# INTERNATIONAL STANDARD

# IEC 60137

Fifth edition
2003-08



## Insulated bushings for alternating voltages above 1 000 V

*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

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## Insulated bushings for alternating voltages above 1 000 V





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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# INSULATED BUSHINGS FOR ALTERNATING VOLTAGES ABOVE 1 000 V

## FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of 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, IEC publishes International Standards, Technical Specifications, Technical Reports, and Guides (hereafter referred to as “IEC Publication(s)”). 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. 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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International Standard IEC 60137 has been prepared by sub-committee 36A: Insulated bushings, of IEC technical committee 36: Insulators.

This fifth edition cancels and replaces the fourth edition, published in 1995, and constitutes a technical revision.

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

- standard values of highest voltage for equipment of 550 kV and 800 kV to replace 525 kV and 765 kV;
- consideration of the development in the use of non-ceramic insulating envelopes and to special requirements for bushings used in air-insulated ducting;
- special requirements for bushings fitted to transformers.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 36A/111/FDIS | 36A/114/RVD |

Full information on the voting for the approval of this standard 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 2003. At this date, the publication will be

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- withdrawn;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

# INTRODUCTION

To reflect the current usage of the term "composite bushing", the definition has been changed to mean a bushing with an insulating envelope consisting of a resin impregnated fibre tube with rubber compound covering. The previous definition of a multi-dielectric bushing is given the term "combined insulation bushing".

For bushings operating in air-insulated ducting, locally high ambient air temperatures have a significant effect on their current rating. This edition defines a limit to this temperature and specifies corresponding test conditions.

The term "highest voltage for equipment" is introduced into this standard in preference to "rated voltage". This change is in line with other equipment standards.

Gas-insulated and gas-impregnated bushings have become a mature technology, for use in gas insulated switchgear. Limiting values for temperature rise and dielectric dissipation factor have therefore been introduced.

The special requirements addressed for bushings fitted to transformer have not been considered necessary for bushings fitted to switchgear or used for other applications. A high level of integrity is needed to ensure that the bushing will not fail, or be the initiator of internal flashover in the transformer under test. Dry power-frequency withstand test voltage levels for transformers bushings should be increased according to 9.3. Extension of the range of application of lightning impulse and switching impulse tests, included in IEC 60076-3, is not considered technically or commercially justified for bushing routine or type tests.

The dynamic current withstand test is not mentioned in the text, because insufficient experience has so far been collected to design a realistic test.

# INSULATED BUSHINGS FOR ALTERNATING VOLTAGES ABOVE 1 000 V

## 1 Scope

This International Standard specifies the characteristics and tests for insulated bushings.

This standard is applicable to bushings, as defined in Clause 3, intended for use in electrical apparatus, machinery, transformers, switchgear and installations for three-phase alternating current systems, having highest voltage for equipment above 1 000 V and power frequencies of 15 Hz up to and including 60 Hz.

Subject to special agreement between purchaser and supplier, this standard may be applied, in part or as a whole, to the following:

- bushings used in other than three-phase systems;
- bushings for high-voltage, direct current systems;
- bushings for testing transformers;
- terminals for power cables (potheads);
- bushings for capacitors.

Special requirements and tests for transformer bushings in this standard apply also to reactor bushings.

This standard is applicable to bushings made and sold separately. Bushings which are a part of an apparatus and which cannot be tested according to this standard, should be tested with the apparatus of which they form part.



## 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 60038:1983, *IEC standard voltages*
Amendment 2 (1997)

IEC 60050(212):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 212: Insulating solids, liquids and gases*

IEC 60059:1999, *IEC standard current ratings*

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-2-17:1994, *Basic environmental testing procedures – Part 2: Tests – Test Q: Sealing*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60076-5:2000, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60216-2:1990, *Guide for the determination of thermal endurance properties of electrical insulating materials – Part 2: Choice of test criteria*

IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*

IEC 60354:1991, *Loading guide for oil-immersed power transformers*

IEC 60505:1999, *Evaluation and qualification of electrical insulation systems*

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

IEC 60815:1986, *Guide for the selection of insulators in respect of polluted conditions*

IEC 61462:1998, *Composite insulators – Hollow insulators for use in outdoor and indoor electrical equipment – Definitions, test methods, acceptance criteria and design recommendations*

IEC 61463:1996, *Bushings – Seismic qualification*

IEC 62155:2003, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*

## 3 Terms and definitions

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

**3.1**
**bushing**
device that enables one or several conductors to pass through a partition such as a wall or a tank, and insulates the conductors from it. The means of attachment (flange or fixing device) to the partition forms part of the bushing

[IEV 471-02-01, modified]

NOTE 1 The conductor may form an integral part of the bushing or be drawn into the central tube of the bushing.

NOTE 2 The bushing may be of the types as prescribed in 3.2 to 3.21.

**3.2**
**liquid-filled bushing**
bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with oil

**3.3**
**compound-filled bushing**
bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with an insulating compound

**3.4**
**liquid-insulated bushing**
bushing in which the major insulation consists of oil or another insulating liquid

**3.5**
**gas-filled bushing**
bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with gas (other than ambient air) at atmospheric pressure or higher

NOTE This definition includes bushings which are intended to form an integral part of gas-insulated equipment, the gas of the equipment being in communication with that of the bushing.

**3.6**
**gas-insulated bushing**
bushing in which the major insulation consists of gas (other than ambient air) at atmospheric pressure or higher

NOTE 1 This definition includes bushings which are intended to form an integral part of gas-insulated equipment, the gas of the equipment being in communication with that of the bushing.

NOTE 2 A bushing which contains solid insulating materials other than the envelope containing the gas (e.g. support for conducting layers or insulating cylinder), is a combined insulation bushing (see 3.13).

**3.7**
**gas-impregnated bushing**
bushing in which the major insulation consists of a core wound from paper or plastic film (GIF) and subsequently treated and impregnated with gas (other than ambient air) at atmospheric pressure or higher, the space between the core and the insulating envelope being filled with the same gas

**3.8**
**oil-impregnated paper bushing**
**OIP**
bushing in which the major insulation consists of a core wound from paper and subsequently treated and impregnated with an insulating liquid, generally transformer oil

NOTE The core is contained in an insulating envelope, the space between the core and the insulating envelope being filled with the same insulating liquid as that used for impregnation.

**3.9**
**resin-bonded paper bushing**
**RBP**
bushing in which the major insulation consists of a core wound from resin-coated paper

NOTE 1 During the winding process, each paper layer is bonded to the previous layer by its resin coating and the bonding achieved by curing the resin.

NOTE 2 A resin-bonded paper bushing can be provided with an insulating envelope, in which case the intervening space can be filled with an insulating liquid or another insulating medium.

**3.10**
**resin-impregnated paper bushing**
**RIP**
bushing in which the major insulation consists of a core wound from untreated paper and subsequently impregnated with a curable resin

NOTE A resin-impregnated paper bushing can be provided with an insulating envelope, in which case the intervening space can be filled with an insulating liquid or another insulating medium.

**3.11**
**ceramic, glass or analogous inorganic material bushing**
bushing in which the major insulation consists of a ceramic, glass or analogous inorganic material

**3.12**
**cast or moulded resin-insulated bushing**
bushing in which the major insulation consists of a cast or moulded organic material with or without an inorganic filler

**3.13**
**combined insulation bushing**
bushing in which the major insulation consists of a combination of at least two different insulating materials

**3.14**
**capacitance graded bushing**
bushing, in which a desired voltage grading is obtained by an arrangement of conducting or semiconducting layers incorporated into the insulating material

[IEV 471-02-02, modified]

**3.15**
**indoor bushing**
bushing, both ends of which are intended to be in ambient air at atmospheric pressure, but not exposed to outdoor atmospheric conditions

[IEV 471-02-03]

**3.16**
**outdoor bushing**
bushing, both ends of which are intended to be in ambient air at atmospheric pressure and exposed to outdoor atmospheric conditions

[IEV 471-02-04]

**3.17**
**outdoor-indoor bushing**
bushing, both ends of which are intended to be in ambient air at atmospheric pressure

NOTE One end is intended to be exposed to outdoor atmospheric conditions, and the other end not to be exposed to outdoor atmospheric conditions.

[IEV 471-02-05]

**3.18**
**indoor-immersed bushing**
bushing, one end of which is intended to be in ambient air but not exposed to outdoor atmospheric conditions and the other end to be immersed in an insulating medium other than ambient air (e.g. oil or gas)

[IEV 471-02-06]

NOTE This definition includes bushings operating in air at temperatures above ambient, such as occur with air-insulated ducting.

