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Information technology — Office equipment — Test pages and methods for measuring monochrome printer resolution

Technologies de l'information — Équipement de bureau — Diagrammes et méthodes pour mesurer la résolution des imprimantes monochromes

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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 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on 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 the following URL: www.iso.org/iso/forward.html.

This document was prepared by Technical Committee ISO/IEC JTC1, *Information technology*, Subcommittee SC 28, *Office equipment*.

This first edition cancels and replaces ISO/IEC TS 29112:2012.

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

The purpose of this document is to provide a process for the objective measurement of print quality characteristics that contribute to perceived resolution in pages printed on paper or similar opaque materials using monochrome electro-photographic printing processes.

This document prescribes the following:

— Definitions of print quality characteristics that contribute to perceived resolution.

— Definitions of conformance methods to qualify a reflection scanner for use as a measuring device.

— A testing procedure based upon:

a) a well-documented printer and printing environment setup,

b) well-controlled printing of specified test pages, and

c) subsequent measurement of print quality characteristics using reflection scans of test pattern elements on the printed test pages.

— Definitions of methods for measuring the contributing print quality characteristics using printed test pattern elements of the specified test pages and analysing the resulting data to derive an assessment of printer resolution.

— Requirements for the report of a printer resolution assessment that define the context of the assessment and describe the results of the assessment.

Printer resolution, a quantification of the ability of a digital printing system to depict fine spatial detail, is a perceptually complex entity with no single, simple, objective measure. Five print quality characteristics that meaningfully contribute to resolution are described in this document. These print quality characteristics are: native addressability, effective addressability, edge blurriness, edge raggedness and the printing system spatial frequency response characteristic (SFR).

— Native or physical addressability refers to the imaging framework in a digital printing process, usually a rectangular grid of printable spots, which enables depiction of fine spatial detail. Native addressability specifies only one facet of the perceived resolution of a printing system. The common unit for native addressability is DPI (dots per inch).

— Effective addressability is a measure of the minimum pitch by which the centre of a printed object (e.g. line segment) can be displaced and evaluates the effects of imaged spot position modulation, size modulation or exposure modulation.

— Edge blurriness provides an optical measure of the geometric transition width of an edge between an unprinted substrate region and a printed solid area region.

— Edge raggedness provides an optical measure of the geometric deviations of a printed edge from a requested straight line.

— The spatial frequency response characteristic (SFR) describes the ability of a linear imaging system to depict fine spatial detail. This is the spatial analogue of frequency response used to characterize sound reproduction. A common synonym of the SFR characteristic is the modulation transfer function (MTF). The ability to depict fine spatial detail is affected by edge blurriness and edge raggedness as well as the spot size and shape of the printer's marking technology and any adjacency effects that can occur in the reproduction of fine detail. Two measurement methods are described that provide estimates of the printing system's spatial frequency response including contributions from edge blurriness, edge raggedness, spot-size, spot shape and adjacency effects.

An essential part of the development of this document was verification that the specified measurement methods correlate well with perceived printer resolution (the ability of a digital printing system to depict fine spatial detail) and that the measurements are reproducible across laboratories and instruments.

The steps in and results of this process to verify the utility of the measurement methods specified in this document are presented in more detail in Annex F. The applicability of the measurement methods specified in this document could be expanded by undertaking similar verification processes with other printing technologies.

Information technology — Office equipment — Test pages and methods for measuring monochrome printer resolution

1 Scope

This document defines methods for the objective measurement of the print quality characteristics that contribute to the perceived resolution of reflection mode monochrome printed pages produced by digital electro-photographic printers. The measurement methods of this document are derived from several existing techniques for the assessment of an imaging system's resolution characteristics. Each of these measurement methods is intended for the engineering evaluation of a printing system's perceived resolution and is not intended to be used for purposes of advertising claims.

The methods of this document are applicable only to monochrome prints produced in reflection mode by electro-photographic printing technology. This document is intended for monochrome printers utilizing PostScript®[1)] interpreters capable of accepting PostScript and encapsulated PostScript (EPS) jobs.

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

ISO/IEC 24790, *Information technology — Office equipment — Measurement of image quality attributes for hardcopy output — Monochrome text and graphic images*

3 Terms, definitions and abbreviations

3.1 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

3.1.1
addressability
number of uniquely identifiable printable spot positions per unit distance

1) PostScript® and Encapsulated PostScript® are registered trademarks for freely usable page description formats controlled and defined by Adobe Systems Incorporated. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO/IEC.

3.1.2
bitmap
two-dimensional rectangular matrix of values representing the *pixels* (3.1.21) in a printed page

3.1.3
cross-track
oriented perpendicular to the direction of print substrate motion (cross-track direction)

3.1.4
cross-track addressability
addressability (3.1.1) of the printer in the direction perpendicular to the motion of the print substrate through the printer

3.1.6
edge blurriness
appearance of being hazy or indistinct in outline, giving a noticeable transition of density from a line element to the background substrate whose transition width is zero for an ideally sharp edge

Note 1 to entry: The measured optical width of the transition region perpendicular to the straight edge boundary between an unprinted substrate area and a solid printed area provides an assessment of edge blurriness.

3.1.7
edge raggedness
appearance of geometric distortion of an edge from its ideal position

Note 1 to entry: Measurement of the geometric deviations from straightness of a contour at a specific reflectance ratio in the edge boundary region between the unprinted substrate area and the solid printed area of a requested straight edge provides an assessment of edge raggedness.

Note 2 to entry: An ideal edge should be absolutely straight along the length of a straight line.

3.1.8
edge transition width
distance between the points of a *normal edge profile* (3.1.19) identified at 70 % of the edge transition reflectance range and 10 % of that reflectance range, the region in which *edge blurriness* (3.1.6) is measured

Note 1 to entry: The edge transition reflectance range is the reflectance difference between the maximum measured reflectance factor, R_{max}, typically of the substrate, and the minimum measured reflectance factor, R_{min}, typically of a region printed at a maximum printing value.

3.1.9
edge spread function
normalized spatial signal distribution in the scanned output of a printing system resulting from imaging a theoretical infinitely sharp edge

Note 1 to entry: In measurement of the edge spread function, the tone-scale of the scanning system is corrected to be linear in reflectance. See ISO 12231.

3.1.10
effective addressability
one over the minimum pitch by which the centre of a printed object can be displaced, with the constraint that the objects compared are of constant dimension in the direction parallel to the centroid position change direction

Note 1 to entry: The effective addressability of a printer can be greater than its native addressability. This higher effective addressability is generally controlled algorithmically within the digital data path processing of the printer and is generally not accessible to a user of the printer.

3.1.11
human eye modulation response
response of the human visual system to viewed sinusoidal *modulation* (3.1.15) patterns as a function of the spatial frequency of these modulation patterns

3.1.12
in-track
oriented along the direction of print substrate motion

3.1.13
in-track addressability
addressability (3.1.1) of the printer in the direction parallel to the motion of the print substrate through the printer

3.1.14
limiting resolution
spatial frequency at which the *modulation* (3.1.15) of alternating printed high-contrast lines and spaces is 10 % of the zero-frequency spatial frequency response of the printing system

3.1.15
modulation
difference between the maximum and minimum signal levels divided by the sum of these two levels

3.1.16
modulation transfer function
MTF
spatial frequency response
SFR
ratio, as a function of spatial frequency, of the measured *modulation* (3.1.15) response in a print produced by a printing system, to the stimulus modulation presented to that printing system

3.1.17
monochrome
printing using a single colorant, in particular, a single black colorant

3.1.18
native addressability
one over the minimum pitch between adjacent *spots* (3.1.35) that can be independently controlled and produced by the printer

3.1.19
normal edge profile
NEP
reflectance trace across the transition region perpendicular to the boundary of a straight edge between an unprinted substrate area and a solid printed area

Note 1 to entry: For the edge blurriness measurement specified in this document, the transition region is measured between the 10 % and 70 % reflectance levels.

Note 2 to entry: The normal edge profile can be represented as the convolution of an edge spread function and an infinitely sharp edge transition. In turn, for a linear system, the edge spread function is the Fourier transform of the spatial frequency response (or modulation transfer function). For printing systems, which are usually not linear systems, this latter relationship is only approximate.

3.1.20
Nyquist limit
Nyquist frequency
spatial frequency equal to one half the inverse of the sampling spacing for an adjacent pair of sampling points

Note 1 to entry: This can also be expressed as one half of the spatial sampling frequency.

3.1.21
pixel
smallest addressable element of a digital source image

3.1.22
raster image processor
RIP
component used in a printing system which produces a *bitmap* (3.1.2)

3.1.23
reflectance factor
ratio of the reflected flux as measured to the reflected flux under the same geometrical and spectral conditions for an ideal 100 % diffuse reflecting surface

3.1.24
resolution enhancement technology
control of the printed spot (3.1.36) position to a pitch that is less than the *native addressability* (3.1.18) of the printing system accomplished through local control of one or more spot characteristics

Note 1 to entry: The spot characteristics are spot reflectance (gray-level modulation), size of a spot (size modulation) or local position of a spot (position modulation).

3.1.25
reflectance threshold
R_p
level in the reflectance gradient profile of an edge that is at some specified percentage of the transition from the minimum reflectance factor, R_{min} (3.1.27), to the maximum reflectance factor, R_{max} (3.1.26), as: $R_p = R_{min} + p\%(R_{max} - R_{min})$

3.1.26
R_{max}
maximum measured *reflectance factor* (3.1.23), typically of the substrate

3.1.27
R_{min}
minimum measured *reflectance factor* (3.1.23), typically of a region printed at a maximum printing value

3.1.28
R_{10}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 10 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{10} = R_{min} + 10\ \% \ (R_{max} - R_{min})$

3.1.29
R_{25}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 25 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{25} = R_{min} + 25\ \% \ (R_{max} - R_{min})$

3.1.30
R_{40}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 40 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{40} = R_{min} + 40\ \% \ (R_{max} - R_{min})$

3.1.31
R_{70}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 70 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{70} = R_{min} + 70\ \% \ (R_{max} - R_{min})$

3.1.32
sampling efficiency
fraction of the *Nyquist frequency* (3.1.20) corresponding to the frequency where the *spatial frequency response* characteristic (3.1.16) has dropped to 10% of its zero-frequency value

3.1.33
sampling frequency
spatial frequency of adjacent sampling points where sampling points are conventionally oriented along the direction of print substrate motion, the *in-track direction* (3.1.12), or perpendicular to the direction of print substrate motion, the *cross-track direction* (3.1.3)

3.1.34
scanner tone-scale calibration
opto-electronic conversion function
OECF
digital signal conversion that adjusts the relationship between the reflectance values of large imaged areas and the corresponding digital code values

Note 1 to entry: Code values are the reflection scanner response to a scanned reflection stimulus, e.g. *test elements* (3.1.37). Scanner tone-scale calibration can be used to adjust the relationship between scanned pixel values and large area reflectance to an aim relationship, e.g. scanned pixel values that have a linear relationship with measured print reflectance.

3.1.35
spot
smallest mark that can be placed under user control at a desired position on a printed page, independently from all other adjacent marks

3.1.36
tangential edge profile
TEP
array of geometric positions of a contour at a specific *reflectance threshold* (3.1.25) along the printed rendition of a perfectly straight edge boundary between an unprinted substrate area and a solid printed area

Note 1 to entry: For the edge raggedness measure specified in this document, the contour is taken at a 40 % reflectance level.

3.1.37
test element
elemental part of a test pattern used to assess a particular aspect of a printing system

3.1.38
test page
arrangement in a printable page of *test elements* (3.1.37) or *test patterns* (3.1.39) designed to test one or more particular aspects of a printing system

3.1.39
test pattern
specified arrangement of printable objects [*test elements* (3.1.37)] designed to test a particular aspect of a printing system

3.1.40
test suite
set of printable *test pages* (3.1.38) designed to test a number of different aspects of a printing system

3.2 Abbreviations

Abbreviation	Term
cy/mm	cycles per millimetre NOTE 1 This is the unit for specifying spatial frequency.
dpi (DPI)	dots per inch NOTE 2 This is the common unit for printing system native addressability.
lp/mm	line pairs per millimetre NOTE 3 This is the unit for specifying resolution in terms of the number of equal width black and white line pairs per millimetre that can be resolved according to a criterion such as limiting resolution (3.1.14).
MTF	modulation transfer function (3.1.16)
NEP	normal edge profile (3.1.19)
ppi (PPI)	pixels per inch NOTE 4 This refers to the physical addressability of a digital scanning system.
RIP	raster image processor (3.1.22)
TEP	tangential edge profile (3.1.36)
SFR	spatial frequency response (3.1.16)
spi (SPI)	spots per inch NOTE 5 The printing system native addressability can be expressed in spots per inch. This is an alternative to the more common term DPI.

4 Print resolution characteristics — Methods for measurement and analysis

4.1 Conformance requirements

4.1.1 General

The print resolution characteristic measurement methods defined in this document rely on the objective evaluation of digital images scanned from printed test pages. The single exception to this is the method for native addressability which relies on the visual evaluation of a printed test page.

The test pages, the printing process employed to print test page samples for evaluation, the characteristics of the scanner employed for objective evaluation and the measurement methods utilized shall all meet conformance requirements to ensure that the reported measurements are valid.

4.1.2 Test page conformance

The test pages used with the measurement methods specified in this document are available from http://standards.iso.org/iso-iec/29112/ed-1/en in the ZIP file named Test pages.zip.

— The latest collection of these test pages shall always be used.

— The test page name and version used in printer resolution assessment shall be recorded in the test report.

— Test page names referred to in this document are base file names without a version number suffix. Version numbers will be incremented in later collections of test pages.

These test pages are provided for PostScript compatible printers in Encapsulated PostScript (EPS) format and in PostScript Document Format (PDF). The EPS format, that permits automatic matching of the test page content to the addressability characteristics of the printer's raster image processor (RIP), is the preferred format for use in printing test pages for evaluation using the measurement methods specified in this document. For printing systems with a native addressability known to be either 600 spi or 1 200 spi, test pages for these known addressabilities are also provided in PostScript-based PDF format.

Test pages provided for use with the measurement methods specified in this document are encoded as separation black which avoids colour re-interpretation in most workflows so that only the black printer colorant is used. Colour mixtures and half-tone reproduction of test pages shall be avoided. The provided EPS files can be edited to evaluate the resolution capability of printing systems using any separation colorant. The black separation colorant provides the highest contrast for measurement.

The name and version of a test page used in printer resolution assessment shall be recorded in the test report.

4.1.3 Printing process conformance

The printing process specified in this document avoids the re-interpretations of test page content provided by many imaging or graphics applications. The assessment of printer resolution characteristics is thus made independent of application features and is therefore representative of the inherent capability of the printer.

The procedure specified in Annex A shall be used to submit the test pages for this printer resolution assessment to the printer being assessed. The name of the printer, the settings of the low-level printing application used to submit the test pages and a specification of the printing application, as specified in 6.2 and in Annex A, shall be recorded in the test report.

To ensure that the printer is properly warmed up, one or more pages shall be printed prior to an assessment.

4.1.4 Scanner characteristics conformance

Many of the measurement methods utilized in this document employ a reflection scanner as an analytic measurement device. These measurements provide an accurate assessment of printer resolution characteristics only if the scanner capabilities are high enough, so that the scanner itself does not limit the assessment, and if the scanner control application is configured to deliver accurate and repeatable imagery. Annex B specifies the conditions that shall be met by a reflection scanner and its scanner control application for qualification as a measurement device with the measurement methods specified in this document.

4.1.5 Measurement method conformance

The procedures specified in Annex C shall be used to qualify the measurement method implementations specified in this document.

Failure to use a compliant implementation of the measurement methods specified in this document shall invalidate any test results obtained using that implementation. The name of the implementation and its conformance shall be recorded in the test report as specified in 6.2 for each measurement method used in printer resolution assessment.

4.2 Native addressability

4.2.1 General

Native addressability, often referred to as physical addressability, or simply addressability, can differ in the in-track direction and in the cross-track direction of the printing process.

A PostScript printer RIP provides a value for the printer addressability when queried. When printed, the EPS version of the native addressability test page automatically obtains addressability values from the RIP.

NOTE In most cases, an evaluation of the printed target simply verifies the native addressability reported by the printer's RIP.

4.2.2 Method for measuring native addressability

Unlike the other measurement methods specified in this document, visual evaluation is used to determine the native addressability of a printing system. This visual evaluation procedure can be iterative. The context for printing the test page and evaluating the native addressability of a printing system is summarized in Table 1.

Table 1 — Native addressability

Test page:	TP1_NativeAddr.eps (from latest Test pages.zip)
Test page editing:	(Optional) To over-ride addressability values reported by the RIP
Printing method:	According to the procedure specified in Annex A
Samples to print:	Single printed sample
Analysis method:	Visual evaluation

Print the test page TP1_NativeAddr.eps according to the method specified in Annex A. The native addressability test page contains four types of elements as shown in Figure 1.

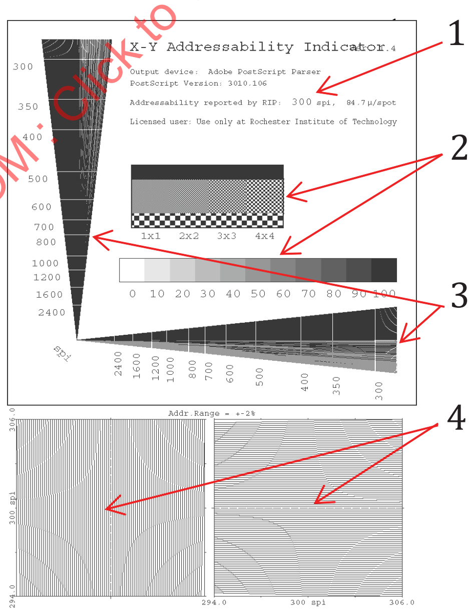


Figure 1 — Native addressability test page

<u>Printing status and configuration check elements:</u>

Element type 1 shows the native addressability reported by the RIP. Element type 2 indicates the two check elements to be visually evaluated to verify that the printing configuration allows correct native addressability assessment. All four checkerboard patterns and all eleven levels of the tone scale ramp shall be evident and distinct. If not evident and distinct, a workflow or RIP configuration error is indicated (improper resolution, high-contrast tone-scale, binary rendition, etc.) which shall be remedied before utilizing this target.

Coarse native addressability assessment scales:

Element type 3 indicates cross-track and in-track scales used to estimate the approximate native addressability of a printing system. Moiré patterns in these elements disappear at the printer resolution. Visual assessment of these scales provides an indication of the approximate native addressability.

Fine native addressability assessment scales:

Element type 4 indicates cross-track and in-track scales used for precise estimation of native addressability.

Visual assessment of the position where the moiré patterns in these elements disappear provides a very precise and accurate measure of the native addressability of the printing system under assessment.

The TP1_NativeAddr.eps file queries the addressability characteristics of the printer's raster image processor (RIP) and adjusts the test page content to exactly match these reported addressability characteristics.

NOTE 1 In most cases, the evaluation of a printed page of the TP1_NativeAddr.eps file simply verifies the native addressability that is reported by the printer RIP and displayed in the upper right corner area of the target.

Visual assessment of the native addressability test page is complete when these two conditions are met:

1) The native addressability indicated by examination of the coarse native addressability assessment scales is within two percent of the native addressability reported by the RIP.

2) The native addressability indicated by examination of the fine native addressability assessment scales is within 0,2 pixels per centimetre (or 0,5 pixels per inch) of the native addressability reported by the RIP.

If the visual inspection results differ from the value reported by the RIP by more than two percent, then the fine assessment scales are out of range and do not provide an unambiguous measure of the printing system's true native addressability. Further investigation is required and consists of three steps:

1) Open a renamed copy of the TP1_NativeAddr.eps file in a text editor and edit the `/SetDPI` line in this PostScript text file that is used to over-ride use of the RIP queried values for in-track and cross-track native addressability values to reflect the values determined by visual inspection of the original sample print of the native addressability target. The `/SetDPI` line of the PostScript text file is illustrated below.

```
/SetDPI 0 def          % You can set the DPI that the program will adapt to. When
                       % set to zero, this will be done automatically, by checking the
                       % number of addressability steps per inch of the output device.
                       % Zero should be the normal setting. But, if it is necessary to
                       % adjust the center spi to show in the large squares (because
                       % the automatic adjustment is off center) then it is possible to
                       % set it here.
```

2) Print and evaluate the edited and saved test page. When the coarse in-track and cross-track native addressability obtained by evaluation of the most recently printed test page are each within two percent of the addressability values entered through the text editor into the defining fields of the test page file, then the fine native addressability scales are in range and visual evaluation can provide a measurement of the true native addressability of the printing system that is accurate to

within 0,2 pixels per centimetre (or 0,5 pixels per inch). This is the tolerance required for evaluation of printer native addressability.

3) If the visual inspection of the printed test page still indicates an addressability outside the two percent range of the fine native addressability scales, continue to refine the edited native addressability setting in the Postscript file in order to evaluate the printing system native addressability by repeating steps 1 to 3.

NOTE 2 Usually, one iteration of this process is sufficient to provide an accurate estimate of the native addressability of a printing system.

NOTE 3 If editing the EPS file, the PRange variable controls the fine addressability range displayed in a print. This variable can be changed to display a different range and assess printer addressability to a different accuracy.

The values obtained through this evaluation process for in-track native addressability and for cross-track native addressability shall be entered into the printer resolution test report as described in 6.3.

4.3 Effective addressability

4.3.1 General

The effective addressability of a printer can be greater than its native addressability. This higher effective addressability is generally controlled algorithmically within the digital data path processing of the printer and is generally not accessible to a user of the printer. The effective addressability of a printer can differ in the in-track direction and in the cross-track direction.

