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Information technology — Print cartridge characterization —

Part 1: General: terms, symbols, notations and cartridge characterization framework

Technologies de l'information — Caractérisation des cartouches d'impression —

Partie 1: Généralités : termes, symboles, notations et cadre pour la caractérisation des cartouches

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Foreword

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

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 or www.iec.ch/members_experts/refdocs).

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) or the IEC list of patent declarations received (see patents.iec.ch).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

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

This second edition cancels and replaces the first edition (ISO/IEC 29142-1:2013), which has been technically revised.

The main changes compared to the previous edition are as follows:

— revision of the term “black-only printer” in order to harmonize with ISO/IEC 22505.

A list of all parts in the ISO/IEC 29142 series can be found on the ISO and IEC websites.

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 and www.iec.ch/national-committees.

Introduction

The purpose of this document is to define the framework for characterizing ink and toner cartridges used in printing devices that have a digital input printing path, including multi-function devices. This document defines terms, symbols, and notations used throughout the ISO/IEC 29142 series to characterize such ink and toner cartridges.

Customer information related to ink and toner cartridges is not consistent in the global marketplace.

Cartridge manufacturers, including original, non-original manufacturers, refillers, and remanufacturers, have each communicated expressions of cartridge characteristics.

The ISO/IEC 29142 series is provided to aid transparency between manufacturers, suppliers and their customers regarding selected cartridge characteristics. The selected cartridge characteristics do not allow an exhaustive cartridge characterization. Where applicable, cartridge attributes and the associated characterization tests are used consistently with both ink and toner cartridge technologies. The selected cartridge attributes are defined for all cartridges, regardless of manufacturing methodology.

Information technology — Print cartridge characterization —

Part 1: General: terms, symbols, notations and cartridge characterization framework

1 Scope

This document establishes terms, symbols, notations and a framework for characterizing toner and ink cartridges used in printing devices that have a digital input printing path, including multi-function devices. This document is intended for equipment used in office environments.

It primarily provides a foundation for measuring, evaluating, or specifying characteristics of such toner and ink cartridges.

The terms, symbols, notations and framework established herein can be applied to such cartridges.

The characterizations associated with the terms, symbols, notations, and framework established herein are specified throughout the ISO/IEC 29142 series.

2 Normative references

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

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

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

ISO/IEC 29142-2, *Information technology — Print cartridge characterization — Part 2: Cartridge characterization data reporting*

3 Terms and definitions

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

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

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

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

3.1
all-in-one toner cartridge
cartridge that includes at least: a *toner* (3.64) *containment part* (3.15), a *photoreceptor part* (3.47) and a *developer part* (3.20)

Note 1 to entry: See Annex A for the term categorization.

3.2
monochrome printer
printer (3.51) only capable of printing black and not configurable to print another colourant

Note 1 to entry: More than one black cartridge can be installed simultaneously if they have the same *cartridge identifier* (3.10).

[SOURCE: ISO/IEC 22505:2019, 3.8, modified — The term was originally "monochrome inkjet printer".]

3.3
binomial attribute
attribute which either occurs or does not occur and which is characterized by a count of the number of times it occurs in a particular number of observations

Note 1 to entry: A random process is said to be binomial if it satisfies four basic properties:

a) it consists of a sequence of n trials for some $n > 1$,

b) each trial has exactly two possible outcomes, A and B, which are mutually exclusive,

c) P(A), the probability of A, takes the same value P on all n trials. P(B) is likewise fixed at 1-p,

d) the n trials are independent of one another.

3.4
cartridge
user replaceable unit (3.67) operating with a printing system that includes at least a containing mechanism designed for materials intended for deposition on a *substrate* (3.62)

3.5
cartridge-attribute test report
report including the information of a cartridge *customer report* (3.18) and the detailed cartridge-characterization results of an ISO/IEC 29142 *cartridge-characterization test* (3.6) reported for customer presentation according to a required format

Note 1 to entry: The format is prescribed according to each ISO/IEC 29142 standardized or specified cartridge-characterization test and is in conformance with ISO/IEC 29142-2.

3.6
cartridge-characterization test
test method provided in conformance with this document for the purpose of evaluating an attribute of a cartridge or *cartridge set* (3.12) of interest to cartridge and cartridge set users

3.7
cartridge collector
party providing a cartridge *take-back* (3.63) or collection program

EXAMPLE A business entity designated to collect cartridges.

3.8
cartridge element
sub piece of a cartridge other than the *containment part* (3.15) of the cartridge

3.9
cartridge end-of-life
point in a cartridge life cycle from which the cartridge is no longer used for its intended purpose without additional non-customer interaction

3.10
cartridge identifier
formatted human readable arrangement of information uniquely specifying a distinct cartridge

3.11
cartridge life percent completion point
point in the life of a cartridge computed as a percent of *expected cartridge life* (3.25)

3.12
cartridge set
group of colourants and their assignment to one or more cartridges as defined by a printer manufacturer to be necessary and sufficient to produce the fully functional default colour renditions

EXAMPLE 1 A *printer* (3.51) often has more than one fully functional cartridge set.

EXAMPLE 2 Default colour renditions: printed black, red, green, blue, cyan, magenta, and yellow.

3.13
cartridge supplier
cartridge marketer, manufacturer, *remanufacturer* (3.57), *refiller* (3.55), or distributor, being the party or parties responsible for marketing the cartridge and providing customer support for the cartridge

3.14
colour printer
printer (3.51) with an operating part to apply *ink* (3.28) or *toner* (3.64) on a *substrate* (3.62), with a functionality to produce print output containing colours

3.15
containment part
part containing the mechanism designed for materials intended for deposition on a *substrate* (3.62)

3.16
continuous attribute
attribute which can take on any of a range of values

3.17
cross-systems attribute tolerance range
CSATR
range of actual attribute values for a cartridge-characterization attribute of a particular cartridge-characterization test method, determined from evaluation of exemplary systems to which the test method applies

3.18
customer report
report, including a cartridge notification, and a cartridge-attribute checklist, with summary results of selected ISO/IEC 29142 cartridge-attribute characterization tests, presented according to a required format

Note 1 to entry: The format is prescribed according to each ISO/IEC 29142 standardized or *specified cartridge-characterization test* (3.6) and is in conformance with ISO/IEC 29142-2.

3.19
deposition material
material, *ink* (3.28) or *toner* (3.64), liquid or solid, colourant or non-colourant, that can be contained in a cartridge, and that is designed for deposition on a surface by means of a printing system

3.20
developer part
physical mechanism, which is often a *cartridge element* (3.8), which functions to apply *toner* (3.64) particles to the latent image on the *photoreceptor part* (3.47) of an electrophotographic printing system

3.21
discrete attribute
attribute which can take only a finite number of values within a range, such as an integer count

3.22
dye ink
material designed for liquid state deposition on a *substrate* (3.62), including a chemical dye colourant

3.23
electrophotographic printer
printer (3.51) principally using optoelectronic phenomena and electrostatic attraction to move *toner* (3.64) to a *substrate* (3.62)

3.24
end-of-life
phase in a cartridge life cycle when the cartridge can no longer be used for its intended purpose without additional non-customer interaction

3.25
expected cartridge life
approximate number of pages likely to be printed from a cartridge when ran to *cartridge end-of-life* (3.9) according to an ISO/IEC 29142 standardized or specified test method

3.26
filled cartridge
user replaceable unit (3.67) of a printing system that includes at least *ink* (3.28) or *toner* (3.64) materials, intended for deposition on a *substrate* (3.62) and a containing mechanism for such materials

3.27
incineration
disposal method that involves combustion of waste material converting it into heat, gas, steam and ash but not including smelting

3.28
ink
material, which often includes colourant, designed for liquid state deposition on a *substrate* (3.62)

3.29
ink cartridge
user replaceable unit (3.67) of a printing system that includes at least a containing mechanism designed for *ink* (3.28) intended for deposition on a *substrate* (3.62)

3.30
ink deposition mechanism
imaging apparatus for depositing *ink* (3.28) on a printing *substrate* (3.62)

EXAMPLE A printhead.

