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Imaging materials — Scratch resistance of photographic prints —

Part 2: Sclerometer test method

Matériaux pour l'image — Résistance à la rayure des épreuves photographiques —

Partie 2: Méthode d'essai au scléromètre

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Foreword

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

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

A list of all parts in the ISO 18951 series can be found on the ISO website.

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

Introduction

This method is one of a series ISO 189xx relating to permanence and durability of image prints, which is their resistance to mechanical, chemical and/or environmental stresses in conditions of use. The permanence of the image under environmental stresses is tested by each stress factor individually: light (ISO 18937[6]), heat (ISO 18936[5]), ozone (ISO 18941[7]), and humidity (ISO 18946[8]). These stress factors are given by the ambient conditions, over which the user often has limited control. The exposure to mechanical and physical stress may often be controlled by the user, unless intense handling is integral to intended use. Tests for rubbing of prints resulting in abrasion or smearing of the image are handled in ISO 18947-1[9] and ISO 18947-2[10], scratch resistance (of film) is addressed in ISO 18922[3] and durability tests to simulate accidental exposure to water are described ISO 18935[4].

Photographic prints are also susceptible to scratching when handled. This problem is particularly evident with digital prints, which may be composed of various layers and may include colorants on the surface that are not protected from physical damage. Test methods for evaluating the scratch resistance of photographic prints are another means to characterise the physical durability of photographic prints.

This document provides standardized requirements to evaluate the scratch resistance of image prints in their various formats. Scratch might occur accidentally or repeatedly by handling of the image. The following are some examples of sources of scratching:

— fingernails;

— sharp edge of metallic or mineral object (e.g. accessories such as rings);

— improper cleaning.

Test devices for scratch tests allow a wide variety of test conditions and parameters. Therefore, the test method and test conditions should be carefully determined considering the print material and its expected use.

Scratching tends to occur in a specific location at a single point of contact, as opposed to abrasion which affects larger areas of the print material.

There is no general correlation between damage to digital prints from abrasion and from scratches. For example, some inkjet prints show both abrasion and scratch damage, while other inkjet prints are damaged from scratches but not abrasion. Similarly, some digital press samples are damaged by abrasion, but not from scratches[14].

All types of digital prints may benefit from additional protection against abrasion and scratches. Polyester or polyethylene sleeves and laminates, including liquid, thermal, and pressure-sensitive materials, can provide this additional protection. Eliminating contact with adjacent surfaces, which is achieved with window-matted prints, is also effective in preventing damage from abrasion and scratches[5].

As a test method for scratching, the pencil test is well-known[2]. However, it was determined to be insufficient for photographic prints through round-robin testing in this committee because scratch resistance of photographic prints has wider variety than the scale of pencil hardness. The pencil test also proved difficult to carry out in a reproducible manner with photographic prints.

The sclerometer[13] is also used extensively in determining the scratch resistance of paints and varnishes[1][12].

Imaging materials — Scratch resistance of photographic prints —

Part 2: Sclerometer test method

1 Scope

This document specifies test parameters, test procedures, test targets, and reporting requirements for determining the scratch resistance of photographic prints using the sclerometer test method. It is applicable to photographic prints that have no protection as well as photographic prints that are protected by a coating or lamination. It is specifically useful as a low-cost, easily implemented procedure for evaluating scratch resistance of these prints.

It is not the purpose of this document to define limits of acceptability or failure. Limits would be determined by the user and the intended application.

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 18913, *Imaging materials — Permanence — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18913 and the following 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
sclerometer
handheld, pen-like instrument used to determine scratch susceptibility of a material by drawing a tungsten carbide tip across the material at a specified force

Note 1 to entry: The shape and size of the tungsten carbide tip, as well as its angle towards the surface under test, affects the severity of scratching for a given force. The force is adjusted by means of a compressed spring in the pen-like instrument.

4 Principle

4.1 General

Scratch resistance is a desirable property of prints and substrates. The degree to which it is required depends on the intended applications of the photographic print.

