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Non-destructive testing — Penetrant and magnetic particle testing using blue light

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Essais non destructifs - Essais par ressuage et essais par magnétoscopie à la lumière bleue

Zerstörungsfreie Prüfung - Eindring- und Magnetpulverprüfung unter Anwendung von blauem Licht

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Foreword

This document (CEN/TR 16638:2014) has been prepared by Technical Committee CEN/TC 138 “Non-destructive testing”, the secretariat of which is held by AFNOR.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

1 Scope

This Technical Report specifies the requirements for penetrant and magnetic particle testing, the materials and viewing conditions when using fluorescent detection media excited by actinic blue light.

It is not intended that this “sub-method” technique is used as a substitute for the existing colour contrast and fluorescent techniques standardised in the EN ISO 3452 series and EN ISO 9934 series.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1330-7:2005, *Non-destructive testing - Terminology - Part 7: Terms used in magnetic particle testing*

CEN/TR 14748, *Non-destructive testing - Methodology for qualification of non-destructive tests*

EN ISO 3059, *Non-destructive testing - Penetrant testing and magnetic particle testing - Viewing conditions (ISO 3059)*

EN ISO 3452-1:2013, *Non-destructive testing - Penetrant testing - Part 1: General principles (ISO 3452-1:2013)*

EN ISO 3452-2:2013, *Non-destructive testing - Penetrant testing - Part 2: Testing of penetrant materials (ISO 3452-2:2013)*

EN ISO 3452-4, *Non-destructive testing - Penetrant testing - Part 4: Equipment (ISO 3452-4)*

EN ISO 9712, *Non-destructive testing - Qualification and certification of NDT personnel (ISO 9712)*

EN ISO 9934-1, *Non-destructive testing - Magnetic particle testing - Part 1: General principles (ISO 9934-1)*

EN ISO 9934-2, *Non-destructive testing - Magnetic particle testing - Part 2: Detection media (ISO 9934-2)*

EN ISO 9934-3, *Non-destructive testing - Magnetic particle testing - Part 3: Equipment (ISO 9934-3)*

EN ISO 12706:2009, *Non-destructive testing - Penetrant testing - Vocabulary (ISO 12706:2009)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12706:2009, EN 1330-7:2005 and the following apply.

3.1
actinic blue light
monochromatic blue light in a specific range which excites fluorescent penetrants and fluorescent magnetic particles used for the purpose of non-destructive testing

4 Safety precautions

Actinic blue light has the potential to rapidly cause injury to the retina. Precautions shall therefore be taken to avoid direct vision of sources and reflections.

All relevant international, regional, national and local regulations including health and safety shall be taken into account.

5 General principles

5.1 General

This sub-method of non-destructive testing comprises the use of fluorescent detection media with actinic blue light for the purpose of detecting material imperfections. It is recommended that qualification of this sub-method is carried out in accordance with CEN/TR 14748.

The actinic blue light sub-method may be suitable under specific conditions for example penetrant testing on materials that fluoresce under UV-A irradiation or for detection of defects where some ambient light is present.

Implementation of the actinic blue light sub-method for magnetic particle testing may be particularly suitable where the combination of detection media, viewing conditions and test method have been shown to provide good contrast and defect visibility.

The fluorescent response of detection media for the actinic blue light sub-method shall not be assumed to be the same as for conventional UV techniques.

To ensure adequate contrast and to eliminate actinic blue light reaching the inspectors eyes inspection shall be carried out using suitable yellow or amber filters. For general inspection this is usually in the form of contrast glasses.

WARNING — It has been shown that fluorescent detection media not developed for the actinic blue light sub-method can show different behaviour in terms of sensitivity. Therefore sensitivity levels as determined using UV shall not be used and there will be a need to demonstrate, that the sensitivity for this sub-method is appropriate to the application.

