BRITISH STANDARD

BS EN
60137:1996
IEC 137:1995

Insulated bushings for alternating voltages above 1 kV

The European Standard EN 60137:1996 has the status of a British Standard

ICS 29.080.20

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Committees responsible for this British Standard

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Contents

	Page
Committees responsible	Inside front cover
National foreword	ii
Foreword	2
Text of EN 60137	5
List of references	Inside back cover

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National foreword

This British Standard has been prepared by Subcommittee PEL/36/1 and is the English language version of EN 60137, *Insulated bushings for alternating voltages above 1 kV*, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 137:1995 published by the International Electrotechnical Commission (IEC).

The foreword of the EN makes reference to the "date of withdrawal", dow, of the relevant national standard. In this case the relevant national standard is BS 223 which will be withdrawn on 1996-09-01.

Cross-references

Publication referred to	Corresponding British Standard
HD 472 S1:1989 (IEC 38:1983)	BS 7697:1993 *Nominal voltages for low voltage public electricity supply systems*
	BS 4727 *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms* Part 1 *Terms common to power, telecommunications and electronics*
IEC 50(212):1990 IEC 50(471):1984	Group 10:1991 *Insulating solids, liquids and gases* Group 12:1991 *Insulators*
HD 588.1 S1:1991 (IEC 60-1:1989)	BS 923 *Guide on high-voltage testing techniques* Part 1:1990 *General*
EN 60068-2-17:1994 (IEC 68-2-17:1994)	BS EN 60068 *Environmental testing* BS EN 60068-2-17:1995 *Test methods. Test Q. Sealing*
EN 60071-1:1995 (IEC 71-1:1993)	BS EN 60071 *Insulation coordination* Part 1:1996 *Definitions, principles and rules*
HD 398.5 S1:1983 (IEC 76-5:1976)	BS 171 *Power transformers* Part 5:1978 *Specification for ability to withstand short circuit*
HD 611.2 S1:1992 (IEC 216-6:1990)	BS 5691 *Guide for the determination of thermal endurance properties of electrical insulating materials* Part 2:1995 *Choice of test criteria*
HD 329 S1:1977 (IEC 233:1974)	BS 4963:1973 *Specification for tests on hollow insulators for use in high voltage electrical equipment*
IEC 270:1981 IEC 354:1991	BS 4828:1985 *Guide for partial discharge measurements* BS 7735:1994 *Guide to loading of oil-immersed power transformers*
EN 60507:1993 (IEC 507:1991)	BS EN 60507:1993 *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*
EN 60517:1996 (IEC 517:1990)	BS EN 60517:1996 *Gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above*
IEC 943:1989	PD 6524:1989 *Guide to specifying permissible temperature and temperature rise for parts of electrical equipment, in particular for terminals*
IEC 1263:1994	BS 7515:1995 *Radiation protection instrumentation. Portable potential alpha meter for rapid measurements in mines*

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, the EN title page, pages 2 to 36, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60137

January 1996

ICS 29.080.20

Descriptors: Bushings, transformers, ceramic, glass, inorganic materials, resin, composite insulation

English version

Insulated bushings for alternating voltages above 1 kV

(IEC 137:1995)

Traversées isolées pour tensions alternatives supérieures à 1 kV
(CEI 137:1995)

Isolierte Durchführungen für Wechselspannungen über 1 kV
(IEC 137:1995)

This European Standard was approved by CENELEC on 1995-11-28. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 36A/45/FDIS, future edition 4 of IEC 137, prepared by SC 36A, Insulated bushings, of IEC TC 36, Insulators, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60137 on 1995-11-28.

The following dates were fixed:

— latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1996-09-01

— latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1996-09-01

Annexes designated "normative" are part of the body of the standard. In this standard, Annex ZA is normative. Annex ZA has been added by CENELEC.

Contents

		Page
Foreword		2
Introduction		4
1	General	5
1.1	Scope	5
1.2	Normative references	5
2	Definitions	6
3	Ratings	10
3.1	Standard values of rated voltage (U_r)	10
3.2	Standard values of rated current (I_r)	10
3.3	Standard values of rated thermal short-time current (I_{th})	10
3.4	Standard values of rated dynamic current (I_d)	10
3.5	Minimum withstand values of cantilever load	10
3.6	Angle of mounting	10
3.7	Minimum nominal creepage distance	10
3.8	Temperature limits and temperature rise	11
3.9	Standard insulation levels	11
3.10	Test tap on transformer bushings	11
4	Operating conditions	11
4.1	Temporary overvoltages	11
4.2	Altitude	12
4.3	Temperature of ambient air and immersion media	12
5	Ordering information and markings	12
5.1	Enumeration of characteristics	12
5.2	Markings	13
6	Test requirements	14
6.1	General requirements	14
6.2	Test classification	14
6.3	Condition of bushings during dielectric and thermal tests	15
7	Type tests	15
7.1	Dry or wet power-frequency voltage withstand test	15
7.2	Dry lightning impulse voltage withstand test	16
7.3	Dry or wet switching impulse voltage withstand test	16
7.4	Thermal stability test	17
7.5	Temperture rise test	18
7.6	Verification of thermal short-time current withstand	19
7.7	Cantilever load withstand test	20

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		Page
7.8	Tightness test on liquid-filled, compound-filled and liquid-insulated bushings	21
7.9	Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings	21
7.10	External pressure test on partly or completely gas-immersed bushings	21
7.11	Verification of dimensions	22
8	Routine tests	22
8.1	Measurement of dielectric dissipation factor (tan δ) and capacitance at ambient temperature	22
8.2	Dry lightning impulse voltage withstand test	22
8.3	Dry power-frequency voltage withstand test	22
8.4	Measurement of partial discharge quantity	23
8.5	Tests of tap insulation	23
8.6	Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings	23
8.7	Tightness test on liquid-filled, compound-filled and liquid-insulated bushings	24
8.8	Tightness test on gas-filled, gas-insulated and gas-impregnated bushings	24
8.9	Tightness test at the flange or other fixing device	24
8.10	Visual inspection and dimensional check	25
9	Requirements and tests for bushings of rated voltages equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or composite insulation	25
9.1	Temperature requirements	26
9.2	Level of immersion medium	26
9.3	Markings	26
9.4	Test requirements	26
Annex ZA (normative) Normative references to international publications with their corresponding European publications		36
Figure 1 — Marking plate for bushings for rated voltages greater than 100 kV		27
Figure 2 — Marking plate for bushings for rated voltages equal to or less than 100 kV, except for bushings for which Figure 3 is applicable		27
Figure 3 — Marking plate for bushings for rated voltages equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or composite insulation		27
Table 1 — Minimum values of cantilever withstand load		28
Table 2 — Maximum values of temperature and temperature rise above ambient air		29
Table 3 — Temperature of ambient air and immersion media		30
Table 4 — Correction of test voltages		30
Table 5 — Maximum values of tan δ and tan δ increase		31
Table 6 — Maximum values of partial discharge quantity		31
Table 7 — Standard insulation levels for rated voltages less than 300 kV		32
Table 8 — Standard insulation levels for rated voltages equal to or greater than 300 kV		33
Table 9 — Dry power-frequency withstand test voltages for rated voltages equal to or greater than 300 kV		33
Table 10 — Applicability of type tests		34
Table 11 — Applicability of type tests for bushings according to clause **9**		34
Table 12 — Applicability of routine tests		35
Table 13 — Applicability of routine tests for bushings according to clause **9**		35

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Introduction

In this edition of IEC 137 special account is taken of the requirements for bushings to be fitted to transformers, and the range of bushings addressed in this edition has been extended to include bushings of rated voltages equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or composite insulation.