4.3.2 Method for measuring effective addressability

Create a renamed copy of the files TP2-H2x_EffAddrHorz.eps and TP2-V2x_EffAddrVert.eps. Open these copies in a text editor and edit the line that specifies the native addressability of the printer to be tested.

Print the edited and saved test page files according to the method specified in Annex A. The effective addressability test pages shall be edited, saved and printed separately to evaluate in-track effective addressability and to evaluate cross-track effective addressability. The context for printing the test page and evaluating the effective addressability of a printing system is summarized in Table 2.

Table 2 — Effective addressability

Test page:	TP2-H2x_EffAddrHorz.eps (from latest Test pages.zip)
	TP2-V2x_EffAddrVert.eps (from latest Test pages.zip)
Test page editing:	(Required) To specify addressability
Printing method:	According to the procedure specified in Annex A
Samples to print:	Single printed sample of each test page
Scanner conformance:	According to the procedure specified in Annex B
Scanner OECF:	Reflectance
Measurement conformance:	According to the procedure specified in Annex C
Measurement method:	ISOIEC29112_EffectiveAddressability (.exe or .m) (Use latest version)

The set of sample prints created by printing the edited and saved test page files shall be scanned at a resolution equal to or greater than the native addressability of the printing system being assessed, at a scanning resolution that is at least half of the effective addressability of the printing system being assessed or 1 200 ppi, whichever is greatest. Each of the sample prints of an effective addressability test page shall be rotated ~45° on the platen of the scanner. Measurement of effective addressability can require re-scanning at a higher scan resolution. The test page and measurement procedure are designed to allow the effective addressability to exceed the scan resolution. The scanner characteristics at this resolution shall conform to the requirements specified in Annex B to provide valid lossless image files for analysis. An illustrative region of a printed TP2-H2x_EffAddrHorz.eps file is illustrated in Figure 2. The direction of paper motion in Figure 2 is from right to left. The element labelled 1 indicates printed line segments spaced from a fiducial line, element 2, at fractions of the native addressability. Printer capability quantizes these spacings.

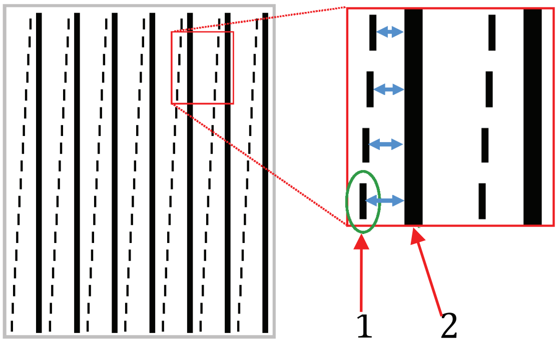


Figure 2 — Horizontal effective addressability test page

Figure 2 illustrates measurement of in-track effective addressability using the TP2-H2x_EffAddrHorz test page. Horizontal and vertical refer to the direction of centre displacement being evaluated in a test page. In-track refers to the direction of paper motion (or paper track) through the printing system. Cross-track refers to the direction that is perpendicular to the direction of paper motion.

Analyse the scanned image files using the effective addressability measurement method specified in this document. If the analysis shows two peaks, the effective addressability reported by the analysis is obtained from the position of the second peak. If the analysis shows only a single peak, the effective addressability test pages shall be renamed, edited, saved, reprinted and reanalysed until the analysis shows two peaks. The process to be followed if the analysis shows only a single peak is as follows:

1. Open a re-named copy of the effective addressability test pages and edit the PostScript line specifying the target resolution. Increase the target resolution multiplier by a factor of two from its previous value (the initial value of the target resolution multiplier in any evaluation shall be 2). The effective addressability of the printing system being assessed is the target resolution times the target resolution multiplier.

2. Save and print the edited copies of the effective addressability test pages according to the method specified in Annex A.

3. These newly printed samples shall be scanned at a resolution equal to or greater than the native addressability of the printing system being assessed, at a scanning resolution that is at least half of the effective addressability of the printing system being assessed, or 1 200 ppi, whichever is greatest. The scanner characteristics at this resolution shall conform to the requirements specified in Annex B to provide valid lossless image files for analysis. Each sample page shall be rotated ~45° on the platen for scanning.

4. Analyse the scanned image files using the effective addressability measurement method specified in this document. If the analysis shows two peaks, the effective addressability reported by the analysis is obtained from the position of the second peak. If the analysis shows only a single peak, the process outlined in these steps 1 to 4 shall be repeated until two peaks are identified.

The result reported by this measurement method provides a measurement of the effective addressability value of the printer for the selected test page orientation. In-track effective addressability and cross-track effective addressability are measured separately based on scans of the printed test page sets created for each of these two orientations. The values obtained for both in-track and cross-track effective addressabilities shall be entered into the printer resolution test report as specified in 6.3. In-track effective addressability is a measure of the minimum pitch by which the centre of a printed object can be displaced along the direction of paper motion through the printing system.

— Depending on the orientation of the substrate being transported through the printing system, in-track effective addressability can be measured using either the horizontal or the vertical effective addressability test page.

— Similarly, cross-track effective addressability is a measure of the minimum pitch by which the centre of a printed object can be displaced perpendicular to the direction of paper motion through the printing system.

4.4 Edge blurriness and edge raggedness

4.4.1 General

Two characteristics of straight edges are of particular importance in characterizing a printing system:

— The normal edge profile (NEP) illustrates how rapidly a transition is made perpendicular to a straight edge. The width of this transition is directly related to the perceived edge blurriness of a printing system.

— The tangential edge profile (TEP) illustrates how much a straight printed edge deviates from its requested straight line behaviour. The magnitude of the deviations from straight line behaviour is directly related to the perceived edge raggedness of a printing system.

These two edge characteristics are illustrated in Figure 3.

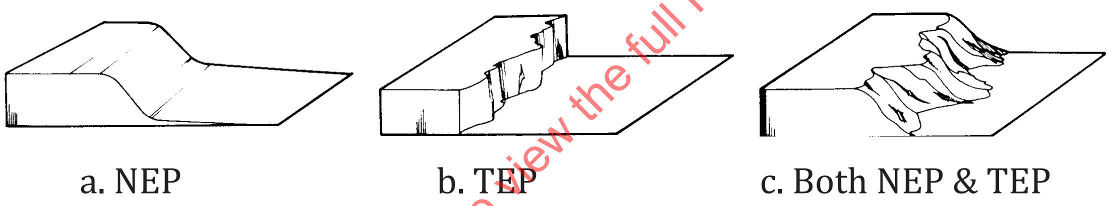


Figure 3 — Edge blurriness and edge raggedness

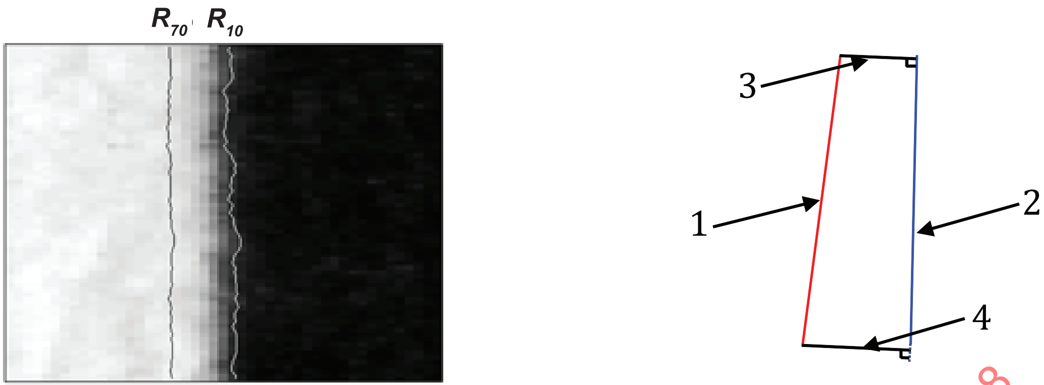
4.4.2 Edge blurriness

The measured width of the transition region perpendicular to a straight edge between a solid printed area and a bare substrate area correlates well with the perceived blurriness of a printing system.

— A smaller transition width correlates with smaller perceived edge blurriness (i.e. greater perceived edge sharpness).

— Edge blurriness is a characteristic of the normal edge profile (NEP) of a printed edge that is also defined in ISO/IEC 24790.

The blurriness of a printed edge is evaluated across the transition region between an unprinted substrate area, with a measured reflectance factor R_{max}, and a printed solid area, with a measured reflectance factor R_{min} as shown in Figure 4 a) and b).



a) **Edge transition**　　b) **Edge blurriness computation**

Figure 4 — Edge transition and edge blurriness computation

The region of interest (ROI) used in the evaluation of edge blurriness shall extend at least 10 mm along the printed edge and at least 4 mm perpendicular to the printed edge, extending at least 2 mm into the unprinted area and 2 mm into the printed area. The scanned image of this ROI, corrected by an OECF LUT to provide a reflectance measure, is analysed to determine the constant reflectance factor contours within the transition region at reflectance threshold values of 70 %, and 10 % ($R_{70,}$ and R_{10} contours). The $R_{70,}$ and R_{10} contours are then each fitted to a straight line. Since the lines fitted to the R_{70} contour (element 1 in Figure 4 b), corresponding to the contour line in the light region of Figure 4 a) and the R_{10} contour [element 2 in Figure 4 b), corresponding to the contour line in the dark region of Figure 4 a)] are not always parallel, the average distance between the R_{70} and R_{10} contours, $d_{70\text{-}10}$, is calculated by averaging the two distances at the ends of the fitted line segments [elements 3 and 4 in Figure 4 b), respectively], according to Formula (1).

$$d_{70-10} = (d3 + d4)/2 \tag{1}$$

The final edge blurriness value, α, is the average distance between the two fitted lines, $d_{70\text{-}10}$, weighted by the square root of the average density of the printed solid area region, according to Formula (2).

$$\alpha = d_{70-10} / \sqrt{D_{avg}} \tag{2}$$

The printed solid area density, D_{avg}, is measured in an area of at least 10 mm^2 within the R_{min} solid area, at least 1 mm away from any edge or light area (e.g. at the centre of one of the elements illustrated in Figure 5). Edge blurriness is measured using the edge transitions along the sides of the objects illustrated in Figure 5.

4.4.3 Edge raggedness

Edge raggedness is a measure of the deviations of a printed straight edge from its expected straight line behaviour.

Edge raggedness is a characteristic of the tangential edge profile (TEP) of a printed edge.

The raggedness of a printed edge (also defined in ISO/IEC 24790) is evaluated within the transition region between an unprinted substrate area, with a measured reflectance factor R_{max}, and a printed solid area, with a measured reflectance factor R_{min}.

— The region of interest (ROI) used in the evaluation of edge raggedness shall extend at least 10 mm along the printed edge and at least 4 mm perpendicular to the printed edge, extending at least 2 mm into the unprinted area and 2 mm into the printed area.

— The scanned image of this ROI, corrected by an OECF LUT to provide a reflectance measure, is analysed to determine the constant reflectance factor contour within the transition region at a reflectance factor of 40 % (R_{40} contour).

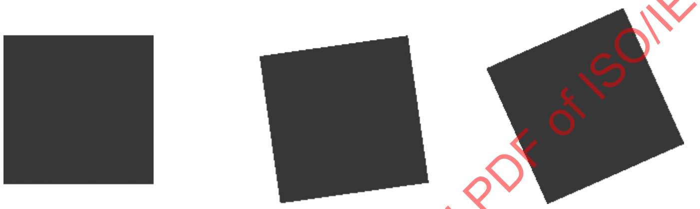
The edge raggedness measure, β, is the standard deviation of the distances between the R_{40} contour and a straight line fitted through the R_{40} contour, according to Formula (3).

$$\beta = \frac{1}{n}\sum_{j=1}^{n}\sqrt{\frac{1}{k-1}\sum_{i=1}^{k}(r)^2} \qquad (3)$$

where r represents the residuals from a line.

4.4.4 Method for measuring edge blurriness and edge raggedness

Print the test page file TP3_EdgeMeasures.eps according to Annex A. A printed version of this file is illustrated in Figure 5 and contains elements used to estimate the edge characteristics of a printer. The context for printing and evaluating the edge characteristics of a printing system are summarized in Table 3.



a) 0° orientation   b) 8° orientation   c) 24° orientation

Figure 5 — Edge characteristics test page elements

The set of sample prints created by printing the test page file shall be scanned at a resolution greater than or equal to the native addressability of the printing system being assessed or 1 200 ppi, whichever is greater.

Table 3 — Edge blurriness and edge raggedness

Test page:	TP3_EdgeMeasures.eps (from latest Test pages.zip)
Printing method:	According to the procedure specified in Annex A
Samples to print:	Single printed sample (single angle, at least 5 instances)
Scanner conformance:	According to the procedure specified in Annex B
Scanner OECF:	Reflectance
Measurement conformance:	According to the procedure specified in Annex C
Measurement method:	ISOIEC29112_EdgeMeasures (.exe or .m) (Use latest version)

The scanner characteristics at this resolution shall conform to the requirements specified in Annex B to provide valid lossless image files for analysis.

Select each of the appropriate angled elements in the scanned image files for separate, independent analysis using the conforming blurriness and raggedness measurement methods initially defined in ISO/IEC 24790 and specified in 4.4.2 and 4.4.3. The results reported by these measurement methods provide measurements of the blurriness and raggedness of the printer for the selected test page orientation.

The values reported for edge blurriness and for edge raggedness shall be entered into the printer resolution test report as specified in 6.3.

4.5 Spatial frequency response

4.5.1 General

The spatial frequency response of a printing system provides an effective method of describing the capability of a printing system to depict detail as a function of spatial frequency. In this document, two methods for estimating complementary aspects of detail rendition capability are specified.

4.5.2 Printer SFR estimation from edge characteristics

Slanted-edge SFR (spatial frequency response) analysis of printed edge transition characteristics contributes to a measure of the printer's spatial frequency response from the Fourier transform of the edge spread function. This estimate of the printer SFR characteristic reflects the contribution of edge sharpness to the perceived resolution of a printing system.

The TP3_EdgeMeasures.eps test page, illustrated in Figure 5, contains objects that can provide an estimate of the printer SFR characteristic based on the slanted-edge SFR method; see 4.5.3.

SFR estimates can be made using in-track, cross-track or slanted edges. These estimates of the printer SFR characteristic reflect the contribution of edge sharpness to the perceived resolution of a printing system. A choice is available to select between three sets of edges provided in the TP3_EdgeMeasures.eps test page: 0° and 90° in-track and cross-track edges, 8° and 98° slanted edges and 24° and 114° slanted edges.

4.5.3 Method for measuring printer SFR from edge characteristics

Print the test page file TP3_EdgeMeasures.eps according to Annex A. The elements used to provide an estimate of the printer's SFR characteristic are illustrated in Figure 5. The context for printing and evaluating the SFR characteristic from the EdgeMeasures test page is summarized in Table 4.

Table 4 — SFR from edge characteristics

Test page:	TP3_EdgeMeasures.eps (from latest Test pages.zip)
Printing method:	According to the procedure specified in Annex A
Samples to print:	Single printed sample (single angle, at least 5 instances)
Scanner conformance:	According to the procedure specified in Annex B
Scanner OECF:	Reflectance
Measurement conformance:	According to the procedure specified in Annex C
Measurement method:	ISOIEC29112_SlantedEdge_PrinterSFR (.exe or .m) (Use latest version)

The set of sample prints created by printing the test page file shall be scanned at a resolution greater than or equal to the native addressability of the printing system being assessed or 1 200 ppi, whichever is greater. The scanner characteristics at this resolution shall conform to the requirements specified in Annex B to provide valid lossless image files for analysis.

The slanted-edge SFR measurement method was developed in ISO 12233 and is specified for use with reflection scanners in ISO 16067-1. The ISOIEC29112_SlantedEdge_PrinterSFR reference implementation of this measurement method, provided for use with this document, is an extension of the ISO 16067-1 Matlab®[2)] routine sfrmat3 that employs ROI size and position variation, defined in 4.6, and scanner SFR normalization, defined in B.4.4. Results reported by this measurement method provide measurements of the SFR characteristic of the printer based on edge characteristics for the selected test element orientation.

2) Matlab® is a registered trademark of The Mathworks Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO/IEC.

Printer SFR characteristic estimates provided by the slanted-edge SFR method are as follows:

— The spatial frequency at 50 % modulation provides an estimate of the perceived sharpness of edge detail, and the spatial frequency at 10 % modulation provides an estimate of the limiting resolution of edge detail. Sampling efficiency provides a Nyquist frequency normalization of the 10 % modulation frequency.

— The cascaded modulation transfer acutance, CMTA[2], a weighting of the printing system SFR by the human eye modulation response function, provides an overall figure of merit for printing system sharpness.

— These measurements shall be recorded in the printer resolution test report as described in 6.3.

4.5.4 Printer SFR estimation from 1-D repeating patterns

Patterns that repeat at a variety of spatial frequencies provide a basis for estimating the printer SFR characteristic that is much more sensitive to spot size, spot shape and adjacency effects than a measurement based purely on edge characteristics. Fourier analysis of a repeating one-dimensional square-wave pattern provides a printer SFR characteristic estimate that reflects the contributions of spot size, spot shape and adjacency effects to the perceived resolution of a printing system.

The SquareWaveSFR test page, illustrated in Figure 6, is utilized in the estimation of the printer SFR characteristic from 1-D square-wave patterns repeated along both horizontal and vertical axes.

— If printed in the manner illustrated in Figure 6, the horizontal orientation test element with bars repeating at several different spatial frequencies along the direction of paper motion is used to measure in-track SFR.

— The vertical orientation test element with bars repeating at several different spatial frequencies across the direction of paper motion is used to measure cross-track SFR.

— Analysis of the printed one-dimensional square-wave patterns provides odd harmonic amplitudes which, in comparison with the expected amplitudes of an ideal square wave's harmonics, probe the spatial frequency response of the printer at many different spatial frequencies.

— These estimates of the printer SFR characteristic reflect the contributions of edge sharpness as well as spot size, spot shape and adjacency effects to the perceived resolution of a printing system.

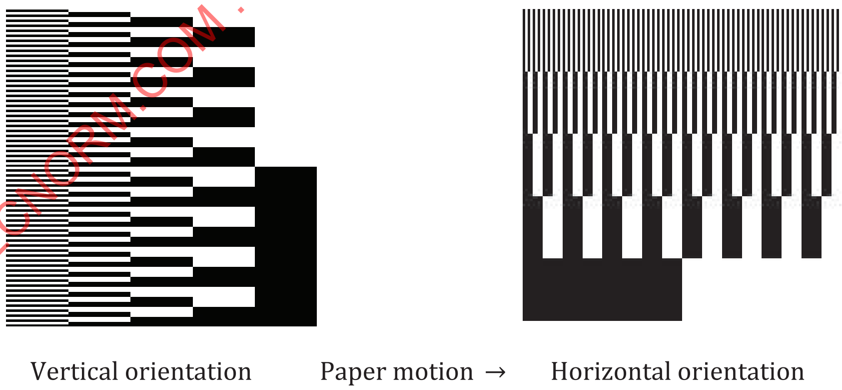


Figure 6 — Line characteristics test page

4.5.5 Method for measuring printer SFR from 1-D repeating pattern characteristics

Print the test page file TP4V_SquareWaveSFR.eps according to Annex A. The elements used to provide an estimate of a printer's SFR characteristic are illustrated in Figure 6. It is critically important in printing the test page for square-wave SFR evaluation that the addressability of the test page exactly matches the printing system addressability. Annex E provides an illustration of the aliasing that occurs if test page and printing system addressabilities do not match. A bitmap version of this test page (TP4B_SquareWaveSFR.eps) is provided for use if the vector code of TP4V_SquareWaveSFR.eps is mis-interpreted by the printer RIP. Preset test page files are distributed for 600 dpi and for 1 200 dpi printing systems. The context for printing and for evaluation of the SFR characteristics from the square-wave test page is summarized in Table 5.

If the printing system being assessed has an addressability different than 600 spi, editing a copy of the distributed TP4V_SquareWaveSFR.eps test page is required.

1) Open a renamed copy of the TP4V_SquareWaveSFR.eps file or the TP4B_SquareWaveSFR.eps file in a text editor and edit the `/SetDPI` line in this PostScript text file that is used to over-ride use of the RIP queried values for in-track and cross-track native addressability values to reflect the actual addressabilities of the printing system. The `/SetDPI` line of the PostScript text file is illustrated below.

Table 5 — SFR from line characteristics

Test page:	TP4V_SquareWaveSFR.eps (use latest Test pages.zip)
	TP4B_SquareWaveSFR.eps (bitmap version)
Test page editing:	(Required) To specify addressabilty
Printing method:	According to the procedure specified in Annex A
Samples to print:	Single printed sample (horz and vert, at least five instances each)
Scanner conformance:	According to the procedure specified in Annex B
Scanner OECF:	Reflectance
Measurement conformance:	According to the procedure specified in Annex C
Measurement method:	ISOIEC29112_SquareWave_PrinterSFR (.exe or .m) (use latest version)

```
/SetDPI 0 def        % You can set the DPI that the program will adapt to. When
                     % set to zero, this will be done automatically, by checking the
                     % number of addressability steps per inch of the output device.
```

2) Print and evaluate the edited and saved test page. When the bars of the square wave elements all print uniformly, proceed with the evaluation.

Scan the set of sample prints created by printing the test page file, at a resolution greater than or equal to the native addressability of the printing system being assessed or 1 200 ppi, whichever is greater.

The scanner characteristics at this resolution shall conform to the requirements specified in Annex B to provide valid lossless image files for analysis.

