INTERNATIONAL STANDARD

ISO 19264-1

First edition
2021-06

Photography — Archiving systems — Imaging systems quality analysis —

Part 1: Reflective originals

Photographie — Systèmes d'archivage — Analyse de la qualité des systèmes d'image —

Partie 1: Documents réfléchissants

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Reference number
ISO 19264-1:2021(E)

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Published in Switzerland

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Foreword

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

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

This document was prepared by Technical Committee ISO/TC 42, *Photography*.

This first edition of ISO 19264-1 cancels and replaces the first edition of ISO/TS 19264-1, which has been technically revised.

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

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Introduction

Electronic imaging systems, such as scanners and cameras, can be used for digitizing physical records, e.g. documents, pictures, maps. The resulting digital images can be more or less accurate in terms of how well they reproduce the original record's tones, colours, details, etc. These and other characteristics of a digital image can be assessed by imaging systems' quality analysis. In general, the achievable accuracy of digital reproductions depends on the nature of the original record and the digitization, especially the performance of the imaging system and the applied system settings.

In some organizations, e.g. within the archiving and cultural heritage field, where considerable resources are put into digitization projects, it is key to ensure that the required imaging systems' quality is met and that it is consistent. To this end, imaging systems' quality analysis can assist those developing or acquiring imaging systems with the assessment and verification of system performance, such as the specified resolution and dynamic range of a scanner, and the comparative performance of different imaging systems. Imaging systems' quality analysis is also used for setting up and calibrating imaging systems as well as for enhancing their performance. Finally, imaging systems' quality analysis is used for assessing accuracy and controlling imaging consistency over time. Note, that while the need to ensure imaging systems' quality is generic, the required level of imaging systems' quality and accuracy is use-case specific. For example, when digitizing watercolours it is usually essential to reach a high degree of accuracy in the capture of the colour information, while this is not normally equally critical when digitizing newspapers. Also, some image processing programs, such as Optical Character Recognition (OCR), are more accurate if the contrast is enhanced during imaging.

In practice, imaging systems' quality is analysed by digitizing a physical reference target (test chart) with known (measured) values and comparing these reference values to the corresponding captured values represented in the digital image file (see Figure 1).

The use of a test chart ensures that the imaging systems' quality characteristics can be determined objectively. However, to be usable the quality of the target needs to exceed the performance of the imaging system. For example, to determine the resolution of an imaging system, the target needs to have a technical pattern with more details than the system is capable of resolving. Imaging systems' quality analysis reports how accurately the imaging system reproduces the reference target. Therefore, if the original record differs significantly from the target, e.g. with respect to tone, tonal range, colours, details, and light reflectance/absorbance, this may, in spite of a well performing system, compromise the accuracy of the reproduced image. See also References [29] and [32] Ideally, the targets should resemble the nature of the original material. However, given the many different types of original records this is often not practical or technically impossible. Even though systems may perform differently on the different types of originals this document provides tools to verify if a system is accurately calibrated and in general performs well on a selected type of original. This is sufficient in most cases because systems are usually designed to handle various types of originals (being close to the Luther condition[42]) Performance on specific types of originals however can only be verified if the tools are made of that material. It is also important to note that an accurate reproduction usually requires subsequent processing to render a visually pleasing image.

There are ISO standards for objectively measuring different performance characteristics of imaging systems, e.g. resolution, noise, dynamic range, tone and colour reproduction (see Clause 2). This document combines all of the standards that relate to the imaging systems quality analysis for cultural heritage and defines a tool set to apply them to these devices and workflows. These tools are based on the use of a test chart with multiple technical patterns coupled with software that allows the user to analyse several imaging systems' quality characteristics simultaneously and receive comprehensive results. However, these tools are not based on a standardized image quality analysis method, which has caused confusion among users. With the publication of this specification imaging systems' quality analysis tools can refer to an ISO document.

To support this document a standard with a glossary including all relevant terms and definitions has been developed (ISO 19262). Further this document is accompanied by a Technical Report (ISO/TR 19263-1) that provides practical guidance on how to use this document.

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Photography — Archiving systems — Imaging systems quality analysis —

Part 1: Reflective originals

1 Scope

This document describes a method for analysing imaging systems quality in the area of cultural heritage imaging. The method described analyses multiple imaging systems quality characteristics from a single image of a specified test target. The specification states which characteristics are measured, how they are measured, and how the results of the analysis need to be presented.

This specification applies to scanners and digital cameras used for digitization of cultural heritage material.

NOTE This document addresses imaging of reflective originals, a future part two will address imaging of transparent originals.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12233, *Photography — Electronic still picture imaging — Resolution and spatial frequency responses*

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

ISO 15739, *Photography — Electronic still-picture imaging — Noise measurements*

ISO 16067-1, *Photography — Spatial resolution measurements of electronic scanners for photographic images — Part 1: Scanners for reflective media*

ISO 17957, *Photography — Digital cameras — Shading measurements*

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

ISO/CIE 11664-4, *Colorimetry — Part 4: CIE 1976 L*a*b* colour space*

3 Terms and definitions

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

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

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

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

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3.1
acutance
numerical value that correlates to some extent with subjective image sharpness

[SOURCE: ISO 19262:2015, 3.1]

3.2
banding
unwanted stripes or bands that occur in a digital image

Note 1 to entry: Bands are usually caused by fixed pattern noise of sensors in scanners, interference problems between electronic parts of a camera, or by too-coarse quantization.

[SOURCE: ISO 19262:2015, 3.9, modified — addition of "or by too-coarse quantization" in the Note 1 to entry.]

3.3
checkerboard
regular squared dark and bright structure on a surface like the one used on a chess board

[SOURCE: ISO 19262:2015, 3.18]

3.4
colour misregistration
colour-to-colour spatial dislocation of otherwise spatially coincident colour features of an imaged object

[SOURCE: ISO 19262:2015, 3.42]

3.5
digitization
act of generating a digital (quantized) representation of a continuous signal

[SOURCE: ISO 20998-1:2006, 2.7, modified — The Note 1 to entry has been deleted.]

3.6
distortion
geometric distortion
displacement from the ideal shape of a subject (lying on a plane parallel to the image plane) in the recorded image

Note 1 to entry: It basically derives from variation of lateral magnification in the image field of a camera lens and results in straight lines being rendered as curves. There are other factors to induce geometric distortion, for example rotational asymmetry of a camera lens or position shift processing in a camera imaging process.

[SOURCE: ISO 19262:2015, 3.82]

3.7
dynamic range
difference, over a given luminance range, between maximum and minimum signal levels, expressed in decibels, contrast ratios or f-stops

Note 1 to entry: The minimum signal level needs to be greater than a specified usable signal level.

Note 2 to entry: This definition is derived from IEC 702-04-23 but was altered to match the imaging and archiving application.

[SOURCE: ISO 19262:2015, 3.87]

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3.7.1
ISO scanner dynamic range
difference of the maximum density where the incremental gain is higher than 0,5, as determined according to ISO 21550 to the minimum density that appears unclipped

[SOURCE: ISO 21550:2004, 3.13]

3.8
exposure
H
<photographic> total quantity of light allowed to fall upon a photosensitive emulsion or an imaging sensor

Note 1 to entry: The exposure is measured in lux per second.

[SOURCE: ISO 10934-1:2002, 2.50, modified — A symbol, the field of application and a note to entry have been added.]

3.9
fast scan direction
scan direction corresponding to the direction of the alignment of the addressable photoelements in a linear array image sensor

[SOURCE: ISO 16067-1:2003, 3.7]

3.10
gain modulation
variation of the gain over the signal level

Note 1 to entry: One example for a gain modulation is the application of a gamma to an image.

[SOURCE: ISO 19262:2015, 3.109]

3.11
grey scale pattern
test chart consisting of test pattern based on spectrally neutral or effectively spectrally neutral, and consists of a large number of different reflectance or transmittance values in a prescribed spatial arrangement

Note 1 to entry: Grey scale patterns are typically used to measure opto-electronic conversion functions.

3.12
limiting resolution
value of that portion of a specified *resolution* (3.21) test pattern, measured in line widths per picture height, which corresponds to an average modulation value equal to some specified percentage of the modulation value at a specified reference frequency

Note 1 to entry: The limiting resolution could be the test pattern value, in line widths per picture height (w_l/h_p), corresponding to a camera output modulation level of 10 % of the camera output modulation level at a reference frequency of 10 w_l/h_p.

3.13
modulation
difference between the minimum and maximum signal levels divided by the sum of these levels

[SOURCE: ISO/IEC 29112:2012, 3.17]

3.14
noise
unwanted variations in the response of an imaging system

[SOURCE: ISO 15739:2013, 3.9]

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3.15
opto-electronic conversion function
OECF
relationship between the log of the input levels and the corresponding digital output levels for an opto-electronic digital image capture system

Note 1 to entry: If the input log exposure points are very finely spaced and the output noise is small compared to the quantization interval, the OECF possibly has a step-like character. Such behaviour is an artefact of the quantization process and needs to be removed by using an appropriate smoothing algorithm or by fitting a smooth curve to the data.

[SOURCE: ISO 17321-1:2012, 3.3]

3.16
original-referred
scene-referred
image state associated with image data that represents the colour-space coordinates of the elements of a two dimensional hardcopy or softcopy image, typically produced by scanning artwork, photographic transparencies or prints, or photomechanical or other reproductions

Note 1 to entry: When the phrase "original-referred" is used as a qualifier to an object, it implies that the object is in an original-referred image state. For example, original-referred image data are image data in an original-referred image state.

Note 2 to entry: Original-referred image data are related to the colour-space coordinates of the original, typically measured according to ISO 13655, and do not include any additional veiling glare or other flare.

Note 3 to entry: The characteristics of original-referred image data that most generally distinguish them from scene-referred image data are that they refer to a two-dimensional surface, and the illumination incident on the two-dimensional surface is assumed to be uniform (or the image data corrected for any non-uniformity in the illumination).

Note 4 to entry: There are classes of originals that produce original-referred image data with different characteristics. Examples include various types of artwork, photographic prints, photographic transparencies, emissive displays, etc. When selecting a colour re-rendering algorithm, it is usually necessary to know the class of the original in order to determine the appropriate colour re-rendering to be applied. For example, a colourimetric intent is generally applied to artwork, while different perceptual algorithms are applied to produce photographic prints from transparencies, or newsprint reproductions from photographic prints. In some cases the assumed viewing conditions are also different between the original classes, such as between photographic prints and transparencies, and will usually be considered in well-designed systems.

Note 5 to entry: In a few cases, it can be desirable to introduce slight colourimetric errors in the production of original-referred image data, for example to make the gamut of the original more closely fit the colour space, or because of the way the image data were captured (such as a Status A densitometry-based scanner).

[SOURCE: ISO 22028-1:2016, 3.32, modified — A term has been slightly modified and second one added.]

3.17
output-referred
image state associated with image data that represents the colour-space coordinates of the elements of an image that has undergone colour-rendering appropriate for a specified real or virtual output device and viewing conditions

Note 1 to entry: When the phrase "output-referred" is used as a qualifier to an object, it implies that the object is in an output-referred image state. For example, output-referred image data are image data in an output-referred image state.

Note 2 to entry: Output-referred image data are referred to the specified output device and viewing conditions. A single scene can be colour-rendered to a variety of output-referred representations depending on the anticipated output-viewing conditions, media limitations, and/or artistic intents.

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Note 3 to entry: Output-referred image data can become the starting point for a subsequent reproduction process. For example, sRGB output-referred image data are frequently considered to be the starting point for the colour re-rendering performed by a printer designed to receive sRGB image data.

[SOURCE: ISO/TS 22028-3:2012, 3.16]

3.18
profiling
creation of (ICC) colour profiles for imaging devices in order to enhance the accuracy in colour reproduction

[SOURCE: ISO 19262:2015, 3.197]

3.19
reference target
arrangement of test patterns designed to test particular aspects of an imaging system

Note 1 to entry: See examples in ISO 12233:2017, ISO 16067-1 and ISO 16067-2.

