Technical Specification

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Graphic technology — Image quality evaluation methods for printed matter —

Part 31:
Evaluation of the perceived resolution of printing systems with the Contrast–Resolution chart

Technologie graphique — Méthodes d'évaluation de la qualité d'image pour les imprimés —
Partie 31: Évaluation de la résolution perçue des systèmes d'impression avec un graphique de contraste–résolution

Reference number
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Contents

Page

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 document 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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This document was prepared by Technical Committee ISO/TC 130, *Graphic technology*.

This second edition cancels and replaces the first edition (ISO/TS 18621:2020), which has been technically revised.

The main changes are as follows:

— in subclause 5.5:

  — Formula (1) has been corrected, including interchanging symbols ‘*f*’ and ‘*g*’;

  — in the NOTE the ‘Sample’ and ‘Ref’ arguments are switched;

— the text for step 13 in subclause 5.6 has been concretized;

— steps 18 and 19, also in Figure 8, have been adapted with a change from ‘unacceptable’ to ‘suspect’;

— the text in Annex A, before Table A.2, has been concretized;

— the text in E.2, 3rd paragraph, has been concretized;

— replacement of the three PDF files in the ‘TestCharts’ folder at the ISO server for ‘Electronic Inserts’ by a single ZIP file ‘TestCharts_2020correction.zip’.

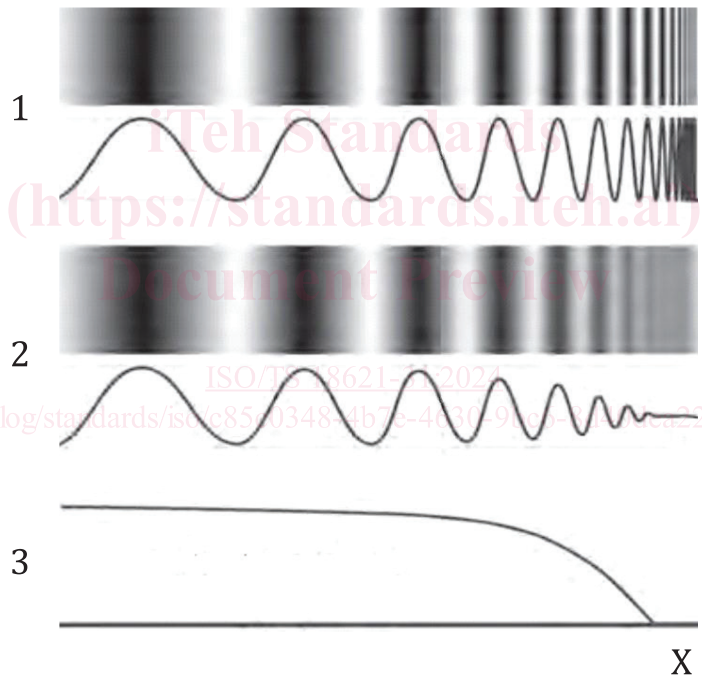
A list of all parts in the ISO 18621 series can be found on the ISO website.

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.

Introduction

Perceived resolution, the capability to perceive fine detail, is a measure of full system capability and depends upon characteristics of the printing system (substantially more than just its addressability), characteristics of the substrate, of the viewing conditions, and of the observer. Perceived resolution depends critically upon tonal differences between elements of an image – there is no perceived detail, hence no measure of resolution, when there is no tonal difference in an image. The three major contributors to the perceived resolution of a printing system are the capability of a printing system to maintain a desired spatial separation between nearby elements printed on a substrate (the addressability of a printing system indicates what the minimum spatial separation can be), the capability of the printing system to carry tonal differences (contrast) between these nearby printed elements, and the capability of the human visual system to perceive the printed detail. The design of a test chart and an evaluation process for measuring a printing system's capability to carry fine detail must reflect these major contributors.

Fourier analysis has proven very useful in analysing the reproduction capability of image forming systems[1]. In this formalism, spatial separation is measured in terms of spatial frequency (e.g. cycles per millimetre) and contrast is measured in terms of modulation (the dimensionless ratio of a change in perceived luminance to its average luminance) at a particular spatial frequency. The ratio of the reproduced modulation to the original (desired) modulation can be used to describe the capability of a printing system to reproduce a sinusoidal input at a particular spatial frequency. This ratio, taken over a range of spatial frequencies is called the modulation transfer function (MTF).