3.31
inkjet printer
printer (3.51) with an operating part, for example, a printhead, to apply *ink* (3.28) on a *substrate* (3.62)

3.32
integrated ink cartridge
cartridge that includes at least: an ink *containment part* (3.15) and an *ink deposition mechanism* (3.30)

3.33
landfilled
waste disposal in a landfill or other non-reuse, -recycle, -remanufacture, -waste to energy, or -incineration depository, excluding the residuals from *waste to energy* (3.68) and *incineration* (3.27)

3.34
life cycle
consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposition

Note 1 to entry: See ISO 14040.

3.35
lifetime attribute
cartridge *performance attribute* (3.45) which can only be measured by printing to *cartridge end-of-life* (3.9) according to an ISO/IEC 29142 standardized or specified test method

3.36
material safety data sheet
MSDS
safety data sheet
SDS
form containing safety information about the *ink* (3.28) or *toner* (3.64) contained in cartridges designed for use in printing applications which includes physical, chemical, and toxicological properties, regulatory information, and recommendations to ensure safe handling

3.37
multi-chamber ink cartridge
ink cartridge (3.29) that is designed to contain two or more inks

3.38
multi-function printer
MFP
printer (3.51) with an operating part to apply *ink* (3.28) or *toner* (3.64) on a *substrate* (3.62), and also providing additional functions such as fax and copy

3.39
non-colourant ink
material designed for liquid state deposition on a *substrate* (3.62), such as gloss optimizers and fixatives, not containing a colourant

3.40
non-colourant toner
solid material, not containing colourant, capable of taking on an electrostatic charge, designed for deposition on a *substrate* (3.62) under the control of electrostatic forces in conjunction with a surface having a controlled distributed charge such as gloss optimizers and fixatives

3.41
non-original cartridge
cartridge that is marketed by a company other than the company that markets the printing system for which the cartridge is intended

3.42
original cartridge
cartridge that is marketed by the company that markets the printing system for which the cartridge is intended

3.43
original equipment manufacturer
company that markets a printing system

3.44
page-attribute value
value of a performance *point attribute* (3.50) that is the value of that attribute evaluated from a complete single printed page

3.45
performance attribute
attribute which can be determined only through printing with the cartridge(s) installed in an operational *printer* (3.51)

3.46
photo printer
printer (3.51) with an operating part to apply *ink* (3.28) or *toner* (3.64) on a *substrate* (3.62), with the functionality to print images on photo paper sizes and types

3.47
photoreceptor part
photoconductor
physical mechanism, such as OPC, that includes a surface that accepts a uniform electrostatic charge, with a surface that can subsequently be selectively discharged by exposure to light, and which facilitates transfer of *toner* (3.64) to media after such exposure

3.48
physical attribute
attribute which can be determined directly from the cartridge and which is independent of print systems

3.49
pigment ink
material designed for liquid-state deposition on a *substrate* (3.62), including a chemical pigment colourant

3.50
point attribute
performance attribute which can be measured on pages printed at any point during the life of the cartridge

3.51
printer
device intended to apply colourant(s) to a *substrate* (3.62) in response to a digital signal

3.52
recovery
process to divert cartridges and/or cartridge materials from the solid waste stream and into productive uses

3.53
recycle
reuse (3.58), *remanufacture* (3.56) or otherwise divert from a solid waste stream

3.54
refill
operation to replace *ink* (3.28) or *toner* (3.64) in a customer's cartridge that does not involve the replacement or refurbishing of worn cartridge components

3.55
refiller
cartridge supplier (3.13) that *refills* (3.54) customer's cartridges

3.56
remanufacture
operation to replace or clean components and add *ink* (3.28) or *toner* (3.64) using cartridges from cartridge *take-back* (3.63) or collection programs

3.57
remanufacturer
cartridge supplier (3.13) that produces or markets *remanufactured* (3.56) cartridges

3.58
reuse
operation in which a whole or a component part of a cartridge is incorporated in the manufacture or *remanufacture* (3.56) of a cartridge, such that the whole or component part is intended to be put into service for the same purpose for which it was conceived

3.59
single chamber ink cartridge
ink cartridge (3.29) that is designed to contain one ink

3.60
single function printer
SFP
printer (3.51) with an operating part to apply *ink* (3.28) or *toner* (3.64) on a *substrate* (3.62), having no additional functions such as fax or scan

3.61
standard error goal
allowed upper limit of the error in *page-attribute value* (3.44) measurements, determined as the upper limit of the standard error of the estimated mean of the measurements

3.62
substrate
user selectable imageable surfaces

EXAMPLE Paper, cloth.

3.63
take-back
programs sponsored by *cartridge suppliers* (3.13) and conducted by *cartridge collectors* (3.7) for the purpose of obtaining cartridges after *cartridge end-of-life* (3.9)

3.64
toner
solid material, capable of taking on an electrostatic charge, designed for deposition on a *substrate* (3.62) under the control of electrostatic forces in conjunction with a surface having a controlled distributed charge

3.65
toner cartridge
user replaceable unit (3.67) of a printing system that includes at least a containing mechanism designed for *toner* (3.64) intended for deposition on a *substrate* (3.62)

3.66
toner deposition mechanism
imaging apparatus for depositing *toner* (3.64) on a printing *substrate* (3.62)

EXAMPLE A surface having a controlled distributed charge.

3.67
user replaceable unit
part of a printing system that is designed to be removed and replaced by a user

3.68
waste to energy
form of *recovery* (3.52) in which the energy generated from *incineration* (3.27) is captured and used as energy

4 Requirements

The framework explained in this document shall not be used directly for comparison of products. For a comparison using test-method standards compliant with the framework of this document, the minimum requirement is that the conditions for measuring parameters, as well as the entire test conditions explained in such compliant standards are required to be in agreement.

5 Structure of the ISO/IEC 29142 series

5.1 Data reporting

This document establishes the product and package labelling requirements, and related reporting requirements for toner and ink cartridges used in printing devices that have a digital input printing path, including multi-function devices.

Cartridge-characterization tests standardized or specified in the ISO/IEC 29142 series to be compliant with this document, and environmental standards compliant with ISO/IEC 29142-3, shall adhere to the labelling, notification and reporting specifications in ISO/IEC 29142-2. For conformance with the ISO/IEC 29142 series, according to ISO/IEC 29142-2, four levels of labelling, notification and reporting are established:

— a cartridge label,

— a cartridge notification,

— a customer report,

— a cartridge-attribute test report.

Customer and cartridge-attribute test reports from ink and toner cartridge-attribute characterization testing shall include results from the test performed directly on each printing system that shall be claimed in the cartridge reporting.

The provisions for traceability between these notification and reporting levels and the related cartridges are specified.

Processes applied after cartridge end-of-life can include recycling cartridges for new cartridges and other new uses, such as in the manufacture of non-cartridge products, refill of cartridges, recovery of cartridges, and remanufacture of cartridges for another usage cycle. Taken together, these processes can result in directing materials from cartridges so that the materials are diverted from the solid waste stream.

