3.

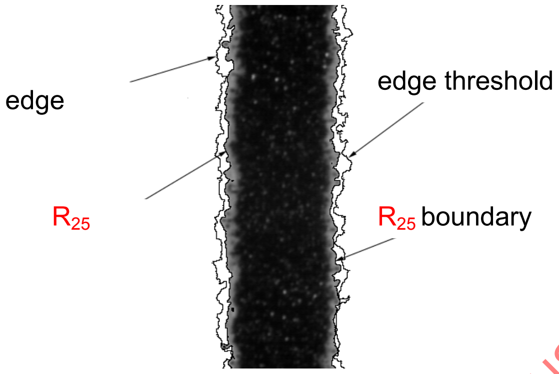


Figure 12 — Character darkness

5.3.5 Blurriness

1) Find an ROI that includes lines at least 1 mm long and background. The recommended width of the ROI is no less than (line width) +2 mm, the height no less than 5 mm.

2) Compute the R_{70} and R_{10} boundary threshold using maximum reflectance factor R_{max} and minimum reflectance factor R_{min} within ROI.

3) Compute the distance between R_{70} and R_{10} boundary of each scan and compute the average distance ($DIS_{70\text{-}10}$) of two or more scans. If the line is broken off inside the ROI, select a different ROI as measurement is impossible.

4) Compute the R_{25} boundary threshold using the maximum reflectance factor R_{max} and the minimum reflectance factor R_{min} within the ROI.

5) Compute the Line Image Density (*LID*) by averaging the density within the R_{25} boundary. The average optical density should be converted from the average reflectance factor. The R_{25} boundary is determined based on the R_{max} and R_{min} defined in step 2.

6) Compute the average blurriness by the following equation;

$$\text{Blurriness metric} = DIS_{70-10} \, / \sqrt{LID} \qquad (21)$$

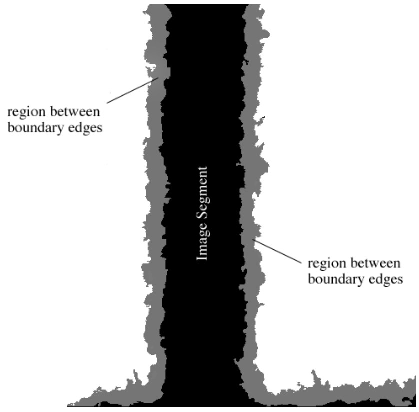


Figure 13 — Blurriness

5.3.6 Raggedness

1) Find an ROI that includes lines at least 1 mm long and background.
The recommended width of the ROI is no less than (line width)+2 mm, the height no less than 5 mm.

2) Compute the edge threshold R_{40} using the maximum reflectance factor R_{max} and the minimum reflectance factor R_{min} within ROI.

3) Compute the standard deviation of the residuals from a straight line fitted to the edge threshold boundary (calculated perpendicular to the fitted straight line).

4) Compute the average of right and left side standard deviations by the following equation.

$$\text{Raggedness metric} = \frac{1}{n}\sum_{j=1}^{n}\sqrt{\frac{1}{k-1}\sum_{i=1}^{k}(\text{residuals from a line})^2} \quad (22)$$

NOTE The raggedness evaluation is optimized for use with edges containing aperiodic noise.

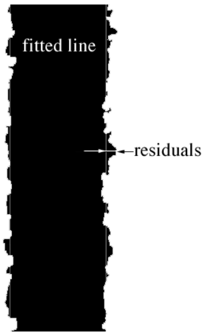


Figure 14 — Raggedness

5.3.7 Fill

1) Find an ROI that includes line segment, character image, or other glyph image and background.

2) Compute the R_{25} boundary threshold using the maximum reflectance factor R_{max} and the minimum reflectance factor R_{min} within the ROI.

3) Transform the image into binary data using the R_{25} boundary value as the threshold. If there is small scattering (noise), it will be removed, and I-1 is created.

4) All the holes within I-1 are filled and the image I-2 is created.

