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IS 2099 (1986): Bushings for alternating voltages above 1 000 Volts [ETD 6: Electrical Insulators and Accessories]

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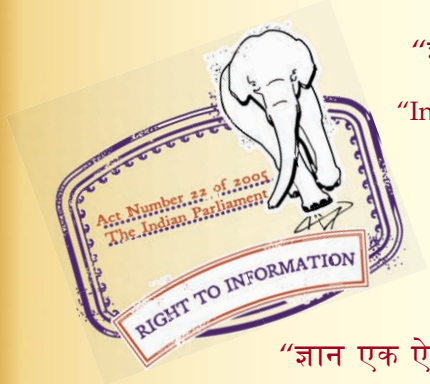

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"Knowledge is such a treasure which cannot be stolen"

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IS : 2099 - 1986
(Reaffirmed 2003)

Indian Standard

SPECIFICATION FOR BUSHINGS FOR ALTERNATING VOLTAGES ABOVE 1 000 VOLTS

(Second Revision)

Third Reprint SEPTEMBER 2007
(Including Amendment No. 1 & 2)

UDC 621·315·626·027·5

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 8 *December* 1986

AMENDMENT NO. 2 JANUARY 1993
TO
IS 2099 : 1986 SPECIFICATION FOR BUSHINGS FOR ALTERNATING VOLTAGES ABOVE 1 000 VOLTS

(Second Revision)

(*Page* 29, *clause* **11.15.3**, *last line*) — Substitute '**9.2**' *for* '**9.3**'.

(ET 06)

Printed at Simco Printing Press, Delhi

AMENDMENT NO. 1 JANUARY 1989
TO
IS : 2099 - 1986 SPECIFICATION FOR BUSHINGS FOR ALTERNATING VOLTAGES ABOVE 1 000 VOLTS

(Second Revision)

(*Page* 21, *clause* **11.7.2.4**) — Substitute the following for the existing clause :

'**11.7.2.4** The test shall be carried out at $I_N \pm 2$ percent, all parts of the bushings being substantially at earth potential.'

(ETDC 3)

Printed at Simco Printing Press, Delhi, India

Indian Standard

SPECIFICATION FOR BUSHINGS FOR ALTERNATING VOLTAGES ABOVE 1 000 VOLTS

(Second Revision)

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(*Continued on page* 2)

0.5 The dimensions of the porcelain bushings and their related parts have been covered separately as follows:

a) Porcelain transformer bushings for normal and lightly polluted atmospheres in Section 1 of each IS : 3347 (Part 1) to (Part 7)*,

b) Porcelain transformer bushings for heavily polluted atmospheres in IS : 8603-1977 †,

c) Oil impregnated paper insulated condenser bushings — IS under preparation, and

d) Ceramic bushings for terminals in IS : 10314-1982‡.

0.6 In the preparation of this standard, assistance has been derived from IEC publication 137 (1984) 'Bushings for alternating voltages above 1 000 V (*third edition*)', issued by the International Electrotechnical Commission (IEC).

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960§. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

---

1. SCOPE

1.1 This standard covers rated values, performance requirements and tests for bushings for three-phase alternating current systems, having rated voltage above 1 000 volts and frequencies between 15 and 60 Hz.

1.2 This standard applies to bushings which are supplied separately, intended for use in electrical apparatus and installations for three-phase alternating current system having rated voltages above 1 000 volts and frequencies between 15 to 60 Hz.

NOTE 1 — The application of this standard to bushings for other than three-phase systems shall be subject to special agreement between the purchaser and the manufacturer.

NOTE 2 — This standard does not apply to bushings for use with rectifiers, rotating machines, testing transformer, dc converter transformers, or terminals for power cables (pot heads). Such bushings shall be subject to special agreement between the purchaser and the manufacturer.

---

*Dimensions for porcelain transformer bushings for use in normal and lightly polluted atmospheres.

†Dimensions for porcelain transformer bushings for use in heavily polluted atmospheres.

‡Dimensions for ceramic bushings for terminals.

§Rules for rounding off numerical values (*revised*).

NOTE 3 — Moreover, this standard is not applicable to insulating structures similar to bushings which are used as support insulators inside metal enclosed switchgear.