Key

X spatial fequency

1 modulation of original (constant amplitude)

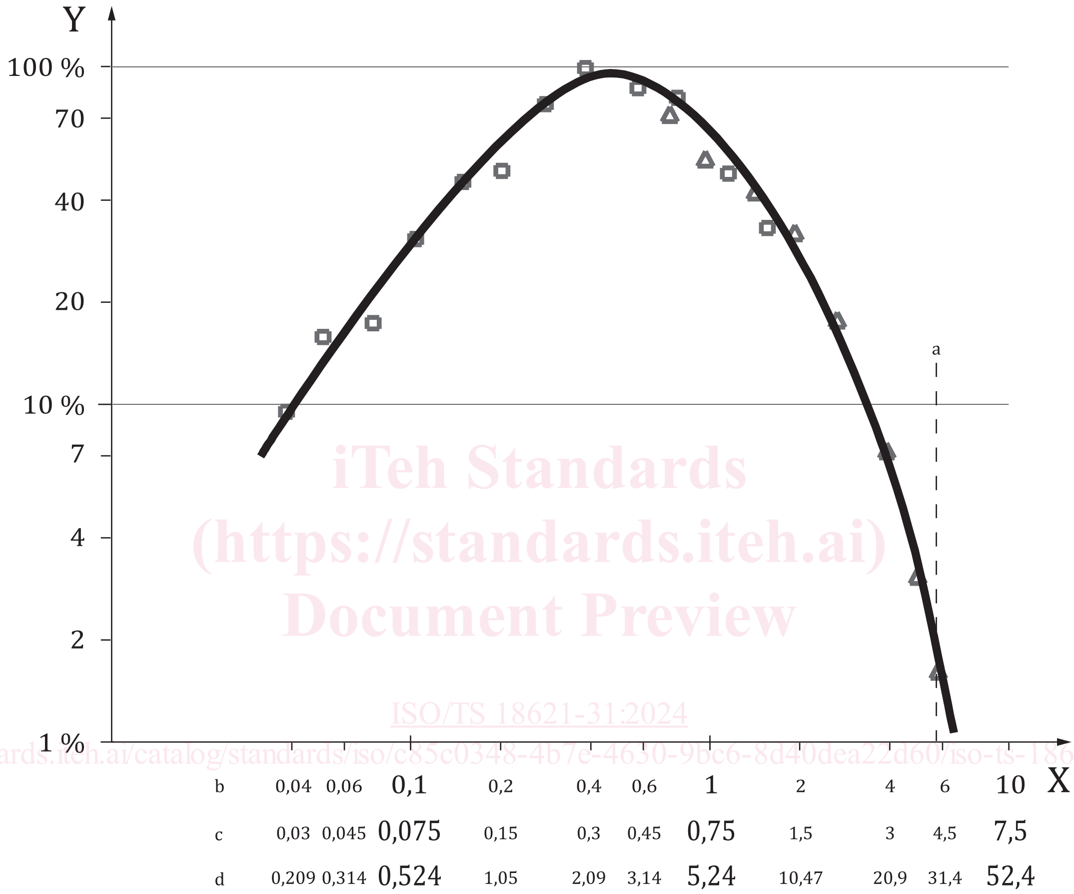
2 modulation of reproduction (with limited resolution)

3 modulation transfer function (decreases due to limited resolution)

Figure 1 — Modulation transfer function of a printing system

The MTF characteristic shows the ratio of the reproduced modulation to the original (input) modulation as a function of spatial frequency and provides a very useful description of printing system capability. The decrease at high frequencies of the modulation transfer function shown in Figure 1 characterizes the common degradation in printing system image detail capability at high spatial frequencies.

