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TECHNICAL SPECIFICATION

Guidance on the measurement of hydrophobicity of insulator surfaces

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TECHNICAL SPECIFICATION

Guidance on the measurement of hydrophobicity of insulator surfaces

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

GUIDANCE ON THE MEASUREMENT OF HYDROPHOBICITY OF INSULATOR SURFACES

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62073, which is a technical specification, has been prepared by IEC technical committee 36: Insulators.

This second edition cancels and replaces the first edition published in 2003. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Changed wettability to hydrophobicity throughout the document
- b) Redefined the criteria for the determination of hydrophobicity class in paragraph 3.4;

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
36/363/DTS	36/367/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

The wetting properties of a surface by water are commonly described by the terms hydrophobic (or hydrophobicity) and hydrophilic (or hydrophilicity). A hydrophobic surface is water-repellent, while a surface that is easily wetted by water is hydrophilic.

The wetting phenomenon of a surface is complex and many different parameters can influence its hydrophobic properties. Some important parameters include: type of insulator material, surface roughness, heterogeneities of the surface, chemical composition (e.g. due to ageing) and presence of pollution. For insulator materials in common use, the hydrophobic properties can change over time, due to the influence of the ambient conditions. This change can be either reversible or irreversible. Thus, the result of the measurement of the hydrophobicity may be influenced by the ambient conditions and the HV corona or dry-band arcing to which the insulator has been previously exposed. This dynamic behaviour of the hydrophobicity is more or less specific to different insulator materials. These types of materials, which have an ability to retain and transfer hydrophobicity, are commonly called Hydrophobicity Transfer Materials (HTM).

The dynamic behaviour of the hydrophobicity exhibited by insulator materials is due to their chemical composition. Different processes such as oxidation, hydrolysis, migration of low molecular weight compounds, formation of complex compounds between e.g. siloxanes and water, rotation of flexible polymer chains, inter- and intra-molecular rearrangements, microbiological growth, deposition of contaminants, adhesion and encapsulation of contaminant particles, may take place at different rates, depending on material and ambient conditions. Thus hydrophobicity along and around an insulator can vary, due to differences in the exposure to solar radiation, rain, corona discharges, deposited pollution, etc. Therefore, hydrophobicity of insulators is usually measured on several separate areas of the insulator.

Measurement of the hydrophobicity of a surface is readily performed in the laboratory on well defined, homogeneous, smooth and planar surfaces of prepared specimens. In the case of insulators, for which non-destructive measurements are usually required (and where cut-out of material samples is usually not desired), these conditions do not exist and measurement with high precision is a difficult task. This is especially true when the measurement has to be performed on an insulator installed in an overhead line, substation or even in a high voltage test set-up in the laboratory.

Previously wettability class (WC) was used as equivalent technology.

GUIDANCE ON THE MEASUREMENT OF HYDROPHOBICITY OF INSULATOR SURFACES

1 Scope

The methods described in this technical specification can be used for the measurement of the hydrophobicity of the shed and housing material of composite insulators for overhead lines, substations and equipment or ceramic insulators covered or not covered by a coating. The obtained value represents the hydrophobicity at the time of the measurement.

The object of this technical specification is to describe three methods that can be used to determine the hydrophobicity of insulators. The determination of the ability of water to wet the surface of insulators may be useful to evaluate the condition of the surface of insulators in service, or as part of the insulator testing in the laboratory.

2 Terms and definitions

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

2.1

hydrophobicity

state of a surface with a low surface tension and thus is water-repellent

2.2

hydrophilicity

state of a surface with a high surface tension and thus is wetted by water (in the form of a film)

2.3

surface tension

region of finite thickness (usually less than 0,1 µm) in which the composition and energy vary continuously from one bulk phase to the other

Note 1 to entry: The pressure (force field) in the interfacial zone has a gradient perpendicular to the interfacial boundary. A net energy is required to create an interface (surface) by transporting the matter from the bulk phase to the interfacial (surface) zone. The reversible work required to create a unit interfacial (surface) area is the surface tension and is defined thermodynamically as follows:

$$\gamma = \left(\frac{\partial G}{\partial A} \right)_{T,P,n}$$

where

γ is the surface (interfacial) tension or surface energy;

G is the Gibbs free energy of the total system;

A is the surface (interfacial) area;

T is the temperature;

P is the pressure;

n is the total number of moles of matter in the system.

The surface tension (γ) is usually expressed in mN/m (1 mN/m = 1 dyn/cm).

2.4

static contact angle

angle of a drop of liquid resting on the surface of a solid, and a gas is in contact with both, the forces acting at the interfaces are in balance

Note 1 to entry: These forces are due to surface tensions acting in the direction of the respective surfaces. From Figure 1 it follows that:

$$\gamma_{GL} \cos \theta_s = \gamma_{GS} - \gamma_{SL}$$

where

θ_s is the static contact angle of the edge of the drop with the solid surface,

γ_{GL} is the surface tension of the gas-liquid interface,

γ_{GS} is the surface tension of the gas-solid interface, and

γ_{SL} is the surface tension of the solid-liquid interface.

Note 2 to entry: The above equation (Young's equation) is only valid for ideal and smooth surfaces.

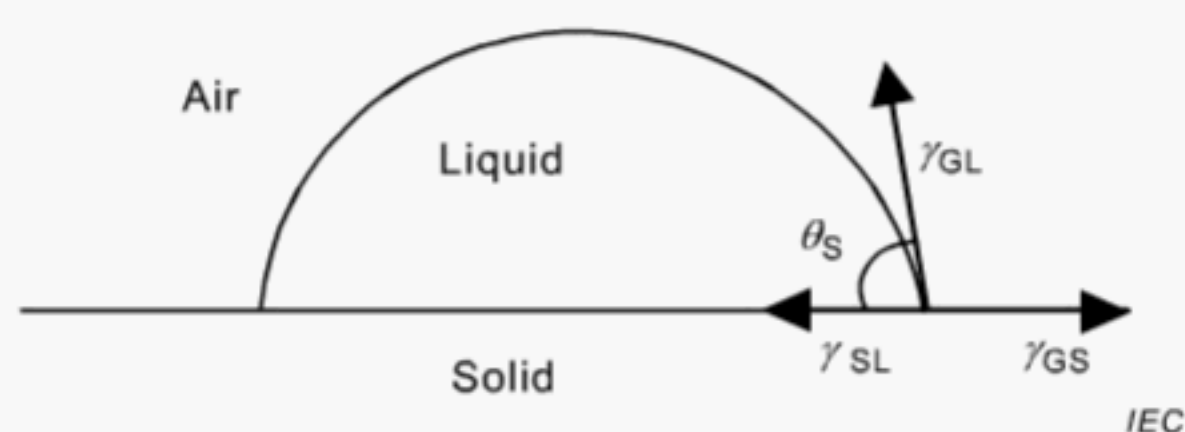


Figure 1 – Definition of the static contact angle

The right side of the above equation (the difference between the surface tensions of the gas-solid and the solid-liquid interfaces) is defined as the surface tension of the solid surface. It is not a fundamental property of the surface but depends on the interaction between the solid and a particular environment.

When the gas is air saturated with vapour of the liquid, γ_{GL} will be the surface tension of the liquid. If the contact angle is 0° , the liquid is said to just wet the surface of the solid, and in this particular case (since $\cos \theta_s = 1$), the surface tension of the solid will be equal to the surface tension of the liquid.

2.5

advancing and receding contact angle (dynamic contact angles)

angles of a droplet on an inclined solid surface that exhibits two different angles

Note 1 to entry: The advancing contact angle (θ_a) is the angle inside the water droplet between the solid surface and the droplet surface at the lower part of the droplet on the inclined surface (see Figure 2). The receding contact angle (θ_r) of a droplet on an inclined surface is the angle inside the droplet between the solid surface and the droplet surface at the droplet rear (highest part on the inclined surface). If the receding contact angle is zero, a completely wetted trace of water is formed as the drop moves along the solid inclined surface (see Figure 2). The general physical relation between the advancing and receding contact angle and the static contact angle defined in 2.4 is: $\theta_r \leq \theta_s \leq \theta_a$.

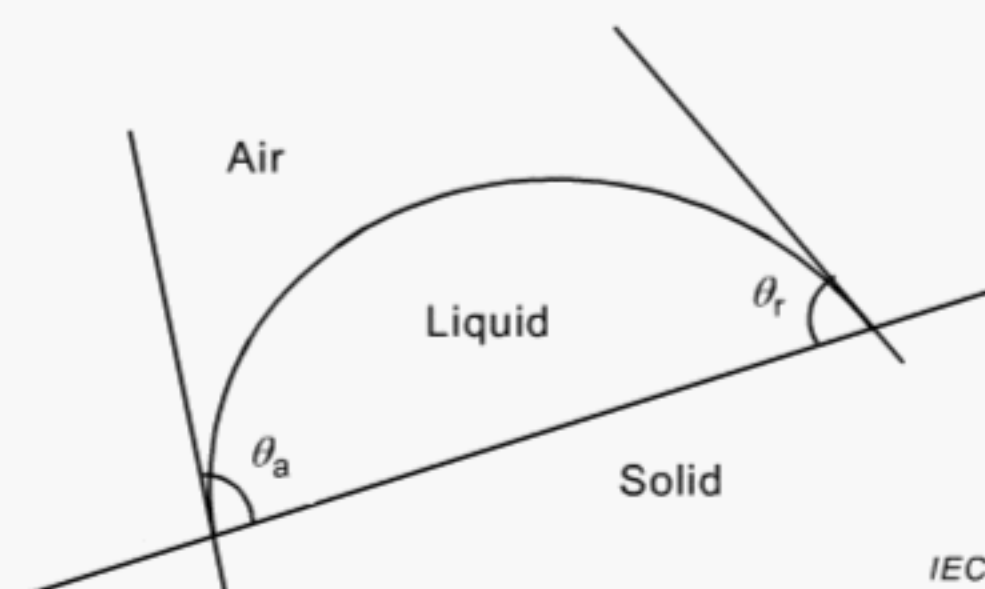


Figure 2 – Definition of the advancing angle (θ_a) and the receding angle (θ_r) inside a liquid drop resting on an inclined solid surface

2.6

hydrophobicity class

HC

specific level of the scale used in the spray method (Method C)

Note 1 to entry: Seven classes, HC/1 to HC/7, have been defined. HC/1 corresponds to the most hydrophobic surface and HC/7 to the most hydrophilic surface.

