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Paints and varnishes — Coating systems for wind-turbine rotor blades —

Part 5: Measurement of transmittance properties of UV protective coatings

Matériaux de revêtement pour pales de turbines éoliennes —

Partie 5: Mesurage des propriétés du facteur de transmission des revêtements de protection anti UV

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes,* Subcommittee SC 9, *General test methods for paints and varnishes*.

A list of all parts in the ISO/TS 19392 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.

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Introduction

In the wind energy industry, coatings are applied to rotor blades surface to protect the glass fibre reinforced polymer composite substrate from environmental stresses. Rain drops and hailstones can damage these coatings in such a way that individual layers come off or the whole coating delaminates from the substrate. This applies mostly to the leading edge. Glass fibre reinforced polymer composites and other blade materials can be also sensitive to UV degradation and thus can be damaged during outdoor operation, if not protected accurately against irradiation by solar radiation. Failure of protection can lead to delamination and a subsequent failure of the full blade.

An important function of the rotor blade coating is therefore to protect the blade material from UV radiation. This applies to the leading edge, but also to the other surface areas of the blade.

The damage by solar radiation is mainly induced by the most energetic ultraviolet (UV) radiation, but also visible (VIS) radiation (e.g. violet or blue radiation) is still energetic enough to have a negative input on the appearance and durability of the blade.

Pigments and organic or inorganic UV absorbers can be used to reduce the coating film transmittance against UV (and visible) radiation and cause a positive effect on lifetime and functional aspects of the blade material. Pigments and UV absorbers can affect the transmittance in the visible range. This may lead to colour change of the coated blade.

This document, as part of the ISO/TS 19392 series on rotor blade coatings, describes a method to measure the spectral transmittance or the transmittance in a specific wavelength range. This allows evaluating the UV and VIS radiation protection quality of a coatings film on the sensitive blade substrate below. The focus is to avoid damage of the blade by natural solar radiation especially caused by the most energetic part, the ultraviolet and short wavelength visible radiation.

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Paints and varnishes — Coating systems for wind-turbine rotor blades —

Part 5: Measurement of transmittance properties of UV protective coatings

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1 Scope

This document specifies a test method to measure the ultraviolet (UV) and visible (VIS) spectral transmittance in the wavelength range from 280 nm to 700 nm of coatings for wind turbine rotor blades. Single and multilayer coatings or coating systems can be tested.

From the spectral transmittance the transmittance of UV, VIS and the combined UV and VIS wavelength range can be calculated.

It is applicable to free coatings films or coatings applied on a UV-transparent quartz substrate.

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.

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 3270, *Paints and varnishes and their raw materials — Temperatures and humidities for conditioning and testing*

ISO 4618, *Paints and varnishes — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 and the following apply.

ISO and IEC maintain terminology 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
transmittance
τ

quotient of transmitted radiant flux, Φ_t, and incident radiant flux, Φ_m, $\tau = \frac{\Phi_t}{\Phi_m}$

Note 1 to entry: Transmittance is also defined spectrally in terms of wavelength, in which case, “spectral” is added before the quantity name.

Note 2 to entry: Due to energy conservation, $\alpha + \rho + \tau = 1$ except when polarized radiation is observed, where α is absorptance and ρ is reflectance.

Note 3 to entry: Transmittance, τ, is the sum of regular transmittance, τ_r, and diffuse transmittance, τ_d: $\tau = \tau_r + \tau_d$.

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Note 4 to entry: The transmittance has unit one.

[SOURCE: CIE S 017:2020; 17-24-065]

3.2
ultraviolet radiation
UV
radiation in a wavelength range from 280 nm to 400 nm

3.3
visible radiation
VIS
radiation in a wavelength range from 400 nm to 700 nm

4 Principle

The UV and VIS transmittance through a coating film is measured using an UV/VIS spectrophotometer equipped with a radiation source, a limiting aperture, an integrating sphere, and a spectroradiometer with a diffraction element and a detector. See Annex B for application and evaluation references.

A beam of optical radiation, limited by an aperture, with an incident radiant flux, Φ_m, is directed on a film specimen. The transmitted radiant flux, Φ_t, enters an integrating sphere. The sphere is equipped with the input optics of a spectroradiometer with which spectrally resolved measurements of the unfiltered radiant flux $\Phi_m(\lambda)$ and the filtered (transmitted) radiant flux $\Phi_t(\lambda)$ can be performed. The quotient $\Phi_t(\lambda)/\Phi_m(\lambda)$ is the spectral transmittance $\tau(\lambda)$.