**3.19**
**outdoor-immersed bushing**
bushing, one end of which is intended to be in ambient air and exposed to outdoor atmospheric conditions and the other end to be immersed in an insulating medium other than ambient air (e.g. oil or gas)

[IEV 471-02-07]

**3.20**
**completely immersed bushing**
bushing, both ends of which are intended to be immersed in an insulating medium other than ambient air (e.g. oil or gas)

[IEV 471-02-08, modified]

**3.21**
**bushing for separable connector**
plug-in type bushing
bushing, one end of which is immersed in an insulating medium and the other end designed to receive a separable insulated cable connector, without which the bushing cannot function

**3.22**
**highest voltage for equipment**
$U_m$
highest r.m.s. value of phase-to-phase voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standard

[IEV 604-03-01]

**3.23**
**rated phase-to-earth voltage**
maximum r.m.s. value of the voltage which the bushing withstands continuously between the conductor and the earthed flange or other fixing device, under the operating conditions specified in Clause 5

**3.24**
**rated current**
$I_r$
maximum r.m.s. value of current which the bushing can carry continuously under the operating conditions specified in Clause 5, without exceeding the temperature rise limits of Table 2

**3.25**
**rated thermal short-time current**
$I_{th}$
r.m.s. value of a symmetrical current which the bushing withstands thermally for the rated duration ($t_{th}$) immediately following continuous operation at rated current with maximum temperatures of ambient air and immersion media in accordance with 5.3

**3.26**
**rated dynamic current**
$I_d$
peak value of a current which the bushing withstands mechanically

**3.27**
**temperature rise**
difference between the measured temperature of the hottest spot of the metal parts of the bushing which are in contact with insulating material and the ambient air temperature (see 4.8)

**3.28**
**rated frequency**
$f_r$
frequency at which the bushing is designed to operate

[IEV 421-04-03, modified]

**3.29**
**minimum operating pressure of gas for insulation**
minimum pressure, referenced to 20 °C, assigned by the bushing supplier, at which the rated insulating level applies

**3.30**
**maximum internal operating gas pressure**
pressure, when the bushing is in operation, carrying rated current at the highest temperatures in accordance with 5.3

**3.31**
**maximum external operating gas pressure**
maximum pressure of the gaseous insulating medium in which the bushing is partially or completely immersed when in operation

**3.32**
**design pressure (of the enclosure)**
pressure used to determine the thickness of the enclosure

(see IEC 60517)

**3.33**
**leak rate of gas-filled, gas-insulated, gas-impregnated and gas-immersed bushings**
quantity of dry gas at a given temperature that flows through a leak per unit of time and for a known difference of pressure across the leak

(see IEC 60068-2-17)

NOTE The basic SI unit for leak rate is "Pascal cubic metre per second (Pa $\times$ m$^3$/s)". The derived units "Pa $\times$ cm$^3$/s" and "bar $\times$ cm$^3$/s" are used in this standard, as they better conform with the orders of magnitude used in common industrial practice. It should be remembered that: 1 Pa $\times$ m$^3$/s = 10$^6$ Pa $\times$ cm$^3$/s = 10 bar $\times$ cm$^3$/s.

**3.34**
**insulating envelope**
hollow insulator which is open from end to end, with or without sheds

[IEV 471-01-17, modified]

NOTE An insulating envelope may consist of one insulator unit or two or more permanently assembled insulator units.

**3.35**
**creepage distance**
shortest distance along the surface of an insulator between two conductive parts

NOTE 1 The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance.

NOTE 2 If high-resistance coating is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surfaces and the distance over them is included in the creepage distance.

[IEV 471-01-08]

**3.36**
**arcing distance**
shortest distance in air external to the insulator between metallic parts which normally have the operating voltage between them

NOTE The terms "dry arcing distance" or "taut string distance" are also used.

[IEV 471-01-07, modified]

**3.37**
**test tap**
measuring tap
tan $\delta$ tap
connection, accessible from outside the bushing, insulated from the flange or other fixing device, made to one of the outer conducting layers of a capacitance graded bushing in order to allow measurements of dissipation factor, capacitance and partial discharge whilst the flange of the bushing is earthed

NOTE 1 This connection should be earthed directly when it is not used.

NOTE 2 When the test tap is used for condition monitoring, in service, care should be taken to avoid an open circuit.

**3.38**
**voltage tap**
potential tap
capacitance tap
connection, accessible from outside the bushing, insulated from the flange or other fixing device, made to one of the outer conducting layers of a capacitance graded bushing in order to provide a voltage source whilst the bushing is in operation

NOTE 1 This connection should be earthed directly when it is not used.

NOTE 2 This tap can also be used for the measurement of dissipation factor, capacitance and partial discharge.

**3.39**
**rated voltage of the voltage tap**
maximum voltage at which the tap is designed to supply the associated equipment, with the rated load connected thereto, when the rated phase-to-earth voltage is applied to the bushing at the rated frequency

**3.40**
**composite bushing**
bushing with an insulating envelope consisting of a resin impregnated fibre tube with or without a rubber compound covering

NOTE For bushings defined in 3.9 to 3.12, the rubber may be applied directly on to the bushing major insulation.

**3.41**
**capacitance (of bushing)**

**3.41.1**
**main capacitance**
$C_1$
capacitance between the high-voltage conductor and the test tap or the voltage tap of a capacitance-graded bushing

**3.41.2**
**tap capacitance**
$C_2$
capacitance between the test tap or the voltage tap and the mounting flange of a capacitance-graded bushing

**3.41.3**
**capacitance**
$C$
capacitance between the high voltage conductor and the mounting flange of a bushing without a voltage tap or test tap

# 4 Ratings

## 4.1 Standard values of highest voltage for equipment ($U_m$)

The values of $U_m$ of a bushing shall be chosen from the standard values of the highest voltage for equipment, defined in IEC 60038 as given below, in kilovolts:

3,6 – 7,2 – 12 – 17,5 – 24 – 36 – 52 – 72,5 – 100 – 123 – 145 – 170 – 245 – 300 – 362 – 420 – 550 – 800 kV.

NOTE The values 525 kV and 765 kV are also used.

## 4.2 Standard values of rated current ($I_r$)

The values of $I_r$ of a bushing shall be chosen from the standard values as given below, in amperes:

100 – 250 – 315 – 400 – 500 – 630 – 800 – 1 000 – 1 250 – 1 600 – 2 000 – 2 500 – 3 150 – 4 000 – 5 000 – 6 300 – 8 000 – 10 000 – 12 500 – 16 000 – 20 000 – 25 000 – 31 500 – 40 000 A.

The above series of currents are in accordance with the values indicated in IEC 60059.

In the case of transformer bushings with the conductor drawn into the central tube, the supplier shall indicate the value of the cross-section, and the material of the conductor which correspond to $I_r$ in accordance with 4.8.

Bushings for transformers selected with $I_r$ not less than 120 % of rated current of the transformer are considered to be able to withstand the overload conditions according to IEC 60354 without further clarification or tests.

## 4.3 Standard values of rated thermal short-time current ($I_{th}$)

Unless otherwise specified, the standard value of $I_{th}$ shall be 25 times $I_r$, $t_{th}$ being 1 s. For bushings with $I_r$ equal to or greater than 4 000 A, $I_{th}$ shall always be 100 kA.

For transformer bushings, $t_{th}$ shall be 2 s, unless otherwise stated, with reference to IEC 60076-5.

For durations of $t_{th}$ greater than 1 s, the relationship between current and time is assumed to be in accordance with

$$I^2_{th} \times t_{th} = \text{constant}$$

NOTE For transformer bushings, where the conductor is drawn into the central tube, the conductor cross-section corresponding to the operating current may be less than that indicated in 4.2. In such a case, the operating current and cross-section should conform with the requirements of 8.6.

## 4.4 Standard values of rated dynamic current ($I_d$)

The standard value of $I_d$ shall have an amplitude of the first peak of 2,5 times the value of $I_{th}$ in accordance with 4.3.

NOTE In some cases, values greater than 2,5 times the value of $I_{th}$ indicated in 4.3 may be necessary with respect to the transformer characteristics. The transformer manufacturer should stipulate such requirements in the bushing ordering information (see 6.1.3).

### 4.5 Minimum withstand values of cantilever load

The bushings shall withstand the cantilever load given in Table 1, Level I or II. Level I is normal load and shall be generally applied, unless a purchaser specifies a heavy load of Level II.

### 4.6 Angle of mounting

All bushings shall be designed for mounting at any angle of inclination not exceeding 30° from the vertical. Any other angle of mounting shall be subject to agreement between purchaser and supplier.

NOTE A bushing operating at an angle up to and including 30° from the vertical is considered a vertical bushing. A bushing operating at an angle equal to or greater than 70° from the vertical is considered a horizontal bushing. A bushing operating at any other angle is considered a tilted bushing (see 6.1.4).