NOTE 4 — If a bushing, due to its design or use, cannot be tested separately under the conditions specified in this standard, the test procedure is to be agreed upon between the purchaser and the manufacturer.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Bushing — A structure carrying one or several conductors through a partition such as a wall or tank, and insulating it or them therefrom, incorporating the means of attachment (flange or other fixing device) to the partition.

The conductor may form an integral part of the bushing or be drawn through.

2.2 Liquid Filled Bushing — A bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with oil or another insulating liquid.

2.3 Liquid Insulated Bushing — A bushing in which the major insulation consists of oil or another insulating liquid.

NOTE — The definitions in 2.2 and 2.3 also include bushings which are intended to form an integral part of liquid insulated equipment, the liquid of the equipment being in communication with that of the bushing.

2.4 Gas Filled Bushing — A 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 or higher pressure.

NOTE — The 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 — A bushing in which the major insulation consists of gas (other than ambient air) at atmospheric or higher pressure.

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 (for example, support for conducting layers or insulating cylinder) is a composite bushing (*see* 2.11).

2.6 Oil Impregnated Paper Bushing — A bushing in which the major insulation consists of a core wound from untreated paper and subsequently impregnated with an insulating liquid, generally the 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.

2.7 Resin Bonded Paper Bushing — A 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 is achieved by curring the resin.

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

2.8 Resin Impregnated Paper Bushing — A bushing in which the major insulation consists of a core wound from untreated paper and subsequently impregnated with a curable resin.

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

2.9 Ceramic, Glass or Analogous Inorganic Material Bushing — A bushing in which the major insulation consists of a ceramic, glass or analogous inorganic material.

2.10 Cast Resin Insulated Bushing — A bushing in which the major insulation consists of a cast organic material with or without an inorganic filler.

2.11 Composite Bushing — A bushing in which the major insulation consists of a combination of different insulating materials.

2.12 Capacitance Graded Bushing — A bushing in which metallic or non-metallic conducting layers are arranged within the insulating material for the purpose of controlling the distribution of the electric field of the bushing.

NOTE 1 — Generally, the major insulation of a capacitance graded bushing is constituted of one of the following:

a) Oil impregnated paper,

b) Resin bonded paper,

c) Resin impregnated paper,

d) Cast resin,

e) Gas or other insulating fluid, and

f) Composite.

NOTE 2 — A capacitance graded bushing may be provided with an insulating envelope, in which case the intervening space may be filled with an insulating liquid or another insulating medium.

2.13 Indoor Bushing — A bushing, both ends of which are intended to be in ambient air but not exposed to external atmospheric conditions.

NOTE 1 — In indoor installations, moisture condensation on the surface of the bushing is to be prevented, if necessary by ventilation or heating.

NOTE 2 — This definition includes bushings operating in air at temperatures above ambient, such as occurs with air-insulated ducting.

2.14 Outdoor Bushing — A bushing, both ends of which are intended to be in ambient air and exposed to external atmospheric conditions.

2.15 Outdoor-Indoor Bushing — A bushing, both ends of which are intended to be in ambient air. One end is intended to be exposed to external atmospheric conditions and the other end is intended not to be so exposed (*see also* notes under **2.13**).

2.16 Indoor-Immersed Bushing — A bushing, one end of which is intended to be in ambient air but not exposed to external atmospheric conditions and the other end to be immersed in an insulating medium other than ambient air (for example, oil or gas) (*see also* notes under **2.13**).

2.17 Outdoor-Immersed Bushing — A bushing, one end of which is intended to be in ambient air and exposed to external atmospheric conditions and the other end to be immersed in an insulating medium other than air (for example, oil or gas).

2.18 Completely Immersed Bushing — A bushing both ends of which are intended to be immersed in insulating media other than ambient air (for example, oil or gas).

2.19 Rated Voltage (U_N) — The highest rms phase-to-phase voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standard.

This voltage is the maximum value of the highest voltage of the system for which the equipment is used.

2.20 Rated Phase-to-Earth Voltage — The highest rms value of the voltage which the bushing can withstand continuously between the conductor and flange or other fixing device, under the operating conditions specified in **6.**

2.21 Rated Current (I_N) — The rms value of current which the bushing can carry continuously under the operating conditions specified in **6.**

2.22 Rated Thermal Short Time Current (I_{th}) — The rms value of symmetrical current which the bushing can withstand thermally for the rated duration (t_{th}), immediately following continuous operation at I_N with

maximum temperatures of ambient air and immersion media in accordance with 6.4.