Many clauses have been modified, considering the evolution of technology, and to align with current revisions of the IEC standards. New types of bushings, e.g. gas-filled, gas-insulated and gas-impregnated bushings, are considered.

For bushings fitted to transformers special requirements not considered necessary for bushings fitted to switchgear, or used for other applications have been addressed. 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 **8.3**.

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

1 General

1.1 Scope

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

This standard is applicable to bushings, as defined in clause **2**, intended for use in electrical apparatus, machinery, transformers, switchgear and installations for three-phase alternating current systems, having rated voltages above 1 000 V and power-frequencies of 15 Hz up to and including 60 Hz.

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

This standard may also be used analogously for bushings for use in other than three-phase systems, e.g. for rectifiers, testing transformers, or for terminals for power cables (potheads) and capacitors. Such bushings should be subject to special agreement between purchaser and supplier.

This standard is not applicable to insulating structures similar to bushings, which are used as support insulators inside metal-enclosed switchgear.

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.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties involved in agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 38:1983, *IEC standard voltages.*

IEC 50(212):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 212: Insulating solids, liquids and gases.*

IEC 50(471):1984, *International Electrotechnical Vocabulary (IEV) — Chapter 471: Insulators.*

IEC 59:1938, *IEC standard current ratings.*

IEC 60-1:1989, *High-voltage test techniques — Part 1: General definitions and test requirements.*

IEC 68-2-17:1994, *Environmental testing — Part 2: Tests — Test Q: Sealing.*

IEC 71-1:1993, *Insulation co-ordination — Part 1: Definitions, principles and rules.*

IEC 76-1:1993, *Power transformers — Part 1: General.*

IEC 76-2:1993, *Power transformers — Part 2: Temperature rise.*

IEC 76-5:1976, *Power transformers — Part 5: Ability to withstand short circuit.*

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IEC 216-2:1990, *Guide for the determination of thermal endurance properties of electrical insulating materials — Part 2: Choice of test criteria.*

IEC 233:1974, *Test on hollow insulators for use in electrical equipment.*

IEC 270:1981, *Partial discharge measurements.*

IEC 354:1991, *Loading guide for oil-immersed power transformers.*

IEC 505:1975, *Guide for the evaluation and identification of insulation systems of electrical equipment.*

IEC 507:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems.*

IEC 517:1990, *Gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above.*

IEC 815:1986, *Guide for the selection of insulators in respect of polluted conditions.*

IEC 943:1989, *Guide for the selection of permissible temperature and temperature rise for parts of electrical equipment, in particular for terminals.*

IEC 1264:1994, *Ceramic pressurized hollow insulators for high-voltage switchgear and controlgear.*

2 Definitions

For the definitions of generally used terms in the present standard, reference should be made to IEC 50(471).

For the purposes of this International Standard, the following definitions apply.

2.1
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 **2.2** to **2.20**.

2.2
liquid-filled or compound-filled bushing

bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with oil, or an insulating compound

2.3
liquid-insulated bushing

bushing in which the major insulation consists of oil or another insulating liquid

2.4
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.

2.5
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 composite bushing (see **2.12**).

2.6
gas-impregnated bushing

bushing in which the major insulation consists of a core wound from paper or plastic film 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

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2.7
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. 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

2.8
resin-bonded paper bushing (RBP)

bushing in which the major insulation consists of a core wound from resin-coated paper. 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

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

2.9
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

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

2.10
ceramic, glass or analogous inorganic material bushing

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

2.11
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

2.12
composite bushing

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

2.13
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]

2.14
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, modified]

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

2.15
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]

2.16
outdoor-indoor bushing

bushing, both ends of which are intended to be in ambient air at atmospheric pressure. 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, modified]

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2.17
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]

2.18
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]

2.19
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 analogous]

2.20
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

2.21
rated voltage (U_r)

value assigned by the manufacturer for a specified operating condition of a bushing [IEV 151-04-03 analogous]

2.22
rated phase-to-earth voltage

maximum r.m.s. value of the voltage which the bushing shall withstand continuously between the conductor and the earthed flange or other fixing device, under the operating conditions specified in clause **4**

2.23
rated current (I_r)

maximum r.m.s. value of current which the bushing can carry continuously under the operating conditions specified in clause **4**, without exceeding the temperature rise limits of Table 2

2.24
rated thermal short-time current (I_{th})

r.m.s. value of a symmetrical current which the bushing shall withstand 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 **4.3**

2.25
rated dynamic current (I_d)

peak value of a current which the bushing shall withstand mechanically

2.26
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 **3.8**)

2.27
rated frequency (f_r)

frequency at which the bushing is designed to operate (see IEC Multilingual Dictionary of Electricity, Electronics and Telecommunications)

2.28
minimum pressure of insulating gas

minimum pressure, referenced to 20 °C, assigned by the supplier, at which the rated insulating level applies

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2.29
maximum internal operating gas pressure

pressure when the bushing is in operation carrying rated current at the highest temperatures in accordance with **4.3**

2.30
maximum external operating gas pressure

maximum pressure of the gaseous insulating medium in which the bushing is partially or completely immersed when in operation

2.31
design pressure (of the enclosure)

pressure used to determine the thickness of the enclosure [see IEC 517]

2.32
leak rate of gas-filled, gas-insulated, gas-impregnated and gas-immersed bushings

quantity of a 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 68-2-17)

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

2.33
insulating envelope

hollow insulator which is open from end to end, with or without sheds [IEV 471-01-17]

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

2.34
creepage distance

shortest distance along the surface of an insulator between two conductive parts [IEV 471-01-08]

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

2.35
arcing distance

shortest distance in air external to the insulator between metallic parts which normally have the operating voltage between them [IEV 471-01-07]

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

2.36
test 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. This connection shall be earthed directly when it is not used

NOTE The terms measuring tap and tan δ tap are also used.

2.37
voltage 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. This connection shall be earthed directly when it is not used

NOTE 1 The terms potential tap and capacitance tap are also used.
NOTE 2 This tap can also be used for the measurement of dissipation factor, capacitance and partial discharge.

2.38
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

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3 Ratings

3.1 Standard values of rated voltage (U_r)

The values of U_r of a bushing shall be chosen from the standard values of the highest voltage for equipment, U_m, defined in IEC 38 and IEC 71-1 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 – 525 – 765.

3.2 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.