The scratch test for the print is applied using a stylus which moves relative to the print with a specific force. The vertical load on the stylus may cause a surface indentation. When the stylus moves along the surface, the friction induces compressive/tensile/shear stress and deformation in the print surface. It can cause deformation and damage at four different levels:

Level 0: No damage observed.

Level 1: Plastic deformation of the surface which forms a dent or line of indentation as pressure line or changes to the surface gloss without cohesive failure of the coating layers;

Level 2: Cracking, flaking, and surface delamination resulting from cohesive failures of the coating layers or buckling that is the result of internal delamination.

Level 3: Rupture with delamination, peeling and ploughing resulting from adhesive failure between the coating layers and the base material or between different coating layers.

The critical load, F_c, means the load to cause the damage assigned in each levels. Critical loads, $F_{c,1}$, $F_{c,2}$, and $F_{c,3}$, can be defined for just reaching damage levels 1, 2 and 3, respectively.

NOTE L_c is also used as a symbol of the critical load instead of F_c.

The type of damage varies widely depending on its physical properties (coefficient of friction, smoothness of the surface, total layer thickness, coating and inter-layer adhesion strength, elasticity and resistance to deformation of the image layer/substrate).

Scratch resistance greatly depends upon the hardness of the stylus material and the tip size used in the test. Styli for the sclerometer test are tungsten carbide and are typically 0,50 mm, 0,75 mm, or 1,00 mm in diameter. Three pressure springs with a range of 0 N to 3 N, 0 N to 10 N, and 0 N to 20 N or 0 N to 30 N allow a variety of forces to be applied to the surface of the material being tested.

The 0,5 mm tip proved best for evaluating the scratch resistance of a wide range of photographic prints since larger tip diameters tended to damage the surface of the photographic print without actually scratching it. For scratch sensitive materials, however, the 0,5 mm tip may not result in appropriate differentiation of scratch resistance, as scratches already occurred at lowest values of the spring force. In that case, the use of the 1,0 mm tip may be used in addition.

While not required for this test method, a fixture or trolley that holds the sclerometer at a fixed angle relative to the sample during testing can prove useful.

Visual assessment of the damage due to the scratch on the test sample compared to damage on a reference sample allows for qualitative evaluation, while measurements of the damage width at a constant load or the critical load which causes a constant damage may be suitable for quantitative evaluation. Colorimetric or densitometric measurements are generally not suitable for characterizing damage.

Additional relevant information on factors that affect the determination of scratch resistance is given in ISO 18951-1[11].

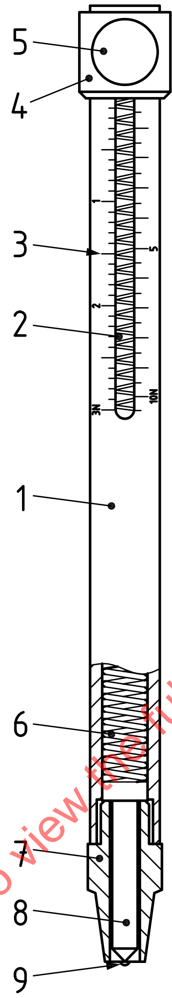
4.2 Constant load

This method can be used to compare the scratch resistance of specific products when tested using a fixed load.

5 Test device

5.1 Test device description

This sclerometer allows scratch tests on flat and curved surfaces. The instrument consists of a sleeve with a pressure spring that can be compressed to various tensions by using a slide. The spring acts on a tungsten carbide needle with its tip extending out of the sleeve. A locking screw fixes the slide, thus maintaining constant spring compression. The devices are composed of as shown in Figure 1:



Key

1 metal housing
2 slot
3 scales
4 slider
5 locking screw
6 pressure spring
7 headboard
8 ballsticks with spherical hard metal attachment
9 spherical hard metal attachment

Figure 1 — Example of sclerometer

5.2 Selection of stylus

The stylus shall be a 0,50 mm diameter spherical tungsten carbide tip. For better differentiation of scratch sensitive materials, a 1,00 mm diameter spherical tungsten carbide tip may be used in addition.

