

BS EN 60060-1:2010



BSI Standards Publication

High-voltage test techniques

Part 1: General definitions and test requirements

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National foreword

This British Standard is the UK implementation of EN 60060-1:2010. It is identical to IEC 60060-1:2010. It supersedes BS 923-1:1990, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/42, Testing techniques for high voltages and currents.

A list of organizations represented on this committee can be obtained on request to its secretary.

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ISBN 978 0 580 68953 6

ICS 17.220.20; 19.080

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2011.

Amendments issued since publication

Amd. No.	Date	Text affected
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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 60060-1

December 2010

ICS 17.220.20

Supersedes HD 588.1 S1:1991

English version

High-voltage test techniques - Part 1: General definitions and test requirements (IEC 60060-1:2010)

Technique des essais à haute tension -
Partie 1: Définitions et exigences
générales
(CEI 60060-1:2010)

Hochspannungs-Prüftechnik -
Teil 1: Allgemeine Begriffe und
Prüfbedingungen
(IEC 60060-1:2010)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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Foreword

The text of document 42/277/FDIS, future edition 3 of IEC 60060-1, prepared by IEC/TC 42, High-voltage testing techniques, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60060-1 on 2010-12-01.

This European Standard supersedes HD 588.1 S1:1991.

This EN 60060-1:2010 includes the following technical changes with respect to HD 588.1 S1:1991:

- The general layout and text was updated and improved to make the standard easier to use.
- Artificial pollution test procedures were removed as they are now described in EN 60507.
- Measurement of impulse current has been transferred to a new standard on current measurement (EN 62475).
- The atmospheric correction factors are now presented as formulas.
- A new method has been introduced for the calculation of the time parameters of lightning impulse waveforms. This improves the measurement of the time parameters of lightning impulses with oscillations or overshoot.

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

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2011-09-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2013-12-01 |

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60060-1:2010 was approved by CENELEC as a European Standard without any modification.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application 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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60060-2	-	High-voltage test techniques - Part 2: Measuring systems	EN 60060-2	-
IEC 60270	-	High-voltage test techniques - Partial discharge measurements	EN 60270	-
IEC 60507	1991	Artificial pollution tests on high-voltage insulators to be used on a.c. systems	EN 60507	1993
IEC 61083-1	-	Instruments and software used for measurement in high-voltage impulse tests - Part 1: Requirements for instruments	EN 61083-1	-
IEC 61083-2	-	Digital recorders for measurements in high- voltage impulse tests - Part 2: Evaluation of software used for the determination of the parameters of impulse waveforms	EN 61083-2	-
IEC 62475	-	High-current test techniques - Definitions and requirements for test currents and measuring systems	EN 62475	-

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HIGH-VOLTAGE TEST TECHNIQUES –

Part 1: General definitions and test requirements

1 Scope

This part of IEC 60060 is applicable to:

- dielectric tests with direct voltage;
- dielectric tests with alternating voltage;
- dielectric tests with impulse voltage;
- dielectric tests with combinations of the above.

This part is applicable to tests on equipment having its highest voltage for equipment U_m above 1 kV.

NOTE 1 Alternative test procedures may be required to obtain reproducible and significant results. The choice of a suitable test procedure should be made by the relevant Technical Committee.

NOTE 2 For voltages U_m above 800 kV meeting some specified procedures, tolerances and uncertainties may not be achievable.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60507:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*

IEC 61083-1, *Instruments and software used for measurement in high-voltage impulse tests – Part 1: Requirements for instruments*

IEC 61083-2, *Digital recorders for measurements in high-voltage impulse tests – Part 2: Evaluation of software used for the determination of the parameters of impulse waveforms*

IEC 62475, *High-current test techniques: Definitions and requirements for test currents and measuring systems*

3 Terms and definitions

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

3.1 Definitions related to characteristics of discharges

3.1.1

disruptive discharge

failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between electrodes to practically zero

NOTE 1 Non-sustained disruptive discharge in which the test object is momentarily bridged by a spark or arc may occur. During these events the voltage across the test object is momentarily reduced to zero or to a very small value. Depending on the characteristics of the test circuit and the test object, a recovery of dielectric strength may occur and may even allow the test voltage to reach a higher value. Such an event should be interpreted as a disruptive discharge unless otherwise specified by the relevant Technical Committee.

NOTE 2 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric the loss may be only temporary.

3.1.2

sparkover

disruptive discharge that occurs in a gaseous or liquid dielectric

3.1.3

flashover

disruptive discharge that occurs over the surface of a dielectric in a gaseous or liquid dielectric

3.1.4

puncture

disruptive discharge that occurs through a solid dielectric

3.1.5

disruptive-discharge voltage value of a test object

value of the test voltage causing disruptive discharge, as specified, for the various tests, in the relevant clauses of the present standard

3.1.6

non-disruptive discharge

discharge between intermediate electrodes or conductors where the test voltage does not collapse to zero

NOTE 1 Such an event should not be interpreted as a disruptive discharge unless so specified by the relevant Technical Committee.

NOTE 2 Some non-disruptive discharges are termed “partial discharges” and are dealt with in IEC 60270.

3.2 Definitions relating to characteristics of the test voltage

3.2.1

prospective characteristics of a test voltage

characteristics which would have been obtained if no disruptive discharge had occurred. When a prospective characteristic is used, this shall always be stated.