[SOURCE: ISO 19262:2015, 3.207]

3.20
reproduction scale
ratio of the size of an object in a digital image and the size of the original object

[SOURCE: ISO 19262:2015, 3.215]

3.21
resolution
measure of the ability of a camera system, or a component of a camera system, to depict picture detail

Note 1 to entry: Resolution measurement metrics include resolving power, limiting resolution, spatial frequency response (SFR), MTF and OTF.

[SOURCE: ISO 12233:2017, 3.22, modified — Two new terms and a Note 1 to entry have been added.]

3.22
sampling rate
number of samples per unit of time, angle, revolutions or other mechanical, independent variable for uniformly sampled data

[SOURCE: ISO 18431-1:2005, 3.13]

3.23
scene referred
image state image state associated with image data that represents estimates of the colour-space coordinates of the elements of a scene

Note 1 to entry: When the phrase "scene-referred" is used as a qualifier to an object, it implies that the object is in a scene referred image state. For example, scene-referred image data are image data in a scene-referred image state.

Note 2 to entry: Scene-referred image data can be determined from raw DSC image data before colour-rendering is performed. Generally, DSCs do not write scene-referred image data in image files, but some do so in a special mode intended for this purpose. Typically, DSCs write standard output-referred image data where colour-rendering has already been performed.

Note 3 to entry: Scene-referred image data typically represents relative scene colourimetry estimates. Absolute scene colourimetry estimates can be calculated using a scaling factor. The scaling factor can be derived from additional information such as the image OECF, F-number or ApertureValue, and ExposureTime or ShutterSpeedValue tags.

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Note 4 to entry: Scene-referred image data can contain inaccuracies due to the dynamic range limitations of the capture device, noise from various sources, quantization, optical blurring and flare that are not corrected for, and colour analysis errors due to device specific spectral sensitivities. In some cases, these sources of inaccuracy can be significant.

Note 5 to entry: The transformation from raw DSC image data to scene-referred image data depends on the relative adopted whites selected for the scene and the colour space used to encode the image data. If the chosen scene adopted white is inappropriate, additional errors will be introduced into the scene-referred image data. These errors can be correctable if the transformation used to produce the scene-referred image data are known, and the colour encoding used for the incorrect scene-referred image data has adequate precision and dynamic range.

Note 6 to entry: The scene can correspond to an actual view of the natural world, or be a computer-generated virtual scene simulating such a view. It can also correspond to a modified scene determined by applying modifications to an original scene to produce some different desired scene. Any such scene modifications need to leave the image in a scene referred image state, and need to be done in the context of an expected colour-rendering transform.

[SOURCE: ISO/TS 22028-3:2012, 3.18]

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4 System setup and calibration

4.1 General

The image capture system needs to be carefully set up to ensure consistent, repeatable, and high quality results. Prior to checking or confirming the quality of the system, it always needs to be accurately calibrated and adjusted. For a more detailed description on how to set up and calibrate an imaging system prior to imaging systems quality analysis see ISO/TR 19263-1.

4.2 System configuration

The camera needs to be mounted on a solid stand that does not move during exposure. Any ambient light that does not originate from the desired illumination shall be avoided.

4.3 Camera/scanner settings

The lowest sensitivity and lowest image compression rate, i.e. the highest image quality, should be selected.

4.4 Exposure

The exposure shall be adjusted so a diffuse white flat surface (a test chart may be used for this) is captured and recorded using encoding values that have an L^* value equal to the actual L^* value of the diffuse white flat surface. In the case of a three-dimensional original the placement and orientation of the diffuse white flat surface are left to the photographer, but should result in a reasonable image appearance (when displayed accurately) compared to viewing the original. The user needs to make sure that the dark areas are also not clipped. If clipping in the black areas is encountered, the user needs to ensure that the system is able to capture the dynamic range of the original referring to the measurement described in ISO 21550.

4.5 White balancing

The white balance shall be measured on a grey card or a white card (without optical brighteners) to ensure correct and consistent results. This grey reference is required to be spectrally neutral in reflection and the surrounding shall not have a dominating colour. These settings shall be stored and used for production afterwards. This process shall be repeated on a regular basis to compensate for the spectral change of the light source over its lifetime. Depending on the type of light source the interval in which this needs to be done varies.

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White balance performed on different tonal levels can vary. Highlights are generally more sensitive to errors. To check the variances of a system, it is best to use a grey scale and try different tonal levels.

4.6 ICC Profiling

If the originals are captured using a colour imaging system, an ICC profile should be created to characterize the system. For the purpose of ICC profiling, an ideal colour test chart reflects the type of originals to be digitized in terms of matching material and colourants.

If the software does not support ICC colour management, it is critical to determine if the system sensor, or any internal calibration, reaches accurate colour reproduction in the desired encoding before you decide to purchase or use the system.

4.7 Focusing

The system shall correctly be focused on the original. It depends on the tools the system has available how a good focus level can be achieved. Auto focus systems are often not reliable and may have problems focusing on certain originals without the introduction of focus aids.

4.8 Colour encoding

The desired colour encoding should be selected based on the intended application requirements and workflow preferences. In ISO 22028-1:2016, Annex B lists the characteristics and source standards for a number of standard colour encodings and Annex C provides criteria for selection of colour encodings.

In general, original- and scene-referred encodings are most appropriate for digital archiving systems. Examples of original-referred images are provided in ISO 12640-3, and examples of scene-referred images are provided in ISO 12640-5. However, at the time of the drafting of this document, very few scanners and digital cameras or raw processing applications supported either original- or scene-referred encodings, making it necessary to adapt output-referred encodings to this use.

When adapting output-referred encodings for the purpose of digital archiving, several changes to normal practice should be made in the processing, encoding, interpretation and display of the image data:

a) When processing the image data for encoding, any colour rendering should be turned off to the extent possible, so that the image colourimetry encoded accurately represents the colourimetry of the original object, with chromatic adaptation to the encoding white point. Particular attention should be paid to processing controls that apply nonlinear tone reproduction, or black or white clipping.

b) If it is not possible to turn off the colour rendering in the processing, profiling should be used to undo it to the extent possible, and the resulting profile assigned to the image, instead of the profile normally associated with the colour encoding used. For example, if a camera captures an Adobe RGB image, and the scanner or camera has been profiled, which this document recommends, the profile assigned to the image should be the appropriate scanner or camera profile rather than the Adobe RGB profile.

It should be noted that most output-referred RGB encodings use encoding 0 to represent the encoding reference medium black point, as opposed to an absolute black. This can cause several problems:

— In some cases, converting to the encoding could result in clipping of tones darker than the reference medium black point, which should be avoided. When original- or scene-referred images are stored using output-referred encodings, the reference medium should be ignored, and encoding 0 should be considered to represent absolute black.

— Likewise, in some cases converting from an output-referred encoding could cause a lightening of the dark tones, if the code values are interpreted as representing colours above the encoding reference medium black, as opposed to above absolute black.

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— When displaying images, operating systems and application software may apply black point compensation, where the encoding black point is scaled to the display black point. This may be desirable in some cases, even with digital archive images, to avoid clipping of tones darker than the display black point. However, it should be noted that when black point compensation is applied, the dark tones will be displayed somewhat lighter and with lower contrast than they appear on the original. Applications with sophisticated colour management interfaces may offer the option to turn black point compensation on or off. However, it should also be noted that many display profiles set the display black point to 0, in which case turning black point compensation off will still not result in correct rendition of the dark tones.

Hopefully in the future support for original- and scene-referred colour encodings will become more widespread, avoiding most of these issues.

4.9 Reproduction scale

If a camera system with an area sensor is used the reproduction scale depends on the focal length as well as the object distance. This may need to be adjusted in the final image.

5 Imaging system quality analysis procedure

To determine the quality of an imaging system according to this document one or more test charts as described in the Annexes A and C needs to be digitized with the system that has been set up and calibrated according to the aspects described in the previous paragraph.

The digital image is then analysed according to the individual quality aspects mentioned in Clause 6. For some of the measurement procedures (e.g. colour reproduction) reference data for the test chart is required. There are commercially available software tools that can do the analysis, see Figure 1.

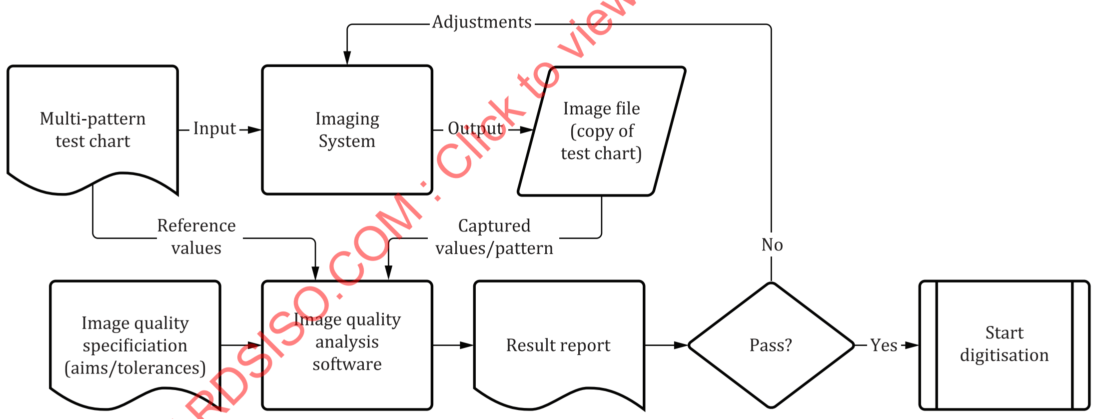

Figure 1 — Schematic representation of imaging systems quality analysis procedure

In order to decide whether or not the quality of the system is sufficient for the intended application a set of aims and tolerances is required. Annex B describes three tolerance levels A, B and C, which can be used or combined into a customized list for aims and tolerances for a specific project or application.

6 Imaging systems quality characteristics and metrics

6.1 General

The following tables describe the image characteristics that should be used to analyse the quality of a digital image. Each table provides a description of the image characteristic, references the related standards used to measure the characteristic, states a summary of the measuring method, and a specification of which technical patterns of the reference target should be used for the measurement.

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The tables also include aim values for optimal imaging systems quality. Annex B contains aims and tolerances for producing accurate and acceptable digital reproductions.

The image characteristics are grouped according to the basic metric they relate to: Tones and Noise (tone reproduction, gain modulation, dynamic range, noise, banding, defect pixels), Colour (white balance, colour reproduction), Details (sampling rate, resolution, sharpening, acutance), and Geometry (illumination non-uniformity, colour mis-registration, distortion, reproduction scale).

Even though this document details a specific multi-pattern chart, these values can also be measured using the charts outlined in the different standards, e.g. in ISO 12233, or other charts that fulfil the requirements described in the standards.

6.2 Tones and noise

Characteristic	**Tone reproduction**
Description	The opto-electronic conversion function (OECF) describes the relationship between the input light levels and the corresponding digital output levels for an opto-electronic digital image capture system. To produce an accurate reproduction it is important that this curve is shaped in a way that the Lightness (CIE L^*) levels of the original are transferred into digital values that represent the same L^* values in the selected colour encoding of the image.
Related standards	ISO 14524 (cameras) ISO 21550 (scanners)
Measurement	Tone reproduction/response curve (TRC) Measurement in L^* values and tolerances for L^* differences between original and captured image
Reference target	Grey scale (spectrally neutral) in a test chart as defined in Annex A that is ideally equally spaced in L^* values.
Aim	The smaller the deviation between the L^* of the patches in the reference target and the L^* values represented by the digital code values the more accurate the tone reproduction. Correct tonal capture is expected from L^* 95 to ≈ L^* 5
Notes	Also known as tone response.

