

AS 1931.1—1996

IEC 60-1:1989

IEC 60-1:1989/Cor.:1992

Australian Standard[®]

High-voltage test techniques

Part 1: General definitions and test requirements

This Australian Standard was prepared by Committee EL/7, Power Switchgear. It was approved on behalf of the Council of Standards Australia on 10 November 1995 and published on 5 March 1996.

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Australian British Chamber of Commerce
Australian Chamber of Commerce and Industry
Australian Electrical and Electronic Manufacturers Association
Electricity Supply Association of Australia
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Railways of Australia
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This Standard was issued in draft form for comment as DR 95212.

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High-voltage test techniques

Part 1: General definitions and test requirements

PUBLISHED BY STANDARDS AUSTRALIA
(STANDARDS ASSOCIATION OF AUSTRALIA)
1 THE CRESCENT, HOMEBUSH, NSW 2140

ISBN 0 7337 0231 70



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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL/7 on Power Switchgear. It is identical with and has been reproduced from IEC 60-1:1989, *High-voltage test techniques*, Part 1: *General definitions and test requirements*, and the Corrigendum to supersede AS 1931.1—1976, *High voltage testing techniques*, Part 1: *General definitions, test requirements, test procedures and measuring devices*.

This Standard is the result of a consensus among representatives on the Joint Committee to produce it as an Australian Standard.

This Standard is Part 1 of AS 1931, *High-voltage test techniques*, which is published in Parts as follows:

Part 1: General definitions and test requirements

Part 2: Measuring systems

The objective of this Standard, in addition to that stated in Clause 2, is to bring it into line with IEC 60-1.

The correction required by the Corrigendum is marked with a marginal bar.

As this Standard is reproduced from an international Standard, the following applies:

- (a) Its number is shown only on the cover and title page, while the international Standard number appears only on the cover.
- (b) In the source text, 'this International Standard' should read 'this Australian Standard'.
- (c) A full point substitutes for a comma when referring to a decimal marker.

References to international Standards should be replaced by equivalent Australian Standards, as follows:

<i>References to International Standard</i>		<i>Australian Standards</i>	
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34	Rotating electrical machines	—	
34-4	Part 4: Methods for determining synchronous machine quantities from tests		
52	Recommendations for voltage measurement by means of sphere-gaps (one sphere earthed)	2886	Voltage measurement—Sphere-gap method (one sphere earthed)
60	High-voltage test techniques	1931	High-voltage test techniques
60-3	Part 3: Measuring devices	1931.2	Part 2: Measuring systems
60-4	Part 4: Application guide for measuring devices		
270	Partial discharge measurements	1018	Partial discharge measurements
507	Artificial pollution tests on high-voltage insulators to be used on a.c. systems	—	

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Originated as AS C94—1942 (being endorsement of
BS 923—1940 without Amendment).
Previous edition AS 1931.1—1976.
Second edition 1996.

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AUSTRALIAN STANDARD

HIGH VOLTAGE TEST TECHNIQUES

PART 1:
GENERAL DEFINITIONS AND TEST REQUIREMENTS

Section 1: General

1 Scope

This standard is applicable to:

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

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

This standard is not intended to be used for electromagnetic compatibility tests on electric or electronic equipment.

2 Object

The object of this standard is:

- to define terms of both general and specific applicability;
- to present general requirements regarding test objects and test procedures;
- to describe methods for generation and measurement of test voltages and currents;
- to describe test procedures;
- to describe methods for the evaluation of test results and to indicate criteria for acceptance or refusal.

Definitions and requirements concerning approved measuring devices and checking methods are given in IEC Publication 60-3: High Voltage Test Techniques—Measuring Devices.

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.

Section 2: General Definitions

3 Impulses

An impulse is an intentionally applied aperiodic transient voltage or current which usually rises rapidly to a peak value and then falls more slowly to zero.

For special purposes, impulses having approximately linearly rising fronts or transients of oscillating or approximately rectangular form are used.

The term “impulse” is to be distinguished from the term “surge” which refers to transients occurring in electrical equipment or networks in service.

3.1 *Lightning and switching impulses*

A distinction is made between lightning and switching impulses on the basis of duration of the front. Impulses with front duration up to 20 μs are defined as lightning impulses and those with longer fronts are defined as switching impulses.

Generally, switching impulses are also characterized by total durations considerably longer than those of lightning impulses.

