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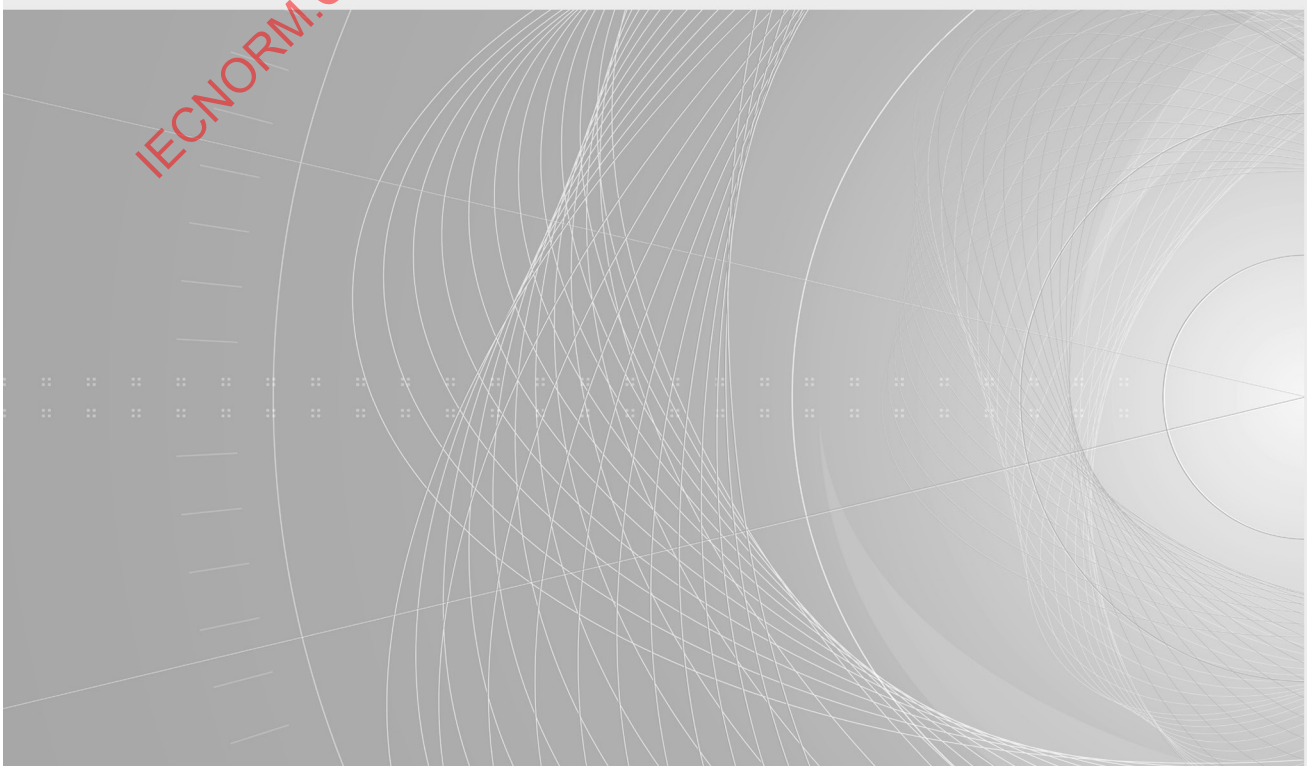
INTERNATIONAL STANDARD

Printed electronics –
Part 302-4: Equipment – Inkjet – Medium for inkjet printing dot placement evaluation



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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PRINTED ELECTRONICS –

Part 302-4: Equipment – Inkjet – Medium for inkjet printing dot placement evaluation

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The text of this International Standard is based on the following documents:

Draft	Report on voting
119/496/FDIS	119/506/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Until recently, inkjet technologies were used only for imaging printing (conventional “graphic printing”). However, recent developments of inkjet technologies, such as technologies for inkjet print-head, functional ink or print-head driving technologies, make it possible to extend their applications to printed electronics. For these applications, the accuracy requirement for inkjet drop placement tends to be higher than in graphic printing.

This document considers that “'inkjet print dot placement accuracy” is the key parameter to obtain an appropriate output that has adequate print quality. In order to evaluate the inkjet printing system, inkjet print dot placement accuracy is measured. For that purpose, an appropriate medium is used, since the “accuracy” of the printed position is only secured by using an appropriate medium that shows actual dot placement. This document describes what kinds of parameters of an appropriate medium are useful to obtain actual accuracy of dot placement evaluation for printed electronics.