In characterizing perceived resolution, a single component of the imaging chain cannot be isolated since we look at the results of the complete system. The printing system imaging chain starts with the process of placing marks on a substrate. In many printing systems, the individual marks can provide only a limited number of tonal levels and the full tonal range is provided by subsequent area modulation (screening) of the marks. This screening process can strongly affect the image detail capability of a printing system. The characteristics of the substrate can affect both the effectiveness of placing these marks (e.g. surface roughness) and affect the interplay between the placed marks and the illumination required for viewing the printed image (e.g. light scattering in the substrate). Finally, perceived resolution depends upon the viewing conditions (illumination, viewing distance, and magnification) as well as the capability of the human observer to perceive detail. The capability of normal human vision to perceive spatial detail can be characterized by a modulation transfer function (see Reference [2]). This is shown in Figure 2.



Key

X spatial frequency

Y relative contrast sensitivity

[a] 6/6 visual limit.

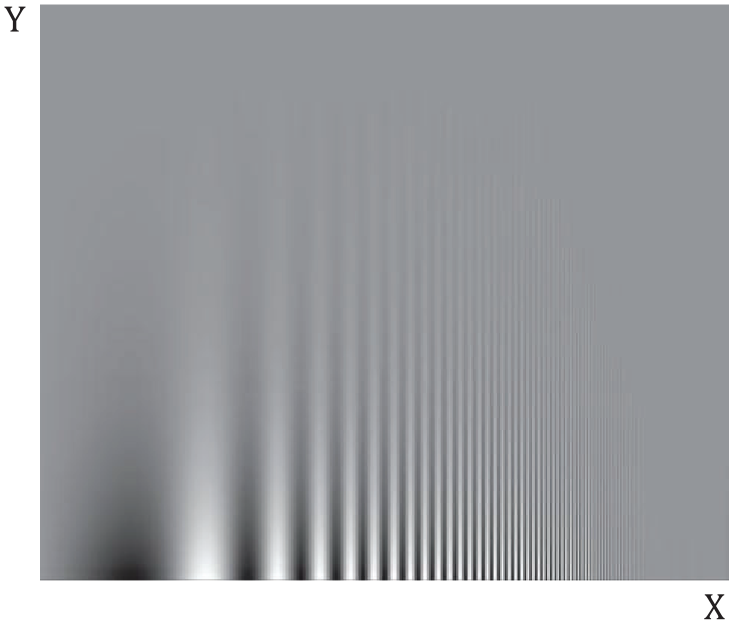
[b] cy/mm at 300 mm.

[c] cy/mm at 400 mm.

[d] cy/degree.

Figure 2 — Contrast sensitivity function of a human observer

The natural units for the perceptual contrast sensitivity function are cycles per degree, which are independent of viewing distance. Shown as a dotted line on the right of Figure 2 is the ophthalmological limit of visual acuity known as 6/6 vision in metric units which means a person being examined can see the same level of detail at 6 m as a person with "normal" visual acuity would see at 6 m distance. This visual limit corresponds to a spatial frequency of about 6 cy/mm at 300 mm viewing distance or about 4,5 cy/mm at a viewing distance of 400 mm. At a viewing distance of 400 mm the human visual system response to spatial detail peaks at about 0,4 cy/mm (0,5 cy/mm at 300 mm), decreasing in sensitivity at both higher and lower spatial frequencies.