2.23 Rated Dynamic Current (I_d) — The peak value of current which the bushing shall withstand mechanically.

2.24 Temperature Rise — The 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* 8).

2.25 Rated Frequency — The frequency by which the bushing is designated.

2.26 Rated Density of Insulating Gas — The density assigned by the supplier at which the bushing is intended to be operated in service.

2.27 Minimum Operating Density of Insulating Gas — The density assigned by the supplier below which the rated values of insulating level no longer apply.

2.28 Maximum Operating Pressure — The maximum permissible pressure when the bushing is in operation carrying nominal current at the highest temperature given in 6.4.

2.29 Leakage Rate of Gas Filled and Gas Insulated Bushings — The permissible annual escape of gas expressed as a percentage of the total gas quantity in the bushing.

2.30 Insulating Envelope — An envelope of inorganic or organic material, such as ceramic or cast resin, placed round the whole or part of a bushing.

2.31 Creepage Distance — The shortest distance (or the sum of the shortest distances) along the contour of the external insulating surface between the metal parts which normally have the operating voltage between them.

NOTE — A semi-conducting layer of high resistance on the external surface of the insulating envelope should be included while measuring the creepage distance.

2.32 Arcing Distance — The shortest distance (or the sum of the shortest distances) outside the bushing between metal parts which normally have the operating voltage between them.

2.33 Test Tap — A connection, 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 whilst the flange of the bushing is earthed.

NOTE — This connection is earthed directly when it is not being used to carry out measurements. The tap is accessible from outside the bushing.

2.34 Voltage Tap — A connection, insulated from the flange or other fixing device, made to one of the outer conducting layers of a capacitance graded

bushing in order to provide a voltage source whilst the bushing is in operation.

NOTE — This connection is generally earthed directly when it is not being used to carry out measurements or as a voltage source. The tap is accessible from outside the bushing.

2.35 Rated Voltage of the Voltage Tap — The highest 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 of the bushing is applied to the bushing, at the nominal frequency.

2.36 Type Test — Tests carried out to prove conformity with the specification. These are intended to prove the general qualities and design of a given type of bushing.

2.37 Acceptance Test — Tests carried out on samples taken from a lot for the purpose of acceptance of the lot.

2.38 Lot — All the bushings of the same type and design, manufactured under similar conditions of production, offered for acceptance; a lot may consist of whole or a part of the quantity offered.

2.39 Routine Test — Tests carried out on each bushing to check requirements which are likely to vary during production.

3. REFERENCE ATMOSPHERIC CONDITIONS

3.1 The reference atmospheric conditions at which the bushing characteristics shall be expressed for the purpose of comparison shall be as given in 3.5.2 to 3.5.2.2 of IS : 2071 (Part 1)-1974*.

NOTE 1 — A pressure of 1 013 mbar is equivalent to a pressure of 760 mm in a mercury barometer at 0°C. If the height of the barometer is H mm of mercury and temperature t°C, the atmospheric pressure in millibar is:

$$b = \frac{1\,013\,H}{760}(1 - 1{\cdot}8 \times 10^{-4}t)$$

NOTE 2 — The standard reference temperature 27°C and corresponding humidity have not been specified because of the non-availability of the test voltages and correction factors for these conditions. These conditions will replace those specified above when the corresponding test voltages and correction factors are available.

NOTE 3 — Except by agreement between the manufacturer and the purchaser, tests shall not be made if the relative humidity exceeds 85 percent.

NOTE 4 — Correction of test voltage for atmospheric conditions differing from 3.1 shall be applied in accordance with Appendix A.

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*Methods of high voltage testing: Part 1 General definitions and test requirements *first revision*).

4. GENERAL REQUIREMENTS

4.1 The porcelain (ceramic) components (*see* **11.1.1**) shall comply with the requirements laid down in IS : 5621-1980*.

4.2 The design of the bushing shall be such that stresses due to expansion and contraction in any part of the bushing shall not lead to deterioration.

4.3 Cement used in the construction of a bushing shall not cause fracture by expansion or loosening by contraction. Cement thickness shall be as small and even as practicable.

4.4 The surface finish for ferrous parts shall be hot-dip galvanizing according to IS : 4759-1984† or zinc plating according to IS : 1573-1970‡ or cadmium plating with chromate passivation Cd8Cr according to IS : 1572-1968§ or any other surface finish subject to agreement between the manufacturer and the purchaser.