3.2.2

actual characteristics of a test voltage

those characteristics which occur during the test at the terminals of the test object

3.2.3

value of the test voltage

as defined in the relevant clauses of this standard

3.2.4

withstand voltage of a test object

specified prospective voltage value which characterizes the insulation of the object with regard to a withstand test

NOTE 1 Unless otherwise specified, withstand voltages are referred to standard reference atmospheric conditions (see 4.3.1).

NOTE 2 This applies to external insulation only.

3.2.5

assured disruptive-discharge voltage of a test object

specified prospective voltage value which characterizes its performance with regard to a disruptive-discharge test

3.3 Definitions relating to tolerance and uncertainty

3.3.1

tolerance

constitutes the permitted difference between the measured value and the specified value

NOTE 1 This difference should be distinguished from the uncertainty of a measurement.

NOTE 2 A pass/fail decision is based on the measured value, without consideration of the measurement uncertainty.

3.3.2

uncertainty (of measurement)

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could be reasonably attributed to the measurand

[IEV 311-01-02]

NOTE 1 In this standard, all uncertainty values are specified at a level of confidence of 95 %.

NOTE 2 Uncertainty is positive and given without sign.

NOTE 3 It should not be confused with the tolerance of a test-specified value or parameter.

3.4 Definitions relating to statistical characteristics of disruptive-discharge voltage values

3.4.1

disruptive-discharge probability of a test object

p

probability that one application of a certain prospective voltage value of a given shape will cause disruptive discharge in the test object

NOTE The parameter p may be expressed as a percentage or a proper fraction.

3.4.2

withstand probability of a test object

q

probability that an application of a certain prospective voltage value of a given shape does not cause a disruptive discharge on the test object

NOTE If the disruptive-discharge probability is p , the withstand probability q is $(1 - p)$.

3.4.3

p % disruptive-discharge voltage of a test object

U_p

prospective voltage value which has p % probability of producing a disruptive discharge on the test object

NOTE 1 Mathematically the p % disruptive-discharge voltage is the quantile of the order p (or p quantile) of the breakdown voltage.

NOTE 2 U_{10} is called the “statistical withstand voltage” and U_{90} is called the “statistical assured disruptive-discharge voltage”.

3.4.4

50 % disruptive-discharge voltage of a test object

U_{50}

prospective voltage value which has a 50 % probability of producing a disruptive discharge on the test object

3.4.5

arithmetic mean value of the disruptive-discharge voltage of a test object,

U_a

$$U_a = \frac{1}{n} \sum_{i=1}^n U_i$$

where

U_i is the measured disruptive-discharge voltage and

n is the number of observations (discharges).

NOTE For symmetric distributions U_a is identical to U_{50} .

3.4.6

standard deviation of the disruptive voltage of a test object

s

a measure of the dispersion of the disruptive voltage estimated by

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (U_i - U_a)^2}$$

where

U_i is the i^{th} measured disruptive voltage and

U_a is the arithmetic mean of the disruptive voltages (in most cases it is identical to U_{50}).

n is the number of observations (discharges).

NOTE 1 It can also be evaluated by the difference between the 50 % and 16 % disruptive-discharge voltages (or between the 84 % and 50 % disruptive-discharge voltages). It is often expressed in per unit or percentage value referred to the 50 % disruptive-discharge voltage.

NOTE 2 For successive disruptive-discharge tests the standard deviation s is defined by the formula. For multiple level and up-and-down tests it is defined by the difference of the quantiles. The methods are equivalent because, between $p = 16$ % and $p = 84$ % all distribution functions are nearly identical.

3.5 Definitions relating to classification of insulation in test objects

3.5.1

external insulation

air insulation and the exposed surfaces of solid insulation of the equipment, which are subject both to dielectric stresses and to the direct effects of atmospheric and other external conditions

3.5.2

internal insulation

internal solid, liquid or gaseous elements of the insulation of equipment protected from the direct effects of external conditions such as pollution, humidity and vermin

3.5.3

self-restoring insulation

insulation which completely recovers its insulating properties after a disruptive discharge caused by the application of a test voltage

[IEV 604-03-04, modified]

3.5.4

non-self-restoring insulation

insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge caused by the application of a test voltage

[IEV 604-03-05, modified]

NOTE In high-voltage apparatus, parts of both self-restoring and non-self-restoring insulation are always operating in combination and some parts may be degraded by repeated or continued voltage applications. The behaviour of the insulation in this respect should be taken into account by the relevant Technical Committee when specifying the test procedures to be applied.

4 General requirements

4.1 General requirements for test procedures

The test procedures applicable to particular types of test objects, for example, the test voltage, the polarity to be used, the preferred order if both polarities are to be used, the number of applications and the interval between applications shall be specified by the relevant Technical Committee, having regard to such factors as:

- the required accuracy of the test results;
- the random nature of the observed phenomena;
- any polarity dependence of the measured characteristics and
- the possibility of progressive deterioration with repeated voltage applications.

At the time of a test, the test object shall be complete in all essential details, and it should have been processed in the normal manner for similar equipment.

At the time of a test, the test object should have become acclimatised as much as practicable to the ambient atmospheric conditions of the test area. The period allocated to reach equilibrium should be recorded.