3 Methods for measurement of hydrophobic properties

3.1 General

Three methods for measurement of the hydrophobicity, differing in accuracy, simplicity, size of measured surface area and applicability, are described in this technical specification and are as follows:

- a) the contact angle method;
- b) the surface tension method;
- c) the spray method.

Guidance relative to the specific use of the three methods is found in Annex A.

3.2 Method A – Contact angle method

3.2.1 General

The contact angle method is a measurement that involves the evaluation of the contact angle formed between the edge of a single droplet of water and the surface of a solid material. If done on a horizontal surface, the advancing and receding contact angles can be measured by adding water to or withdrawing water from the droplet.

The contact angles depend strongly on the surface roughness and contact angles measured on polluted surfaces may differ significantly from contact angles measured on smooth, clean and planar surfaces.

3.2.2 Equipment

Different commercial equipment for measuring the contact angle is available. Simple measurements are made using a magnifying device with a graduated reticle (goniometer) fixed on a frame with a syringe for application of the droplet on the test specimen. Another method involves magnifying the droplet using a light projector (behind the droplet) and projecting an image of the droplet onto a graduated background. Some equipment includes camera, display and computer for analysis of the measurements.

3.2.3 Measurement procedure

3.2.3.1 General recommendations

General recommendations include:

- a) the receding contact angle (θ_r) reflects the hydrophobic properties of an insulator more than the advancing contact angle (θ_a) and the static contact angle (θ_s);
- b) it is often necessary to cut out a test specimen from the insulator under investigation. The test specimen selected should be as planar as possible and the size should allow for the application of at least three droplets on separate surface areas adjacent to each other. The surface to be measured should not be touched and the specimen should be carefully stored until the measurement has been performed. The measurement should be performed as soon as possible;
- c) the water used should not contain impurities affecting the water surface tension (e.g. tensides, solvents, oil residues, etc.). De-ionized water is suitable;

- d) the volume of water in the droplet is not very critical. Volumes in the range 5 μl to 50 μl may be used. 50 μl is the recommended volume. For rough surfaces, a larger droplet volume may be needed. To limit a possible influence of the water droplet volume, the volume should be kept as constant as possible when comparing different specimens;
- e) the measurement of the contact angles should be performed as soon as possible (within a minute) after the application of the droplet on the surface. This is especially important when the ambient temperature is high and the relative humidity is low, which increases the rate of evaporation of the droplet. If the measurement is performed in a chamber with saturated water vapour, it eliminates the influence of evaporation.

NOTE Small droplet volumes have the advantage that the contact angle is less influenced by gravity. On the other hand, for rough surfaces and other surfaces that could have high advancing contact angles and low receding angles, a too small droplet volume makes the measurement of the dynamic contact angles very difficult. A small droplet volume will also be more sensitive to evaporation, which could affect the measurement. The optimal droplet volume may thus be dependent on type of surface and ambient temperature and humidity.

3.2.4 Static contact angle measurements

The measurement of the static contact angle (θ_s) can be performed by applying a water droplet to the horizontal surface of a test specimen, using a pipette or a syringe with a scale.

3.2.5 Dynamic contact angle measurements

The measurement of the receding contact angle (θ_r) can be performed on a horizontal plane by withdrawing water from the droplet by using a syringe with a scale (see Figure 3). θ_r is the angle at the moment when the liquid front recedes. Measurement of θ_r should be performed on both projected sides of the droplet. At least three measurements on droplets applied on adjacent areas on the test specimen shall be performed. If three droplets are applied, this gives a total of six values.

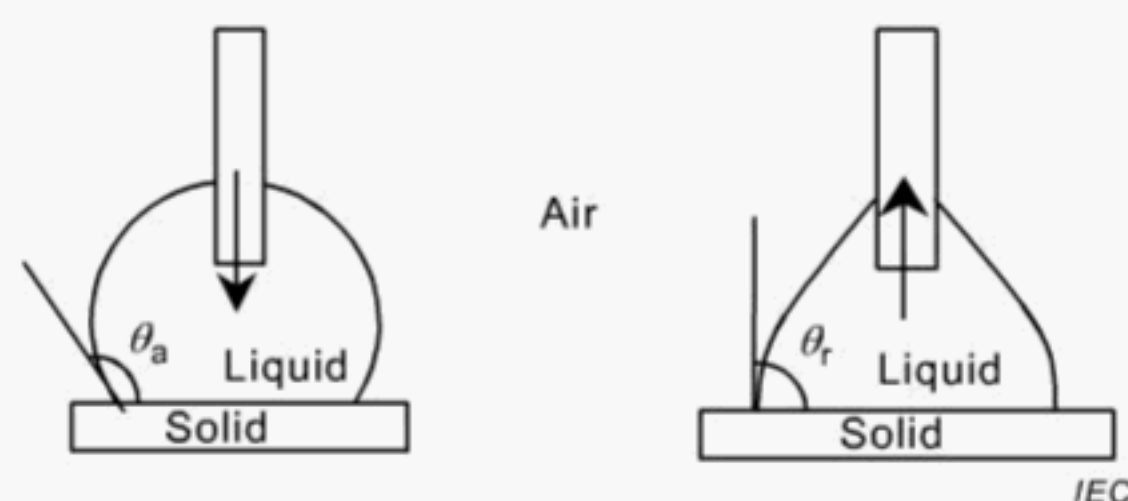


Figure 3 – Measurements of the advancing angle (θ_a) and the receding angle (θ_r) by adding or withdrawing water from a droplet

It is recommended to keep the capillary pipette of the syringe immersed in the droplet during the entire measurement in order to avoid vibrations and distortions of the droplet that otherwise may affect the result.

There exist other methods to measure the dynamic contact angles. Examples of such methods are given in Annex B.

NOTE Prior to the measurement of θ_r the advancing contact angle (θ_a) can be measured by adding water to the droplet. θ_a is the angle at the moment when the water droplet front starts to advance on the surface.

3.2.6 Evaluation

To obtain a good indication of the hydrophobicity of the whole insulator, several contact angle measurements should be performed on different areas along and around the insulator. Low or zero receding angles on all measured areas indicate a hydrophilic insulator, especially if also the advancing angles are low or zero. On the contrary, high receding (and advancing) angles indicate that the insulator is hydrophobic. Measurement on a single spot of the insulator surface is only valid for that location and is not sufficient to draw conclusions on the hydrophobicity of the whole insulator.

3.3 Method B – Surface tension method

3.3.1 General

The determination of the surface tension of an insulator surface is based on the phenomenon that drops of a series of organic liquid mixtures, with gradually increasing surface tension, have different ability to wet the insulator surface. Any trace of surface-active impurities in the liquid reagents or on the surface may affect the results. It is, therefore, important that the surface to be tested should not be touched or rubbed, that all equipment is clean and that reagent purity is carefully controlled.

This method is an extension of IEC 60674-2:1988, *Specification for plastic films for electrical purposes – Part 2: Methods of test*, which is used for the determination of the surface tension of polyethylene and polypropylene films. In particular this method implies the adoption of a larger number of liquids to cover a wider range of surface tension, which is needed to perform measurements on both hydrophobic and hydrophilic insulators. There may be restrictions in using this method on polluted insulator surfaces (see Annex A).

3.3.2 Safety precautions

The organic liquids used as reagents may affect health if not used properly. Formamide (HCONH_2) may cause skin irritation and is particularly dangerous in direct contact with eyes. Ethylene-glycolmonoethyl-ether ($\text{CH}_3\text{OCH}_2\text{CH}_2\text{OH}$) (or ethyl cellosolve) is a highly flammable solvent. Both formamide and ethyl cellosolve are toxic. Adequate safety precautions should be adopted, e.g. safety goggles should be worn and there should be adequate ventilation when handling these liquids and performing the measurements.

3.3.3 Equipment and reagents

3.3.3.1 Preparation of reagents

Tables C.1, C.2 and C.3 are used for the preparation of the required mixtures. For surface tension outside the range 30 mN/m to 56 mN/m, reference is made to mixtures in Tables C.2 and C.3. Commercially available marker pens already prepared with solutions of different surface tension may be an alternative to making own mixtures.

If desired, add dye (e.g. Victoria Pure Blue BO at a maximum concentration of 0,03 %) to each of the different reagent mixtures. The dye used should be of such a colour as to make drops clearly visible on the surface of the organic material considered. Furthermore, the dye shall be of such a chemical composition that it will not measurably affect the wetting tension of the liquid mixtures. It is recommended that the surface tension of the liquid mixture be checked weekly. Any surface tension method applied in the laboratory is suitable. Although the shown liquid mixtures are relatively stable, exposure to temperatures above 30 °C and a relative humidity in excess of 70 % should be avoided.

3.3.3.2 Equipment

Three different applicators are available to apply the reagent solutions on the insulator surface:

- cotton-tipped wooden applicators;
- small soft paintbrushes fixed into the caps of the bottles with the reagents;
- commercially available marker pens already prepared with solutions of different surface tension.

For applicators a) and b), additional equipment is required:

- two graduated bottles of 50 ml;
- other bottles, 100 ml with caps and labels. The bottles should be cleaned with chrome-sulfuric acid and rinsed with distilled water.

3.3.4 Measurement procedure

Wet the extreme tip of the cotton applicator (if cotton applicators are used) with one of the reagent mixtures or remove the soft paintbrush fixed into the cap of the bottle with the reagent. Use only a minimum amount of liquid as an excess of reagent may affect the result.

The same measurement procedure is then used with any of the three applicators.

Spread the liquid lightly over an area of approximately 5 cm² (25 mm of diameter) of the insulator surface at the selected location. Note the time required for the continuous liquid coverage formed on the surface to break up into droplets. If the continuous liquid coverage holds for more than 2 s, proceed to a higher surface tension mixture, but if the continuous liquid coverage breaks into droplets in less than 2 s proceed to a lower surface tension mixture. For each application of a new reagent mixture, a new adjacent surface should be selected to avoid contamination from the previously applied reagent. If measurements on the same surface area are desirable and possible without disturbance, the surface may be gently cleaned with a dry cloth (without the use of any detergent) to remove the remaining reagent previously applied. If cleaning is not performed, it is recommended to start with the lower surface tension mixtures and progressively continue to higher surface tension mixtures to minimize erroneous results due to contamination from the previously applied reagent mixture. When a cotton applicator is used, a clean, new applicator shall be used each time to avoid contamination of the solution. If the soft paintbrushes fixed into the caps are used, the brush may be cleaned in a small volume of the reagent before it is re-inserted into the reagent bottle again.