An advice is given in 5.2.3 and 5.2.4 for penetrant testing as well as in 5.3.3 for magnetic particle testing regarding tests to compare the flaw detecting capability with other methods or techniques using components containing natural defects, with known defect standards. Tests shall be qualified by an appropriate method, for example according to CEN/TR 14748.

It shall also be demonstrated that for the application the actinic blue light does not damage the detecting media or the fluorescent stability.

Tests shall be documented.

5.2 Penetrant testing: description of the sub-method

5.2.1 General requirements

Penetrant testing within this sub-method is basically carried out as described in EN ISO 3452-1 but using detection media specifically qualified for the application and actinic blue light for producing indications under the viewing conditions defined herein. It is important to carry out techniques, and implement any referenced standards, only to the extent covered by the qualification previously carried out.

5.2.2 Process sequence

The sequence of operations is generally as illustrated in EN ISO 3452-1:2013, Annex A. However, only penetrants qualified to this Technical Report shall be used.

Testing proceeds through the following stages:

a) preparation and precleaning: see EN ISO 3452-1:2013, 8.2;

b) application of penetrant: see EN ISO 3452-1:2013, 8.4;

c) excess penetrant removal and drying: see EN ISO 3452-1:2013, 8.5 except:

   1) use blue light of a minimum of 3 W/m^2 with no more than 150 lx ambient light at the surface of the part, when the blue source is off; blue fluorescent tubes or domestic architectural LEDs luminaries are convenient;

   2) for the purpose of penetrant removal the blue light shall have a peak emission from 440 nm to 450 nm and a full width at half maximum (FWHM) of not more than 50 nm;

d) application of developer: see EN ISO 3452-1:2013, 8.6;

e) inspection: see EN ISO 3452-1:2013, 8.7 except 8.7.1 and

   1) light sources shall be in accordance with 6.3;

   2) viewing equipment shall be in accordance with 6.4;

   3) viewing conditions shall be in accordance with 8.1;

   4) for recording, if a camera is used, a filter similar to that described in 6.4.1 is needed;

f) postcleaning and protection: see EN ISO 3452-1:2013, 8.8;

g) retesting: see EN ISO 3452-1:2013, 8.9.

5.2.3 Effectiveness

The effectiveness of penetrant testing depends upon many factors including:

a) the types of penetrant materials;

b) the testing equipment;

c) surface preparation, condition and temperature;

d) the material under examination

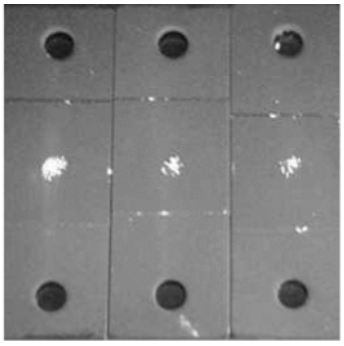
e) expected discontinuities;

f) penetration and development time;

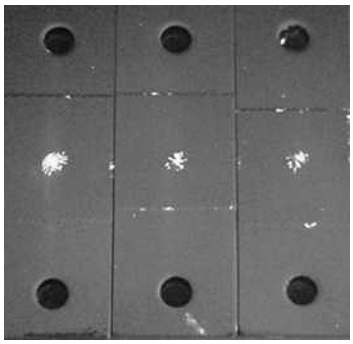
g) viewing conditions.

A substantiation test shall be carried out to demonstrate that the correct parameters are used.

Effectiveness can be best demonstrated using known defect standards containing defects or artificial defects of various sizes (e.g. EN ISO 3452-3, type 2) comparing the results obtained using the conventional UV method with the results of this blue light sub-method (see Figure 1). Other test panels (e.g. EN ISO 3452-3, type 1) may be adequate for use, but may provide less information.



a) UV-A



b) actinic blue light

Figure 1 — UV-A vs. actinic blue light showing acceptable results

5.2.4 Sensitivity

Sensitivity levels shall be specifically defined for this sub-method. Sensitivity levels defined using UV-A light in EN ISO 3452-2 do not apply.