The above series of currents are in accordance with the values indicated in IEC 59.

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 material of the conductor which correspond to I_r in accordance with **3.8**.

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 354 without further clarification or tests.

3.3 Standard values of rated thermal short-time current (I_{th})

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 always be 2 s, with reference to IEC 76-5.

NOTE For durations of t_{th} other than 1 s, the relationship between current and time is assumed to be in accordance with $I^2_{th} \times t_{th}$ = constant

3.4 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 **3.3**.

NOTE In some cases, values greater than 2,5 times the value of I_{th} indicated in **3.3** may be necessary with respect to the transformer characteristics. The transformer manufacturer shall stipulate such requirements in the bushing ordering information (see **5.1.3.6**).

3.5 Minimum withstand values of cantilever load

The bushings shall withstand the cantilever load given in Table 1, level I or II (see **5.1.3.8**). Level I is normal load and shall be generally applied unless a purchaser specifies a heavy load of level II.

3.6 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 (see also **5.1.4.11**).

3.7 Minimum nominal creepage distance

Unless otherwise agreed between purchaser and supplier, or demonstrated by a test, the creepage distance in accordance with IEC 815 is determined by

d_{cs} (mm/kV) × U_r (kV) × k_D

where

d_{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

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k_D is the correction factor depending on the averaged diameter D_m of the insulator, the classes of which are:

— < 300 mm: $k_D = 1$

— 300 to 500 mm: $k_D = 1{,}1$

— > 500 mm: $k_D = 1{,}2$

D_m shall be determined in accordance with IEC 815.

If artificial pollution tests are required they shall be performed in accordance with IEC 507.

NOTE The actual value of creepage distance can differ from the nominal one by the manufacturing tolerances stated in IEC 233, clause **7**.

3.8 Temperature limits and temperature rise

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

— 120 °C for resin-bonded and resin-impregnated paper: class E;

— 105 °C for oil-impregnated paper: class A.

The temperature rise above maximum daily mean ambient air temperature in accordance with clause **4.3** (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 216-2 and IEC 505.

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 **3.2**.

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

3.9 Standard insulation levels

The standard values of insulation level of a bushing having U_r less than 300 kV are to be chosen from the values given in Table 7.

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

The specified standard values of insulation level are in accordance with IEC 71-1.

3.10 Test tap on transformer bushings

A test tap according to **2.36** shall be provided on transformer bushings of U_r 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 5 000 pF;

— a dielectric dissipation factor (tan δ) of 0,05 measured at power-frequency.

A lower maximum value of test tap capacitance to earth may be agreed between purchaser and supplier (see **5.1.3.9**).

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.

4 Operating conditions

4.1 Temporary overvoltages

The maximum phase-to-earth voltage of the system may exceed U_r 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_r for bushings of which U_r is equal to or less than 170 kV;

— 0,8 U_r for bushings of which U_r is greater than 170 kV.

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

4.2 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

$$1\% \times \frac{2\,800\ \text{m} - 1000\ \text{m}}{100\ \text{m}} = 18\ \%$$

4.3 Temperature of ambient air and immersion media

Bushings shall be designed for operation at temperatures not exceeding the limits given in Table 3 (see **5.1.4.3**).

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

5 Ordering information and markings

5.1 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.

5.1.1 ***Application***

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

Attention shall be drawn to any features (including tests) of the completed apparatus which may affect the design of the bushing (see **6.3**).

5.1.2 Classification of bushings

Classification according to **2.2** to **2.20**.

5.1.3 Ratings

5.1.3.1 Rated voltage (U_r) (see **2.21**)

5.1.3.2 Rated phase-to-earth voltage (see **2.22**)

5.1.3.3 Standard insulation level (see **3.9**) and if necessary the induced and/or applied test voltage level of the transformer (see **8.3**)

5.1.3.4 Rated current (I_r) (see **2.23**)

5.1.3.5 Rated thermal short-time current (I_{th}) and rated duration (t_{th}), if deviating from the values given in **3.3**

5.1.3.6 Rated dynamic current (I_d), if deviating from the value given in **3.4**

5.1.3.7 Rated frequency (see **2.27**)

5.1.3.8 Minimum withstand values of cantilever load in accordance with **3.5**

5.1.3.9 Maximum value of test tap capacitance in accordance with **3.10**, if a lower value is necessary

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5.1.4 Operating conditions

5.1.4.1 Temporary overvoltages, if applicable (see **4.1**)

5.1.4.2 Altitude, if exceeding 1 000 m (see **4.2**) (relevant only to indoor and outdoor bushings according to **2.14** to **2.18**)

5.1.4.3 Ambient air and immersion media temperature if deviating from normal values (see **4.3** and Table 3) (relevant to bushings according to **2.14** to **2.20**)

5.1.4.4 Type of immersion medium (relevant only to partly or completely immersed bushings according to **2.17** to **2.20**)

5.1.4.5 Minimum level of immersion medium (relevant only to partly or completely immersed bushings according to **2.17** to **2.20**)

5.1.4.6 Maximum operating pressure of immersion media (relevant only to partly or completely immersed bushings according to **2.17** to **2.20**)

5.1.4.7 Type of insulating gas (relevant only to gas-filled, gas-insulated and gas-impregnated bushings according to **2.4** to **2.6** when the gas of the equipment is in communication with that of the bushing)

5.1.4.8 Minimum pressure of insulating gas (see **2.28**) (relevant only to gas-filled, gas-insulated and gas-impregnated bushings according to **2.4** to **2.6** when the gas of the equipment is in communication with that of the bushing)

5.1.4.9 Maximum internal operating gas pressure (see **2.29**) (relevant only to gas-filled, gas-insulated and gas-impregnated bushings according to **2.4** to **2.6** when the gas of the equipment is in communication with that of the bushing)

5.1.4.10 Maximum external operating gas pressure (see **2.30**) (relevant only to partly or completely gas-immersed bushings according to **2.17** to **2.19**)

5.1.4.11 Angle of mounting if exceeding the standard values (see **3.6**)

5.1.4.12 Minimum nominal specific creepage distance (see **3.7**) (relevant only to the outdoor part of bushings according to **2.15**, **2.16** and **2.18**)

5.1.4.13 Unusual climatic conditions (extreme high and low temperatures, tropical humidity, severe contamination).

5.1.5 Design

5.1.5.1 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

5.1.5.2 Particular dimensional requirements, if any

5.1.5.3 Test tap or voltage tap if required (see **2.36** and **2.37**)

5.1.5.4 The length of earthed sleeve located next to the flange or other fixing device, if any

5.1.5.5 General information concerning the position of the bushing in relation to the earthed parts of the apparatus for which the bushing is foreseen (see **6.1**)

5.1.5.6 Whether protective gaps are to be fitted or not

5.1.5.7 Special requirements for corrosion protection of metallic parts

5.1.5.8 Oil level in central tube of a transformer bushing with the conductor drawn into the central tube, if lower than 1/3 of the height of the external part (see **7.5**)

5.1.5.9 Provision of an oil sample valve.

5.2 Markings

Each bushing of U_r greater than 100 kV shall carry the following markings. For bushings of U_r equal to or less than 100 kV markings according to **5.2.1**, **5.2.2**, **5.2.3** and **5.2.5** are sufficient. Markings for bushings according to clause **9**, see **9.3**.