Alignment of the printed page on the platen is critical for correct assessment using this measurement method. An edge of the printed page shall be aligned with an edge of the platen.

— Misalignment by 0,25° or more can affect the measurement results.

— The reference implementation specified in Annex C verifies alignment.

Analyse the scanned image files using the square-wave SFR measurement method specified in Table 5. The results reported by this measurement method provide measurements of the SFR characteristic of the printer based on line characteristics for the selected test page orientation.

From the printer SFR characteristic estimates provided by the square-wave SFR method:

— The spatial frequency at 50 % modulation provides an estimate of the perceived sharpness of repeated detail, and the spatial frequency at 10 % modulation provides an estimate of the limiting resolution of repeated detail. Sampling efficiency provides a Nyquist frequency normalization of the 10 % modulation frequency measure.

— The cascaded modulation transfer acutance, CMTA[2], based on a weighting of the printing system SFR by the modulation response function of the human eye, provides an overall figure of merit for printing system sharpness.

— These measured characteristics shall be entered into the printer resolution test report as described in 6.3.

4.6 ROI size and shape variation

The size and shape of the ROI chosen for use in the measurement methods specified in this document can affect the measurement result. Windowing techniques have been developed to minimize similar sensitivity in traditional Fourier analysis.

An effective compensation technique utilized in this document is to perform analysis on an ensemble of ROI positions and sizes, then utilize the mean value of the resulting distribution as the reported value from the analysis.

— An ensemble of 81 variations (three variations in X position, three variations in Y position, three variations in ROI width and three variations in ROI height) has proven effective in driving this sensitivity from an approximately 10 % noise level to well below a 2 % level. More detail can be found in F.1.2.

— Averaging of the analysis results from this ensemble of variations is implemented in the reference implementations of the measurement methods for scanner SFR, edge blurriness, edge raggedness, slanted-edge printer SFR and square-wave printer SFR.

5 Test set-up, configurations and procedure

5.1 Printer set-up and configuration

The printer shall be set up on a level surface according to the installation guide provided by the printer manufacturer. The most recent software (printer driver, etc.) available from the manufacturer shall be used. Check the manufacturer's website for the most recent printer driver that is compatible with the computer operating system that will be used for testing. The printer driver version should be documented in the test report.

Printer maintenance shall be performed according to the printer manufacturer's user's manual. All printing device consumables and operating components shall be those specified as acceptable for use by the manufacturer (or otherwise noted).

Prior to the start of the test, the state of the replaceable printing system components, usually toner cartridges, shall be documented in the component condition field of the test report. This usually takes the form of the percentage of expected life remaining or the total number of prints made using a cartridge.

The operating configuration in which a printing system is assessed is as important as the measurement. A particularly important operating configuration is the manufacturer's default configuration.

— This configuration provides an assessment representative of the majority of a printer's usage. Many manufacturers also define a “best practice” configuration for achieving optimal print quality.

— The “best practice” configuration can utilize specialty substrates or operate more slowly than the default configuration, but an assessment of this configuration is apt to evaluate the optimized capability of a printing system.

— The printer configuration used in testing shall be documented in the test report.

— Conditions and settings that differ from the printing device defaults shall be documented in the test report.

To assure that the test pages utilized in an assessment of printer resolution are printed correctly, no page size modifiers such as "Fit to Page" shall be used and font substitution shall be turned off.

— The test pages shall be printed using the fonts embedded in the file and shall be rendered on the page in a size corresponding to the dimensions specified in the test page description.

— Page placement modifiers such as page centring can be used to place the image properly on the page.

5.2 Printer testing environment

The test environment, including temperature and humidity, shall be within the ranges recommended by the manufacturer for operating the printer. If no recommendation is available, the following ranges shall apply:

— Temperature: 18 °C to 25 °C

— Relative humidity: 30 % to 70 %

The printer, all supplies, consumables, etc. shall be acclimated to the test environment for a minimum of 24 hours. Record the temperature and relative humidity at the time of the assessment in the test report.

The printer shall be connected to a supply of power that is within the manufacturer specified operating voltage and operating frequency range.

5.3 Substrate

The substrate used in printer resolution assessment shall represent a compatible substrate for the printer and shall conform to the manufacturer's list of approved substrates.

— The substrate weight, coating and surface characteristics shall be documented in the test report.

— The substrate manufacturer and substrate name should be documented in the test report.

5.4 Test platform connection to the printer

Connection to the computer serving as the platform for printer resolution testing should be determined by the manufacturer's targeted usage.

5.5 Printing process

One of the procedures specified in Annex A shall be used to submit the printer resolution assessment test pages to the printer being assessed for use with this document. For reference, the name, version and settings of the low-level printing application used to submit the test pages should be recorded in the test report.

— The printing process specified in Annex A avoids the re-interpretations of test page content provided by many imaging or graphics applications.

— This assessment method is most independent of application features and is therefore most representative of the inherent capability of the printer.

One or more pages shall be printed prior to an assessment to ensure that the printer is properly warmed up.

5.6 Test pages

The test pages for use with this document are specified in Clause 4. These test pages are available from http://standards.iso.org/iso-iec/29112/ed-1/en, in the ZIP file Test pages.zip.

— The latest collection of these test pages shall always be used.

— The test page name and version used in printer resolution assessment shall be recorded in the test report.

— Test page names referred to in this document are base file names without a version number suffix. Version numbers will be incremented in later collections of test pages.

5.7 Sample size

The residual noise of the printing process is substantially reduced in the assessment analysis by averaging measurements over a number equivalent test elements. The residual noise is further reduced with the use of larger numbers of sample prints (at the expense of measurement and analysis time).

— For most printing systems, multiple prints from the same run provide the most stable printing condition.

— The number of test elements and sample prints utilized in the analysis of the print quality characteristics contributing to attribute measures of perceived resolution shall be documented in the test report.

It is imperative that printing artefacts are avoided for an accurate assessment of printer resolution. Cleanly printed samples with properly reproduced test elements are essential.

For each different printer set-up and configuration:

— A single cleanly printed sample test page is recommended for visual evaluation of native addressability.

— A single cleanly printed sample test page is recommended for the measurement of effective addressability.

— At least five equivalent, cleanly printed test elements are recommended for the measurement of edge characteristics (edge blurriness, edge raggedness and slanted-edge SFR) and for the measurement of square-wave SFR. These can be provided in the layout of a single cleanly printed sample test page.

5.8 Set-up procedure

1) Qualify the reflection scanner and the scanner control application that will be used for assessment measurement according to Annex B.

   Re-qualification is not required for each assessment.

2) Qualify the ISO/IEC 29112 measurement method implementations used to analyse scanned data from printed test pages according to Annex C.

   Re-qualification is not required for each assessment.

3) Obtain, install and verify the appropriate low-level printing application as specified in Annex A.

4) Perform printer maintenance according to the printer manufacturer's user's manual.

5) Set up and configure the printer according to 5.1 to 5.5. Record the printer configuration.

6) Configure the printing application according to Annex A and record the printing method used. For reference, the name, version and settings of the low-level printing application should be recorded.

7) Obtain test pages (Test pages.zip) from: http://standards.iso.org/iso-iec/29112/ed-1/en.

5.9 Testing procedure for visual evaluation

1) Print at least one copy of the visual evaluation test page to ensure that the printer is properly warmed up.

2) Print a copy of the visual evaluation test page specified in this document, using the configured low-level printing application, the configured printer driver and the configured printer, according to the printing process specified in Annex A. A single clean print is all that is required for visual evaluation. Record the orientation of the test page through the printing system paper path.

3) Evaluate the printed test page visually according to the method specified in 4.2.2.

4) If required, edit the copy of the visual evaluation test page according to the method specified in 4.2.2.

5) Iterate steps 1), 2) and 3) until an unambiguous visual evaluation result is obtained.

6) Record the results of the visual evaluation printer native addressability.

5.10 Testing procedure for scanner-based measurement

1) Print at least one copy of the visual evaluation test page to ensure that the printer is properly warmed up.

2) Configure the scanner control application according to Annex B and record the application settings.

3) Print and use at least the recommended number of samples (see 5.7) of each of the instrumental measurement test pages specified for use with this document, using the low-level printing application, the printer driver and the printer, according to the printing process specified in Annex A. Record the orientation of the test page through the printing system paper path.

4) Warm-up the scanner by scanning at least one full-size page at the desired resolution prior to scanning any printed samples for evaluation.

5) Scan each of the printed samples of the test pages using a qualified scanner with the configured scanner application and save lossless image files of each print sample according to Annex B.

6) Analyse the image files of each print sample using the qualified analysis methods specified in this document. Record the analysis results. Record whether scanner SFR normalization is employed or not. Ensure that multiple samples are properly averaged in the analysis to create a single, more accurate result.

6 Presentation of results

6.1 General

A report presenting the results of a printer resolution assessment according to this document shall include the information specified in Clause 6. Guidelines for assessment, dealing with workflow issues and representative samples of test reports can be found in Annex D.

The information required in an assessment report of printer resolution according to this document can be divided into two categories:

1. Assessment configuration documentation is specified in 6.2 and Table 6.

2. The requirements for reporting assessment measurement results are specified in 6.3 and Tables 7 and 8.

The operating configuration in which a printing system is assessed is as important as the measurement results. Each change in the printer settings represents a new printing system configuration and requires a separate assessment.

NOTE Two particularly useful printing system configurations for resolution assessment are:

— the printer manufacturer's default printer configuration, which is representative of the majority use of a printing system, and

— the configuration representing the printer manufacturer's recommended "best practice" for optimal printing, generally providing a higher perceived resolution.

6.2 Required assessment configuration documentation

The information required to document the configuration employed in the assessment of printer resolution is specified in Table 6.

The documentation of assessment configuration shall include:

1. Documentation of the assessor and the environmental conditions in which the assessment is done.
2. Documentation of the printer, its setup configuration and its state at the time of the assessment.
3. Documentation of the substrate used for assessment. The substrate weight, surface and classification are required. The manufacturer and name of the substrate are optional, but often very useful.
4. Documentation of the test page submission process.
5. Documentation of the test page orientation, as printed, for entering the measured element orientation.
6. Documentation of the setup and the conformance of the scanner and scanner control application used for measuring a printing system's resolution characteristics.

The intent of this test documentation is to provide sufficient context of the setup and testing processes used in an assessment of printing system resolution to permit equivalent assessment at a later date. The elements in the test report should be given in a logical order.

Table 6 shows the assessment context documentation needed for a report. Examples of test reports are provided in Annex D.

If a detailed comparison of different printing systems is desired, the details of the component condition can be particularly important (e.g. are all components used in the imaging process new?). The actual substrate used (an optional item shown in *italics* in Table 6) can also be important and should be recorded.

If the assessment is for internal use only and is always performed using the same scanning system, then the requirement to provide a normalized scanning system spatial frequency response characteristic may be waived and scanner SFR normalization as specified in B.4.4 is not required.

Table 6 — Test context documentation for an assessment report

		Item:	Information:	Units:
Printing:	Test conditions:	Assessment date:	e.g. dd-Month-yyyy	
		Assessor or assessing organization:	e.g. name	
		Environmental conditions:	e.g. 25 °C, 40 %RH	°C, %RH
	Printer:	Manufacturer and model:	e.g. name, number	
		Configuration:	e.g. best quality or default	
		Component condition:	e.g. toner cartridge % life or # pages	
		Printer driver version:	e.g. version 2.1	
		Paper motion orientation:	e.g. along the long edge	
		Reported printer addressability:	e.g. 600 spi	spi
		Substrate weight, surface and type:	e.g. 80 gsm, uncoated bond	
		(Substrate manufacturer and name):	*e.g. Hammermill LaserPrint*	
	Submission:	Method of test page submission:	e.g. command window, copy	

Table 6 *(continued)*

		Item:	Information:	Units:
Scanning:	Scanning:	Scanner manufacturer:	e.g. Epson 10000XL	
		Resolution setting:	e.g. 1 200 ppi	ppi
		Scanning conformance:	e.g. yes	
		Scanner OECF compensation:	e.g. reflection aim	
		Scanner SFR normalization:	e.g. none or ISO 29112 aim	

If assessment measurements are made at multiple locations, or with differing equipment, or compared openly, then individual scanner SFR normalization to a common aim as specified in B.4.4 is required.

6.3 Required assessment measurement documentation

Several important attributes of a printing system's perceived resolution can be assessed using the methods specified in this document. Each of the measurement methods specified in this document is intended for the engineering evaluation of a printing system's perceived resolution and is not intended for purposes of advertising claims.

The required documentation of measurement results as shown in Table 7 and Table 8 shall include:

1. Documentation of the configuration of the printer, when reporting assessment results for multiple configurations of the same printer. This supersedes the conventional reporting of printing system configuration as part of the test configuration table.

2. For each attribute, documentation of the test page, the measurement method and the conformance of the measurement method used.

3. For each attribute, the orientation of the assessed element with respect to the paper motion direction through the printer.

4. The measurement results.

Table 7 — Context documentation for a measurement

	Item:	Information:
For each configuration:	Configuration:	e.g. best quality or default
For each measurement:	Measurement name / conformance:	e.g. ISOIEC29112_EffectiveAddressability_v1 / compliant
	Test page name:	name & version (ISO website) e.g. TP2-H2x_EffAddrHorz_v1.eps
	Assessment element orientation:	e.g. XT (Horz target, portrait orientation, long-edge motion => XT)

NOTE In this example, the assessed element orientation for short-edge motion through the printer is In-track (IT).

All attribute measures shall be reported with the attribute name, its orientation, its measurement values, the number of elements assessed, the number of samples printed to obtain the elements assessed and the units of the measured values in the format illustrated in Table 8.

For ease of interpretation, the results in the test report should be grouped in a logical order. For results that share the same test pages and measurement methods, the measurement context specified in Table 7 is required only once for each measurement method. The measurement results for multiple orientations of an attribute shall each be recorded in complete, separate rows of the report table.

Table 8 — Documentation of measurement results

Attribute name:	Orientation:	Data:	Meas:	Pages:	Units:
Native addressability:	IT & XT	Values	e.g. 1	1	spi
Effective addressability:	IT & XT	Values	e.g. 1	1	spi
Edge blurriness:	XT (8°), IT (98°)	Values <mean, stdev, min max>	e.g. 5	1	microns
Edge raggedness:	XT (8°), IT (98°)	Values <mean, stdev, min max>	e.g. 5	1	microns
Slanted-edge SFR:	XT (8°), IT (98°)	Values <mean, stdev, min max>	e.g. 5	1	Accutance or Sampling Efficiency
Square-wave SFR:	XT (0°), IT (90°)	Values <mean, stdev, min max>	e.g. 5	1	Accutance or Sampling Efficiency

The measurement context documentation specified in Table 7 shall be associated with the table of measurement results specified in Table 8 for each assessed printing system configuration. If only a single printing system configuration is being assessed, the specification of printing system configuration can move back to the test configuration documentation specified in Table 6. The test context documentation specified in Table 6 shall be associated with the measurement context documentation specified in Table 7 and the measurement data specified in Table 8. Examples of reports are provided in Annex D.

Annex A
(normative)

Printing process

A.1 Application effects

Imaging and graphics applications generally have their own individual ideas about how a file should be printed. These ideas have been known to change from version to version. Printing test page files from an imaging or graphics application is not recommended due to the many changes that an application can make to the intent of the standardized printing files utilized in the assessment of printer resolution specified in this document.

A.2 Print driver effects

Printer drivers often attempt to assist the user in printing information. This assistance can destroy the attempt to analytically estimate printer resolution and shall be avoided. Printer drivers are an essential part of the printing data path but should be accessed at a low level to avoid unnecessary assistance.

A.3 Test page files for PostScript printers

The test page files for the assessment of PostScript printer resolution are supplied in EPS (Encapsulated PostScript) format. This is a well-documented, freely usable Adobe format that can be sent directly to Postscript compatible printers from a Microsoft Windows®, Linux or Apple Macintosh® platform[3]. The printer resolution test page files of this document are able to adapt to the characteristics of the printer under assessment. This adaptation takes two forms: 1) dynamic adaptation, and 2) static adaptation.

With dynamic adaptation, an EPS file sent to the printer under assessment queries the printer RIP for information.

— The information requested is the cross-track and in-track native addressability of the printer and printer identification information such as name, version, time and date that are subsequently displayed as informative text in the printed test page.

— The cross-track and in-track native addressability data returned by the printer is also utilized to precisely configure the test page to the printer characteristics.

— This adaptation avoids a mismatch between the resolution assessment test page file addressability and the printer addressability, as long as the printer correctly reports its own addressability.

— Dynamic adaptation is the default state of the printer resolution test page files of this document.

With static adaptation, the user can over-ride a dynamic configuration of the test page. The user edits the header portion of the test page file to explicitly define the cross-track and in-track addressability to be utilized to configure the test page for the actual addressability of a printer. These edited values are used instead of the addressability reported by the printer to configure the test page file for printing.

3) Windows® and Macintosh® are registered trademarks of Microsoft Corporation and Apple Corporation, respectively. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO/IEC.

Test pages are also supplied in PDF format.

— The completely static (compiled) nature of this format does not permit a submitted PDF test page to adapt to a printer's reported addressability.

— The test pages are provided in PDF format for convenience of use with printing systems of known 600 spi or 1 200 spi addressability. A printable PDF file with arbitrary addressability can be created from an EPS test page using a suitable PDF compiler.

A.4 Printing protocol

A.4.1 General

There are two approaches for avoiding undesirable printer driver effects in printing test pages for analytic interpretation:

1) Access the printers at a low level from the operating system (using DOS commands for Microsoft Windows® based systems and using UNIX command shell commands for Linux and Apple Macintosh® operating systems).

2) Utilize dedicated printing applications that are written to control and access printers at a low level.

A.4.2 Low-level operating system printing protocol

For Linux and Apple Macintosh® operating systems, the `term` utility (Applications:Utilities:term.app for Macintosh) provides the required interface to the operating system.

— Open a `term` window and type `lpstat -a` to get a listing of the detailed printer names that the operating system is connected to. The detailed name for a printer is needed to properly direct a file for printing to the printing device using the operating system. Place the files to be printed in an easy to navigate to location within the computer's file system.

— Type lpr -P <Detailed_Printer_Name> <Print_File_Path> to send the print file to the printer (the brackets that separate the two arguments should not be typed).

Figure A.1 shows an example of the use of the `lpstat` and `lpr` commands. The detailed printer name, e.g. `HP_Color_LaerJet_CP2025dn_2588F0`, found using the `lpstat` command, is what is needed to properly direct the printing of the EdgeMetric test page in this example. The printer will probably need to be told manually which tray to print from.

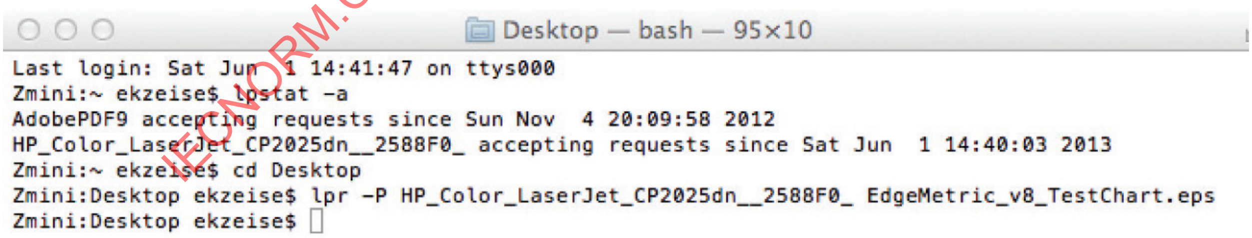


Figure A.1 — term window (Macintosh or LINUX low level printing)

For printing from a Microsoft Windows® based system, the same kind of information is needed and the same general procedure is followed.

— Details vary between versions of the operating systems.

— For Windows, the detailed printer name known to the operating system is found in the Printer Properties settings.

— From Start, select Settings, then Printer and select the printer to which you want to send the test page files.

— This opens the Printer Queue window.

— Select Properties from the Printer Queue window menus and navigate to the Ports or Details pane.

— Select the Port to which the printer is attached and look at the details of the Port configuration. The Port Name and the Printer Name can be found there.

— Figure A.2 shows the final window in this sequence.

The subsequent low-level operating system printing operation requires knowledge of this printer name used by the Windows operating system.

— Open a DOS command window (Start then Programs then Accessories and select Command Prompt).

— There appear to be two ways of sending files to a printer from the Command Prompt window.

— Figure A.3 shows a direct method for sending the content of a file directly to a printer.

— If the printer's Ethernet address is known, then for many printers an equivalent method is to type at the command prompt: copy /b <File_name> <Ethernet address>.

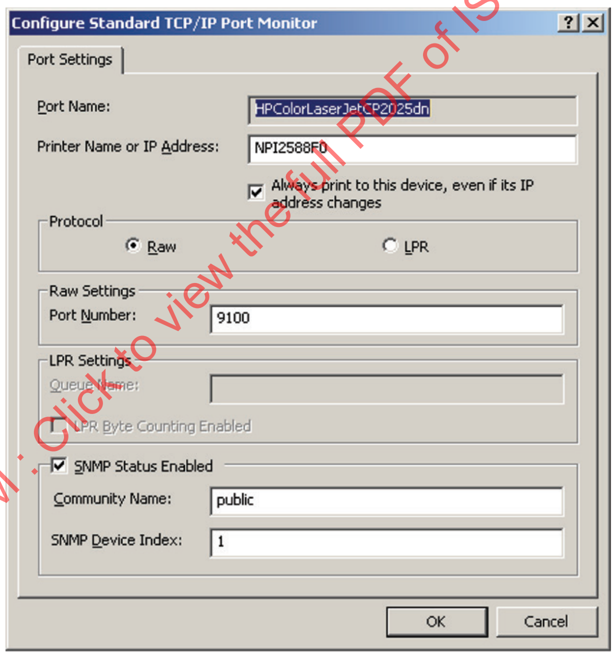


Figure A.2 — Windows Printer Name

Figure A.3 — Windows copy

Figure A.4 shows a somewhat more indirect method utilizing network re-direction to an otherwise unused printer port that becomes associated with the destination printer.