The fluorescence of the detection media will have an effect on sensitivity. The fluorescent coefficient can be measured in cd/W and, if appropriate, compared with the fluorescent coefficient using UV radiation to obtain a fluorescent factor. This is of particular relevance when considering viewing conditions (see Clause 8).

Known defect standards containing defects or artificial defects of various sizes (e.g. EN ISO 3452-3, type 2) can be used to monitor the relative sensitivity of different penetrants and to compare the behaviour of a penetrant when using UV-A and actinic blue light.

The contrast ratio will have an effect on sensitivity and shall be considered.

5.3 Magnetic particle testing

5.3.1 General requirement

Magnetic particle testing within this sub-method is basically carried out as described in EN ISO 9934-1 but using detection media specifically qualified for the application and actinic blue light for producing indications

under the viewing conditions defined herein. It is important to carry out techniques, and implement any referenced standards, only to the extent covered by the qualification previously carried out.

5.3.2 Process sequence

The sequence of operations is generally as in EN ISO 9934-1. However, only detection media qualified to this Technical Report shall be used.

Testing proceeds through the following stages:

a) preparation and precleaning: see EN ISO 9934-1;

b) magnetising and applying detection media, see EN ISO 9934-1;

c) inspection:

   1) light sources shall be in accordance with 6.3;

   2) viewing equipment shall be in accordance with 6.4;

   3) viewing conditions shall be in accordance with 8.1;

   4) for recording, if a camera is used, a filter similar to that described in 6.4.1 is needed.

d) demagnetisation, post cleaning and protection: see EN ISO 9934-1.

5.3.3 Effectiveness

Before testing begins, an overall performance test is recommended to reveal discrepancies in either the procedure, the magnetisation technique or the detection media.

The most reliable test is to inspect a representative part containing natural or artificial discontinuities of a known type, location, size and size distribution. Test parts shall be demagnetised and free from indications resulting from previous tests.

In the absence of actual production parts with known discontinuities, fabricated test pieces with artificial discontinuities, e.g. flux shunting indicators of the cross- or shim-type may be used.

5.3.4 Detection media

Fluorescent magnetic detection media shall be used with actinic blue light, because they fluoresce generally green, yellow orange or red. Colour contrast detection media shall not be used.

The detection media shall be in accordance with 7.3.

6 Equipment

6.1 Magnetic particle testing equipment

Equipment shall be in accordance with EN ISO 9934-3 except for the equipment mentioned in 6.3 to 6.5.

6.2 Penetrant testing equipment

Equipment shall be in accordance with EN ISO 3452-4 except for the equipment mentioned in 6.3 to 6.5.

6.3 Actinic blue light sources

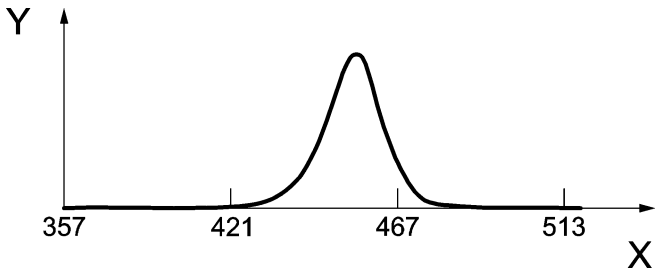
The actinic blue light shall meet the following requirements:

a) peak wavelength: (440 ± 5) nm;

b) full width at half maximum 30 nm;

c) the output at less than or equal to 400 nm and greater than or equal to 480 nm shall be less than 1 % of the maximum output.

An example of a suitable spectral output distribution is given in Figure 2.



Key
Y – relative output
X - wavelength

Figure 2 — Example of a suitable spectral output distribution

6.4 Viewing equipment

6.4.1 General

For inspection or recording purposes filters shall be used to remove actinic blue light used for excitation and shall not significantly impair the visibility of indications.