Achieving minimal waste after cartridge end-of-life requires that cartridge suppliers, manufacturers, remanufacturers, cartridge collectors, and users conduct each stage of the cartridge life cycle in a manner consistent with this objective. The requirements of ISO/IEC 29142-2 specify information to be provided by cartridge suppliers, and cartridge collectors so that users are enabled to conduct the use stage of the cartridge life cycle in a manner consistent with diverting cartridge materials from the solid waste stream after cartridge end-of-life.

5.2 Environmental

This document establishes a framework of environmental provisions, distinct from the cartridge-characterization framework of this document, for environmental standards for toner and ink cartridges used in printing devices that have a digital input printing path, including multi-function devices.

ISO/IEC 29142-3 harmonizes aspects of selected environmental standards, reporting forms such as material safety data sheets that provide customers with health and safety information, and eco-labels pertaining to toner and ink cartridges, to establish requirements for uniform measurable

environmental, health and safety provisions that inform and benefit the user regarding potential environmental impacts throughout the product life cycle.

Provisions selected in ISO/IEC 29142-3 are included to support these objectives:

a) minimization of environmental impact throughout the cartridge life cycle,

b) minimization of environmental impact associated with end-of-life processes.

Legal requirements and customer expectations are considered associated with material use, manufacturing operations, packaging, and/or end-of-life processes.

ISO/IEC 29142-3 provides the following:

— the terms and definitions related to cartridge environmental attributes (Clause 3 and Annex A),

— cartridge environmental attributes for inclusion in environmental labels, standards and green procurement criteria,

— test methods that manufacturers, test laboratories, etc., use to determine values for the defined cartridge environmental attributes,

— methods for determination of declared values from the test results,

— methods for declaration of conformance to provisions that do not require measurement.

5.3 Toner and ink cartridge characterization

Parts of the ISO/IEC 29142 series specify cartridge-characterization test methods that evaluate attributes of toner and ink cartridges used in printing devices that have a digital input printing path, including multi-function devices. These cartridge-characterization test methods pertain to cartridges for equipment used in office environments.

The ISO/IEC 29142 series defining cartridge-characterization test methods is required to comply with the framework for cartridge characterization defined in this document. The framework requires robust, repeatable, objective measurements and testing procedures that include specification of the test timing relative to cartridge lifetime, and specification of test operating conditions such as temperature and humidity. The print-related attributes tested in ISO/IEC 29142 cartridge-characterization test methods are specified with respect to selected paper properties and values.

ISO/IEC 29142 cartridge-characterization test methods do not pertain to characterization testing of toner or ink cartridges for printers whose minimum printable output size is equal to or greater than A3 (420 mm x 297 mm) or to toner or ink cartridges sold only for photo-only printers. The particular test methods include additional constraints to limit their applicability to subsets of cartridges or to particular types of cartridges.

ISO/IEC 29142 cartridge-characterization test methods are required to be specified in accordance with the terms, symbols, notations and framework of this document and shall be declared and reported as specified in ISO/IEC 29142-2.

6 Framework overview for cartridge characterization

6.1 Elements of a print system

In the context of digital information systems, a printing system contains at least the following operational functionalities:

— computational functionality,

— converts the general form of the digital source content to the information layout of the required print output,

— converts the digital source colour information to the encoding values of the printing system colourant(s),

— determines the spatial distribution of the one or more deposition materials, including the one or more colourant(s),

— control and hardware functionality,

— applies the deposition material(s) to the substrate,

— affixes the deposition material(s) to the substrate.

The computational functional operations are implemented in a variety of ways, including implementation in a single component with the control and hardware functionality, or implementation distributed over several components that are not co-located with the actual material deposition and fixing functionality.

Cartridges and the deposition materials they contain are used by the control and hardware functionality of a printing system and have significant impact on that portion of any printing system. In addition, certain aspects of cartridges and the deposition material(s) they contain are considered in the operation of the computational functionality.

6.2 Cartridge configurations

Ink and toner cartridges can be implemented in a variety of functional configurations. For the purpose of the ISO/IEC 29142 series, a cartridge is a user-replaceable unit operating with a printing system that includes at least a containment part for toner or ink. Within this overarching definition, three functional configurations of toner cartridges and two functional configurations of ink cartridges are defined in the ISO/IEC 29142 series.

Toner cartridge functional configurations are:

a) single-part toner cartridge: a toner cartridge that includes only a toner containment part,

b) two-part toner cartridge: a toner cartridge that includes a toner containment part and a developer part and does not include a photoreceptor part,

c) all-in-one toner cartridge: a toner cartridge that includes a toner containment part and a developer part and a photoreceptor part.

Ink cartridge functional configurations are:

a) single part ink cartridge: a cartridge that includes only an ink containment part,

b) integrated ink cartridge: a cartridge that includes an ink containment part and an ink deposition mechanism.

Each of the ink and toner cartridge functional configurations contains one or more deposition materials, ink or toner, colourant or non-colourant, for use in a printing system. For example, a single multi-chamber ink cartridge contains more than one ink.

The provisions of ISO/IEC 29142-3 and cartridge-characterization test methods of the ISO/IEC 29142 series are structured to apply equally to these functional and multi-chamber cartridge configurations.

6.3 Performance attributes measured on a printed page

Cartridges are intrinsically involved in depositing ink or toner on the substrate in use in a printing system. Because of this, certain cartridge attributes are characterized using measurements of printed pages. Although cartridge performance is recognized as critical to print quality, traditional print quality attributes are not measured in cartridge characterization due to the interaction of the entire

print system in delivering these print quality results. The cartridge-characterization framework of this document provides for selective cartridge characterization, with the selected characteristics emphasizing the cartridge performance over that of the general print system.

Each cartridge attribute characterized by means of a printed page test method should be chosen after satisfying the following criteria:

a) the attribute is noticeable to users,

b) the attribute can be measured using standardized objective methods,

c) across the various cartridge configurations, the attribute is 50 % or more due to processes and parts that directly apply the deposition material to the substrate,

d) the attribute is testable using a rigorous and statistically valid test method.

6.4 Physical attributes

The cartridge-characterization framework of the ISO/IEC 29142 series provides test methodology requirements applicable to selective characterization of physical attributes, independent of print systems.

NOTE The environmental, health, and safety provisions of ISO/IEC 29142-3 address the physical attributes of cartridges, fundamentally involving the cartridge materials.

7 Attribute framework for testing and characterizing cartridges

7.1 Overview

The cartridge-characterization framework of this document draws a distinction between physical attributes and performance attributes of cartridges. Physical attributes are those that can be evaluated directly from the cartridge without inserting the cartridge into a printer. For example, the material of a cartridge is a physical attribute. Performance attributes, by contrast, are those determined through the interaction of the cartridge with a printer.

Cartridge performance attributes fall broadly into two categories. The first is lifetime attributes. These by their nature are reflective of the performance over cartridge life. The most obvious of this type is cartridge yield, which can only be measured by running cartridges in printers until the cartridge reaches cartridge end-of-life according to an ISO/IEC standardized cartridge yield test method. The second category is point attributes, which can be evaluated at any single test point while running cartridges. An example of this type is an attribute of print on a specific page or within a specific region on a page that has been printed using the cartridge.

Cartridge performance attributes shall not include page-attribute value assessments of absolute colourant colour values, with the understanding that such an assessment weighs heavily toward the colourant design rather than the cartridge itself.

Any attribute can also be categorized as either discrete or continuous according to the definitions in Clause 3. Discrete attributes can have only a limited number of values. For example, an attribute that can only be quantified using a qualitative scale (such as poor, fair, good, very good, etc.) is discrete. Binomial attributes are the limiting special case of discrete attributes, with only 2 possible values, such as yes or no, pass or fail, present or absent, 0 or 1, etc. For example, cartridge part breakage during a life test could be categorized as a binomial attribute. If a part breaks during the test, then the value of the attribute for the cartridge in which it broke is “Yes.” If no part breaks, then the value is “No.”