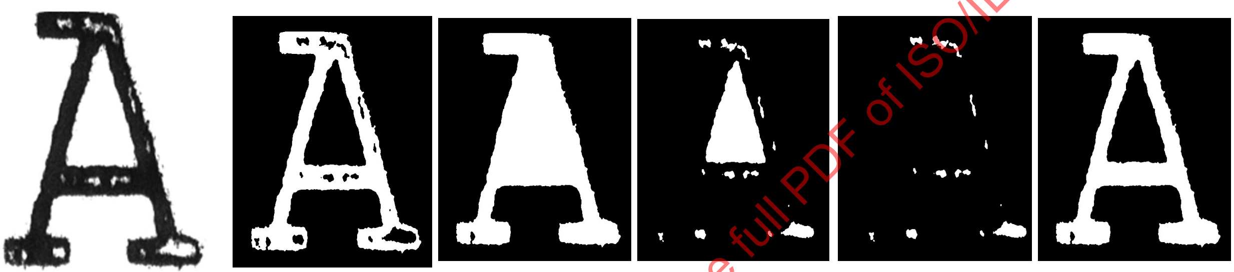
5) Compute the exclusive OR (XOR) of I-1 and I-2, and I-3 is created.

6) Create the image I-4 by eliminating part of character design holes in the image I-3, and compute the total area A_4 of the portion which remained.

7) Compute the OR image of I-1 and I-4, and I-5 is created. And compute the image area A_5 of I-5.

8) Compute the ratio of the area A_4 to the area A_5 using the following equation;

$$Fill\ metric = \frac{A_4}{A_5} \qquad (23)$$



(I-1) (I-2) (I-3) (I-4) (I-5)

Figure 15 — Fill and transformed images (Original, I-1 - 5)

5.3.8 Character surround area extraneous mark

1) Find an ROI within a character surround area.

Compute the edge threshold R_{40} using the maximum reflectance factor R_{max} within the ROI and the minimum reflectance factor R_{min} within the image area.

2) Compute the area A_{EM} (in square micrometres) within the edge threshold of each mark which can be any shape but must have a computed area greater than the area (7 850 μ m^2) of a 100 micrometer diameter circle.

3) Compute the ratio of the area of the marks to the total area A_{CF} of the character surround area by the following equation.

$$Extraneous\ mark\ metric = \frac{A_{EM}}{A_{CF}} \qquad (24)$$

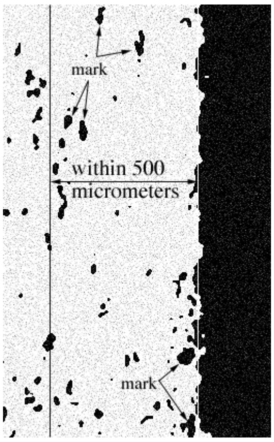


Figure 16 — Character surround area extraneous mark

5.3.9 Character surround area haze

1) Find an ROI in the character surround area (with marks excluded).

2) Measure the mean reflectance factor R_{HC} of the character surround area (with extraneous marks and image elements excluded) and the reflectance factor R_{BKG} of the nearby background area (outside any character surround area).

3) Compute the ratio of reflectance factor R_{HC} to R_{BKG} by the following equation.

$$\text{Character surround area haze metric} = \frac{R_{HC}}{R_{BKG}} \qquad (25)$$

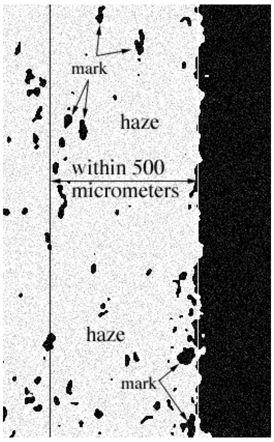


Figure 17 — Character surround area haze

6 System conformance

The purpose of this test is to verify that the complete measuring system (hardware, software, and operator) has been well calibrated and that it is accurate and precise enough for the requirements of this Technical Specification. This clause does not describe a calibration procedure. It describes a procedure for verifying that suitable calibration has been achieved.

6.1 Conformance standard

The instrument system used to carry out the procedures of this Technical Specification shall be tested using the test objects and procedures specified below to assure that it is operating in conformance with the requirements of this Technical Specification.