Key

X spatial frequency

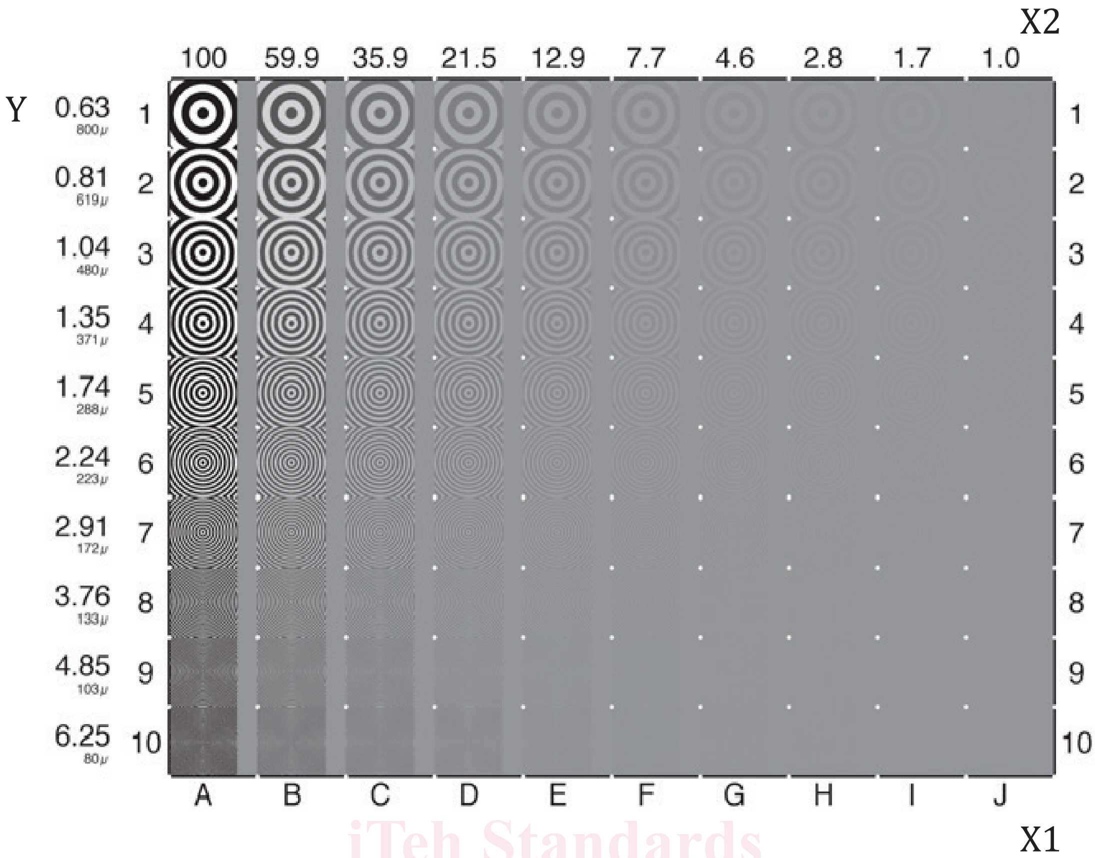
Y contrast

Figure 3 — Illustrative contrast sensitivity function (Reference [3])

A visual illustration of the dependence of perceptual detail reproduction capability on both spatial frequency (horizontal axis) and contrast (vertical axis) is shown in Figure 3 (see Reference [3]). The perception of fine detail is frequency dependent and can be perceived well at high contrast, but not as well at low contrast.

For given viewing conditions (illumination, viewing distance, magnification), measurements at extreme spatial frequencies are irrelevant to the characterization of the perceived resolution of a printing system as their effects cannot be seen (e.g. the far right side of Figure 2 or Figure 3).

The illustration shown in Figure 3 also illustrates the peak in visual sensitivity in the mid spatial frequency range and is a major motivation for the test chart design utilized in this method for evaluating the perceived resolution of a printing system. A test chart that explores modulation or contrast along one axis and spatial frequency along an orthogonal axis covers a large fraction of the major contributors to the perceived resolution of a printing system. Figure 4 shows the Contrast–Resolution test chart[4].



Key

X1 contrast

X2 reference tone value = 50 %

Y resolution, line pairs per millimetre, log steps

NOTE Reproduced with permission from Sicofilm A.G.

Figure 4 — Elements of the Contrast–Resolution test chart

In Figure 3, contrast and spatial frequency vary continuously. In Figure 4, each circularly symmetric element explores a particular sampled contrast and spatial frequency – the individual patches in the target. The spatial frequency of separation of these circularly symmetric marks and spaces in each patch is varied logarithmically along the vertical axis of the target and the contrast, or depth of modulation, is varied logarithmically along the horizontal axis. This logarithmic spacing mimics the largely logarithmic response characteristics of the human visual system. This representation of contrast vs. spatial frequency resembles the Campbell and Robson illustration flipped on its side. The circularly symmetric shape, and the range of values explored in the Contrast–Resolution test chart are well suited to the characterization of digital printing workflows.