Characteristic	**Gain modulation**
Description	The gain is a measure for the slope of the OECF. The gain modulation describes the variation of the slope in an L^* original versus L^* output curve. If the gain changes significantly it can happen that even with the tone reproduction being within tolerances the slope is too flat to differentiate tonal values that are close to each other.
Related standards	ISO 21550
Measurement	Calculation of the incremental gain from the tone reproduction curve (TRC) is done for grey scale steps with a tonal difference of at least 10 L^* values. For a grey scale with an increment between the patches of 5 L^* values every other patch of the grey scale will be compared. This means the gain is calculated for patch i = 1 and 3, 2 and 4, 3 and 5 …*s* $g_i = \frac{L^*_{\text{img } i+2} - L^*_{\text{img } i}}{L^*_{\text{org } i+2} - L^*_{\text{org } i}}$
Reference target	Grey scale (spectrally neutral) in a test chart as defined in Annex A that is ideally equally spaced in L^* values.
Aim	g_i is supposed to be 1 from L^* 95 to ≈ L^* 5
Notes	

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Characteristic	Noise
Description	Noise is unwanted variations in the response of an imaging system. It is introduced into the system by the camera originating from the sensor, the electronics, or the image processing. Also referred to as visual noise.
Related standards	ISO 15739 (cameras) ISO 21550 (scanners)
Measurement	Noise is measured in uniform areas of an image and expressed as standard deviation of the signal in these areas. ISO 15739 describes the method to determinate the RMS (Root Mean Square) noise. To describe the noise the RMS of the L^* values are determined on the patches of the gray scales. $$\sigma = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(L^* - \overline{L}^*)^2}$$
Reference target	The grey scale patches of the target defined in Annex A are used to determine the noise at varying signal levels.
Aim	The maximum noise level should be low enough so that noise is not visible in the images.
Notes	Signal to Noise Ratio (SNR), according to ISO 15739 and ISO 21550, is not measured by this document.

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Characteristic	ISO scanner dynamic range
Description	Dynamic range in this case describes the ratio of the brightest patch in the original that is not clipped and the darkest patch that is above the noise (SNR of 1)
Related standards	ISO 21550, ISO 15739
Measurement	$$d = d_{max} - d_{min}$$ The dynamic range is measured from a grey scale where d_{min} is the density of the brightest patch where the output signal of the OECF appears to be unclipped and d_{max} is the density of the patch with a signal to noise ratio of 1 (see ISO 21550 for details).
Reference target	Grey scale (spectrally neutral) in a test chart as defined in Annex A that is ideally equally spaced in L^* values with a contrast exceeding that of the image capture device.
Aim	d shall be as large as possible but at least exceed the contrast range of typical objects that are digitized with the image capture device.
Notes	

Characteristic	Banding
Description	Unwanted stripes or bands that occur in a digital image. Often times these structures occur as a regular pattern in an image. The origin can be a characteristic of the sensor, the power supply or other electronic influences on the image capture. Mistakes in the image processing can also be a source for banding.
Related standards	unknown
Measurement	A quantization of banding is difficult but averaging the columns of multiple lines in a uniform area and displaying the digital values of the average line helps determining potential bands. A frequency analysis performed on that line identifies regular structures by providing a peak at the frequency of the banding structure.
Reference target	To be measured on uniform grey, white, and black stripes in chart as defined in Annex A.

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Characteristic	Banding
Aim	The mean value for the columns of each of the stripes shall be in the range of expected fixed pattern noise. Max and min values of the signal deviation for the averaged lines should be defined. A max value for a single frequency peak should be defined.
Notes	Vertical and horizontal but sometimes also diagonal. Averaging several lines or columns perpendicular to measured direction.

Characteristic	Defect pixels
Description	Pixel or subpixel that operates in a way other than the one in which it is driven. (see ISO 9241-302)
Related standards	ISO 9241-302
Measurement	Due to the different characteristics of defect pixels the measurement needs to be performed on a black image, a grey image, and a white image. For the black image the sensor does not get exposed to light during the image capture. This can be done by closing the lens cap or for scanners by switching off the light. For the grey and the white image the sensor needs to uniformly be exposed to light so that the digital output level reaches a value close to the centre value of the digital output value range (e.g. 127 for an 8 bit image) for grey and close to the maximum output level for white. A range around the typical noise values needs to be defined for those pixels that are ok and all other pixels outside the range (outliers) are then specified as defect.
Reference target	Uniform light source or target like an integrating sphere or a uniformly illuminated white target.
Aim	Identification of single pixels or clusters that do not represent the original respectively are out of the expected value range. The smaller the amount of these pixels the better.
Notes	This may not be required for every imaging system‘s quality check because it is mostly taken care of by the manufacturer of the capture device. Only if pixels occur that show problems this may be evaluated. Determining defect pixels is not part of the required measurements for imaging systems quality analysis.

6.3 Colour

Characteristic	White balance
Description	Adjustment of electronic still picture colour channel gains or image processing so that radiation with relative spectral power distribution equal to that of the scene illumination source is rendered as visually neutral (see ISO 14524). This ensures that neutral greys in the original are visually neutral in the image.
Related standards	ISO 14524
Measurement	Calculated from tone reproduction/response curve (TRC) with values in $L^*a^*b^*$. The image needs to be converted from RGB to $L^*a^*b^*$ using the colour encoding description of the colour encoding the image is in (like sRGB, Adobe RGB, ...). White balance is measured using CIE ΔE 2000 (CIE 015:2018) but without lightness information (L*) to check chroma and hue differences but not luminance ones $\Delta E\ ab\ 2000=\sqrt{\left(\frac{\mathrm{DC}'}{\mathrm{Kc\,Sc}}\right)^2+\left(\frac{\mathrm{DH}'}{\mathrm{Kh\,Sh}}\right)^2+Rt\left(\frac{\mathrm{DC}'}{\mathrm{Kc\,Sc}}\right)\left(\frac{\mathrm{DH}'}{\mathrm{Kh\,Sh}}\right)}$
Reference target	Grey scale patches in the target defined in Annex A.
Aim	The smaller the white balance the more accurate the reproduction. Tolerances to be defined in ΔE_{ab}.2000.

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Characteristic	White balance
Notes	The CIE *L* a* b** approach has been selected over an RGB approach because CIE *L* a* b** better describes the visibility of colours. NOTE: ΔE_{ab} has been used instead of ΔC^* (in the version of 2017) to check both chroma and hue errors in case the grey scale patches are not perfectly neutral.

Characteristic	Colour reproduction
Description	The difference between selected physically measured input colours and their intended output rendering for a given colour space. This expresses how well an imaging system captures and encodes colours. In digital cameras colours are captured and encoded as combinations of Red (R), Green (G) and Blue (B). The colour encoding selected describes how these RGB values are related to CIELab values. Since none of the cameras or scanning systems matches the colour matching functions of the human visual system, the colour reproduction can strictly speaking only be optimal for a specific set of colours for which the system has been calibrated (profiled). Currently there are only two sets of commonly used colours to profile scanners and cameras. One is the IT8 Target according to ISO 12641-1 and the other one is the ColourChecker SG (Semi Gloss surface) target. However there are other targets that are available and may be used. After profiling the system by using these targets the targets are scanned again and the colour difference is measured using CIE ΔE 2000 (CIE 015:2018) approach with $SL = 1$ (ΔE 2000 SL1) which gives equal weight to the entire grey scale. The mean and max ΔE 2000 values for all patches shall be determined.
Related standards	ISO/CIE 11664-4, ISO/CIE 11664-6,
Measurement	CIELAB colour difference measure (ΔE) according ISO/CIE 11664-4 specifications.
Reference target	Colour patches of Target defined in Annex A.
Aim	The smaller the colour differences ΔE (L^*a^*b) the more accurate the colour reproduction.
Notes	This measurement only provides useful information if the system has been calibrated and profiled correctly for colour reproduction. It does not provide a colour reproduction quality estimation for other than the chart colours and may show inaccurate colour reproduction for certain types of originals. For monitoring the system with a test chart other than the above-mentioned profiling charts a reference scan can be made using the chart described in Annex A right after the verification. Each monitoring scan can then be compared to the reference scan.

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Characteristic	Colour misregistration
Description	Colour-to-colour spatial dislocation of otherwise spatially coincident colour features of an imaged object.
Related standards	ISO 12233 (resolution measurement) ISO 19084 (chromatic displacement)
Measurement	Determination of edge location on a per channel basis for all slanted edges over the imaging field.
Reference target	Slanted edges in the test chart defined in Annex A.
Aim	Geometric distance between the edge location in the different colour channels shall be as small as possible.
Notes	If a dislocation of the edges in different colour channels is uniform over the field a standard colour mis-registration is present. If it varies over the field e.g. from centre to corners a chromatic aberration is present. For a line scanner it may be visible in just one direction. For a line scanning system there may also be a dislocation that comes and goes due do inconsistent motion.

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6.4 Details

Characteristic	Sampling rate (obtained)
Description	Sampling rate in pixels per unit of space determined from imaging a test chart with known geometric structures.
Related standards	
Measurement	Determine the number of pixels for a block with a given geometric size in the image of a test chart and convert to number of pixels per inch.
Reference target	Checkerboard structure on Target defined in Annex A.
Aim	The obtained sampling rate should be as close as possible to the claimed sampling rate provided in the metadata of the image file.
Notes	Also known as sampling frequency. Sampling rate should not be confused with limiting resolution. The sampling rate of a digital reproduction can be used to calculate the size of the physical record if stored in an uncompressed format. The sampling rate limits the maximum possible resolution of an imaging system. According to the Nyquist theorem, it is necessary to have at least two detecting points (pixels) on a cycle of a harmonic signal to be able to reproduce the signal. In other words, to scan a black-and-white test structure, you should have at least one pixel for the white part and one pixel for the black part to be able to reproduce the structure.

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Characteristic	Resolution (limiting resolution)
Description	Measure of the ability of a camera system, or a component of a camera system, to depict picture detail (see ISO 12233).
Related standards	ISO 12233, ISO 16067-1
Measurement	Analysis of the edge spread function in a slanted edge target. Use the sampling frequency at 10 % modulation threshold for limiting resolution.
Reference target	The slanted edge structures in the target defined in Annex A are designed for SFR (spatial frequency response) measurements.
Aim	Reaching a frequency as high as possible but not higher than Nyquist (to avoid aliasing) for the 10 % modulation threshold (limiting resolution). Depending on the sampling rate the maximum resolution that can be reached varies. The resolution should be constant over the field of imaging and the difference in different directions (horizontal and vertical respectively slow scan and fast scan direction) should be as small as possible.
Notes	Also known as true optical resolution. Note that resolution measurements based on slanted edge analysis requires uncompressed and unsharpened data. The ratio between the limiting resolution and the theoretical Nyquist limit is based on the obtained sampling rate.

Characteristic	Sharpening
Description	Amplification of the spatial frequency response by means of image processing to achieve sharper appearing images. Also, a class of image processing operations that enhances the contrast of selective spatial frequencies, usually visually important ones.
Related standards	ISO 12233, ISO 16067-1
Measurement	Analysis of the edge spread function in a slanted edge target. For an image without sharpening the SFR should at no frequency significantly exceed the value of 1.
Reference target	The slanted edge structures in the Target defined in Clause 6 are designed for SFR (spatial frequency response) measurements.

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Characteristic	Sharpening
Aim	The SFR should not significantly exceed the value of 1.
Notes	

Characteristic	MTF 50 (limiting resolution)
Description	Measure of frequency based on the SFR measurement where a 50 % contrast level is reached (see ISO 12233). This is an indicator for the sharpness of an image.
Related standards	ISO 12233, ISO 16067-1
Measurement	Analysis of the edge spread function in a slanted edge target. Use the sampling frequency at 50 % modulation threshold as a sharpness indicator.
Reference target	The slanted edge structures in the target defined in Annex A are designed for SFR (spatial frequency response) measurements.
Aim	Reaching a frequency as high as possible but not higher than Nyquist (to avoid aliasing) for the 50 % modulation threshold.
Notes	

Characteristic	Acutance
Description	The visual perception of sharpness that describes the quality of being crisp or of containing detail.
Related standards	
Measurement	The acutance measure is the SFR weighted with the contrast sensitivity function (CSF) of the human eye for a given viewing condition. The used viewing condition in this specification shall be the 100 % viewing (e.g. on a computer monitor) with a 100 ppi pixel pitch viewed from 0,5 m distance. $\text{Acutance} = \frac{A}{A_r}$ where $A = \int_0^\infty SFR_L(v) \times CSF(v)dv$ $A_r = \int_0^\infty CSF(v)dv$
Reference target	The slanted edge structures in the target defined in Annex A are designed for SFR (spatial frequency response) measurements.
Aim	The acutance shall be as close as possible to the max value of 1.
Notes	The CSF shall be calculated and applied as described in ISO 15739 with the viewing condition being a 100 % viewing on a monitor with 100 ppi viewed from a 0,5 m distance.