4.2 Arrangement of the test object in dry tests

The disruptive-discharge characteristics of a test object with external insulation may be affected by its general arrangement (for example, proximity effects such as distance in air from other live or earthed structures, height above ground level and the arrangement of its high-voltage lead). The general arrangement should be specified by the relevant Technical Committee.

NOTE 1 A clearance to extraneous structures not less than 1,5 times the length of the shortest possible discharge path on the test object usually makes such proximity effects negligible. In wet or pollution tests, or wherever the voltage distribution along the test object and the electric field around its energized electrode are sufficiently independent of external influences, smaller clearances may be acceptable, provided that discharges do not occur to extraneous structures.

NOTE 2 In the case of a.c. or positive switching-impulse voltage tests above 750 kV (peak) the influence of an extraneous structure may be considered as negligible if its distance from the energized electrode is also not less than the height of this electrode above the ground plane. A guide for recommended minimum clearance is given in Figure 1, as a function of the highest test voltage. Significant shorter clearances may be suitable in individual

cases. However, an experimental adaptation or a field calculation, taking into account a voltage dependent maximum field strength as described in the literature [1, 2]¹, is recommended.

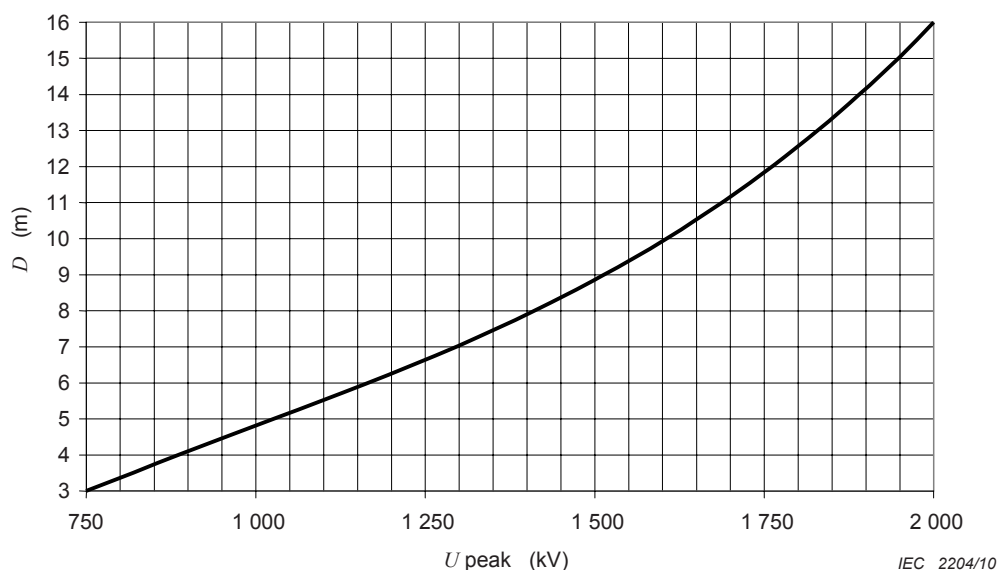


Figure 1 – Recommended minimum clearance D of extraneous live or earthed objects to the energized electrode of a test object, during an a.c. or positive switching impulse test at the maximum voltage U applied during test

If not otherwise specified by the relevant Technical Committee, the test should be made at ambient atmospheric conditions in the test area without extraneous precipitation or pollution. The procedure for voltage application shall be as specified in the relevant clauses of this standard.

4.3 Atmospheric corrections in dry tests

4.3.1 Standard reference atmosphere

The standard reference atmosphere is:

- temperature $t_0 = 20\text{ °C}$;
- absolute pressure $p_0 = 1\,013\text{ hPa}$ (1 013 mbar) ;
- absolute humidity $h_0 = 11\text{ g/m}^3$.

NOTE 1 An absolute pressure of 1 013 hPa corresponds to the height of 760 mm of the mercury column in a mercury barometer at 0 °C. If the barometer height is H mm of mercury, the atmospheric pressure in hectopascal is approximately:

$$p = 1,333 H \text{ hPa}$$

Correction for temperature with respect to the height of the mercury column is considered to be negligible.

NOTE 2 Instruments automatically correcting pressure to sea level are not suitable and should not be used.

4.3.2 Atmospheric correction factors for air gaps

The disruptive discharge of external insulation depends upon the atmospheric conditions. Usually, the disruptive-discharge voltage for a given path in air is increased by an increase in either air density or humidity. However, when the relative humidity exceeds about 80 %, the disruptive-discharge voltage becomes irregular, especially when the disruptive discharge occurs over an insulating surface.

¹ Numbers in square brackets refer to the Bibliography.

NOTE Atmospheric corrections do not apply to flashover, only to sparkover.

The disruptive-discharge voltage is proportional to the atmospheric correction factor K_t that results from the product of two correction factors:

- the air density correction factor k_1 (see 4.3.4.1);
- the humidity correction factor k_2 (see 4.3.4.2).

$$K_t = k_1 k_2$$

4.3.3 Application of correction factors

4.3.3.1 Standard procedure

By applying correction factors, a disruptive-discharge voltage measured in given test conditions (temperature t , pressure p , humidity h) may be converted to the value, which would have been obtained under the standard reference atmospheric conditions (t_0 , p_0 , h_0).

