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Optics and photonics — Optical coatings —

Part 3: Environmental durability

Optique et photonique — Traitements optiques —

Partie 3: Durabilité environnementale

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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 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).

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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.

This document was prepared by Technical Committee *[or Project Committee]* ISO/TC 172, *Optics and photonics*, Subcommittee SC 3, *Optical materials and components*.

This third edition cancels and replaces the second edition (ISO 9211-3:2008), which has been technically revised.

The main changes are as follows:

— Included ISO 9211-2 in bibliography.

— Add new section that explains the test code notation to use when specifying a coating environmental durability test.

— Remove previous Annex A and move test sequence tables for standard categories into relevant sections.

— Update notation for standard test sequence tables to include conditioning method and degree of severity test code notation.

— Clarify that category O is for non-standard test sequences that are also similar to other standard categories of use.

— Add new section for a general use case when specifying coating environmental durability tests and the sequence they follow. This is used for test sequences that are not similar to any of the standard categories of use.

— Add statement that if specifying a temperature requirement for a coating, this notation is described in ISO 9211-2.

— Add new Annex A that includes the previously shown Table 1.

— Update previous Table 1 to include conditioning method and degrees of severity test code notation.

— Add new relevant degrees of severity from ISO 9022-2/Amd.1 and ISO 9022-4/Amd.1.

— Add conditioning methods and degrees of severity shown in ISO 9211-5 to ISO 9211-8 not listed previously.

— Clarify descriptions in previous Table 1 to match what is listed in the conditioning method table for each test.

— Separate solvent solubility line in previous Tables A.2, A.3 and A.4 to two lines, separating acetone and ethanol.

— Add new Annex B explaining how to use category 0.

A list of all parts in the ISO 9211 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.

Optics and photonics — Optical coatings —

Part 3: Environmental durability

1 Scope

ISO 9211 (series) describes surface treatments of components and substrates excluding ophthalmic optics (spectacles) by the application of optical coatings and gives a standard form for their specification. It defines the general characteristics and the test and measurement methods whenever necessary, but it is not intended to define the process method.

This document specifies general use and standard categories of use for optical coatings and identifies which environmental tests are necessary to prove that the coatings meet the required specification. The mechanical and chemical properties of coated optical elements, and more generally their environmental durability, can be assessed by a variety of methods. The test methods are generally described in various parts of ISO 9022 and in ISO 9211-4. These test methods are selected to give meaningful results representative of actual exposure of optical elements in their operating environment, alternatively to the minimum requirements as described in ISO 9211-5 to ISO 9211-8, which are coating type related.

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 9022-1, *Optics and photonics — Environmental test methods — Part 1: Definitions, extent of testing*

ISO 9022-2, *Optics and photonics — Environmental test methods — Part 2: Cold, heat and humidity*

ISO 9022-4, *Optics and photonics — Environmental test methods — Part 4: Salt mist*

ISO 9022-6, *Optics and photonics — Environmental test methods — Part 6: Dust*

ISO 9022-9, *Optics and photonics — Environmental test methods — Part 9: Solar radiation and weathering*

ISO 9022-11, *Optics and photonics — Environmental test methods — Part 11: Mould growth*

ISO 9022-12, *Optics and photonics — Environmental test methods — Part 12: Contamination*

ISO 9022-14, *Optics and photonics — Environmental test methods — Part 14: Dew, hoarfrost, ice*

ISO 9211-4, *Optics and optical instruments — Optical coatings — Part 4: Specific test methods: abrasion, adhesion and resistance to water*

3 Terms and definitions

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

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

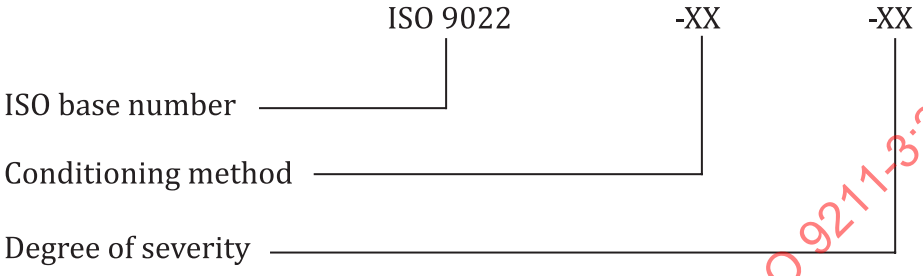
— ISO Online browsing platform: available at https://www.iso.org/obp