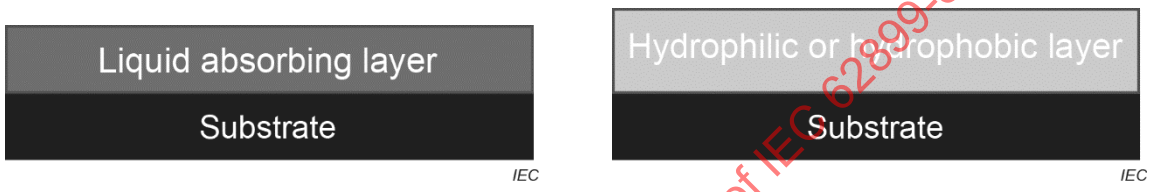
PRINTED ELECTRONICS –

Part 302-4: Equipment – Inkjet – Medium for inkjet printing dot placement evaluation

1 Scope

This part of IEC 62899 provides measurement methods and specifications for a medium to measure actual inkjet dot placement for printed electronics applications.

NOTE For this document, a medium is a substrate with (a) certain functional layer(s) to facilitate the ink pinning process (or step). These functional layers are either (a) a liquid absorbing layer or (b) a hydrophilic or hydrophobic layer as shown in Figure 1.



a) Medium with a liquid absorbing layer **b) Medium with a hydrophilic or hydrophobic layer**

NOTE These figures are examples, and do not show all the required layers of a medium.

Figure 1 – Examples of a medium for actual dot placement

2 Normative reference

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 216, *Writing paper and certain classes of printed matter – Trimmed sizes – A and B series, and indication of machine direction*

ISO 534, *Paper and board – Determination of thickness, density and specific volume*

ISO 4287, *Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters*

ISO 8226-1, *Paper and board – Measurement of hygroexpansivity – Part 1: Hygroexpansivity up to a maximum relative humidity of 68 %*

ISO 8226- 2, *Paper and board – Measurement of hygroexpansivity – Part 2: Hygroexpansivity up to a maximum relative humidity of 86 %*

ISO 9513, *Metallic materials – Calibration of extensometer systems used in uniaxial testing*

ISO 11359-2, *Plastics – Thermomechanical analysis (TMA) – Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 18910, *Imaging materials – Photographic film and paper – Determination of curl*

3 Terms and definitions

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

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

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
humidity dependency (hygroexpansivity)
characteristic(s) (of a medium) which can vary depending on the surrounding humidity

3.2
flatness (curl)
quality of a planar medium level

3.3
smoothness (surface roughness)
quantity (or parameter) intended to measure how much the medium deviates from its perfect flat form

Note 1 to entry: In IEC 62899-201:2016, 3.2, roughness is defined as: “surface property of a substrate which indicates a high-frequency component of irregular elements in the profile curve”.

3.4
bow and twist
distortion in the dimensions of a plastic object which occurs after moulding or processing

[SOURCE: IEC 62899-201:2016, 3.1, modified – the note and Figure 1 and Figure 2 have been removed.]

3.5
micro-waviness
deviation from the average line of the measured profile curve (determining the deviation curve)

3.6
liquid absorption capacity
maximum quantity of a liquid that a medium will take in

3.7
surface wettability
surface energy modification for controlling ink spreading and repellency, either hydrophilic or hydrophobic

4 Parameters and measurement methods

4.1 General

Since inkjet printing is realized on a medium, the characteristics of the medium are particularly important to ensure that the functional material shows the intended function. However, to evaluate inkjet dot placement, there are some specific parameters of the medium that directly affect the accuracy of the evaluation. In order to evaluate dot placement accurately, it is important to have an appropriate medium for that purpose.

It is noted that in order to evaluate dot placement accuracy, any kind of substrate of a medium, for example a glass, a metal foil, a silicon wafer, a plastic film or a sheet of paper, can be used, in so far as it will not change the significant characteristics of the inkjet printing system itself, such as the distance between the inkjet print head and the medium, and in so far that it has an appropriate liquid absorbing layer or something similar to allow actual dot placement measurement, such as a hydrophilic layer.

Since the functionality comes from printed material, contamination at the inkjet head(s) is not desirable. To avoid that contamination, it is assumed that the ink for measurement is going to be the same as for an actual printing or a similar ink that is only a solvent (liquid) that does not have any pigment or functional material. However, if there is an agreement between the customer and supplier, it is possible to use ink other than the actual ink. If that is the case, dot placement accuracy can be different from the actual printing using the actual printing ink. When using a different ink, it will be necessary for the customer and supplier to know the behaviour of that ink beforehand.