NOTE $\tau(\lambda)$ multiplied by 100 represents the percentage of the transmitted radiant flux at a specific wavelength or wavelength range passing through the film compared to the incident radiant flux $\Phi_m(\lambda)$.

From the spectral transmittance, the transmittance in a specific wavelength range can be calculated as described in 6.4.

The spectral transmittance is recorded in wavelength increments over the entire wavelength range of 280 nm to 700 nm continuously during a wavelength scanning (e.g. in 2 nm to 10 nm steps depending on the apparatus used and the resolution needed). Depending on the application the transmittance of the specific wavelength ranges for UV, VIS and UV + VIS can be calculated.

5 Apparatus and materials

5.1 Film applicator for coating material

A suitable blade or spatula to apply coatings films of defined wet layer thickness shall be used.

NOTE A typical dry layer thickness is approx. 90 µm to 120 µm.

5.2 Substrate for free coating film preparation

5.2.1 Preparation of free film and test specimen

A clean and plane substrate shall be used to apply the wet coating materials to prepare the free coating films of correct uniform layer thickness. For a substrate to separate the coating film without damage, it is ideal to use a polytetrafluoroethylene (PTFE) coated smooth metal plate or a PE-, PP-foil or silicone paper fixated on a smooth glass or metal plate, for example. In case of lower viscosity coatings, silicone rubber rings can be used after balancing them horizontally, on a glass plate to fill in the liquid coating material for example. The coating material shall be sufficiently dry. This normally requires drying for a

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minimum of 7 days or better, 28 days at (23 ± 2) °C at (50 ± 10) % relative humidity in accordance with ISO 3270 or as per the coating supplier's specification.

NOTE Soaking in water is another suitable method for the detachment of free films from a substrate. However, this method of preparation of free films can influence the test results. The usual method for preparation of free films is without using water on a low energy substrate such as polypropylene. Alternatively, the coatings can be measured directly on a UV-transparent substrate like quartz.

For each coating, a minimum of three specimens shall be cut out from a uniform section of the film without any damages. The size of the specimens shall be adjusted to the specific spectrophotometer under use.

5.2.2 Coating application

The coating shall be applied on a 1 mm to 2 mm thick quartz substrate with a spectral transmittance of at least 90 % in the wavelength range from 280 nm to 700 nm.

5.3 Film thickness measurement

The film thickness shall be measured in accordance with ISO 2808.

5.4 UV/VIS spectrophotometer

The following are the minimum requirements for the UV/VIS spectrophotometer:

a) wavelength range: 280 nm to 700 nm;

b) Radiation source: alternatively or both:

   1) Deuterium,

   2) 1 000 W quartz halogen lamp [FEL] lamp (see Reference [5]);

c) Limiting aperture: defines the radiation beam so that all radiation enters the integrating sphere;

d) Integrating sphere: to guarantee that all transmitted radiation is measured, including:

   1) cosine response. The normalized response matches the ideal cosine function to within 6 % of the cosine value up to incident angles of 60° and to within 8 % up to 80°,

   2) minimum sphere diameter 50 mm (see NOTE 4);

   3) maximum size of the input aperture: 20 % of the sphere diameter;

   4) barium sulfate or PTFE coated;

e) Spectroradiometer: to measure the spectral irradiance:

   1) stray light suppression: dynamic range 3 decades (see NOTE 1),

   2) dark current correction: shall be performed appropriate (see NOTE 2),

   3) higher order correction: shall be performed appropriate (see NOTE 3),

   4) facility for wavelength calibration,

   5) wavelength resolution 2 nm,

   6) measuring increments at least 2 nm,

   7) detector sensitive in the wavelength range from 280 nm to 700 nm;

f) software to calculate the spectral transmittance.

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NOTE 1 Stray light level is the ratio of a measured signal in the blocking range of an absorption filter to the maximum desired signal. Stray light results from a wavelength range which is not part of the measured wavelength range and depends on the used radiation source and the geometry of the spectrophotometer. Stray light influences the dynamic range of the spectrophotometer.