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

4 General information for use

4.1 Environmental test code

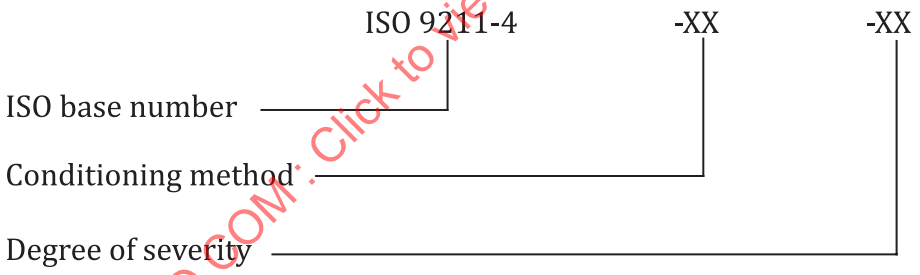
The coating environmental durability tests should be listed according the environmental test code notation. In the case that the ISO base number is the ISO 9022 series, the part of ISO 9022 shall not to be listed, as per the notation in ISO 9022-1, as shown in Figure 1. Only the conditioning method and degree of severity shall be listed following the ISO 9022 base number for the test code.



NOTE The test code notation from ISO 9022-1 is slightly different in that this description does not include the statement "Environmental test". The environmental test name should be included as a descriptor to the environmental test code to avoid confusion, but is not directly a part of the environmental test code.

Figure 1 — Code for environmental tests

If the environmental durability test is one specified from ISO 9211-4, the ISO base number shall be listed as 9211-4, as shown in Figure 2. This notation still includes the conditioning method and degree of severity.



NOTE The test code notation from ISO 9211-4 is slightly different in that this description does not include the statement "Coating environmental durability test". The coating environmental durability test name should be included as a descriptor to the environmental test code to avoid confusion, but is not directly a part of the environmental test code.

Figure 2 — Code for coating environmental durability tests

4.2 Standard categories of use

4.2.1 General

Four standard categories of use and one non-standard category of use are defined. The four standard categories of use represent different environmental conditions that a component may experience. Each category requires either different environmental tests and/or different degrees of severity. These categories are listed below in order of severity of requirement. These categories are a summary of use cases and are not exhaustive of all instances.

A complete description of environmental durability tests, necessary for all standard categories of use, shall be implemented as provided in Annex A.

4.2.2 Category A

This category refers to components in applications which would normally only apply when they are to be mounted internally within sealed units. In this category, handling is in a protected and controlled environment and should only take place with extreme care. Physical contact with the optically coated surface is discouraged. See Table 1 for complete test sequence.

Table 1 — Default test sequence for Category of use A (one test sample is used)

Test step	Test code	Test	Description	Sample 1
1	ISO 9022-10-05	Cold	Expose to a temperature of −25 °C ± 3 °C for 16 h	x
2	ISO 9022-11-03	Dry heat	Expose to an atmosphere of 55 °C ± 2 °C (below 40 % relative humidity) for 16 h	x

4.2.3 Category B

This category refers to applications where components will be exposed only to a controlled environment. Such applications may involve mild abrasion such as occurs with carefully controlled cleaning. See Table 2 for complete test sequence.