4.5 The surface finish for non-ferrous parts shall be electrotinning according to IS : 1359-1977‖ subject to agreement between the manufacturer and the purchaser.

5. RATED VALUES

5.1 Rated Voltage (U_N) — The values of U_N of a bushing shall be chosen from the standard values of the highest voltage (in kilovolts) for equipment (U_m) and installation as given below:

3·6, 7·2, 12, 17·5, 24, 36, 52, 72·5, 123, 145, 245 and 420.

5.2 Rated Current (I_N) — The values of I_N of a bushing shall be chosen from the standard values (in amperes) given below:

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 and 40 000.

NOTE 1 — In case of transformer bushings with the conductor drawn into the central tube, the manufacturer shall at least indicate the value of the cross section, material of the conductor and the level of oil in the central tube which corresponds to I_N.

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*Specification for hollow insulators for use in electrical equipment (*first revision*).

†Specification for hot-dip zinc coatings on structural steel and other allied products (*second revision*).

‡Specification for electroplated coatings of zinc on iron and steel (*first revision*).

§Specification for electroplated coatings of cadmium on iron and steel (*first revision*).

‖Specification for electroplated coatings of tin (*second revision*).

NOTE 2 — I_N of the bushing need not necessarily be identical to the rated current of the complete apparatus. It may be higher or lower, depending on how the actual operating conditions deviate from the standard test conditions for the bushing. The general rule for the permissible operating current should be that the temperature limits should be in accordance with 8.

NOTE 3 — Bushings for transformers selected with I_N not less than 120 percent of rated current of the transformer are considered to be able to withstand the overload conditions according to IS : 6600-1972* without further clarification or tests.

5.3 Rated Thermal Short Time Current (I_{th}) — Unless otherwise stated, the standard value of I_{th} shall be 25 times I_N, t_{th} being 1 second. For bushings with I_N greater than or equal to 4 000 A, I_{th} shall always be 100 kA. t_{th} shall always be 2 seconds for transformer bushings.

5.4 Rated Dynamic Current (I_d) — The standard value of I_d shall have an amplitude of the first peak of 2·5 times the values of I_{th} according to 5.3.

5.5 Minimum Withstand Values of Cantilever Load — Unless otherwise specified, the bushings shall withstand the following cantilever test load for 60 s, applied to the midpoint of the terminal or terminals, perpendicular to the bushing axis:

U_N (kV)	CANTILEVER TEST LOAD (N) I_N (A)			
	800 *and Below*	*Above* 1 000 *and Up to* 1 600	2 000 *and* 2 500	3 150 *and Above*
52 and below	1 000	1 250	2 000	3 150
72·5 and 123	1 000	1 250	2 000	4 000
145 and 245	1 250	1 600	2 500	4 000
420	2 500	2 500	3 150	5 000

5.5.1 The maximum permanent cantilever load in operation, including wind, which the bushing shall withstand in any direction should be limited to:

a) 50 percent of the test values when the bushing is installed at any angle not exceeding 30° from the vertical, or

*Guide for loading of oil-immersed transformers.

b) 30 percent of the test values when the bushing is installed at any angle exceeding 30° from the vertical.

6. OPERATING CONDITIONS

6.1 Temporary Overvoltages — In normal operation the maximum phase-to-earth voltage of the system should not exceed U_N divided by $\sqrt{3}$.

Bushings shall be able to operate at phase-to-earth voltage equal to U_N for bushings of which U_N is equal to or less than 145 kV and 0·7 U_N for bushings of which U_N is equal to or above 245 kV for periods not exceeding 8 hours in any 24 hours and of which the total period does not exceed 125 hours per year.

For systems in which overvoltages in excess of this may occur, it may be advisable to choose a bushing with a higher U_N. In such cases the manufacturer's advice should be sought.

6.2 Angle of Mounting — Unless otherwise stated, it shall be assumed that bushings according to **2.13, 2.14, 2.15** and **2.18** are designed for mounting at any angle of inclination and that bushings according to **2.16** and **2.17** are designed for mounting at any angle of inclination not exceeding 30° from the vertical.

6.3 Altitude — Unless otherwise stated, it shall be assumed that bushings of which one or both ends are intended to be in ambient air are suitable for operation at altitudes not exceeding 1 000 metres.

NOTE — The air density at high altitudes is lower than that at sea level. The dielectric strength of the air is thus reduced and arcing distances may be insufficient.