Since the medium for this measurement can have a certain liquid absorbing layer, there is the possibility of having a chemical reaction between that layer and the ink. In some cases, that chemical reaction can generate a dot mark for this measurement. Another possible approach, is to use a medium having appropriate wettability, either hydrophilic or hydrophobic.

As the purpose of this measurement is to evaluate dot placement accuracy of an actual inkjet printing, other parameters for measuring an inkjet printing system, such as distance between the inkjet head and the medium, the waveform, the inkjet head placement, shall be the same as for the actual printing, as much possible. If there is any difference between the measurement condition and the actual printing, that difference shall be noted.

4.2 Environmental conditions

The measurement shall be performed under the following conditions or at the actual printing environmental conditions:

- temperature (23 ± 1) °C
- humidity (50 ± 5) %

NOTE The air pressure is also an important parameter for inkjet printing. However, since the air pressure is difficult to control, it is treated as a reporting parameter instead.

If there is an agreement between the customer and supplier, the measurement can be performed when a medium becomes stable in the environmental conditions. As the stable condition depends upon the medium, it shall be pre-determined by agreement between the customer and supplier.

4.3 Parameters

The parameters of the medium that affect the accuracy of the evaluation are as follows:

– size;
– thermal dependency;
– humidity dependency (hygroexpansivity);
– thickness;
– flatness (curl);
– evenness of thickness;
– smoothness (surface roughness);
– liquid absorption capacity;
– surface wettability;
– roundness of dropped ink (including after it has dried);

– capability of having a watermark for the transparent ink;
– stability of dropped position, after printing and before measuring;
– other parameters, such as coating.

4.4 Measurement methods

4.4.1 Size

The measurement of the size of the medium shall be in accordance with ISO 216.

4.4.2 Thermal dependency

The thermal dependency of the medium shall be measured using the measurement method for the linear coefficient of thermal expansion, such as the thermomechanical analysis (TMA) (see ISO 11359-2) or the digital image correlation (DIC) (see ISO 9513) method.

It is important to evaluate dot placement under the actual printing environment conditions.

NOTE Since in most cases, thermal dependency of the medium can have an x-y direction dependency, in order to evaluate thermal dependency, it is useful to measure thermal dependency for the x-direction and y-direction independently.

4.4.3 Humidity dependency (hygroexpansivity)

Humidity dependency of a medium shall be measured in accordance with ISO 8226-1 for hygroexpansivity up to a maximum relative humidity of 68% and ISO 8226-2 for hygroexpansivity up to a maximum relative humidity of 86%, with an allowance of humidity of ±5 %.

It is important to evaluate dot placement under the actual printing environment conditions.

NOTE Since in most cases, humidity dependency of a medium can have an x-y direction dependency, in order to evaluate thermal dependency, it can be useful to measure humidity thermal dependency for the x-direction and the y-direction independently.

4.4.4 Thickness

The thickness of the medium shall be measured by the measurement method defined in ISO 534.

4.4.5 Flatness (curl)

Humidity can affect the flatness of the medium. The flatness of the medium shall be measured in accordance with ISO 18910 at a humidity of 33 %, 66 % or 86 %, with a tolerance for the humidity of ±5 %.

4.4.6 Smoothness (surface roughness)

The smoothness of the medium is going to directly affect the dot placement because when liquid hits the medium, the liquid drop tends to move to follow a lower contour surface.

The smoothness (or roughness) of the medium surface shall be measured in accordance with ISO 4287, unless the supplier and customer agree to use alternate methods. Another preferred test method is IEC 62899-201 which defines the white light interferometry (WLI) method.

4.4.7 Liquid absorption capacity

The liquid absorption capacity (liquid content) is going to affect dot placement when the medium has more ink than it can absorb. When the medium takes more liquid than it can take, that liquid can spill over onto the surface.

Liquid content can be measured using the method described in ISO 535.

4.4.8 Surface wettability

The wettability of the surface of the medium, which can be either hydrophilic or hydrophobic, is going to affect dot placement directly when a dot hits that surface. Also, when the surface of the medium has appropriate wettability, that medium can be used as a medium to measure dot placement. Any substrate pre-treatment, such as corona treatment, should be noted as this will affect the surface wettability.

Wettability can be measured using the method described in ISO 8296.