Proceed in the direction indicated above continually repeating the prescribed steps until it is possible to select the right mixture according to the evaluation in 3.3.5.

3.3.5 Evaluation

The mixture is considered as wetting the insulator surface when it remains intact as a continuous coverage of the liquid for at least 2 s. Shrinkage of the periphery of the continuous liquid coverage does not indicate lack of wetting. Only breaking into droplets within 2 s indicates lack of wetting. Severe peripheral shrinking may be caused when too much liquid is placed upon the surface. The surface tension of the applied mixture (in mN/m), which remains intact during 2 s as close as possible, is called the surface tension of the measured insulator surface.

3.4 Method C – The spray method

3.4.1 General

The spray method is based on the response that an insulator surface gives after exposure to a fine water mist for a short period. The hydrophobicity after the mist exposure is evaluated.

NOTE The method will not give exact measurements of the advancing and receding contact angle but is a practical method for an estimation of the hydrophobicity in field. This method is intended to be performed on unenergized insulator

3.4.2 Equipment

The equipment needed is a device that can produce a fine mist, such as a common spray bottle. The spray bottle is filled with water. The water shall not contain any impurities, which could influence the surface tension of the water, such as detergents, solvents, etc. Tap water of high quality does usually not contain impurities that significantly influence the surface tension of the water. Tap water of high quality could thus be used for the measurement. If there are any uncertainties about the water quality, de-ionized water or distilled water should be used

NOTE 1 Additional equipment which may facilitate the measurement include a magnification glass (for an easier judgement of droplet shape) and a lamp.

3.4.3 Measurement procedure

The test area should preferably be approximately 50 cm² to 100 cm². The ratio between the length and width of the test area should not be larger than 1:3. If this requirement cannot be met, this should be noted in the measurement report. Apply the mist from a distance of 20 cm \pm 10 cm. The surface shall be exposed to the mist for a period of 10 s to 20 s. Typically, the amount of water sprayed during the 10 s to 20 s should be sufficient enough so that the water is dripping of the sheds. The measurements of the hydrophobicity shall be performed within 10 s after the spraying has been completed.

The measurement should be performed in such a way that a clear picture of the variation of the hydrophobicity along and around the insulator is obtained.

The measurement might be difficult to perform in high winds. If such difficulties are present it may be necessary to perform the spraying from a shorter distance than 20 cm \pm 10 cm. This should be noted in the measurement report, together with any other possible deviations from given recommendations, e.g. smaller test area.

NOTE 1 For long insulators, it is possible to only examine some selected sheds from the upper, middle and lower part of the insulator.

NOTE 2 If necessary, a photographic camera can be used to record the surface condition.

3.4.4 Evaluation

The appearance on the insulator surface after mist exposure has to be identified with one of the seven hydrophobicity classes (HC), which is a value between 1 and 7. The criteria for the different HCs are given in Table 1. Typical photos of surfaces with different HCs are shown in Annex D.

A surface with the HC value 1 is the most hydrophobic surface and a surface with the HC value 7 is the most hydrophilic surface.

Two visual criteria are used to judge the HC value:

- a) the shape of droplets;
- b) the percentage part of the surface which is wetted.

NOTE The uncertainty in the visual evaluation is usually not larger than ± 1 hydrophobicity class.

Table 1 – Criteria for the determination of hydrophobicity class (HC)

HC	Description	Approximate receding contact angle θ_r
1	Only discrete droplets are formed. Their shape when viewed perpendicular to the surface is practically circular.	$>60^\circ$
2	Only discrete droplets are formed. The major part of the surface is covered by droplets with a shape, as seen perpendicular to the surface, still regular but deviates from circular form.	40 to 60°
3	Only discrete droplets are formed. The major part of the surface is covered by droplets with an irregular shape.	10 to 40°
4	Both discrete droplets and wetted traces from the water runnels or water film are observed (i.e. $\theta_r = 0^\circ$ for some of the droplets). Less than 10 % of the observed area is covered by water runnels or film.	0 to 10°
5	Both discrete droplets and wetted traces from the water runnels or water film are observed (i.e. $\theta_r = 0^\circ$ for some of the droplets). More than 10 % but less than 90 % of the observed area is covered by water runnels or film.	0 to 10°
6	More than 90 % but less than 100 % of the observed area is covered by water runnels or film (i.e. small non-wetted areas/spots/traces are still observed).	0 to 5°
7	Continuous water film is formed over the whole-observed area.	0°

3.5 Documentation

The measurement report should include the following information:

a) General information

- 1) location, station, line or laboratory conditions;
- 2) method used (A, B or C);
- 3) date and time of the measurement and sample collection date and droplet volume for method A;
- 4) weather conditions (temperature, wind, precipitation);
- 5) who performed the test.

b) Test object

- 1) type of insulator or apparatus;
- 2) insulator material and shed profile;
- 3) identity (item No., position in substation or tower No.);
- 4) voltage class, arcing distance, creepage distance;
- 5) date of installation or application of coating (type of coating);
- 6) installation position (vertical, horizontal, angle);
- 7) information on the pollution state of the insulator.

c) Result

The results of the measurement performed at different positions should be documented, e.g. along the insulator (shed No.), along the surface within each shed sequence (top, bottom, large shed, small shed, trunk, etc.), and differences (if any) around the insulator circumference should be noted.

Annex A

(normative)

Guidelines regarding the applicability and comments on the limitations of the different methods described in this technical specification

A.1 General

The suitability of each method and its applicability depends not only on its associated procedure but also on the specific case to be evaluated. All three methods are well suited for hydrophobicity measurements in the laboratory. In the field, it may be difficult to use method A. Method B can be used without too much difficulty while Method C can readily be used. Some considerations relevant to each method are outlined below:

a) Method A: Contact angle measurement

- gives an accurate value of the hydrophobicity of the area measured,
- is more accurately performed in the laboratory than in the field,
- the measurement is easily performed on practically flat surfaces,
- if aging has affected the surface morphology, i.e. presence of cracks, fissures or filler, the measurement may be adversely affected, and
- requires many measurements if a complete evaluation of the insulator surface is required.

b) Method B: Surface tension measurement

- gives an accurate value of the hydrophobicity of the area measured provided the spatial variation in the hydrophobicity is compatible with the area required for the measurement,
- is fairly easy to perform,
- requires certain safety precautions,
- may be difficult to use if the surface is covered with a layer of loosely adhering pollution,
- may be affected by interaction between certain types of surface pollution and the measuring agents may occur, and
- requires many measurements if a complete evaluation of the insulator surface is required.

c) Method C: Spray method

- gives a global assessment of the hydrophobicity of the insulator surface and its variation along and around the insulator,
- is easy to perform and requires simple equipment,
- depends on subjective visual examination of the surface,
- can be used to evaluate bare and polluted surfaces, and
- may be affected by an interaction between certain types of surface pollution and the spray water (i.e. modification of the equivalent salt deposit density (ESDD) level of the surface contaminant applied for laboratory pollution tests).

A.2 Typical results obtained with the three methods

Typical results obtained with the three methods are as follows:

a) Hydrophobic surface

- high value of receding contact angle ($>80^\circ$),
- low value of surface tension (<30 mN/m),
- low HC value (HC = 1 or HC = 2).

b) Intermediate surface

- intermediate value of receding contact angle (10° to 80°),
- intermediate value of surface tension (30 mN/m to 60 mN/m),
- intermediate HC value (HC = 3 to HC = 5).

c) Hydrophilic surface

- low value of receding contact angle ($<10^\circ$),
- high value of surface tension (>60 mN/m),
- high HC value (HC = 6 or HC = 7).

Annex B (normative)

Method A – Contact angle method

There are several different methods to measure the dynamic contact angles. The captive bubble technique is illustrated in Figure B.1. In this technique the specimen is immersed in water. An air bubble (or a liquid immiscible with water) is formed by injecting air (or liquid) on the lower side of the immersed specimen. Young's equation, as given in 2.4, is also valid in this case.