6.3.1 The puncture strength and the flashover voltage in the immersion medium of a bushing are not affected by altitude.

6.3.2 Although the insulation level refers to sea level, bushings corresponding to this standard are suitable for operation at any altitude not exceeding 1 000 metres. In order to ensure that the external withstand voltages of the bushing are sufficient at altitudes exceeding 1 000 metres, the arcing distance normally required must be increased by a suitable amount. It is not necessary to adjust the radial thickness of the insulation or the clearance of the immersed end.

6.3.3 The arcing distance of a bushing intended for operation at altitudes exceeding 1 000 metres shall be such that if the bushings could be tested at an altitude below 1 000 metres, the arcing distance would withstand the application of higher test voltages.

6.3.4 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 manufacturer may demonstrate by any other means that the arcing distance is adequate.

6.3.5 For general guidance, the amount by which the insulation level on which the arcing distance is based, should be increased is 1·0 percent for each 100 metres in excess of 1 000 metres above sea level.

Example :

Altitude of installation	= 2 800 m
Increase in insulation level	= (28 − 10) × 1·0
	= 18 percent

Preferably, the next higher standard insulation level should be selected.

6.4 Temperature of Ambient Air and Immersion Media — Unless otherwise stated, it shall be assumed that bushings are designed for operation at temperatures (in degree Celsius) not exceeding the following limits:

a) Ambient air	Maximum	50°C
	Maximum daily mean	40°C
	Maximum annual mean	32°C
	Minimum	−5°C
b) Oil in transformers (*see* Note 1)	Maximum	100°C
	Maximum daily mean	90°C
c) Other media (gaseous and non-gaseous)	*See* Note 2	

6.4.1 The daily mean temperature of the immersion medium may be calculated by averaging 24 consecutive hourly readings.

NOTE 1 — The values for oil in transformers are in accordance with the various parts of IS : 2026-1977* and are applicable to all transformers bushings.

NOTE 2 — In the absence of other information, reference should in principle be made to the relevant equipment 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 3 — By agreement between the purchaser and the manufacturer, other temperature ranges may be adopted.

7. CREEPAGE DISTANCE

7.1 The minimum specific creepage distance (in millimetres per unit of U_N) for bushings, one or both ends of which are intended to be outdoors, shall be as given below:

a) For lightly polluted atmospheres 16 mm/kV

*Specification for power transformers.

b) For medium polluted atmospheres 20 mm/kV

c) For heavily polluted atmospheres 25 mm/kV

d) For very heavily polluted atmospheres 31 mm/kV

7.1.1 The value of creepage distance in the rain shadow at an angle of precipitation of 90° to the bushing axis should generally not exceed 50 percent of the total creepage distance

NOTE — The definition for the various pollution classes is under consideration.

8. TEMPERATURE LIMITS

8.1 The temperature limits commonly used under usual operating conditions of maximum daily mean ambient air temperature according to **6.4** shall be as given below:

a) 120°C for resin bonded and resin impregnated paper, and

b) 105°C for oil impregnated paper.

8.2 Consequently, the temperature rise above ambient air temperature of the hottest spot of metal parts shall not exceed the values given below:

a) 80°C where in contact with resin bonded and resin impregnated paper, and

b) 65°C where in contact with oil impregnated paper.

NOTE 1 — In case of other insulating materials, the temperature limits shall be as agreed between the purchaser and the manufacturer.

NOTE 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 also be made to the notes under **5.2**.

9. STANDARD INSULATION LEVELS

9.1 The standard values of insulation level of a bushing shall be as given in Table 1.

9.2 Maximum Values of Capacitance and Dielectric Dissipation Factor of the Test Tap on Transformer Bushings

9.2.1 In view of its use for partial discharge measurements on transformers, the values for the test tap shall not exceed:

a) a capacitance of 5 000 pF with respect to earth, and

b) a dielectric dissipation factor ($\tan \delta$) of 0·1 measured at power frequency.

NOTE 1 — A lower maximum value of test tap capacitance with respect to earth may be agreed between the manufacturer and the purchaser.

NOTE 2 — At the request of the purchaser, the manufacturer should indicate the values of dielectric dissipation factor for the insulating material of the tap at frequencies used for partial discharge measurement on transformers.

NOTE 3 — 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.