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6.5 Geometry

Characteristic	Illumination non-uniformity
Description	The illuminance non-uniformity consists of two components: it depends on how evenly the scene to be captured is illuminated, and on the degree of shading introduced by the imaging system.
Related standards	ISO 17957 (shading measurement)
Measurement	Capture of a uniform white original and analyse for lightness non-uniformity according to ISO 17957 and determine the L^* value at at least 1 200 points equally spread over the field of view and report the ΔL^* between the max and the min L^* value.
Reference target	Uniform white paper or derived from checkerboard pattern in the target defined in Annex A on which only the patches with the same reflectance (e.g. white patches) are analysed.
Aim	The illuminance should be as uniform as possible.

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Characteristic	Illumination non-uniformity
Notes	Make sure no part in the image is clipped. Surrounding light should be avoided to not influence the measurement.

Characteristic	Chrominance non-uniformity
Description	Depending on the type of device, the infrared cut-off filter, sensor geometry and angle of incidence there can be a colour shift in the image that gets extremely visible in case of a uniform white or grey original.
Related standards	ISO 17957 (shading measurement)
Measurement	Capture of a uniform white original and analyse for colour shading according to ISO 17957 and determine the chrominance deviation from the average for each block at at least 1 200 points equally spread over the field of view. Report the maximum value of the chrominance deviation as the chrominance non-uniformity D_C.
Reference target	Uniform white paper or derived from checkerboard pattern in the target defined in Annex A on which only the patches with the same reflectance (e.g. white patches) are analysed.
Aim	The chrominance non-uniformity should be as small as possible.
Notes	Make sure no part in the image is clipped. Surrounding light should be avoided to not influence the measurement.

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Characteristic	Distortion
Description	Displacement from the ideal shape of a subject (lying on a plane parallel to the image plane) in the recorded image. The distortion measured can originate from three different aspects: lens geometric distortion, scanner motion distortion, image processing distortion.
Related standards	ISO 17850
Measurement	For a regular grid of dots, crosses or line intersections the locations are evaluated on a sub pixel accuracy basis. These locations are compared to a regular grid generated from the central area of the image.
Reference target	The chart can be a dedicated dot or cross chart or the chart as specified in Annex A.
Aim	The distortion shall be as small as possible.
Notes	Distortion can usually be characterized and compensated. Evaluation may be done with activated compensation if system allows for such compensation.

Characteristic	Reproduction scale
Description	Describes how far a given geometric distance in the original is represented in the image
Related standards	
Measurement	Is reflected in the claimed versus obtained sampling rate.
Reference target	Derived from checkerboard pattern in the target defined in Annex A.
Aim	Should be as close as possible to the original. Tolerances are project dependent.
Notes	The reproduction scale relates to dimensional accuracy.

7 Reporting results

7.1 General

Together with the list of results the following information shall be reported:

— Camera/scanner manufacturer, model and serial number

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— Lens manufacturer, model and serial number (if applicable)

— Lighting (if applicable)

— Date, Time, Location of the measurement

— Used image processing software (name and version)

— Camera settings that impact the imaging quality

— Including aperture, shutter speed, ISO (sensitivity/speed)

— Important image data

— Including image width and image height, claimed sampling rate, bits per sample (bit depth), colour encoding, colour profile

7.2 Example report for tone reproduction results

Based on the tolerance range for the individual application, the L^* values extracted from the image of the test chart shall be reported against the L^* values of the original. In case the results are presented as a table the differences between the original and the image shall be stated in a third column and the minimum and maximum differences at the bottom of the table show if the values are within or out of the tolerances. Another option for using the max and min values is the coloured indication of values that are out of the defined tolerances, see Table 1.

Table 1 — Max and min values need to be in the given range based on the tolerances for the specific application

Original L^*	Camera/ Scanner L^*	ΔL^*
95	96	−1
90	88	2
85	85	0
80	79	1
75	75	0
70	69	1
65	66	−1
60	59	1
55	54	1
50	50	0
45	44	1
40	39	1
35	35	0
30	29	1
25	23	2
20	19	1
15	14	1
10	9	1
5	6	−1
	max	2
	min	−1

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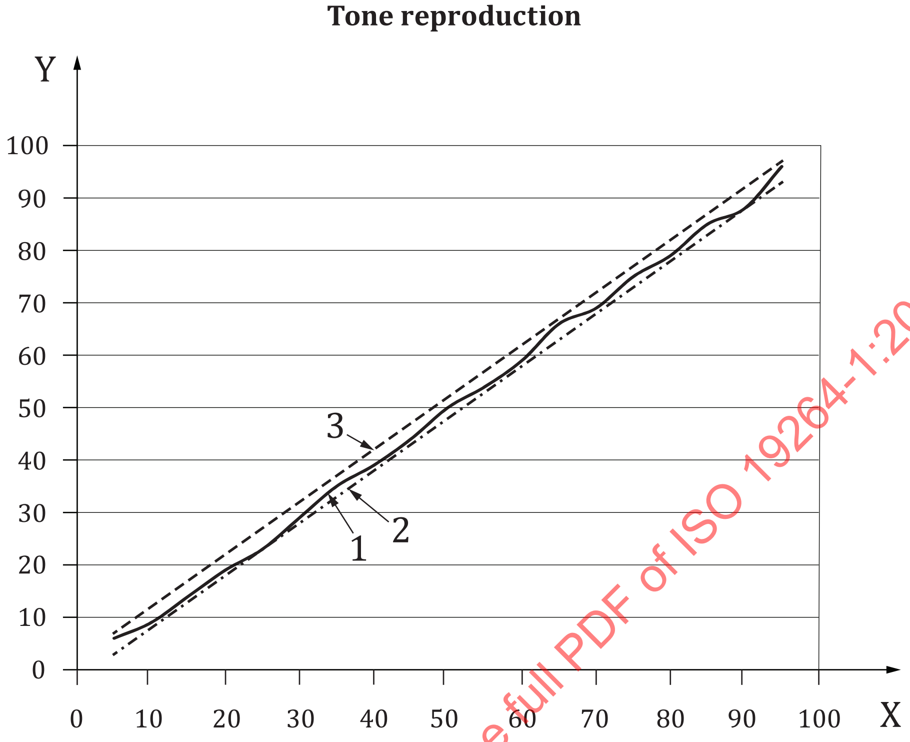
In case of the presentation in a graph the tolerances shall clearly be indicated by separate lines or marking the area of values within tolerance.



Key

X tonal values original [*L**]

Y tonal values reproduction [*L**]

1 camera/scanner *L**

2 lower tolerance

3 upper tolerance

Figure 2 — Graphical representation for the tone reproduction

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7.3 Gain modulation

Table 2 with the results for gain modulation shall contain either the pair of the patches for which the gain modulation was calculated or the average *L** value of the two compared patches in the first column and the calculated gain modulation in the second column.

Table 2 — Gain modulation
(max and min values need to be in the specified tolerance level)

Patch	Gain modulation
1/3	1,1
2/4	1
3/5	1
4/6	0,9
5/7	1
6/8	1,2
7/9	0,9

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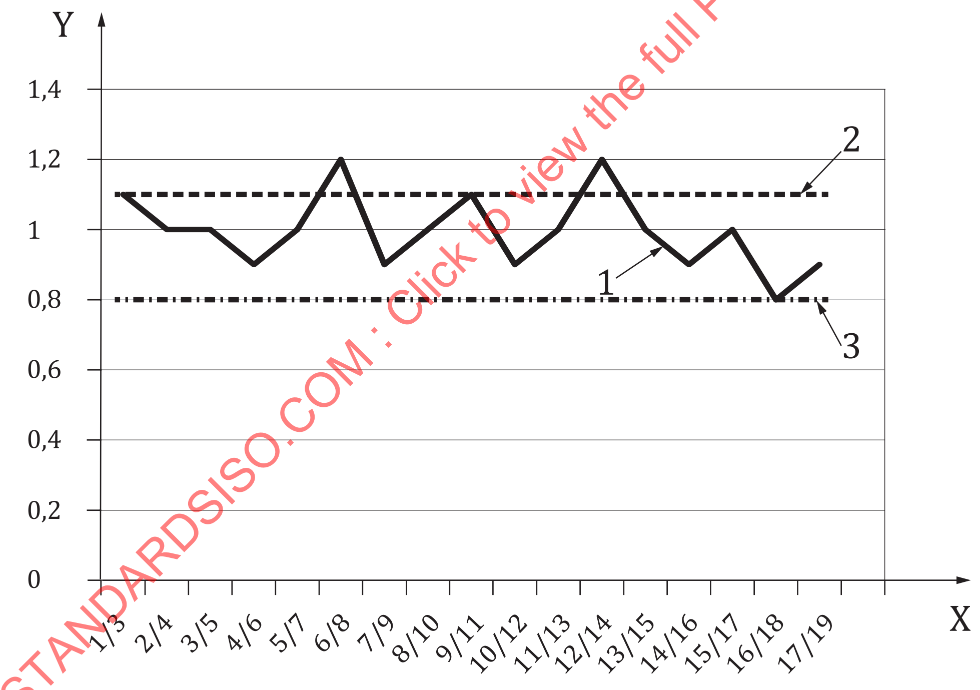
Table 2 *(continued)*

Patch	Gain modulation
8/10	1
9/11	1,1
10/12	0,9
11/13	1
12/14	1,2
13/15	1
14/16	0,9
15/17	1
16/18	0,8
17/19	0,9
max	1,2
min	0,8

In case of a graphical presentation the indication of the upper and lower tolerance level is helpful.

Gain modulation



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Key

X grayscale patch

Y gain

1 gain modulation

2 upper tolerance

3 lower tolerance

Figure 3 — Graphical representation of gain modulation

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7.4 Dynamic range

Dynamic range is reported as a single value in densities like 3,00 densities.

Alternatively the dynamic range can be expressed in:

— a contrast range like e.g. 1 000:1 (10^D:1),

— an fstop range like 10 fstops (D/0,3010),

— or a dB value (20*D).

7.5 Noise

The noise value is reported as RMS noise according to ISO 15739 over the L^* value of the individual grey patches.