By contrast, a continuous attribute is one that can take on any value within a range. For example, a print attribute of a page as measured with a device such as a spectrophotometer is typically a continuous attribute.

The understanding of continuous and discrete attribute types is a necessary step in determining how to statistically model variation in attribute values. Data points from continuous attributes can be modelled with familiar continuous distributions such as the normal, log-normal, or Student-t distributions. Discrete attributes are appropriately modelled using binomial, Poisson, geometric, or a large number of other distributions. Under certain restricted conditions it is acceptable to use continuous distributions to model discrete attributes.

There is much less information content in discrete attributes than in continuous attributes so in general they are less desirable for use in characterizing performance.

Cartridge characterizations according to this document shall allow the following attribute types.

a) Continuous attributes measured with objective instruments such as spectrophotometers which can provide at least 10 different values for each sample within the range of interest.

   NOTE The values of a continuous variable are generally broken down to discrete levels based on the resolution of the instrument being used for measurement. Nonetheless, there is value in using the simplifying assumption that such data streams are continuous rather than discrete so that tools such as *t*-tests or confidence bounds based on normal distributions can be used. On the other hand, treatment as a continuous attribute is not appropriate for attributes that have only a limited number of values.

b) Discrete attributes which are objective in nature and which have a range of possible values of 10 or more and, therefore, can be modelled as continuous. Attributes of this type include page counts for determination of cartridge yield. For the purposes of this document, such attributes shall be considered continuous attributes so that their variation can be modelled using continuous distribution approximations. Discussions pertaining to modelling continuous attributes in subsequent sections also pertain to discrete attributes meeting these specified conditions.

c) Binomial attributes, these are of some interest and therefore methods are included for treating them. However, the sample sizes are increased to compensate for the poor information content in these types of attributes.

This document does not include methods for characterizing cartridges with subjective, multi-level grading systems (e.g. poor, fair, good, very good, etc.).

The attribute types that can be characterized in accordance with this document are illustrated in Figure 1.

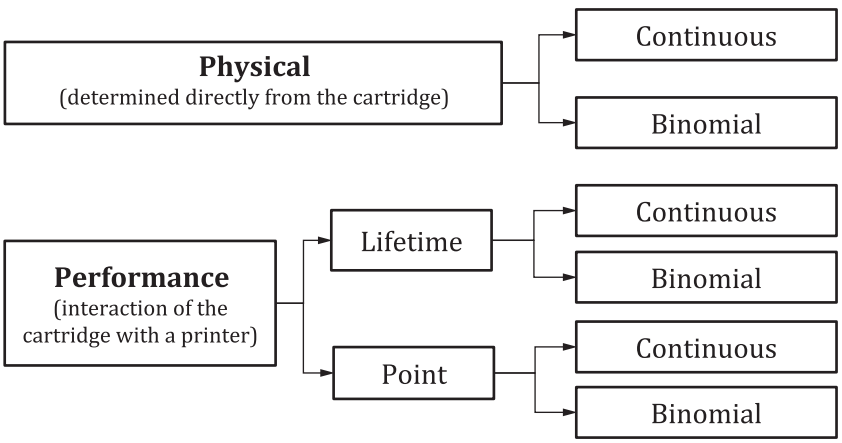

Figure 1 — Attribute categories

Any test method constructed according to this cartridge-characterization framework to evaluate performance attributes shall require running multiple cartridges on multiple printers, with the cartridges ran in each printer to the cartridge life percent completion point or points required in the test

method. The use of an appropriate number of cartridges and printers in such tests enables a statistical evaluation of results, including determination of the mean response and statistical confidence bounds for both the mean and individual observations.

This framework provides minimum requirements for testing cartridge attributes. Test procedures for individual attributes often add additional constraints.

7.2 Special considerations for binomial and continuous performance point attributes

Due to the many sources of variability which can influence point attributes, a single measurement of point attributes is not sufficient to characterize cartridge performance. In order to adequately characterize cartridge performance in regard to point attributes, it is necessary to measure the attributes multiple times. For example, the measurements can be required at multiple spots on a test page and/or at multiple points within cartridge life.

As defined in this document, a point attribute evaluated from a test chart or test file page shall be represented by a single value denoted as the page-attribute value. The appropriate method to determine a page-attribute value can depend on the specific attribute. For example, a test chart may provide a specific number of regions of interest that are to be evaluated. A page-attribute value can be defined as, for example, the average, minimum, maximum, or some other statistic derived from each region of interest.

Because point attributes are evaluated at a single test point, test methods which evaluate point attributes shall require that the cartridge-attribute test report includes the cartridge life percent completion point or points at which point-attribute data were collected throughout the entire cartridge life.

As recommended in this document, point attributes can be measured in conjunction with the appropriate yield standard defined in ISO/IEC 19752, ISO/IEC 19798, the ISO/IEC 24711 series, ISO/IEC 22505 or ISO/IEC 29102.

7.3 Special considerations for point and lifetime binomial attributes

A binomial treatment of an attribute is established by the use of a two-state criterion. Such a two-state criterion can be applied to the results of a metric that produces a continuous range of values or to an attribute that intrinsically has two value states. A cartridge shall be determined to either have or not have the attribute under observation. This determination shall be made according to evaluation criteria unambiguously defined in the test method.

For example, the occurrence of an attribute value in a region of interest can be evaluated as a binomial point attribute. An example two-state criterion rule for this is:

Count only the attribute occurrences meeting the specific criterion x, y, z and consider the cartridge to have such attribute occurrences only if the attribute occurs in *n* test charts collected at each of *m* points of the cartridge lifetime.

The statistics collected are the number of cartridges for which the attribute occurs and the number of cartridges tested.

7.4 Special considerations for performance testing with page-attribute values

In performance-attribute test methods dealing with page-attribute values, a statistically valid measurement plan shall be determined and incorporated into the test method and test chart design. The measurement plan shall compensate the measurement of page-attribute values for variability expected in the measurement equipment and for variability expected within the printing systems used to test the cartridges.

NOTE The measurement plan does not compensate for variability between printers.

For each test method, specific replicate measurements shall be required in accordance with a specified standard error goal and cross-systems attribute tolerance range (CSATR) for the page-attribute value under test.

A standard error goal shall be specified in each page-attribute value test method. The standard error goal, the upper limit of the standard error of the estimated mean of the measurements, shall be specified as 10 % of CSATR of the page-attribute value under test. The CSATR of the page-attribute value under test shall be determined for the systems to which the test method applies and shall be specified in the test method.

The test procedure shall include specification of measurement equipment capabilities in accordance with the measurement plan of the test procedure, as required to achieve the standard error goal.

The test method shall require the number of measurements per test chart component and the number of replicate test chart prints as necessary to achieve the standard error goal specified in the test method, according to the relationship:

$$N_{s,eg} = \max\left\{2,\ \text{roundup}\ [(s/s_{eg})^2]\right\}$$

where

$N_{s,eg}$ is the required number of measurements to achieve the standard error goal;

s is the standard deviation of the attribute measurements as tested with a particular print system to which the test method applies;

s_{eg} is the standard error goal, which is 10 % of the CSATR of the page-attribute value under test.

The $N_{s,eg}$ replicate test chart component measurement values shall be required to be averaged and treated as a single measurement within the page-attribute value evaluation of the test method.