Table 2 — Default test sequence for Category of use B (two test samples are used)

Test step	Test code	Test	Description	Sample 1	Sample 2
1	ISO 9211-4-02-01	Adhesion: tape test	Slow tape removal	x	x
2	ISO 9211-4-01-01	Abrasion: cheesecloth/ eraser test	50 strokes cheesecloth	x	
3	ISO 9022-10-07	Cold	Expose to a temperature of −35 °C ± 3 °C for 16 h		x
4	ISO 9022-11-05	Dry heat	Expose to an atmosphere of 70 °C ± 2 °C (below 40 % relative humidity) for 6 h		x
5	ISO 9022-12-06	Damp heat	Expose to climatic conditions of 90 % to 95 % relative humidity and 55 °C ± 2 °C for 6 h		x
6	ISO 9022-14-02	Slow temperature change	−25 °C ± 3 °C to +55 °C ± 2 °C Number of cycles: 5 Dwell time: wait until sample has reached a temperature within at least 3 K of the test chamber temperature but not less than 2,5 h Test chamber temperature change rate: between 0,2 K/min and 2 K/min		x
7	ISO 9022-87-01	Laboratory agent: Acetone (CH_3COCH_3)	5 min	x	
8	ISO 9022-87-01	Laboratory agent: Ethanol (C_2H_5OH)	5 min	x	
9	ISO 9211-4-02-01	Adhesion: tape test	Slow tape removal	x	x

4.2.4 Category C

This category refers to applications where components will be exposed to normal outdoor ambient conditions and cleaning but without severe abrasion and scratching. See Table 3 for complete test sequence.

Table 3 — Default test sequence for Category of use C (three test samples are used)

Test step	Test code	Test	Description	Sample 1	Sample 2	Sample 3
1	ISO 9211-4-02-02	Adhesion: tape test	Quick tape removal	x	x	x
2	ISO 9211-4-01-02	Abrasion: cheesecloth/ eraser test	100 strokes cheesecloth	x		
3	ISO 9211-4-04-01	Resistance to water: exposure to water	Immerse in distilled or deionized water at a temperature of 23 °C ± 2 °C for 6 h			x
4	ISO 9211-4-04-07	Resistance to water: exposure to water	Immerse in boiling distilled or deionized water for 5 min			x
5	ISO 9022-10-07	Cold	Expose to a temperature of −35 °C ± 3 °C for 16 h		x	
6	ISO 9022-11-05	Dry heat	Expose to an atmosphere of 70 °C ± 2 °C (below 40 % relative humidity) for 6 h		x	
7	ISO 9022-12-07	Damp heat	Expose to climatic conditions of 90 % to 95 % relative humidity and 55 °C ± 2 °C for 16 h		x	
8	ISO 9022-14-05	Slow temperature change	−35 °C ± 3 °C to +63 °C ± 2 °C Number of cycles: 5 Dwell time: wait until sample has reached temperature within at least 3 K of the test chamber temperature but not less than 2,5 h Test chamber temperature change rate: between 0,2 K/min and 2 K/min		x	
9	ISO 9022-87-01	Laboratory agent: Acetone (CH_3COCH_3)	5 min	x		
10	ISO 9022-87-01	Laboratory agent: Ethanol (C_2H_5OH)	5 min	x		
11	ISO 9211-4-02-02	Adhesion: tape test	Quick tape removal	x	x	x

4.2.5 Category D

This category refers to applications where components will be exposed to severe outdoor ambient conditions and uncontrolled cleaning with the risk of severe abrasion and scratching. See Table 4 for complete test sequence.

Table 4 — Default test sequence for Category of use D (four test samples are used)