Table 3 — RMS noise value in table form
(the max value should be below the specified tolerance level)

Original L^*	RMS noise
95	0,00
90	0,40
85	0,54
80	0,85
75	1,21
70	1,70
65	2,04
60	1,81
55	1,33
50	1,24
45	1,16
40	1,10
35	0,97
30	0,93
25	0,80
20	0,70
15	0,58
10	0,30
5	0,00
max	2,04
mean	0,93

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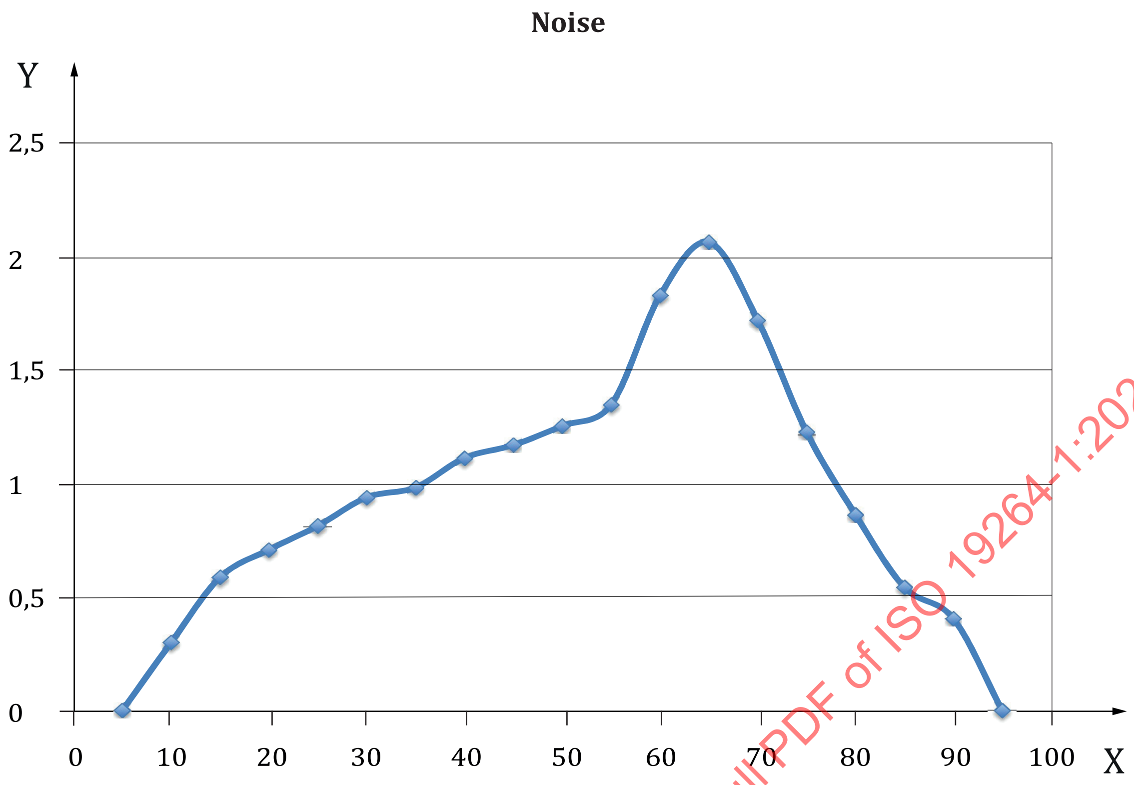

Key

X *L**

Y RMS noise

Figure 4 — Graphical presentation of RMS noise over the *L value of the grey scale**

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7.6 Banding

For Banding the graphical representation can be the digital values over pixels.

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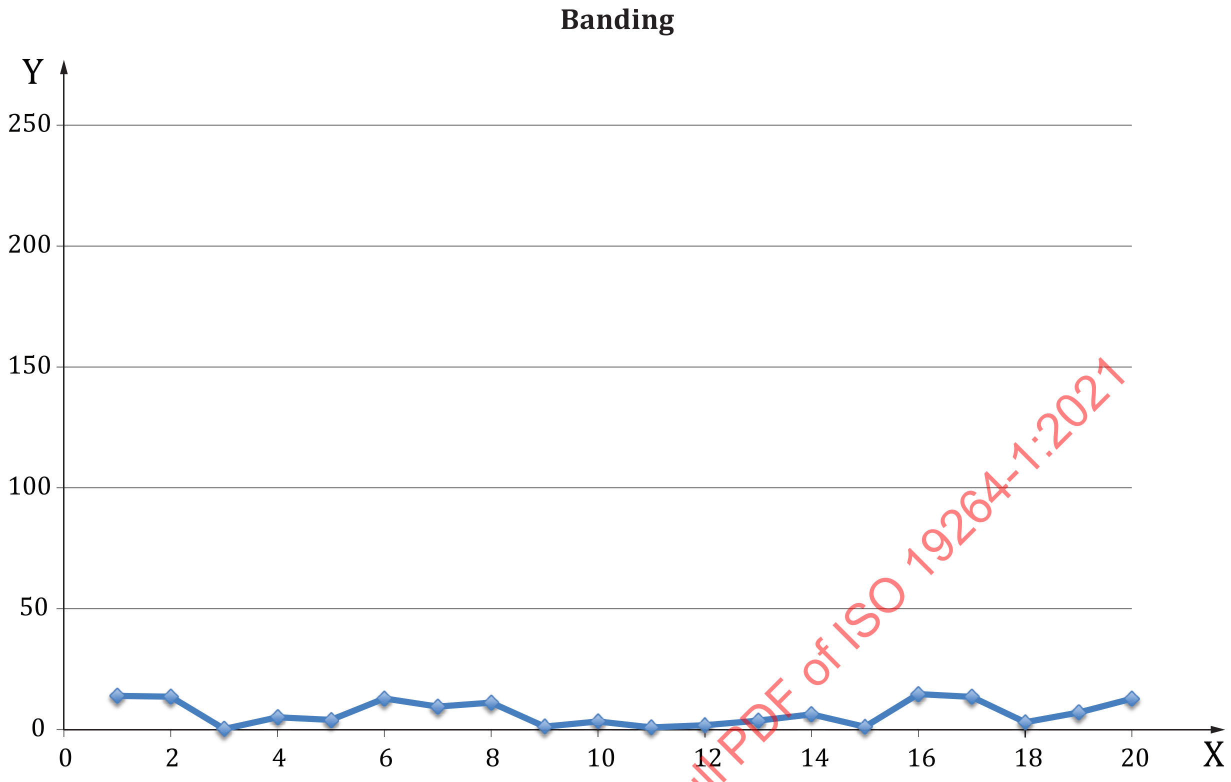

Key

X pixel

Y digital value

Figure 5 — Digital values over pixels
(Regular peaks in this structure indicate the presence of banding in images)

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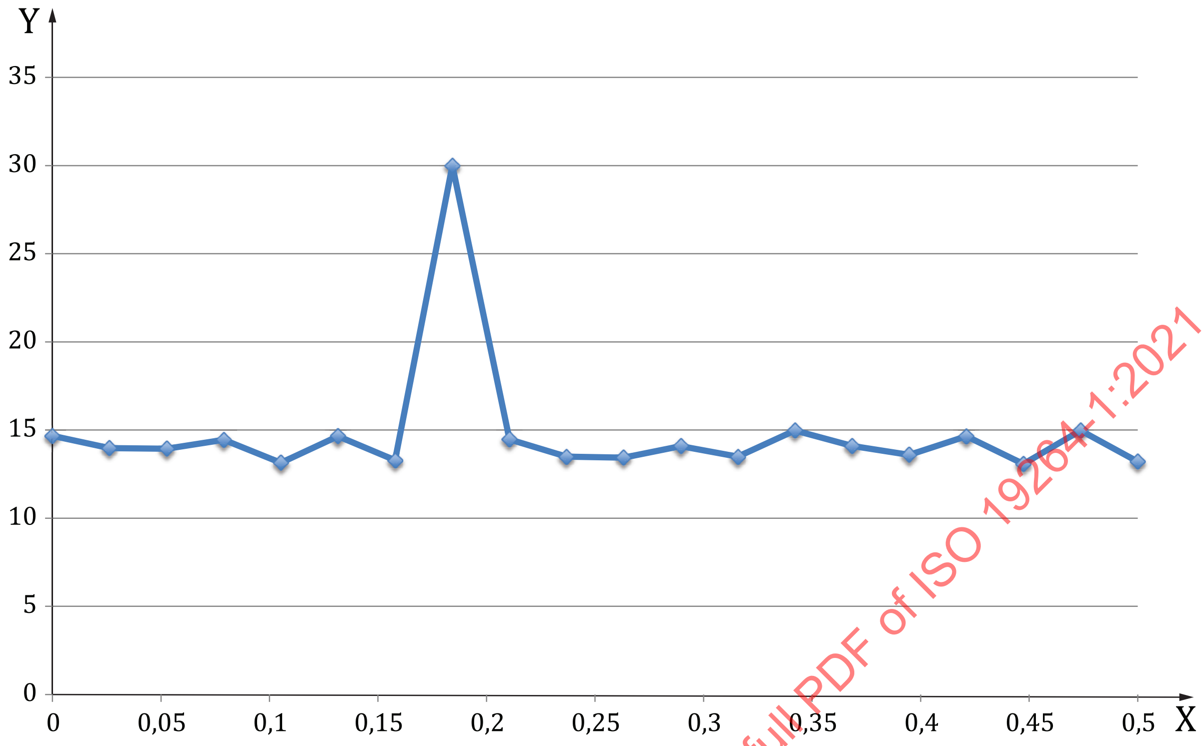

Key

X frequency (cycles per pixel)

Figure 6 — Frequency peak in the Fourier transform of the pixel values representation (one or multiple peaks indicate the presence of banding)

7.7 Defect pixels

For the evaluated area the number of pixels outside of the expected range are reported. In case of the intention to correct them, a pixel map/table with the x, y coordinates of the defect pixels can be reported.

7.8 White balance

Table 4 — White balance over the L^* values
(the tolerance level is specified for the max ΔE_{ab})

Original L^*	White balance ΔE_{ab}
95	0,14
90	0,22
85	0,18
80	0,15
75	0,22
70	0,35
65	0,3
60	0,7
55	0,9
50	1,1

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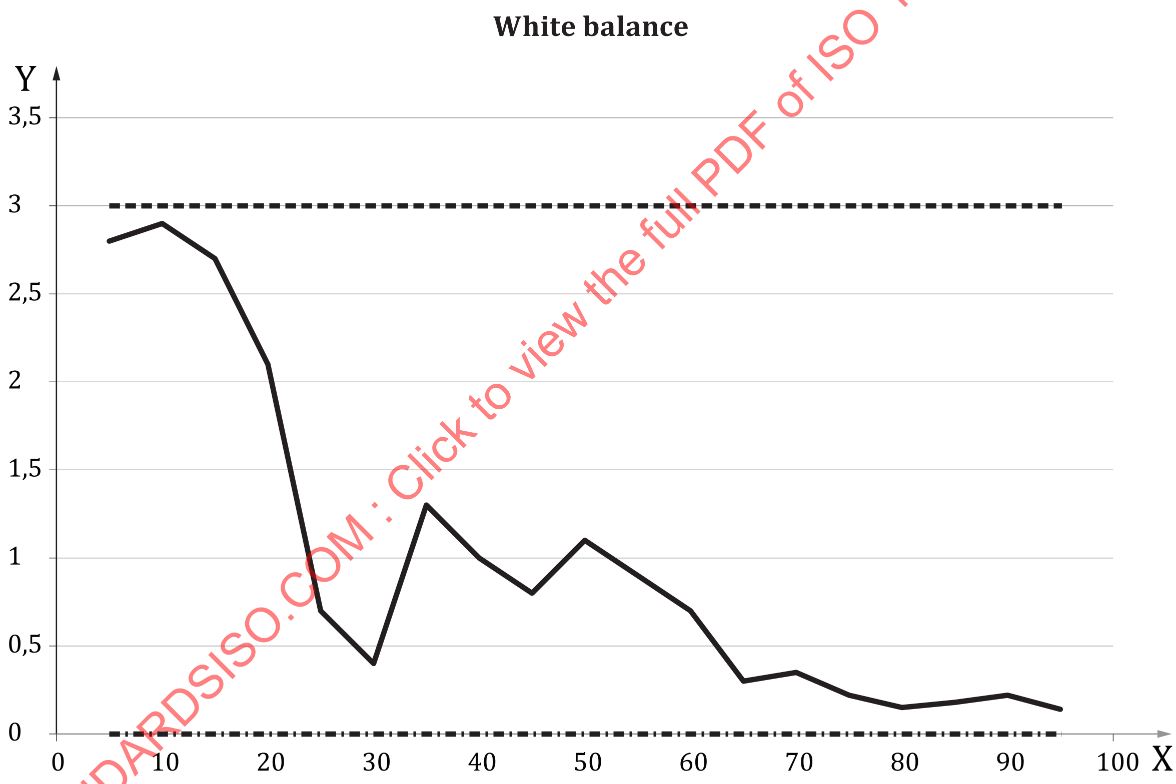
Table 4 *(continued)*

Original L^*	White balance ΔE_{ab}
45	0,8
40	1
35	1,3
30	0,4
25	0,7
20	2,1
15	2,7
10	2,9
5	2,8



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Key

X L^*

Y ΔE_{ab} 2000

Figure 7 — Graphical representation of the white balance over the L^* value with the upper and lower tolerance levels

7.9 Colour reproduction

For the colour reproduction the ΔE 2000 values should be reported in form of a table for each individual patch together with the result for the mean and the max value for all patches.