The net use command associates the printer port with the printer (with the name of the host computer, in this case ROCTL82CNPD1, preceding the detailed name of the printer that is known to (or served by) the host computer, in this case NP12588F0 (where 12588F0 are the last digits of the printer's MAC address).

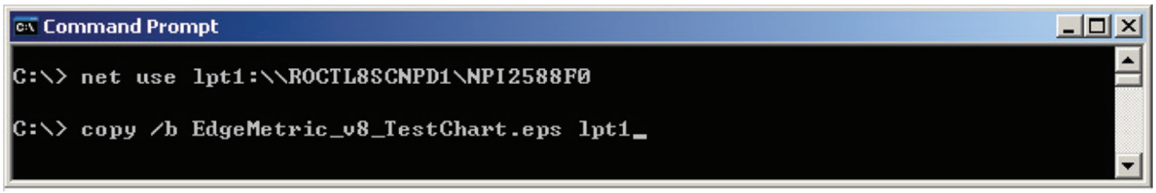


Figure A.4 — Windows copy (alternative)

A.4.3 Dedicated printing application printing protocol

For a Microsoft Windows® platform, a low-level printing utility such as PrintFile (www.lerup.com/printfile) is recommended as the mechanism for sending resolution assessment test page files of this document to a printer. This utility connects to the Windows printer driver of the printer under assessment at a low level and directly transfers the test page information to the printer, thus avoiding the application and driver effects mentioned above.

— Some configuration of the PrintFile utility is required, as specified here.

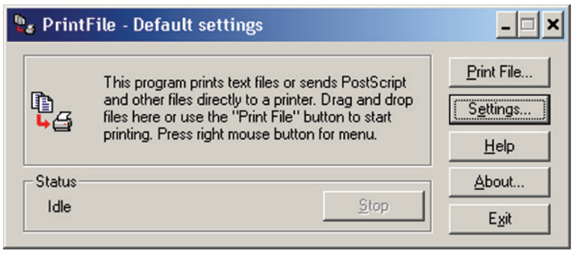
— With the PrintFile application running, click on the Settings button [Figure A.5 a)], then in the More pane (Figure A.5 b)), click on the PostScript button.

In the Encapsulated PostScript pane of this dialog box, shown in Figure A.5 c), check the "Keep original size and place" button and then click the "OK" button of the PostScript Settings dialog box and the "Apply" button of the PrintFile Settings dialog box.

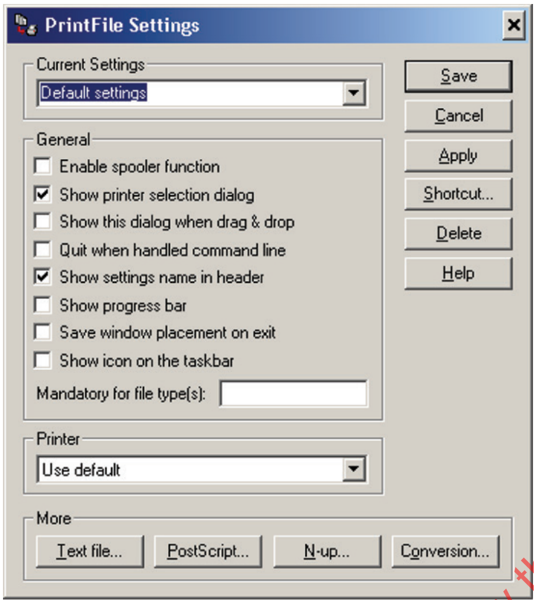
— If any of the test page content is clipped by printing boundaries, the "Center on page" button can be utilized.

— Do not use the "Center and scale to fit page" button as this shall invalidate the measurements. This completes the configuration of the PrintFile utility.

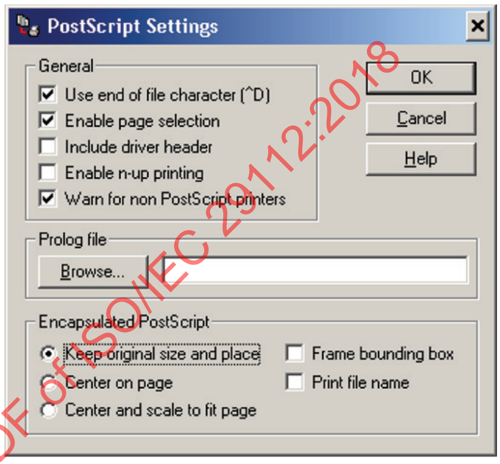
On an Apple Macintosh® platform, the test page file should be directly dragged to the icon of the printer under assessment. This process explicitly avoids the application and upper-level driver effects mentioned above.



a) **Default settings**



b) **More pane**



c) **PostScript settings**

Figure A.5 — PrintFile configuration

Annex B
(normative)

Scanner conformance

B.1 General

Many of the measurement methods specified in this document to estimate the attributes of printer resolution employ a reflection scanner as an analytic measurement device.

These measurements provide an accurate assessment of printer resolution attributes only if the scanner capabilities are high enough, so that the scanner itself does not limit the assessment, and if the scanner control application is configured to deliver pristine imagery.

This annex specifies the conditions that shall be met by a reflection scanner and its scanner control application to qualify a scanner as a usable measurement device for use with the measurement methods specified in this document.

B.2 Required scanner characteristics

Five characteristics of a reflection scanner shall be evaluated to qualify a reflection scanner for use with the measurement methods specified in this document. These characteristics are:

— interpolation effects in the sensor array of the scanner;

— the spatial frequency response characteristics and usable addressability of the scanner;

— the tone-scale or opto-electronic conversion function (OECF) characteristics of the scanner;

— the scan uniformity over the tone scale and stability over time;

— scanner SFR uniformity over the area required for assessment.

Several other characteristics of a reflection scanner can affect the measurement processes specified in this document, but are generally sufficiently well controlled in the commercially available reflection scanners that have met the scanner qualification requirements above to be of small concern in application to office printer resolution characterization. These characteristics are:

— the scanner dynamic range capability (minimum to maximum density, free of saturation effects). ISO 21550[1] specifies a measure of this property. A qualified scanner should cover the range between 0,1D and 1,5D for office printer resolution assessment;

— the geometric distortion of the scanner;

— the flare or integrating cavity effects of the scanner.

The filter array of the sensor in a qualified scanner shall not compromise scanned data spatial resolution.

— Scanners utilizing multiple sensors, one for each colour, can qualify for use with the measurement methods specified in this document.

— Scanners utilizing a single linear sensor with an alternating colour filter array compromise the spatial resolution of scanned data and shall not be used since spatial information is interpolated.

— Full fast-scan resolution is required for scanner conformance.

A reflection scanner qualified for use with the measurement methods specified in this document shall have a sufficiently large field of view to scan an entire A4 or Letter-size test page without re-positioning the test page. Over this field of view, a qualified reflection scanner shall have a minimum scanning resolution equal to or greater than the native addressability of the printing system being assessed or 1 200 ppi, whichever is greater, and a capability of providing at least 256 different tonal levels without clipping or saturation effects. This corresponds to at least an 8-bit scanner data path and provides headroom for OECF calibration.

For comparison between measurements made with different scanning systems, the scanners employed should have similar characteristics: addressability, illumination, tone scale, spatial response and spectral response (see Clauses B.3. and B.4).

B.3 Scanner OECF characteristic

B.3.1 General

The scanner spatial uniformity and temporal stability shall permit calibration of the scanner to provide a monotonic OECF characteristic that utilizes the full 256 levels of the scanner data path and that does not saturate at either end of its range for the reflection characteristics of the printed test pages specified in this document.

The calibrated OECF characteristic for all measurement methods is a reflectance aim.

The gray-scale step tablet used for the creation of an OECF characteristic should have twelve or more steps. The minimum optical density in the gray-scale step tablet should be 0,1 or less and the maximum optical density should be 1,7 or more.

B.3.2 Method for evaluating the scanner OECF characteristic

A fully populated look-up-table (LUT) that captures the calibrated OECF characteristic of the scanner is required by the assessment methods specified in this document.

— Calibration of a reflection scanner in the form of this required LUT shall be done in accordance with the procedure defined in ISO 14524 or ISO/IEC 24790.

— The standard error of the scanner calibration shall be less than 1 % of the required dynamic range (0,015D which corresponds to a 0,03 reflectance factor) to provide a sufficiently stable OECF calibration.

B.3.3 Required scanner OECF stability

Scanner OECF repeatability shall be evaluated by performing sixteen consecutive scans of the same OECF calibration test element (e.g. ISO 16067-1, ISO/IEC 24790 or equivalent test page) at a scanning resolution of 1200 pixels per inch.

The OECF characteristic for each of these sixteen consecutive scans shall be evaluated. The deviation of the OECF characteristic for any individual scan from the averaged OECF characteristic of the sixteen scans shall remain within ±1% of the maximum reflectance factor over the entire tone scale.

NOTE The surface texture of an OECF calibration test page can introduce noise in OECF calibration depending on the scanner illumination geometry. Minimum texture or a gloss surface is preferred.

B.4 Scanner SFR characteristic

B.4.1 General

The detail carrying capability of scans provided by the reflection scanner used for measurement methods specified in this document shall exceed the detail carrying capability of the printer system that is being evaluated with the procedures specified in this document.

B.4.2 Required element placement for SFR evaluation

The slanted-edge elements to be evaluated for SFR characteristics shall be placed in the central third of the scanner platen along both the slow-scan and fast-scan axes of the scanner to avoid potentially significant variations in the scanner SFR characteristic. Refer to the discussion of scanner stability in F.1.2.

If the SFR characteristics of a qualified scanner have been measured to be effectively constant over a larger fraction of the platen along an axis (e.g. slow-scan), then measurements can be made over the fraction of the platen where the SFR shift has been measured to vary by less than 0,035 at 12 cy/mm.

B.4.3 Required scanner SFR characteristics

The detail carrying capability of a scanner shall be evaluated in accordance with the procedure defined in ISO 16067-1.

The Matlab function ISOIEC29112_ScannerSFR implements this procedure.

To be qualified to evaluate the SFR characteristic of a printing system, the scanning system shall maintain its SFR capability at 12 cy/mm such that there is a level shift of less than 0,035 over the platen area used for evaluation.

To be qualified to evaluate the SFR characteristic of a printing system, the scanning system, with the super-resolution capability provided by the slanted-edge SFR evaluation method, shall provide at least 25 % headroom over the measured printing system SFR. This means that a 1 200 ppi scanning system that maintains an SFR level of 0,20 at 12 cy/mm is qualified to assess a printing system whose measured SFR characteristic maintains a level of 0,16 at 12 cy/mm. For current office printing systems, the minimum scanner SFR requirement for qualification is the maintenance of a 0,20 level at 12 cy/mm. An aim scanner SFR requirement is the maintenance of a 0,25 level at 12 cy/mm (see Annex F for details).

NOTE As printing system capability improves, a qualified scanning system could require a scanning resolution greater than 1 200 ppi to maintain the 25 % headroom requirement. The 25 % headroom requirement avoids significant distortion of an evaluated printing system SFR by a limiting scanner SFR.

B.4.4 Method for normalizing scanner SFR

The normalized SFR characteristic of a scanner shall be computed with this procedure to match a standard aim characteristic that is representative of a population of qualified 1 200 ppi scanners.

This procedure is similar to the procedure defined in ISO/IOEC 24790 and adopts the same aim SFR characteristic.

The system SFR (scanner and target) is measured as specified in ISO 16067-1, using the slanted edge element of an ISO/IEC 24790 test page.

— The test element is placed on the scanner such that its edges are rotated between 5° and 10° from the horizontal and vertical scanner axes.

— Different normalizations are assumed to be required for the two different edge orientations of the slanted-edge SFR element (i.e. nearly vertical edges vs. nearly horizontal edges).

The normalized scanner SFR characteristic is measured as specified in the following eight steps:

1. Scan the slanted edge patch of the ISO/IEC 24790 test page with a scanner in RGB mode (or grayscale mode), 8 bits/channel, at 1 200 ppi, under the conditions specified in this annex.

2. Compute the SFR (spatial frequency response) of the G (green) channel (or grayscale channel) for each of the four edge orientations using the measurement method ISOIEC29112_ScannerSFR, which employs the computational method defined in ISO 16067-1.

3. The measured system SFR characteristic, C_{measured}, is the G channel SFR (or grayscale channel) characteristic, averaged over the two similar edge orientations, in the frequency range from 0 (DC) to the Nyquist frequency. This provides $C_{\text{Hmeasured}}$ and $C_{\text{Vmeasured}}$

4. Compute the scanner SFR normalization characteristic from the averaged measured system SFR characteristic (step 3) and the aim system SFR characteristic: $C_{\text{Hnormalization}} = C_{\text{aim}}/C_{\text{Hmeasured}}$ and $C_{\text{Vnormalization}} = C_{\text{aim}}/C_{\text{Vmeasured}}$.

   The 1 200 ppi aim system SFR, which is the average SFR of a set of qualified 1 200 ppi scanners, is defined by Formula (B.1) and shown in Figure B.1. This scanner SFR aim is valid for spatial frequencies up through 24 cy/mm.

$$C_{\text{aim}}(f) = 1 - 0{,}103\,096\,f + 0{,}004\,226\,88\,f^2 - 0{,}000\,091\,552\,1\,f^3 + 0{,}000\,001\,030\,79\,f^4 \qquad \text{(B.1)}$$

   where f is the spatial frequency in cycles/millimetre (cy/mm).

   If the measured system SFR is identical to the average SFR of the set of qualified scanners, then the scanner SFR normalization characteristic is unity at all frequencies.

   — If the measured system SFR is lower than the aim system SFR (a less capable system), then the scanner SFR normalization characteristic at non-zero frequencies is mostly above one.

   — If the measured system SFR is higher than the aim system SFR (a more capable system), then the scanner normalization characteristic at non-zero frequencies is mostly below one (at zero frequency, SFR characteristics are normalized to one). These cases are illustrated in Figure B.2 a) and b).

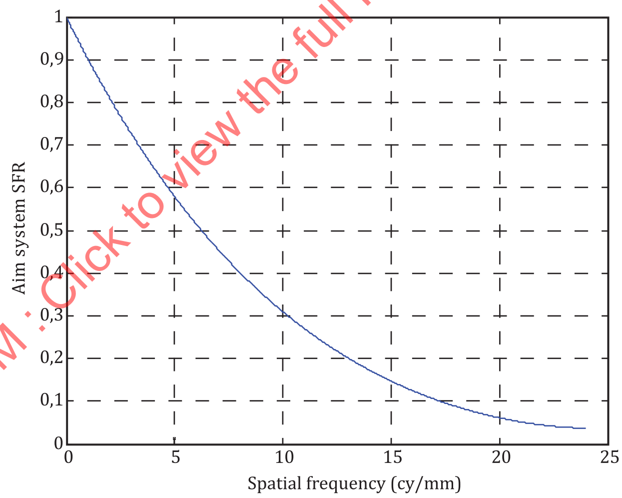
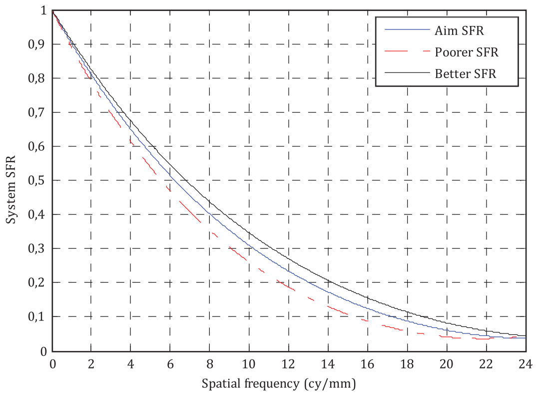


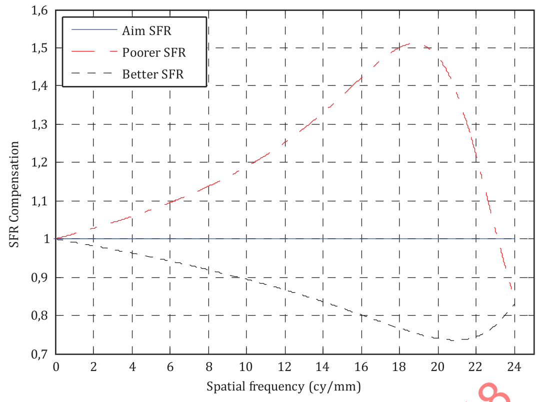
Figure B.1 — Average qualified scanner SFR characteristic

By use of the normalization characteristics shown in Figure B.2 b), the SFR characteristics that are "poorer than" or "better than" the aim SFR characteristic are compensated to achieve the aim SFR characteristic.

The scanner SFR normalization characteristic is then utilized in the following procedure to normalize measurements made using that scanner to a standard condition corresponding to a scanner with aim SFR characteristics.



a) Scanner SFR characteristics



b) SFR normalization characteristics

Figure B.2 — Scanner normalization

5. For each ROI image used in computing a measurement of an attribute, derive the optical reflectance factor values, *R (x, y)*, for each pixel in the ROI image, using the reflectance OECF for calibration of scanner output values.

6. Compute the two-dimensional discrete cosine transform (DCT) spectrum of the ROI image, F ($R(x, y)$).

7. Compute two separate SFR normalization matrices, one using the horizontal SFR normalization characteristic computed in step 4 and the second using the vertical SFR normalization characteristic computed in step 4. Each of these normalization matrices is a 2-D radially symmetric interpolated matrix of identical size as the DCT of the ROI image. The normalization matrices are created by interpolating the 1-D horizontal or vertical SFR normalization characteristic as a function of $R(fx, fy)$, the spatial frequency distance of the matrix element (corresponding element by element with the DCT matrix) from the matrix origin (corresponding with the zero frequency point of the DCT matrix), as shown in Formulae (B.2) and (B.3).

$$C_{\text{Vnormalization}}(R) = interpolate\_2D(C_{\text{Hnormalization}}(R), R(fx, fy)) \tag{B.2}$$

$$C_{\text{Hnormalization}}(R) = interpolate\_2D(C_{\text{Vnormalization}}(R), R(fx, fy)) \tag{B.3}$$

8. Compute the SFR normalized ROI image, using the two-dimensional inverse DCT, where the two-dimensional SFR normalization is being applied as a simple matrix multiplication in the spatial frequency domain.

$$\chi_{\text{Hnormalized}} = \mathrm{F}^{-1}[[\mathrm{F}(\chi(x, y))] * C_{\text{Hnormalization}}(fx, fy)] \tag{B.4}$$

$$\chi_{\text{Vnormalized}} = \mathrm{F}^{-1}[[\mathrm{F}(\chi(x, y))] * C_{\text{Vnormalization}}(fx, fy)] \tag{B.5}$$

where χ stands for ROI.

The ROI normalized by the horizontal SFR normalization characteristic, Formula (B.4), is used in the evaluation of horizontally oriented ROIs. The measurement of horizontal scanner SFR should utilize a target with angled edges identical to the angled edges of the element used to evaluate horizontal printer SFR.

The ROI normalized by the vertical SFR normalization characteristic, Formula (B.5), is used in the evaluation of vertically oriented ROIs. The measurement of vertical scanner SFR should utilize a target with angled edges identical to the angled edges of the element used to evaluate vertical printer SFR.

Sometimes, the additional computational complexity of scanner SFR normalization is not necessary in limited studies where a single measurement device (scanner) is employed to examine trends.

Scanner SFR normalization is required when measurements are made on multiple devices (scanners), when measurements are made at multiple sites or when quantitative results rather than trends are desired.

B.5 Required scanner control application characteristics

Like imaging and graphics applications, scanner control applications are designed to help the user to produce aesthetically pleasing imagery.

— This aim is usually at odds with the requirement of providing analytic measurements that are accurate and repeatable.

— A scanner control application that is usable for analytic measurement in the ISO/IEC 29112 assessment of printer resolution shall be capable of being run in a completely manual manner.

— All automatic features of the application that are designed to enhance the scanned image shall be disabled.

— Any auto-exposure capability shall be disabled.

— Any automatic tone-scale correction capability shall be disabled.

— Any scanned image filtering (e.g. sharpening, un-sharp masking, blurring, etc.) shall be disabled.

— Any colour management capability shall be disabled.

— Scanned imagery shall be saved in a lossless format (e.g. uncompressed, LZW or ZIP).

— The scanner control software requirements specified here complement the printing path requirements specified in Annex A to provide meaningful measurement results.

Annex C
(normative)

Reference measurement methods and conformance

C.1 Installation

C.1.1 General

This annex serves three purposes:

1) To document the distribution set of test pages and measurement method executables or routines utilized for evaluation of the measurement methods specified in this document.

2) To document the distribution set of test files required for verifying measurement method conformance.

3) To specify the conformance processes used to verify the correct operation of the measurement methods specified in this document.

The latest set of test pages shall always be used with the measurement methods specified in this document. Subclause C.1.2 shows how these test pages can be downloaded.

Any implementation of a measurement method specified in this document shall conform to the intended practice specified in this document. A distribution set of reference implementations and associated support files is made available for this purpose. Subclause C.1.3 shows how the reference implementations can be downloaded. The process by which an implementation of the measurement methods specified in this document is verified to be in conformance with the intended practice is specified in this annex. Conformance can be verified using either the measurement method applications or the Matlab routines available in the reference distribution file set. A set of reference bitmap files are provided for each of the measurement methods, along with required support files and their expected reference implementation measurement results, for conformance testing of implementations of the measurement methods specified in this document.