4 Characteristics related to disruptive discharge and test voltages

4.1 *Disruptive discharge*

In this standard, the term “disruptive discharge” (sometimes referred to as “electrical breakdown”) relates to phenomena associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes practically to zero. It applies to electrical breakdown in solid, liquid and gaseous dielectrics and combinations of these.

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 permit 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.

Non-disruptive discharges such as those between intermediate electrodes or conductors may also occur without reduction of the test voltage to zero. Such an event should not be interpreted as a disruptive discharge unless so specified by the relevant Technical Committee.

Some non-disruptive discharges are termed “partial discharges” and are dealt with in IEC Publication 270: Partial Discharge Measurement.

The term “sparkover” is used when a disruptive discharge occurs in a gaseous or liquid medium.

The term “flashover” is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

The term “puncture” is used when a disruptive discharge occurs through a solid dielectric.

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.

4.2 *Characteristics of the test voltage*

The characteristics of a test voltage are those characteristics specified in this standard for designating the different types of voltage excursion that define the test voltage.

4.2.1 *Prospective characteristics of a test voltage*

The prospective characteristics of a test voltage causing disruptive discharge are the characteristics which would have been obtained if no disruptive discharge had occurred. When a prospective characteristic is used, this shall always be stated.

4.2.2 *Actual characteristics of a test voltage*

The actual characteristics of a test voltage are those which occur during the test at the terminals of the test object.

4.2.3 *Value of the test voltage*

The value of the test voltage is defined in the relevant Clauses of the present standard.

4.3 *Disruptive discharge voltage of a test object*

The disruptive discharge voltage of a test object is the value of the test voltage causing disruptive discharge, as specified, for the various tests, in the relevant Clauses of the present standard.

4.4 *Statistical characteristics of disruptive discharge voltages*

Disruptive discharge voltages are subject to random variations and, usually, a number of observations must be made in order to obtain a statistically significant value of the voltage. The test procedures, described in the present standard, are generally based on statistical considerations. Information on the statistical evaluation of test results is given in Appendix A.

4.4.1 *Disruptive discharge probability p of a test object*

The disruptive discharge probability p of a test object is the probability that one application of a certain prospective voltage value of a given shape will cause disruptive discharge in the test object. The parameter p may be expressed as a percentage or a fraction.

4.4.2 *Withstand probability q of a test object*

The withstand probability q of a test object is the probability that one application of a certain prospective voltage value of a given shape does not cause a disruptive discharge on the test object. If the disruptive discharge probability is p , the withstand probability q is $(1 - p)$.

4.4.3 *50% disruptive discharge voltage U_{50} of a test object*

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

4.4.4 *$p\%$ disruptive discharge voltage U_p of a test object*

The $p\%$ disruptive discharge voltage of a test object is the prospective voltage value which has $p\%$ probability of producing a disruptive discharge on the test object.

4.4.5 *Conventional deviation z of the disruptive discharge voltage of a test object*

The conventional deviation z of the disruptive discharge voltage of a test object is the difference between its 50% and 16% disruptive discharge voltages. It is often expressed in per unit or percentage value, referred to the 50% disruptive discharge voltage.

NOTE — If the disruptive-discharge probability function (see Appendix A) is close to a Gaussian function, z is correspondingly close to its standard deviation.

4.5 *Withstand voltage of a test object*

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

Unless otherwise specified, withstand voltages are referred to standard reference atmospheric conditions (see Clause 11.1).

4.6 *Assured disruptive discharge voltage of a test object*

The assured disruptive discharge voltage of a test object is a specified prospective voltage value which characterizes its performance with regard to a disruptive discharge test.

5 **Classification of insulation in test objects**

Insulation systems of apparatus and high voltage structures must basically be classified into self-restoring and non-self-restoring insulation and may consist of external and/or internal insulation.

5.1 *External insulation*

External insulation is the air insulation and the exposed surfaces of solid insulation of the equipment, which are subject both to dielectric stresses and to the effects of atmospheric and other external conditions such as pollution, humidity and vermin.

5.2 *Internal insulation*

Internal insulation comprises the internal solid, liquid or gaseous elements of the insulation of equipment, which are protected from the effects of atmospheric and other external conditions such as pollution, humidity and vermin.

5.3 *Self-restoring insulation*

Self-restoring insulation is the insulation which completely recovers its insulating properties after a disruptive discharge caused by the application of a test voltage.