In a conventional printing system, there are processes at four spatial frequencies that interact with each other to form an image on the substrate. The first frequency is the spatial frequency of detail in an imaged scene (this is represented by the vertical axis of the Contrast–Resolution test chart). The second spatial frequency is the sampling frequency of the pixel grid in the digital image to be reproduced. The Contrast–Resolution test chart shown in Figure 4 is vector based, not a bitmap, therefore there are no image pixels. The third spatial frequency is the addressability grid of the printing device. The printing system raster image processor (RIP) maps the image pattern to the addressability grid and then decides, for each individual addressability location, how to image that spot. For a binary printing device (e.g. offset or flexo printing), the spot is either turned on or off. For a non-binary output device (e.g. some electrostatic or inkjet systems), where the output spots can be imaged at more than one gray level, the RIP also determines at which gray level the output spot needs to be imaged. These individual spots are utilized by the RIP to build the screening pattern that carries the tone scale of the image. The spatial repetition frequency of this screen is the fourth frequency in this printing process. All of these frequencies have the potential to interfere with one another, and hence have the potential to introduce moiré.

The Contrast–Resolution test chart was designed for visual evaluation. Evaluation starts at the top of column A (lowest spatial frequency and highest contrast) and moves down the target towards higher spatial frequencies – note how a moiré pattern gradually develops between the circular lines and addressability grid of the printer. The observer is tasked to find, for each column of the target, the patch at the highest spatial frequency at which the circular lines in the patch are still recognizably reproduced – where no lines or spaces are missing or overlap and where the level of moiré interference does not obscure the circles. For each column in the target, an index value that is the row number (each row is a single spatial frequency) of the last recognizable patch is recorded. This operation maps the threshold curve along columns in the Contrast–Resolution target where circular elements are no longer recognizable. The area enclosed by this threshold curve can be used as a capability score for the printing process. In observation, the circular nature of the lines in each pattern tends to average out any angular dependencies in system resolution.