Failure to use a compliant implementation of the measurement methods specified in this document shall invalidate any test results obtained using that implementation.

C.1.2 Test page ZIP file availability

The latest set of test pages to be utilized with the measurement methods specified in this document is available in a ZIP file "Test pages.zip". This ZIP file shall be downloaded from http://standards.iso.org/iso-iec/29112/ed-1/en.

The following steps shall be followed to enable use of the latest test pages with the measurement methods specified in this document.

— Download the ZIP file "Test pages.zip" from the ISO website.

— Un-zip the reference distribution ZIP file to provide the directory Test pages.

The Test pages directory, shown in Table C.1, contains four sub-directories, one for each of the measurement methods defined in this document.

— The EdgeMeasures sub-directory contains a single file for evaluation of edge blurriness, edge raggedness, and for evaluation of printer SFR characteristics using the slanted-edge SFR measurement method.

— The EffectiveAddressability sub-directory contains twelve files, arranged in four groups of three files. Each group contains an EPS file that automatically adjusts to the resolution reported by the printer for evaluation of Effective Addressabilty, a 600 spi PDF file for evaluation of Effective Addressability for a 600 spi printer and a 1 200 spi PDF file for evaluation of EffectiveAddressability for a 1 200 spi printer. The files within each of the four groups are, respectively, for 2× evaluation of horizontal effective addressability where the suspected capability is at the printer resolution, for 4× evaluation of horizontal effective addressability where the suspected capability is at twice the printer resolution, for 2× evaluation of vertical effective addressability where the suspected capability is at the printer resolution and for 4× evaluation of vertical effective addressability where the suspected capability is at twice the printer resolution.

— The NativeAddressability sub-directory contains three files: an EPS file that automatically adjusts to the resolution reported by the printer for evaluation of native addressability, a 600 spi PDF file for confirmation of native addressability of a 600 spi printer and a 1 200 spi PDF file for confirmation of native addressability of a 1 200 spi printer.

— The SquareWaveSFR sub-directory contains an EPS file and PDF files for evaluation of printing system SFR characteristics. The EPS file automatically adjusts to the resolution reported by the printer. The PDF files are supplied for 600 spi and 1 200 spi printers in two variations: the "V" variation contains vector code that is usually interpreted well by PostScript RIPs; the "B" variation contains bitmap code for the rare instances where a RIP misinterprets the vector code. The EPS file can be edited to utilize vector code (default), bitmap code, or both.

Table C.1 — Content of the ISO29112_TestPages directory

[EdgeMeasures]		
	TP3_EdgeMeasures.pdf	PDF file to print for evaluation of edge measures (blurriness, raggedness & slanted-edge SFR)
[EffectiveAddressability]		
	TP2-H2x_EffAddrHorz.eps	EPS file (2× auto-resolution, horizontal effective addressability)
	TP2-H2x_EffAddrHorz_600.pdf	PDF file (2× horizontal effective addressability at 600 spi)
	TP2-H2x_EffAddrHorz_1200.pdf	PDF file (2× horizontal effective addressability at 1 200 spi)
	TP2-H4x_EffAddrHorz.eps	EPS file (4× auto-resolution, horizontal effective addressability)
	TP2-H4x_EffAddrHorz_600.pdf	PDF file (4× horizontal effective addressability at 600 spi)
	TP2-H4x_EffAddrHorz_1200.pdf	PDF file (4× horizontal effective addressability at 1 200 spi)
	TP2-V2x_EffAddrVert.eps	EPS file (2× auto-resolution, vertical effective addressability)
	TP2-V2x_EffAddrVert_600.pdf	PDF file (2× vertical effective addressability at 600 spi)
	TP2-V2x_EffAddrVert_1200.pdf	PDF file (2× vertical effective addressability at 1 200 spi)
	TP2-V4x_EffAddrVert.eps	EPS file (2× auto-resolution, vertical effective addressability)
	TP2-V4x_EffAddrVert_600.pdf	PDF file (4× vertical effective addressability at 600 spi)
	TP2-V4x_EffAddrVert_1200.pdf	PDF file (4× vertical effective addressability at 1 200 spi)
[NativeAddressability]		
	TP1_NativeAddr.eps	EPS file (auto-resolution evaluation of native addressability)
	TP1_NativeAddr_600.eps	PDF file (600 spi native addressability)
	TP1_NativeAddr_1200.eps	PDF file (1 200 spi native addressability)
[SquareWaveSFR]		
	TP4_SquareWaveSFR.eps	EPS file (square wave SFR, vector, bitmap & combo code)
	TP4V_SquareWaveSFR_600.eps	PDF file (600 spi square wave SFR, vector code)
	TP4V_SquareWaveSFR_1200.eps	PDF file (1 200 spi square wave SFR, vector code)
	TP4B_SquareWaveSFR_600.eps	PDF file (600 spi square wave SFR, bitmap code)
	TP4B_SquareWaveSFR_1200.eps	PDF file (1 200 spi square wave SFR, (bitmap code)

C.1.3 Reference distribution ZIP file availability

A reference distribution set of Windows applications, Matlab source routines and associated files that implement and test conformance of each of the measurement methods specified in this document are available in a ZIP file "Reference distribution.zip". This ZIP file shall be downloaded from http://standards.iso.org/iso-iec/29112/ed-1/en.

As shown in Table C.2, there are six top level directories in the reference distribution ZIP file.

Table C.2 — Directory structure of the Reference distribution.zip file

[OECF]	Folders and files pertaining to OECF calibration
[Scanner_SFR]	Folders and files pertaining to slanted-edge scanner SFR measurement
[EdgeMeasures]	Folders and files pertaining to edge blurriness and edge raggedness measurement
[EffectiveAddressability]	Folders and files pertaining to effective addressability measurement
[Slantededge_PrinterSFR]	Folders and files pertaining to slanted-edge printer SFR measurement
[Squarewave_PrinterSFR]	Folders and files pertaining to square-wave printer SFR measurement

Each of these directories has a sub-directory that contains test files for conformance evaluation of the associated measurement methods. The upper grouping of sub-directories (OECF and Scanner_SFR) contains utility routines, the lower grouping of sub-directories contains the measurement method implementations.

The "OECF" directory shown in Table C.3 contains several files and a single sub-directory, "OECF_Conformance", which contains the files required to verify proper OECF calibration for the measurement methods specified in this document. Accompanying this sub-directory are the ISOIEC29112_autoOECF application, the source code on which the autoOECF application is based ('ISOIEC29112_autoOECF.m' and 'ISOIEC29112_guiOECF.m'), a PDF users guide for this application and four configuration files for OECF calibration using standard hard-copy step tablets.

Table C.3 — Content of the OECF directory

[OECF_Conformance]		
	ISO24790_1200ppi_OECF.tif	Scanned image of an ISO 24790 step tablet
	OECF_Report_expected.xls	Expected OECF report from successful calibration
	OECF_Dens_expected.txt	Expected density OECF calibration file
	OECF_Refl_expected.txt	Expected reflectance OECF calibration file
ISOIEC29112_autoOECF_v1.exe		Executable OECF application
ISOIEC29112_autoOECF_v1.m		OECF Matlab function
ISOIEC29112_guiOECF_v1.m		OECF Matlab GUI function
Config_OECF_ISO16067.xls		Configuration file for ISO 16067-1 step tablet
Config_OECF_ISO24790.xls		Configuration file for ISO 24790 step tablet
Config_OECF_MunsellNVS.xls		Configuration file for Munsell NVS step tablet
Config_OECF_Q62.xls		Configuration file for Applied Image Q62 step tablet
autoOECF_UsersGuide.pdf		OECF application users guide

The "ScannerSFR" directory shown in Table C.4 contains a single sub-directory, "ScannerSFR_Conformance", which contains the files required to verify accurate evaluation of scanner SFR using the ISOIEC29112_ScannerSFR application, a version of the ISO 16067 Matlab application "sfrmat3" extended for use with this document. Accompanying this sub-directory are the ISOIEC29112_ScannerSFR application, the source code on which the ScannerSFR application is based ('ISOIEC29112_ScannerSFR.m') and a PDF users guide for this application.

Table C.4 — Content of the Scanner_SFR directory

[ScannerSFR_Conformance]	
OECF_Refl_example.txt	OECF calibration file (sfrmat3_v4 conformance evaluation)
ISO24790_SE_1200ppi.tif	Scanned slanted-edge element (ISO 24790 test chart)
ISO24790_SE_1200ppi_ScannerSFRreport_G_expected.csv	Expected results file from the conformance evaluation
ISOIEC29112_ScannerSFR_v1.exe	Scanner SFR evaluation application
ISOIEC29112_ScannerSFR_v1.m	Scanner SFR evaluation Matlab function
ScannerSFR_UsersGuide.pdf	Users guide for sfrmat3_v4

The "EdgeMeasures" directory shown in Table C.5 contains a sub-directory, "EdgeMeasures_Conformance", which contains the files required to verify accurate evaluation of edge characteristics using the blurriness and raggedness measurement methods specified in this document. Accompanying this sub-directory are the EdgeMeasures application, the source code of the "ISOIEC29112_EdgeMeasures_v1.m" Matlab routine on which the EdgeMeasures application is based and a PDF users guide for this application.

Table C.5 — Content of the EdgeMeasures directory

[EdgeMeasures_Conformance]	
SlantedEdge_1200ppi_Reference.tif	Scanned image of a printed slanted-edge element
OECF_LUTs_Refl_example.txt	Scanner OECF compensation file (used in analysis)
ScannerSFRreport_G_example.csv	Scanner SFR measurement file (used in analysis)
SlantedEdge_1200ppi_Reference_EdgeReport.txt	Expected results file from the conformance evaluation
ISOIEC29112_EdgeMeasures_v1.exe	Executable edge attributes analysis application
ISOIEC29112_EdgeMeasures_v1.m	Edge attributes code (basis for edge application)
EdgeMeasures_UsersGuide.pdf	Edge attributes analysis application users guide

The "Effective Addressability" directory shown in Table C.6 contains a single sub-directory, "EffectiveAddressability_Conformance", which contains the files required to verify accurate evaluation using the effective addressability measurement method specified in this document and several files. Accompanying this sub-directory are the EffectiveAddressability application, the Matlab EffectiveAddressability source code routines on which the EffectiveAddressability application is based and a PDF users guide for this application.

Table C.6 — Content of the Effective Addressability directory

[EffectiveAddressability_Conformance	
EffAddr_RefBitmap.tif	Scanned image of Horz effective addressability element
EffAddr_Histogram_expected.png	Expected effective addressability results graphical histogram
EffAddr_Results_expected.txt	Expected effective addressability results text file
ISOIEC29112_EffectiveAddressability_v1.exe	Executable effective addressability analysis application
ISOIEC29112_EffectiveAddressability_v1.m	Effective addressability code (basis for addressability application)
ISOIEC29112_EffectiveAddressability_v1.fig	Effective addressability GUI (basis for addressability application)
EffectiveAddressability_UsersGuide.pdf	Effective addressability analysis application users guide

The "SlantedEdge_PrinterSFR" directory shown in Table C.7 contains a sub-directory "SlantedEdge_PrinterSFR_Conformance", which contains the files required to verify accurate evaluation of a printing system's SFR characteristic using the slanted-edge SFR measurement method specified in this document. Accompanying this sub-directory are the "ISOIEC29112_SlantedEdge_PrinterSFR.exe" application for slanted-edge printer SFR evaluation, the "ISOIEC29112_SlantedEdge_PrinterSFR.m" Matlab source code on which the slanted-edge printer SFR evaluation application is based and a PDF users guides for the SlantedEdge_PrinterSFR evaluation method.

Table C.7 — Content of the Slantededge_PrinterSFR directory

[SlantedEdge_PrinterSFR_Conformance]	
SlantedEdge_1200ppi_Reference.tif	Scanned image of a printed slanted-edge element
OECF_LUTs_Refl_example.txt	Scanner OECF compensation file (used in analysis)
ScannerSFRreport_G_example.csv	Scanner SFR measurement file (used in analysis)
SlantedEdge_1200ppi_Reference_SEprinterSFRreport_G_expected.csv	Expected scanned image Slantededge SFR results
ISOIEC29112_SlantedEdge_PrinterSFR_v1.exe	Executable, slanted-edge printer SFR application
ISOIEC29112_SlantedEdge_PrinterSFR_v1.m	Slanted-edge printer SFR analysis code
SlantedEdge_PrinterSFR_UserGuide.pdf	Slanted-edge printer SFR application users guide

The "Squarewave_PrinterSFR" directory shown in Table C.8 contains a single sub-directory, "SquareWave_PrinterSFR_Conformance", which contains the files required to verify accurate evaluation using the square-wave printer SFR measurement method specified in this document. Accompanying this sub-directory are the "ISOIEC29112_SquareWave_PrinterSFR.exe" application for square-wave printer SFR evaluation, the "ISOIEC29112_SquareWave_PrinterSFR.m" Matlab source code on which the square-wave printer SFR evaluation application is based, a PDF users guides for the square-wave printer SFR evaluation method and three configuration files used in selecting the horizontally and vertically oriented bar patterns of the scanned square-wave SFR target.

Table C.8 — Content of the Square-wave SFR directory

[Squarewave_PrinterSFR_Conformance]	
SquareWave_1200ppi_Reference.tif	Scanned image of a printed slanted-edge element
OECF_LUTs_Refl_example.txt	Scanner OECF compensation file (used in analysis)
ScannerSFRreport_G_example.csv	Scanner SFR measurement file (used in analysis)
Squarewave_1200ppi_Reference_SWprinterSFRreport_G_expected.csv	Expected scanned image Square-wave SFR results
ISOIEC29112_SquareWave_PrinterSFR_v1.exe	Executable, square-wave printer SFR application
ISOIEC29112_SquareWave_PrinterSFR_v1.m	Square-wave printer SFR analysis code
SquareWave_PrinterSFR_UsersGuide.pdf	Square-wave printer SFR application users guide
Config_SqWvSFR_5bar.txt	Configuration file for 5-bar SWprinterSFR
Config_SqWvSFR_6bar.txt	Configuration file for 6-bar SWprinterSFR
Config_SqWvSFR_7bar.txt	Configuration file for 7-bar SWprinterSFR

C.1.4 Using the reference distribution Matlab routines

Utilization of the distributed Windows applications requires installation of the v2012b Matlab Component Runtime library on the computer where measurements of the scanned bitmaps will take place. A ZIP file of the Matlab Component Runtime library installation executable, ISOIEC29112_Matlab_MCRInstaller_v2012b.exe, is available from http://standards.iso.org/iso-iec/29112/ed-1/en.

The following steps shall be followed to enable proper use of the distribution applications:

— Download the file "ISOIEC29112_Matlab_MCRInstaller_v2012b.exe" from the ISO website.

— Double-click this ISOIEC29112_Matlab_MCRinstaller_v2012b.exe file to initiate installation of the v2012b Matlab Component Runtime library.

— Ensure that the MCR_library.dll file that is installed by the MCR installer is above any other Matlab libraries in the Windows path.

— Double-click on the appropriate measurement method application file to run an evaluation. The MCR library is unpacked on the first running of one of the measurement method applications, which takes time. See Clauses C.2 and C.3 for details.

Utilization of the Matlab source routines requires a licensed Matlab application, including the Matlab Signal Processing and Image Processing toolboxes, v2007 or later, to be installed on the computer where measurements of the scanned bitmaps will take place. The following steps shall be followed to enable proper use of the distribution routines:

— Start the Matlab application and type `ver` at the Matlab prompt to obtain a list of installed products.

— Verify that the listed Matlab version is v2007 or later and that the Signal Processing and Image Processing toolboxes are available.

— Navigate to the appropriate folder containing an appropriate measurement method Matlab m-file to run an evaluation. See Clauses C.2 and C.3 for details.

— Use the syntax provided in this annex for running the measurement method.

C.2 Utilities, evaluation and conformance

C.2.1 General

There are two utility applications and Matlab routines that accompany the measurement methods specified in this document. These two utilities are required for proper evaluation of the measurement methods defined in this document. Proper use of these utilities is documented in the following clauses.

1) OECF (opto-electronic conversion function) calibration is required to provide an analytic meaning (using the OECF calibration file) for the code values (e.g. 0 – 255 for 8-bit data) provided by reflection scanners. The OECF calibration file is required by each of the measurement methods specified in this document.

2) The slanted-edge SFR evaluation method, developed in ISO 12233 and specified in ISO 16067-1, is required for determination of the spatial frequency response characteristic of the qualified reflection scanner utilized in the measurement methods specified in this document.

C.2.2 Scanner OECF calibration and conformance

C.2.2.1 General

The OECF characteristic of a reflection scanner, specified in ISO 14524, provides an analytic interpretation of the code values (e.g. 0 – 255 for 8-bit data) provided by a reflection scanner. As the first step in OECF calibration, a reflective step tablet, consisting of a series of neutral patches uniformly spanning a sufficient range of optical density, shall be measured and the measurements tabulated to provide optical density values for each of these patches. The second step in OECF calibration is to scan the measured step tablet with the scanner to be calibrated, under conditions specified in Annex B and used in all measurement processes, to provide an image file of code values. The application, "autoOECF.exe", and the Matlab routine, "autoOECF.m", match the tabulated measurement data with the average code value for each patch, provided by analysis of the scanned image of the step tablet, and fit these data pairs to create a model-based table of reflectance or density values for every possible code value that the scanner can provide. These ISO 14524 compliant tables are saved as OECF calibration text files and used by the measurement methods specified in this document to accurately interpret scanned code values as percent reflectance or as reflection density in their analyses.

C.2.2.2 Target definition files

A target definition file is a tab separated text document that contains three sets of data, identified by tag strings and lengths in the first column of the file. The tabular form of a QA62 twenty patch step tablet test target is illustrated in Table C.9. The units for X and Y locations are millimetres.

Table C.9 — Target definition file structure

Target	Name
1	Applied Image QA62 SFR & OECF

Fiducials	ID	X	Y	Prompt
4	ULC	4	4	Click on upper-left " + " mark.
	URC	70	4	Click on upper-right " + " mark.
	LRC	70	70	Click on lower-right " + " mark.
	LLC	4	70	Click on lower-left " + " mark.

Calibration	ID	X	Y	dX	dY	Dvis
20	T1	13.5	13.032	4.752	4.752	0.111
	T2	23.3	13.032	4.752	4.752	0.162
	T3	32.5	13.032	4.752	4.752	0.196
	T4	41.478	13.032	4.752	4.752	0.276
	T5	50.982	13.032	4.752	4.752	0.384
	R6	60.486	13.032	4.752	4.752	0.485
	R7	60.486	22.47	4.752	4.752	0.551
	R8	60.486	31.974	4.752	4.752	0.577
	R9	60.486	41.478	4.752	4.752	0.666
	R10	60.486	50.982	4.752	4.752	0.719
	B11	60.486	60.486	4.752	4.752	0.796
	B13	41.478	60.486	4.752	4.752	0.93
	B14	32.5	60.486	4.752	4.752	0.984
	B15	23.3	60.486	4.752	4.752	1.043
	L16	13.5	60.486	4.752	4.752	1.085
	L17	13.5	50.982	4.752	4.752	1.191
	L18	13.5	41.478	4.752	4.752	1.278
	L19	13.5	31.974	4.752	4.752	1.421
	L20	13.5	22.47	4.752	4.752	1.66

The data associated with the 'Target' tag has one value and one field: "Name". In the instance shown in Table C.9, the "Name" is "Applied Image QA62 SFR & OECF". The data associated with the "Fiducials" tag has four values in each of four fields: "ID", "X", "Y" and "Prompt". In the instance shown in Table C.9, the "ID" refers to corner marks in ULC (upper left corner), URC, LRC or LLC corner of the target, their associated X and Y positions, and the text strings used to prompt a user to identify each of the fiducial positions, in turn. The data associated with the "Calibration" tag has 20 values in each of 6 or 9 fields: "ID", "X", "Y", "dX", "dY" and "Dvis" (or "Dr", "Dg", "Db" and "Dvis"). In the instance shown in Table C.9, "ID" identifies each of the 20 patches in the target. Associated with each patch are the "X" and "Y" centre positions of each patch, the width, "dX", and height, "dY", of each patch and the measured density, "dVis" of the patch. For a grayscale calibration, "Dvis" is the visual reflection density for each patch tabulated from measurement of all patches with a calibrated reflection densitometer. For an RGB OECF calibration, four measurement fields, corresponding to reflection densities measured through red, green, blue and visual filters, ("Dr", "Dg", "Db" and "Dvis") are tabulated instead of one field, "Dvis", for the grayscale case.

A target definition file shall be created by the user of this document, in the manner specified here, for every target utilized in OECF calibration of scanners employed in attribute evaluation using the measurement methods specified in this document.

C.2.2.3 Scanner OECF calibration

OECF calibration of any reflection scanner used in the measurement methods specified in this document is required. OECF calibration of a qualified reflection scanner is a four step process, summarized below and in Table C.10.

1) A physical instance of a step tablet target with at least ten steps shall be selected. The uniform patches of this target shall span the range of densities expected in the set of print samples to be evaluated with the measurement methods specified in this document.

2) An individual target definition file shall be created for each step tablet target used for OECF calibration. Variability in the manufacture of these step tablet targets is too large to permit use of a generic target definition file for a class of step tablets. Illustrative target definition files are provided in the reference distribution for a generic QA62 test target from Applied Image, a generic ISO 16067-1 target, a generic ISO/IEC 24790 conformance target and a generic arrangement of the Neutral Value Scale patches available from the Munsell division of the X-Rite Corporation.