Disruptive-discharge voltages, U , measured at given test conditions are corrected to U_0 corresponding to standard reference atmosphere by dividing by K_t :

$$U_0 = U / K_t$$

The test report shall always contain the actual atmospheric conditions during the test and the correction factors applied.

4.3.3.2 Converse procedure

Conversely, where a test voltage is specified for standard reference conditions, it shall be converted into the equivalent value under the test conditions and this may require an iterative procedure.

If not otherwise specified by the relevant Technical Committee, the voltage U to be applied during a test on external insulation is determined by multiplying the specified test voltage U_0 by K_t ;

$$U = U_0 K_t$$

However, as U enters into the calculation of K_t , an iterative procedure might have to be used (see Annex E).

NOTE 1 The test for the correct choice of U for the calculation of K_t is to divide U by K_t . If the result is the specified test voltage, U_0 , then a correct choice of U has been made. If U_0 is too high, U has to be reduced but if it is too low, it has to be increased.

NOTE 2 When K_t is close to unity, iterative calculation is not necessary.

NOTE 3 In correcting power-frequency voltage the peak value has to be used, because the discharge behaviour is based on the peak value.

4.3.4 Correction factor components

4.3.4.1 Air density correction factor, k_1

The air density correction factor k_1 depends on the relative air density δ and can be generally expressed as:

$$k_1 = \delta^m$$

where m is an exponent given in 4.3.4.3.

When the temperatures t and t_0 are expressed in degrees Celsius and the atmospheric pressures p and p_0 are expressed in the same units, the relative air density is:

$$\delta = \frac{p}{p_0} \times \frac{273 + t_0}{273 + t}$$

The correction is considered reliable for $0,8 < k_1 < 1,05$.

4.3.4.2 Humidity correction factor, k_2

The humidity correction factor may be expressed as:

$$k_2 = k^w$$

where w is an exponent given in 4.3.4.3 and k is a parameter that depends on the type of test voltage and may be obtained as a function of the ratio of absolute humidity, h , to the relative air density, δ , using the following equations (Figure 2):

DC $k = 1 + 0,014(h/\delta - 11) - 0,00022(h/\delta - 11)^2$ for $1 \text{ g/m}^3 < h/\delta < 15 \text{ g/m}^3$

AC $k = 1 + 0,012(h/\delta - 11)$ for $1 \text{ g/m}^3 < h/\delta < 15 \text{ g/m}^3$

Impulse $k = 1 + 0,010(h/\delta - 11)$ for $1 \text{ g/m}^3 < h/\delta < 20 \text{ g/m}^3$

NOTE The impulse equation is based on experimental results for positive lightning-impulse waveforms. This equation also applies to negative lightning-impulse voltages and switching-impulse voltages.

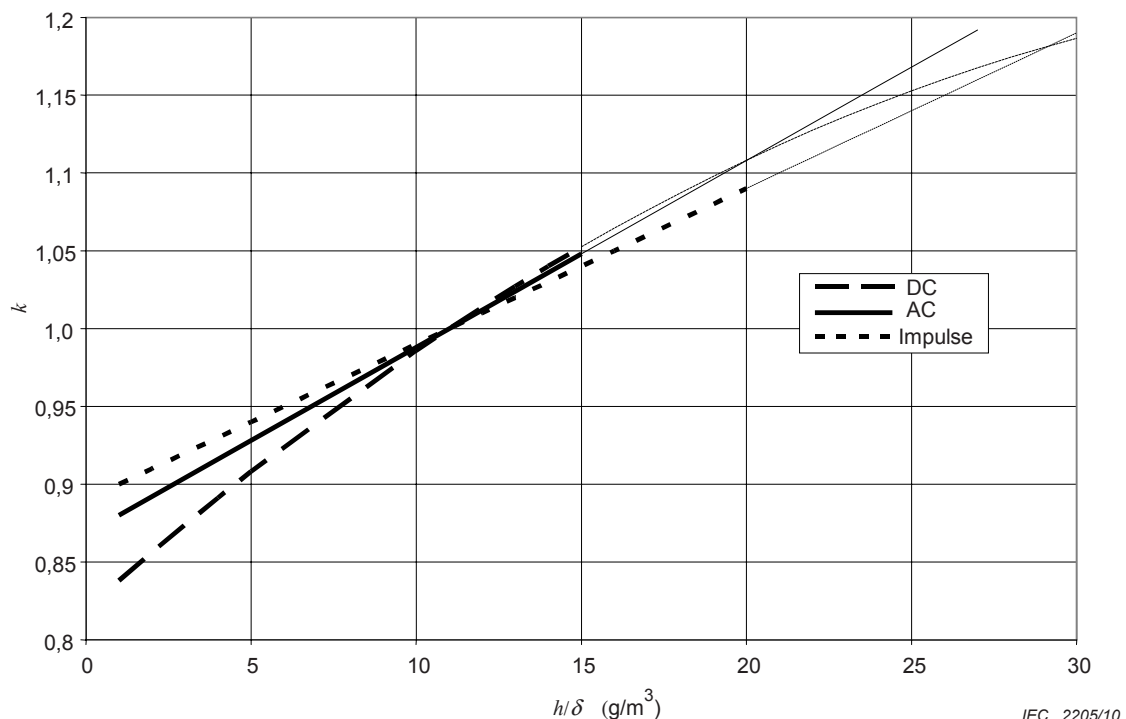


Figure 2 – k as a function of the ratio of the absolute humidity h to the relative air density δ (see 4.3.4.2 for limits of applicability)

For U_m below 72,5 kV (or approximately gap lengths $l < 0,5$ m) no humidity correction can at present be specified.