5.4 *Non-self-restoring insulation*

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

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 shall be taken into account by the relevant Technical Committee when specifying the test procedures to be applied.

Section 3: General Requirements Relating to Test Procedures and Test Objects

6 General requirements for test procedures

The test procedures applicable to particular types of test objects, for example, 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 test results;
- the random nature of the observed phenomenon and any polarity dependence of the measured characteristics;
- the possibility of progressive deterioration with repeated voltage applications.

7 General arrangement of the test object

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.

The disruptive discharge characteristics of an object may be affected by its general arrangement (for example, by its clearance from other live or grounded structures, its height above ground level and the arrangement of its high voltage lead). The general arrangement should be specified by the relevant Technical Committee.

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.

In the case of a.c. or positive switching impulse 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 practical lower limit to this clearance is given in figure 1, as a function of the highest test voltage.

A withstand test may be acceptable when successfully performed with shorter distances to earthed objects.

8 Dry tests

The test object shall be dry and clean. If not otherwise specified by the relevant Technical Committee, the test should be made at ambient temperature and the procedure for voltage application shall be as specified in the relevant Clauses of this standard.

9 Wet tests

The preferred wet test procedure, described in 9.1, is intended to simulate the effect of natural rain on external insulation and is a revision of earlier test methods. It is recommended for tests with all types of test voltages and on all types of apparatus, but either of the alternative test methods given below are permitted if specified by the relevant Technical Committee.

Two earlier test methods, not intended to simulate natural rain, are described in 9.2. They have been in use for many years for tests with alternating voltages on apparatus having U_m up to 420 kV and many test data obtained by these methods exist.

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

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

9.1 Standard wet test procedure

The test object shall be sprayed with water of prescribed resistivity and temperature (see table 1) 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, 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 but not completely mask 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 1.

Any type and arrangement of nozzles meeting the requirements given in table 1 may be used. Examples of several nozzles which have been found satisfactory in practice are shown in figures 2a, 2b and 2c, together with typical performance data for each type. Greater spray distances may be obtained if the nozzles are directed upward at an angle of about 15°—25° to the horizontal. Note that if the water pressure is increased above the recommended limits, the water jets may break up prematurely and cause an unsatisfactory spray at the test object.

Table 1 — Precipitation conditions for standard procedure

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
Resistivity of water	Ωm	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.

9.2 Traditional procedures for wet tests with alternating voltages

For alternating voltage tests, two other procedures are also in use, details of which are given in table 2. They differ from the standard procedure, 9.1, primarily in that the precipitation rates are higher and that the minimum pre-wetting time is only 1 m.

Only the vertical component of the spray is specified; determination of the horizontal component is replaced by a visual estimate of the spray angle which should be approximately 45° at the test object.

Table 2 — Precipitation conditions for traditional procedures with alternating voltages

Characteristics		European practice	Practice in U.S.A.
Average precipitation rate of all measurements:			
— vertical component	mm/min	$3 \pm 0,3$	$5 \pm 0,5$
Limits for any individual measurement	mm/min	$3 \pm 0,75$	$5 \pm 1,25$
Water temperature	°C	Ambient temperature ± 15	
Water resistivity	Ωm	100 ± 10	178 ± 27
Type of nozzle as shown in figures		2a, 2b, 2c	figure 2d
Duration of wet withstand test	s	60	10

10 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.

The following specifications give some general guidance on artificial pollution testing. It is left to the relevant Technical Committee to introduce variations or to give more specific requirements for particular classes of apparatus. Such specific information is given in one instance by IEC 507.

The effects of washing of insulators in service by natural rain is not taken into consideration in any of the specified procedures.

10.1 *Preparation of test object*

Before testing for the first time, the metal parts of the test object, and any cement joints, may be painted with salt-water-resistant paint to ensure that corrosion products will not contaminate the insulating surfaces during a test.

The test object should then be carefully cleaned by washing with tap water to which trisodium phosphate (Na_3PO_3) has been added and rinsed with clean tap water. It shall not subsequently be touched by hand. Usually the insulating surfaces can be considered sufficiently clean and free of grease or other contaminating material if large continuous wet areas are observed during wetting.

It is left to the relevant Technical Committee to decide whether the test object should be tested in a vertical, horizontal or an inclined position.

10.2 *Test procedures*

Artificial pollution tests involve application of the pollution and the simultaneous or subsequent application of voltage. Generally, only methods in which the test voltage is held constant for at least several minutes are recommended. Other methods in which the voltage is raised gradually to flashover are not proposed for standardization but may be used for special purposes.