   — The individual target definition file for each physical step tablet instance involves tabulation of the density measurements for each patch of the step tablet target in the target definition file, either from Dvis values, for a grayscale calibration, or from Dr, Dg, Db and Dvis values for the red, green, blue and visual filter density measurements, both obtained from a well-calibrated reflection densitometer for each patch of the step tablet.

   — If the physical arrangement of patches in a step tablet to be used for OECF calibration differs from the arrangement documented in the reference distribution files, these fields in the individual target definition file shall be updated with position and size measurements from the individual step tablet target.

   — If a different set of fiducial marks or a different set of user prompt strings are to be used, the relevant fields in the target definition files shall be updated accordingly.

Table C.10 — OECF calibration process

OECF calibration step tablet target:	At least ten steps
	Uniform patches
	Spans printer density range
Target definition file:	Name of physical step tablet target
	Location of all fiducials
	User prompt string for each fiducial
	Location of each patch centre
	Size of each patch
	Measured density of each patch
	(Dvis or Dr, Dg, Db and Dvis)
Scan of step tablet target:	According to Annex B specifications
ISOIEC29112_autoOECF	Input: Target definition file for step tablet target
(Application or	Input: Lossless bitmap scan file of step tablet target
Matlab function):	Output: OECF calibration process report file
	Output: OECF calibration file

3) With a calibrated target definition file associated with the individual step tablet target to be used for OECF calibration of a qualified scanner, the individual step tablet target shall be scanned with the qualified scanner in accordance with Annex B and a lossless bitmap file of the scanned step tablet shall be saved.

4) With the target definition file for the individual step tablet target from step 2 to guide the extraction of image regions from the scanned step tablet from step 3 for each of the patches in the target, the

average scanned image code value for each patch region shall be related with the measured density values of those patches. A model-based least-squares fit of this relationship then provides a fit characteristic from which fitted density or reflectance values can be associated with every integer code value provided by the scanner, according to ISO 14524 specifications, and saved as a scanner calibration text file. This process is provided by either the application, "ISOIEC29112_autoOECF.exe", or the Matlab routine, "ISOIEC29112_autoOECF.m". A report file, summarizing the quality of the calibration process is also provided.

C.2.2.4 Scanner OECF conformance

The OECF_Conformance sub-directory of the OECF directory in the reference distribution file structure contains three files: a lossless bitmap scan file of the step tablet region of an ISO/IEC 24790 conformance test page, "ISO24790_1200ppi_OECF.tif", an example of the OECF process report, "OECF_Report_expected.xls", and an example of an OECF calibration file, "OECF_refl_expected.txt".

Before use, an implementation of the OECF calibration process provided by the "ISOIEC29112_autoOECF" application or the "ISOIEC29112_autoOECF.m" Matlab routine shall be verified to be in conformance with the specifications of this document using the following process. Use either the "ISOIEC29112_autoOECF" application or the "ISOIEC29112_autoOECF.m" Matlab routine to perform an OECF calibration process utilizing the bitmap scan file "ISO24790_1200ppi_OECF.tif" in the OECF_Conformance sub-directory and the target definition file "Config_OECF_ISO24790.xls" in the OECF directory. The standard error of the OECF fit, as reported by the "OECF_report" file created by the calibration process, shall be less than one percent of the measurement range, which should look very similar to the "OECF_Report_expected.xls" file in the reference distribution file structure.

The "OECF_refl.txt" file created by the calibration process shall be substantially similar to the "OECF_refl_expected.txt" file in the reference distribution file structure, matching element by element to within one percent. This conformance process is summarized in Table C.11 and the expected fit results are shown in Figure C.1.

Table C.11 — OECF calibration conformance verification

ISOIEC29112_autoOECF:	Input: Target definition file: "Config_OECF_ISO24790.xls"
(Application	Input: Lossless bitmap scan file: "ISO24790_1200ppi_OECF.tif"
or Matlab file)	Output: OECF calibration process report file Matches "OECF_Report_expected.xls" with fit error of <1 %
Annex B compliant scan	Output: OECF calibration file All elements match "OECF_LUTS_Refl_expected.txt" within 1 %

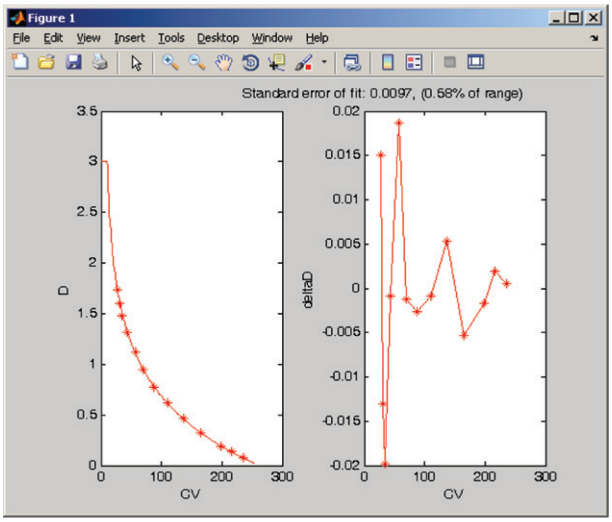


Figure C.1 — OECF calibration conformance fit

C.2.3 Scanner SFR evaluation and conformance

C.2.3.1 General

Slanted-edge SFR (spatial frequency response) analysis of the scan of a sharp slanted edge can provide an accurate characterization of that scanner's spatial frequency response capability. Slanted-edge SFR analysis was developed in ISO 12233 and has been specified as a method for characterizing reflection scanning systems in ISO 16067-1. The implementation of the sfrmat3 Matlab routine, developed for ISO 16067-1, has been extended to include the ROI size and position variation technique discussed in 4.6 in the ISOIEC29112_ScannerSFR application utilized here.

C.2.3.2 Scanner SFR evaluation

Evaluation of a reflection scanning system's spatial frequency response characteristic requires a reflection test target with a sharp edge transition. The Dmin – Dmax slanted-edge element of an ISO/IEC 24790 conformance test target provides the sharp edge transitions for this purpose.

The reflection scanning system to be evaluated shall be set up according to Annex B specifications.

— The ISO/IEC 24790 conformance test target shall be placed near the centre of the scanner platen so that the slanted square element of the test target is centred on the platen and the edges of the slanted square element are rotated between 5° and 10° from the platen edges.

— The test target region containing the slanted square element shall be scanned using a reflection scanner and a scanner utility compliant with the specifications of Annex B to provide a lossless scanned bitmap of the slanted square region for analysis.

— Use of several identical scans is encouraged to minimize noise in the analysis.

Slanted-edge SFR analysis of the scanned bitmap images is summarized in Table C.12 and can utilize either the application "ISOIEC29112_ScannerSFR.exe" or the "ISOIEC29112_ScannerSFR.m" Matlab routine. In either case, OECF calibration of the scanning system as specified in C.2.2 and ROI size and shape variation as specified in 4.6 shall be employed to minimize the bias introduced by any particular ROI choice. The scanner SFR characteristic provided by this analysis shall be documented and saved for use with other measurement methods specified in this document.

Table C.12 — Scanner SFR analysis process

Annex B compliant scanning:	Target to scan: ISO/IEC 24790 conformance test target
	Target positioning: Square element centred and page edges parallel to platen
	Output: Lossless bitmaps of slanted square region
ISOIEC29112_ScannerSFR:	Input: Lossless bitmaps of slanted square region
	Input: Scanner OECF characterization file
	Output: Scanner SFR report file

C.2.3.3 Scanner SFR conformance

The ScannerSFR_Conformance sub-directory of the Scanner_SFR directory in the reference distribution file structure contains three files: a lossless bitmap scan file of the slanted square region of an ISO/IEC 24790 conformance test page, "ISO24790_SE_1200ppi.tif", an example of the expected scanner SFR analysis process report, "ISO24790_SE_1200ppi_Summary_G_expected.xls", and the OECF calibration file required for conformance evaluation, "OECF_LUTs_Refl_example.txt".

Table C.13 — Scanner SFR conformance process

Reference implementation:	ISOIEC29112_ScannerSFR.exe or ISOIEC29112_ScannerSFR.m
Reference bitmap file:	ISO24790_SE_1200ppi.tif
OECF file:	OECF_LUTs_Refl_example.txt
Expected evaluation results file:	ISO24790_SE_1200ppi_ScannerSFRreport_G_expected.csv
Expected evaluation results:	Smoothed sampling efficiency (left, right, top, bottom): 89.0, 83.9, 63.6, 64.4
Conformance tolerance:	Within 1 %

Before use, an implementation of the scanner SFR evaluation process that is provided by the "ISOIEC29112_ScannerSFR" application or the "ISOIEC29112_ScannerSFR.m" Matlab routine shall be verified to be in conformance with the specifications of this document using the following process. Use either the "ISOIEC29112_ScannerSFR.exe" application or the "ISOIEC29112_ScannerSFR.m" Matlab file to analyze the scanned bitmap image of the conformance test page, "ISO24790_SE_1200ppi.tif" using the scanner OECF calibration file, "OECF_LUTs_Refl_example.txt", both obtained from the "ScannerSFR_Conformance sub-directory of the Scanner_ SFR directory in the reference distribution file structure.

The values reported in the "ISO24790_SE_1200ppi_Summary_G.csv" file shall match the values in the "ISO24790_SE_1200ppi_Summary_G_expected.csv" file in the ScannerSFR_Compliance sub-directory of the Scanner_SFR directory in the reference distribution file structure to within one percent for conformance. This conformance process is summarized in Table C.13.

C.3 Measurement methods, evaluation and conformance

C.3.1 General

The native addressability measurement method is a purely subjective evaluation and does not require conformance testing aside from the printing system requirements specified in Annex A. The evaluation and conformance process for the effective addressability, edge blurriness, edge raggedness, slanted-edge SFR and square-wave SFR measurement methods is specified in this annex. The implementations of the measurement methods for evaluation of edge blurriness, edge raggedness, slanted-edge SFR and square-wave SFR each include the technique for ROI size and shape variation discussed in 4.6 and the scanner SFR normalization technique discussed in B.4.4.

C.3.2 Effective addressability measurement method evaluation

The effective addressability of a printing system shall be evaluated from scans of the newest available effective addressability test pages as specified in 4.3, printed according to the specifications of Annex A and scanned according to the specifications of Annex B. Printed samples of the effective addressability test pages shall be placed on the scanner platen such that the edges of the printed samples are rotated 45° with respect to the edges of the scanner platen. This is summarized in Table C.14.

Table C.14 — Effective addressability analysis process

Annex B compliant scanning:	Target to scan: TP2-H2x_EffAddrHorz or TP2-V2x_EffAddrVert
	Target positioning: Page centred and rotated 45° from the platen edges
	Output: Lossless bitmaps of scanned target samples
ISOIEC29112_EffectiveAddressability:	Input: Lossless bitmaps of scanned target samples
	Input: Scanner OECF characterization file
	Output: EffAddr_Results report file

C.3.3 Effective addressability evaluation conformance

Before use, an implementation of the effective addressabiltity measurement method shall be verified to be in conformance with the specifications of this document using the process specified here and shown in Figures C.2 and C.3 and Table C.15.

Conformance verification for effective addressability:

1. Run the effective addressability implementation (ISOIEC29112_EffectiveAddressability (.exe or .m).
2. Enter the file name of the reference bitmap file (EffAddr_RefBitmap.tif) using the "Browse" button
3. Keep default options, but select 9 subsections (if an out-of-memory error occurs, select 16).
4. Press "Run".
5. Conformance is confirmed when the effective address results graph that appears at the end of the analysis closely resembles Figure C.2 above or the image file EffAddr_Histogram_expected.png.

Table C.15 — Effective addressability conformance

Reference implementation:	ISOIEC29112_EfffectiveAddressability (.exe or .m)
Reference bitmap file:	EffAddr_RefBitmap.tif
Expected evaluation results file:	EffAddr_Histogram_expected.png
Expected evaluation result:	See Figure C.2

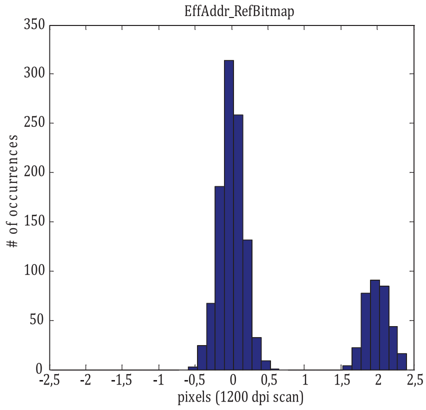


Figure C.2 — Expected results (figure)

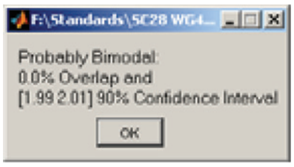


Figure C.3 — Expected results (information)

Figure C.2 and C.3 show the expected graphical and informative output of the conformance evaluation of the reference bitmap image. A conforming implementation of the effective addressability method shall provide a result that closely resembles Figure C.2 with two well separated peaks. The left peak (at zero) shall have approximately three times the area as the right (non-zero) peak. The location of the second peak indicates the effective addressability which in this case is 600 ppi (two 1 200 ppi pixels). If the GUI "Default" output is selected, files of the figure (.fig and .png format) and of the analysis information (.txt format) are saved in the directory of the analyzed image file.

C.3.4 Edge blurriness and edge raggedness measurement method evaluation

The edge blurriness measurement method and the edge raggedness measurement method shall be evaluated from scans of the newest available TP3_EdgeMeasures test page as specified in 4.4, printed according to the specifications of Annex A and scanned according to the specifications of Annex B. The elements of the printed samples to be analyzed shall be centred in the platen area (see B.4.2) with the edges of the sample page parallel to the platen edges. This is summarized in Table C.16.

Table C.16 — Edge blurriness and edge raggedness analysis process

Annex B compliant scanning:	Target to scan: TP3_EdgeMeasures
	Target positioning: Page centred on elements to analyze (see B.4.2), page & platen edges parallel
	Output: Lossless bitmaps of scanned target samples
ISOIEC29112_EdgeMeasures:	Input: Lossless bitmaps of scanned target samples
	Input: Scanner OECF characterization file
	Output: EdgeReport file

C.3.5 Conformance of the edge blurriness measurement method

Before use, an implementation of the edge blurriness measurement method shall be verified to be in conformance with the specifications of this document using the process specified here and shown in Table C.17.

Conformance verification for edge blurriness:

1. Run the edge blurriness implementation [ISOIEC29112_EdgeMeasures (.exe or .m)].
2. When prompted, select the reference bitmap file (SlantedEdge_1200ppi_Reference.bmp).
3. When prompted, select the OECF calibration file (OECF_LUTS_Refl_example.txt) for use with this bitmap.
4. When prompted, select the scanner SFR measurement file (ScannerSFR_Summary_G_example.csv).
5. Select the 8° orientation element (click near the centre of the element).
6. The analysis results are saved as a text file (SlantedEdge_1200ppi_Reference_EdgeReport.txt).
7. Open the results file. If the reported evaluation results for edge blurriness match the expected evaluation results of Table C.15 for edge blurriness within 1 % tolerance, conformance is confirmed.

Table C.17 — Edge blurriness conformance

Reference implementation:	ISOIEC29112_EdgeMeasures (.exe or .m)
Reference bitmap file:	SlantedEdge_1200ppi_Reference.tif
OECF file:	OECF_LUTs_Refl_example.txt
ScannerSFR measurement file:	ScannerSFR_Summary_G_example.csv
Expected evaluation results file:	SlantedEdge_1200ppi_Reference_EdgeReport_expected.txt
Expected evaluation result:	Edge blurriness (left, right, top, bottom): 51.2, 53.2, 56.9, 51.5
Conformance tolerance:	Within 1 %

C.3.6 Conformance of the edge raggedness measurement method

Evaluation of edge blurriness and edge raggedness result from a single slanted-edge analysis using the ISOIEC29112_EdgeMeasures.exe application of the ISOIEC29112_EdgeMeasures.m routine. Conformance of the edge raggedness measure can be obtained through the same analysis used for verification of the edge blurriness measure.

Before use, an implementation of the edge raggedness measurement method shall be verified to be in conformance with the specifications of this document using the process specified here and shown in Table C.18.

Conformance verification for edge raggedness:

1. Run the edge raggedness implementation [ISOIEC29112_EdgeMeasures (.exe or .m)].
2. When prompted, select the reference bitmap file (SlantedEdge_1200ppi_Reference.bmp).
3. When prompted, select the OECF calibration file (OECF_LUTS_Refl_example.txt) for use with this bitmap.
4. When prompted, select the scanner SFR measurement file (ScannerSFR_Summary_G_example.csv).
5. Select the 8° orientation element (click near the centre of the element).
6. The analysis results are saved as a text file (SlantedEdge_1200ppi_Reference_EdgeReport.txt).
7. Open the results file. If the reported evaluation results for edge raggedness match the expected evaluation results of Table C.18 for edge raggedness within 1 % tolerance, conformance is confirmed.

Table C.18 — Edge raggedness conformance

Reference implementation:	ISOIEC29112_EdgeMeasures (.exe or .m)
Reference bitmap file:	SlantedEdge_1200ppi_Reference.bmp
OECF file:	OECF_LUTs_Refl_example.txt
ScannerSFR measurement file:	ScannerSFR_Summary_G_example.csv
Expected evaluation results file:	SlantedEdge_1200ppi_Reference_EdgeReport_expected.txt
Expected evaluation result:	Edge raggedness (left, right, top, bottom): 8.36, 8.03, 8.96, 8.32
Conformance tolerance:	Within 1 %

C.3.7 Slanted-edge printer SFR measurement method evaluation

The slanted-edge printer SFR measurement method shall be evaluated from scans of the newest available TP3_EdgeMeasures test page as specified in 4.5 and particularly 4.5.3, printed according to the specifications of Annex A and scanned according to the specifications of Annex B. The elements of the printed samples to be analyzed shall be centred in the platen area (see B.4.2) with the edges of the sample page parallel to the platen edges. This is summarized in Table C.19.

Table C.19 — Slanted-edge printer SFR analysis process

Annex B compliant scanning:	Target to scan: TP3_EdgeMeasures
	Target positioning: Page centred on elements to analyze (see B.4.2), page & platen edges parallel
	Output: Lossless bitmaps of scanned target samples
ISOIEC29112_SlantedEdge_PrinterSFR:	Input: Lossless bitmaps of scanned target samples
	Input: Scanner OECF characterization file
	Output: SEprinterSFRreport

C.3.8 Conformance of the slanted-edge SFR measurement method

Before use, an implementation of the slanted-edge SFR measurement method shall be verified to be in conformance with the specifications of this document using the process specified here and shown in Table C.20.

Conformance confirmation for slanted-edge SFR:

1. Run the slanted-edge SFR implementation ISOIEC29112_SlantedEdge_PrinterSFR.exe or ISOIEC29112_SlantedEdge_PrinterSFR.m.
2. When prompted, select the reference bitmap file (SlantedEdge_1200ppi_Reference.tif).
3. Select the OECF calibration file (OECF_LUTS_Refl_example.txt) for use with this bitmap.
4. Select the scanner SFR normalization file for use with this bitmap ("ScannerSFR_example.txt").
5. Select the 8° orientation element (click and drag, or default for double-click).
6. The analysis results are saved as a text file, SlantedEdge_1200ppi_Reference_SEprinterSFRreport_G.txt.
7. Open the results file. When the reported evaluation results for slanted-edge SFR match the expected evaluation results of Table C.20 for slanted-edge SFR within 1%, conformance is confirmed.

Table C.20 — Slanted edge SFR conformance

Reference implementation:	ISOIEC29112_SlantedEdge_PrinterSFR (.exe or .m)
Reference bitmap file:	SlantedEdge_1200ppi_Reference.tif
OECF file:	OECF_LUTs_Refl_example.txt
ScannerSFR measurement file:	ScannerSFRreport_G_example.csv
Expected evaluation results file:	SlantedEdge_1200ppi_Reference_SEprinterSFRreport_G_expected.csv
Expected evaluation result:	Smoothed sampling efficiency (left, right, top, bottom): 57.9, 57.3, 47.6, 57.5
Conformance tolerance:	Within 1 %

C.3.9 Square-wave SFR measurement method evaluation

The square-wave SFR measurement method shall be evaluated from scans of the newest available TP4V_SquareWaveSFR test page as specified in 4.5 and particularly 4.5.5, printed according to the specifications of Annex A and scanned according to the specifications of Annex B, with careful attention to alignment on the scanner platen. A bitmap version of this test page (TP4B_SquareWaveSFR.eps) is provided for use if the vector code of TP4V_SquareWaveSFR.eps is mis-interpreted by the printer RIP.

The elements of the printed samples to be analyzed shall be centred in the platen area (see B.4.2) with the edges of the sample page carefully aligned parallel to the platen edges (see 4.5.5, within 0,25°). This is summarized in Table C.21.

Table C.21 — Square wave SFR analysis process

Annex B compliant scanning:	Target to scan: TP4V_SquareWaveSFR (or TP4B_SquareWaveSFR if RIP mis-interpretation)
	Target positioning: Page centred on elements to analyze (see B.4.2), page & platen edges parallel
	Output: Lossless bitmaps of scanned target samples
ISOIEC29112_SquareWave_PrinterSFR:	Input: Lossless bitmaps of scanned target samples
	Input: Scanner OECF characterization file
	Output: SWprinterSFRreport

C.3.10 Conformance of the square-wave SFR measurement method

Before use, an implementation of the square-wave SFR measurement method shall be verified to be in conformance with the specifications of this document using the process specified here and shown in Table C.22.