NOTE For specific apparatus, the relevant Technical Committee has specified other procedures (e.g. IEC 62271-1).

4.3.4.3 Exponents m and w

As the correction factors depend on the type of pre-discharges, this fact can be taken into account by considering the parameter:

$$g = \frac{U_{50}}{500 L \delta k}$$

where U_{50} is the 50 % disruptive-discharge voltage (measured or estimated) at the actual atmospheric conditions, in kilovolt peak,

L is the minimum discharge path in m,

δ is the relative air density and

k is the dimension less parameter defined in 4.3.4.2.

In the case of a withstand test where an estimate of the 50 % disruptive-discharge voltage is not available, U_{50} can be assumed to be 1,1 times the test voltage, U_0 .

The exponents, m and w , are obtained from Table 1 for the specified ranges of g (Figure 3).

Table 1 – Values of exponents, m for air density correction and w for humidity correction, as a function of the parameter g

g	m	w
$<0,2$	0	0
0,2 to 1,0	$g(g-0,2)/0,8$	$g(g-0,2)/0,8$
1,0 to 1,2	1,0	1,0
1,2 to 2,0	1,0	$(2,2-g)(2,0-g)/0,8$
$>2,0$	1,0	0

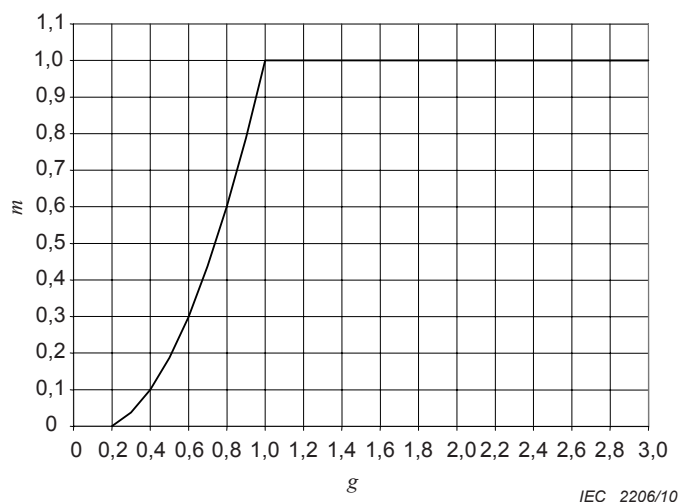


Figure 3a – Values of exponent m for air density correction as a function of parameter g

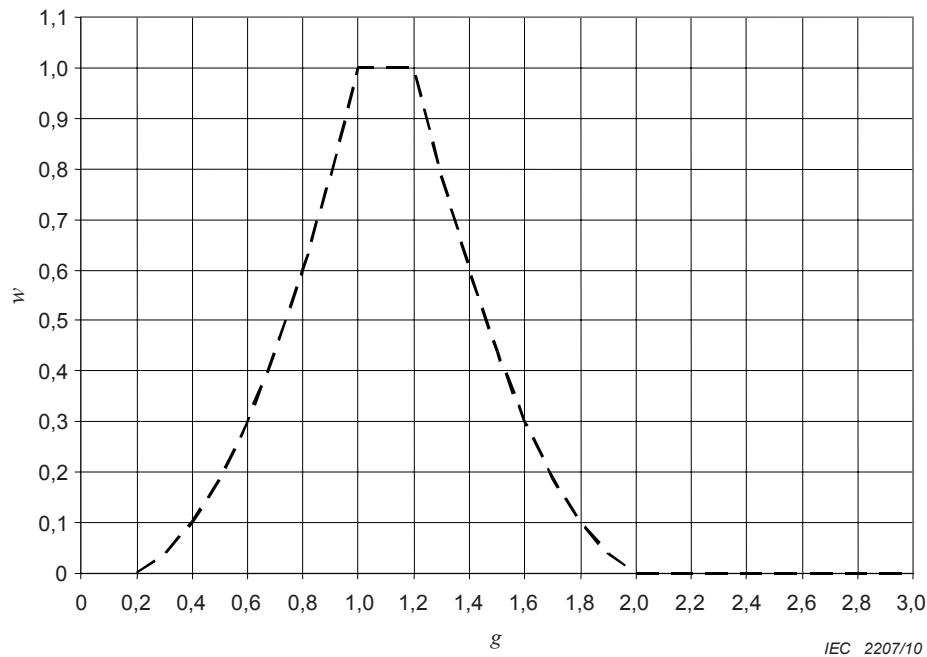


Figure 3b – Values of exponent w for humidity correction as a function of parameter g

Figure 3 – Values of exponents m and w

4.3.5 Measurement of atmospheric parameters

4.3.5.1 Humidity

The humidity should preferably be determined with an instrument measuring directly the absolute humidity with an expanded uncertainty not larger than 1 g/m^3 .