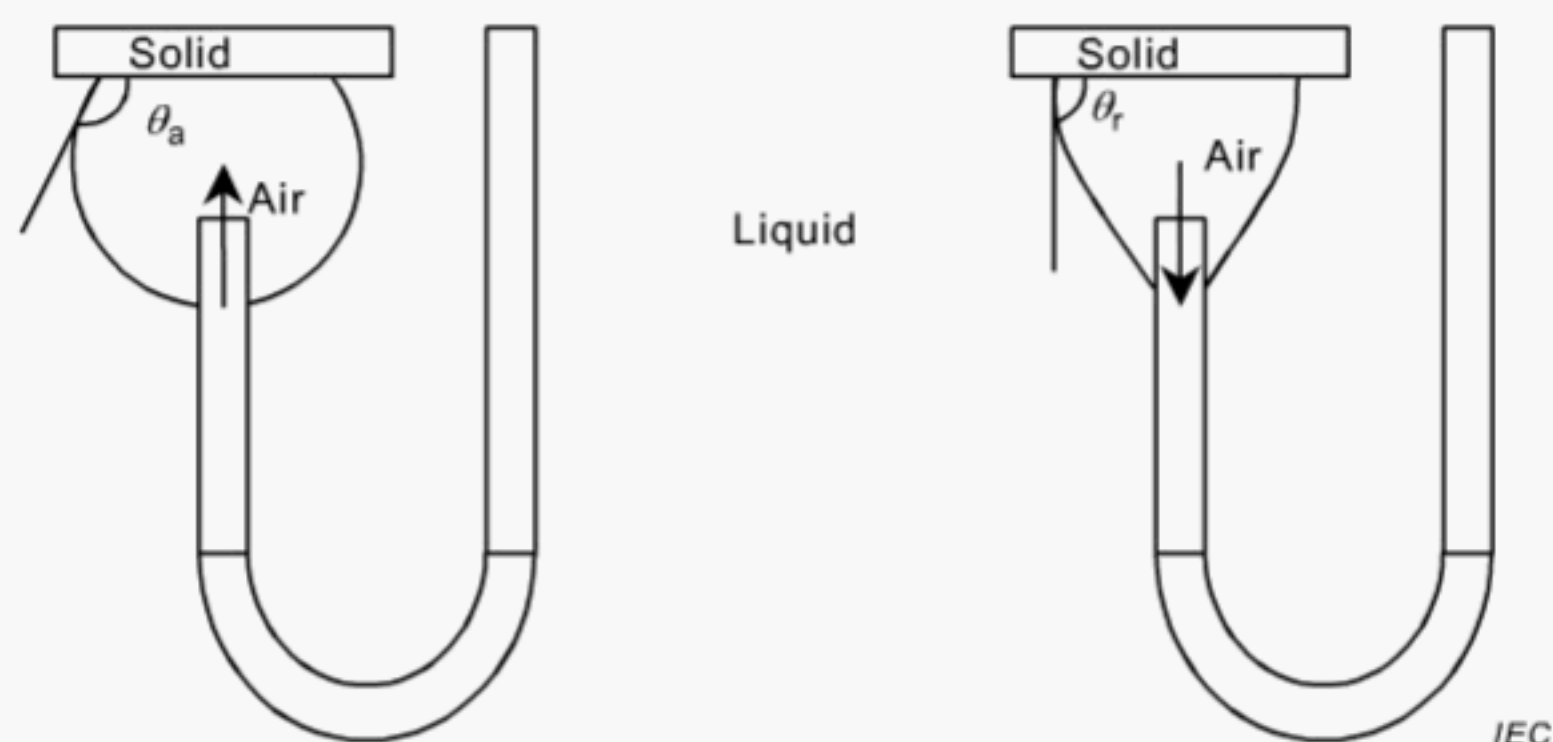


Figure B.1 – Measurement of the advancing angle (θ_a) and the receding angle (θ_r) by using the captive bubble technique

It is also possible to measure the advancing and receding contact angles (θ_a and θ_r , respectively) on an inclined surface. This method, the tilting base technique, uses a water droplet that is placed on the surface, which is tilted at a progressively higher angle until the droplet starts to move, allowing the determination of advancing and receding contact angles. The tilting base technique is illustrated in Figure 2.

Annex C (normative)

Method B – Surface tension method

Tables C.1, C.2 and C.3 are to be used for the preparation of the required mixtures in order to perform the surface tension method.

Table C.1 – Concentrations of ethylene-glycol-monoethyl-ether (cellosolve), formamide mixtures used in measuring surface tension of insulator surfaces in the range 30 mN/m to 56 mN/m ($T = 20\text{ °C}$)

Surface tension mN/m	Formamide volume %	Cellosolve volume %
30	0	100,0
31	2,5	97,5
32	10,5	89,5
33	19,0	81,0
34	26,5	73,5
35	35,0	65,0
36	42,5	57,5
37	48,5	51,5
38	54,0	46,0
39	59,0	41,0
40	63,5	36,5
41	67,5	32,5
42	71,5	28,5
43	74,7	25,3
44	78,0	22,0
45	80,3	19,7
46	83,0	17,0
48	87,0	13,0
50	90,7	9,3
52	97,3	6,3
54	96,3	3,7
56	99,0	1,0
NOTE The surface tension of liquids vary linearly with temperature. The surface tension for small molecule liquids decreases with about 0,1 mN/m per degree Celsius at ordinary temperatures.		

Table C.2 – Concentrations of distilled water and formamide mixture used in measuring surface tension of insulator surfaces in the range 58 mN/m to 73 mN/m ($T = 20\text{ °C}$)

Surface tension mN/m	Formamide volume %	Cellosolve volume %
58	0,0	100,0
59	9,5	90,5
60	21,3	78,7
61	34,0	66,0
62	41,5	58,5
63	50,0	50,0
64	57,4	42,6
65	64,4	35,6
66	71,3	28,7
67	77,3	22,7
68	82,0	18,0
69	86,2	13,8
70	89,5	10,5
71	93,7	6,3
72	97,5	2,5
73	100	0,0

Table C.3 – Concentrations of distilled water and sodium chloride in mixtures used in measuring surface tension of insulator surfaces in the range 73 mN/m to 82 mN/m ($T = 20\text{ °C}$)

Surface tension mN/m	NaCl %	Distilled water %
73	0,0	100,0
74	4,0	96,0
75	7,2	92,8
76	10,1	89,9
77	12,9	87,1
78	15,6	84,4
79	18,2	81,8
80	20,6	79,4
81	22,8	77,2
82	24,9	75,1

Annex D (normative)

Method C – Spray method

Typical examples of surfaces with hydrophobicity class (HC) from 1 to 6 are shown in Figure D.1. HC 7 is a surface that is completely hydrophilic with no dry spots observed.

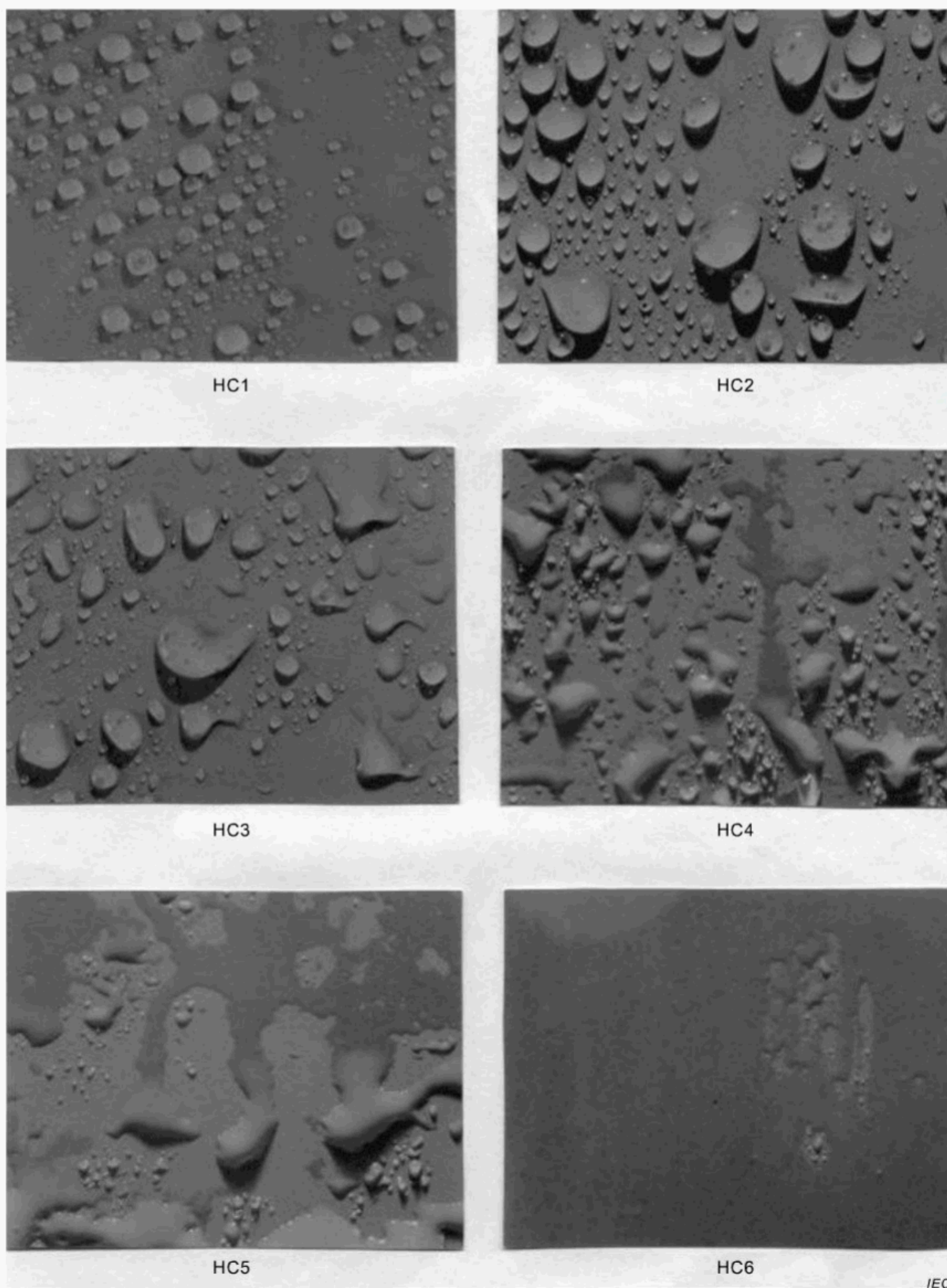


Figure D.1 – Examples of surfaces with hydrophobicity class (HC) from 1 to 6

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**NORME
INTERNATIONALE
INTERNATIONAL
STANDARD**

**CEI
IEC**

60721-3-0

Edition 1.1

2002-10

Edition 1:1984 consolidée par l'amendement 1:1987
Edition 1:1984 consolidated with amendment 1:1987

Classification des conditions d'environnement –

Partie 3:

**Classification des groupements des agents
d'environnement et de leurs sévérités –
Introduction**

Classification of environmental conditions –

Part 3:

**Classification of groups of environmental
parameters and their severities –
Introduction**



Numéro de référence
Reference number
CEI/IEC 60721-3-0:1984+A1:1987

Numérotation des publications

Depuis le 1er janvier 1997, les publications de la CEI sont numérotées à partir de 60000. Ainsi, la CEI 34-1 devient la CEI 60034-1.

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Classification des conditions d'environnement –

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Introduction**

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Part 3:

**Classification of groups of environmental
parameters and their severities –
Introduction**

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International Electrotechnical Commission
Международная Электротехническая Комиссия

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

CLASSIFICATION DES CONDITIONS D'ENVIRONNEMENT –

Partie 3: Classification des groupements des agents d'environnement et de leurs sévérités – Introduction

AVANT-PROPOS

- 1) La CEI (Commission Electrotechnique Internationale) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de la CEI). La CEI a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. A cet effet, la CEI, entre autres activités, publie des Normes internationales. Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec la CEI, participent également aux travaux. La CEI collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
- 2) Les décisions ou accords officiels de la CEI concernant les questions techniques représentent, dans la mesure du possible, un accord international sur les sujets étudiés, étant donné que les Comités nationaux intéressés sont représentés dans chaque comité d'études.
- 3) Les documents produits se présentent sous la forme de recommandations internationales. Ils sont publiés comme normes, spécifications techniques, rapports techniques ou guides et agréés comme tels par les Comités nationaux.
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La Norme internationale CEI 60721-3-0 a été établie par le comité d'études 104 de la CEI: Conditions, classification et essais d'environnement.¹⁾

La présente version consolidée de la CEI 60721-3-0 comprend la première édition (1984) [documents 75(BC)13 et 75(BC)17, son amendement 1 (1987) [documents 75(BC)21 et 75(BC)28 et son corrigendum 1 (1985).