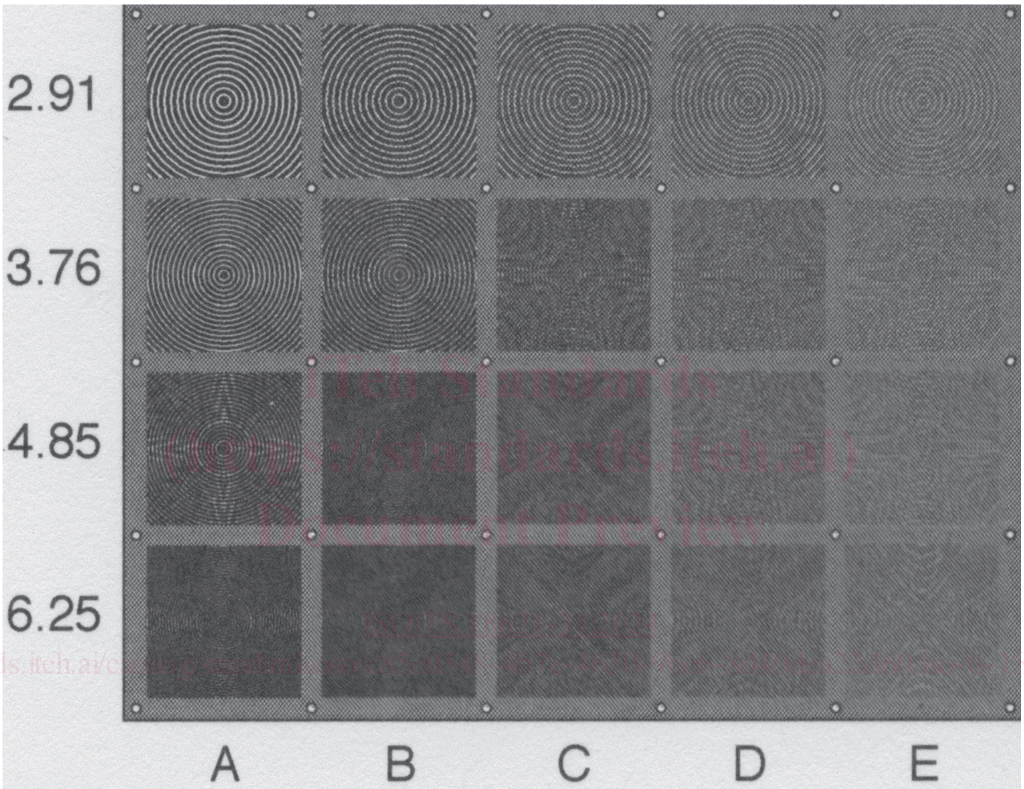


Figure 5 — Enlarged portion of a Contrast–Resolution target print

Figure 5 shows an enlarged portion of a print made with a 1 200 spot per inch addressability, utilizing a 133 line per inch dot screen. The circular patterns of the 2,91 cy/mm Row in Columns A through E are clear. The circular patterns of the 3,76 cy/mm Row in Columns A and B are clear, but are not legible in Columns C, D or E. The circular pattern of the 4,85 cy/mm Row in Column A is present with some aliasing. The circular pattern of the 6,25 cy/mm Row in Column A is barely legible with significant aliasing. The resolution capability of this printer configuration degrades significantly as the contrast is lowered – none of the other patches in Figure 5 shows a recognizably circular pattern. An illustration of an index value threshold curve (white line) and its enclosed area (above the white line) is shown in Figure 6.

The procedure specified in this document provides an automated, objective measurement surrogate of the detailed visual examination process previously used in the evaluation of the Contrast–Resolution test chart. The initial form of this procedure, developed by Liensberger[5], provided a single valued score (L-score) that correlated well with subjective impression, based upon the area of a threshold curve derived from normalized cross-correlation coefficients. A refinement of this automated procedure proposed by Uno and Sasahara[6] and called resolution-score forms the basis for this document. An international verification test was conducted, involving both objective measurements, using this improved procedure, and subjective evaluation of Contrast–Resolution test charts printed with a variety of printing systems. These experiments showed very good correlation of objective measurements with subjective evaluations using the improved resolution-score procedure.