The measuring system is calibrated suitably if it can obtain a value within acceptable tolerances of the goal values given in Annex E for each attribute and for each test object specified in Clause **6.3**, independent of the orientation of the object and of its location within the field of view.

6.2 Instrument

The measures of attributes in this Technical Specification must be carried out with an instrument that has a minimum of 1 200 spi and 8 bits per pixel (256 gray levels), with a large field of view (for example, a 1 200 spi flatbed scanner) and a dynamic range of optical density at least 0,1 to 1,5 according to ISO 21550. A 1 200 spi instrument has an optical sampling pitch of 21,2 micrometers in the vertical and horizontal direction and a sampling window of close to 21,2 mm x 21,2 micrometers. The measures described in the Technical Specification assume that data has been collected on such an instrument.

Any instrument may be used, however, as long as the conformance standard in this clause can be met.

NOTE To achieve optimal comparison between systems, instruments should have similar characteristics (spi, illumination, spectral response).

An OECF created with the following procedures as specified in ISO 14524 is used for measurement of image quality attributes except mottle, graininess, and banding.

(1) Measure the visual reflection density Dv of each gray scale step.

(2) Calculate for the visual reflectance Rv from the visual reflection density Dv.

$$Rv_i = 10^{-Dvi} \qquad (26)$$

where, i is a step of gray scale.

(3) Scan gray scale with a scanner in RGB mode, and calculate the average output signal O_i of the G channel of each gray scale step.

(4) Develop the regression equation which predicts the visual reflectance Rv_i by the 5th degree polynomial of the average output signal O_i.

(5) In the polynomial, when the visual reflectance Rv_i becomes smaller than 0,001, set the visual reflectance Rv_i to 0,001, and when the visual reflectance Rv_i is larger than 0,933, clip the visual reflectance Rv_i in 0,933.

NOTE The gray scale used for creation of an OECF should be with 12 or more steps.The minimum density should be 0,07 or less and the maximum density should be 1,8 or more.

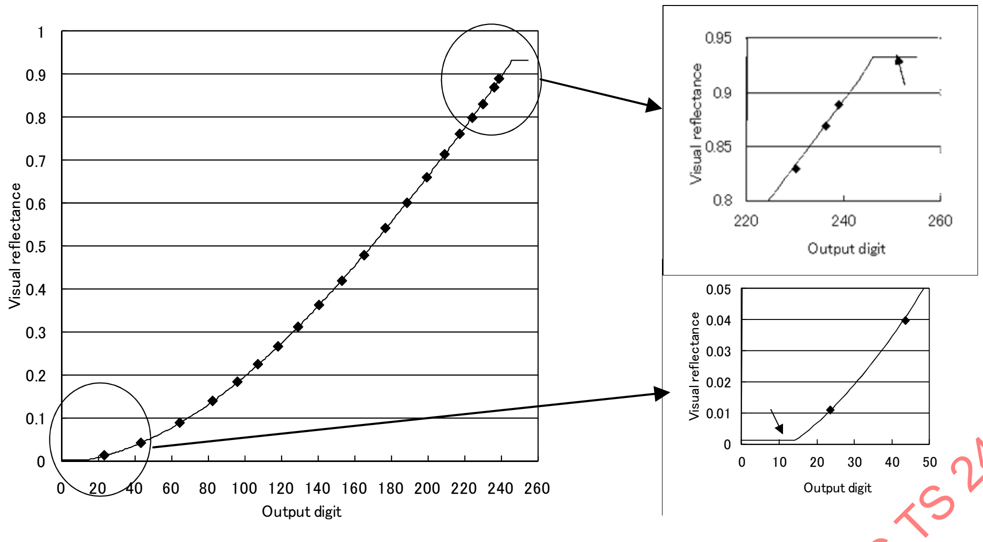


Figure 18 — An example of Scanner OECF

6.3 Test objects

The system conformance procedure requires the use of several test lines and area patterns. These test objects shall be produced as specified.

6.3.1 Specification for production of lines

6.3.1.1 Line set 1

Line set 1 is built from the 800 dpi bitmaps in Annex A. Each test line is produced by duplicating the corresponding bitmap at least 50 times to produce a line that is at least 30 mm long.