6.4.2 Yellow filters

Yellow filters as defined below may be used with any qualified detection media:

a) cut-off wavelength: the transmission at less than or equal to 480_{0}^{+5} nm shall be less than 1 %;

b) transmission at 550 nm and above shall be a minimum of 70 %; this can be checked with a monochromatic green source and an illuminance meter.

6.4.3 Amber filters

Amber filters as defined below may be used only with orange/red fluorescent PT and MT products. They are not suitable for green/yellow fluorescent PT and MT products. Amber filters can give better result in terms of contrast with orange/red products especially when used in daylight.

a) cut-off wavelength: the transmission at less than or equal to 480_{0}^{+5} nm shall be less than 1 %;

b) transmission at 600 nm and above shall be a minimum of 70 %.

6.5 Measurement equipment

Actinic blue light shall be measured using a radiometer with a spectral response as defined below:

a) the relative spectral response shall not exceed 105 % for any wavelength;

b) the peak relative spectral response shall occur between 430 nm and 450 nm;

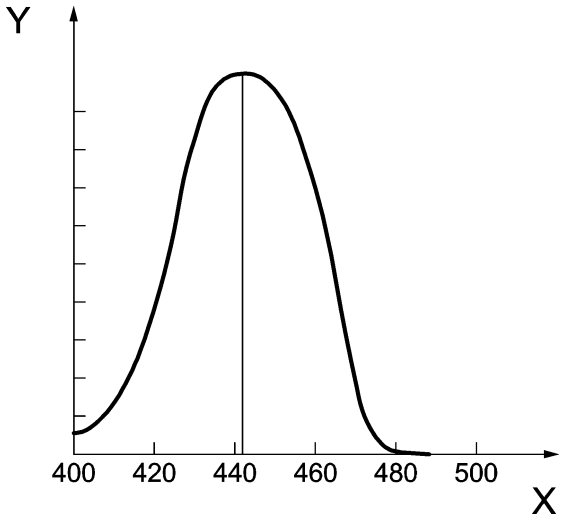
c) the relative spectral response at a wavelength of 395 nm shall be less than 10 %;

d) the relative spectral response at a wavelength of 485 nm shall be less than 2 %.

The relative spectral response is the ratio of the response of the sensor to radiation of a given wavelength to the response at 440 nm.

Cosine factor shall be better than 0,8.

An example of a suitable spectral output distribution is given in Figure 3.



Key
Y – relative response
X - wavelength

Figure 3 — Example of a suitable spectral response

7 Test products

7.1 General

Suppliers of detection media qualified for this sub-method shall provide certification which includes the fluorescence coefficients and the fluorescent factor.

7.2 Penetrant testing

7.2.1 General

Penetrants materials shall be tested according to EN ISO 3452-2, type I products except:

a) there are no sensitivity classes (EN ISO 3452-2:2013, 6.2 does not apply);

b) the fluorescent brightness test is replaced by determining the fluorescent coefficients (see 7.2.2);

c) actinic blue light stability replaces UV-A stability (see 7.2.3);

d) the thermal stability test is performed using actinic blue light instead of UV-A (see 7.2.4).

7.2.2 Fluorescent coefficients

The fluorescent coefficients for actinic blue light and UV-A shall be determined in accordance with Annex A.

7.2.3 Actinic blue light stability

Prepare 10 filter paper specimens using the candidate penetrant and method in accordance with Annex A. Protect five from heat, light and air currents, while exposing the other 5 specimens to actinic blue light irradiation for 1 h while protecting them from heat and air currents. The fluorescent coefficient of each specimen is determined using the method given in Annex A.

The average fluorescent coefficient of the actinic blue light irradiated specimens shall be greater than 70 % of the non-irradiated specimens.