NOTE The contact area between stylus and print depends on elasticity and softness of the image layer/substrate. With the 0,50 mm diameter round stylus tip, the width of the contact area is typically much less than 0,50 mm. The situation is analogous for the 1,0 mm diameter tip.

6 Samples

6.1 General

Samples to be tested may be test targets consisting of defined regions of primary colours, secondary colours, and black or they may be pictorial or graphical prints representative of specific applications. Samples may be prints treated on either side (varnished, laminated, bonded, backed, etc.). Samples shall be of a size appropriate for the test device to be used.

When photo-images are printed on coated substrates, media direction does not generally affect the test results, and the test may be carried out without regard to substrate direction. On the other hand, for anisotropic media or printing processes samples shall be tested in two perpendicular directions.

Initial test shall be carried out in both directions and if the test results are significantly different then the test shall be carried out in two perpendicular directions for all similar samples.

6.2 Test target

Scratch resistance is highly dependent on the amount of colorant applied to the image layer. Consequently, the test target should contain at least one single colour (YMCK), at least one secondary colour (RGB), composite black, and white or D_{min}. To observe the scratch mark, solid colour patches are recommended as test prints. In addition, patches must be larger than 1 cm in the scratch direction in order to allow enough space for the scratch test. An example test target is given in Figure 2.

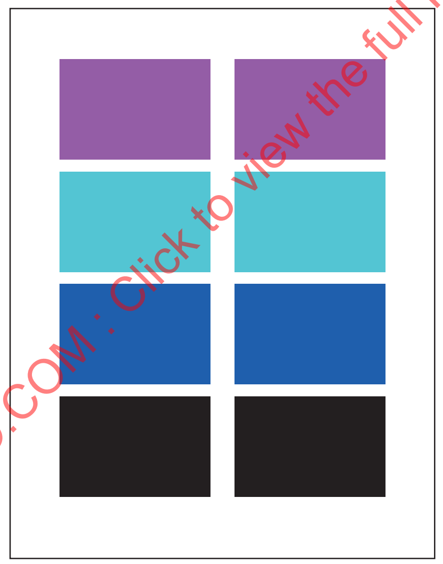


Figure 2 — Example of test target

6.3 Preparation

The method of printing and handling of the printed test samples shall be consistent with the anticipated product end use, including the presence of an image overcoat or laminate if the print will generally be supplied with an overcoat or laminate.

6.4 Conditioning

Scratch tests shall be conducted after conditioning. Prints of any type that do not require a specific extended period of curing/stabilization/dry-down shall be conditioned face-up for 24 h or longer at (23 ± 2) °C and (50 ± 10) % relative humidity. Aqueous and solvent inkjet prints and prints of any type that require curing/stabilization/dry-down shall be conditioned until the process is finished. If the duration of curing is unknown, prints should be conditioned for 14 days after printing, in an environment with a temperature of (23 ± 2) °C, with a relative humidity of (50 ± 10) % prior to scratch testing.

A shorter conditioning time may be agreed upon when the purpose of the test is to evaluate the scratch resistance at a shorter time after printing.

If tests shall be performed under different climatic conditions, specimens shall be conditioned to those conditions.

7 Test procedure

7.1 General

The following are the key parameters that shall be reported for the sclerometer being used:

— the diameter of the spherical tungsten carbide tip;

— the force applied to stylus on the specimen, expressed in newtons;

Test results strongly depend on the type of sample and the parameters of testing. There shall be prior agreement on the test parameters between parties, when comparative results are intended.

If unknown samples are to be investigated, preparatory tests with different parameter settings should be performed to identify appropriate test conditions. The process of identifying the optimum test parameters shall be documented. For example, if the appropriate load is unknown, the load shall be determined before the actual test. When the sclerometer causes no damage, the force may be increased or a stylus with a smaller tip size may be used to increase the applied stress.