Conformance confirmation for square-wave SFR:

1. Run the square-wave SFR implementation ISOIEC29112_SquareWave_PrinterSFR.exe or ISOIEC29112_SquareWave_PrinterSFR.m.

2. Select the configuration file for the target to be analyzed (Config_SqWvSFR_5bar.txt).

3. Select the OECF calibration file for the scanner used in the evaluation (OECF_LUTS_Refl_example.txt).

4. Select the measured SFR characteristic file for the scanner used in the evaluation (ScannerSFRreport_G_example.csv).

5. Select the reference bitmap file (SqareWave_1200ppi_Reference.tif).

6. When an image of the reference bitmap file is displayed, drag a selection rectangle around a single set of horizontal and vertical bars with white space outside of the outermost rectangle surrounding the sets of bars.

7. With the selected region displayed, use the "Rotate Clockwise" button to orient the image so that the text specifying the number of printer spots employed in each bar of square-waves is oriented for easy horizontal reading, then press the "Continue" button to start the analysis.

8. Yellow rectangles are displayed indicating the regions of interest (ROIs) used for analysis (defined in the configuration file). Scanner SFR normalization plots for horizontal and vertical patterns are then displayed, followed by the analysed square-wave SFR graphs for horizontal and vertical patterns.

9. Open the results file. Conformance is confirmed when the reported evaluation results for square-wave SFR match the expected evaluation results of Table C.22 for square-wave SFR within 1 %.

Table C.22 — Square wave SFR conformance

Reference implementation:	ISOIEC29112_SquareWave_PrinterSFR (.exe or .m)
Reference bitmap file:	SquareWave_1200ppi_Reference.tif
OECF file:	OECF_LUTs_Refl_example.txt
Scanner SFR measurement file:	ScannerSFRreport_G_example.csv
Target Definition file:	Config_SqWvSFR_6bar_example.xls
Expected evaluation results file:	SquareWave_1200ppi_Reference_SWprinterSFRreport_expected.csv
Expected evaluation result:	Smoothed sampling efficiency (Horizontal, Vertical) 74,4, 65,2
Conformance tolerance:	Within 1 %

Annex D
(informative)

Reporting

D.1 Single configuration report

The intent of an assessment report is to provide the measured results of the assessment along with a context of the setup and testing processes of the resolution assessment sufficient to reproduce the assessment. These are shown in Table D.1. As specified in 6.2, the required configuration documentation for the assessment of a single printer configuration includes:

1. Documentation of the assessor and the environmental conditions in which the assessment is done.
2. Documentation of the printer, its setup configuration, paper motion direction and state at assessment.
3. Documentation of the substrate used for assessment.
   - — The substrate weight, surface and classification are required.
   - — The manufacturer and name of the substrate are optional, but often very useful.
4. Documentation of the test page submission process.
5. Documentation of the setup and the conformance of the scanner and scanner control application used for measuring a printing system's resolution characteristics along with names of associated scanner files.

Table D.1 — Example of single configuration assessment documentation

	Item:	**Information:**	**Units:**
Test conditions:	Assessment Date:	27-Aug-18	
	Assessor or assessing organization:	Benchmarks-R-US	
	Environmental conditions:	25 °C, 40% RH	°C, % RH
Printer:	Manufacturer and model:	Acme HeRes-1200	
	Configuration:	Default settings (1 200 spi, RET on)	
	Component condition:	New printing cartridge (5 prints)	
	Printer driver version:	v. 2.1	
	Paper motion orientation:	Along the long edge	
	Reported printer addressability:	800 spi	spi
Substrate:	Substrate weight, surface and type:	80 gsm, uncoated, Bond	
	Substrate manufacturer and name:	*Hammermill LaserPrint Bond*	
Submission:	Method of test page submission:	Copy, using a command Window	
Scanning:	Scanner manufacturer:	E-scan S-2400	
	Resolution setting:	1 200 ppi	ppi
	Scanner conformance:	Yes	
	Scanner OECF compensation:	Reflection aim	
	Scanner SFR normalization:	None (for internal use only)	

Table D.1 *(continued)*

	Item:	Information:	Units:
Measurements, test pages & conformance:	Measurement name/conformance:	Native Addressability / compliant	
	Native addressability test page name:	TP1_NativeAddr_v1.eps (set at 806.4 spi)	
	Assessment element orientation:	IT / XT	
	Measurement name/conformance:	ISOIEC29112_EffectiveAddressability_v1 / compliant	
	Effective addressability test page name:	TP2-H2x_EffAddrHorz_v1.eps (set at 806.4 spi)	
	Effective addressability test page name:	TP2-V2x_EffAddrVert_v1.eps (set at 806.4 spi)	
	Assessment element orientation:	IT / XT	
	Measurement name/conformance:	ISOIEC29112_EdgeMeasures_v1 / compliant	
	Edge blurriness test page name:	TP3_EdgeMeasures_v1.eps	
	Assessment element orientation:	8° (nearly XT), 98° (nearly IT)	
	Measurement name/conformance:	ISOIEC29112_EdgeMeasures_v1 / compliant	
	Edge raggedness test page name:	TP3_EdgeMeasures_v1.eps	
	Assessment element orientation:	8° (nearly XT), 98° (nearly IT)	
	Measurement name/conformance:	ISOIEC29112_SlantedEdge_PrinterSFR_v1 / compliant	
	Slanted-edge SFR test page name:	TP3_EdgeMeasures_v1.eps	
	Assessment element orientation:	8° (nearly XT), 98° (nearly IT)	
	Measurement name/conformance:	ISOIEC29112_SquareWave_PrinterSFR_v1 / compliant	
	Square-wave SFR test page name:	TP4V_SquareWaveSFR_v1.eps (set at 806.4 spi)	
	Assessment element orientation:	IT / XT	

As specified in 6.3, the required documentation of associated measurement results includes:

6. For each attribute, documentation of the measurement method used and its conformance, the test page used and the orientations of the test page elements with respect to paper motion through the printer.

7. A full enumeration of the assessment results including the name of the characteristic, its orientation, its measured values, the number of elements contributing to the measured values and their units.

The full assessment documentation can be tabulated in a single table or can take a two-part form such as that shown in Tables D.1 and D.2, with the second table tabulating the measurement results.

As noted in Clause 6, the native addressability as reported by a printing system is documented in the configuration documentation. Native addressability, separately evaluated with the native addressability test page, and the measurement results of other attributes specified in this document are reported in the associated measurement results table.

Table D.2 shows an assessment in which all the print quality characteristics contributing to the perceived resolution of the assessed printer were measured and reported.

For measurements that share the same analysis method and test page, there is no need to report the analysis method, test page name and analysis method conformance in duplicate.

Table D.2 — Example of single configuration measurement documentation

Attribute name:	Orientation:	Data: mean, stdev, min, max	# Elements:	Units:
Native addressability	Horz, XT, 0° & Vert, IT, 90°	1 200, 1 200	1	spi
Effective addressability	Horz, XT, 0° & Vert, IT, 90°	1 200, 1 200	1	spi
Edge blurriness	Horz, XT, 0°	5,7, 0,8, 3,0, 6,4	6	microns
Edge blurriness	Vert, IT, 90°	6,2, 0,9, 3,3, 7,9	6	microns
Edge blurriness	8°	6,9, 1,2, 4,2, 9,3	6	microns
Edge blurriness	98°	7,0, 1,3, 4,1, 9,4	6	microns
Edge raggedness	Horz, XT, 0°	9,1, 1,5, 5,8, 12,7	6	microns
Edge raggedness	Vert, IT, 90°	9,5, 1,5, 6,1, 13,0	6	microns
Edge raggedness	8°	12,2, 2,4, 8,5, 16,0	6	microns
Edge raggedness	98°	12,4, 2,5, 8,6, 16,5	6	microns
Slanted-edge SFR	Horz, XT, 0°	5,2, 0,3, 4,7, 5,7	6	cy/mm @ 50 % SFR
Slanted-edge SFR	Vert, IT, 90°	5,3, 0,3, 4,7, 5,9	6	cy/mm @ 50 % SFR
Slanted-edge SFR	8°	4,5, 0,4, 3,8, 5,3	6	cy/mm @ 50 % SFR
Slanted-edge SFR	98°	4,4, 0,4, 3,7, 5,2	6	cy/mm @ 50 % SFR
Square-wave SFR	Horz, XT, 0°	5,1, 0,3, 4,6, 5,6	5	cy/mm @ 50 % SFR
Square-wave SFR	Vert, IT, 90°	5,2, 0,3, 4,7, 5,7	5	cy/mm @ 50 % SFR

D.2 Multiple configuration report

The intent of a report of a multiple configuration assessment is to provide the measured results of the assessment along with a context of the setup and testing processes of the resolution assessment sufficient to reproduce the assessment.

As specified in 6.2, the required configuration documentation for the assessment of multiple printer configurations includes:

1. Documentation of the assessor and the environmental conditions in which the assessment is done.
2. Documentation of the printer, its setup configuration, paper motion direction and state at assessment.
3. Documentation of the substrate used for assessment.
   - The substrate weight, surface and classification are required.
   - The manufacturer and name of the substrate are optional, but often very useful.
4. Documentation of the test page submission process.
5. Documentation of the setup and the conformance of the scanner and scanner control application used for measuring a printing system's resolution characteristics along with names of associated scanner files.

The required documentation of associated measurement results, as specified in 6.3, includes:

1. Documentation of the configuration of the printer.
   - This supersedes the conventional reporting of printing system configuration as part of the test configuration table.

2. For each attribute, documentation of the measurement method used and its conformance, the test page used and the orientations of the test page elements with respect to paper motion through the printer.

3. A full enumeration of the assessment results including the name of the characteristic, its orientation, its measured values, the number of elements contributing to the measured values and their units.

A convenient report structure is to report those documentation entries that are common to all configurations in one table, and then the documentation entries that vary with configuration, along with their associated measurement results, in a second group of tables, one table per configuration.

Table D.3 — Example of common documentation for a multiple configuration assessment

	Item:	Information:	Units:
Test conditions:	Assessment Date:	27-Aug-14	
	Assessor of assessing organization:	Benchmarks-R-US	
	Environmental conditions:	25 °C, 40 % RH	°C, % RH
Printer:	Manufacturer and model:	Acme HeRes-1200	
	Component condition:	New printing cartridge (5 prints)	
	Printer driver version:	v. 2.1	
	Paper motion orientation:	Along the long edge	
	Reported printer addressability:	800 spi	spi
Substrate:	Substrate weight, surface and type:	80 gsm, uncoated, Bond	
	Substrate manufacturer and name:	Hammermill LaserPrint Bond	
Submission:	Method of test page submission:	Copy, using a command Window	
Scanning:	Scanner manufacturer:	E-scan S-2400	
	Resolution setting:	1 200 ppi	ppi
	Scanner conformance:	Yes	
	Scanner OECF compensation:	Reflection aim	
	Scanner SFR compensation:	None (for internal use only)	
Measurements, test pages & conformance:	Measurement name/conformance:	Native Addressability / compliant	
	Native Addressability test page name:	TP1_NativeAddr_v1.eps (set at 806.4 spi)	
	Assessment element orientation:	IT / XT	
	Measurement name/conformance:	ISOIEC29112_EffectiveAdressability_v1 / compliant	
	Effective addressability test page name:	TP2-H2x_EffAddrHorz_v1.eps (set at 806.4 spi)	
	Effective addressability test page name:	TP2_V2x_EffAddrVert_v1.eps (set at 806.4 spi)	
	Assessment element orientation:	IT / XT	
	Measurement name/conformance:	ISOIEC29112_EdgeMeasures_v1 / compliant	
	Edge blurriness test page name:	TP3_EdgeMeasures_v1.eps	
	Assessment element orientation:	8° (nearly XT), 98° (nearly IT)	
	Measurement name/conformance:	ISOIEC29112_EdgeMeasures_v1 / compliant	
	Edge raggedness test page name:	TP3_EdgeMeasures_v1.eps	
	Assessment element orientation:	8° (nearly XT), 98° (nearly IT)	
	Measurement name/conformance:	ISOIEC29112_SlantedEdge_PrinterSFR_v1 / compliant	
	Slanted-edge SFR test page name:	TP3_EdgeMeasures_v1.eps	
	Assessment element orientation:	8° (nearly XT), 98° (nearly IT)	
	Measurement name/conformance:	ISOIEC29112_SquareWave_PrinterSFR_v1 / compliant	
	Square-wave SFR test page name:	TP4V_SquareWaveSFR.eps (set at 806.4 spi)	
	Assessment element orientation:	IT / XT	

The example shown here is in multiple tables, the first containing common documentation, the second containing documentation and measurement results pertaining to the first printing system configuration, and the third table containing documentation and measurement results pertaining to the second printing system configuration.

This documentation shown in Table D.3 is common to both of the configurations whose individual configurations and associated measurement values are reported in Tables D.4 and D.5.

Table D.4 — Example of the first configuration measurement results of a multiple configuration assessment

Configuration:	Default settings (1 200 spi, RET on)

Attribute name:	Orientation:	Data: mean, stdev, min, max	# Elements:	Units:
Native addressability	Horz, XT, 0° & Vert, IT, 90°	1 200, 1 200	1	spi
Effective addressability	Horz, XT, 0° & Vert, IT, 90°	1 200, 1 200	1	spi
Edge blurriness	Horz, XT, 0°	5,7, 0,8, 3,0, 6,4	5	microns
Edge blurriness	Vert, IT, 90°	6,2, 0,9, 3,3, 7,9	5	microns
Edge blurriness	−8°	6,9, 1,2, 4,2, 9,3	5	microns
Edge blurriness	82°	7,0, 1,3, 4,1, 9,4	5	microns
Edge raggedness	Horz, XT, 0°	9,1, 1,5, 5,8, 12,7	5	microns
Edge raggedness	Vert, IT, 90°	9,5, 1,5, 6,1, 13,0	5	microns
Edge raggedness	−8°	12,2, 2,4, 8,5, 16,0	5	microns
Edge raggedness	82°	12,4, 2,5, 8,6, 16,5	5	microns
Slanted-edge SFR	Horz, XT, 0°	5,2, 0,3, 4,7, 5,7	5	cy/mm @ 50 % SFR
Slanted-edge SFR	Vert, IT, 90°	5,3, 0,3, 4,7, 5,9	5	cy/mm @ 50 % SFR
Slanted-edge SFR	−8°	4,5, 0,4, 3,8, 5,3	5	cy/mm @ 50 % SFR
Slanted-edge SFR	82°	4,4, 0,4, 3,7, 5,2	5	cy/mm @ 50 % SFR
Square-wave SFR	Horz, XT, 0°	5,1, 0,3, 4,6, 5,6	5	cy/mm @ 50 % SFR
Square-wave SFR	Vert, IT, 90°	5,2, 0,3, 4,7, 5,7	5	cy/mm @ 50 % SFR

Table D.5 — Example of the second configuration measurement results of a multiple configuration assessment

Configuration:	LowRes settings (600 spi, RET off)

Attribute name:	Orientation:	Data: mean, stdev, min, max	# Elements:	Units:
Native addressability	Horz, XT, 0° & Vert, IT, 90°	600, 600	1	spi
Effective addressability	Horz, XT, 0° & Vert, IT, 90°	600, 600	1	spi
Edge blurriness	Horz, XT, 0°	5,8, 0,8, 2,9, 6,5	5	microns
Edge blurriness	Vert, IT, 90°	6,3, 0,9, 3,2, 8,1	5	microns
Edge blurriness	−8°	8,2, 1,2, 5,2, 11,3	5	microns
Edge blurriness	82°	8,5, 1,5, 4,0, 12,4	5	microns
Edge raggedness	Horz, XT, 0°	9.0, 1,5, 5,8, 12,5	5	microns
Edge raggedness	Vert, IT, 90°	9,6, 1,5, 6,2, 13,1	5	microns
Edge raggedness	−8°	15,2, 2,9, 8,0, 18,0	5	microns
Edge raggedness	82°	15,4, 3,0, 8,2, 18,5	5	microns
Slanted-edge SFR	Horz, XT, 0°	5,3, 0,3, 4,7, 5,8	5	cy/mm @ 50 % SFR
Slanted-edge SFR	Vert, IT, 90°	5,3, 0,3, 4,6, 5,9	5	cy/mm @ 50 % SFR
Slanted-edge SFR	−8°	3,5, 0,4, 3,0, 4,3	5	cy/mm @ 50 % SFR
Slanted-edge SFR	82°	3,4, 0,4, 2,9, 4,2	5	cy/mm @ 50 % SFR
Square-wave SFR	Horz, XT, 0°	5,1, 0,3, 4,6, 5,6	5	cy/mm @ 50 % SFR
Square-wave SFR	Vert, IT, 90°	5,2, 0,3, 4,7, 5,7	5	cy/mm @ 50 % SFR

Note that the printer configuration record that was part of the configuration documentation shown for a single configuration assessment in Table D.4 has moved to the top of each of the tables summarizing the measurement results for each of the individual configurations to provide each table with the required configuration context.

If any other record of the common documentation for a multiple configuration assessment changes in any of the different configurations assessed, that record moves from the common documentation illustrated in Table D.3 to the top of each of the tables summarizing measurement results for a configuration.

For instance, if the substrate type is changed, this change creates a new assessment, or if the age (number of prints) of an imaging component is followed over its effective life, each of the evaluations along the component lifetime that the printing system is assessed becomes a separate assessment.

Annex E
(informative)

Usage

E.1 General

The measurement methods specified in this document provide a quantitative assessment of attributes that are known to correlate with the perception of printing system resolution.

— The measurement methods specified in this document involve analysis of binary, vector-based, PostScript elements.

— High contrast (binary) printing is a leading indicator of the detail-carrying capability of a printing system throughout its tone scale. The test pages created and specified for use with this document have not yet been, but could be, ported to other printing system control languages.

— The test page implementation currently restricts usage of this document to PostScript-based printing systems.

— The content encoding capabilities of PostScript provide the most reliable means of controlling the printing system workflow to avoid printing artefacts that compromise measurements.

Test pages are provided in two different formats for the evaluation of native addressability, for the measurement of effective addressability and for the measurement of the printing system SFR characteristic using square-wave elements:

1. Encapsulated PostScript (EPS) format.

   The EPS format is adaptable to the addressability of the printing system raster image processor and can be reliably sent to any RIP with knowledge that the test page content will correctly adapt to the addressability reported by the RIP.

2. PostScript-based Portable Document Format (PDF).

   PDF is a final form format that can be created for the exact addressability of the printing system to be evaluated but is simple to send to a printing system. The test pages for use with this document are provided in PDF format for the common printing system addressabilities, 600 spi and 1 200 spi. A printable PDF file with arbitrary addressability can be created from an EPS test page using a suitable PDF compiler.

Annex A specifies a procedure that can be reliably used to submit a PDF or an EPS file to be printed by a printing system.

The measurement methods specified in this document have been developed in as general a manner as possible to avoid dependencies on characteristics of any particular printing technology. So far, these measurement methods have been verified only for electro-photographic printing systems.

Future revisions of this document could reflect additional verification experiments that demonstrate and extend the applicability of these measurement methods to other printing technologies.

Annex F summarizes the verification studies carried out with electro-photographic printing technology.

E.2 Printing system workflow concerns

Applications and printer drivers both "help" to produce a pleasing print. In many cases, the help provided creates significant issues in the ability to correctly render and print a test page. Annex A specifies procedures that usually avoid these "helpful" re-interpretations of test page content so that correct prints of the test pages required for the use of this document can be produced. The aim of this clause is to acquaint the user of this document with potential test page printing problems and the severity of their effect on the printing system resolution attribute measurement methods.

The most frequent printing system problem is scaling. Scaling affects some of the test page elements more than others. Table E.1 summarizes the major causes of scaling error and the severity of their effects on attribute measurements. The most common forms of scaling error are encountered when application or driver scaling are not both explicitly set to 100 %. Never use page size modifiers such as "Fit to Page" or "Scale to Fit".

Another important cause of scaling error occurs when a PDF test page distilled for one printing system addressability, say 600 spi, is submitted to a printing system with a different addressability, say 800 spi. Aliasing between these two different frequencies occurs and measurements are significantly affected. For a printing system whose addressability is neither 600 spi nor 1 200 spi, an appropriate PDF test page can be created using an appropriate PDF compiler, the EPS version of the test page and knowledge of the true addressability of the printing system to be evaluated. The required editing of the EPS test page content to provide an appropriate native addressability test page is documented in 4.2.2. The documentation for the required editing of the effective addressability test page is documented in 4.3.2 and the documentation for the required editing of the square-wave SFR test element is documented in 4.5.5.

In most cases, the necessity for distilling an appropriate PDF test page for a printing system addressability not directly supported by the distributed PDF test pages can be avoided by submitting the EPS version of the test page instead of a PDF version. An important but rare exception can occur if the RIP does not report the true addressability of a printing system. In this case, the exact printing system addressability can be found either by consulting the printing system documentation or by using the capability of the native addressability test page to show the true printing system addressability. Once found, the EPS version of the test page can be edited to explicitly define the true printing system addressability, then the edited test page can be correctly submitted.

Table E.1 — Scaling error

Scaling error:	Solution:
Application scaling:	Set scaling to 100 % or 1:1
Printer driver scaling:	Set scaling to 100 % or 1:1
Addressability mismatch:	Use EPS test page or correct PDF test page
Incorrect RIP addressability:	Set EPS test page to true addressability

Test page:	Sensitivity to scaling error:	Artefact:
Native addressability:	Adapts for up to 2 % scaling error	No transition in fine scales
Effective addressability:	Moderate to severe	Non-uniform lines of line spacing
Blurriness:	Not sensitive	Element too small
Raggedness:	Not sensitive	Element too small
Slanted-edge SFR:	Not sensitive	Element too small
Square-wave SFR:	Severe	Non-uniform lines and/or spaces

Any scaling error artefact observed in a print of a test page is a fatal printing error. To correct this error, scaling should be explicitly set to 100 % or 1:1. Then the test page can be re-printed and verified to be free of any scaling artefact.