7.2.4 Thermal stability

Prepare 10 filter paper specimens using the candidate penetrant and method in accordance with Annex A. Protect five from heat, light and air currents, while placing the other 5 specimens on a clean metal plate in a dead air oven at (115 ± 2) °C for 1 h. The fluorescent coefficient of each specimen is determined using the method given in Annex A.

The average fluorescent factor of the actinic blue light irradiated specimens shall be greater than 70 % of the non-irradiated specimens.

7.3 Magnetic particle testing

Detection media which has been tested in accordance with EN ISO 9934-2 shall be further qualified before use by carrying out the following additional tests using actinic blue light:

a) every test in EN ISO 9934-2 which requires the use of UV-A radiation shall be repeated using actinic blue light, e.g. fluorescent coefficient, fluorescence stability.

b) the fluorescent coefficient for actinic blue light shall be determined by the method in EN ISO 9934-2, using actinic blue light.

8 Viewing conditions

8.1 General

The actinic blue light irradiance shall be greater than 15 W/m^2 on the test surface.

A measurement to verify this shall be carried out when the output from the source has stabilized.

Detection media with a high fluorescent factor will produce discernible indications with higher levels of visible ambient light than materials with a low fluorescent factor. It is recommended that in all cases the following are used as maximum permitted levels of visible ambient light:

a) when using yellow filters maximum 100 lx;

b) when using amber filters maximum 200 lx.

However the user shall ensure the lighting conditions are suitable for the material used.

Measurement of the ambient light shall be performed without the actinic blue light. It is important that the response of the illuminance meter is similar to the photopic response of the human eye.

NOTE CIE 69 provides further information on evaluation of light meters.

With the exception of filter glasses that meet the requirements of 6.4.2 and 6.4.3, permanently tinted spectacles or those which darken under inspection conditions shall not be worn.

Filter glasses or a contrast shield which meet the requirements of 6.4.2 and 6.4.3 shall be used for inspection.

The combination of high level and long duration of actinic blue light irradiance should be avoided (generally not more than 50 W/m^2).

8.2 Visual acuity

The visual acuity of NDT personnel shall be adequate for the NDT task carried out and shall meet the requirements of EN ISO 9712.

8.3 Viewing conditions

8.3.1 General

While the requirements herein shall be met it is important to provide the best viewing conditions in order to obtain the best results. Visual operator comfort will allow longer periods of reliable inspection.

In addition to quantitative requirements, due account shall be taken of the following qualitative issues including illuminance and glare.

8.3.2 Shielding against glare

Glare, which may arise from extraneous sources or reflection can impede inspection and shall be avoided. Special care is needed to avoid glare when the direction of view is above horizontal.

Shielding can be used, for example blinds at windows or shades over lamps, to eliminate glare.

8.3.3 Illuminance on the immediate surrounding area

The ambient illumination incident on the inspection surface and the adjacent, surrounding area shall be controlled such that there is even illumination of the test surface and gradual change at the edges.

Large spatial variations in illuminances around the task area can lead to visual stress and discomfort.

9 Verification and calibration of instruments

The verification and calibration procedures for instruments shall be carried out so that during the calibration interval the measuring error remains within limits given in this document. This shall be done, following the recommendations of the manufacturer of the instrument and in accordance with the quality assurance system of the user.

The working range of irradiation, luminance and illuminance meters shall be calibrated at the frequency recommended by the manufacturer using equipment and a system which is traceable to a national, European or International Standard. This period shall not exceed 12 months.

10 Qualification records

The information used to substantiate the inspection technique shall be documented and available for review as required. This shall include work carried out to establish sensitivity, effectiveness, media suitability and viewing conditions in accordance with 5.2.3, 5.2.4, 5.3.3, 7.3 and Clause 8.

11 Test report

A test report shall be prepared in accordance with EN ISO 9934-1 for magnetic particle testing and EN ISO 3452-1 for penetrant testing.