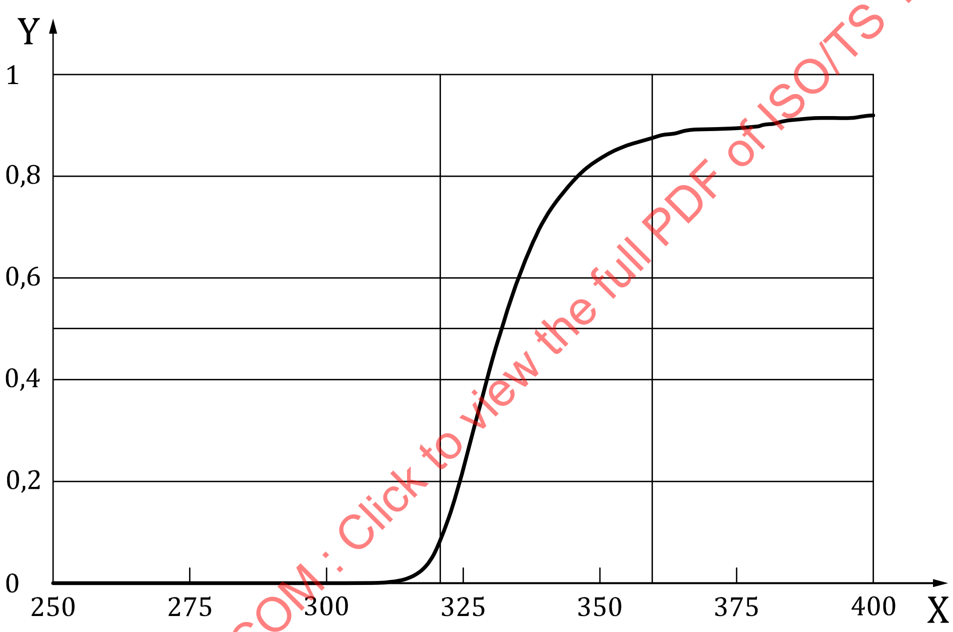
NOTE 2 Dark current is connected to the noise of the electronic amplifier (signal-to-noise ratio).

NOTE 3 State of the art spectrophotometers provide high order correction automatically with appropriate filters.

NOTE 4 The diameter of the integrating sphere can have an influence on the measurement. A larger diameter can lead to more accurate results, but the limiting factor is the amount of signal that the detector is capable of measuring.

5.5 Long pass specification for check

The long pass filter shall have a transmittance lower than 10^{-4} in the absorption range. The 0,5 transmittance shall be in the range from 320 nm to 360 nm. See Figure 1 for an example.



Key

X wavelength, in nanometres

Y spectral transmittance

Figure 1 — Example of a spectral transmittance of an absorption filter

The filter can be used to check the performance of a UV/VIS spectrophotometer.

6 Test procedure

6.1 Test procedure with spectrophotometer

6.1.1 Measure the spectral irradiance with the spectrophotometer without any filter or films. Dark current measurement and higher order correction shall be provided, if appropriate.

NOTE Information about dark current measurement and higher order correction are provided by the instrument manufacturer.

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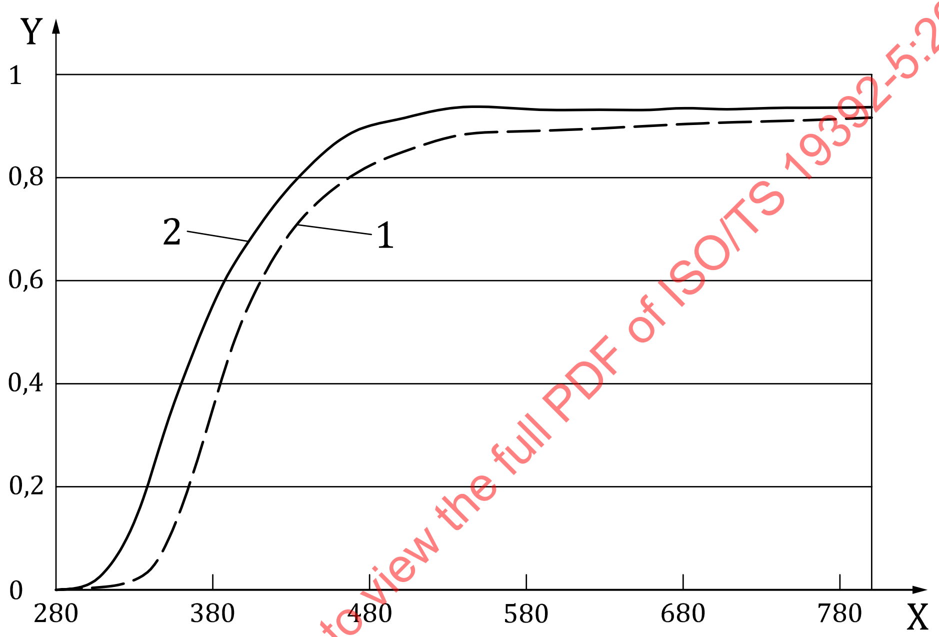
6.1.2 Put and mount the prepared specimen as close as possible to the entrance port of the integrating sphere to ensure that also all the scattered radiation enters the sphere.