TABLE 1 STANDARD INSULATION LEVELS

(*Clauses* 9.1, 11.1.2, 11.1.2.1 *and* 11.13.3)

RATED VOLTAGE (U_N) kV (rms)	DRY LIGHTNING IMPULSE WITHSTAND VOLTAGE 1·2/50 μs kV (peak)	POWER FREQUENCY WITHSTAND VOLTAGE, DRY AND WET kV (rms)	SWITCHING IMPULSE WITHSTAND VOLTAGE, DRY AND WET 250/2 500 μs kV (peak)
(1)	(2)	(3)	(4)
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	—
123	550	230	—
145	650	275	—
245	1 050	460	—
420	1 425	630*	1 050

*Wet power frequency test is not applicable to 420 kV bushings.

10. MARKING

10.1 Each bushing shall carry the following markings:

a) Manufacturer's name or trade-mark;

b) Year of manufacture and serial number or type;

c) Rated voltage, U_N (*see* **2.19**);

d) Rated phase-to-earth voltage (*see* **2.20**);

e) Rated frequency;

f) Lighting impulse and switching impulse or power frequency withstand test voltages;

g) Rated current, I_N (*see* 2.21);

h) Type of insulating gas and minimum operating density, if applicable;

j) Mass, if above 100 kg; and

k) Maximum angle of mounting.

NOTE — It may be difficult to include all the above markings on smaller bushings. In this case, marking of 10.1 (a) and (b) shall be mandatory; other markings may be agreed between the manufacturer and the purchaser.

10.1.1 The product may also be marked with Standard Mark.

10.1.2 The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manufactures or producers may be obtained from the Bureau of Indian Standards.

11. TESTS

11.1 General

11.1.1 As far as tests on insulating envelopes of ceramic material are applicable to this standard, IS : 5621-1980* shall be followed.

11.1.2 The values of the applicable withstand test voltages for newly manufactured bushings are indicated in Table 1.

11.1.2.1 For bushing which have been in service, the dry power frequency withstand test voltages shall be reduced to 85 percent of the values indicated in Table 1.

11.1.2.2 The bushing shall not be damaged by the tolerated flashovers in air when tested according to 11.3, 11.4, 11.5 and 11.12. However slight marks remaining on the surface of the insulating parts shall be acceptable. Marks on cast resin bushings shall be a matter of agreement between the manufacturer and the user.

11.1.3 Unless otherwise stated, during all tests the temperature of the ambient air and immersion media, if any, shall be between 10 and 40°C.

11.1.4 While conducting dielectric tests (*see* 11.3 to 11.5), the corrections of test voltage for atmospheric conditions differing from 3.1 shall be applied in accordance with Appendix A.

*Specification for hollow insulators for use in electrical equipment (*first revision*).

11.1.5 The supplier shall provide the 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 which 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.

11.2 Classification of Tests

11.2.1 *Type Tests* — The following shall constitute type tests (*see* Note 1 below):

a) Wet power frequency voltage withstand test (*see* **11.3**),

b) Dry lightning impulse voltage withstand test (*see* **11.4**),

c) Dry or wet switching impulse voltage withstand test (*see* **11.5**),

d) Thermal stability test (*see* **11.6**),

e) Temperature rise test (*see* **11.7**),

f) Thermal short time current withstand test (*see* **11.8**),

g) Dynamic current withstand test (*see* **11.9**),

h) Cantilever load withstand test (*see* **11.10**), and

j) Tightness test on liquid filled and liquid insulated bushings (*see* **11.11**).

NOTE 1 — The bushing which has passed the routine test given in **11.2.2** shall be tested for type tests.

NOTE 2 — The order of possible combination of tests shall be at the discretion of the manufacturer unless otherwise agreed between the manufacturer and the user.

NOTE 3 — Before and after the thermal and dielectric tests, measurements of tan δ and capacitance (**11.12**) and partial discharge quantity (**11.14**) shall be carried out in order to check whether a puncture or other significant damage has occurred.

NOTE 4 — If, at the request of purchaser, the lightning and/or switching impulse voltage withstand tests should be carried out as routine tests to check the internal insulation of the bushings, only three impulses of negative polarity shall be applied.

11.2.2 *Acceptance Tests* — A separate list of acceptance tests is not considered necessary but tests given in **11.2.3** may be conducted on assembled bushings. Similarly, no sampling plan is considered for inclusion in this standard as the number of bushings in a single order is not large.