Each page-attribute value test method shall require that the cartridge-attribute test report shall include documentation of the number of replicate test chart prints, replicate test chart components, measurements per test chart component, measurement equipment used, and the standard error of the estimated mean of the measurements, achieved in the test.

The CSATR of the page attribute under test can be determined based on available industry data or be determined through testing during the test method development process. In the case of testing for CSATR, intentionally choose a broadly diverse range of print systems and cartridges within the scope of the test method, and measure the page attribute under test. CSATR is determined as the difference between the minimum and maximum page-attribute values obtained from the tested systems.

The estimate of the standard deviation of the page-attribute value measurements shall include the variability due to the measuring instrument and the printed inconsistencies of the test chart print(s) within a particular representative print system and is given by s in the following:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n-1}}$$

where

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

n is the number of replicate measurements made.

To determine $N_{s,eg}$, measure s with n = 10 in two ways: measurements taken in 10 locations within a single undisturbed printed region of interest, and one measurement taken from within each of 10

printed regions of interest. Screen the data for outliers and extremes. Use the larger value of s when calculating $N_{s,eg}$.

The standard error of the estimated mean of the measurements, s_e, is equal to the estimate of the standard deviation of the measurements divided by the square root of the number of measurements, as follows:

$$s_e = \frac{s}{\sqrt{n}}$$

To develop the measurement plan of the test method, evaluate the following.

1. The standard error of the estimated mean of the measurements—as a function of the measurement equipment and the print consistency within a single test chart print component as follows.

   Use $N_{s,eg}$ measurements per test chart print component and compute s and s_e using the multiple measurement values within a test chart print component, after discarding outliers and extreme values.

   NOTE 1 For an example, see ASTM E 1345.

2. The standard error of the estimated mean of the measurements—as a function of the measurement equipment and the print system page-to-page consistency and in-page consistency as follows.

   Use $N_{s,eg}$ replicate test chart components either within a single page test chart design or across replicate prints of the test chart, take one measurement per test chart component and compute s and s_e using single measurements for each of the replicate test chart components, after discarding outliers and extreme values.

   NOTE 2 For an example, see ASTM E 1345.

3. The combined standard error of the estimated mean of the measurements across replicate test chart components, with multiple measurements within each test chart component as follows.

   Use $N_{s,eg}$ as the number of replicate test chart components times the number of measurements per test chart component, and compute s and s_e using the multiple measurements across the replicate test chart components, after discarding outliers and extreme values.

   NOTE 3 For an example, see ASTM E 1345.

The use of replicate regions of interest improves the validity of test results in cases where noticeable printed inconsistencies are present.

Using the information of the three standard error of the estimated mean of the measurements evaluations, specify the allocation of $N_{s,eg}$ number of measurements as replicate test chart components and measurements per test chart component to achieve the desired standard error goal in the test procedure.

For example, consider whether the standard error of the estimated mean of the measurements—as a function of the measurement equipment and the print consistency within a single test chart print component or as a function of the measurement equipment and the print system page-to-page consistency and in-page consistency—would dominate a combined measurement result. Consider specifying measurements of multiple replicates rather than multiple measurements within a single region of interest in the case of expected significant print system page-to-page and in-page inconsistencies.

7.5 Test requirements for all attributes

7.5.1 Set-up

When testing performance attributes, place test printers on a horizontal surface and set-up the printers according to the installation guide provided in the printer user's manual. Use the most recent printer driver available from the manufacturer's website or the driver supplied with the printer. The driver version used shall be specified on the cartridge-attribute test report. Cartridge installation shall be completed following the instructions in the cartridge installation guide. If there is a contradiction between the printer and cartridge manuals for the cartridge installation, the cartridge manual shall take precedence except if changes are recommended for printer or driver settings.

If the cartridges used in testing are colourant replenishment or colourant bottle types, then one set of cartridges shall be used to cartridge end-of-life according to the ISO/IEC 29142 standardized or specified test method in each printer before the start of the test. The pages printed to deplete these priming cartridges shall not be recorded and printing can be conducted at any environment. The priming cartridges are used to bring the printing system to a set colourant level condition.

The cartridges used to bring the printing system to a set colourant level condition shall not start out full. For large capacity systems, using a complete cartridge could result in tens of thousands of pages printed just to bring the system to a set condition.

All image and print quality modifiers shall be at their factory pre-set configuration for the printer and default installed condition for the driver. If the printer and driver differ, then the driver defaults shall be used. Any user selectable colourant conservation modes shall be disabled during testing.

Cartridge-characterization testing shall use simplex printing as the basis for characterizing cartridge attributes. Modifying each component in the printing operation to simplex is required if that is not the default. Exception or optional cases for duplex operation is specifically required within a test method. Page order shall be specified in each test method.

Test methods that evaluate page-attribute values shall require the driver selection for paper/media type to match the actual paper/media specified and used in the test. In test methods that do not include measurement of page-attribute values, the driver selection for paper/media shall be 'plain paper' or the closest equivalent available in the driver. If auto media detection is available on the printer, it shall be disabled if possible, to avoid inaccurate sensing of the media. If the auto media detection is present and cannot be disabled, this shall be required to be reported in the cartridge-attribute test report.

7.5.2 Sample size for continuous attributes

The sample size for each continuous attribute value shall be a minimum of nine physical cartridge sets. Performance attributes shall be tested using a minimum of three printers.

For lifetime attributes, an equal number of cartridge sets shall be tested on each printer. For example, a test method often requires three sets of cartridges to be tested on three printers with each printer using three sets of cartridges. In the case of a typical four colour printer with four single colour cartridges this would result in 36 cartridges being tested, 9 black (K), 9 cyan (C), 9 magenta (M) and 9 yellow (Y).

For point attributes, data shall be collected for all cartridges installed until the test is completed. This means that results for more than the minimum number of cartridges are often included and it means that results can include data for cartridges only partially depleted.

7.5.3 Sample size for binomial attributes

Many more observations are required to make sound statistical statements for binomial attributes than for continuous attributes. In conformance with this test method framework, binomial attributes shall be tested to at least a 90 % confidence level. Furthermore, the sampling shall be such that, within the confidence bound, the detection limit of the occurrences of the attribute in the population is 5 % or less, or 95 % or more. Therefore, in conformance with this test method framework, the sample size

shall be determined such that for each binomial attribute value a minimum of 45 physical cartridge sets are tested. For performance attributes, a minimum of three printers shall be used. 45 is chosen because it is the minimum test quantity required to resolve at 90 % confidence that a binomial attribute occurs less than 5 % of the time or more than 95 % of the time (e.g. if no occurrences are observed in 45 observations, then at 90 % confidence the occurrence rate is less than 5 %).

For performance binomial attributes, an equal number of cartridge sets shall be tested on each printer. For example, a total of 45 sets of cartridges could be tested on three printers with each printer using 15 sets of cartridges. In the case of a typical four colour printer with four single colour cartridges this means that 180 cartridges are tested, 45 black (K), 45 cyan (C), 45 magenta (M) and 45 yellow (Y).

For performance binomial attributes, data shall be collected for all cartridges installed until the test is completed. That means results for more than the minimum number of cartridges shall be included for the cartridges with the higher depletion rates.

7.5.4 Additional cartridge sampling considerations

When testing additional engines and cartridges above the minimum, an equal number of cartridges shall be tested on each engine.

When testing cartridges for a commercially available product, it is recommended that cartridges and printers be procured from various sources, or sampled from different production lots. The printers and cartridges shall be within their useful life as stated in the product user's manual.

NOTE Additional engines and/or cartridges available for testing can mitigate the possibility of cartridge and/or printer failure during testing.