### 4.7 Minimum nominal creepage distance

Unless otherwise agreed between purchaser and supplier, or demonstrated by a test, the creepage distance for ceramic insulating envelopes in accordance with IEC 60815 is determined by

$$d_{\mathrm{cs}}\ (\mathrm{mm/\ kV}) \times U_{\mathrm{m}}(\mathrm{kV}) \times k_{\mathrm{D}}$$

where

$d_{\mathrm{cs}}$ is the minimum nominal specific creepage distance, the values of which for the various pollution levels are

| | |
|---|---|
| I light: | 16 mm/ kV |
| II medium: | 20 mm/ kV |
| III heavy: | 25 mm/ kV |
| IV very heavy: | 31 mm/ kV |

$k_{\mathrm{D}}$ is the correction factor depending on the averaged diameter $D_{\mathrm{m}}$ of the insulator, the classes of which are

| | |
|---|---|
| <300 mm | $k_{\mathrm{D}} = 1$ |
| 300 mm to 500 mm | $k_{\mathrm{D}} = 1,1$ |
| >500 mm | $k_{\mathrm{D}} = 1,2$ |

$D_{\mathrm{m}}$ shall be determined in accordance with IEC 60815.

If artificial pollution tests are required, they shall be performed in accordance with IEC 60507.

NOTE 1 The actual value of creepage distance can differ from the nominal one by the manufacturing tolerances stated in IEC 62155.

NOTE 2 Requirements for composite insulators are under consideration by TC 36: Insulators.

### 4.8 Temperature limits and temperature rise

The temperature limits of metal parts in contact with insulating material under normal operating conditions, are as follows:

– 105 °C for oil-impregnated paper: Class A;

– 120 °C for resin-bonded and resin-impregnated paper: Class E;

– 130 °C for gas-impregnated film: Class B.

The temperature rise above maximum daily mean ambient air temperature in accordance with 5.3 (30 °C) of the hottest spot shall not exceed the values given in Table 2. In the case of other insulating materials, the temperature limits shall be stated by the supplier. Reference shall be made to IEC 60216-2 and IEC 60505.

For bushing terminals and connections, the temperature rises are also given in Table 2.

Bushings used as an integral part of apparatus, such as switchgear or transformers, shall meet the thermal requirements for the relevant apparatus. For transformer bushings, reference shall be made to 4.2.

NOTE For gaskets in contact with metallic parts, special attention should be paid to the ability of the material to withstand the temperature rise.

### 4.9 Standard insulation levels

The standard values of insulation level of a bushing having $U_m$ less than 300 kV shall be chosen from the values given in Table 7.

The standard values of insulation level of a bushing having $U_m$ equal to or greater than 300 kV shall be chosen from values given in Table 8.

The specified standard values of insulation level are in accordance with IEC 60038 and IEC 60071-1.

### 4.10 Test tap on transformer bushings

A test tap according to 3.37 shall be provided on transformer bushings of $U_m$ equal to or greater than 72,5 kV. In view of its use for partial discharge measurements on transformers, the values for the test tap shall not exceed:

– a capacitance to earth of 10 000 pF;

– a dielectric dissipation factor (tan $\delta$) of 0,05 measured at power-frequency.

Other values of test tap capacitance to earth may be agreed between purchaser and supplier.

The bushing shall not incorporate substantial capacitances to earth which may divert the partial discharge current and so give rise to incorrect or misleading partial discharge measurements on the transformer.

## 5 Operating conditions

### 5.1 Temporary overvoltages

The maximum phase-to-earth voltage of the system may exceed $U_m$ divided by $\sqrt{3}$. For periods not exceeding 8 h in any 24 h, and of which the total period does not exceed 125 h per year, bushings shall be able to operate phase-to-earth at a voltage of

– $U_m$ for bushings of which $U_m$ is equal to or less than 170 kV;

– 0,8 $U_m$ for bushings of which $U_m$ is greater than 170 kV.

For systems in which overvoltages in excess of this may occur, it is advisable to choose a bushing with a higher $U_m$.

### 5.2 Altitude

Although the insulation level refers to sea level, bushings corresponding to this standard are declared suitable for operation at any altitude not exceeding 1 000 m. In order to ensure that the external withstand voltages of the bushing are sufficient at altitudes exceeding 1 000 m, the arcing distance normally required shall be increased by a suitable amount. It is not necessary to adjust the radial thickness of insulation or the clearance of the immersed end. The puncture strength and the flashover voltage in the immersion medium of a bushing are not affected by altitude.

Owing to the limitations of puncture strength and flashover voltage in the immersion medium, it may not always be possible to check the adequacy of the increased arcing distance by actual tests at any altitude lower than that of operation. In such a case the supplier shall demonstrate, by the amount of increase of the arcing distance, that the bushing is adequate.

For general guidance, an increase of 1,0 % of the arcing distance necessary at sea level for each 100 m in excess of 1 000 m up to a maximum of 3 000 m above sea level should be applied.

EXAMPLE Altitude of installation 2 800 m:

Increase in arcing distance

$$1\ \% \times \frac{2\ 800\ \text{m} - 1\ 000\ \text{m}}{100\ \text{m}} = 18\ \%$$

For altitudes in excess of 3 000 m above sea level, correction factors shall be agreed between purchaser and supplier.

### 5.3 Temperature of ambient air and immersion media

Bushings shall be designed for operation at temperatures not exceeding the limits given in Table 3. Consideration should be given to the operating conditions of completely immersed bushings and bushings operating in air-insulated ducting.

Moisture condensation on the surface of the indoor part of the bushing is to be prevented, if necessary by ventilation or heating.

### 5.4 Seismic conditions

When seismic qualification is required, reference should be made to IEC 61463.



## 6 Ordering information and markings

### 6.1 Enumeration of characteristics

When ordering, the purchaser shall furnish as much of the following information as necessary, as well as any additional information needed to determine clearly the required characteristics.

#### 6.1.1 Application

Application, including type of apparatus for which the bushing is intended, and the corresponding IEC apparatus standard shall be given.

Attention shall be drawn to any features (including tests) of the completed apparatus which may affect the design of the bushing (see 7.3).

### 6.1.2 Classification of bushings

Classification according to 3.2 to 3.21.

### 6.1.3 Ratings

The ratings shall be as follows:

- highest voltage for equipment ($U_m$) (see 3.22);
- rated phase-to-earth voltage (see 3.23);
- standard insulation level (see 4.9) and if necessary the induced and/or applied test voltage level of the transformer (see 9.3);
- rated current ($I_r$) (see 3.24);
- rated thermal short-time current ($I_{th}$) and rated duration ($t_{th}$), if deviating from the values given in 4.3;
- rated dynamic current ($I_d$), if deviating from the value given in 4.4;
- rated frequency (see 3.28);
- minimum withstand values of cantilever load in accordance with 4.5;
- maximum value of test tap capacitance, if lower value is required, in accordance with 4.10.

### 6.1.4 Operating conditions

The operating conditions shall be as follows:

- temporary overvoltages, if applicable (see 5.1);
- altitude, if exceeding 1 000 m (see 5.2) (relevant only to indoor and outdoor bushings according to 3.15 to 3.19);
- ambient air and immersion media temperature if deviating from normal values (see 5.3 and Table 3) (relevant to bushings according to 3.15 to 3.21);
- type of immersion medium (relevant only to partly or completely immersed bushings according to 3.18 to 3.21);
- minimum level of immersion medium (relevant only to partly or completely immersed bushings according to 3.18 to 3.21);
- maximum operating pressure of immersion media (relevant only to partly or completely immersed bushings according to 3.18 to 3.21);
- type of insulating gas (relevant only to gas-filled, gas-insulated and gas-impregnated bushings according to 3.5 to 3.7 when the gas of the equipment is in communication with that of the bushing);
- minimum operating pressure of gas for insulation (see 3.29) (relevant only to gas-filled, gas-insulated and gas-impregnated bushings according to 3.5 to 3.7 when the gas of the equipment is in communication with that of the bushing);
- maximum internal operating gas pressure (see 3.30) (relevant only to gas-filled, gas-insulated and gas-impregnated bushings according to 3.5 to 3.7 when the gas of the equipment is in communication with that of the bushing);
- maximum external operating gas pressure (see 3.31) (relevant only to partly or completely gas-immersed bushings according to 3.18 to 3.20);
- angle of mounting if exceeding the standard values (see 4.6);
- minimum nominal specific creepage distance (see 4.7) (relevant only to the outdoor part of bushings according to 3.16, 3.17 and 3.19);

- unusual climatic conditions (extreme high and low temperatures, tropical humidity, severe contamination, high wind);
- seismic conditions, if qualification is required (see 5.4).

### 6.1.5 Design

The design shall cover:

- for bushings supplied without a conductor: diameter, type (cable, solid or hollow stem), material and position of the conductor with which the bushing will be fitted in operation;
- particular dimensional requirements, if any;
- test tap or voltage tap if required (see 3.37 and 3.38);
- the length of earthed sleeve located next to the flange or other fixing device, if any;
- general information concerning the position of the bushing in relation to the earthed parts of the apparatus for which the bushing is foreseen (see 7.1);
- whether protective gaps are to be fitted or not;
- special requirements for corrosion protection of metallic parts;
- oil level in central tube of a transformer bushing with the conductor drawn into the central tube, if lower than one-third of the height of the external part (see 8.5);
- provision of an oil sample valve.