Le contenu technique de cette version consolidée est donc identique à celui de l'édition de base et à son amendement; cette version a été préparée par commodité pour l'utilisateur.

Elle porte le numéro d'édition 1.1.

Une ligne verticale dans la marge indique où la publication de base a été modifiée par l'amendement 1 et le corrigendum.

Il est à noter que la présente norme constitue une partie d'une série consacrée aux sujets suivants:

- Classification des agents d'environnement et de leurs sévérités (CEI 60721-1).
- Conditions d'environnement présentes dans la nature (CEI 60721-2).
- Classification des groupements des agents d'environnement et de leurs sévérités (CEI 60721-3).

¹⁾ Le comité d'études 75 de la CEI: «Classification des conditions d'environnement» a été transformé en comité d'études 104.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

**Part 3: Classification of groups of environmental parameters
and their severities – Introduction**

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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- 3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
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- 6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60721-3-0 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.¹⁾

This consolidated version of IEC 60721-3-0 consists of the first edition (1984) [documents 75(CO)13 and 75(CO)17], its amendment 1 (1987) [documents 75(CO)21 and 75(CO)28] and its corrigendum 1 (1985).

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 1.1.

A vertical line in the margin shows where the base publication has been modified by its amendment 1 and corrigendum.

It should be noted that this standard forms one part of a series intended to deal with the following subjects:

- Classification of environmental parameters and their severities (IEC 60721-1).
- Environmental conditions appearing in nature (IEC 60721-2).
- Classification of groups of environmental parameters and their severities (IEC 60721-3).

¹⁾ IEC technical committee 75: "Classification of environmental conditions" has been transformed into technical committee 104.

La publication suivante de la CEI est citée dans la présente norme.

CEI 60068: *Essais fondamentaux climatiques et de robustesse mécanique.*

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant 2007.
A cette date, la publication sera

- reconduite;
- supprimée;
- remplacée par une édition révisée, ou
- amendée.

The following IEC publication is quoted in this standard:

IEC 60068, *Basic environmental testing procedures*

The committee has decided that the contents of this publication will remain unchanged until 2007.
At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

CLASSIFICATION DES CONDITIONS D'ENVIRONNEMENT –

Partie 3: Classification des groupements des agents d'environnement et de leurs sévérités – Introduction

1 Domaine d'application

La CEI 60721-3, définit les catégories des agents d'environnement et leurs degrés de sévérités, couvrant les conditions extrêmes (de courte durée) auxquelles un produit peut être exposé lorsqu'il est transporté, installé, mis en stock et utilisé. Ces catégories dépendent des applications du produit (par exemple à poste fixe protégé des intempéries, monté dans des véhicules terrestres, transporté). Le degré de restriction de l'emploi du produit est aussi considéré par les catégories, en partant de conditions très limitées (par exemple enceinte à température contrôlée) jusqu'à des conditions non limitées.

La classification couvre à la fois les conditions naturelles et les conditions créés par l'homme.

2 Objet

Cette introduction est un guide pour l'emploi de toutes les parties de la CEI 60721-3. Elle contient des informations générales y compris des renseignements sur l'application et les limites des catégories indiquées dans les différentes parties de la CEI 60721-3. Elle définit les différences entre les conditions d'environnement auxquelles le produit sera confronté pendant sa vie, décrites par les catégories dans la CEI 60721-3, et les conditions d'essais utilisées pour s'assurer que le produit se comportera de manière satisfaisante face à de telles conditions. L'emploi de la CEI 60721-3 pour la construction, la délimitation des conditions et la protection est aussi prévu. Les différences entre des conditions extrêmes qui ont très peu de chances d'être dépassées, et dont on ne s'approche que pendant de courtes périodes, et des conditions normales d'environnement pour des périodes de plus longue durée sont aussi expliquées.

La présente introduction donne également des directives pour appliquer les facteurs de durée et de fréquence des événements lors de la détermination de la contribution apportée par un agent de classe important.

Une référence à la présente CEI 60721-3-0 est fortement recommandée afin d'éviter un emploi abusif des catégories définies dans les autres parties de la CEI 60721-3.

3 Contenu et présentation

Des groupes séparés de catégories de conditions d'environnement sont donnés pour les applications suivantes du produit:

CEI 60721-3-1: *Stockage;*

CEI 60721-3-2: *Transport;*

CEI 60721-3-3: *Utilisation à poste fixe, protégé contre les intempéries;*

CEI 60721-3-4: *Utilisation à poste fixe, non protégé contre les intempéries;*

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 3: Classification of groups of environmental parameters and their severities – Introduction

1 Scope

IEC 60721-3, covering the extreme (short-term) conditions which may be met by a product when being transported, installed, stored and used. Separate groups of classes are given for different product applications (e.g. weather-protected stationary, mounted in ground vehicles, transportation). The classes also take into account the degree of restriction of the use of the product from very restricted conditions (e.g. in temperature-controlled rooms) to unrestricted conditions.

The classification covers natural as well as man-made conditions.

2 Object

This introduction is a guide for the use of all parts of IEC 60721-3. It contains background information including information on application and limitation of the classes given in various parts of IEC 60721-3. It describes the difference between the environmental conditions the product will meet during its life, described by the classes in IEC 60721-3, and conditions of test used to assure that the product will work satisfactorily under such environmental conditions. The use of IEC 60721-3 in the design, limitation of conditions and protection is also included. The difference are explained between extreme environmental conditions with a small probability of being exceeded, normally approached only for short periods, and more long-lasting normal environmental conditions.

This introduction also gives guidance for applying factors of duration and frequency of occurrence in characterizing the contribution of a significant parameter of a class.

Reference to IEC 60721-3-0 is strongly recommended in order to avoid misuse of the classes defined in the other part of IEC 60721-3.

3 Content and layout

Separate groups of classes of environmental conditions are given for the following product applications:

IEC 60721-3-1: *Storage*;

IEC 60721-3-2: *Transportation*;

IEC 60721-3-3: *Stationary use, weather-protected*;

IEC 60721-3-4: *Stationary use, non-weatherprotected*;

CEI 60721-3-5: *Installations des véhicules terrestres;*

CEI 60721-3-6: *Environnement des navires;*

CEI 60721-3-7: *Utilisation en déplacement.*

Les catégories sont identifiées par:

- un chiffre définissant l'application (1 pour le stockage, 2 pour le transport, 3 pour l'utilisation à poste fixe, etc.);
- une lettre pour les conditions climatiques (K), conditions biologiques (B), substances chimiquement actives (C), substances mécaniquement actives (S) ou conditions mécaniques (M). Liste à augmenter si nécessaire;
- un autre chiffre indiquant la sévérité, un chiffre plus élevé indiquant normalement des conditions plus sévères. Une catégorie peut être en outre divisée en H (haute) et L (basse) pour tenir compte de conditions où, par exemple, la température peut être particulièrement basse, sans jamais être haute.

Exemple: Catégorie 2K3

où

2 = transport;

K = conditions climatiques;

3 = sévérité.

Les parties de la CEI 60721-3 contiennent des tableaux indiquant toutes les catégories, y compris la sévérité de chaque agent d'environnement pour chaque catégorie. En outre, chaque publication comprend une annexe donnant des détails sur les conditions que le produit est susceptible de rencontrer et qui forment la base des catégories. Ces annexes sont destinées à guider l'utilisateur de la publication dans son choix de la catégorie convenable pour son application spéciale du produit.

4 Informations générales pour le choix des agents d'environnement et des sévérités pour les catégories

Les agents d'environnement spécifiés pour une catégorie sont ceux, par la catégorie, auxquels le produit sera soumis. Ils sont choisis en utilisant le jeu complet des agents d'environnement de la CEI 60721-1, en tant que liste de contrôle.

Les sévérités spécifiées pour chaque agent d'environnement sont celles qui sont dépassées soit pendant une fraction insignifiante de la durée totale de l'exposition continue (par exemple, condition de température), soit pendant une fraction insignifiante du nombre total d'événements (par exemple, chocs). Ainsi les catégories données dans la CEI 60721-3 peuvent être utilisées pour définir les contraintes d'environnement maximales de courte durée d'un produit mais ne donnent aucune information sur les contraintes d'environnement pour une longue durée ou pour la durée de vie totale du produit. Cela est illustré dans la Figure 1.

IEC 60721-3-5: *Ground vehicle installations*;

IEC 60721-3-6: *Ship environment*;

IEC 60721-3-7: *Portable and non-stationary use*.

The classes are identified by:

- a digit defining the application (1 for storage, 2 for transportation, 3 for stationary use, etc.);
- a letter for climatic conditions (K), biological conditions (B), chemically active substances (C), mechanically active substances (S) or mechanical conditions (M). To be extended if necessary;
- a further digit indicating severity, where a higher digit normally indicated more stringent conditions. A class may be further divided into H (High) or L (Low) to allow for conditions where, for example, the temperature may be severely low but never high.

Example: Class 2K3

where

2 = transportation;

K = climatic conditions;

3 = severity.

The parts of IEC 60721-3 contain tables giving all classes, including the severity of each environmental parameter for each class. In addition, every publication includes an appendix giving details of conditions which products are assumed to meet and which form a basis for the classes. These appendices are intended to guide the user of the publication in his selection of the class appropriate to his special product application.

4 Background information for the selection of environmental parameters and severities for the classes

The environmental parameters listed for a class are the conditions covered by the class to which a product will be subjected. They are selected by using the complete set of environmental parameters in IEC 60721-1 as a "check list".

The severities given for each environmental parameter are those which are exceeded either for an insignificant part of the continuous exposure time (e.g. temperature conditions), or for an insignificant fraction of the total number of events (e.g. shocks). Thus the classes given in IEC 60721-3 can be used for defining the maximum short-term environmental stresses of a product, but do not give any information of the long-term, or total live duration of the product environmental stresses. This is illustrated in Figure 1.