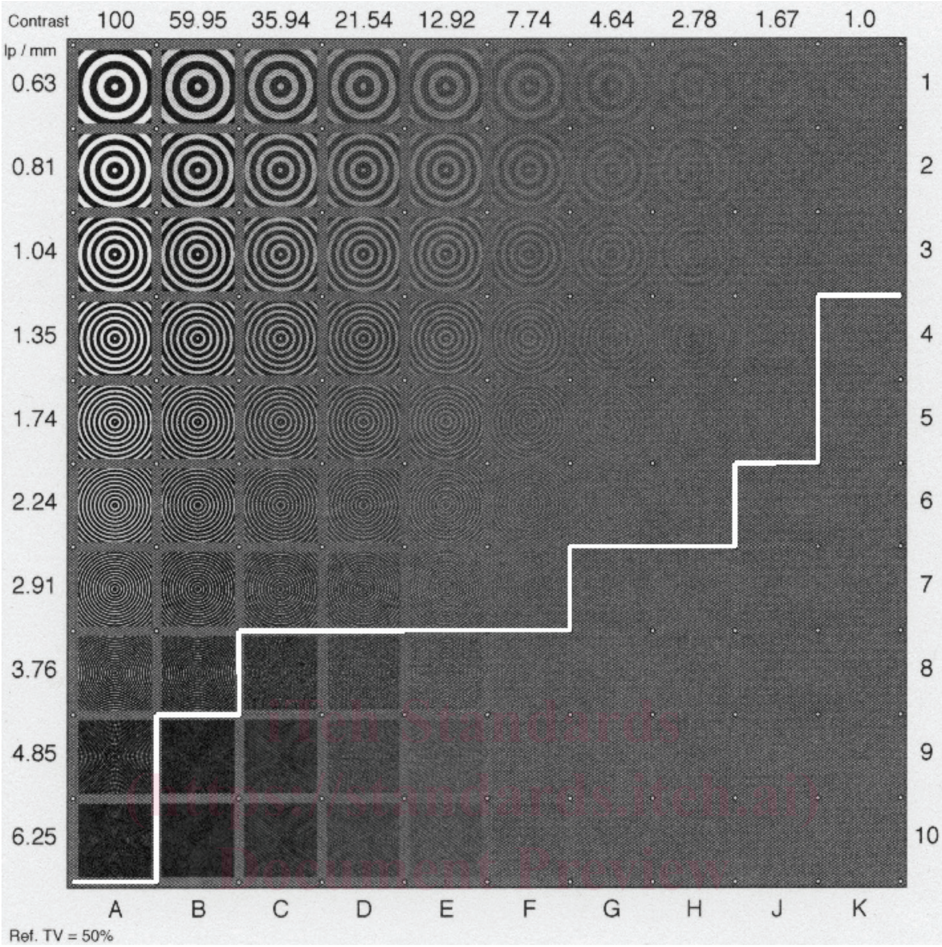


Figure 6 — Enclosed area above an index value threshold curve

Both objective measurement and subjective evaluation of Contrast–Resolution test charts printed with process colorants are minimally affected by the low levels of colorant mis-registration present in modern, well maintained printing systems. The level of colorant mis-registration in printed test charts should be verified to be low when utilizing the procedure specified in this document with process color printing.

Clause 4 specifies the requirements of the workflow settings needed to effectively print the Contrast–Resolution test chart, the setup requirements of the printer utilized to reproduce these test charts, the requirements of the scanner characteristics needed to effectively digitize the information reproduced on the printed test charts, and the requirements of the scanner data processing path needed to properly represent this information for automated evaluation.

Clause 5 specifies the resolution-score measurement procedure.

Clause 6 specifies the reporting of results obtained with the process specified in Clause 5.

Graphic technology — Image quality evaluation methods for printed matter —

Part 31: Evaluation of the perceived resolution of printing systems with the Contrast–Resolution chart

1 Scope

This document specifies the Contrast–Resolution test chart, the requirements on the printing process needed to reproduce this test chart, the required characteristics of a high resolution scanner needed to digitize the information reproduced on printed test charts, and the requirements on the interpretation of this digitized data. It also specifies the resolution-score method for evaluating the perceptual resolution of printed material using the Contrast–Resolution test chart.

The procedure specified in this document is intended for a characterization of the perceived resolution of a graphic arts production printing system using the Contrast–Resolution test chart.

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 5 (all parts), *Photography and graphic technology — Density measurements*

ISO 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

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

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

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 https://www.electropedia.org/

3.1
aliasing
output image artifacts that occur in a sampled imaging system for input images having significant energy at frequencies higher than one half the spatial sampling frequency of the system

3.2
luminance factor
CIE Y
Y
dimensionless ratio of the luminance of the surface element, in the given direction, to that of the perfect reflecting diffuser identically illuminated and viewed

Note 1 to entry: It is defined by the CIE and denoted as CIE Y.

Note 2 to entry: The luminance factor of the perfect reflecting diffuser identically illuminated is 100.

3.3
CIE L*
L*
metric lightness
function of luminance factor, defined by the CIE which approximates the human visual system response to achromatic stimuli

Note 1 to entry: For luminance factors greater than 0,008 856, $L^* = 116(Y/Y_n)^{1/3} - 16$. For luminance factors less than or equal to 0,008 856, $L^* = 903,3\ (Y/Y_n)$.

Note 2 to entry: Y_n is the luminance factor of a white achromatic reference, typically the perfect reflecting diffuser.

3.4
ICC profile
International Color Consortium's file format used to store transforms from one colour encoding to another, e.g. from device colour coordinates to profile connection space, as part of a colour management system

Note 1 to entry: The colour management system is standardized as ISO 15076-1[7].

3.5
modulation
difference between the minimum and maximum signal levels divided by the sum of these levels

3.6
modulation transfer function
MTF
ratio, as a function of spatial frequency, of the measured modulation response in a print produced by a printing system, to the stimulus modulation presented to that printing system

3.7
opto-electronic conversion function
OECF
relationship between the input levels and the corresponding digital output levels for an opto-electronic digital image capture system

3.8
perceived resolution
subjective impression of the capability of an imaging system to depict fine detail

3.9
reflectance factor
dimensionless ratio of the radiant or luminous flux reflected in the directions delimited by the given cone to that reflected in the same directions by a perfect reflecting diffuser identically irradiated or illuminated

3.10
resolution
measure of the ability of a digital imaging system to depict fine detail