It is sufficient to report the mean and the max value only, see Table 4.

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Table 4 — Colour reproduction values

Colour checker SG	ΔE mean	ΔE max
results	2,34	5,2

7.10 Colour mis-registration

For the maximum of the edge shift between the R/G and B/G channels for all edge positions shall be reported as a single number.

7.11 Sampling rate

The claimed and obtained sampling rates shall be reported as single numbers.

7.12 Resolution

The ratio between the limiting resolution at 10 % modulation and the obtained sampling rate shall be reported for at least 9 positions over the field of view. One of the positions being in the centre and the farthest position from the centre being at least 65/100 from the centre of the field of view.

7.13 MTF 50/MTF 10

The ratio of the frequency where the 50 % modulation threshold is reached and the frequency where the 10 % modulation threshold is reached gets reported.

7.14 Sharpening

The sharpening shall be the max determined contrast value of all of the measured spatial frequency response curves.

7.15 Acutance

The acutance value shall be measured according to the table in 6.4 and be reported for all positions where the SFR/resolution is measured and the minimum value shall be marked.

7.16 Lightness non-uniformity

The lightness shall be reported for the at least 1 200 points equally spread over the field of view and the ΔL^* between the max and the min L^* value shall be reported as a single number.

7.17 Chrominance non-uniformity

The chrominance deviation from the mean shall be determined for the at least 1 200 points equally spread over the field of view and the maximum value shall be reported as colour non-uniformity.

7.18 Distortion

The max distortion level for the entire field of view shall be reported as a single number.

7.19 Reproduction scale

In case the reproduction scale differs from 1 the scale shall be reported as a ratio between the size in the digital file and the size in the original e.g. like 2:1 in case the digital file includes a magnification of 2.

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Annex A
(normative)

Test chart requirements

The test chart shall be designed to evaluate the imaging systems quality of scanners and other digital input devices used to create digital images of documents, photos and other reflective media. Individual measurements and regular checks of the target ensure that the results obtained from the measurements are reliable.

For flatbed or reprographic scanners it should be mounted on a solid backing material like aluminium or other suitable material.

The standard chart defined in this document is designed for a maximum sampling rate of 600 dots per inch (dpi). In case a manufacturer creates a chart with a resolution higher than 600 dpi, it should be indicated on the chart.

Problems with the illumination systems of test devices shall be avoided by using a material that consists of a non structured surface. For the target in combination with the production process a max density at a minimum of 2,3. Therefore the target will usually be produced on glossy material. The material shall have a white substrate with a L^* value of 94 ± 2, an a^* value between −1,0 and 1,0, and a b^* value between $-4{,}0 < b^* < 0$.

Each feature of the test target can have one or multiple functions.

The target shall be suited for visual and automatic evaluation that covers all the basic aspects of imaging systems quality and at the same time is scalable. Depending on the field of view of the system or the size of the originals that are intended to be scanned respectively, the target needs to be varied in size.

All structures designed to be neutral grey at different brightness levels should have a spectral reflectance as uniform as possible over the visual spectrum. The patches shall appear uniform under typical halogen, tungsten, and fluorescent lighting. The measured a^* and b^* values for all neutral patches (D50, 2° observer) shall not exceed the ±4 range.

The chart shall consist of the following structures:

— The size shall be that of the largest original that is intended to be scanned with the system.

— It shall contain at least one gray scale in horizontal and one in vertical position. The L^* values should be between 5 and 95 and shall be between 10 and 90. A minimum of 15 steps is required and they should be equally spaced over the L^* value range.

— At least 9 slanted edges fulfilling the requirement of the ISO 16067-1 resolution standard in combination with structures for visual resolution analysis. One edge positioned in or close to the centre and the other edges spread as a regular grid over the imaging field with the farthest distance from the centre being at least 65 % of the imaging field (diagonal).

— All edges shall be on the same target to ensure the same focus position for all evaluations.

— A regular grid (crosses, checkerboard etc.) shall surround all other structures to enable distortion and Illumination measurement.

— A black white and grey line shall cover the width and length of the entire chart to enable banding and defect pixel analysis for scanners.

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— Colour reproduction is determined on a colour checker SG which does not fit on the chart in addition to the other structures. But the chart may contain colours (e.g. a subset of the colour checker SG) that can be used for monitoring the colour reproduction.

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Annex B
(informative)

Guidelines for imaging performance aims and tolerances

Depending on the application each quality aspect may be of different importance, e.g. if a book is scanned to apply an OCR to it and make it inducible and searchable the colour accuracy is of minor importance and a high tolerance can be accepted. Therefore this document creates three quality levels for each of the characteristics. Users may combine the different quality levels they require for each characteristic to a full set of specifications.

For a manufacturer to advertise a level A compliant device according to this document the device shall be within all aim and tolerances stated for level A devices.

	Level A	Level B	Level C
Tone reproduction (of gray scale next to image centre)	$\Delta L^* \leq \pm 2$	$\Delta L^* \leq \pm 3$	$\Delta L^* \leq \pm 4$
Gain Modulation highlights Patches (L^*between 95 and 85*) (of gray scale next to image centre)	Gain between 0,8 and 1,1	Gain between 0,7 and 1,2	Gain between 0,6 and 1,3
Gain Modulation all other Patches (of gray scale next to image centre)	Gain between 0,7 and 1,3	Gain between 0,6 and 1,4	Gain between 0,3 and 1,6
Noise (RMS noise)	≤1,6	≤2	≤2,2
Dynamic range (of gray scale next to image centre)	≥2,3	≥2,1	≥1,9
Banding	Based on visual inspection, no banding	Based on visual inspection, no banding	Based on visual inspection, slight banding
Defect pixels (flat field illumination required)	No defects measurable	Less than 0,1 per million	Less than 1 per million
White balance (over field)	$\Delta E_{ab}^* \leq 3$	$\Delta E_{ab}{}^* \leq 4$	$\Delta E_{ab}{}^* \leq 5$
Colour reproduction	Max ΔE^* is recommended to be ≤ ±10 Mean $\Delta E^* \leq \pm 4$	Max ΔE^* is recommended to be ≤ ±15 Mean $\Delta E^* \leq \pm 5$	Max ΔE^* is recommended to be ≤ ±15 Mean $\Delta E^* \leq \pm 5$
Sampling rate (Difference between claimed and obtained)	≤2 %	≤3 %	≤4 %
Resolution measured as frequency where 10 % Modulation is reached (MTF10) according to ISO 16067-1 at each location in the image and in both directions horizontal / vertical	≥85 % of claimed Sampling rate	≥80 % of claimed Sampling rate	≥70 % of claimed Sampling rate
Sharpening	Max SFR contrast value ≤1,05	Max SFR contrast value ≤1,1	Max SFR contrast value ≤1,2

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	Level A	Level B	Level C
Tone reproduction (of gray scale next to image centre)	Δ*L** ≤ ±2	Δ*L** ≤ ±3	Δ*L** ≤ ±4
MTF 50	≥0,5 × the minimum frequency required for MTF10	≥0,45 × the minimum frequency required for MTF10	≥0,45 × the minimum frequency required for MTF10
Illumination non-uniformity for A3 and smaller	Δ*L** ≤ 3	Δ*L** ≤ 3	Δ*L** ≤ 3
Illumination non-uniformity for > A3 and ≤ A2	Δ*L** ≤ 4	Δ*L** ≤ 5	Δ*L** ≤ 5
Illumination non-uniformity for > A2 and ≤ A0	Δ*L** ≤ 5	Δ*L** ≤ 6	Δ*L** ≤ 6
Colour mis-registration	≤0,4 pixel	≤0,7 pixel	≤1 pixel
Distortion	≤1,5 %	≤2 %	≤5 %

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Annex C
(informative)

Example of multi-pattern chart: Universal Test Target (UTT)

C.1 Overview

The UTT test chart is designed to evaluate the imaging systems quality of scanners and other digital input devices used to create digital images of documents, photos and other reflective media. Individual measurements and regular checks of the target ensure that the results obtained from the measurements are reliable.

The target can be produced by any person or institution as long as the technical specs are met. It should be available as single sheet that can be used even for pull through scanners. For flatbed or reprographic scanners it may be mounted on a solid backing material like aluminium or other suitable material.

Problems with the illumination systems of test devices shall be avoided by using a material that consists of a non structured surface. For this target a max density at a minimum of 2,3 and a sufficient size of the colour space to produce colour patches are required. Therefore the target will usually be produced on glossy material. The material shall have a white substrate with a L^* value of 94 ± 2, an a^* value between −1,0 and 1,0 and a b^* value between $-4{,}0 < b^* < 0$.

C.2 Chart features

Each feature of the test target has one or multiple functions and of course there is no such thing as a perfect target. There are always compromises in one feature for the benefit of another.

But with the UTT test chart we hope to provide a target based on the experience of a group of people who have used scanners and digital cameras for years.

The idea behind the UTT test chart was to have a universal target for visual and automatic evaluation that covers all the basic aspects of imaging systems quality and at the same time is scalable. Therefore we have implemented a variety of features that will be explained in the following subclauses.

All structures designed to be neutral grey at different brightness levels should have a spectral reflectance as uniform as possible over the visual spectrum. In order to drop the cost of the target a compromise for spectral non uniformity needs to be made but kept in mind for the production process. The patches shall appear uniform under typical halogen, tungsten, and fluorescent lighting. The measured a^* and b^* values for all patches (D50, 2° observer) shall not exceed the ±4 range.

C.3 Scalability

Designed as a 420 mm × 300 mm (approximately A3) chart the target can repeatedly be put together to sizes up to A0 or even bigger. The Grey bars and scales are designed in a way that they go through the whole width and length of the target and the slanted edges are spread at equal distances of 140 mm. see Figures C.1 to C.4.

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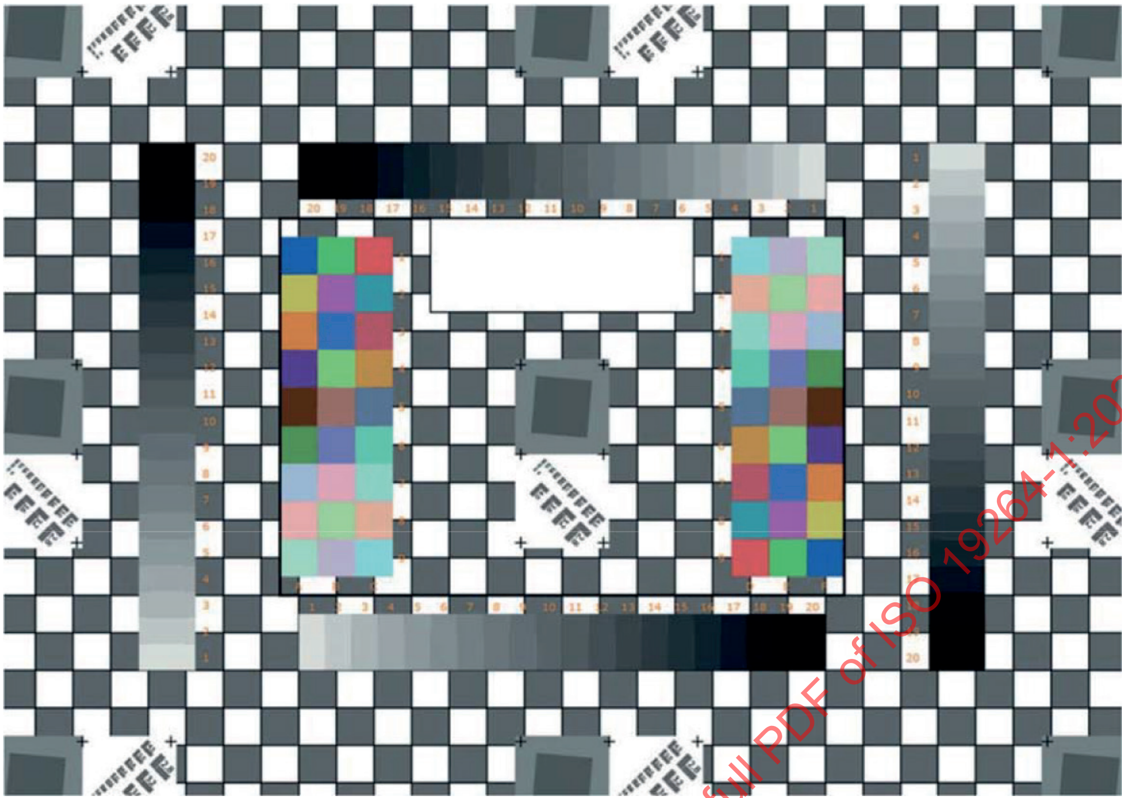