1) In each bitmap, “0” defines a white pixel. “1” defines a black pixel.

2) Each pixel shall be square and sharp, with an area between 700 square micrometers and 1 000 square micrometers.

3) The total area of any 3 x 3 block of adjacent pixels shall be between 7 600 and 9 600 square micrometers.

4) The substrate shall have an ISO brightness of at least 85 as specified in ISO 2470-1.

5) The colorant shall have an average density of 1,3 or higher.

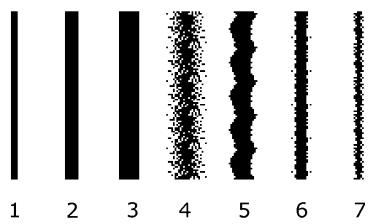


Figure 19 — Sample of line set 1 for conformance test (For illustration only. Not to be used to test conformance)

6.3.1.2 Line set 2

Line set 2 is built from the line width specified in Table 3, assuming a bitmap addressability of 800 dpi.

1) Any 3 x 3 pixels shall be square and sharp, with an area between 700 square micrometers and 1 100 square micrometers.

2) The total area of any 9 x 9 block of adjacent pixels shall be between 7 600 and 9 600 square micrometers.

3) The substrate shall have an ISO brightness of at least 85 as specified in ISO 2470-1.

4) The colorant shall have an average density of 1,3 or higher.

Table 3 — The specification of line set 2 (Assumed as 800dpi resolution)

Line Name	Pixel width	Line width (µm)
64	2	63,5 ± 5
95	3	95,3 ± 5
191	6	190,5 ± 5
318	10	317,5 ± 5

Figure 20 — Sample of line set 2 for conformance test
(For illustration only. Not to be used to test conformance)

6.3.1.3 Line set 3

Line set 3 for haze, mark and fill is built from the bitmaps specified in Figure 21 to 23, assuming a bitmap addressability of 800 dpi.

1) A test line is produced by duplicating the corresponding bitmap at least 20 times to produce a line that is at least 30 mm long.

2) In each bitmap, “0” defines a white pixel. “1” defines a black pixel.

3) Each pixel shall be square and sharp, with an area between 700 square micrometers and 1 000 square micrometers.

4) The total area of any 3 x 3 block of adjacent pixels shall be between 7 600 and 9 600 square micrometers.

5) The substrate shall have an ISO brightness of at least 85 as specified in ISO 2470-1.

6) The colorant shall have an average density of 1,3 or higher.

```
10001000100010011111111001000100010001
00000000000000011111111000000000000000
00000000000000011111111000000000000000
00000000000000011111111000000000000000
10001000100010011111111001000100010001
00000000000000011111111000000000000000
00000000000000011111111000000000000000
00000000000000011111111000000000000000
10001000100010011111111001000100010001
00000000000000011111111000000000000000
00000000000000011111111000000000000000
00000000000000011111111000000000000000
10001000100010011111111001000100010001
00000000000000011111111000000000000000
00000000000000011111111000000000000000
00000000000000011111111000000000000000
10001000100010011111111001000100010001
00000000000000011111111000000000000000
00000000000000011111111000000000000000
00000000000000011111111000000000000000
```

Figure 21 — Bitmap for line set 3 for the conformance test of haze

```
00110000000000011111111000000000000000
01111000000000011111111000000000000000
01111000000000011111111000000000000000
00110000000000011111111000011000000000
00000000000000011111111000111100000000
00000000111000011111111000111100000000
00000001111100011111111000111100000000
00000001111110011111111000001100000000
00000001111110011111111000000000000000
00000000111110011111111000000000000000
00000000011100011111111000000000111000
00000000000000011111111000000001111100
00000000000000011111111000000011111100
00001100000000011111111000000011111100
00011110000000011111111000000011111000
00011110000000011111111000000001110000
00011110000000011111111001100000000000
00001100000000011111111011110000000000
00000000000000011111111011110000000000
00000000000000011111111001100000000000
```

Figure 22 — Bitmap for line set 3 for the conformance test of mark

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 1
1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 1
1 1 1 0 0 0 1 1 1 1 0 0 0 1 1 1
1 1 1 0 0 0 1 1 1 1 0 0 0 1 1 1
1 1 1 0 0 0 1 1 1 1 0 0 0 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