Test step	Test code	Test	Description	Sample 1	Sample 2	Sample 3	Sample 4
1	ISO 9211-4-02-02	Adhesion: tape test	Quick tape removal	x	x	x	x
2	ISO 9211-4-01-03	Abrasion: cheesecloth/ eraser test	20 strokes eraser	x			
3	ISO 9211-4-04-02	Resistance to water: exposure to water	Immerse in distilled or deionized water at a temperature of 23 °C ± 2 °C for 24 h			x	
4	ISO 9211-4-04-05	Resistance to water: exposure to water	Immerse in salt water (45 g NaCl/l) at a temperature of 23 °C ± 2 °C for 24 h			x	
5	ISO 9211-4-04-08	Resistance to water: exposure to water	Immerse in boiling distilled or deionized water for 15 min			x	
6	ISO 9211-4-04-09	Resistance to water: exposure to water	Immerse in boiling salt water (45 g NaCl/l) for 5 min			x	
7	ISO 9022-10-09	Cold	Expose to a temperature of −55 °C ± 3 °C for 16 h		x		
8	ISO 9022-11-06	Dry heat	Expose to an atmosphere of 85 °C ± 2 °C (below 40 % relative humidity) for 6 h		x		
9	ISO 9022-12-03	Damp heat	Expose to climatic conditions of 90 % to 95 % relative humidity and 40 °C ± 2 °C for 10 d		x		
10	ISO 9022-14-07	Slow temperature change	−50 °C ± 3 °C to +70 °C ± 2 °C Number of cycles: 5 Dwell time: wait until sample has reached a temperature within at least 3 K of the test chamber temperature but not less than 2,5 h Test chamber temperature change rate: between 0,2 K/min and 2 K/min		x		
11	ISO 9022-40-08	Salt mist	Expose to salt spray fog of 35 °C ± 2 °C for 24 h				x
12	ISO 9022-87-01	Laboratory agent: Acetone (CH_3COCH_3)	5 min	x			
13	ISO 9022-87-01	Laboratory agent: Ethanol (C_2H_5OH)	5 min	x			
14	ISO 9211-4-02-02	Adhesion: tape test	Quick tape removal	x	x	x	x

4.2.6 Category O

This category refers to applications which require special, non-standard, specifications that follow similar test sequences as Categories A to D. Since the specification of the components in such cases will not exactly fit into one of the categories A to D, the recommended way to specify in such a case is to indicate first the category in which most requirements are satisfied. The exceptional requirements can then be specified from other categories or by indicating the test degree of severity.

EXAMPLE "Category C; Abrasion tests: cheesecloth/eraser test, Damp heat: Category B; Adhesion tests: tape test 03".

NOTE An example of the description and implementation of Category O specification is provided in Annex B.

4.3 General use case

In the instance that the environmental durability tests do not follow similar test sequences as Categories A to D, all environmental tests shall be noted either as explicit text or shown in a tabular format. This description shall be indicated on a drawing or shown in a coating specification document.

4.4 Operating and storage conditions

The optical coating environmental durability specifications are intended as transport, storage or unprotected conditions. These would be considered a state of operation 0 or 1 as per ISO 9022-1. Due to the nature of optical coating environmental durability tests, it is not necessary to include the state of operation when listing the environmental test code.

4.5 Temperature conditions

For some types of coating, e.g. bandpass filters and accurate edge filters, it may be necessary that spectral tolerances shall be maintained within a certain temperature range. This should be specified separately, according to the requirements of the application. This specification would occur in the optical coating numerical specification of spectral characteristics as defined in ISO 9211-2.

4.6 Influence of the substrate

It should be kept in mind that it is not the coating but the entire coating-substrate combination which determines the category of use. For instance, coatings on glass, normally satisfying category C, might not do so when applied to sensitive or unstable substrates. This is likely to become apparent with the rain, solubility, humidity, heat, and salt spray tests, for example.

4.7 Cemented coatings

This document does not apply to cemented coatings. The environmental stability of such a substrate-coating-cement-substrate combination depends too much on properties of the cement, as well as the (relative) properties, e.g. thermal expansion, of the two substrate components involved.

5 Indications on drawings

5.1 Standard categories of use

The standard categories of use are indicated on a drawing by a statement identifying coating environmental durability test and category they follow. No further information is necessary regarding the test codes, test steps, and number of samples to test.

EXAMPLE “Coating environmental durability test: Category A”.

5.2 General use case

5.2.1 General

The general use case for coating environmental durability tests shall be indicated on a drawing by either direct statements listing the coating environmental durability test, test steps, test code, and number of samples to test as text statements or shown in a tabular format.

It is also suggested to include the test description along with the test code.

A complete list and description of environmental durability tests relevant for optical coatings shall be implemented as provided in Annex A.

5.2.2 Direct description

An example coating environmental durability test sequence is shown below. This notation is suggested to be written on a coating specification document that accompanies a drawing.