Measurement of relative humidity and the ambient temperature can also be used for the determination of the absolute humidity, using the formula below, provided that the accuracy of the absolute humidity determination in this case is the same as required above.

$$h = \frac{6,11 \times R \times e^{\frac{17,6 \times t}{243+t}}}{0,4615 \times (273 + t)}$$

where

h is the absolute humidity in g/m^3 ,

R is the relative humidity in percent and

t is the ambient temperature in $^{\circ}\text{C}$.

NOTE This measurement may also be made by means of a ventilated wet and dry bulb hygrometer. The absolute humidity as a function of the thermometer readings is determined from Figure 4, which also permits determination of the relative humidity. It is important to provide adequate airflow so as to reach a steady state and to read the thermometers carefully in order to avoid excessive errors in the determination of the humidity.

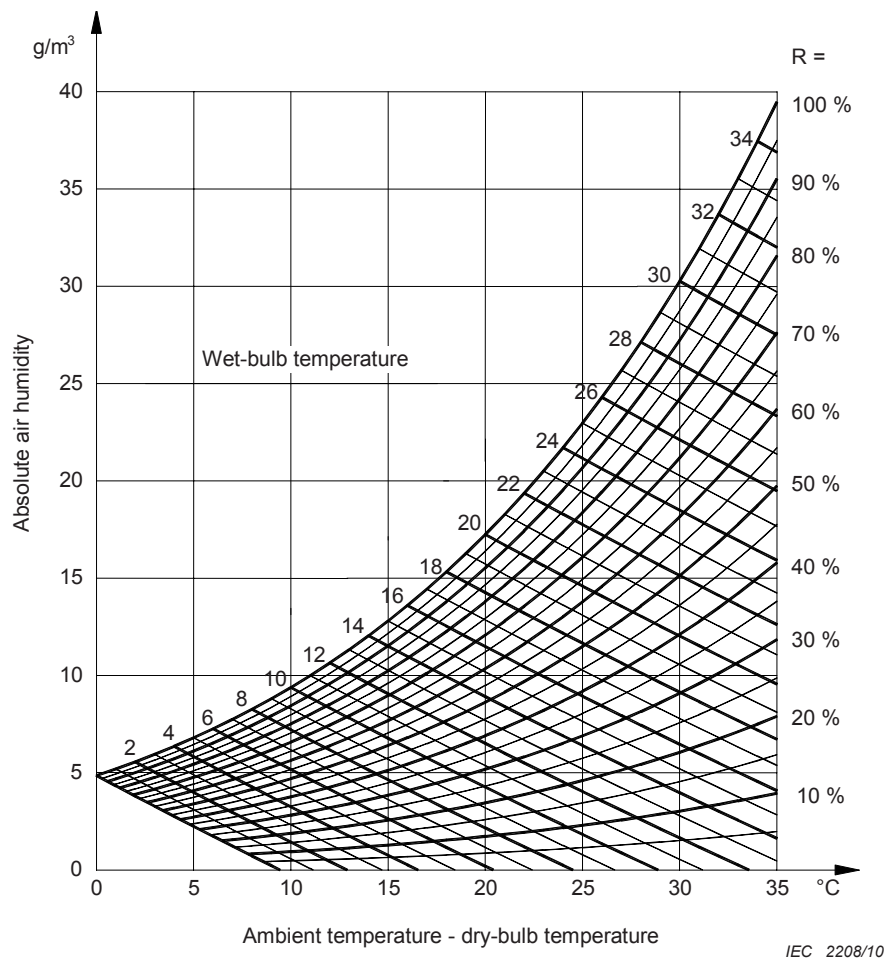


Figure 4 – Absolute humidity of air as a function of dry- and wet-bulb thermometer readings

4.3.5.2 Temperature

The ambient temperature should be measured with an expanded uncertainty of not larger than 1 °C.

4.3.5.3 Absolute pressure

The ambient absolute pressure should be measured with an expanded uncertainty of not larger than 2 hPa.

4.3.6 Conflicting requirements for testing internal and external insulation

While withstand levels are specified under standard reference atmospheric conditions, cases will arise where the application of atmospheric corrections (due to atmospheric conditions differing from the standard reference ones) results in the withstand level for internal insulation appreciably in excess of that for the associated external insulation. In such cases measures to enhance the withstand level of the external insulation shall be adopted to permit application of the correct test voltage to the internal insulation. These measures should be specified by the relevant Technical Committee with reference to the requirements of particular classes of apparatus and could include immersion of the external insulation in liquids or compressed gases.

For those cases where the test voltage of the external insulation is higher than that of the internal insulation, the external insulation can only be correctly tested when the internal

insulation is especially designed with increased strength. If not, the internal insulation should be tested with the rated value and the external insulation be tested by means of test fixtures unless the relevant Technical Committee states otherwise, in which case it shall specify the test procedure to be used.

4.4 Wet tests

4.4.1 Wet test procedure

This wet test procedure is intended to simulate the effect of natural rain on external insulation. It is recommended for tests with all types of test voltages and on all types of apparatus.

The relevant Technical Committee should specify the arrangement of the test object during the test.

The test object shall be sprayed with water of prescribed resistivity and temperature (see Table 2) falling on it as droplets (avoiding fog and mist) and directed so that the vertical and horizontal components of the spray intensity are approximately equal. These intensities are measured with a divided collecting vessel having openings of 100 cm² to 750 cm², one horizontal and one vertical with the vertical opening facing the spray.