The pollution test may be made either to determine the maximum degree of pollution of the test object which allows a given test voltage to be withstood, or to determine the withstand voltage for a specified degree of pollution. For the purpose of comparing the results of several tests, or the performance of several test objects, the former procedure is preferable. Whichever test procedure is adopted, the number of measurements should be sufficient to obtain consistent average values, taking into account the statistical nature of the phenomenon. The number of tests required shall be specified by the relevant Technical Committee.

The pollution tests fall into two categories, the salt-fog method and the pre-deposited pollution method.

a) *The salt-fog method*

The test object is placed in a special chamber which can be filled by a salt fog. The method for producing the fog is described in Appendix B1. The ambient temperature in the chamber at the start of the test shall not be less than 5°C, nor greater than 30°C and the test object and the salt water shall be in thermal equilibrium with the ambient temperature.

The test object is thoroughly wetted with clean tap water. The salt-fog system, supplied by water of the prescribed salinity, is started when the test object is still wet and, simultaneously, the voltage is applied to the test object, raised rapidly to the specified value and kept constant during the specified time, usually 1 h, or until flashover

occurs. This procedure is repeated several times. Before each procedure the test object is thoroughly washed with clean tap water to remove any trace of salt.

For the salt-fog method, the minimum distance between any part of the test object and any earthed object other than the jets and the structure which supports the insulator shall be not less than 0,5 m per 100 kV of the test voltage and, in any case, not less than 2 m.

If the test is intended to determine the maximum degree of salinity for a specified withstand voltage, the whole procedure must be repeated using various salinities.

Pre-conditioning of the test object by a number of flashovers during the application of pollution is required before the real test begins. This pre-conditioning should be followed by a washing.

b) The pre-deposited pollution method

The test object is coated with a reasonably uniform layer of a conductive suspension and shall be permitted to dry. The ambient temperature in the test chamber at the start of the test should not be less than 5°C nor greater than 30°C and the test object should be in thermal equilibrium with the ambient. The wetting shall be accomplished by means of a steam fog generator which provides a uniform fog distribution over the whole length and around the test object. The temperature of the fog in the vicinity of the test object shall not exceed 40°C. To obtain the necessary wetting within a reasonable time, enough steam fog shall be introduced inside the test chamber. The steam generation rate shall be specified by the relevant Technical Committee.

In one procedure the voltage is applied before the test object is wetted by the fog and continues until flashover or for about twice the time for the insulator to achieve its maximum conductivity. In another procedure, the test voltage is applied only when the conductivity has reached its maximum value, which should occur between 20 and 40 min from the start of fogging. The voltage shall be kept constant during the specified 15-min test time or until flashover occurs.

Examples of suitable coating and wetting procedures and of the measurement of the surface resistivity are given in Appendix B.

The procedure above may be repeated several times; before each test, the test object shall be washed, re-coated and allowed to dry.

When the test is intended to determine the maximum degree of pollution for a specified withstand voltage, the coating, wetting and test procedures must be repeated using various suspension resistivities.

The minimum distance between any part of the test object and any earthed object other than the structure which supports the test object shall be not less than 0,5 m per 100 kV of the test voltage.

10.3 *Degree of pollution*

The degree of pollution of a test object is specified by the salinity (g/L) of the salt fog, by the surface conductivity (μS) or by the amount of salt (NaCl) per square centimetre of the insulating surface (gm/cm^2). This latter is normally referred to as the Salt Deposit Density (S.D.D). Information about these methods is given in Appendix B.

11 Atmospheric conditions

11.1 Standard reference atmosphere

The standard reference atmosphere is:

temperature $t_0 = 20^\circ\text{C}$

pressure $b_0 = 101,3 \text{ kPa (1013 mbar)}$

absolute humidity $h_0 = 11 \text{ g/m}^3$

NOTE — A pressure of 101,3 kPa corresponds to the height of 760 mm in a mercury barometer at 0°C . If the barometer height is H mm of mercury, the atmospheric pressure in kilopascals is approximately:

$$b = 0,1333H \text{ kPa}$$

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

11.2 Atmospheric correction factors

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.

By applying correction factors, a disruptive discharge voltage measured in given test conditions (temperature t , pressure b , humidity h) may be converted to the value which would have been obtained under the standard reference atmospheric conditions (t_0 , b_0 , h_0). Conversely, a test voltage specified for given reference conditions can be converted into the equivalent value under the test conditions.