EXAMPLE "Coating environmental durability test: test step 1, ISO 9022-12-08 (Damp heat), 1 sample; test step 2, ISO 9211-4-01-01 (Abrasion), 1 sample; test step 3, ISO 9211-4-02-01 (Adhesion), 1 sample."

5.2.3 Tabular description

An example environmental test code table is shown in Table 5. The table shall include an indication of coating environmental durability tests, the test step, test code, number of samples to be tested and in the case of multiple samples tested, the sample on which each test should occur. This notation is suggested to be written directly on a drawing.

Though not required, it is suggested to also include the test description along with the test code.

Table 5 — Example environmental test code table

Coating environmental durability test			
Test step	**Test code**	**Test description**	**Test sample 1**
1	ISO 9022-12-08	Damp heat	x
2	ISO 9211-4-01-01	Abrasion: cheesecloth/eraser test	x
3	ISO 9211-4-02-01	Adhesion: tape test	x

Annex A
(normative)

Environmental tests for optical coatings

The tests in Table A.1 are subdivided into conditioning methods and degrees of severity. The description is condensed information specific to the degree of severity. The full test procedure shall be taken from appropriate International Standards, referenced in Table A.1, or can be specified by mutual agreement between customer and manufacturer.

The requirements for coatings as listed in Table A.1 are typically not accumulative and can be tested individually.

An individual test performed on a one-test-on-one-sample basis can give information about that single property of an optical coating reflected by that test and can be particularly useful for the manufacturer. In reality, optical coatings will face a variety and range of severity of environmental exposures, which can be simulated by certain test sequences. Inevitably, such test sequences represent accumulative requirements.

Additional tests not listed in Table A.1 may be necessary for a given application. In that instance, the test shall be specified following the environmental test code notation in 4.1.

Table A.1 — Overview of environmental tests for optical coatings

No.	Test	Conditioning method	Degree of severity	Description	Reference
1	Abrasion: cheesecloth / eraser test	01	01 02 03 04	50 strokes cheesecloth 100 strokes cheesecloth 20 strokes eraser 40 strokes eraser	ISO 9211-4
2-1	Adhesion: tape test	02	01 02 03	Slow tape removal Quick tape removal Snap tape removal	ISO 9211-4
2-2	Adhesion: crosshatch test	03	—	Crosshatch test	ISO 9211-4
2-3	Adhesion: pull-off test	05	—	Pull-off test	ISO 9211-4
[a] Mould growth (fungus): the resistance of a coating to damage by mould growth shall be specified, not the prevention of mould growth.					

Table A.1 *(continued)*

No.	Test	Conditioning method	Degree of severity	Description	Reference
3	Blowing dust	52	01	Expose to the dust-laden air of velocity 8 m/s to 10 m/s, at a temperature of 18 °C to 28 °C and of relative humidity below 25 % for 6 h. The dust concentration is 5 g/m^3 to 15 g/m^3	ISO 9022-6
			02	Step 1: Expose to the dust-laden air of velocity 8 m/s to 10 m/s, at a temperature of 18 °C to 28 °C and of relative humidity below 25 % for 6 h. The dust concentration is 5 g/m^3 to 15 g/m^3 Step 2: Expose to the dust-laden air of velocity 8 m/s to 10 m/s, at a temperature of 35 °C to 45 °C and of relative humidity below 25 % for 6 h. The dust concentration is 5 g/m^3 to 15 g/m^3	
			03	Step 1: Expose to the dust-laden air of velocity 8 m/s to 10 m/s, at a temperature of 18 °C to 28 °C and of relative humidity below 25 % for 6 h. The dust concentration is 5 g/m^3 to 15 g/m^3 Step 2: Expose to the dust-laden air of velocity 1 m/s to 3 m/s, at a temperature of 55 °C to 65 °C and of relative humidity below 25 % for 16 h Step 3: Expose to the dust-laden air of velocity 8 m/s to 10 m/s, at a temperature of 55 °C to 65 °C and of relative humidity below 25 % for 6 h. The dust concentration is 5 g/m^3 to 15 g/m^3	

[a] Mould growth (fungus): the resistance of a coating to damage by mould growth shall be specified, not the prevention of mould growth.