## 6.2 Markings

Each bushing of $U_m$ equal to or greater than 123 kV shall carry the following markings. For bushings of $U_m$ equal to or less than 100 kV, markings indicated ■ are sufficient. Markings for bushings according to Clause 10 are specified in 10.3.

- ■ supplier's name or trade mark;
- ■ year of manufacture and serial number;
- ■ highest voltage for equipment ($U_m$) (see 3.22) or rated phase-to-earth voltage (see 3.23) and rated frequency (see 3.28);
- ■ rated current ($I_r$) (see 3.24). If the bushing is supplied without conductor, the maximum operating current shall be indicated;
- lightning impulse (BIL) and switching impulse (SIL) and power-frequency withstand test voltages (AC) (see 4.9);
- bushing capacitance (see 3.41) and dielectric dissipation factor;
- type of insulating gas and minimum pressure (see 3.29), if applicable;
- mass if above 100 kg;
- maximum angle of mounting if exceeding 30° from vertical (see 4.6).

For examples of marking plates, see Figures 1 and 2.

NOTE Capacitance and dielectric dissipation factor measurements made on site may differ from factory values given on the nameplate. It is recommended to make reference measurements at installation.

# 7 Test requirements

## 7.1 General requirements

All tests shall be carried out in accordance with the relevant IEC publication referred to in the particular clause. Tests on insulating envelopes of ceramic material shall be carried out in accordance with IEC 62155. Tests on insulators of composite material shall be carried out in accordance with IEC 61462.

All high-voltage tests, in accordance with 8.1, 8.2, 8.3, 9.2 and 9.3 shall be carried out in accordance with IEC 60060-1.

The supplier shall provide a detailed type test certificate at the request of the purchaser. The tests shall have been carried out on bushings of a design that does not differ from that offered to the purchaser in any way that may improve the features to be checked by a type test. Repetition of a type test is only mandatory when specified in a particular contract.

At the request of the purchaser, the supplier shall furnish any information concerning the minimum clearances to earthed parts in the operating arrangement.

The values of the applicable withstand test voltages for newly manufactured bushings are indicated in Tables 7, 8 and 9. For bushings which have been in operation, the routine withstand test voltages shall be reduced to 85 % of the values indicated in the tables.

The bushings shall not be damaged by the tolerated flashover in air when tested in accordance with 8.1, 8.2, 8.3, 9.2 and 9.3, but slight marks remaining on the surface of the porcelain insulating parts are acceptable.

A definition of the terms “flashover” and “puncture” is given in IEC 60050(212), IEV 212-01-37 and IEV 212-01-38, respectively.

## 7.2 Test classification

Tables 10 to 13 show the applicability of the tests to the various types of bushings.

For bushings of highest voltages for equipment equal to or less than 52 kV, made of ceramic, glass or inorganic materials, resin or composite insulation, see Clause 10. For other bushings, tests to check dielectric, thermal and mechanical properties of bushings comprise the following tests.

### 7.2.1 Type tests

- dry or wet power-frequency voltage withstand test (see 8.1);
- dry lightning impulse voltage withstand test (see 8.2);
- dry or wet switching impulse voltage withstand test (see 8.3);
- thermal stability test (see 8.4);
- temperature rise test (see 8.5);
- verification of thermal short-time current withstand (see 8.6);
- cantilever load withstand test (see 8.7);
- tightness test on liquid-filled, compound-filled and liquid-insulated bushings (see 8.8);

- internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings (see 8.9);
- external pressure test on partly or completely gas-immersed bushings (see 8.10);
- verification of dimensions (see 8.11).

### 7.2.2 Routine tests

- measurement of dielectric dissipation factor (tan $\delta$) and capacitance at ambient temperature (see 9.1);
- dry lightning impulse voltage withstand test (see 9.2);
- dry power-frequency voltage withstand test (see 9.3);
- measurement of partial discharge quantity (see 9.4);
- tests of tap insulation (see 9.5);
- internal pressure test of gas-filled, gas-insulated and gas-impregnated bushings (see 9.6);
- tightness test on liquid-filled, compound-filled and liquid-insulated bushings (see 9.7);
- tightness test on gas-filled, gas-insulated and gas-impregnated bushings (see 9.8);
- tightness test at the flange or other fixing device (see 9.9);
- visual inspection and dimensional check (see 9.10).

### 7.2.3 Special tests

Special tests are only performed when contractually agreed upon between purchaser and supplier.

- seismic test (reference to IEC 61463);
- artificial pollution test (reference to IEC 60507).

## 7.3 Condition of bushings during dielectric and thermal tests

During all tests, the temperature of the ambient air and immersion media, if any, shall be between 10 °C and 40 °C. Dielectric and thermal tests shall be carried out only on bushings complete with their fixing flanges or other fixing devices, and all accessories with which they will be fitted when in use, but without protective arcing gaps, if any. Test taps and voltage taps shall be either earthed or held near earth potential.

Liquid-filled and liquid-insulated bushings, according to 3.2 and 3.4, shall be filled to the normal level with the insulating liquid of the quality specified by the supplier.

Gas-filled, gas-insulated and gas-impregnated bushings, according to 3.5, 3.6 and 3.7, shall be filled with the type of insulating gas specified by the supplier and raised to the minimum pressure according to 3.29, at the reference temperature of 20 °C. If, at the beginning of the test, the temperature differs from 20 °C, the pressure shall be adjusted accordingly.

Partly or completely immersed bushings, according to 3.18, 3.19 and 3.20, shall normally be immersed in an immersion medium which is as similar as possible to that used in normal operation. Other media shall be agreed between purchaser and supplier.

The purchaser may use the bushing for a simulation test to prove the adequacy of the operating arrangement. In particular, in the case of bushings intended for use on gas-insulated switchgear and transformers, tests may be required with simulation of adjacent metal parts on the GIS or transformer side. Such tests shall be the subject of previous agreement between purchaser and supplier.

As the dielectric routine tests (see 7.2.2) are intended to check the internal insulation only, it is permissible practice to screen the external metal parts of the bushing during these tests.

A bushing is normally tested in an arrangement having sufficient clearance to surrounding earthed parts to avoid direct flashover to them through the ambient air or the immersion medium.

Normally, GIS and transformer bushings are tested in the vertical position, with the flange earthed or held near to earth potential.

The angle of mounting of the bushing for the wet power-frequency voltage withstand test and wet switching impulse voltage withstand test may be the subject of special agreement between purchaser and supplier.

Before commencing dielectric tests, the insulator shall be clean and dry and in thermal equilibrium with the ambient air.

If the actual atmospheric conditions deviate from the values given in IEC 60060-1, correction shall be made as given in Table 4.

# 8 Type tests

The order or possible combination of the tests is at the discretion of the supplier, except the impulse voltage withstand tests which shall be made before the dry power-frequency voltage withstand test (see 9.3). Before and after the series of type tests, measurements of dielectric dissipation factor and capacitance (see 9.1) and of partial discharge quantity (see 9.4) shall be carried out in order to check whether damage has occurred.

## 8.1 Dry or wet power-frequency voltage withstand test

### 8.1.1 Applicability

The dry test is applicable to all bushings according to 3.15, 3.18 and 3.20, which are not subjected to a routine test (see 9.3).

The wet test is applicable to all outdoor bushings according to 3.16, 3.17 and 3.19, and for which $U_m$ is less than 300 kV.

### 8.1.2 Test method and requirements

The magnitude of the test voltage is given in Table 7. The test duration shall be 60 s, independent of frequency.

#### 8.1.3 Acceptance

The bushing shall be considered to have passed the test if no flashover or puncture occurs. If there is a puncture, the bushing shall be considered to have failed the test. For capacitance graded bushings it is assumed that a puncture has occurred if the capacitance measured after the test raises above the capacitance previously measured by about the amount attributable to the capacitance of one layer. If a flashover occurs, the test shall be repeated once only. If during the repetition of the test no flashover or puncture occurs, the bushing shall be considered to have passed the test.

### 8.2 Dry lightning impulse voltage withstand test (BIL)

#### 8.2.1 Applicability

The test is applicable to all types of bushings.

#### 8.2.2 Test method and requirements

The magnitude of the test voltage is given in Table 7 or 8. The bushing shall be subjected successively to

– 15 full lightning impulses of positive polarity, followed by
– 15 full lightning impulses of negative polarity

of the standard lightning impulse 1,2/50 µs.

Bushings for transformers of $U_m$ equal or greater than 123 kV shall be subjected successively to

– 15 full lightning impulses of positive polarity, followed by
– 1 full lightning impulse of negative polarity, followed by
– 5 chopped lightning impulses of negative polarity, and by
– 14 full lightning impulses of negative polarity.

The time to sparkover on the chopping device shall be between 2 µs and 6 µs. The peak voltage level shall be 115 % of the full wave value.

It is permissible, after changing polarity, to apply some impulses of minor amplitude before the application of the test impulses. The time intervals between consecutive applications of the voltage shall be sufficient to avoid effects from the previous applications of voltage.