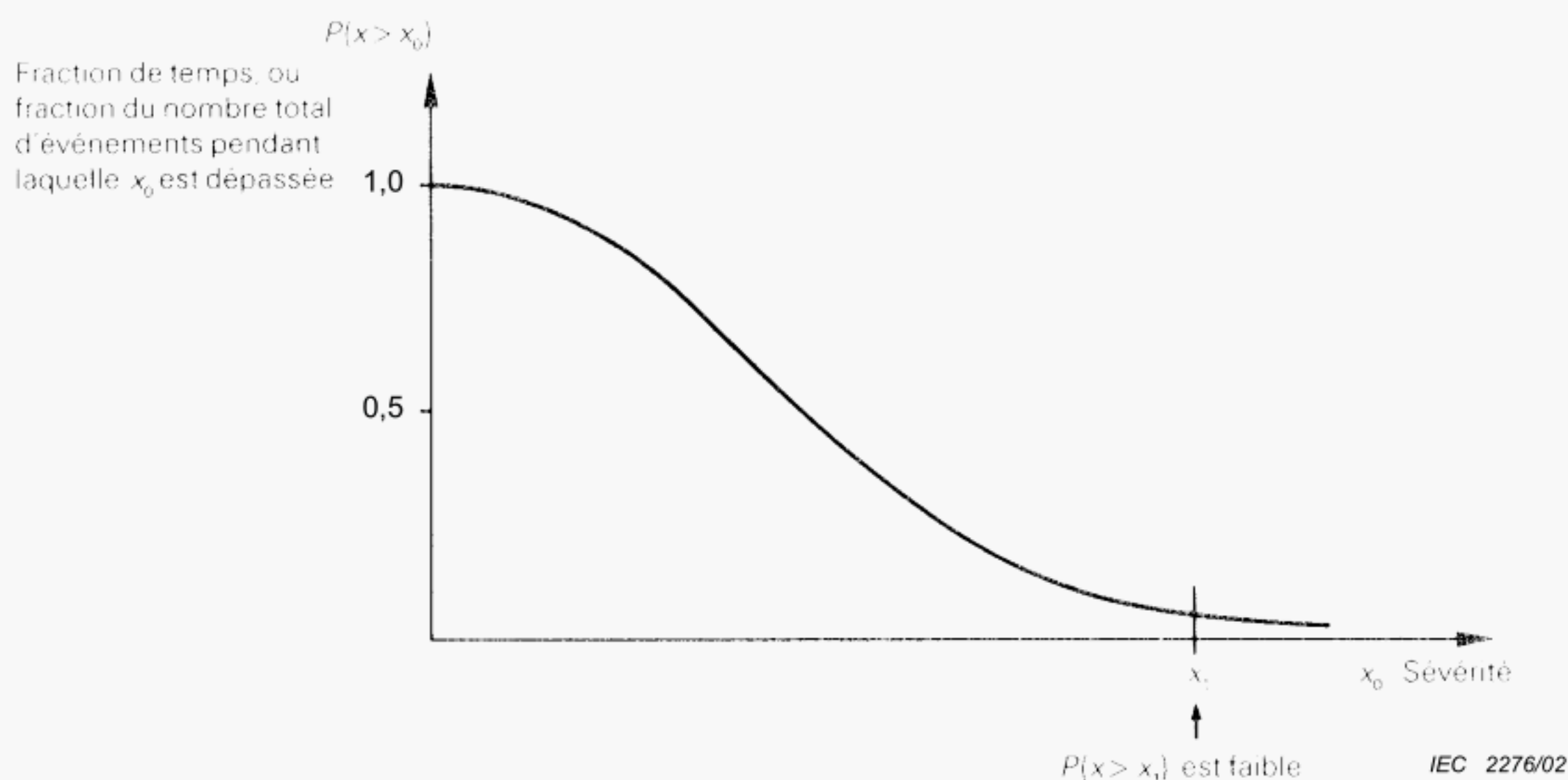


Figure 1 – Illustration de la fraction de temps ou de la fraction du nombre d'événements pendant laquelle une certaine sévérité de l'environnement est dépassée

Les sévérités données dans la classification sont représentées par une seule valeur x_1 , tandis que les informations exigées pour définir les contraintes totales d'environnement pendant la vie d'un produit comprennent la courbe totale $P(x > x_0)$ pour toutes les valeurs de x_0 .

Bien que les données disponibles ne permettent pas de donner une valeur exacte du niveau de probabilité utilisé dans la classification, $P(x > x_1)$ est habituellement considérablement inférieur à 0,01.

Un produit est simultanément exposé à un grand nombre des agents d'environnement. Quelques-uns des agents sont statistiquement dépendants, par exemple vent faible et basse température, rayonnement solaire et température élevée. D'autres agents sont statistiquement indépendants, par exemple vibrations et température (normalement).

La probabilité d'une exposition simultanée aux sévérités extrêmes des agents d'environnement indépendants x et y est égale au produit des probabilités d'exposition à chacun des agents, c'est-à-dire:

$$P(x, y > x_1, y_1) = P(x > x_1) \cdot P(y > y_1)$$

Exemple: Si la probabilité de dépasser chacun des agents

$$P(x > x_1) = P(y > y_1) = 0,01, \text{ alors } P(x, y > x_1, y_1) = 0,0001$$

Il convient de remarquer que, dans de nombreux cas, le produit n'est exposé que pendant des durées limitées à l'environnement dont les données statistiques ont été réunies. Dans de tels cas, ont été choisies des sévérités dans la classification qui ont une probabilité d'être supérieure à 0,01. En conséquence, la probabilité de combinaison de l'exposition du produit à l'environnement et de la limite de sévérité dans la catégorie est raisonnable (ordre de grandeur de 0,01).

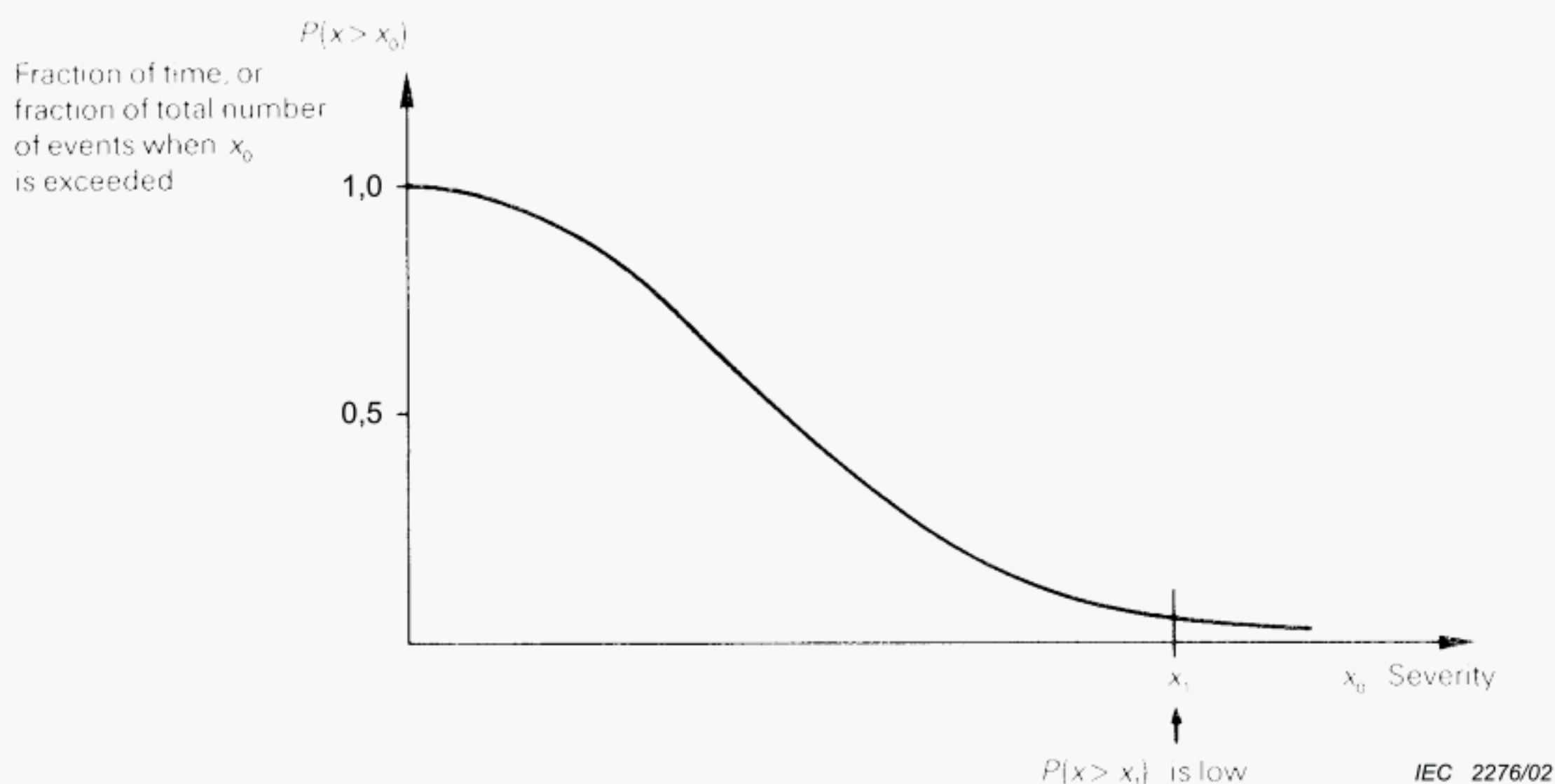


Figure 1 – Illustration of the fraction of time or fraction of the total number of events when a certain environmental severity is exceeded

The severities given in the classification are represented by one value x_1 , whilst the information needed for defining the totality of environmental stresses during the lifetime of a product includes the total curve, $P(x > x_0)$ for all values of x_0 .

Although available data do not make it possible to give an exact figure on the probability level used in the classification, $P(x > x_1)$ is usually considerably less than 0,01.

A product will be simultaneously exposed to a large number of environmental parameters. Some of the parameters are statistically dependent, for example, low air velocity and low temperature, sun radiation and high temperature. Other parameters are statistically independent, for example vibration and temperature (normally).