Table A.1 *(continued)*

No.	Test	Conditioning method	Degree of severity	Description	Reference
4	Resistance to water: exposure to water	04	01	Immerse in distilled or deionized water at a temperature of 23 °C ± 2 °C for 6 h	ISO 9211-4
			02	Immerse in distilled or deionized water at a temperature of 23 °C ± 2 °C for 24 h	
			03	Immerse in distilled or deionized water at a temperature of 23 °C ± 2 °C for 96 h	
			04	Immerse in salt water (45 g NaCl/l) at a temperature of 23 °C ± 2 °C for 6 h	
			05	Immerse in salt water (45 g NaCl/l) at a temperature of 23 °C ± 2 °C for 24 h	
			06	Immerse in salt water (45 g NaCl/l) at a temperature of 23 °C ± 2 °C for 96 h	
			07	Immerse in boiling distilled or deionized water for 5 min	
			08	Immerse in boiling distilled or deionized water for 15 min	
			09	Immerse in boiling salt water (45 g NaCl/l) for 5 min	
			10	Immerse in boiling salt water (45 g NaCl/l) for 15 min	
			11	Immerse in boiling salt water (45 g NaCl/l) for 60 min	
			12	Immerse in boiling distilled or salt water (45 g NaCl/l) for 2 min. Then immerse in distilled water at room temperature for 1 min	
5	Damp heat	12	03	Expose to climatic conditions of 90 % to 95 % relative humidity and 40 °C ± 2 °C for 10 d	ISO 9022-2
			06	Expose to climatic conditions of 90 % to 95 % relative humidity and 55 °C ± 2 °C for 6 h	
			07	Expose to climatic conditions of 90 % to 95 % relative humidity and 55 °C ± 2 °C for 16 h	
			08	Expose to climatic conditions of 95 % to 100 % relative humidity and 50 °C ± 2 °C for 24 h	

[a] Mould growth (fungus): the resistance of a coating to damage by mould growth shall be specified, not the prevention of mould growth.

Table A.1 *(continued)*

No.	Test	Conditioning method	Degree of severity	Description	Reference
6	Cold	10	05	Expose to a temperature of −25 °C ± 3 °C for 16 h	ISO 9022-2
			07	Expose to a temperature of −35 °C ± 3 °C for 16 h	
			09	Expose to a temperature of −55 °C ± 3 °C for 16 h	
			11	Expose to a temperature of −65 °C ± 3 °C for 2 h	
			12	Expose to a temperature of −65 °C ± 3 °C for 5 h	
7	Dry heat	11	03	Expose to an atmosphere of 55 °C ± 2 °C (below 40 % relative humidity) for 16 h	ISO 9022-2
			04	Expose to an atmosphere of 63 °C ± 2 °C (below 40 % relative humidity) for 16 h	
			05	Expose to an atmosphere of 70 °C ± 2 °C (below 40 % relative humidity) for 6 h	
			06	Expose to an atmosphere of 85 °C ± 2 °C (below 40 % relative humidity) for 6 h	
			07	Expose to an atmosphere of 70 °C ± 2 °C (below 40 % relative humidity) for 2 h	
			09	Expose to an atmosphere of 70 °C ± 2 °C (below 40 % relative humidity) for 5 h	
8	Slow temperature change	14	01	−10 °C ± 3 °C to +40 °C ± 2 °C	ISO 9022-2
			02	−25 °C ± 3 °C to +55 °C ± 2 °C	
			05	−35 °C ± 3 °C to +63 °C ± 2 °C	
			07	−50 °C ± 3 °C to +70 °C ± 2 °C	
				Number of cycles: 5	
				Dwell time: wait until specimen has reached a temperature at least within 3 K of the test chamber temperature but not less than 2,5 h	
				Test chamber temperature change rate: between 0,2 K/min and 2 K/min	
9	Salt mist	40	08	Expose to salt spray fog of 35 °C ± 2 °C for 24 h	ISO 9022-4

[a] Mould growth (fungus): the resistance of a coating to damage by mould growth shall be specified, not the prevention of mould growth.