In the case of bushings for gas-insulated switchgear, special test requirements for chopped lightning test may be agreed upon between purchaser and supplier to cover the behaviour of the bushing concerning very fast transient voltage.

Voltage records shall be made for each impulse.

#### 8.2.3 Acceptance

The bushings shall be considered to have passed the test, if

– no puncture occurs at either polarity, and
– the number of flashovers in air does not exceed two for each series of 15 impulses;

except for transformer bushings for which

– no oil-end flashover,

– not more than two flashovers in air at positive polarity, and

– no flashover in air at negative polarity

are permitted.

## 8.3 Dry or wet switching impulse voltage withstand test (SIL)

### 8.3.1 Applicability

The test is applicable to all bushings of $U_m$ equal to or greater than 300 kV. A dry test is applicable to indoor, indoor-immersed and completely immersed bushings, according to 3.15, 3.18 and 3.20.

The wet test is applicable to outdoor bushings, according to 3.16, 3.17 and 3.19. When a wet test is made, a dry test is not necessary.

The dry switching impulse withstand test for transformer bushings of $U_m$ less than 300 kV switching impulse may be applied subject to agreement.

### 8.3.2 Test method and requirements

For these tests, IEC 60060-1 may be used. To simulate service conditions, the bushing shall be mounted on an earthed plane, radially extended from the axis of the bushing at least 0,4 $L$ in every direction, $L$ being the dry arcing distance of the bushing. The high-voltage connection shall extend in line with the axis of the bushing to a point at least 0,4 $L$ above the top of the bushing. In the case of bushings where one end is immersed, the details of immersion shall be subject to agreement.

The magnitude of the test voltage is given in Table 8.

The bushing shall be subjected to

– 15 impulses of positive polarity, followed by

– 15 impulses of negative polarity

of the standard switching impulse 250/2 500 µs.

It is permissible, after changing polarity, to apply some impulses of minor amplitude before the application of the test impulses. The time intervals between consecutive applications of the voltage shall be sufficient to avoid effects from the previous application of voltage.

Voltage records shall be made of each impulse.

### 8.3.3 Acceptance

The bushing shall be considered to have passed the test if

– no puncture occurs at either polarity, and if

– the number of flashovers in air at either polarity does not exceed two in the series of 15 impulses;

except for transformer bushings for which

– no oil-end flashover, and

– not more than two flashovers in air at positive polarity, and

– no flashover in air at negative polarity are permitted.

## 8.4 Thermal stability test

### 8.4.1 Applicability

The test is applicable to all partly or completely immersed bushings, according to 3.18, 3.19 and 3.20. The major insulation of these bushings consists of an organic material, intended for apparatus filled with an insulating medium, the operating temperature of which is equal to or above 60 °C and where $U_m$ is greater than 300 kV for oil- and resin-impregnating paper bushings, and equal to or greater than 145 kV for other types of bushings.

The test can, however, be omitted if it can be demonstrated, based on the results of comparative tests or calculations, that the thermal stability of the bushing is assured.

### 8.4.2 Test method and requirements

The ends of the bushings, which are intended for immersion in oil, or another liquid-insulating medium, shall be immersed in oil. The temperature of the oil shall be maintained at the operating temperature of the apparatus ±2 K, except for transformer bushings where the oil temperature shall be 90 °C ± 2 °C. This temperature shall be measured by means of thermometers, immersed in oil about 3 cm below the surface, and about 30 cm from the bushing.

The ends of the bushings, which are intended for immersion in a gaseous insulating medium other than air at atmospheric pressure, shall be appropriately immersed in insulating gas at minimum pressure as defined in 3.29. The gas shall be maintained at a temperature agreed upon between purchaser and supplier.

The conductor losses corresponding to $I_r$ shall be simulated by appropriate means. One method is to wrap a resistive insulated wire around a conductor dummy and to feed it by a suitable supply. The resistance of the wire and the current shall be adjusted in a such a way as to produce the same losses as the final conductor.

The test voltage shall be

– $U_m$ for bushings of $U_m$ equal to or less than 170 kV,

– 0,8 $U_m$ for bushings of $U_m$ greater than 170 kV.

The test shall not be started until thermal equilibrium between the oil and the bushing has been reached.

During the test, the dielectric dissipation factor shall be measured frequently and the ambient air temperature shall be recorded at each measurement.

The bushing has reached thermal stability when its dielectric dissipation factor shows no appreciable rising tendency, with respect to the ambient temperature, for a period of 5 h.

### 8.4.3 Acceptance

The bushing shall be considered to have passed the test if it reaches thermal stability and subsequently withstands dielectric routine tests without significant change from previous results.

## 8.5 Temperature rise test

### 8.5.1 Applicability

The test is applicable to all types of bushings, excluding liquid-insulated bushings according to 3.4, unless it can be demonstrated by a calculation based on comparative tests that specified temperature limits are met.

### 8.5.2 Test method and requirements

Bushings, one or both ends of which are intended to be immersed in oil or another liquid-insulating medium, shall be appropriately immersed in oil at ambient temperature, except for transformer bushings, where the oil shall be maintained at a temperature of 60 K ± 2 K above the ambient air.

NOTE 1 In some applications (e.g. generator transformer), the transformer top-oil temperature is often restricted to values below the normal IEC limits. Subject to agreement between manufacturer and purchaser, the standard oil temperature rise of 60 K may be reduced to reflect the real transformer top oil temperature.

Bushings with a conductor drawn into the central tube shall be assembled with an appropriate conductor, the cross-section of which shall conform with $I_r$. When the transformer oil is in communication with the bushing central tube, the oil level shall not exceed one-third of the height of the external part.

The end of bushings, which are intended for immersion in a gaseous insulating medium other than air at atmospheric pressure, shall normally be appropriately immersed in an enclosure insulated with gas at minimum pressure, according to 3.29, the gas being at ambient temperature at the beginning of the test.

Gas-insulated bushings shall be at ambient temperature at the beginning of the test.

For transformer bushings operating in air-insulated ducting, the air side shall be enclosed in an appropriate chamber. During the test, the air in the chamber shall be heated to 40 K ± 2 K above ambient air, either by self-heating or indirectly.

An appropriate number of thermocouples or other measuring devices shall, as far as possible, be placed along the bushing conductor, central tube and other current-carrying parts, as well as possibly on the flange or other fixing device, so as to determine the hottest spot of the bushing metal parts in contact with insulating material with reasonable accuracy.

The ambient air temperature shall be measured with lagged thermometers placed around the bushing at mid-height and at a distance of 1 m to 2 m from it.

NOTE 2 A satisfactory degree of lagging is obtained by placing the thermometers in oil-filled containers with a volume of approximately 0,5 l.

The temperature of the oil or gas shall be measured by means of thermometers placed at a distance of 30 cm from the bushing and, in the case of oil, 3 cm below the surface of the oil.

The test shall be carried out at $I_r$ ± 2 % at rated frequency, all parts of the bushing being substantially at earth potential. If the frequency at the test differs from the rated frequency, the current may be adjusted to achieve equivalent losses.

Temporary external connections used for this test shall be of such dimensions that they do not contribute unduly to the cooling of the bushing under test. These conditions are assumed to be fulfilled if the temperature decrease from the bushing termination to a point at 0,5 m distance along the connection does not exceed 2 K.

The test shall be continued until the temperature rise is sensibly constant. This is considered to be the case if the temperature does not vary more than ± 2 K during 2 h.

To avoid destruction of the insulation in the case of bushings with the conductor embedded in the insulating material, the temperature of the hottest spot may, by agreement between purchaser and supplier, be determined as follows:

The maximum conductor temperature $\theta_M$ is deduced by equations (1) and (2):

$$\theta_M = \frac{\left[3\left(\frac{R_C}{R_A}\times\frac{1}{\alpha}+\theta_A\right)-\frac{3}{\alpha}-\theta_1-\theta_2\right]^2-\left[\theta_1\times\theta_2\right]}{3\left[2\left(\frac{R_C}{R_A}\times\frac{1}{\alpha}+\theta_A\right)-\frac{2}{\alpha}-\theta_1-\theta_2\right]} \quad (1)$$

$$M = \left[3\left(\frac{R_C}{R_A}\times\frac{1}{\alpha}+\theta_A\right)-\frac{3}{\alpha}-\theta_1-\theta_2\right]-\theta_M \quad (2)$$

If the result $M$ of equation (2) is positive, the higher temperature of the conductor is $\theta_M$, and it is situated in any point of the conductor between the two extremities. If the result $M$ is negative or zero, the higher temperature of the conductor is $\theta_2$.