Figure 23 — Bitmap for line set 3 for the conformance test of fill

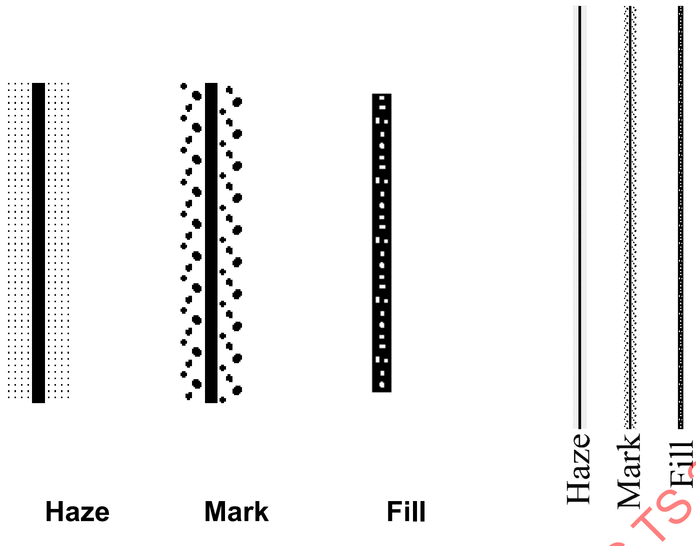

Figure 24 — Sample of line set 3 for conformance test
(For illustration only. Not to be used to test conformance)

6.3.2 Specification for production of large images

The image patterns for the measurement of large area darkness, background haze, graininess, mottle, background extraneous mark and void are specified in **6.3.2.1** - **6.3.2.7**. The bitmap addressability is 2 400 dpi.

6.3.2.1 Graininess pattern

1) Generate a two-dimensional white noise pattern (2 400dpi 32bit Real) with standard deviation 12.

2) Perform bandpass filter processing with a minimum cutoff frequency of 0,2 cycle/mm and a maximum cutoff frequency of 4,0 cycle/mm to the white noise.

3) Create uniform data (2 400dpi 32bit Real) of a level 127.

4) Add the white noise to the uniform data.

5) Convert into 8-bit data (2 400dpi 8bit) without a sign.

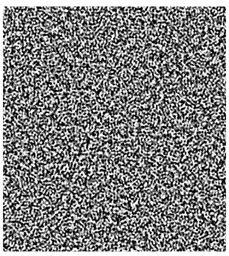

Figure 25 — Sample of graininess pattern for conformance test
(For illustration only. Not to be used to test conformance)

6.3.2.2 Mottle pattern

1) Generate a two-dimensional white noise pattern (2 400dpi 32bit Real) with standard deviation 12.

2) Perform low pass filter processing with a cutoff frequency of 0,6 cycle/mm to the white noise.

3) Create uniform data (2 400dpi 32bit Real) of a level 127.

4) Add the white noise to the uniform data.

5) Convert into 8-bit data (2 400dpi 8bit) without a sign.

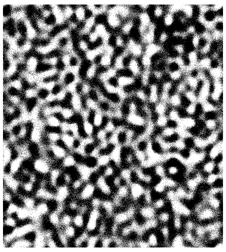

Figure 26 — Sample of mottle pattern for conformance test
(For illustration only. Not to be used to test conformance)

6.3.2.3 Extraneous mark pattern

1) Generate circular dots whose center coordinates and radius change randomly until the area coverage of all circles becomes 2 % in an area of 25,4mm x 25,4 mm.

2) The radius change between adjacent circular dots shall be within range of 6 pixels (0,0635 mm) - 10 pixels (0,1058 mm).

3) A diameter of 0,1 mm or more is maintained.