Figure C.1 — Basic A3 version

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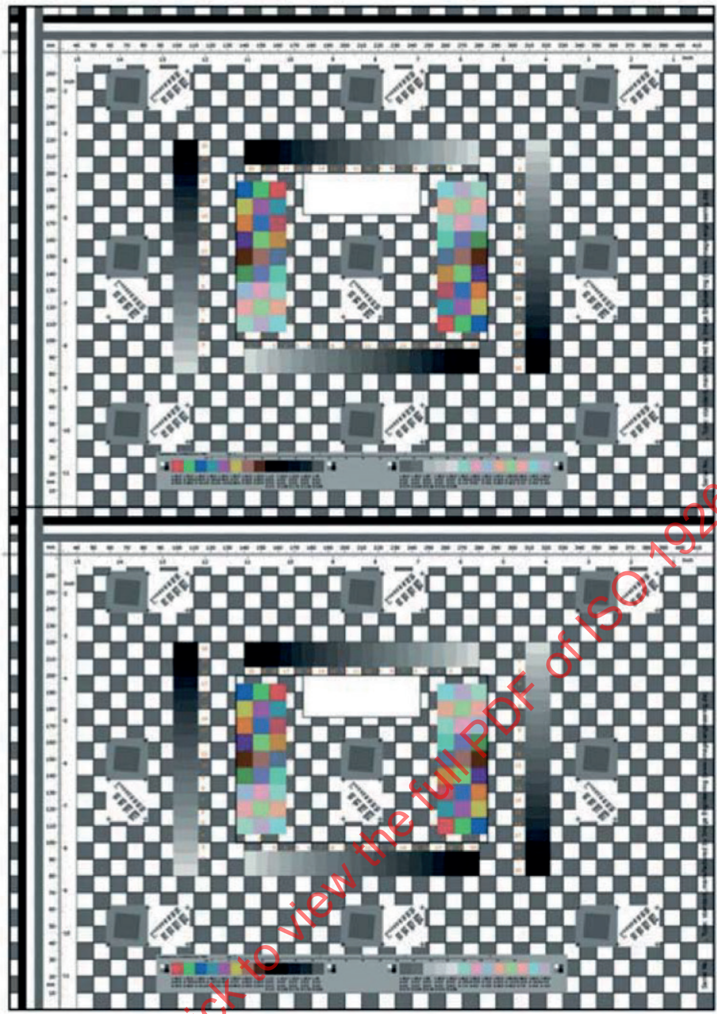

Figure C.2 — A2 arrangement

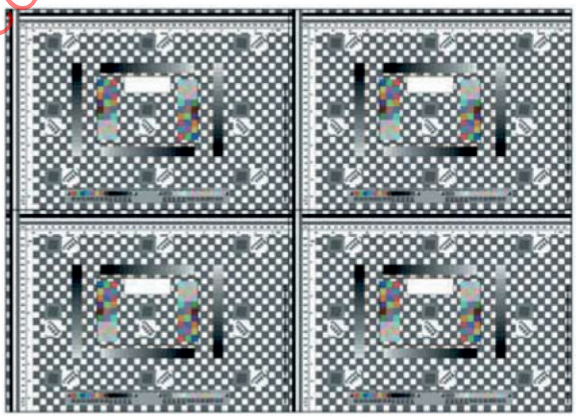

Figure C.3 — A1 combination

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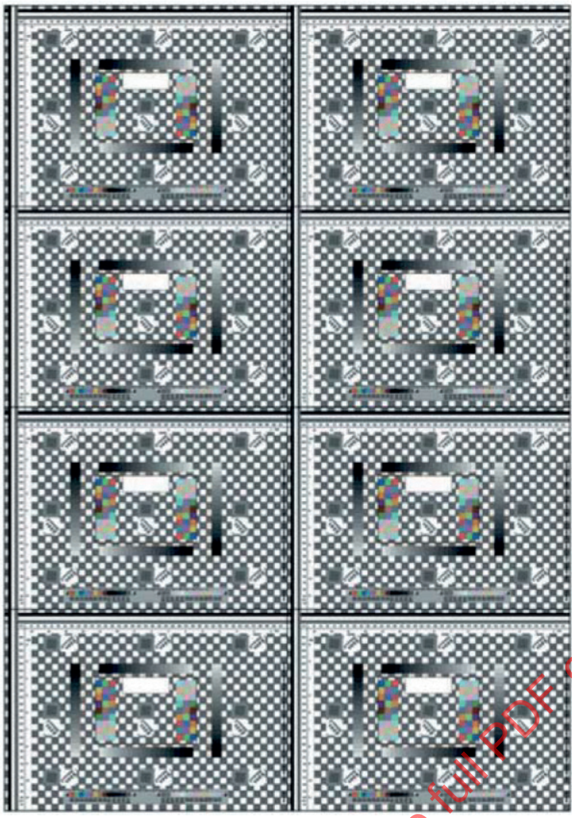

Figure C.4 — 8 targets combined into one A0 chart

C.4 Tolerances

If not otherwise stated the geometric tolerances are a max of 1 per million of the absolute values. This is especially valid for the scale and the checkerboard.

For everything that needs to be mounted on top of the target – like the resolution boxes – the mounting should be within ±1 mm from the assigned position.

ΔL^* and ΔE^* values shall be measured according to ISO/CIE 11664-4 for D50 and the 2° standard observer.

$$\Delta E_i^* = \sqrt{\left(L_i^* + L_{\text{ref}}^*\right)^2 + \left(a_i^* + a_{\text{ref}}^*\right)^2 + \left(b_i^* + b_{\text{ref}}^*\right)^2} \quad \text{(C.1)}$$

$$\Delta L_i^* = \sqrt{\left(L_i^* + L_{\text{ref}}^*\right)^2} \quad \text{(C.2)}$$

For grey patches the overall mean ΔL^* should be <2 and the max ΔL^* should be <3.

The mean ΔE^* (including the colour aspect) for the grey patches should be <2,5 and the max ΔE^* should be <4,5.

Within a single colour patch the ΔL^* value should be <0,5.

For the colour patches the Delta values are defined as in the following Table C.1.

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Table C.1 — Delta values

Tolerances ΔE	Mean	Max
A1:C4, D6:F9	<5	<7
A5:C6, D4:F5	<4	<5
A7:C9, D1:F3	<2	<4

C.5 Surrounding black line

A 1 mm thick line surrounds the target with the centre of the line being a rectangle of 420 mm × 300 mm. The line is needed to combine single targets into larger arrangements of A2 to A0 and to cut the larger arrangements into smaller targets without destruction of any important features. The line lies on top of all other structures described.

C.6 Background checkerboard

A checkerboard structure forms the background of the target. The patch size is 10 mm × 10 mm and starts with a white patch at the left lower corner of the target. The darker patches are neutral grey with a L^* value of 50. Each patch is surrounded by a 0,38 (1 pt) black line. The checkerboard can be used for uniformity analysis, white balance checking, and distortion and deviation analysis.

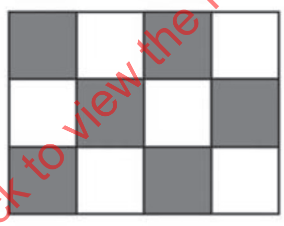

Figure C.5 — Example of checkerboard

C.7 Grey scale pattern

Three horizontal grey bars (substrate white, max black, and L^* 50) are located at the top of the target 5 mm from the border crossing the whole target. A replication of the same 3 bars is also vertically oriented on the left side of the target 5 mm from the border crossing the whole height of the target. These bars are designed for a variety of different purposes. They can be used for white balancing, uniformity checks for scanners, noise analysis, stripes and dead pixel analysis, dark current analysis, etc. The vertical bar lies on top of the horizontal one.

Figure C.6 — Example of grey bars

C.8 Scales

There are two scales, a horizontal and a vertical one with a white background located next to the inside of the colour bars and lying behind the colour bars and on top of the checkerboard. There is one centre line for each scale with a millimetre and an inch scale next to it. On outside of the centre line is the

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millimetre and on the inside is the inch scale. The exact location and dimensions off the scale can be found in the Excel spec sheet. The millimetre scale starts at the left side of the horizontal scale and at the bottom of the vertical one. The inch scale starts at the right side of the chart and at the top. The white background of the scales is located behind the two scales so that the crossing of both scales at 30 mm/30 mm is visible.

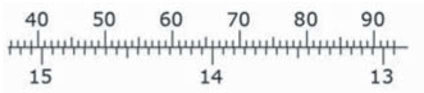

Figure C.7 — Example of scale

The scales are used to check deviation especially but not exclusively for pull through scanners and artefacts that affect the lines of a scale.

C.9 Grey scales

There are 4 grey scales, two horizontal ones and two vertical ones located half way between the border and the centre of the target. That means the vertical ones are vertically centred and located 105 mm left and right of the centre and the horizontal ones are horizontally centred and located 62,5 mm above and below the centre. The vertical version of the scale is 15 mm wide and each patch is 7 mm high. And the horizontal version is 90° tilted.

Each grey scale consists of 20 patches starting at *L** of 5 with 5 *L** value increments (5 to 95) and the last patch representing the max black of the target at a density level of app. 2,3 or above. Tolerances are given in C.3. The left vertical scale stats with *L** 95 at the bottom, the right one with *L** 95 at the top. The upper horizontal scale has L* 95 on the right and the lower on the left side. Exact locations are given in the Excel spec sheet. Patch numbers start at *L** 95 with 1. The numbers shall be printed on the inside of the scale in 8 pt Verdana and orange colour.

The grey levels shall be produced as gray tones without using a screening technology that may affect the noise measurement. In case a screening technology cannot be avoided the actual dot size needs to be 10 times smaller than the size per pixel expected be the camera or scanner. If this requirement cannot be met, noise and signal to noise ration cannot be measured. In this case the tonal values shall also be measured as an average value of a size big enough to cover at least 64 printing dots.

Figure C.8 — Example of grey scale

C.10 Colour patches

The colour patches are a similar to a subset of the x-rite colour checker SG. But with the production cost in mind the colour have been slightly modified. The first 18 colours are similar to the original colour checker and the last 9 colours are the highlight patches of columns D and K of the colour checker SG. In order to perform a detailed colour check the original x-rite colour checker SG or an IT8 target shall be used.

The colour patches with a size of 10 mm × 10 mm for each patch are aligned in 3 columns an 9 rows with the central patch B5 located at 150 mm/150 mm from the left bottom of the target are shown in Figure C.9. A copy of the set is rotated 180° and placed at the same distance from the target centre on its right side (E5 270/150). The exact locations can be found in the Excel spec sheet and tolerances for the colours are given in C.3. The targeted *L**, *a**, *b** values can be found in Table C.2.

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Figure C.9 — Example of colour patches

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Table C.2 — Targeted L^*, a^*, b^* values

Colour patches	L^*	a^*	b^*
A1	18	24	−61
A2	82	3	90
A3	61	38	74
A4	21	35	−32
A5	32	24	32
A6	45	−32	38
A7	85	−2	−9
A8	86	13	7
A9	90	−17	6
B1	53	−45	38
B2	49	56	−14
B3	35	12	−53
B4	72	−25	65
B5	64	20	19
B6	53	8	−27
B7	85	13	0
B8	85	−11	26
B9	85	4	−6
C1	46	64	34
C2	48	−34	−31
C3	48	54	21
C4	71	19	80
C5	47	−5	−25
C6	69	−35	−1

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Table C.2 *(continued)*

Colour patches	*L**	*a**	*b**
C7	86	−19	−1
C8	87	10	18
C9	85	−14	−9

The numbers shall be printed as shown on the bottom and the inside of the scale in 8 pt Verdana and orange colour.