The point of maximum conductor temperature lies at distance $L_M$ from the cooler end.

$$L_M = \frac{L}{1 \pm \sqrt{\frac{\theta_M - \theta_2}{\theta_M - \theta_1}}} \quad (3)$$

where

$\alpha$ is the temperature coefficient of resistance at which conductor resistance $R_A$ is measured;

$\theta_1$ is the measured temperature at the cooler end of the conductor, in degrees Celsius;

$\theta_2$ is the measured temperature at the hotter end of the conductor, in degrees Celsius;

$\theta_A$ is the uniform reference temperature of the conductor, in degrees Celsius;

$\theta_M$ is the maximum temperature of conductor, in degrees Celsius;

$L$ is the length of conductor;

$L_M$ is the distance from the cooler end of the conductor to the point of highest temperature;

$R_A$ is the resistance between the ends of the conductor at uniform temperature $\theta_A$;

$R_C$ is the resistance of the conductor carrying $I_r$ after stabilization of temperature.

### 8.5.3 Acceptance

The bushing shall be considered to have passed the test if the permissible temperature limits in accordance with 4.8 are met, and if there is no visible evidence of damage.

## 8.6 Verification of thermal short-time current withstand

### 8.6.1 Applicability

The verification is applicable to all types of bushings.

### 8.6.2 Verification method and requirements

The ability of the bushings to withstand the standard value of $I_{th}$ shall be demonstrated by the following calculation:

$$\theta_f = \theta_o + \alpha \frac{{I_{th}}^2}{S_t \times S_e} \times t_{th} \qquad (4)$$

where

$\theta_f$ is the final temperature of the conductor, in degrees Celsius;

$\theta_o$ is the temperature of the conductor in degrees Celsius, under continuous operation with $I_r$ at an ambient temperature of 40 °C;

$\alpha$ is 0,8 (K/s)/(kA/cm$^2$)$^2$ for copper, 1,8 (K/s)/(kA/cm$^2$)$^2$ for aluminium;

$t_{th}$ is the rated duration as specified, in seconds;

$I_{th}$ is the standard value as specified above, in kiloamperes;

$S_e$ is the equivalent cross-section, in square centimetres, taking account of skin effect;

$S_t$ is the total cross-section, in square centimetres corresponding to $I_r$.

For other materials the value of $\alpha$ used may be derived from the formula given below:

$$\alpha = \frac{\rho}{c \times \delta} \qquad (5)$$

where

$\rho$ is the resistivity of conductor, in µΩ·cm

$c$ is the specific heat of conductor, in J/(g·K)

$\delta$ is the density of the conductor, in g/cm$^3$.

Values of $\rho$, $c$ and $\delta$ used in the formula should be correct at an average temperature of 160 °C.

In circular conductors of diameter $D$ (cm), the equivalent cross-section shall take skin effect into account. The skin effect may be determined by considering a depth of penetration $d$ of current derived from the formula given below:

$$d = \frac{1}{2\pi} \times \sqrt{\frac{\rho \times 10^3}{f}} \text{ cm} \qquad (6)$$

where $f$ is the rated frequency, in hertz.

Therefore:

$$S_e = \pi d (D - d) \qquad (7)$$

### 8.6.3 Acceptance

The bushing shall be considered to be able to withstand the standard value of $I_{th}$ if $\theta_f$ does not exceed 180 °C.

If the calculated temperature exceeds this limit, the ability of the bushing to withstand the standard value of $I_{th}$ shall be demonstrated by a test. The test shall be carried out as follows:

- the bushing can be installed in any position;
- a current of at least the standard value of $I_{th}$ and of duration $t_{th}$, in accordance with 4.3, shall be passed through the conductor, the cross-section of which shall conform with the rated current $I_r$.

Before the test, the bushing shall carry a current which produces the same stable conductor temperature as the rated current at maximum ambient temperature.

The bushing shall be considered to have passed the test if there is no visual evidence of damage and if it has withstood a repetition of all routine tests without significant change from the previous results.

## 8.7 Cantilever load withstand test

### 8.7.1 Applicability

The test is applicable to the air side of bushings.

### 8.7.2 Test method and requirements

The test values shall be in accordance with Table 1. For bushings according to 3.21, cantilever withstand load test values shall be restricted to:

300 N for $I_r \leq 800$ A

1 000 N for $I_r > 800$ A

The bushing shall be completely assembled and, if applicable, filled with the insulating medium specified. Unless otherwise stated, the bushing shall be installed vertically and its flange rigidly fixed to a suitable device.

A pressure equal to 1 bar ± 0,1 bar above the maximum operating pressure shall be applied inside the bushing, and also inside the central tube in the case of a bushing with a hollow stem with a gasket joint at the terminal to be tested.

For bushings with internal bellows, the pressure shall be stated by the supplier.

The load shall be applied perpendicular to the axis of the bushing at the mid-point of the terminal for 60 s. The load shall be in the direction which will cause the highest stress at the critical parts of the bushing in normal operation.

For bushings with more than one air side terminal, it is generally sufficient to apply the load to one terminal only.

For wall bushings the test load shall be applied to each end of the bushing separately.

### 8.7.3 Acceptance

The bushing shall be considered to have passed the test if there is no evidence of damage (deformation, rupture or leakage) and if it has withstood a repetition of all routine tests without significant change from previous results.

## 8.8 Tightness test on liquid-filled, compound-filled and liquid-insulated bushings

### 8.8.1 Applicability

The test is applicable to all liquid-filled or compound-filled and liquid-insulated bushings, according to 3.2 and 3.4, except those bushings where the liquid filling has a viscosity equal to or greater than $5 \times 10^{-4}$ $m^2/s$ at 20 °C.

### 8.8.2 Test method and requirements

The bushing shall be assembled as for normal operation, filled with the liquid specified and placed in a suitably heated enclosure, maintained at a temperature of 75 °C for 12 h. For bushings where this is not possible, alternative methods may be agreed between purchaser and supplier.

A minimum pressure of 1 bar ± 0,1 bar above the maximum internal operating pressure according to 3.30, shall be maintained inside the bushing during the test.

For bushing with internal bellows, the pressure shall be stated by the supplier.

### 8.8.3 Acceptance

The bushing shall be considered to have passed the test if there is no evidence of leakage. The method of detection shall be the one described in IEC 60068-2-17, Annex C, Clause C.2.

## 8.9 Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings

### 8.9.1 Applicability

The test is applicable to all gas-filled, gas-insulated and gas-impregnated bushings, according to 3.5, 3.6 and 3.7, where the insulating envelope is of ceramic or composite material and intended for use with a permanent gas pressure higher than 0,5 bar gauge, having an internal volume equal to or greater than 1 l (1 000 $cm^3$).

### 8.9.2 Test method and requirements

The test is performed on the insulating envelope in accordance with IEC 61462 or IEC 62155 where appropriate.

The insulating envelope shall be equipped with its fixing devices and fittings, preferably as in the intended application, and with additional plates with valve and pressure gauge for the test.

The insulator shall be completely filled with an appropriate medium. The pressure shall be increased steadily without producing any shock.

Other components should be tested to their appropriate standards.

### 8.9.3 Acceptance

The insulator shall be considered to have passed the test if there is no evidence of cracks, neither in the ceramic nor composite nor in the fittings. Where there is no evidence of the above, the test is considered satisfactory even though the fittings may have been stressed beyond their yield point.

## 8.10 External pressure test on partly or completely gas-immersed bushings

### 8.10.1 Applicability

The test is applicable to all gas-immersed bushings, according to 3.18 to 3.20, intended for use at a permanent gas pressure higher than 0,5 bar gauge.

### 8.10.2 Test method and requirements

The test shall be carried out before the tightness test according to 9.9. The bushing shall be assembled as far as necessary for the test, but there shall not be any internal gas pressure. The end for immersion shall be mounted in a tank as for normal operation at ambient temperature. The tank shall be completely filled with an appropriate liquid. A pressure of three times the external maximum operating pressure (see 3.31) shall be applied for 1 min.

### 8.10.3 Acceptance

The bushing shall be considered to have passed the test if there is no evidence of mechanical damage (e.g. deformation, rupture).

## 8.11 Verification of dimensions

### 8.11.1 Applicability

This verification is applicable to all types of bushings.

### 8.11.2 Acceptance

The dimensions of the bushing under test shall be in accordance with the relevant drawings, particularly with regard to any dimensions to which special tolerances apply and to details affecting interchangeability.

# 9 Routine tests

The order or possible combination of the tests is at the discretion of the supplier, except if the tests include impulse voltage withstand tests, which shall be made before the dry power-frequency voltage withstand test (see 9.3). Before and after the dielectric routine tests, measurements of dielectric dissipation factor (tan $\delta$) and capacitance (see 9.1) shall be carried out in order to check whether damage has occurred. The measurement of partial discharge quantity (see 9.4) shall be made before the last measurement of tan $\delta$.

### 9.1 Measurement of dielectric dissipation factor (tan $\delta$) and capacitance at ambient temperature

#### 9.1.1 Applicability

The measurement is only applicable to capacitance-graded bushings according to 3.14.