7.5.5 Print and test environment

Temperature and humidity can have a profound effect on test results. For this reason, a test method shall fully specify the environmental conditions that can affect the test results and shall be used in conducting the test method. Furthermore, the test method shall specify the control requirements for maintaining the testing and printing environmental conditions throughout the test period.

For the environment conditions specified in a test method, the following shall be specified:

— the sampling time period for measurement of the operating condition,

— the time period over which the running average shall be computed.

In addition, a test method should specify the required operational uniformity over the volume of the print or test environment when testing is conducted that is dependent on conditions in an area or volume distributed from the environmental control mechanisms.

When relative humidity is specified, the running average shall vary no more than ±15 % from the operating control point. When temperature is specified, the running average shall vary no more than ±3 °C from the operating control point.

For example, the following wording is used to specify test environment conditions (the numerical values in the following paragraph are for example only):

> "Printing room temperature operational control point shall be 23,0 °C. The running average of the operational fluctuation, sampled at least every 15 min, shall be within ±3,0 °C of the control point. The temperature operational uniformity in the print environment, determined prior to test start, shall be within ±3 °C of the operational control point. Printing room humidity operational control point shall be 50 % RH. The running average of the operational fluctuation, sampled at least every 15 min, shall be within ±15 % RH of the operational control point. The humidity operational uniformity in the print environment, determined prior to test start, shall be within ±15 % RH of aim, at a constant temperature."

Print environment conditions shall be included in the cartridge-attribute test report. The maximum and minimum running averages for temperature and humidity shall be reported for each cartridge tested.

All print materials shall be temperature acclimated to the print test room environment. Prior to testing, the printer, paper and cartridges shall be acclimated to the above conditions for a minimum of 8 h. Before acclimation, packaging and shipping materials shall be opened with care taken to prevent damage to the cartridges during acclimation. Paper shall be acclimated in the ream wrapper. Water condensation shall be avoided when printer, paper and cartridges are carried in the test environment.

7.5.6 Paper

A performance test method shall specify paper for testing in terms of measurable physical paper attributes. Cartridge test methods shall specify that any papers used in cartridge testing shall be only those deemed acceptable for use by the printer manufacturer.

For page-attribute value test methods, paper should be specified according to an acceptable range of values for paper properties such as:

— grammage (ISO 536),

— grain direction (parallel to short/long edge),

— thickness (ISO 534),

— opacity (ISO 2471),

— stiffness, resistance to bending (ISO 2493-2),

— static and kinetic coefficient of friction (ISO 15359),

— surface smoothness/roughness (ISO 8791-3),

— moisture content (ISO 287),

— gloss 60° for office papers (ISO 8254-1), 20° for photo papers (ISO 8254-3),

— paper colour (ISO 2469, ISO 5631-1),

— CIE whiteness (ISO 11476),

— ISO brightness (ISO 2470-1).

The paper manufacturer, paper name and model number, weight and size, used in the test shall be required in the cartridge-attribute test report. Related paper International Standards are listed in the Bibliography.

7.5.7 Maintenance

Printer maintenance shall be performed per the printer and cartridge user's manual.

NOTE Examples of common maintenance performed during testing can include replacement of transfer belts or print head units.

7.5.8 Test chart files

For performance test methods, one or more test chart file(s) shall be defined to be used for all or portions of the printing during the test. For example, the test chart file is the print file specified in the applicable ISO page yield standard. If a page-attribute value is to be evaluated and there is no existing ISO test chart file that contains an appropriate test chart component for measurement of the page-attribute value, then one or more test chart(s) shall be specified in the test method.

The following test chart file characteristics can influence the outcomes of cartridge-characterization performance test methods:

— colour values digital encoding method,

— visual colour definition of encoded colour values (e.g. ensure that encoded colours are referenced to a human visual colour space such as CIELAB),

— digital page definition language, including mixtures of vector and raster elements,

— pixels per inch resolution of rasterized file elements,

— layout and relationship between digital colour elements over the print page area,

— test chart file compression method.

Test charts files developed for use in ISO/IEC 29142 cartridge-characterization test methods shall be designed with respect to each of these file characteristics to improve consistency when using the test chart.

It is desirable to integrate testing of an attribute within an ISO yield test process in order to limit testing resource. This integrated approach is used for the purpose of additional attribute testing and shall not be used in reporting yield test results.

Test chart designs shall include fiducials on each print page to allow measurement of the test chart prints to ensure that the content is printed at a specified size.

A standard defining a test chart file and its usage shall specify the file reader requirements and the method to be used to generate the printer input and send the file to the printer. A test chart standard allows the use of one or more printing methods with the requirement that each printing method produces colourant writing stimuli equivalent to a customer available printing method. Test chart standards shall require that printing method settings be recorded in the cartridge-attribute test report. The version of the test chart file, the printer driver version, and the file reader version shall be required in cartridge-attribute test reports. Before starting the test, a sample of the test chart file(s) shall be printed to check the image and ensure the proper size.

In the case of raster image file test charts, uncompressed or losslessly compressed standard files should be specified. In this case, if the printing system used in the cartridge test cannot accept the standard image files for printing, the test chart standard shall specify to convert the test chart file (for example, designed and saved as a tiff file) to the highest quality (for example, least compressed) raster file format that the printing system can accept just prior to printing. Ensure that the required patch size and patch spacing is maintained in the converted printable file.

The method used for connection between the host computer and the printer shall be recorded on the cartridge-attribute test report.

The host computer environment such as operating system (OS), memory size, CPU type and application software can affect the test results, so all of this information shall be recorded in the cartridge-attribute test report.

7.6 Test methodology for lifetime and point attributes

7.6.1 Sample interval for printing test charts

Test charts shall be introduced and collected at specified preset points during a cartridge life test based on the expected page yield of the cartridges. The expected cartridge life is simply the approximate number of pages likely to be printed in the print mode chosen for the test. For example, the declared yield from ISO/IEC 19752, ISO/IEC 19798, the ISO/IEC 24711 series, ISO/IEC 22505 or ISO/IEC 29102 is an appropriate expected cartridge life if the test protocol is very similar to the methodologies of those standards. If no expected cartridge life is available, then a test of one or more cartridges shall be run

according to the rules established within the test procedure to estimate an expected cartridge life for use in setting up a cartridge-characterization attribute test.

When a test method specifies test charts to be printed in conjunction with a cartridge life test, the test shall be planned to provide for five sample test charts or more to be collected from each test cartridge. Due to intricacies of the actual test conditions and to possible variation in expected cartridge life within cartridge sets, the actual number of samples can vary.

7.6.2 Test sample frequency calculation for attributes tested in a life test process

Determine the expected cartridge life of the test cartridges as described in 7.6.1. If the test includes cartridges with more than one expected cartridge life point, then choose the highest yield. At minimum, divide this quantity by five. The test shall be interrupted at integer multiples of this divisor quantity for the purpose of sample printing and/or collection.

EXAMPLE 1 A monochrome printer with an expected cartridge life of 10 000 pages. Samples would be collected every 10 000/5 = 2 000 pages.

EXAMPLE 2 A colour printer with an expected cartridge life for cartridges of all colours of 20 000 pages. Samples would be collected every 20 000/5 = 4 000 pages.

EXAMPLE 3 A colour printer with an expected cartridge life of 500 pages for the black cartridge and an expected cartridge life of 250 pages for the cyan, magenta, and yellow cartridges. Samples would be collected every 500/5 = 100 pages. In this case, additional cyan, magenta, and yellow cartridges are added to the test process so that all colours are available until the last black cartridge reaches cartridge end-of-life according to the ISO/IEC standardized cartridge yield test method. The results from any extra cartridges are included in the evaluation of point attributes.