11.2.3 *Routine Tests* — The following shall constitute routine tests:

a) Measurement of dielectric dissipation factor tan δ and capacitance at ambient temperature (*see* **11.12**),

b) Dry power frequency voltage withstand test (*see* **11.13**),

c) Measurement of partial discharge quantity (*see* **11.14**),

d) Tests of tap insulation (*see* **11.15**),

e) Pressure test of gas filled and gas insulated bushings (*see* **11.16**),

f) Tightness test on gas filled and gas insulated bushings (*see* **11.17**),

g) Pressure test on liquid filled and liquid insulated bushings (*see* **11.18**), and

h) Tightness test at flange or other fixing device (*see* **11.19**).

11.3 Wet Power Frequency Voltage Withstand Test

11.3.1 The test shall be applicable to outdoor, outdoor-indoor and outdoor-immersed bushings of which U_N is up to 245 kV. Duration of the test shall be 60 seconds.

11.3.2 The test shall be conducted in accordance with IS : 2071 (Part 2)-1976*. Before the commencement of the test, the bushings shall be exposed to the atmospheric conditions specified in IS : 2071 (Part 1)-1974†. The conditions of the bushing during the test are given in Appendix B.

11.3.3 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.

11.4 Dry Lightning Impulse Voltage Withstand Test

11.4.1 The test shall be applicable to all types of bushings.

11.4.2 The test shall be conducted in accordance with IS : 2071 (Part 2)-1976*. The bushing shall be subjected to fifteen full wave impulses of positive polarity followed by fifteen full wave impulses of negative polarity of the standard wave form 1·2/50 μs.

11.4.3 It shall be permissible to apply some impulses of minor amplitude before the application of the test impulses.

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*Methods of high voltage testing: Part 2 Test procedures (*first revision*).

†Methods of high voltage testing : Part 1 General definitions and test requirements (*first revision*).

11.4.4 The time intervals between consecutive applications of the voltage shall be sufficient to avoid effects from the previous application of voltage.

11.4.5 The bushing shall be considered to have passed the test if no puncture occurs and if the number of flashovers at either polarity does not exceed two, except for transformer bushings for which not more than two flashovers at positive polarity and one flashover at negative polarity shall be permitted.

NOTE 1 — Impulse voltage records are normally made.

NOTE 2 — By special agreement between the purchaser and the manufacturer, chopped wave impulse test may be carried out. In such cases, the method of the test should be agreed between the purchaser and the supplier.

11.5 Dry or Wet Switching Impulse Voltage Withstand Test

11.5.1 The test shall be applicable to bushings of U_N equal to 420 kV.

11.5.1.1 A wet test only is applicable to outdoor, outdoor-indoor and outdoor-immersed bushings of U_N equal to 420 kV.

11.5.1.2 A dry test only is applicable to non-outdoor bushings and completely immersed bushings of U_N equal to 420 kV.

11.5.2 The test shall be conducted in accordance with IS : 8269-1976*. The bushing shall be subjected to fifteen impulses of positive polarity followed by fifteen impulses of negative polarity of the standard wave form 250/2 500 μs.

11.5.3 It shall be permissible to apply some impulses of minor amplitude before the application of the test impulses.

11.5.4 The time intervals between consecutive applications of the voltage shall be sufficient to avoid effects from the previous application of voltage.

11.5.5 The bushing shall be considered to have passed the test if no puncture occurs at either polarity and if the number of flashover at either polarity does not exceed two, except for transformers bushings for which not more than two flashovers at positive polarity and one flashover at negative polarity are permitted.

NOTE — Impulse voltage records are normally made.

11.6 Thermal Stability Test

11.6.1 The test shall be applicable to indoor-immersed, outdoor-immersed and completely immersed bushings, the major insulation of which consists of

*Methods for switching impulse tests on high-voltage insulators.

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_N is greater than 245 kV for oil and resin impregnated paper bushings and equal to or greater than 145 kV for other types of bushings. For oil impregnated paper bushings having U_N greater than 245 kV, 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.

11.6.2 The ends of bushings which are intended for immersion in oil or another liquid insulating medium shall be immersed in oil.

11.6.3 The temperature of the oil shall be maintained at the operating temperature of the apparatus $\pm$ 2°C, except for transformer bushing where the oil temperature shall be 90 $\pm$ 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.