#### 9.1.2 Test method and requirements

During this test, the bushing conductor shall not carry current. The measurement shall be made at an ambient temperature of between 10 °C and 40 °C by means of a Schering bridge, or other similar equipment, at least at:

– 1,05 $U_m / \sqrt{3}$ for bushings of $U_m \leq 36$ kV;

– 1,05 $U_m / \sqrt{3}$ and $U_m$ for bushings of $U_m \geq 52$ kV.

The measurement shall not be made at a voltage exceeding the dry power-frequency withstand voltage.

A measurement of tan $\delta$ and capacitance at a voltage between 2 kV and 20 kV shall be carried out as a reference value for measurements carried out later when the bushing is in operation.

#### 9.1.3 Acceptance

The maximum permissible values of tan $\delta$ and for the increase of tan $\delta$ with voltage are given in Table 5. If the values are not acceptable, it is permitted to wait for 1 h before repeating the test.

The actual temperature during the measurement shall be stated in the test report.

### 9.2 Dry lightning impulse voltage withstand test (BIL)

#### 9.2.1 Applicability

The test as a routine test is applicable only for transformer bushings with lightning impulse level equal to or greater than 850 kVp.

#### 9.2.2 Test method and requirements

– five full lightning impulses of negative polarity shall be applied or, by contractual agreement

– three full lightning impulses of negative polarity, and

– two chopped lightning impulses of negative polarity

shall be applied.

For test conditions, 8.2 shall be followed.

#### 9.2.3 Acceptance

For criteria, 8.2 shall be followed.

## 9.3 Dry power-frequency voltage withstand test

### 9.3.1 Applicability

The test is applicable to all types of bushings. For gas-insulated bushings according to 3.6, which are intended to be used as an integral part of a gas-insulated apparatus, of which the gas filling is common to that of the bushing, this test shall be a type test only, provided the insulating envelope of the bushing has been subjected to an adequate electrical test (e.g. wall test of the porcelain) before assembly.

### 9.3.2 Test method and requirements

The test shall be made or repeated after any impulse voltage withstand test, if required in a series of tests.

The magnitude of the test voltage is given in Tables 7 or 9. Bushings for transformers shall be tested at least 10 % above the induced and/or applied test voltage level of the transformer. The level shall be not lower than the values shown in Tables 7 or 9. If the information on transformer test level is not provided by the purchaser, the test level for the bushing shall be in accordance with Tables 7 or 9.

The test duration shall be 60 s, independent of frequency.

### 9.3.3 Acceptance

The bushing shall be considered to have passed the test if no flashover or puncture occurs. If there is a puncture, the bushing shall be considered to have failed the test. For capacitance graded bushings it is assumed that a puncture has occurred if the capacitance measured after the test rises above the capacitance previously measured by about the amount attributable to the capacitance of one layer. If a flashover occurs the test shall be repeated once only. If, during the repetition of the test, no flashover or puncture occurs, the bushing shall be considered to have passed the test.

## 9.4 Measurement of partial discharge quantity

### 9.4.1 Applicability

The measurement shall be carried out on all types of bushings, except for bushings according to 3.6 and 3.11, for which this test shall be a type test only, provided the insulating envelope of the bushing has been subjected to an adequate electrical test (e.g. wall test of the porcelain) before assembly.

### 9.4.2 Test method and requirements

The test shall be made in accordance with IEC 60270.

When, as a substitute for the measurement of partial discharge quantity, the radio interference voltage, expressed in microvolts, is measured by means of a radio interference meter, the method of calibration to be used is that described in IEC 60270.

Unless otherwise stated, the elements of the test circuit shall be such that background noise and sensitivity at the measuring circuit enable a partial discharge quantity of 5 pC or 20 % of the specific value to be detected, whichever value is higher.

The measurement shall be made after the dry power-frequency withstand voltage test (see 9.3) at the values given in Table 6 during the decrease of the voltage from the dry power-frequency withstand test level; depending on test facilities, the voltage level could be reduced at 2 $U_m/\sqrt{3}$ by agreement between the manufacturer and purchaser.

### 9.4.3 Acceptance

The maximum acceptable values of partial discharge quantity, according to the type of bushing after the last dielectric test, shall be as given in Table 6.

When the measured values at 1,5 $U_m/\sqrt{3}$ are greater than those indicated in Table 6, the supplier may extend the test for a period of up to 1 h to check if the values return to the allowed limits. If the partial discharge at the end of the period is within limits, then the bushing shall be accepted.

Partial discharge measurements before dielectric tests may be requested for information purpose only, and are not subject to guarantee.

## 9.5 Tests of tap insulation

### 9.5.1 Applicability and test requirements

The following power-frequency voltage withstand test with respect to earth shall be applied to all taps:

– test tap (see 3.37): at least 2 kV;

– voltage tap (see 3.38): twice the rated voltage of the voltage tap but at least 20 kV.

The test duration is 60 s, independent of frequency.

After the test $\tan\delta$ and capacitance with respect to earth shall be measured at least at 1 kV.

### 9.5.2 Acceptance

The tap shall be considered to have passed the test if no flashover or puncture occurs.

For test taps the values of $\tan\delta$ and capacitance shall be in accordance with 4.10.

## 9.6 Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings

### 9.6.1 Applicability

The test is applicable to all gas-filled, gas-insulated and gas-impregnated bushings according to 3.5, 3.6 and 3.7.

### 9.6.2 Test method and requirements

The bushing, complete as for normal operation, shall be filled with gas at the choice of the supplier. A pressure of (1,5 × maximum operating pressure) bar ± 0,1 bar shall be produced inside the bushing and maintained for 15 min at ambient temperature.

In the case of bushings where the insulating envelope is made of ceramic or composite material and intended to be operated under pressure, the unassembled insulating envelope shall be previously tested in accordance with IEC 62155 or IEC 61462, where appropriate. Other components should be tested to their appropriate standards.

#### 9.6.3 Acceptance

The bushing shall be considered to have passed the test if there is no evidence of mechanical damage (e.g. deformation, rupture).

### 9.7 Tightness test on liquid-filled, compound-filled and liquid-insulated bushings

#### 9.7.1 Applicability

The test is applicable to all liquid-filled or compound-filled and liquid-insulated bushings according to 3.2 and 3.4, except those bushings where the liquid filling has a viscosity equal to or greater than $5 \times 10^{-4}$ $m^2/s$ at 20 °C.

#### 9.7.2 Test method and requirements

The bushing shall be assembled as for normal operation, filled with the liquid specified at ambient temperature of not less than 10 °C, except bushings for transformers, which shall be filled with the liquid having a minimum temperature of 60 °C. A pressure of 1 bar ± 0,1 bar above the maximum operating pressure shall be applied inside the bushing as soon as possible after filling and maintained for at least 12 h.

For bushings with internal bellows, the pressure shall be stated by the supplier.

#### 9.7.3 Acceptance

The bushing shall be considered to have passed the test if there is no evidence of leakage. The method of detection shall be as described in IEC 60068-2-17, Annex C, Clause C.2.

It is advisable to carry out a preliminary tightness test on components for which the test is considered useful. Special consideration may be necessary for bushings, one or both ends of which are intended to be immersed in a gaseous medium.

### 9.8 Tightness test on gas-filled, gas-insulated and gas-impregnated bushings

#### 9.8.1 Applicability

The test is applicable to all gas-filled, gas-insulated and gas-impregnated bushings, according to 3.5 to 3.7 and 3.18 to 3.20.

For gas-insulated bushings, intended to form an integral part of gas-insulated equipment, and of which assembly is intended to be achieved on site, it is permitted to replace the tightness test on the assembled bushing by a tightness test on each component, completed by a tightness test on each sealing assembly. The sealing assembly method shall be agreed upon between purchaser and supplier.

### 9.8.2 Test method and requirements

The bushings shall be assembled as for normal operation and filled with gas at maximum operating pressure at ambient temperature. The bushing shall be enclosed in an envelope, for example a plastic bag. The concentration of gas in the air inside the envelope shall be measured twice at an interval equal to or greater than 2 h.

Alternative methods of leakage detection may be used by agreement between purchaser and supplier.

It is advisable to carry out a preliminary tightness test on such components as is considered useful.

### 9.8.3 Acceptance

The bushing shall be considered to have passed the test if the calculated escape of gas is equal to or less than 0,5 % per year of the equivalent amount of gas contained inside the bushing in service.

## 9.9 Tightness test at the flange or other fixing device

### 9.9.1 Applicability

The test is applicable to all partly or completely immersed bushings, according to 3.18 to 3.20 intended to be used as an integral part of an apparatus, such as switchgear or transformers, where the bushings contribute to the sealing of the complete apparatus.

The test shall be a type test only in the case of bushings with gaskets of which the final placing is not carried out by the supplier, for example the top cap gasket of draw-through conductor transformer bushings.

The test may be omitted for transformer bushings fitted with a one-piece metal flange, provided the flange has been subjected to a preliminary tightness test, and the bushing has passed the type test in accordance with 8.8 (for example oil-impregnated paper bushings) or the routine test in accordance with 9.7, or the end to be immersed does not include any gaskets.