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 11.2.1);
- the humidity correction factor k_2 (see 11.2.2).

$$K_t = k_1 k_2$$

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 :

$$U = U_0 K_t$$

Similarly, measured disruptive discharge voltages U 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.

11.2.1 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 11.2.3.

When the temperatures t and t_0 are expressed in degrees Celsius and the atmospheric pressures b and b_0 are expressed in the same units (kilopascals or millibars), the relative air density is:

$$\delta = \frac{b}{b_0} \frac{273 + t_0}{273 + t}$$

11.2.2 Humidity correction factor k_2

The humidity correction factor may be expressed as:

$$k_2 = k^w$$

where w is an exponent given in 11.2.3 and k is a parameter that depends on the type of test voltage and that, for practical purposes, may be approximately obtained as a function of the ratio of absolute humidity, h , to the relative air density, δ , using the curves of figure 3. For values of h/δ in excess of 15 g/m^3 humidity corrections are still under consideration, and the curves in figure 3 may be regarded as upper limits.

11.2.3 Exponents m and w

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

$$g = \frac{U_B}{500L\delta k}$$

where U_B is the 50% disruptive-discharge voltage (measured or estimated) at the actual atmospheric conditions, in kilovolts, L the minimum discharge path in metres, with the actual values for the relative air density δ and for the parameter k . In the case of a withstand test where an estimate of the 50% disruptive discharge voltage is not available, U_B can be assumed to be 1,1 times the test voltage.

The exponents m and w are still under consideration. Approximate values are given in figure 4.

11.3 Wet tests, tests under artificial pollution and combined tests

No humidity correction shall be applied for wet tests or for tests with artificial pollution. The question of density correction during such tests is under consideration. For combined tests see Clause 26.5.

11.4 *Conflicting requirements for testing internal and external insulation*

While withstand levels are specified under standard atmospheric conditions, cases will arise where the application of atmospheric corrections (due to laboratory altitude or to extreme climatic conditions) 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 must be adopted to permit application of the correct test voltage to the internal insulation. These measures include immersion of the external insulation in liquids or compressed gases and should be specified by the relevant Technical Committee with reference to the requirements of particular classes of apparatus. In 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 dummies unless the relevant Technical Committee states otherwise, in which case it shall specify the test procedure to be used.

11.5 *Measurement of humidity*

The humidity shall be determined preferably with the meter measuring directly the absolute humidity with an absolute error not larger than 1 g/m^3 . Measurement of relative humidity associated with the temperature measurements also allows determination of the absolute humidity and can be used provided that the accuracy of the absolute humidity determination in this case is the same as required above.

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 5 which also permits determination of the relative humidity. It is important to provide adequate air flow in order to reach a steady state and to read the thermometers carefully in order to avoid excessive errors in the determination of the humidity.

Section 4: Tests with Direct Voltage

12 Definitions for direct voltage tests

12.1 *Value of the test voltage*

The value of the test voltage is defined as its arithmetic mean value.

12.2 *Ripple*

Ripple is the periodic deviation from the arithmetic mean value of the voltage. The amplitude of the ripple is defined as half the difference between the maximum and minimum values. The ripple factor is the ratio of the ripple amplitude to the arithmetic mean value.

13 Test voltage

13.1 *Requirements for the test voltage*

13.1.1 *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 that the ripple factor may be affected by the presence of the test object and by the test conditions, especially in wet tests and in tests under artificial pollution.

13.1.2 *Tolerances*

For test durations not exceeding 60 s, the measured values of the test voltage shall be maintained within $\pm 1\%$ of the specified level throughout the test. For test durations exceeding 60 s, the measured value of the test voltage shall be maintained within $\pm 3\%$ 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 measuring error which is the difference between the measured value and the true value.

13.2 *Generation of the test voltage*

The test voltage is generally obtained by means of rectifiers, though sometimes electrostatic generators are employed. The requirements to be met by the test voltage source depend considerably upon the type of apparatus which 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 13.4.

The source characteristics should be such as to permit charging of the capacitance of the test object in a reasonably short time. In the case of objects having high capacitance, charging times of several minutes must sometimes be accepted. The source, including its storage capacitance, should also be adequate to supply the leakage and absorption currents and any internal and external non-disruptive discharge currents without voltage