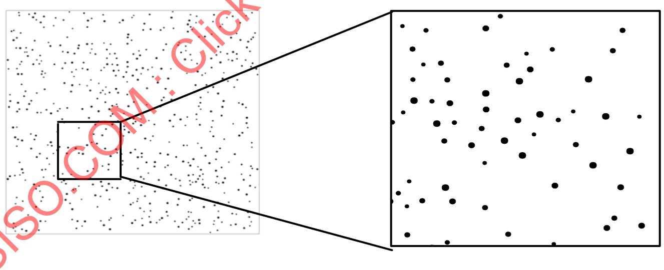

Figure 27 — Sample of extraneous mark pattern for conformance test
(For illustration only. Not to be used to test conformance)

6.3.2.4 Void pattern

1) The void evaluation pattern is generated by inverting the binary Marks evaluation pattern.

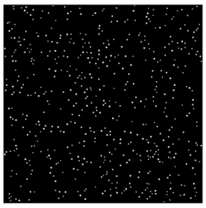

Figure 28 — Sample of void pattern for conformance test
(For illustration only. Not to be used to test conformance)

6.3.2.5 Background haze pattern

1) The background Haze evaluation pattern is a circular dot pattern of 5% area coverage at a dot pitch of 200 line/25,4 mm.

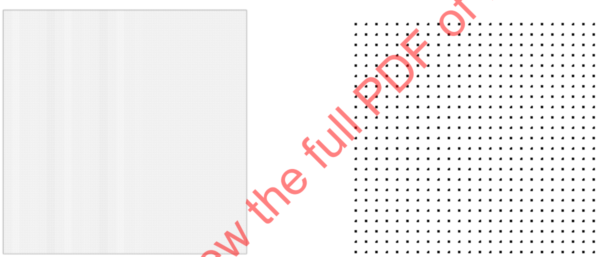

Figure 29 — Sample of haze pattern for conformance test
(For illustration only. Not to be used to test conformance)

6.3.2.6 Large area darkness pattern

1) The large area darkness evaluation pattern consists of 13 patches with specified dot area coverages in per cent of 100, 95, 90, 80, 70, 60, 50, 40, 30, 20, 10, 5 and 0.

2) The size of each patch is 15× 15 mm.

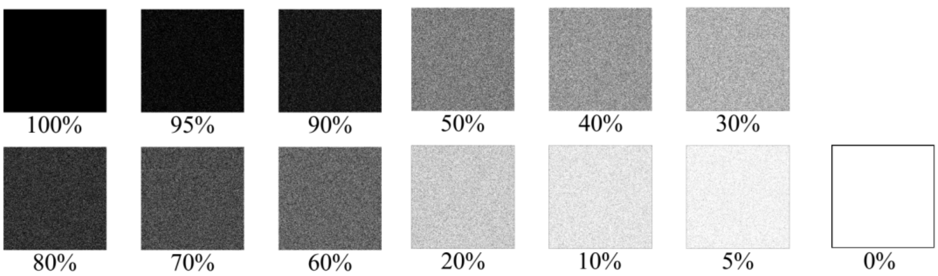

Figure 30 — Sample of large area darkness pattern for conformance test
(For illustration only. Not to be used to test conformance)

6.3.2.7 Banding pattern

1) Generate a pattern synthesized using following three kinds of sine waves (2 400dpi:32bit Real).

Table 4 — The specification of sine waves

Wave length(pixels)	Spatial frequency (cycles/mm)	Amplitude	Initial phase
50	1,89	16	0
200	0,47	16	0
1000	0,09	16	0

2) Create the uniform data (2 400dpi 32bit Real) of a level 127.

3) Add the synthesized pattern to the uniform data.

4) Convert into 8-bit data (2 400dpi 8bit) without a sign

5) Binarize by error diffusion treatment (2 400dpi1bit).