In addition to the sample points calculated above, test charts shall also be collected immediately before the start of the test.

This sample collection process is tied to the printer page count and not directly to the page count for individual cartridges. Samples shall be collected throughout cartridge life but not necessarily at the very beginning or at cartridge end-of-life for all cartridges.

7.6.3 Testing procedure

A performance test method shall include specification of testing procedure steps including:

a) test completion criteria;

b) number of printers and cartridges;

c) preparation of the supplies, printer equipment, print environment, measurement environment, and test charts;

d) conduct of printing and the methodology to determine the cartridge life test points for point attributes' data;

e) handling of multiple cartridges with different yields with respect to sufficient test charts and statistically valid measurement data.

7.6.4 Conditioning and measurement of test chart components for page-attribute values

Prints of any type shall be held for at least 24 h. Measurements shall be conducted after conditioning/print hold. The measurement environment and test chart print holding environment can influence measured colour values and variability in measurement results.

For page-attribute value test methods, measurements and test chart print holding for measurement and next test phase, preparation shall be specified to be conducted in a controlled environment with no time constraint or to be conducted in a less controlled environment with a time constraint.

The specification for the controlled test chart print holding environment with no time constraint shall be the following set of conditions:

> Test chart prints shall be kept in the dark, with temperature and relative humidity conditions controlled to 23 ± 2 °C, 50 ± 10 % RH, while waiting for measurement and while holding between test stages.

The specification for the controlled measurement environment with no measurement process time constraint shall be the following set of conditions:

> Ambient illuminance on the test chart print surface no greater than 200 lx, temperature and relative humidity controlled to 23 ± 2 °C and 50 ± 10 % RH.

The specification for test chart print holding and/or measurement conducted in a less controlled environment after test chart print conditioning shall require that test chart prints be held or measured in the less controlled environment for a maximum of 2 h prior to measurement. The less controlled environment shall be specified to have a maximum temperature of 30 °C and a maximum relative humidity of 75 % RH, with ambient illuminance on the test chart print surface less than or equal to 1 000 lx.

NOTE Stray light decreases the accuracy of measurements taken in less controlled lighting environments. Shielding the measurement instrument from direct lighting so that the actual measurement surface lighting is no more than 200 lx can improve measurement accuracy and repeatability.

The temperature and humidity tolerances for the test chart print holding and measurement environments apply specifically to the vicinities in which the test chart prints are held and measured. Operational fluctuations, operational uniformity, and uncertainty of measurement shall be contained within the stated tolerances in those vicinities.

The measurement environment and test chart print holding environment, with respect to temperature, % RH and light levels, fluctuations, and uniformity shall be required in the cartridge-attribute test report.

If page-attribute values are specified in terms of colorimetry, such attributes shall be measured using a specified measurement condition of ISO 13655. The specified measurement condition requirements shall include the requirement of the relative spectral power distribution of the flux incident on the specimen surface and the metamerism index of the light source, the sample backing and the tristimulus calculation illuminant and observer. The backing used shall be required to be reported in the cartridge-attribute test report. Measurement conditions shall be specified to be consistent throughout the test process.

Conforming to ISO 13655, calculated tristimulus values and corresponding CIELAB values of the measured colorimetry shall be computed using CIE illuminant D50 and the CIE 1931 standard colorimetric observer (often referred to as the 2° standard observer).

If page-attribute values are specified in terms of optical densities, such attributes shall be measured according to ISO 5-3. The test method shall specify whether or not a UV-cut filter shall be used, the specific spectral product (e.g. Status A, Status T) to be used, the sample backing to be used, and shall specify that the reporting shall include these measurement conditions. Measurement conditions shall be specified to be consistent throughout the test process.

A single measurement instrument shall be used for all of the measurements of prints of test chart components that shall be averaged or combined in a calculation or statistic. For example, density values of a particular test chart component in N replicate prints shall be measured using the same measurement instrument.

Inter-instrument agreement, within the same instrument model, assuming both units are in proper order and within their certification parameters, can be 0,8 deltaE average and 2 deltaE maximum. This error bound is given in relation to measurements of reference materials, so actual errors can be higher than these limits. In addition, if comparing instruments across vendors, the unknown absolute calibration error difference between the instruments shall be considered.

7.6.5 Procedure for handling a defective cartridge or printer

7.6.5.1 General

During testing, a failure of the cartridge or printer can occur. Performance test methods shall specify the consistent handling of defective cartridges and printers.

Cartridge failures are defined as occurrences of problems that result in replacement of the cartridge before cartridge end-of-life as defined according to the ISO/IEC 29142 standardized or specified test method. Examples of this in the case of cartridges could be excessive colourant leakage, structural failure, etc. Printer failures are defined as non-user clearable errors that prevent normal printer operation from occurring. An example of this might be the failure of the paper feed mechanism on a printer.

7.6.5.2 Defective cartridge

In the case of a defective cartridge, the number of the test charts printed and reason for failure shall be required in the cartridge-attribute test report. The cartridge shall then be replaced with a new cartridge and the testing continued. ISO/IEC 29142 standardized or specified performance test methods shall specify the treatment of early cartridge end-of-life and whether the cartridge is to be classified as defective. For the purposes of attribute determination, the defective cartridge shall not be used. Performance test methods shall require that, for the test to be considered valid, at least the minimum number of cartridge sets shall be run to the defined cartridge life test points.

7.6.5.3 Defective printer

In the case of a defective printer, performance test methods shall specify that the printer shall be repaired or replaced and new cartridges shall be used for subsequent testing. In the cartridge-attribute test report, the number of the test charts printed by the replaced cartridges shall be required to be recorded and it shall be required to record that the cartridges were replaced due to printer failure. The failure of the printer shall be required to be noted and the replacement printer serial number shall be required to be recorded. For the test to be considered valid, at least the minimum required number of each cartridge per engine shall be run to the defined cartridge life test points. In performance test methods, the data obtained before printer failure cannot be used for attribute calculation unless it can be proved that the printer failure did not affect the previously tested cartridges. This justification shall be required in the cartridge-attribute test report.

8 Framework requirements for determination of declared attribute values

8.1 Determination of the declared value for continuous lifetime or continuous physical attributes

An average and a standard deviation for the continuous lifetime or continuous physical attribute shall be obtained from the test runs (e.g. $n = 9$).

Sample average for a given cartridge is expressed as follows:

$$\bar{X} = \sum_{i=1}^{n} \frac{x_i}{n}$$

Sample standard deviation for a given cartridge is expressed as follows:

$$s = \sqrt{\sum_{i=1}^{n} \frac{\left(x_i - \bar{X}\right)^2}{(n-1)}}$$

where

x_i is the individual cartridge-attribute value (e.g. for yield as in ISO/IEC 19752, the number of standard test pages printed between cartridge installation and cartridge end-of-life);

n is the sample size. In this example, n = 9. (Generally, n shall be greater than or equal to 9).

For attribute values that are normally distributed, it can be stated with 90 % confidence that the true average value for the lifetime attribute of the cartridge is within the following values:

$$B_{LC} = \bar{X} - \left(t_{\alpha,n-1}\right) \times \frac{s}{\sqrt{n}}$$

$$B_{UC} = \bar{X} + \left(t_{\alpha,n-1}\right) \times \frac{s}{\sqrt{n}}$$

where

B_{LC} is the lower confidence bound;

B_{UC} is the upper confidence bound.

The value $t_{\alpha,n-1}$ can be found on a students' t-distribution table with n-1 degrees of freedom (df or 'ν') and an α of 0,1 [in this example, n-1 = (9 − 1) = 8]. This provides a 2-tailed confidence interval with 90 % confidence. This specific t-statistic for 8 degrees of freedom, and 90 % confidence is $t_{\alpha,n-1}$ = 1,860.