5.2.1 Supplier's name or trade mark

5.2.2 Year of manufacture and serial number

5.2.3 Rated voltage (U_r) (see **2.21**) or rated phase-to-earth voltage (see **2.22**) and rated frequency (see **2.27**)

5.2.4 Lightning impulse (BIL) and switching impulse (SIL) or power-frequency withstand test voltages (AC) (see **3.9**)

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5.2.5 Rated current (I_r) (see **2.23**). If the bushing is supplied without conductor, the maximum operating current shall be indicated

5.2.6 Type of insulating gas and minimum pressure (see **2.28** and **5.1.4.7**), if applicable

5.2.7 Mass if above 100 kg

5.2.8 Maximum angle of mounting if exceeding 30° from vertical (see **3.6**).

Examples of marking plates see Figure 1 and Figure 2.

6 Test requirements

6.1 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 233.

All high-voltage tests, in accordance with **7.1**, **7.2**, **7.3**, **8.2** and **8.3** shall be carried out in accordance with IEC 60-1.

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 Table 7, Table 8 and Table 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 **7.1**, **7.2**, **7.3**, **8.2** and **8.3**, 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 50(212), IEC 212-01-37 and IEC 212-01-38 respectively.

6.2 Test classification

For bushings of rated voltages equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or composite insulation, see clause **9**. For other bushings, tests to check dielectric, thermal and mechanical properties of bushings comprise:

6.2.1 Type tests

6.2.1.1 Dry or wet power-frequency voltage withstand test (see **7.1**)

6.2.1.2 Dry lightning impulse voltage withstand test (see **7.2**)

6.2.1.3 Dry or wet switching impulse voltage withstand test (see **7.3**)

6.2.1.4 Thermal stability test (see **7.4**)

6.2.1.5 Temperature rise test (see **7.5**)

6.2.1.6 Verification of thermal short-time current withstand (see **7.6**)

6.2.1.7 Cantilever load withstand test (see **7.7**)

6.2.1.8 Tightness test on liquid-filled, compound-filled and liquid-insulated bushings (see **7.8**)

6.2.1.9 Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings (see **7.9**)

6.2.1.10 External pressure test on partly or completely gas-immersed bushings (see **7.10**)

6.2.1.11 Verification of dimensions (see **7.11**).

6.2.2 Routine tests

6.2.2.1 Measurement of dielectric dissipation factor (tan δ) and capacitance at ambient temperature (see **8.1**)

6.2.2.2 Dry lightning impulse voltage withstand test (see **8.2**)

6.2.2.3 Dry power-frequency voltage withstand test (see **8.3**)

6.2.2.4 Measurement of partial discharge quantity (see **8.4**)

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6.2.2.5 Tests of tap insulation (see **8.5**)

6.2.2.6 Internal pressure test of gas-filled, gas-insulated and gas-impregnated bushings (see **8.6**)

6.2.2.7 Tightness test on liquid-filled, compound-filled and liquid-insulated bushings (see **8.7**)

6.2.2.8 Tightness test on gas-filled, gas-insulated and gas-impregnated bushings (see **8.8**)

6.2.2.9 Tightness test at the flange or other fixing device (see **8.9**)

6.2.2.10 Visual inspection and dimensional check (see **8.10**).

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

6.3 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 **2.2** and **2.3**, 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 **2.4**, **2.5** and **2.6**, shall be filled with the type of insulating gas specified by the supplier and raised to the minimum pressure according to **2.28**, 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 **2.17**, **2.18** and **2.19**, 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 **6.2.2**) 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 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 60-1, correction shall be made as given in Table 4.

7 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 **8.3**). Before and after the series of type tests, measurements of dielectric dissipation factor and capacitance (see **8.1**) and of partial discharge quantity (see **8.4**) shall be carried out in order to check whether damage has occurred.

7.1 Dry or wet power-frequency voltage withstand test

Applicability:

The dry test is applicable to all bushings according to **2.14**, **2.17** and **2.19**, which are not subjected to a routine test (see **8.3**).

The wet test is applicable to all outdoor bushings according to **2.15**, **2.16** and **2.18**, and of which U_r is less than 300 kV.

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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.

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. 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.

7.2 Dry lightning impulse voltage withstand test

Applicability:

The test is applicable to all types of bushings.

Test method and requirements:

The magnitude of the test voltage is given in Table 7 or Table 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 lightningform 1,2/50 μs.

Bushings for transformers of U_r 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.

For 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.

Acceptance:

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

— no puncture occurs at either polarity; and if

— the number of flashovers in air does not exceed two for each series of 15 impulses;

except for transformer bushing 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.

7.3 Dry or wet switching impulse voltage withstand test

Applicability:

The test is applicable to all bushings of U_r equal to or greater than 300 kV. A dry test is applicable to indoor, indoor immersed and completely immersed bushings, according to **2.14**, **2.17** and **2.19**.

The wet test is applicable to outdoor bushings, according to **2.15**, **2.16** and **2.18**. When a wet test is made a dry test is not necessary.

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Test method and requirements:

For these tests IEC 60-1 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 of which one end is immersed, the details of immersion shall be subject to agreement.

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

The bushing shall be subjected to:

— 15 impulses of positive polarity; followed by

— 15 impulses of negative polarity

of the standard waveform 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.

Dry switching impulse withstand test for transformer bushings of U_r less than 300 kV shall be subjected to agreement between supplier and purchaser.

Voltage records shall be made of each impulse.

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.

7.4 Thermal stability test

Applicability:

The test is applicable to all partly or completely immersed bushings, according to **2.17**, **2.18** and **2.19**, the major insulation of which 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 of which U_r 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 that, based on the results of comparative tests, the thermal stability of the bushing is assured.

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 defined in **2.28**. 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 way to produce the same losses as the final conductor.

The test voltage shall be:

— U_r for bushings of U_r equal to or less than 170 kV;

— 0,8 U_r for bushings of U_r greater than 170 kV.

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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.

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.

7.5 Temperature rise test

Applicability:

The test is applicable to all types of bushings, excluding liquid-insulated bushings according to **2.3**, unless it can be demonstrated by a calculation based on comparative tests that specified temperature limits are met.

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.

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 insulating gas at minimum pressure, according to **2.28**, 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.

An appropriate number of thermocouples or other measuring devices, as far as possible, shall 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 A satisfactory degree of lagging is obtained by placing the thermometers in oil-filled containers with a volume of approximately 0,5 I.