C.11 Slanted edges

The slanted edge structures are designed for SFR (spatial frequency response) measurements used to determine sharpness and resolution of the imaging system. They shall be combined with the visual resolution ones into a box of 50 mm × 25 mm. The box located on the imagined centred horizontal line shall be rotated by 90° clockwise. Each slanted edge structure is arranged on an imagined 140 mm grid from the target centre. The slanted edge is located on the left side of the box with a rectangle of 25 mm × 25 mm and a grey level of *L** 63. Centred within that box is another box of 15 cm × 15 cm and a grey level of *L** 34 that is rotated by 5°. On the right side of the outer box there shall be another substrate white box of 25 mm × 25 mm that contains the visual structures described in 4.8. In the corners and the upper and lower centre of the 50 mm × 25 mm box there shall be crosses needed for the automatic detection. These crosses consist of 3 mm black lines with 0,38 mm thickness.

Figure C.10 — Example of slanted edges

The exact dimensions and locations can be found in the Excel spec sheet.

The manufacturer shall be responsible for the sharpness of the slanted edge. The edge shall be sufficient (and not be the bottle neck) to measure scanner resolutions of up to 600 pixels/in (~ 12 LP/mm) according to ISO 16067.

C.12 Visual resolution structures

The visual resolution structures shall be the ones specified in DIN 19051-2 target starting at 2,8 LP/mm up to 18 LP/mm. They shall be centred in the white box and rotated 45° clockwise (see image under 4.7).

The manufacturer shall be responsible for an appropriate resolution up to 18 LP/mm.

C.13 Additional chart border

Those who want to perform an additional more detailed colour check can mount an IT8 target inside of the additional chart border in centre of the ISO 19264 test chart. By doing that the centre SFR structure, the colour patches of the ISO 19264 test chart, and the background checkerboard will be covered and cannot be used.

The additional chart border is a transparent rectangle 150 mm × 100 mm with a 0,76 mm black contour line.

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C.14 Labelling patch (for sponsor logo, provider information etc.)

The labelling patch is a substrate white rectangle with a size of 70 mm × 25 mm and a contour line of 0,38 mm with its centre located at 210 mm/187,5 mm from the bottom left of the target.

In the patch there shall be the name "ISO 19264 test chart" printed in black letters of Verdana Bold 4.94 mm (14 point) centred at 210 mm/195 mm from the bottom left of the target.

The area below the name can be used for custom logos and descriptions.

C.15 Serialization

Each target shall have a serial number provided by the manufacturer, the target type, an expiration date depending on the production process but no longer than 3 years from the production date and the manufacturer mentioned. Manufacturer meaning not the one who provides the target but the institution or person who printed it.

Target types: xxx

The statement shall be printed vertical from bottom to top on the right edge of the target in black letters of Verdana 3.53 mm (10 point) and having the following format: "Serial No. 000001, Type: standard, expires YYYY/MM, manufactured by XXX".

No logos or coloured structures shall be used in this place.

QR code for target serialization can be put in the labelling patch area or in the space for optional test pattern.

C.16 Space for optional test pattern

Optional test pattern shall not be higher than 25 mm and not be wider than 250 mm and shall be horizontally and vertically centred between the bottom and the lower slanted edge boxes.

For internal use every company may use this area for whatever it is needed. If a specific version of the ISO 19264 test chart with optional patches becomes publicly available the manufacturer or integrator should put the specs with tolerances of these on the ISO 19264 test chart website (send to webmaster).

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C.17 Representation of the target

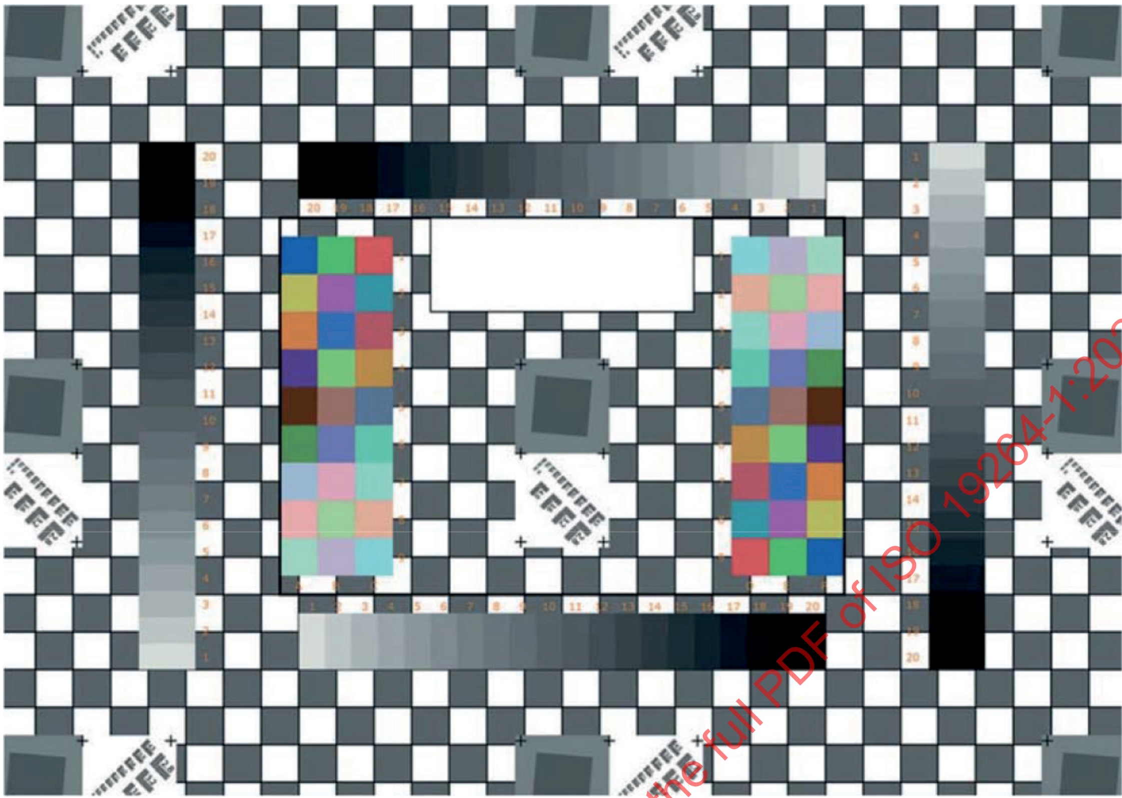

Figure C.11 — Representation of the ISO 19264 test chart designed according to this document

C.18 Chart definition of the ISO 19264 test chart

If not mentioned x and y coordinates describe the lower left corner of the structure and all geometric values are given in millimetres.

Lower left corner of the document is defined as 0,0 mm.

Document height 420

Document width 300

Surrounding black line

The chart is surrounded by a black line with 1mm thickness with the centre of the line being the border of the chart. Line is on top of all structures.

Gray bars	*x*	*y*	Width	Height	Aimed *L** value
horizontal black	0	290	420	5	max black
horizontal white	0	285	420	5	substrate white
horizontal gray	0	280	420	5	50
vertical black	5	0	5	300	
vertical white	10	0	5	300	
vertical gray	15	0	5	300	

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Background Checker-board	*x*	*y*	Width	Height	Aimed L^* value
first white patch	0	0	10	10	substrate white
first grey patch	10	0	10	10	50
continued as checker-board		Each patch is surrounded by a black line of 0,38 mm thickness with the line centre being the border of each patch.			

Vertical scale	*x*	*y*	Width	Height	Aimed L^* value	Contour
centre line	30	0	0	300	max black	0,19
mm lines	29	every mm	1	0	max black	0,19
5 mm lines	28,5	every 5 mm	1,5	0	max black	0,19
10 mm lines	27,5	every 10 mm	2,5	0	max black	0,19
lettering	every 10 mm, Verdana 8 pt on left side of scale					
1/16 Inch lines	30	every 1/16 Inch	1	0	max black	0,19
1/2 Inch lines	30	every 1/2 Inch	1,5	0	max black	0,19
Inch lines	30	every Inch	2,5	0	max black	0,19
lettering	every inch, Verdana 8 pt on right side of scale					
surrounding white	0	20	20	300	substrate white	behind both scales
Scale on top of background checkerboard and behind horizontal grey bars						

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Horizontal scale	*x*	*y*	Width	Height	Aimed L^* value	Contour
centre line	0	272,4	420	0	max black	0,19
mm lines	every mm	272,4	0	1	max black	0,19
5 mm lines	every 5 mm	272,4	0	1,5	max black	0,19
10 mm lines	every 10 mm	272,4	0	2,5	max black	0,19
lettering	every 10 mm, Verdana 8 pt on upper side of scale					
1/16 Inch lines	every 1/16 Inch	271,4	0	1	max black	0,19
1/2 Inch lines	every 1/2 Inch	270,9	0	1,5	max black	0,19
Inch lines	every Inch	269,9	0	2,5	max black	0,19
lettering	every Inch, Verdana 8 pt on lower side of scale					
surrounding white	0	265	420	15	substrate white	behind both scales
Scale on top of background checkerboard and behind vertical grey bars						

In contrast to the rest of the features the position given for the grey scales describe the centre of each patch and not the lower left corner

Left vertical grey scale	*x*	*y*	Width	Height	Aimed L^*	Density
GS_L_1	105	83,5	15	7	95	0,06
GS_L_2	105	90,5	15	7	90	0,12
GS_L_3	105	97,5	15	7	85	0,18

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Left vertical grey scale	*x*	*y*	Width	Height	Aimed L^*	Density
GS_L_4	105	104,5	15	7	80	0,25
GS_L_5	105	111,5	15	7	75	0,32
GS_L_6	105	118,5	15	7	70	0,39
GS_L_7	105	125,5	15	7	65	0,47
GS_L_8	105	132,5	15	7	60	0,55
GS_L_9	105	139,5	15	7	55	0,64
GS_L_10	105	146,5	15	7	50	0,73
GS_L_11	105	153,5	15	7	45	0,84
GS_L_12	105	160,5	15	7	40	0,95
GS_L_13	105	167,5	15	7	35	1,07
GS_L_14	105	174,5	15	7	30	1,21
GS_L_15	105	181,5	15	7	25	1,36
GS_L_16	105	188,5	15	7	20	1,52
GS_L_17	105	195,5	15	7	15	1,72
GS_L_18	105	202,5	15	7	10	1,95
GS_L_19	105	209,5	15	7	5	2,26
GS_L_20	105	216,5	15	7	3	$D_{max} > 2,3$

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Numbering	Colour	Typo
Numbers on right side	orange	Verdana 8pt

Right vertical gray scale	*x*	*y*	Width	Height	Aimed L^*	Density
GS_R_1	315	216,5	15	7	95	0,06
GS_R_2	315	209,5	15	7	90	0,12
GS_R_3	315	202,5	15	7	85	0,18
GS_R_4	315	195,5	15	7	80	0,25
GS_R_5	315	188,5	15	7	75	0,32
GS_R_6	315	181,5	15	7	70	0,39
GS_R_7	315	174,5	15	7	65	0,47
GS_R_8	315	167,5	15	7	60	0,55
GS_R_9	315	160,5	15	7	55	0,64
GS_R_10	315	153,5	15	7	50	0,73
GS_R_11	315	146,5	15	7	45	0,84
GS_R_12	315	139,5	15	7	40	0,95
GS_R_13	315	132,5	15	7	35	1,07
GS_R_14	315	125,5	15	7	30	1,21
GS_R_15	315	118,5	15	7	25	1,36
GS_R_16	315	111,5	15	7	20	1,52
GS_R_17	315	104,5	15	7	15	1,72
GS_R_18	315	97,5	15	7	10	1,95
GS_R_19	315	90,5	15	7	5	2,26
GS_R_20	315	83,5	15	7	3	$D_{max} > 2,3$

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