7.2 Testing conditions

The test device shall be set on a sturdy bench, in a room conditioned to the desired test temperature and relative humidity. Conditions of (23 ± 2) °C and (50 ± 10) % relative humidity shall be used for testing, unless specific product end-use requires different conditions.

The scratching motion shall be applied only once for any position on the print. The following parameters shall be used considering the test device and use case of the print.

Load: 0,1 N to 30 N;

Scan speed: Approximately 10 mm/s;

Scan length: 10 mm.

The axis of the stylus should be kept at 90° (vertical) during the movement especially for the mechanical scan. If it is difficult to keep the axis at 90° (e.g. manual scan), 80° to 90° is allowed. In such case, the angle of the axis and travel direction should be kept under 90°, because the larger angle tends to cause the stylus to bounce. The tip shall be clean and free of dirt. Acetone may be used to clean the tip, if necessary.

The spring tension shall be set to zero at the end of the test procedure.

7.3 Constant load

It is recommended that a preliminary test be used to determine the appropriate tip size and the range of the load for a given usage and application.

The test specimen is placed and fixed on a horizontal plane. The scratch movement is applied with a selected stylus with a specified load. The scratch movement can be achieved by hand or by equipment which has a moving arm with a stylus on a fixed stage or fixed stylus on a moving stage. The spring selected for the sclerometer and the amount of compression on the spring determines the applied load.

A series of scratch tests, during which the constant load is increased in steps, is then suitable to determine the critical load (e.g. $F_{c,2}$).

8 Evaluation

8.1 General

Visual examination shall be done by looking directly or through a microscope[11]. Appearance, width and depth of the scratch at the same conditions can be compared directly. In addition to the visual examination, microscopic measurement of the width/depth of the scratch is also useful.

The surface of some samples has elasticity. In that case, recovery may be observed. Therefore, the timing of evaluation should be carefully determined based on the objectives of the test (e.g. scratch resistance immediately after the scratch or after delay time that is representative for a specific application).

8.2 Visual evaluation of surface deformation

With typical scratches, the following phenomena can occur:

— deformation of the surface, which forms a dent or line of indentation;

— ploughing of the substrate;

— cracking and delamination of the surface layer;

— cracking and internal delamination effects in the tracks;

— rupture with delamination at the edge.

8.3 Scratch susceptibility

A series of scratch tests, during which the constant load is increased in steps, is suitable to determine the critical load, e.g. $F_{c,2}$. At each load setting apply five scratches to the specimen. If at least three of the five samples show the target level of damage then the sample is considered not resistant to the applied force. Report the minimum force level required to cause the target level of damage as scratch susceptibility $F_{c,1}$, $F_{c,2}$, or $F_{c,3}$.

Table 1 — Relationship between scratch susceptibility and sample damage.

Scratch Susceptibility	Damage
$F_{c,1}$	Plastic deformation of the surface which forms a dent or line of indentation as pressure line or changes to the surface gloss without cohesive failure of the coating layers
$F_{c,2}$	Cracking, flaking, and surface delamination resulting from cohesive failures of the coating layers or buckling that is the result of internal delamination
$F_{c,3}$	Rupture with delamination, peeling and ploughing resulting from adhesive failure between the coating layers and the base material or between different coating layers.

For measurements between 0 N and 3 N, report all results to the nearest 0,1 N interval, for measurements between 3 N and 10 N, report results to the nearest 0,5 N interval, and for measurements between 10 N and 30 N, report results to the nearest 1 N interval.

NOTE 1 Appearance of the scratch varies depending on the printing technology and the experimental parameters. For example, when the colorant penetrates deeper, the substrate (typically white) in the bottom of the scratch is less noticeable.

NOTE 2 In order to achieve the required precision for reporting (0 N to 3 N in 0,1 N intervals, 3 N to 10 N in 0,5 N intervals, 10 N to 30 N in 1 N intervals) dedicated suitable springs are needed for each range.