NOTE The operative instructions and size of the needed specimens depend on the type of spectrophotometer used.

6.1.3 Measure the transmitted spectral irradiance with the spectrophotometer with the specimen. Dark current measurement and higher order correction shall be provided, if appropriate.

6.1.4 Record the spectral transmittance (maximum step size 10 nm) in the wavelength range from 280 nm to 700 nm (example see Figure 2).



Key

X wavelength, in nanometres

Y spectral transmittance

1 coating 1 (= less UV-VIS permeable)

2 coating 2 (= more UV-VIS permeable)

Figure 2 — Measured spectral transmittance of two coatings (coating examples 1 and 2)

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6.2 Check of spectrophotometer with long pass filter

Check the measured spectral transmittance of the long pass filter with the default transmittance and file the data. For the check use the following wavelength ranges: 280 nm to 300 nm, 300 nm to 320 nm, 320 nm to 340 nm, 340 nm to 360 nm, 360 nm to 380 nm, 380 nm to 400 nm. In all wavelength ranges the deviation shall be smaller than 5 %. The calculation instruction is given in Annex A.

NOTE 1 The default spectral transmittance can be measured by an appropriate optical laboratory or is provided by the supplier of the filter.

If the spectral transmittance measurement of the long pass filter shows an increasing transmittance in the blocking area, the dark current and noise measurement of the UV/VIS spectrophotometer shall be checked.

NOTE 2 Stray light can also be the cause of the effect. In this case the effect cannot be removed.

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6.3 Spectral transmittance of the specimen (film)

Repeat the test procedure described in 6.2 with the specimen.

6.4 Calculation of transmittance

The transmittance shall be calculated in accordance with Formula (1):

$$\tau_{XY} = \frac{\int_X^Y \Phi_t(\lambda) \cdot d\lambda}{\int_X^Y \Phi_m(\lambda) \cdot d\lambda} \quad (1)$$

where

τ_{XY} is the transmittance in the wavelength range from X to Y;

X is the wavelength where the integration starts;

Y is the wavelength where the integration stops.

τ_{XY} shall be calculated in the following wavelength ranges: UV + VIS: 280 nm to 700 nm, UV: 280 nm to 400 nm and VIS: 400 nm to 700 nm.

7 Precision

There are currently no general data on precision.

8 Test report

The test report shall contain at least the following information:

a) a reference to this document, i.e. ISO/TS 19392-5:2023;

b) the name and address of the testing laboratory and testing person;

c) the identification number of the test report;

d) the spectrophotometer:

   1) type of spectrophotometer,

   2) diameter of integrating sphere,

   3) coating material of integrating-sphere,

   4) spectral wavelength range, bandwidth and wavelength interval,

   5) the result of the check of the spectrophotometer with long pass filter;

e) the name and/or designation of the coating material;

f) any specific method to prepare the free coating films and dry layer thickness of the film specimens prepared;

g) a plot of the spectral transmittance from 280 nm to 700 nm and a table with the transmittance result at each measurement point at a dedicated wave length;

h) the transmittance values for each specimen calculated with Formula (1) in 6.4:

   1) transmittance in the UV-range (280 to 400 nm),

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   2) transmittance in the VIS-range (400 to 700 nm),

   3) total transmittance in the UV and VIS-range (280 to 700 nm);

i) if available sources of error and total measurement uncertainty (measurement conditions, the standard reference, the parameters of calibration curve, variation of test specimen thickness, etc.);

j) any deviation from the test method specified;

k) any unusual features (anomalies) observed during the test.

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Annex A
(normative)

Check of the spectral transmittance of the long pass filter

The long pass filter shall be checked before each spectral transmittance measurement campaign. The result of a measurement is a spectral transmittance of a long pass edge filter. The deviation of the measured spectral transmittance to the reference transmittance shall be calculated in accordance with Formula (A.1):

$$f_{XY} = \frac{\int_X^Y \left|\tau_{ref}(\lambda) - \tau_{fil}(\lambda)\right| \cdot d\lambda}{\int_X^Y \tau_{ref}(\lambda) \cdot d\lambda \cdot 100} \tag{A.1}$$

where

X is the start wavelength, in nanometres;

Y is the end wavelength, in nanometres;

$\tau_{ref(\lambda)}$ is the reference spectral transmittance of the long pass filter;

$\tau_{fil(\lambda)}$ is the measured spectral transmittance of the long pass filter.

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