Annex A
(normative)

Measurement of fluorescent coefficient

A.1 Apparatus

A.1.1 **Glassware**: pipettes and measuring cylinders (volumetric flasks) suitable for accurately preparing 4,0 % solutions; 50 ml beakers.

A.1.2 **Suitable, absorbent, non-fluorescent filter paper**, for example Whatman (R) No. 41): diameter 4 cm.

A.1.3 **Filter paper drying stand**, with “crocodile” clips or similar to hold paper specimens vertically.

A.1.4 **Desiccator**, suitable for holding the filter paper (A.1.3).

A.1.5 **Suitable desiccant**, e.g. silica gel for use in the desiccator (A.1.4).

A.1.6 **Solvent**, fast-drying, 100 % volatile, non-fluorescent, and fully miscible with the penetrant under test.

A.2 Preparation of filter paper specimens, penetrant material test

A.2.1 Accurately prepare separate 4,0 % (volume fraction) solutions of test and standard penetrants in an appropriate solvent.

A.2.2 Pour each solution into a separate glass beaker, then, into each beaker, place, one at a time, five filter paper specimens for 5 s each.

A.2.3 Allow each paper specimen to dry (approximately 5 min) by suspending them vertically in the “crocodile” clips or similar in the desiccator.

A.3 Method

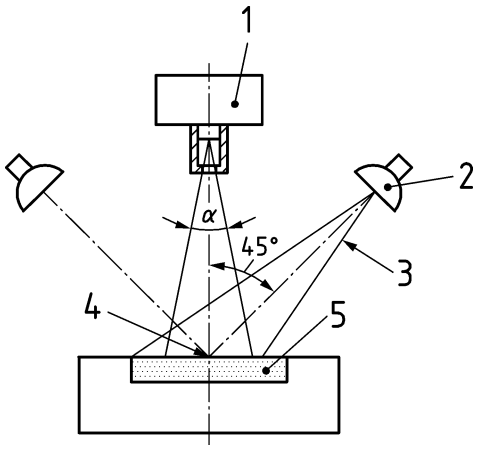
The arrangement of the apparatus used is shown in Figure A.1.

The test specimen shall be evenly illuminated at an angle of (45 ± 5)° using a minimum of 10 W/m^2. The stability of the sources shall be such that the results shall not be compromised (better than 3 % is recommended).

For UV-A irradiation the source and the radiometer used for measurement shall be in accordance with EN ISO 3059.

For actinic blue light the value shall be measured using a radiometer in accordance with 6.5.

A calibrated luminance meter shall be used to make measurements of test samples. When actinic blue light is used a filter as described in 6.4.2 shall be positioned in front of the sensor. It is important to only measure the luminance of the test specimen caused by the actinic blue light or UV-A irradiation. The linearity of the luminance meter shall be appropriate to the task and better than 5 % is recommended.



Key

1 measurement of luminance
2 irradiation source
3 actinic blue light or UV-A radiation
4 measurement point of the irradiance
5 paper specimen

Figure A.1 — Determination of the fluorescent coefficient for materials

NOTE A recommended arrangement is using a luminance meter with a 2 000 cd/m^2 range and a viewing angle (Alpha) of 20° placed 80 mm above the plane sample surface, diameter 40 mm. Irradiation sources are placed so as to give an even irradiance at the paper specimen.

A.4 Calculation

The fluorescence coefficient in cd/W is the ratio of the luminance of the test sample (in cd/m^2) to the excitation irradiation (in W/m^2). The fluorescent factor is determined as a result of comparing the fluorescent coefficient using actinic blue light with that obtained when using UV-A irradiation.

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[3] EN ISO 3452-6, *Non-destructive testing - Penetrant testing - Part 6: Penetrant testing at temperatures lower than 10 degrees C (ISO 3452-6)*

[4] CIE 69, *Methods of characterizing illuminance meters and luminance meters: Performance, characteristics and specifications*

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