The probability of simultaneous exposure to extreme severities of independent environmental parameters x and y is equal to the product of the probabilities of exposure to each of the parameters, i.e.:

$$P(x, y > x_1, y_1) = P(x > x_1) \cdot P(y > y_1)$$

Example: If the probability of exceeding each of the parameters

$$P(x > x_1) = P(y > y_1) = 0,01, \text{ then } P(x, y > x_1, y_1) = 0,0001$$

It should be noted that in many cases the product is exposed for only limited periods to the environment from which the statistical data have been collected. In such cases severities in the classification have been selected which have a probability higher than 0,01 of being exceeded. Consequently, the probability of the combination of the product being exposed to the environment and of the class limit severity is reasonable (in the order of magnitude of 0,01).

5 Guide d'application de la CEI 60721-3

5.1 Conditions générales

Tous les produits doivent être construits de façon à se maintenir et à fonctionner dans des conditions d'environnement plus ou moins sévères. Fondamentalement, ils seront affectés de deux manières par l'environnement:

- par les effets de conditions d'environnement extrêmes de courte durée, lesquelles peuvent directement causer des défauts de fonctionnement ou détruire le produit;
- par les effets d'une exposition de longue durée à des contraintes d'environnement non extrêmes, lesquelles peuvent dégrader le produit lentement et finalement causer un défaut de fonctionnement ou détruire le produit.

Les conditions d'environnement extrêmes de courte durée, définies dans la CEI 60721-3, peuvent se produire à n'importe quel moment de la vie d'un produit. Un produit peut ne pas être influencé par une condition extrême quand il est neuf mais, exposé à la même condition après avoir été utilisé pendant une longue période, il peut être détruit à cause du vieillissement.

Les conditions extrêmes peuvent influencer le produit:

- seulement lorsque le produit ne fonctionne pas (par exemple pendant le stockage et le transport),
- seulement lorsque le produit est en fonctionnement,

ou dans les deux conditions. Pour cette raison, il est très important que la spécification du produit, en faisant référence à une certaine catégorie de la CEI 60721-3, définisse s'il est exigé que le produit soit en état de fonctionner ou seulement de se maintenir sans dommages permanents, quand il est exposé aux conditions décrites par la catégorie.

Les catégories d'environnement peuvent être utilisées comme bases pour le choix des niveaux de construction et d'essai. Cela ne signifie pas que les limites des catégories soient utilisées comme des niveaux de construction et d'essai, ni qu'un taux de défaillances nul soit exigé aux limites de catégorie. Il faut que les niveaux de construction et d'essai soient toujours choisis, de cas en cas, en considérant le risque de défaillance acceptable, c'est-à-dire avec une sévérité plus élevée ou plus faible, selon les conséquences attendues de la défaillance.

5.2 A la construction, à la délimitation des conditions et à la protection

La CEI 60721-3 est surtout destinée à servir de base à la définition des conditions d'environnement réelles pour lesquelles le produit doit être construit. Le constructeur doit avoir conscience de ce que l'influence physique des conditions d'environnement peut être le résultat d'un certain nombre d'agents d'environnement.

Exemple:

La température la plus élevée obtenue à la surface d'un produit peut être le résultat d'une combinaison de la température de l'air ambiant, du rayonnement solaire, du rayonnement calorifique d'un élément chauffant dans le voisinage, d'un four ouvert, etc.

Le fabricant ou l'utilisateur du produit peut réduire la sévérité d'un agent d'environnement en protégeant le produit, par exemple par l'emploi d'un conteneur pour le transport et le stockage ou par le montage du produit sur des dispositifs amortisseurs de vibration et de chocs. Les sévérités d'environnement données par les catégories dans la CEI 60721-3 doivent ensuite être appliquées au produit avec sa protection, et non pas à lui seul.

5 Guidance for the use of IEC 60721-3

5.1 General

All products have to be designed to survive and work in more or less severe environments. Basically they will be affected by the environmental influences in two ways:

- by the effects of short-term extreme environmental conditions, which may directly cause malfunction or destroy the product;
- by the effect of long-term subjection to non-extreme environmental stresses, which may slowly degrade the product and finally cause malfunction or destruction of the product.

The short-term extreme environmental conditions, defined in IEC 60721-3, may occur at any time in the product's life. A product may be unaffected by an extreme condition when it is new but fail when it is subjected to the same condition after being used for a long period due to the effect of ageing.

Extreme conditions may affect the product:

- only when the product is non-operating (e.g. during storage and transportation),
- only when the product is operating,

or both. It is therefore important for the product specification, when referring to a certain class in IEC 60721-3, to define whether the product is required to be capable of operating or only to survive without permanent damage, when being subjected to the conditions described by the class.

The environmental classes may be used as a basis for the choice of design and test levels. This does not imply that the class limits should be used as design and test levels, nor that zero failure rate should be required at the class limits. Design and test levels must always be chosen from case to case with respect to acceptable risk of failure, i.e. with higher or lower severity depending on expected consequences of failure.

5.2 In the design, limitation of conditions and protection

IEC 60721-3 is basically intended to be used as a basis for defining the actual environmental conditions for which a product has to be designed. The designer must be aware that the physical influence of environmental conditions may be the result of a certain number of environmental parameters.

Example:

The highest temperature achieved on the surface of a product may be the result of the combination of the temperature of the surrounding air, solar radiation, heat radiation from a nearby heating element, open oven, etc.

The manufacturer or user of the product may reduce the severity of an environmental parameter by protecting the product, for example, by using an enclosure for transportation and storage or by mounting the product on vibration or shock isolators. The environmental severities given by the classes in IEC 60721-3 shall then be applied to the product including its protection, not to the product itself.

Au moyen des informations données dans les annexes des différentes parties de la CEI 60721-3, il est possible au fabricant et à l'utilisateur du produit de définir des restrictions lors du transport, du stockage ou de l'utilisation du produit, qui conduiront à ranger l'application dans une catégorie de sévérité plus faible.

Il est souvent économique et techniquement important de trouver un optimum entre:

- la résistance à l'environnement du produit non protégé;
- la protection du produit contre les influences d'environnement;
- les restrictions de transport, de stockage et d'utilisation du produit.

Il doit être observé que le surdimensionnement d'un produit, afin qu'il supporte des conditions d'environnement plus sévères que nécessaire, n'aboutira pas nécessairement à une sûreté de fonctionnement plus élevée. Un surdimensionnement ou des dispositifs de protection incorporés sans nécessité peuvent conduire à un produit plus compliqué avec un nombre plus élevé de modes de défaillance. De plus, le surdimensionnement des produits ainsi que des exigences inutiles sur l'emplacement afin de garantir des conditions d'environnement moins sévères que nécessaire, peuvent devenir très coûteux.

5.3 Pour définir les niveaux appropriés aux essais d'homologation

Comme cela a été mentionné au 5.2 ci-dessus, les catégories de la CEI 60721-3 peuvent être utilisées comme base pour la construction, la protection et l'introduction de restrictions. La démonstration de la capacité du produit à satisfaire aux conditions d'environnement comprend un certain nombre d'actions, depuis les instructions sur le choix des matières premières du produit y compris les essais des matériaux, les instructions pour les traitements de surface, etc., jusqu'aux essais des spécimens du produit complet dans des conditions d'environnement simulées.

Les essais sont faits en choisissant les agents d'environnement ou quelquefois des combinaisons de ceux-ci, qui peuvent être nuisibles au produit. Un essai d'environnement prescrit est décrit par:

- l'agent d'environnement;
- la procédure d'essai;
- les sévérités d'essai.

En outre, des exigences relatives au produit particulier sont données, par exemple régime assigné, prescriptions de fonctionnement, dégradation acceptable, etc.

Les procédures des essais climatiques et mécaniques figurent dans la CEI 60068.

Les sévérités utilisées pour les essais doivent être en relation avec la procédure d'essai, qui essaye de produire les effets des environnements réels. Cela diffère souvent de la reproduction des conditions réelles d'environnement.

Exemples:

- Un essai de température élevée sur un produit dissipant de la chaleur est conçu pour simuler l'effet thermique de l'exposition à des conditions de température atmosphérique élevée, au rayonnement solaire et à d'autres sources de chaleur possibles en fonction de l'application.
- Dans un essai de chocs, le produit est exposé à des chocs de formes d'impulsions simples, par exemple semi-sinusoïdales, alors que les conditions réelles ne peuvent pas être décrites par de telles impulsions simples. Une transformation par comparaison du spectre de chocs en conditions réelles avec le spectre de chocs de l'impulsion d'essai est nécessaire.

By means of the information given in the appendices to the various parts of IEC 60721-3 it is possible for the manufacturer and user to define restrictions in the transportation, storage or use of the product, which will bring the application into compliance with a lower severity class.

It is often economical and technically important to find an optimum between:

- the environmental resistance of the unprotected product;
- the protection of the product from environmental influences;
- restrictions in transportation, storage and use of the product.

It should be noted that an overdesign of a product, in order to withstand environmental conditions more extreme than necessary, does not necessarily result in higher reliability. An overdesign or unnecessary built-in protection may lead to a more complex product with an increased number of failure modes. Furthermore, overdesign of products as well as unnecessary requirements on locations in order to ensure environmental conditions less severe than necessary, can become very expensive.

5.3 For defining appropriate levels for qualification testing

As mentioned under 5.2 above, the classes in IEC 60721-3 can be used as basis for design, protection and introduction of restrictions. Demonstration of the capability of the product to meet the environmental condition includes a number of activities, from instructions for selection of basic materials used in the product including material testing, instructions for surface treatments, etc., to testing of samples of the complete product under simulated environmental conditions.

The testing is made in a selection of the environmental parameters, or sometimes combinations thereof, which may be detrimental to the product. An environmental test requirement is described by:

- environmental parameter;
- testing procedure;
- testing severities.

In addition requirements are given related to the specific product, for example rating, functional requirements, acceptable degradation etc.

Environmental testing procedures for testing are standardized in IEC 60068.

The severities used for testing must be related to the testing procedure, which attempts to produce the effects of the actual environment. This reproduction is often different from the actual environmental conditions.