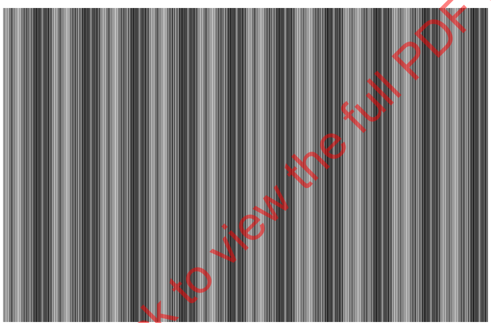

Figure 31 — Sample of banding pattern for conformance test

Annex A
(normative)

Bitmaps for conformance test lines

Table A.1 — Bitmap for Line 1

```
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
000000000011110000000000
```

Table A.2 — Bitmap for Line 2

```
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
000000001111111100000000
```


Table A.3 — Bitmap for Line 3

```
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
0000001111111111111000000
```

Table A.4 — Bitmap for Line 4

```
0000101101111110101010000
1000010111111100101011000
0000010011111111100100000
0000101111111111111000100
0011101111111111110000000
0000001001111111101101000
0000100111111111110100000
0000101001111111110001000
0000000110111111001100000
0111011101111111010011000
0001011101111111111010000
0001100111111101111000110
0000011011011111010110000
0000100011111111100000000
0000000111011111111100000
0110000110110111101001110
0000011010101111111100000
0001011001111111111100000
0000010111111111010110001
0000011111111100100100000
```

Table A.5 — Bitmap for Line 5

000000111111111111000000
000000011111111111110000
000000001111111111100000
000000011111111111100000
000000111111111111000000
000000111111111110000000
000001111111111110000000
000011111111111110000000
000011111111111100000000
000011111111111100000000
000111111111111110000000
000011111111111100000000
000011111111111100000000
000001111111111110000000
000001111111111100000000
000001111111111100000000
000000111111111100000000
000000111111111110000000
000000011111111111000000
000000111111111111000000

Table A.6 — Bitmap for Line 6

000000001111111100000000
000000000111111100000000
000000000111111100000000
000000001111111000000000
000000001111111100000000
000000001111111000000000
000000000111111100000000
000000000111111000000000
000000001111111100000000
000000000111111100000000
000000000111111000000000
000000001111111000000000
000000001111111000000000
000000001111111000000000
000000000111111000000000
000000100111111101000000
000000000111111100000000
000000001111111100000000
000000001111111000000000
000000000111111000000000

Table A.7 — Bitmap for Line 7

```
000000000000111000000000
000000000111110000000000
000000000011100000000000
000000000101111000000000
000000000011110000000000
000000000111101000000000
000000000011100000000000
000000000011110000000000
000000000001110000000000
000000000011101000000000
000000000111110000000000
000000000111110000000000
000000000011111000000000
000000000011110000000000
000000000001110000000000
000000000011111000000000
000000000011100000000000
000000000001110000000000
000000000001110000000000
000000000111101000000000
```

Annex B
(informative)

How to use this Technical Specification

B.1 General

This section provides a procedural outline for use of this Technical Specification. The conditions that shall be met to allow implementation are given in B.2. The stepwise approach required is given in B.3.

B.2 Conditions

1 The page to be evaluated contains background regions, character images, lines, and solid areas of an appropriate size, shape, and orientation to be specified and analyzed according to the methodology of this Technical Specification.

2 The image elements are distributed throughout the page in sufficient quantity and are in locations so as to allow adequate sampling for the statistics required by the task at hand. Adequate sampling will be determined by the image quality variations across the page and by the confidence level required for the assessment.

3 If line data are required for both horizontal and vertical orientations, the procedure is repeated as needed for correspondingly oriented edges and lines.

4 The scanning or imaging hardware employed has resolution equivalent to at least 1 200 spi and field coverage adequate to cover the regions of interest.

5 The data from the scanning or imaging hardware will be analyzed in some way by appropriate software. There are three basic ways to obtain this software:

- The end user develops his own software in a high-level programming language such as C++.
- The algorithms are implemented as a supplementary application (such as a set of macros) for commercial image analysis software. This might be coded by the end user or obtained from a commercial source.
- The end user obtains a complete application package dedicated to implementation of this Technical Specification from a commercial source.

6 Means are available to select appropriate regions of interest, to threshold the image element, and to execute the algorithms as required by this Technical Specification. Such means may be implemented in software.

7 The recommended instrument is a 1 200 spi flatbed scanner. Use of a different instrument type (such as an image analyzer) requires the procedure to be modified as appropriate for the particular instrument used.

B.3 Procedure

1 Establish user's own quality standards and sampling requirements for user's application.

2 OECF calibration of the measuring system as specified in ISO 14524.