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 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:

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The maximum conductor temperature θ_M is deduced by relations (1) and (2):

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

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

If the result M of the relation (2) is positive, the higher temperature of the conductor is θ_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 θ_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:

α is the temperature coefficient of resistance at which conductor resistance R_A is measured;

θ_1 is the measured temperature at cooler end of conductor, in degrees Celsius;

θ_2 is the measured temperature at hotter end of conductor, in degrees Celsius;

θ_A is the uniform reference temperature of conductor, in degrees Celsius;

θ_M is the maximum temperature of conductor, in degrees Celsius;

L is the length of conductor;

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

R_A is the resistance between the ends of the conductor at uniform temperature θ_A;

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

Acceptance:

The bushing shall be considered to have passed the test if the permissible temperature limits in accordance with **3.8** are met; and if there is no visible evidence of damage.

7.6 Verification of thermal short-time current withstand

Applicability:

The verification is applicable to all types of bushings.

Verification method and requirements:

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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:

θ_f is the final temperature of the conductor, in degrees Celsius;

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

α 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.

Acceptance:

The bushing shall be considered to be able to withstand the standard value of I_{th} if θ_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 **3.3**, 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.

7.7 Cantilever load withstand test

Applicability:

The test is applicable to all types of bushings.

Test method and requirements:

The test values shall be in accordance with Table 1.

For bushings according to **2.20** 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 perpendicularly to the axis of the bushing at the mid-point of the terminal for 60 s. It shall be applied only to one terminal at a time. It is generally sufficient to apply the load only to the terminal which will cause the higher stresses at the critical parts of the bushing in normal operation.

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For bushings having more than one terminal at the air end, the full test load shall be applied to each terminal successively.

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.

7.8 Tightness test on liquid-filled, compound-filled and liquid-insulated bushings

Applicability:

The test is applicable to all liquid-filled or compound-filled and liquid-insulated bushings, according to **2.2** and **2.3**, except those bushings of which the liquid filling has a viscosity equal to or greater than 5×10^{-4} m^2/s at 20 °C.

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.

A minimum pressure of 1 bar ± 0,1 bar above the maximum internal operating pressure according to **2.29**, shall be maintained inside the bushing during the test.

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

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 of IEC 68-2-17, Annex C, clause **C.2**.

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

Applicability:

The test is applicable to all gas-filled, gas-insulated and gas-impregnated bushings, according to **2.4**, **2.5** and **2.6**, of which the insulating envelope is of ceramic 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).

The test is also applicable to unassembled insulators tested in accordance with IEC 233.

Test method and requirements:

The hollow ceramic insulator 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.

The insulator shall withstand 4,25 times the design pressure for 5 min.

Acceptance:

The insulator shall be considered to have passed the test if there is no evidence of cracks, either in the ceramic or 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.

7.10 External pressure test on partly or completely gas-immersed bushings

Applicability:

The test is applicable to all gas-immersed bushings, according to **2.17** to **2.19**, intended for use at a permanent gas pressure higher than 0,5 bar gauge.

Test method and requirements:

The test shall be made before the tightness test according to **8.9**. 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 **2.30**) shall be applied for 1 min.

Acceptance:

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

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7.11 Verification of dimensions

Applicability:

This verification is applicable to all types of bushings.

Acceptance:

The dimensions of the bushing in 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.

8 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 **8.3**). Before and after the dielectric routine tests, measurements of dielectric dissipation factor (tan δ) and capacitance (see **8.1**) shall be carried out in order to check whether damage has occurred. The measurement of partial discharge quantity (see **8.4**) shall be made before the last measurement of tan δ.

8.1 Measurement of dielectric dissipation factor (tan δ) and capacitance at ambient temperature

Applicability:

The measurement is only applicable to capacitance graded bushings according to **2.13**.

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:

— for bushings of $U_r \leq 36$ kV: 1,05 $U_r/\sqrt{3}$;

— for bushings of $U_r \geq 52$ kV: 1,05 $U_r/\sqrt{3}$; and U_r;

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

A measurement of tan δ 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.

Acceptance:

The maximum permissible values of tan δ and for the increase of tan δ 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.

It is required to state the actual temperature during the measurement in the test report.

8.2 Dry lightning impulse voltage withstand test

Applicability:

The test as a routine test is applicable only for transformer bushings with U_r equal to or greater than 300 kV.

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, **7.2** shall be followed.

Acceptance:

For criteria, **7.2** shall be followed.

8.3 Dry power-frequency voltage withstand test

Applicability:

The test is applicable to all types of bushings. For gas-insulated bushings according to **2.5**, 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.

Test method and requirements:

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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 Table 7 or Table 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 Table 7 or Table 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 Table 7 or Table 9.

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

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. It is assumed that a puncture has occurred if the capacitance measured after the test raises above the capacitance previously measured by more than 75 % of 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.

8.4 Measurement of partial discharge quantity

Applicability:

The measurement shall be carried out on all types of bushings, except for bushings according to **2.5** and **2.10**, 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.

Test method and requirements:

The test shall be made in accordance with IEC 270.

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 270.

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 **8.3**) at the values as given in Table 6 during the decrease of the voltage from the dry power-frequency withstand test level; depending on the type of bushing and test facilities the voltage level could be reduced at $2\ U_r/\sqrt{3}$ by agreement between the manufacturer and purchaser.

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.

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

8.5 Tests of tap insulation

Applicability and test requirements:

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

— test tap (see **2.36**): at least 2 kV;

— voltage tap (see **2.37**): twice the rated voltage of the voltage tap but at least 2 kV.

The test duration is 60 s, independent of frequency.

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

Acceptance:

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

For test taps the values of tan δ and capacitance shall be in accordance with **3.10**.

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

Applicability:

The test is applicable to all gas-filled, gas-insulated and gas-impregnated bushings according to **2.4**, **2.5** and **2.6**.

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Test method and requirements:

The bushing, complete as for normal operation, shall be filled with gas or liquid 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 case of bushings, of which the insulating envelope is of ceramic material and intended to be under pressure in operation, the ceramic hollow insulator with fittings shall be tested alone, before assembly, at a pressure of three times the design pressure for 1 min, or the insulator body, without fittings, at a pressure of 4,25 times the design pressure for 1 min according to IEC 1264.

Acceptance:

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

8.7 Tightness test on liquid-filled, compound-filled and liquid-insulated bushings

Applicability:

The test is applicable to all liquid-filled or compound-filled and liquid-insulated bushings according to **2.2** and **2.3**, except those bushings of which the liquid filling has a viscosity equal to or greater than

5×10^{-4} m^2/s at 20 °C.

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.

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 of IEC 68-2-17, 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.

8.8 Tightness test on gas-filled, gas-insulated and gas-impregnated bushings

Applicability:

The test is applicable to all gas-filled, gas-insulated and gas-impregnated bushings, according to **2.4** to **2.6** and **2.17** to **2.19**.

For gas-insulated bushings, which are 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.

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 of equal to or greater than 2 h.

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

Acceptance:

The bushing shall be considered to have passed the test if the calculated escape of gas is equal to or less than 1 % per year of the amount of gas contained inside the bushing.

8.9 Tightness test at the flange or other fixing device

Applicability:

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The test is applicable to all partly or completely immersed bushings, according to **2.17** to **2.19** 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 **7.8** (for example oil-impregnated paper bushings) or the routine test in accordance with **8.7** or the end to be immersed does not include any gaskets.