### 9.9.2 Test method and requirements

The bushing shall be assembled at least as far as necessary for the test. The end for immersion shall be mounted on a tank as for normal operation at ambient temperature.

For oil-immersed bushings, the tank shall be filled with air or any suitable gas at a relative pressure of 1,5 bar ± 0,1 bar and maintained for 15 min, or with oil at a relative pressure of 1 bar ± 0,1 bar maintained for 12 h.

For gas-immersed bushings, the tank shall be filled with gas at maximum operating pressure at ambient temperature. The external part of the bushing shall be enclosed in an envelope, where necessary. Liquid-containing bushings shall remain empty and shall have an opening for free gas circulation within the envelope. The concentration of gas in the air inside the envelope shall be measured twice at an interval equal to or greater than 2 h.

### 9.9.3 Acceptance

An oil-immersed bushing shall be considered to have passed the test if there is no evidence of leakage detected by visual inspection (see IEC 60068-2-17, Annex C, Clause C.2).

Gas-immersed bushings shall be considered to have passed the test, if:

– for all parts of a bushing where the leak gas escapes directly to the environment, the calculated total escape of gas is equal to or less than 0,5 % per year of the amount of gas contained in the adjacent switchgear compartment;

– for all parts of a liquid-containing bushing, especially liquid-insulated and oil-impregnated paper bushings, where the leak gas penetrates into the inside of the bushing, the calculated total leak rate (see 3.33) is equal to or less than 0,05 Pa $\times$ cm$^3$/s $\times$ l (5 $\times$ 10$^{-7}$ bar $\times$ cm$^3$/s $\times$ l), "l" being the quantity of liquid inside the bushing in litres;

– for all parts of a bushing, the other end of which is designed for a transformer, where the leak gas penetrates directly into the transformer, the calculated total leak rate (see 3.33) is equal to or less than 10 Pa $\times$ cm$^3$/s (10$^{-4}$ bar $\times$ cm$^3$/s).

### 9.10 Visual inspection and dimensional check

### 9.10.1 Applicability

The inspections are applicable to all types of bushings and shall be made on the complete bushings before release. The visual inspection shall be made on each bushing.

### 9.10.2 Acceptance

No surface defects shall be tolerated which could affect the satisfactory performance in service.

Dimensions of parts for assembling and/or interconnection shall be in accordance with the relevant drawings, checked by sampling.

## 10 Requirements and tests for bushings of highest voltages for equipment equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or combined insulation

This clause is applicable to all bushings where the major insulation consists of ceramic, glass or analogous inorganic materials, cast and moulded resin, or combined insulation, as defined in 3.11 to 3.13.

### 10.1 Temperature requirements

Bushings which may be required to withstand the drying process of the apparatus on which they are mounted, shall be able to withstand a temperature of 140 °C for 12 h without mechanical or electrical damage, provided that no external forces are applied.

### 10.2 Level of immersion medium

For transformer bushings, the supplier shall specify the minimum depth of immersion medium.

### 10.3 Markings

Each bushing shall carry the following marking:

- supplier's name or trade mark;
- year of manufacture;
- type or minimum nominal creepage distance or highest voltage for equipment ($U_m$);
- rated current ($I_r$) or maximum current if the bushing is supplied without conductor.

NOTE It may sometimes be difficult to provide all the above markings on small bushings and, in this case, other markings may be agreed between supplier and purchaser.

An example of a marking plate is given in Figure 3.

### 10.4 Test requirements

The test conditions and requirements shall be equivalent to Clauses 7, 8 and 9. Reference is made in parenthesis to the relevant subclause.

#### 10.4.1 Type tests

The following tests are applicable to all bushings:

- dry or wet power-frequency voltage withstand test (8.1);
- dry lightning impulse voltage withstand test (8.2);
- temperature rise test (8.5);
- verification of thermal short-time current withstand (8.6);
- cantilever load withstand test (8.7);
- verification of dimensions (8.11).

For bushings according to 3.21, cantilever withstand load test values are reduced.

For these bushings, precautions shall be taken to ensure that the end, which is designed to receive the movable part, will withstand the relevant test voltage, where applicable.

#### 10.4.2 Routine tests

The following tests are applicable to all bushings except for ceramic and glass bushings (3.11), where only visual inspection is applicable:

- dry power-frequency voltage withstand test (9.3);
- measurement of the partial discharge quantity (9.4);
- tests of tap insulation (9.5), if applicable;
- visual inspection and dimensional check (9.10).

Tables 11 and 13 show the applicability of the tests to the various types of bushings.

| | | |
|---|---|---|
| MANUFACTURER | | |
| Year ............... | No. ..................... | . |
| $U_m$ .................................kV | $I_r$ ...................................... A | $f_r$ ......................... Hz |
| BIL ................................ kV | SIL ..................................... kV | AC ........................ kV |
| Mass .............................. kg | Max. angle to vertical ........................................................ degree | |
| Capacitance ................... pF | Dissipation factor .................% | |

In addition, for gas-filled, gas-insulated, gas-immersed and gas-impregnated bushings:

| |
|---|
| Type of gas ..................................................................................................................... |
| Minimum gas pressure at 20 °C ........................................................................... bar gauge |

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**Figure 1 – Marking plate for bushings for highest voltage for equipment greater than 100 kV (see 6.2)**

| | | |
|---|---|---|
| MANUFACTURER | | |
| Year ................. | No. ............................................................ | |
| $U_m$ ................................ kV | $I_r$ . ................................................ A | $f_r$ .............................. Hz |

IEC 2002/03

**Figure 2 – Marking plate for bushings for highest voltage for equipment equal to or less than 100 kV, except for bushings for which Figure 3 is applicable (see 6.2)**

| | | |
|---|---|---|
| MANUFACTURER | | |
| Year ..................... | $U_m$ ................... kV | $I_r$ ...................A |

IEC 2003/03

**Figure 3 – Marking plate for bushings for highest voltage for equipment equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or combined insulation (see 10.3)**

**Table 1 – Minimum values of cantilever withstand load (see 4.5 and 8.7)**

| **Highest voltage for equipment** $U_m$ kV | **Rated current** A | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ≤ 800 | | 1 000<br>1 600 | | 2 000<br>2 500 | | ≥3 150 | |
| | **Cantilever operating load** N | | | | | | | |
| | **Bushing installed ≤30° from the vertical** | | | | | | | |
| | I | II | I | II | I | II | I | II |
| ≤36 | 500 | 500 | 625 | 625 | 1 000 | 1 000 | 1 575 | 1 575 |
| 52 | 500 | 800 | 625 | 800 | 1 000 | 1 250 | 1 575 | 1 575 |
| 72,5 to 100 | 500 | 1 000 | 625 | 1 000 | 1 000 | 1 575 | 2 000 | 2 000 |
| 123 to 145 | 625 | 1 575 | 800 | 1 575 | 1 250 | 2 000 | 2 000 | 2 000 |
| 170 to 245 | 625 | 2 000 | 800 | 2 000 | 1 250 | 2 500 | 2 000 | 2 500 |
| ≥300 | 1 250 | 2 000 | 1 250 | 2 000 | 1 575 | 2 500 | 2 500 | 2 500 |
| | **Cantilever test load** N | | | | | | | |
| | I | II | I | II | I | II | I | II |
| ≤36 | 1 000 | 1 000 | 1 250 | 1 250 | 2 000 | 2 000 | 3 150 | 3 150 |
| 52 | 1 000 | 1 600 | 1 250 | 1 600 | 2 000 | 2 500 | 3 150 | 3 150 |
| 72,5 to 100 | 1 000 | 2 000 | 1 250 | 2 000 | 2 000 | 3 150 | 4 000 | 4 000 |
| 123 to 145 | 1 250 | 3 150 | 1 600 | 3 150 | 2 500 | 4 000 | 4 000 | 4 000 |
| 170 to 245 | 1 250 | 4 000 | 1 600 | 4 000 | 2 500 | 5 000 | 4 000 | 5 000 |
| ≥300 | 2 500 | 4 000 | 2 500 | 4 000 | 3 150 | 5 000 | 5 000 | 5 000 |

NOTE 1 Cantilever operating loads include terminal load and wind pressure (70 Pa), reference IEC 61463.

NOTE 2 For bushings operating at an angle >30° to the vertical, the effect of bushing self-load should be considered when selecting test load and procedure. The values given above correspond to vertical bushings that are to be tested in a vertical position. If a tilted or horizontal bushing is to be tested vertically, then an equivalent force should be added to achieve the bending moment at the flange, caused by the weight of the bushing in its operating position. If a vertical bushing is to be tested horizontally, then the test load can be reduced in the same manner.

NOTE 3 Level I = normal load, Level II = heavy load.

NOTE 4 For bushings where upper and lower insulating envelopes are assembled by clamping force on the central fixing conductor, it is recommended to choose the cantilever test load, taking into account the thermal expansion of the conductor due to the rated current flow.