4.4.9 Roundness of dot mark (including after drying)

To obtain an actual dot mark that would have reasonable roundness, it is important that the medium be of appropriate liquid absorption capability. Without that capability, the dropped liquid can move on the medium when its volume is large, and that makes the proper measurement difficult.

Roundness of the dot mark (C) is defined by the following formula. However, due to image processing from a captured analogue image to digital data to calculate roundness, there is always a discretization error. A round dot would otherwise have C = 1, where

$$C = \frac{4\pi A}{P^2} \tag{1}$$

where

A is the area of the dot mark;

P is the perimeter of the dot mark.

A and P can be calculated from a captured image of the dot mark.

NOTE The image capturing method and image processing will be dealt with in IEC 62899-302-7 [1] for inkjet placement measurement.

4.4.10 Capability of having a dot mark for the transparent ink

As described in IEC TR 62899-302-5, for printed electronics, a medium shall have a capability of having a dot mark for transparent ink, since in most cases the ink for printed electronics will not have colour. The capability of having a dot mark for a transparent ink shall be measured by evaluating the contrast ratio from the captured image of a medium that has dot mark(s).

NOTE 1 Image processing to obtain an appropriate image will be dealt with in IEC 62899-302-7.

Since a measurement is involved in determining the position and shape of the dot mark, it is not necessary that the dot mark be visible to the naked human eyes. The dot mark can be determined using directional lighting, special lighting, for example ultra-violet light, or other optical means to obtain adequate contrast ratio rendering the usefulness of that medium for this measurement.

NOTE 2 In some cases, the proprietary chemical nature of the liquid absorbing layer can generate a dot mark.

[1] Under preparation. Stage at the time of publication: IEC CCDV 62899-302-7:2024.

4.4.11 Stability of the dropped position, after printing and before measuring

For the purpose of measuring the actual dot placement accuracy by inkjet printing, the fixing of the dropped position after printing and before measuring is very important. In some cases, printing and measuring may be performed by using different equipment. Although in some cases, printing and measuring can take place using the same equipment, still an actual dot can move for several reasons, such as airflow.

The measurement method of this capability is to evaluate if a dropped dot is fixed or not after printing and before measuring. Since it is not easy to measure whether a dot moves during moving from the printing equipment to the measuring equipment because measuring the actual dot placement at printing equipment is not easy, it is recommended to measure by simulation whether a dot moves or not as follows:

1) Select a desired medium.
2) Put an appropriate volume of an appropriate liquid onto the medium.

NOTE 1 The actual dot placement is affected by many parameters, such as dropped volume, dropping speed, ejecting direction, and more. Since it is not easy to simulate all of those parameters exactly, it can be performed by simulating significant parameters, such as dropped volume and a liquid.

3) Wait for an appropriate period by simulating printing.
4) Capture an image of the dot to measure,

NOTE 2 There are several ways of capturing an image to measure the actual dot position, such as capturing the dot with a physical ruler, and capturing the dot by using alignment marks.

NOTE 3 To measure whether the dot moves or not, it is useful to use a gravity centre method by obtaining the gravity centre from a captured image (see Annex A).

5) Move the medium for an appropriate distance, presumably a similar distance from the printing equipment to measuring equipment.
6) Measure if the placed dot is moved or not, by measuring a gravity centre of the dot.

If the dot moves more than the expected allowance of the printing equipment, it means that the medium does not have this capability. The expected allowance will depend on the printing equipment. In some cases, it will be 1/10 of the expected radii of the printed dots, or in

other cases, it will be 1/4 of the expected radii. Therefore, a customer and a supplier have to discuss and define the expected allowance beforehand.

4.4.12 Other parameters of the medium: Coating

For the purpose of measuring the actual dot placement accuracy by inkjet printing, the totality of a given medium together with its functional layer (liquid absorbing, hydrophilic, or hydrophobic as shown in Figure 1) is the most important. The characteristics of those functional layers of a medium provided by the supplier are not treated here and are outside the scope of this document. It is sufficient to include in the report the nature of these proprietary coatings.

5 Report

The report shall include the following parameters measured by the above measurement methods:

– size,
– thermal dependency,
– humidity dependency (hygroexpansivity)
– thickness,
– flatness (curl),
– evenness of thickness,
– smoothness (surface roughness),
– liquid absorption capacity,
– surface wettability,
– roundness of dropped ink (including after it has dried),
– capability of having a watermark for transparent ink,
– stability of the dropped position, after printing and before measuring
– functional attribute of the coating on the medium,
– any substrate pre-treatment,
– any differences between the measurement conditions and the actual printing.