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 still be 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 of equal to or greater than 2 h.

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 68-2-17, 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 1 % 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 **2.32**) is equal to or less than 0,05 Pa × cm^3/s × l (5 × 10^{-7} bar × cm^3/s × 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 **2.32**) is equal to or less than 10 Pa × cm^3/s (10^{-4} bar × cm^3/s).

8.10 Visual inspection and dimensional check

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.

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.

9 Requirements and tests for bushings of rated voltages equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or composite insulation

This clause is applicable to all bushings of which the major insulation consists of ceramic, glass or analogous inorganic materials, cast and moulded resin, or composite insulation, as defined in **2.10** to **2.12**.

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9.1 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.

9.2 Level of immersion medium

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

9.3 Markings

Each bushing shall carry the following marking:

9.3.1 Supplier's name or trade mark

9.3.2 Year of manufacture

9.3.3 Type or minimum nominal creepage distance or rated voltage (U_r)

9.3.4 Rated current (I_r) or maximum current if the bushing is supplied without conductor.

NOTE It may be sometimes 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.

9.4 Test requirements

The test conditions and requirements shall be equivalent to clauses **6**, **7** and **8**. Reference is made in parenthesis to the relevant subclause.

9.4.1 ***Type tests***

The tests are applicable to all bushings.

For bushings according to **2.20** cantilever withstand load test values are reduced (see **9.4.1.5**).

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.

9.4.1.1 Dry or wet power-frequency voltage withstand test (**7.1**)

9.4.1.2 Dry lightning impulse voltage withstand test (**7.2**)

9.4.1.3 Temperature rise test (**7.5**)

9.4.1.4 Verification of thermal short-time current withstand (**7.6**)

9.4.1.5 Cantilever load withstand test (**7.7**)

9.4.1.6 Verification of dimensions (**7.11**).

9.4.2 ***Routine tests***

The tests are applicable to all bushings except for ceramic and glass bushings (**2.10**), where only **9.4.2.4** is applicable.

9.4.2.1 Dry power-frequency voltage withstand test (**8.3**)

9.4.2.2 Measurement of the partial discharge quantity (**8.4**)

9.4.2.3 Tests of tap insulation (**8.5**), if applicable

9.4.2.4 Visual inspection and dimensional check (**8.10**)

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

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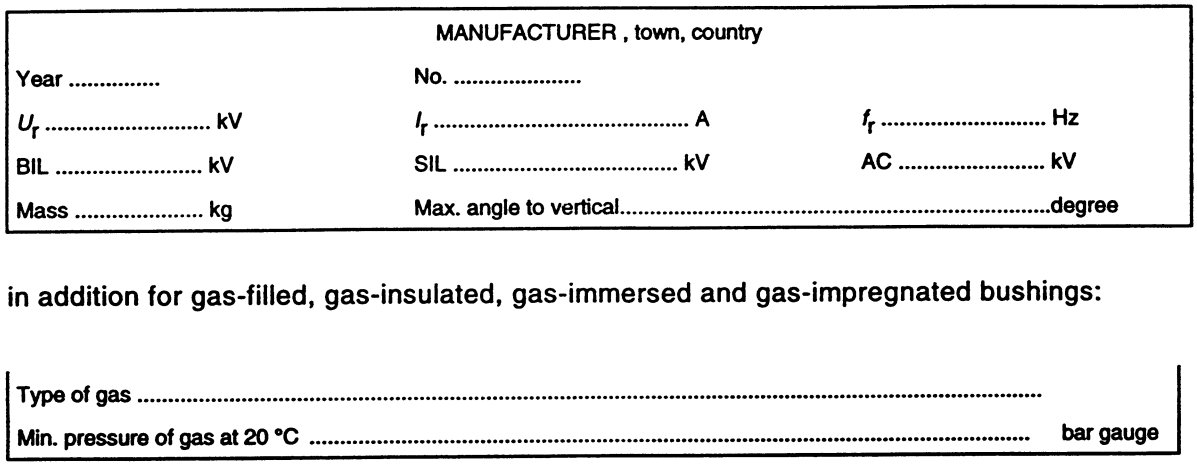

Figure 1 — Marking plate for bushings for rated voltages greater than 100 kV (see **5.2**)

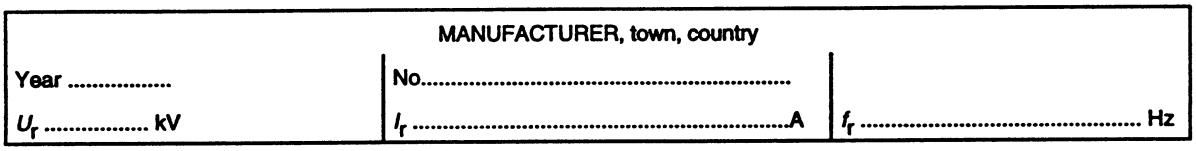

Figure 2 — Marking plate for bushings for rated voltages equal to or less than 100 kV, except for bushings for which Figure 3 is applicable (see **5.2**)

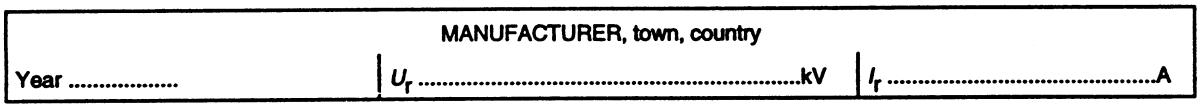

Figure 3 — Marking plate for bushings for rated voltages equal to or less than 52 kV made of ceramic, glass or inorganic materials, resin or composite insulation (see **9.3**)

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Table 1 — Minimum values of cantilever withstand load (see **3.5** and **7.7**)

Rated voltage U_r kV	**Rated current** A							
	≤ 800		1 000 1 600		2 000 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
	Bushing installed > 30° from the vertical							
	I	II	I	II	I	II	I	II
≤ 36	300	300	375	375	600	600	945	945
52	300	480	375	480	600	750	945	945
72,5 to 100	300	600	375	600	600	945	1 200	1 200
123 to 145	375	945	480	945	750	1 200	1 200	1 200
170 to 245	375	1 200	480	1 200	750	1 500	1 200	1 500
≥ 300	750	1 200	750	1 200	945	1 500	1 500	1 500
	Cantilever test load N							
	I	II	I	II	I	II	I	II
≤ 36	1 000	1 000	1 000	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 Level I = normal load, level II = heavy load.
NOTE 2 The bushing shall withstand the cantilever operation load in any direction.
NOTE 3 For non-ceramic bushings the ratio between the test and operating cantilever load values shall be subject to special evaluation.
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.