The position of the test object relative to the vertical and horizontal rain components shall be specified by the relevant Technical Committee.

In general, the reproducibility of wet test results is less than that for other high-voltage discharge or withstand tests. To minimize the dispersion, the following precautions shall be taken:

- The collecting vessel shall be placed close to the test object, but avoiding the collection of drops or splashes from it. During the measuring period, it should be moved slowly over a sufficient area to average the effect of non-uniformities of the spray from individual nozzles. This measuring zone shall have a width equal to that of the test object and a maximum height of 1 m.
- For test objects between 1 m and 3 m in height, the individual measurements shall be made at the top, centre and bottom of the test object. Each measuring zone shall cover only one third of the height of the test object.
- For test objects exceeding 3 m in height, the number of measuring zones shall be increased to cover the full height of the test object without overlapping.
- The above procedures shall be suitably adapted for test objects having large horizontal dimensions.
- The spread of results may be reduced if the test object is cleaned with a surface-active detergent, which has to be removed before the beginning of wetting.
- The spread of results may also be affected by local anomalous (high or low) precipitation rates. It is recommended to detect these by localized measurements and to improve the uniformity of the spray, if necessary.

The spray apparatus shall be adjusted to produce, within the specified tolerances, precipitation conditions at the test object given in Table 2.

Any type and arrangement of nozzles meeting the requirements given in Table 2 may be used.

Table 2 – Precipitation conditions for standard procedure

Precipitation condition	Unit	Range
Average precipitation rate of all measurements:		
– vertical component	[mm/min]	1,0 to 2,0
– horizontal component	[mm/min]	1,0 to 2,0
Limits for any individual measurement and for each component	[mm/min]	±0,5 from average
Temperature of water	[°C]	Ambient temperature ±15
Conductivity of water	[µS/cm]	100 ± 15

The water temperature and resistivity shall be measured on a sample collected immediately before the water reaches the test object. They may also be measured at other locations (e.g., in a storage reservoir) provided that a check ensures that no significant change occurs by the time the water reaches the test object.

The test object shall be pre-wetted initially for at least 15 min under the above-specified conditions and these conditions shall remain within the specified tolerances throughout the test, which should be performed without interrupting the wetting. The pre-wetting time shall not include the time needed for adjusting the spray. It is also possible to perform an initial pre-wetting by unconditioned mains water for 15 min, followed without interruption of the spray by a second pre-wetting for at least 2 min before the test begins, using water with all the correct precipitation conditions, which should be measured immediately before starting the test.

Unless otherwise specified by the relevant Technical Committee, the test procedure for wet tests shall be the same as that specified for the corresponding dry tests. The test duration for an a.c. test shall be 60 s, if not otherwise specified. In general, for alternating and direct voltage wet withstand tests, it is recommended that one flashover should be permitted provided that in a repeat test no further flashover occurs.

NOTE For a.c. apparatus of large dimensions, such as those having a maximum rated voltage, U_m , higher than 800 kV, no appropriate wet test procedure is available at present.

4.4.2 Atmospheric corrections for wet tests

A density correction factor shall be applied as specified in 4.3, but no humidity correction factor shall be applied for wet tests.

4.5 Artificial pollution tests

Artificial pollution tests are intended to provide information on the behaviour of external insulation under conditions representative of pollution in service, although they do not necessarily simulate any particular service conditions. They are described in IEC 60507.

5 Tests with direct voltage

5.1 Definitions for direct voltage tests

5.1.1

value of the test voltage

arithmetic mean value

5.1.2

ripple

periodic deviation from the arithmetic mean value of the test voltage

5.1.3

ripple amplitude

half the difference between the maximum and minimum values

NOTE In cases where the ripple shape is nearly sinusoidal, true r.m.s. values multiplied by $\sqrt{2}$ are acceptable for determination of the ripple amplitude.

5.1.4

ripple factor

ratio of the ripple amplitude to the value of test voltage

5.1.5

voltage drop

instantaneous reduction of the test voltage for a short duration of up to a few seconds

NOTE Voltage drop may be caused by non-disruptive discharges.

5.2 Test voltage

5.2.1 Requirements for the test voltage

5.2.1.1 Voltage shape

The test voltage, as applied to the test object, should be a direct voltage with not more than 3 % ripple factor, unless otherwise specified by the relevant Technical Committee.

NOTE Increasing ripple amplitude is directly related to increasing resistive load currents. Dielectric testing where heavy streamers are present may cause excessive ripple and/or voltage drop. Wet testing and pollution testing by their very nature require sources suitable for high resistive currents, see IEC 60507.

5.2.1.2 Tolerances

For test durations not exceeding 60 s, the measured values of the test voltage shall be maintained within ± 1 % of the specified level throughout the test. For test durations exceeding 60 s, the measured value of the test voltage shall be maintained within ± 3 % of the specified level throughout the test.

NOTE It is emphasized that the tolerance constitutes the permitted difference between the specified value and that actually measured. This difference should be distinguished from the uncertainty of a measurement (see 3.3.1).

The source characteristics should be sufficient to allow charging of the capacitance of the test object in a reasonably short time. In the case of wet or pollution tests, the source, including its storage capacitance, should also be adequate to supply the transient discharge currents of the test object with a voltage drop of < 10 %.