Examples:

- A high temperature test on a heat dissipating product is designed to simulate the thermal effect of subjecting it to conditions of high air temperature, solar radiation and other possible heat sources dependent on the application.
- In a shock test, the product is subjected to shocks of simple pulse shapes (e.g. half-sine), whilst the actual conditions cannot be described by such simple pulses. A transformation by means of comparing the shock spectrum of the actual conditions with the shock spectrum of the test pulse is needed.

(La transformation des conditions réelles en conditions d'essai n'entre pas dans le cadre de la CEI 60721.)

Les conditions données dans la CEI 60721-3 sont celles qui ont une très faible probabilité d'être dépassées, mais sans marges de sécurité. Outre le choix et la transformation des conditions réelles en conditions d'essai, le rédacteur des exigences d'essai peut ajouter des marges pour couvrir ce qui suit:

- tolérances de l'appareillage d'essai et des dispositifs de commande;
- différences entre le spécimen utilisé pour l'essai et d'autres spécimens du produit;
- autres facteurs.

En résumé, il est souligné que les catégories figurant dans la CEI 60721-3 définissent des conditions réelles d'environnement extrêmes. Elles ne doivent pas normalement être mises directement en application pour des essais d'homologation. Elles pourront, cependant, être employées comme données de base pour définir les niveaux de tels essais, ainsi que les méthodes de transformation des conditions réelles en conditions d'essais, les marges de sécurité, etc.

6 Durée et fréquence des événements

6.1 Généralités

Les sévérités spécifiées dans les classes de la CEI 60721-3 sont celles qui ont une faible probabilité d'être dépassées. Elles se présentent seulement pendant une fraction de temps ou en un nombre limité d'occasions.

Pour certaines applications, il peut être important de connaître la durée et la fréquence d'application à un produit de certains agents d'environnement à des niveaux significatifs. En fonction de la situation locale ou du profil d'utilisation d'un produit, la durée ou la fréquence de l'action de certains agents d'environnement peut être différente. Le fait de connaître par avance la durée ou la fréquence des événements peut avoir une influence importante sur la conception du produit ou sur les mesures de protection (détails de construction de bâtiments, etc.) à l'endroit de l'application (pendant le stockage, le transport ou l'utilisation).

Les problèmes sous-jacents sont souvent de nature statistique et très complexe. On ne peut régler de telles situations d'une manière unique. Les tableaux et exemples suivants ne peuvent apporter qu'une information limitée. Ils seront par conséquent utilisés seulement dans des cas simples ou lorsque des informations plus précises sur les durées ne sont pas disponibles.

6.2 Durée et fréquence des événements

6.2.1 Le tableau 1 contient un choix normalisé de durée totales d'application.

6.2.2 Le tableau 2 contient un choix normalisé de durée maximales d'un seul événement, et le tableau 3 un choix normalisé de durées d'événements ou du nombre d'événements par unité de temps. Ces durées et ces fréquences peuvent être appliquées à chaque agent d'environnement d'une classe caractérisant normalement la situation quand l'action de cet agent est significative.

(The transformation of actual conditions into test conditions is not within the scope of IEC 60721.)

The conditions given in 60721-3 are those with a small probability of being exceeded but without safety margins. In addition to selection and transformation of actual conditions into test conditions the designer of test requirements can add margins to cover:

- tolerances of test equipment and control devices;
- inequalities between the sample used for testing and other specimens of the product;
- other factors.

As a summary it is emphasized that the classes in IEC 60721-3 define actual extreme environmental conditions. They should not be directly applied for qualification testing. They may, however, be used as basic material for defining test levels for such testing, together with methods for transformation of actual conditions into test conditions, safety margins, etc.

6 Duration and frequency of occurrence

6.1 General

The severities specified in the classes of IEC 60721-3 are those which will have a low probability of being exceeded. They occur for only a fraction of time or for a limited number of events.

For certain applications it may be important to know how long or how often significant levels of environmental parameters bear upon the product. Depending on the local situation or on the use profile of a product, duration or frequency of occurrence of single environmental parameters may be different. The knowledge of the expected duration or frequency of occurrence may significantly influence the design of the product or protective measures (details of building construction, etc.) at the location of application (during storage, transportation or use).

The underlying problems are often of a statistical and very complex nature. Such situations cannot be dealt with in a standardized manner. The following tables and examples can only convey a limited amount of information. They should therefore be used only in simple cases or when no more relevant information on durations is available.

6.2 Duration and frequency of occurrence

6.2.1 Table 1 contains a standard selection of total durations which may be related to each application.

6.2.2 Table 2 contains a standard selection of maximum durations of a single occurrence, and table 3 contains a standard selection of durations of occurrence or number of events per unit time. These durations or frequencies may be related to each environmental parameter of a class normally characterizing the situation when the contribution of that parameter is significant.

En fonction de la situation, le mot «significatif», dans ce texte, est censé couvrir des situations telles que les suivantes:

- l'état décrit par l'agent est atteint – par exemple condensation, givrage, etc.;
- la valeur de l'agent est supérieure à la sévérité correspondante de la classe immédiatement inférieure – par exemple basse température de l'air, haute température de l'air, faible humidité relative, forte humidité relative, etc.;
- l'agent d'environnement dépasse toute valeur de seuil définie, qu'il faut alors fixer en même temps que la durée et la fréquence retenues.

On peut établir une relation entre les durées et les fréquences des tableaux 2 et 3 et les durées totales d'application du tableau 1.

6.2.3 L'annexe A donne des exemples d'application des valeurs normales de durée et de fréquence de répétition.

Tableau 1 – Durée totale de l'application

Application	Durée				
Stockage	1 mois	6 mois	1 an	2 ans	3 ans
Transport	24 h	1 semaine	1 mois	6 mois	
Utilisation	1 an ¹⁾	5 ans	10 ans	20 ans	40 ans
¹⁾ Des cas exceptionnels peuvent nécessiter une durée très courte, par exemple les sondes météorologiques.					

Tableau 2 – Durée maximale d'un événement

1	s
10	s
1	min
0,5	h
1	h
8	h
24	h
1	semaine
2	semaines
1	mois

Tableau 3 – Fréquence des événements

Durée de l'événement par unité de temps ¹⁾		Nombre d'événements significatifs par unité de temps ¹⁾
0,5 h	ou	1
1 h		2
8 h		5
24 h		10
1 semaine		
2 semaines		
1 mois		
2 mois		
6 mois		
¹⁾ Unités de temps à choisir parmi les suivantes: seconde, minute, heure, 24 h, semaine, mois, an.		

Depending on the situation, the term "significant" is considered in this text to cover situations such as the following:

- the state described by the parameter is reached, for example, condensation, icing, etc.;
- the parameter value is beyond the corresponding severity of the next lower class, for example, low air pressure, high air temperature, low relative humidity, high relative humidity, etc.;
- the parameter exceeds any defined threshold value, which then has to be stated together with the duration or frequency selected.

A relationship between the durations and frequencies of table 2 and table 3, and the total durations of application in table 1 may be given.

6.2.3 Appendix A gives examples of application of standard values of duration and frequency of occurrence.

Table 1 – Total duration of application

Application	Duration				
Storage	1 month	6 months	1 year	2 years	3 years
Transportation	24 h	1 week	1 month	6 months	
Use	1 year ¹⁾	5 years	10 years	20 years	40 years
¹⁾ Exceptional cases may call for a very short duration, for example weather sondes.					

Table 2 – Maximum duration of single occurrence

1	s
10	s
1	min
0,5	h
1	h
8	h
24	h
1	week
2	weeks
1	month

Table 3 – Frequency of occurrence

Duration of occurrence per unit time ¹⁾		Number of significant events per unit time ¹⁾
0,5 h	or	1
1 h		2
8 h		5
24 h		10
1 week		
2 weeks		
1 month		
2 months		
6 months		

1) Unit time to be selected from the following: second, minute, hour, 24 h, week, month, year.

Annexe A

Exemples d'application

Les exemples qui suivent illustrent l'application à des cas concrets des valeurs normales de durée et de fréquence des événements.

A.1 Exemple 1

Le produit sera transporté par les moyens normaux disponibles depuis le lieu de fabrication jusqu'à l'utilisateur, à grande distance, sans précaution ou protection particulières.

Classification d'environnement:	2K4/2B2/2C3/2S2/2M3
Durée du transport:	1 mois
Durée des vibrations significatives:	1 semaine par mois
Nombre de chocs significatifs:	1 par h
Nombre de chutes libres significatives:	10 par mois

A.2 Exemple 2

Le produit est à utiliser dans une installation à poste fixe protégée contre les intempéries.

Classification d'environnement:	3K3/3Z1/3B1/3C2/3S2/3M2
Durée d'utilisation:	10 ans
Durée des vibrations significatives:	1 semaine par an
Durée maximale des vibrations significatives:	8 h
Nombre de chocs significatifs:	1 par 24 h

A.3 Exemple 3

Le produit est à utiliser en déplacement.

Classification d'environnement:	7K4/7Z2/7Z6/7Z10/7B2/7C3/7S3/7M3
Durée d'utilisation:	5 ans
Durée d'humidité (condensation, précipitations, pulvérisation d'eau):	2 mois par an
Durée d'influence significative des substances chimiquement actives:	0,5 h par 24 h
Durée de gel, givre:	1 mois par an
Nombre de chute libres significatives:	2 par an

Appendix A

Examples of application

Application of the standard values of duration and frequency of occurrence to actual cases is exemplified in the following:

A.1 Example 1

The product will be transported by normally available transportation means from the manufacturer to the user over a long distance without special care or protection.

Environmental classification:	2K4/2B2/2C3/2S2/2M3
Duration of transportation:	1 month
Duration of significant vibration:	1 week per month
Number of significant shocks:	1 per h
Number of significant free falls:	10 per month

A.2 Example 2

The product is to be used in a weatherprotected stationary installation.

Environmental classification:	3K3/3Z1/3B1/3C2/3S2/3M2
Duration of use:	10 years
Duration of significant vibration:	1 week per year
Maximum duration of significant vibrations:	8 h
Number of significant shocks:	1 per 24 h

A.3 Example 3

The product is intended for portable and non-stationary use.

Environmental classification:	7K4/7Z2/7Z6/7Z10/7B2/7C3/7S3/7M3
Duration of use:	5 years
Duration of wetness (condensation, precipitation, spraying water):	2 months per year
Duration of significant influence of chemically active substances:	0,5 h per 24 h
Duration of icing, frosting:	1 month per year
Number of significant free falls:	2 per year

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