Page placement modifiers such as page centring can be used to place the image properly on a page, without dimensional change.

Another very common workflow-induced error can be caused by the colour management process of the printing system. The colour representation of all elements in the test pages employed for the attribute measurements specified in this document is Separation-Black. This colour representation is not processed by most colour management systems and is passed through to the printer unchanged as binary information for a single separation of black toner. However, in some instances, a colour management system can have a pre-defined interpretation for Separation Black, which will re-interpret the test page information thereby printing with colorants different from the intended colorant or printing solid objects in an unsaturated manner or with a halftone pattern present. Table E.2 summarizes this error.

Table E.2 — Colour management system induced error

Test page:	Sensitivity to screening:	Artefact:
Any test page	Severe	Gray, unsaturated or halftone pattern. Multiple or unintended colorants

Any test element printed with a halftone pattern is a fatal printing error. The colour management re-interpretation of the page should be corrected then the test page should be re-printed and verified to be free of any halftone content.

E.3 Assessment of electro-photographic printing systems

The measurement methods specified in this document were developed as general tools, independent of any particular printing technology, but they have been verified only for electro-photographic printing systems.

Annex F summarizes the verification experiments that were run to ensure the utility and reproducibility of these measurement methods for electro-photographic printing systems.

Native addressability provides the enabling framework in a digital printing process for depicting fine spatial detail. In many cases, the in-track and cross-track native addressabilities of a printing system differ, often showing a different degree of physical overlap of adjacent printed spots in the two orientations.

— The native addressability claimed by a printing system is a required field in the assessment configuration documentation. Measurement of native addressability using the method specified in this document can be used to confirm the accuracy of the native addressability claimed by the printing system.

— In practice, the native addressability claimed by a printing system is usually correct, and in the few cases where the actual native addressability has differed from the claimed native addressability, the discrepancy has been less than about 1 %.

— However, even such a small discrepancy should be corrected for in the printing of the effective addressability and square-wave SFR test elements.

— When left uncorrected, this level of scaling error is apparent, though somewhat subtle, in the effective addressability test page, but becomes obvious in the square-wave SFR test page in the form of non-uniform width lines and spaces in the test elements.

— Such artefacts severely compromise the integrity of the associated measurement methods and are a fatal error.

Effective addressability is a measure of the minimum pitch by which the centre of an object can be displaced and evaluates the effect of the position modulation, size modulation or exposure modulation utilized by resolution enhancement technologies utilized in a printing system.

— In many cases, the in-track and cross-track effective addressabilities of a printing system differ.

— The measure of the effective addressability of an electro-photographic printing system specified in this document uncovers the inherent capability of a printing system for finer levels of edge placement than the native addressability grid.

Both native addressability and effective addressability are quantized; native addressability as spots per inch (e.g. 600 spi, 1 200 spi or 2 400 spi) and effective addressability often as an integer multiple of the native addressability.

Until dominated by other factors (e.g. minimum spot size), measures of these quantized attributes are clustered, appear to correlate with perceived resolution and are important contributors to the capability of an electro-photographic printing system to depict fine detail.

The slanted-edge element in the test pages specified by this document provides a means for assessing both edge raggedness, edge blur and edge SFR characteristics.

— The normal edge profile (NEP) illustrates how rapidly a transition is made perpendicular to a straight edge.

— The width of this transition is directly related to the perceived edge blurriness of a printing system.

— The tangential edge profile (TEP) illustrates how much a straight printed edge deviates from its requested straight line behaviour.

— Edge raggedness provides a measurement of this deviation from straightness. These profiles are illustrated in Figure 3.

Resolution enhancement technology is often employed in digital printing systems to mitigate the influence along slanted edges of the printing grid defined by the printer native addressability.

— Edge raggedness provides a measure of the deviations of a printed edge from a requested straight line and provides a means for assessing the reduction in edge raggedness when resolution enhancement technology is effectively employed. Edge raggedness often depends strongly on the orientation of the evaluated edge.

— In-track edge raggedness is evaluated across edge boundaries oriented along the cross-track direction.

— Cross-track edge raggedness is evaluated across edge boundaries oriented along the in-track direction.

— Measures of edge raggedness for edges oriented at a small angle from the in-track or cross-track directions (e.g. 8° and 98°) most clearly show any limitations that the resolution enhancement technology can have.

The transition width of an edge provides a measure of edge blurriness that contributes to the perceived resolution of a printing system.

— In a linear system, the line spread function is related through a Fourier transform to the printing system spatial frequency response characteristic.

— In-track edge transition width is measured across boundaries oriented along the cross-track direction.

— Cross-track edge transition width is measured across boundaries oriented along the in-track direction.

— An increased level of edge blur is often a leading indicator of poor maintenance or aged components in electro-photographic printing systems.

The recommended 1 200 ppi minimum optical resolution of scanning systems qualified for use with this document along with the statistical super-resolution capability of the slanted-edge method is sufficient for the evaluation of blur, raggedness and spatial frequency response of the current electrophotographic printing systems encountered in office imaging.

If scanner capability, time and scanned bitmap storage allow, scanning at higher optical resolutions can provide cleaner measurement data. See Annex B for guidance.

The different SFR assessment methods employed in ISO/IEC 29112 are sensitive to different printing system process characteristics.

— The 1-D square-wave SFR method is sensitive to edge, spot-size, spot-shape and adjacency effects.

  — Test page addressability shall be set to the exact printing system addressability to avoid fatal artefacts.

  — Alignment of print sample edges to the scanner platen edges within 0,25° when scanning is important.

  — If the spot size or adjacency effects of the printing system are large, the SFR characteristics derived from high spatial frequency fundamentals may disagree with those derived from lower spatial frequency fundamentals. A high spatial frequency bar may be removed from the analysis by editing the configuration file in order to provide a consistent measure of printing system SFR.

  — Behaviour of the SFR characteristic derived from the fundamentals of the various bar patterns provides a useful printing system diagnostic: inconsistent SFR characteristics indicate a printing system behaviour that changes with the frequency of the bar patterns. For instance, a bar pattern can be filled in more than expected at the highest frequencies and provide much lower modulation in the square-wave SFR analysis.

  — Examine the relative size of marks and spaces in the bar patterns to understand identified nonlinearities.

  — On rare occasions, a printing system has mis-interpreted the vector code of the TP4V_SquareWaveSFR test page. A bitmap version of this test page (TP4V_SquareWaveSFR) has been provided for backup.

  — Ensure that the square-wave edges are sharp. The bitmap version of the SquareWaveSFR target is rendered by some RIPs as quasi-sine waves, which are not correctly analyzed.

— The slanted-edge SFR characteristic at 0° is evaluated across a boundary oriented along the cross-track printing direction and evaluates the slow-scan characteristics of a printing system.

— The slanted-edge SFR characteristic at 90° is evaluated across a boundary oriented along the in-track printing direction and evaluates the fast-scan characteristics of a printing system.

— Angled slanted-edge SFR characteristics evaluate the capability of a printing system to reproduce a straight, angled edge. When evaluated at small angles with respect to the cross-track or in-track printing directions (e.g. 8° or 98°), the slanted-edge SFR measure is sensitive to the smoothing effectiveness of resolution enhancement technology.

For the blurriness, raggedness and SFR measurements, elements oriented along horizontal, vertical, 0° or 90° axes evaluate the printing system capabilities along the cross-track or in-track directions.

— Elements tilted at a slight angle (e.g. 8°) evaluate the printing system including resolution enhancement capabilities.

— Elements tilted at a larger angle (e.g. 24°) generally evaluate the printing system in a less critical manner than with the 8° tilt.

— Depending on system characteristics, a scanner resolution greater than the printing system addressability can be required.

— Further details regarding the correlation of the measurement methods specified in this document with the perception of fine levels of detail through psychometric scaling studies for a wide range of electro-photographic printing systems are presented in the verification experiments summary provided in Annex F.

— In these verification experiments, the observed range of edge blurriness was small and other attributes were dominant.

Table E.3 summarizes the recommended measures for the assessment of electro-photographic printing system resolution.

Table E.3 — Measurement recommendations for electro-photographic printing system assessment

Measure:	Recommendation:
Native addressability:	Reported in assessment configuration documentation
Effective addressability:	Recommended measure to show inherent printing system capabilities
Edge blurriness:	Recommended (but limited response in verification experiments [see Annex F)]
Edge raggedness:	Recommended
Slanted-edge SFR:	Recommended
Square-wave SFR:	Recommended (but critically dependent on proper test page printing and alignment)

Verification experiments have only been made for electro-photographic printing systems. Separate experiments are required to verify the applicability of the measurement methods specified in this document for assessing the perceived resolution of other printing technologies. See Annex F.

Annex F
(informative)

Electro-photographic system measurement method verification example

F.1 Verification of repeatability and reproducibility

F.1.1 General

Two sets of experiments were run to verify the utility of the measurement methods specified in this document. The second set of experiments was a large-scale printing experiment involving parallel subjective and objective evaluation paths involving multiple facilities. This experiment is discussed in Clause F.2.

The first set of experiments, run at six different sites with eight different, qualified reflection scanning systems, examined the repeatability and reproducibility of measurement methods, using a carefully controlled set of print samples with a wide variety of reflection scanning systems.

This experiment and its analysis provided guidance for the scanner qualification recommendations and for the definition of the scanner SFR normalization method specified in Annex B for scanning system qualification.

The results of this set of experiments are discussed here.

F.1.2 Verification of measurement repeatability

Two major dependencies, repeatability and reproducibility were evaluated in these verification experiments. The repeatability of two major calibration steps, scanner OECF and scanner SFR, were evaluated by performing sixteen consecutive scans of the same test page, with evaluation of the scanner OECF characteristic and the scanner SFR characteristic after each scan.

— This experiment was run on several different reflection scanning systems to determine the variance in repeated measurements.

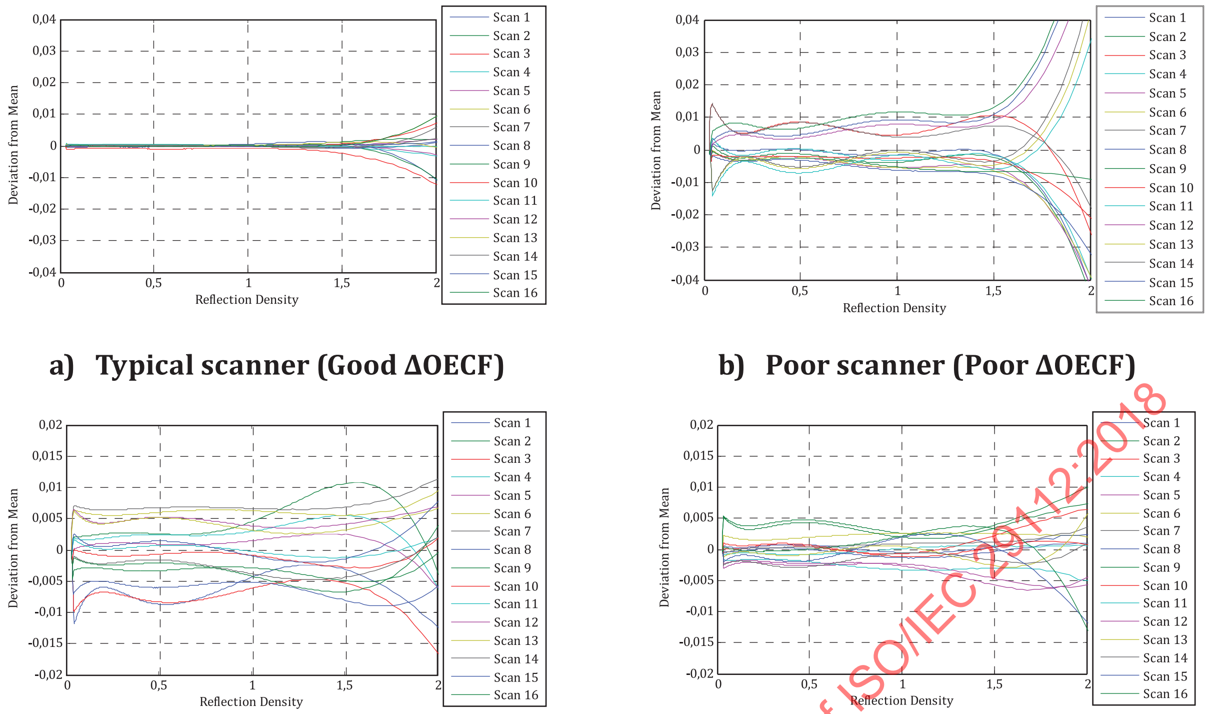
— Figure F.1 a) shows a typical deviation of the OECF characteristic for individual scans from its average OECF value.

— The deviation generally increases in absolute value at higher densities, but stays well within 1 % of the maximum density.

— For long scans at high-resolution, some scanning systems employing a cold-cathode fluorescent lamp for illumination exhibited significantly larger variation.

— A particularly poor case is shown in Figure F.1 b). This condition could not be corrected sufficiently to exhibit sufficient stability for conformance. The control software for this scanner could also be run in a faster scan mode that traded quicker scans for a slightly increased level of noise.

— The ΔOECF characteristic for this scanner is shown in Figure F.1 c). The deviations are in reflectance, 0–1.



a) Typical scanner (Good ΔOECF)

b) Poor scanner (Poor ΔOECF)

c) Problem scanner (Questionable ΔOECF)

d) Problem scanner (Acceptable ΔOECF)

Figure F.1 — OECF repeatability

Note the different Y-axis scales between Figure F.1 a) and b) compared to Figure F.1 c) and d). With the faster scanning mode and shorter scan times, the light intensity fluctuation is less, as shown in Figure F.1 d). This provides scanning repeatability results more consistent with the other scanning systems. The temporal repeatability test for scanning system qualification, specified in C.3.3, was established with a limit of ±0,01D variation from the mean to guard against excessive variation in the long scans required for high-resolution measurement.

The position and shape of the region of interest (ROI) used in the evaluation of SFR characteristics are major factors in SFR evaluation repeatability.

— A series of sixteen sequential scans of a single slanted-edge element were each evaluated using a large set (625) of small changes in ROI position and shape with maximum amplitude of 100 µm.

— The left portion of Figure F.2 shows the statistics of these sixteen evaluations (Scan1 to Scan16).

— Figure F.2 is a bar graph showing maximum and minimum values at the extreme ends of each bar; mean values are indicated by the centre dash in each bar and the mean value ± one standard deviation are indicated by the boxes above and below the centre dash.

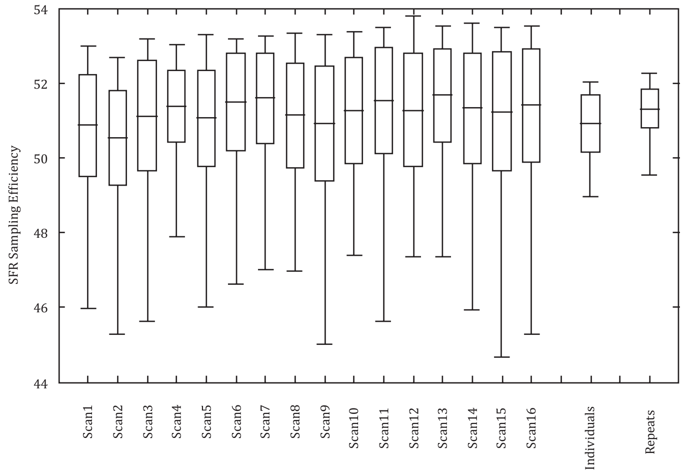


Figure F.2 — SFR repeatability

The mean sampling efficiency (the fraction of the Nyquist frequency corresponding to the frequency where the SFR characteristic has dropped to 10 % of its zero-frequency value) is statistically identical for all sixteen scans — the mean values over the variations in ROI position and shape for each evaluated scan are well within ± one standard deviation, σ, of each other.

— The boxes in Figure F.2 represent ± one standard deviation from the mean value shown by the central line.

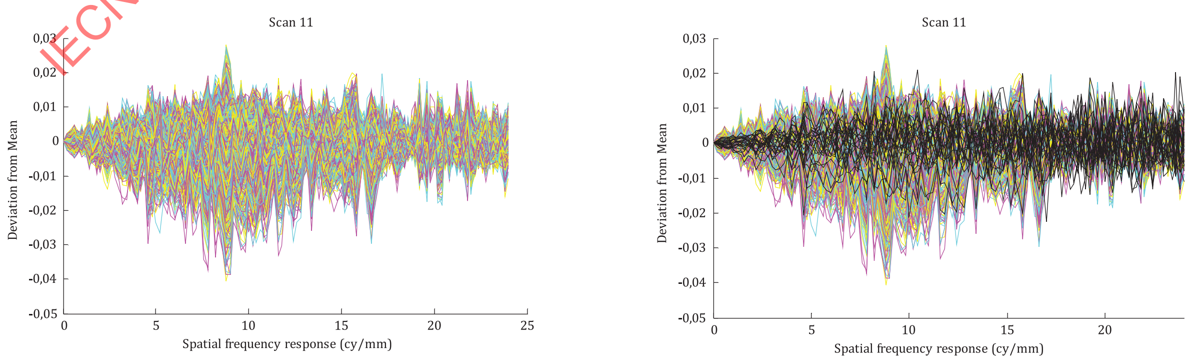
— The fingers at the top and bottom show the maximum and minimum values for each set of evaluations over ROI position and shape.

— Small changes in the ROI position and shape used in evaluating the SFR characteristic can introduce substantial bias in a measurement.

— Shown towards the right side of Figure F.2 (labeled "Individuals") are the statistics from single SFR evaluations of each of the sixteen scans of a single slanted-edge element using identical ROIs.

— These sixteen single-ROI evaluations are also statistically identical with the evaluations of the same scans using a large set of small changes in ROI position and shape.

— Shown at the far right of Figure F.2 (labeled "Repeats") are the statistics of a set of sixteen evaluation repetitions of a single scan of the slanted-edge element using virtually identical ROIs (round-off errors in algorithmic positioning of the ROIs) that are statistically identical to all the other evaluations.



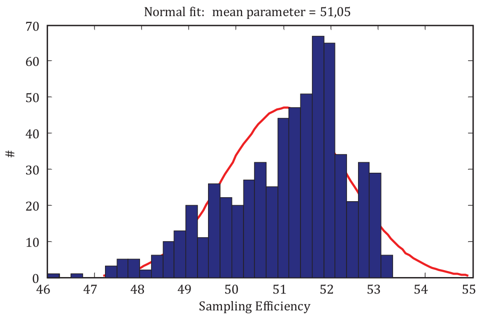
a) SFR variability

b) SFR variability with single evaluations (black)

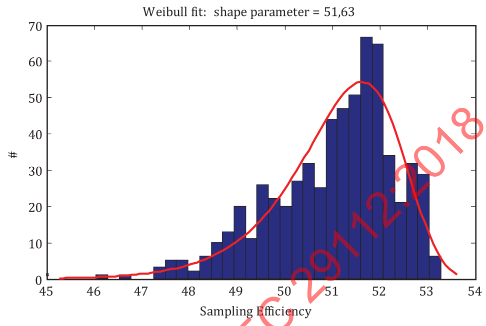
Figure F.3 — Variability of single-scan, multiple ROIs vs. multiple-scan, single ROI

Figure F.3 a) shows the SFR variability, as a deviation from the mean SFR characteristic, of a single scanned slanted-edge element evaluated over the large set of small changes in ROI position and shape with a maximum amplitude of 100 µm. This is the data summarized as "Scan 11" in Figure F.2. Figure F.3 b) shows the identical SFR variability as Figure F.3 a), with the sixteen scans of a single slanted-edge element each evaluated using the same ROI superimposed with black lines (summarized as "Individual" SFR characteristics statistics in Figure F.2).

The upper envelopes of the two SFR characteristic variations are very similar.



a) Normal distribution fit of SFR variability



b) Weibull distribution fit of SFR variability

Figure F.4 — SFR variability distribution

The variations from the large set of small changes explore a larger, but somewhat sparse, range in lower SFR capability. This is also seen in the long lower tail of the statistics shown in Figure F.4. Sampling efficiency (the fraction of the Nyquist frequency corresponding to the frequency where the SFR characteristic has dropped to 10 % of its zero-frequency value) is again used in this analysis.

— A fit with a normal distribution, parameterized by a mean value and standard deviation, illustrated in Figure F.4 a) is simple to obtain.

— A fit with a Weibull distribution, illustrated in Figure F.4 b), handles the observed tails better and the shape parameter of this distribution provides a better single parameter estimate than the mean value, but is significantly more difficult to calculate.

The single-evaluation variability of the simple set of repeat measurements or the range of evaluation results obtained with the large set of small variations in ROI position and shape show the necessity of evaluating a set of ROI variations to obtain a central estimate for reporting printing system SFR capability.

— The standard deviations of the large set of small ROI variations evaluated for each of the sixteen separate scans shown in Figure F.2 ranges from ~0,95 for Scan4 to ~1,59 for Scan15.

— The evaluated sampling efficiency values span a range from 44,7 to 53,8.

— The standard deviation of the mean values of these sixteen distributions is only ~0,29. The mean values of these distributions span a range of ~1,1.

— The mean value of an evaluated distribution is clearly much more stable than an individual evaluation value.

— The minimum number of evaluations forming the distribution from which the mean value is to be reported, as specified in 4.5, is 81 (three variations each in x-position, y-position, width and height of the ROI used in evaluation).