5.2.2 Generation of the test voltage

The test voltage is generally obtained by means of transformer rectifier circuits. The requirements to be met by the test-voltage source depend considerably upon the type of apparatus that is to be tested and on the test conditions. These requirements are determined mainly by the value and nature of the test current to be supplied, the important constituents of which are indicated in 5.2.4.

5.2.3 Measurement of the test voltage

The measurement of the arithmetic mean value, the ripple factor and any transient in the test voltage shall be made with approved measuring systems (see IEC 60060-2).

Attention is drawn to the requirements the on response characteristics of converting devices used for measuring ripple, transients or voltage stability.

5.2.4 Measurement of the test current

When measurements of current are made through the test object, a number of separate components may be recognized. These differ from each other by several orders of magnitude for the same test object and test voltage. They consist of:

- the capacitive current, due to the initial application of the test voltage and to any ripple or other fluctuations imposed on it;
- the dielectric absorption current, due to slow charge displacements within the insulation and persisting for periods of a few seconds up to several hours. This process is partially reversible, currents of the opposite polarity being observed when the test object is discharged and short-circuited;
- the continuous leakage current, which is the final steady direct current attained at constant applied voltage after the above components have decayed to zero;
- partial discharge currents.

Measurement of the first three components necessitates the use of instruments covering a wide range of current magnitudes. It is important to ensure that the instrument, or the measurement of any one component of the current, is not adversely affected by the other components. Information concerning the condition of the insulation may sometimes be obtained by observing current variations with respect to time, during non-destructive tests.

The relative magnitude and the importance of each component of current depend on the type and the condition of the test object, the purpose for which the test is being made and the duration of the test. Accordingly, the measurement procedures should be specified by the relevant Technical Committee, especially when it is required to distinguish a particular component.

Current measurements shall be made with a calibrated measuring system.

Measurements of partial discharge pulse currents are made with special instruments, which are dealt with in IEC 60270.

NOTE Voltage protective devices should always be used in d.c. current measurement circuits due to the possibility of disruptive-discharge currents occurring that are much larger than the normal currents.

5.3 Test procedures

5.3.1 Withstand voltage tests

The voltage should be applied to the test object starting at a value sufficiently low to prevent any effect of overvoltage due to switching transients. It should be raised sufficiently slowly to permit reading of the measuring instruments, but not so slowly as to cause unnecessary prolongation of stress to the test object near the test voltage U . These requirements are in general met if the rate of rise is about 2 % of U per second when the applied voltage is above 75 % of U . It shall be maintained for the specified time and then reduced by discharging the circuit capacitance, including that of the test object, through a suitable resistor.

The test duration shall be specified by the relevant Technical Committee taking into consideration that the time to reach the steady-state voltage distribution depends on the resistances and capacitances of the test object components. When not otherwise specified by the relevant Technical Committee, the duration of a withstand test shall be 60 s.

The polarity of the voltage or the order in which voltages of each polarity are applied, and any required deviation from the above specifications, shall be specified by the relevant Technical Committee.

The requirements of the test are satisfied if no disruptive discharge occurs on the test object.

5.3.2 Disruptive-discharge voltage tests

The voltage shall be applied and raised continuously, as for a withstand voltage test, until a disruptive discharge occurs on the test object. The last value of the test voltage recorded before the instant of the disruptive discharge shall be recorded. This shall be repeated for the number of times n specified in the test procedure to give a set of n measured voltages.

The relevant Technical Committee shall specify the rate of voltage rise, the number of voltage applications and the procedure for evaluating the test results (see Annex A).

5.3.3 Assured disruptive-discharge voltage tests

The voltage shall be applied and raised continuously, as for a withstand voltage test, until a disruptive discharge occurs on the test object. The last value of the test voltage reached just before the instant of the disruptive discharge shall be recorded. This shall be repeated for the number of times n specified in the test procedure to give a set of n measured voltages.

The requirements of the test are satisfied if no voltage in this set exceeds the assured disruptive-discharge voltage.

The relevant Technical Committee shall specify the number of voltage applications and the rate of voltage rise.

6 Tests with alternating voltage

6.1 Definitions for alternating voltage tests

6.1.1

peak value of an alternating voltage

average of the magnitudes of the positive and negative peak values

NOTE In many cases instruments measuring only one polarity peak are used. Measuring only one polarity is acceptable as long as waveform symmetry is within the limits set in 6.2.1.1.

6.1.2

value of the test voltage

its peak value divided by $\sqrt{2}$

NOTE The relevant Technical Committee may require a measurement of the r.m.s. value of the test voltage instead of the peak value for cases where the r.m.s. value may be of importance, for instance, when thermal effects are involved.

6.1.3

r.m.s. value

square root of the mean value of the square of the voltage values during a complete cycle

6.1.4

voltage drop

instantaneous reduction of the test voltage for a short duration of up to a few periods

6.2 Test Voltage

6.2.1 Requirements for the test voltage

6.2.1.1 Voltage waveshape

The test voltage shall be an alternating voltage generally having a frequency in the range 45 Hz to 65 Hz, normally referred to as power-frequency test voltage. Special tests may be required at frequencies considerably below or above this range, as specified by the relevant Technical Committee.