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Table 2 — Maximum values of temperature and temperature rise above ambient air (see **3.8**)

Description of component		**Maximum temperature rise** K	**Maximum temperature** °C	**Comments** Note 1
Spring contacts	Copper and copper alloys, uncoated			Note 4
	— in air	45	75	
	— in SF_6	60	90	
	— in oil	50	80	Note 2
	Tinned in air, SF_6 or oil	60	90	
	Silver/nickel-plated			
	— in air or SF_6	75	105	
	— in oil	60	90	Note 2
Screwed contacts	Copper, aluminium and their alloys, uncoated			
	— in air	60	90	
	— in SF_6	75	105	
	— in oil	70	100	Note 2
	Tinned			
	— in air or SF_6	75	105	
	— in oil	70	100	Note 2
	Silver/nickel-plated			
	— in air or SF_6	85	115	
	— in oil	70	100	Note 2
Terminals to be connected to exterior conductors by screws or bolts	Copper, aluminium and their alloys,			
	— uncoated	60	90	
	— tinned	75	105	Note 3
	— silver or nickel-plated	75	105	
Metallic parts in contact with	Insulation class			
	— A (OIP)	75	105	
	— E (RBP and RIP)	90	120	

NOTE 1 The temperature rise values are based on IEC 943 with a maximum daily mean temperature of 30 °C. For further information reference should be made to IEC 943, Table VI.
NOTE 2 For synthetic insulating liquids (silicone, esters), higher values may be agreed between purchaser and supplier.
NOTE 3 If heavy oxidation is to be expected, the temperature rise shall be limited to 50 K.
NOTE 4 A spring contact is a connection maintained by spring pressure for example a plug-in connection.

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Table 3 — Temperature of ambient air and immersion media (see **4.3**)

Subject		Temperature °C
Ambient air:		
— maximum		40
— maximum daily mean		30
— maximum annual mean		20
— minimum		
indoors	class 1, see note 3	– 5
	class 2	– 25
	class 3	– 40
outdoors	class 1, see note 3	– 25
	class 2	– 40
	class 3	– 60
Oil in transformers:		
— maximum		
for normal load		100
for emergency duty, see note 2		115
— maximum daily mean		90
Other media: (gaseous and non-gaseous)		See note 4

NOTE 1 The daily mean temperature of the immersion medium shall be calculated by averaging 24 consecutive hourly readings.
NOTE 2 The values for oil in transformers are in accordance with IEC 76-1 and IEC 76-2. The value for emergency duty is in accordance with IEC 354.
NOTE 3 The normal minimum ambient air temperature is class 1.
NOTE 4 In absence of other information, reference should be made in principle to the corresponding IEC apparatus standard for which the bushing is intended, whereby particular attention should be paid to bushings one end of which is to be immersed in gas.
NOTE 5 By agreement between purchaser and supplier, other temperature ranges may be adopted.

Table 4 — Correction of test voltages (see **6.3**)

Clause	Test	Correction
7.1	Dry power frequency voltage withstand test	Multiply by $k_1 \times k_2$ in the conditions indicated below
7.1	Wet power-frequency voltage withstand test	Multiply by k_1
7.2	Dry lightning impulse voltage withstand test	Multiply by $k_1 \times k_2$ in the conditions indicated below
7.3	Dry switching impulse voltage withstand test	Multiply by $k_1 \times k_2$ in the conditions indicated below
7.3	Wet switching impulse voltage withstand test	Multiply by k_1 in the conditions indicated below
7.4	Thermal stability test	None
8.1	Measurement of dielectric dissipation factor and capacitance	None
8.3	Dry power frequency voltage withstand test	None
8.4	Measurement of partial discharge quantity	None
8.5	Tests of tap insulation	None

NOTE 1 k_1 and k_2 shall be determined according to IEC 60-1.
NOTE 2 In the case of impulse tests when the correction leads to a test voltage value lower than that specified, such correction shall be made on the polarity for which the external withstand voltage is the most critical one, whereas the opposite polarity shall be applied with at least the full voltage value.
When the correction factor is higher than 1, the correction applies to both polarities, but if the correction factor is higher than 1,05 the purchaser and supplier shall agree as to whether the test shall or shall not be performed.

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Table 5 — Maximum values of tan δ and tan δ increase (see **8.1**)

Type of bushing insulation	**Maximum value of tan δ**	
	Value at $1{,}05\ U_r/\sqrt{3}$	**Increase between** $1{,}05$ and $U_r/\sqrt{3}$ and U_r **See note 1**
Oil-impregnated paper	0,007	0,001
Resin-impregnated paper	0,007	0,001
Resin-bounded paper	0,015	0,004
Gas	0,015	0,004
Cast or moulded resin	0,015	0,004
Composite	See note 2	
Other	See note 2	

NOTE 1 Not applicable to bushings of $U_r \leq 36$ kV.
NOTE 2 The supplier shall indicate the values.

Table 6 — Maximum values of partial discharge quantity (see **8.4**)

Type of bushing insulation	**Maximum discharge quantity** pC **measured at**		
	U_r **See note 1**	$1{,}5\ U_r/\sqrt{3}$ **See note 2**	$1{,}05\ U_r/\sqrt{3}$
Oil-impregnated paper	10	10	5
Resin-impregnated paper	10	10	5
Resin-bonded paper	—	250	100
See note 3			
— with metal layers	See note 4	See note 4	300
Gas-impregnated	10	10	5
Gas	—	10	5
Cast and moulded resin	—	10	5
Composite		See note 4	
Other		See note 4	

NOTE 1 Only applicable to transformer bushings.
NOTE 2 For switchgear bushings, the discharge quantities may be measured at a lower voltage to an agreement between purchaser and supplier.
NOTE 3 For resin-bonded paper bushings for use on power transformers, lower discharge quantities may be agreed between purchaser and supplier.
NOTE 4 The maximum permissible values of discharge quantity shall be agreed between purchaser and supplier.

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Table 7 — Standard insulation levels for rated voltages less than 300 kV
(see **3.9**, **7.1**, **7.2**, **8.2** and **8.3**)

Rated voltage kV (r.m.s.)	**Dry lightning impulse withstand voltage** kV (peak)	**Power-frequency withstand voltage wet and dry** kV (r.m.s.)
3,6	40	10
7,2	60	20
12	75	28
17,5	95	38
24	125	50
36	170	70
52	250	95
72,5	325	140
100	380	150
	450	185
123	450	185
	550	230
145	450	185
	550	230
	650	275
170	550	230
	650	275
	750	325
245	650	275
	750	325
	850	360
	950	395
	1 050	460

NOTE 1 The values are in accordance with IEC 71-1.
NOTE 2 Attention is drawn to special requirements for transformer bushings concerning dry power-frequency withstand voltage (see **8.3**).

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Table 8 — Standard insulation levels for rated voltages equal to or greater than 300 kV
(see **3.9**, **7.2**, **7.3** and **8.2**)

Rated voltage kV (r.m.s.)	**Dry and wet switching impulse withstand voltage** kV (peak)	**Dry lightning impulse withstand voltage** kV (peak)
300	750	850 950
300/362	850	950 1 050
362/420	950	1 050 1 175
420/525	1 050	1 175 1 300 1 425
525	1 175	1 300 1 425 1 550
765	1 300	1 425 1 550 1 800
	1 425	1 550 1 800 2 100
	1 550	1 800 1 950 2 400
NOTE The values are in accordance with IEC 71-1.		