This can be used in the above calculation only. A different sample size and/or different confidence interval yields a different $t_{\alpha,n-1}$.

If the attribute values are not normally distributed, then alternate methods shall be used to determine the confidence bounds. For example, the data are functionally transformed to a set of values that are normally distributed. The confidence bounds for the transformed data can then be found. These values can then be reverse transformed to establish the confidence bounds for the actual attribute.

When higher values for a lifetime or physical attribute are obviously preferable, then the declared value shall be determined so that it is at or below the calculated lower 90 % confidence value. When lower values for a lifetime or physical attribute are obviously preferable, then the declared value shall be determined so that it is at or above the calculated upper 90 % confidence value. When no value is obviously preferable, then the declaration of the attribute shall include the mean and the upper and lower 90 % confidence bounds.

8.2 Determination of the declared value for continuous point attributes

When the minimum of 3 cartridge sets are printed per printer, the sampling interval defined for the determination of point attributes should result in the collection of approximately 15 test charts or test file pages of each type from each printer. For a test with the minimum of 3 printers and 3 cartridge sets per printer, the total number of test samples collected is approximately 45. This provides the determination of approximately 45 page-attribute values. Sample size grows when more printers or more cartridge sets are used in the test. The actual number of samples is a few higher or lower than the calculated value due to variation in the yield among cartridges.

For each point attribute, an average and a standard deviation for the point attribute is obtained from the page-attribute values (e.g. n = 45).

Sample average for a given point attribute is expressed as follows:

$$\bar{X} = \sum_{i=1}^{n} \frac{x_i}{n}$$

Sample standard deviation for a given point attribute is expressed as follows:

$$s = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \bar{X})^2}{(n-1)}}$$

where

x_i is the individual page-attribute value;

n is the sample size, in this example, n = 45.

For attribute values which are normally distributed, it can be stated with 90 % confidence that the true average page value of the point attribute is within the following values:

$$B_{LC} = \bar{X} - (t_{\alpha,n-1}) \times \frac{s}{\sqrt{n}}$$

$$B_{UC} = \bar{X} + (t_{\alpha,n-1}) \times \frac{s}{\sqrt{n}}$$

where

B_{LC} is the lower confidence bound;

B_{UC} is the upper confidence bound.

For attribute values which are normally distributed, it can also be stated with 90 % confidence that individual page values of the point attribute are within the following values:

$$B_{LC,I} = \bar{X} - (t_{\alpha,n-1}) \times s$$

$$B_{UC,I} = \bar{X} + (t_{\alpha,n-1}) \times s$$

where

$B_{LC,I}$ is the lower confidence bound for individuals;

$B_{UC,I}$ is the upper confidence bound for individuals.

The value $t_{\alpha,n\text{-}1}$ can be found on a students' t-distribution table with n-1 degrees of freedom (df or 'ν') and an α of 0,1 [in this example, n-1 = (45 − 1) = 44]. This provides a 2-tailed confidence interval with 90 % confidence. This specific t-statistic for 44 degrees of freedom, and 90 % confidence is $t_{\alpha,n\text{-}1}$ = 1,680.

This can be used in the above calculation only. A different sample size and/or different confidence interval yields a different $t_{\alpha,n\text{-}1}$.

If the attribute values are not normally distributed, then alternate methods shall be used to determine the confidence bounds. For example, the data are functionally transformed to a set of values that are normally distributed. The confidence bounds for the transformed data can then be found. These values can then be reverse transformed to establish the confidence bounds for the actual attribute.

When reporting values for point attributes in the customer report cartridge-characterization results and in the cartridge-attribute test report, all of the following shall be included: the mean, upper and lower 90 % confidence bounds on the mean, and upper and lower 90 % confidence bounds for individual values.

8.3 Determination of the declared value for lifetime, point and physical binomial attributes

The performance of a cartridge type relative to a binomial attributes shall be described by determining the mean value for the attribute and the 90 % confidence limits for the attribute based on the binomial distribution using the Clopper-Pearson method. For example, if 3 occurrences of a binomial attribute are observed in a 45-cartridge test, then:

— the mean value is 6,7 %,

— the lower 90 % confidence bound is 1,8 %,

— the upper 90 % confidence bound is 16,4 %.

All of these values are to be included in any declaration of the binomial attribute.

9 Framework requirements for reporting cartridge-characterization results

In conformance with ISO/IEC 29142-2, each cartridge-characterization test compliant with the cartridge-characterization framework of this document shall specify the reporting of cartridge-characterization results in a customer report and cartridge-attribute test report cartridge characterization results.

A template shall be provided in each cartridge-characterization test which shall specify the data to be presented, data format, presentation data descriptors, and data units of measure, for the reporting of summary cartridge-characterization results. The summary cartridge-characterization results template shall be suitable for use to include the summary cartridge-characterization results in a customer report as required in ISO/IEC 29142-2 and for use to include the summary cartridge-characterization results in a cartridge-attribute test report according to the cartridge-attribute test report template of the cartridge-characterization test method standard.

A template shall be provided in each cartridge-characterization test method standard which shall specify the complete presentation of the cartridge-attribute test report of the cartridge-characterization test, in accordance with the data computation and reporting requirements of the cartridge-characterization framework of this document. The cartridge-attribute test report shall include a presentation of the summary cartridge-characterization results. The template shall include specification of data to be reported, data format, presentation data descriptors, and data units of measure, for technical cartridge-characterization results. All of the parameters specified and configurable in the procedure along with all of the test condition information data shall be included in the technical cartridge-characterization results.

Annex A
(informative)

Terms cross-reference

A.1 Terms common to inkjet and toner systems

1. Monochrome printer
2. Cartridge
3. Cartridge element
4. Cartridge collector
5. Cartridge identifier
6. Cartridge set
7. Cartridge supplier
8. Colour printer
9. Containment part
10. Deposition material
11. Filled cartridge
12. Multi-function printer (MFP)
13. Non-original cartridge
14. Original cartridge
15. Original equipment manufacturer (printer OEM)
16. Photo printer
17. Printer
18. Single function printer
19. Substrate
20. User replaceable unit

A.2 Ink cartridge and ink-related printing terms

1. Dye ink
2. Ink
3. Ink cartridge
4. Ink deposition mechanism
5. Inkjet printer

6. Integrated ink cartridge
7. Multi-chamber ink cartridge
8. Non-colourant ink
9. Pigment ink
10. Single chamber ink cartridge

A.3 Toner cartridge and toner-related printing terms

1. All in one toner cartridge
2. Developer part
3. Electrophotographic printer
4. Non-colourant toner
5. Photoreceptor part
6. Toner
7. Toner deposition mechanism
8. Toner cartridge

A.4 Environmental terms

1. End-of-life
2. Incineration
3. Landfilled
4. Life cycle
5. Material safety data sheet (MSDS) or safety data sheet (SDS)
6. Recycle
7. Recovery
8. Refill
9. Refiller
10. Remanufacture
11. Remanufacturer
12. Reuse
13. Take-back
14. Waste to energy

A.5 Test method terms

1. Binomial attribute

2. Cartridge-attribute test report
3. Cartridge-characterization test
4. Cartridge end-of-life
5. Cartridge life percent completion point
6. Continuous attribute
7. Cross-systems attribute tolerance range
8. Customer report
9. Discrete attribute
10. Expected cartridge life
11. Lifetime attribute
12. Page-attribute value
13. Performance attribute
14. Physical attribute
15. Point attribute
16. Standard error goal

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