Table 9 — Dry power-frequency withstand test voltages for rated voltages equal to or greater than 300 kV (see **8.3**)

Dry lightning impulse withstand voltage kV (peak)	**Dry power-frequency withstand voltage** kV (r.m.s.)
850	360
950	395
1 050	460
1 175	510
1 300	570
1 425	630
1 550	680
1 800	790
1 950	830
2 100	880
2 400	975
NOTE Attention is drawn to special requirements for transformer bushings concerning dry power-frequency withstand voltage (see **8.3**).	

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Table 10 — Applicability of type tests (see **6.2.1,** excluding bushings according to clause **9**)

Subclause	Short title	Applicable to bushing type	Bushing defined in subclause
7.1	AC dry	All indoor, indoor immersed and completely immersed < 300 kV	**2.14**, **2.17**, **2.19**
7.1	AC wet	All outdoor < 300 kV	**2.15**, **2.16**, **2.18**
7.2	Lightning	All	
7.3	Switching	All ≥ 300 kV	
	— dry	— indoor, indoor immersed and completely immersed	**2.14**, **2.17**, **2.19**
	— wet	— outdoor	**2.15**, **2.16**, **2.18**
7.4	Thermal stability	All partly or completely immersed, immersion medium ≥ 60°C and	**2.17**, **2.18**, **2.19**
		— > 300 kV for OIP and RIP	
		— ≥ 145 kV for others	
7.5	Temperature rise	All, except liquid-insulated as in **2.3**	
7.6	Thermal short-time	All, if calculated temperature is too high	
7.7	Cantilever	All	
7.8	Tightness for liquid	All liquid-filled and insulated, except with highly viscous filling	**2.2**, **2.3**
7.9	Pressure	All containing gas of ≥ 1 l and > 0,5 bar gauge, and a ceramic envelope	**2.4**, **2.5**, **2.6**
7.10	External pressure	All partly or completely immersed in gas, gas pressure > 0,5 bar gauge	**2.17**, **2.18**, **2.19**
7.11	Dimensions	All	

Table 11 — Applicability of type tests for bushings according to clause 9 (see **9.4.1**)

Paragraph	Short title	Applicable to bushing type	Bushing defined in subclause
9.4.1.1	AC dry	Indoor, outdoor immersed and completely immersed	**2.10**
	AC wet	All outdoors	**2.10** to **2.12**
9.4.1.2	Lightning	All	**2.10** to **2.12**, **2.20**
9.4.1.3	Temperature rise	All	Ditto
9.4.1.4	Thermal short time	All, if calculated temperature is too high	Ditto
9.4.1.5	Cantilever	All (reduced requirement for type 2.20)	Ditto
9.4.1.6	Dimensions	All	Ditto

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Table 12 — Applicability of routine tests (see **6.2.2**, excluding bushings according to clause **9**)

Subclause	Short title	Applicable to bushing type	Bushing defined in subclause
8.1	Tan δ/capacity	All capacitance graded	**2.13**
8.2	Lightning	All ≥ 300 kV for transformers	
8.3	AC dry	All, except gas-insulated as in **2.5**, if ceramic is pretested	
8.4	Partial discharges	All, except gas-insulated as in **2.5**	
8.5	Tap	All with a tap	
8.6	Internal pressure	All gas-containing	**2.4**, **2.5**, **2.6**
8.7	Tightness for liquid	All liquid-containing, except with highly viscous filling	**2.2**, **2.3**
8.8	Tightness for gas	All gas-containing with some exceptions	**2.4**, **2.5**, **2.6** **2.17**, **2.18**, **2.19**
8.9	Tightness at flange	All partly or completely immersed in oil or gas with some exceptions	**2.17**, **2.18**, **2.19**
8.10	Visual and dimensions	All	

Table 13 — Applicability of routine tests for bushings according to clause 9 (see **9.4.2**)

Subclause	Short title	Applicability to bushing type	Bushing defined in subclause
9.4.2.1	AC dry	All, except ceramic and glass as in **2.10**	**2.11**, **2.12**, **2.20**
9.4.2.2	Partial discharges	Ditto	Ditto
9.4.2.3	Tap	Ditto, with a tap	Ditto
9.4.2.4	Visual and dimensions	All	**2.10** to **2.12** and **2.20**

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Annex ZA (normative)
Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision For undated references the latest edition of the publication referred to applies (including amendments).

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

Publication	Year	Title	EN/HD	Year
IEC 38 (mod)	1983	*IEC standard voltages*[a]	HS 472 S1	1989
IEC 50(212)	1990	*International Electrotechnical Vocabulary (IEV) Chapter 212: Insulating solids, liquids and gases*	—	—
IEC 50(471)	1984	*Chapter 471: Insulators*	—	—
IEC 59	1938	*IEC standard current ratings*	—	—
IEC 60-1	1989	*High-voltage test techniques Part 1: General definitions and test requirements*	HD 588.1 S1	1991
IEC 68-2-17	1994	*Environmental testing Part 2: Tests — Test Q: Sealing*	EN 60068-2-17	1994
IEC 71-1	1993	*Insulation co-ordination Part 1: Definitions, principles and rules*	EN 60071-1	1995
IEC 76-1	1993[b]	*Power tranformers Part 1: General*	—	—
IEC 76-2	1993[c]	*Part 2: Temperature rise*	—	—
IEC 76-5 (mod)	1976	*Part 5: Ability to withstand short-circuit*	HD 398,5 S1	1983
IEC 216-2	1990	*Guide for the determination of thermal endurance properties of electrical insulating materials Part 2: Choice of test criteria*	HD 611.2 S1	1992
IEC 233	1974	*Tests on hollow insulators for use in electrical equipment*	HD 329 S1	1977
IEC 270	1981	*Partial discharge measurements*	—	—
IEC 354	1991	*Loading guide for oil-immersed power transformers (corrigendum 1992)*	—	—
IEC 505	1975	*Guide for the evaluation and identification of insulation systems of electrical equipment*	—	—
IEC 507	1991	*Artificial pollution tests on high-voltage insulators to be used on a.c. systems*	EN 60507	1993
IEC 517	1990	*Gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above*	EN 60517[d]	1996
IEC 815	1986	*Guide for the selection of insulators in respect of polluted conditions*	—	—
IEC 943	1989	*Guide for the specification of permissible temperature and temperature rise for parts of electrical equipment, in particular for terminals*	—	—
IEC 1264	1994	*Ceramic pressurized hollow insulators for high-voltage switchgear and controlgear*	—	—

[a] The title of HD 472 S1 is: Nominal voltages for low voltage public electricity supply systems.

[b] IEC 76-1:1976, mod. is harmonized as HD 398.1 S1:1980.

[c] IEC 76-2:1976, mod. is harmonized as HD 398.2 S1:1980.

[d] IEC 517 includes the corrigendum April 1995 and A1:1994 to IEC 517.

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List of references

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