11.6.4 The test voltage shall be equal to U_N for bushings of which U_N is equal to or below 145 kV and 0·7 U_N for all other bushings.

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

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

11.6.7 The bushing shall be considered to have reached thermal stability when its dielectric dissipation factor shows no appreciable rising tendency with respect to ambient air temperature for a period of five hours.

11.6.8 The bushing shall be considered to have successfully passed the test if it has reached thermal stability and if it has withstood a repetition of routine tests according to **11.12** and **11.14** without significant change from the previous results.

NOTE — If the bushing cannot be tested according to **11.6**, the test procedure shall be agreed upon between the purchaser and the manufacturer.

11.7 Temperature Rise Test

11.7.1 The test shall be applicable to bushings of all types unless it can be demonstrated by a calculation based on comparative tests that the specified temperature limits will be complied with.

11.7.1.1 The bushing shall be considered to have passed the test if the permissible temperature rise limits specified in **8** are met and if there is no visible evidence of damage.

11.7.2 *Test Procedure*

11.7.2.1 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 50 ± 2°C above the ambient air. The level of the oil shall be maintained at least up to the mounting flange of the bushing.

11.7.2.2 The ends of bushings which are intended for immersion in a gaseous insulating medium other than air at atmospheric pressure shall normally be appropriately immersed in gas at minimum operating density, the gas being at ambient temperature at the beginning of the test.

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

11.7.2.4 The test shall be carried out at $I_N + 2$ percent, all parts of the bushing being substantially at earth potential.

11.7.2.5 Bushings with a conductor drawn into the central tube shall be assembled with an appropriate conductor, the cross section of which shall correspond with I_N.

11.7.2.6 Temporary external connections used for this test shall be of such dimensions that they do not contribute unduly to the cooling or the heating of the bushing under test. These conditions are assumed to be fulfilled if the temperature difference between the bushing termination and a point at 0·5 m distance along the connection does not exceed 2°C.

11.7.2.7 The test shall be continued until the temperature rise is sensibly constant. This is considered to be the case if temperature does not vary by more than ±2°C during two hours.

11.7.3 *Measurement of Temperature*

11.7.3.1 *Temperature of metal parts* — The temperature of the hottest spot of metal parts of the bushing shall be measured by means of thermocouples or equivalent devices.

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

To avoid destruction of the insulation in case of bushings with the conductor embedded in the insulation material, the temperature of the

hottest spot may be determined as follows:

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

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

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

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 a distance L_M from the cooler end given by:

$$L_M = \frac{L}{1 \pm \sqrt{\frac{\theta_M-\theta_2}{\theta_M-\theta_1}}}$$

where

θ_M = maximum temperature of conductor, in degree Celsius;

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

R_C = resistance of conductor carrying I_N after stabilization of temperature;

a = temperature coefficient of resistance at which conductor resistance R_A is measured;

θ_A = uniform reference temperature of conductor, in degree Celsius ;

θ_1 = measured temperature at cooler end of conductor, in degree Celsius;

θ_2 = measured temperature at hotter end of conductor, in degree Celsius;

L = length of conductor; and

L_M = distance from cooler end of conductor to point of highest temperature.

11.7.3.2 *Temperature of ambient air* — The ambient air temperature shall be measured with lagged thermometers placed around the bushing at mid-height and at 1 to 2 m distance 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 litre.

11.7.3.3 *Temperature of the oil or gas* — The temperature of the oil or gas shall be measured by means of thermometers placed 30 cm distant from the bushing and in the case of oil 3 cm below the surface of the oil.

11.8 Thermal Short Time Current Withstand Test

11.8.1 Unless otherwise agreed between the purchaser and the manufacturer, the ability of the bushing to withstand the standard value of I_{th} shall be demonstrated by the following calculation:

$$\theta_f = \theta_o + a \frac{I_{th}^2}{S_t S_e} \times t_{th}$$

where

θ_f = final temperature of the conductor, in degree Celsius;

θ_o = temperature of the conductor, in degree Celsius, under continuous operation with I_N at an ambient temperature of 40°C;

a = 0·8 (°C/s)/(kA/cm²)² for copper, and
1·8 (°C/s)/(kA/cm²)² for aluminium;

I_{th} = standard value as specified above in kiloamperes;

S_t = total cross-section in square centimetres corresponding to I_N;

S_e = equivalent cross-section taking account of skin effect; and

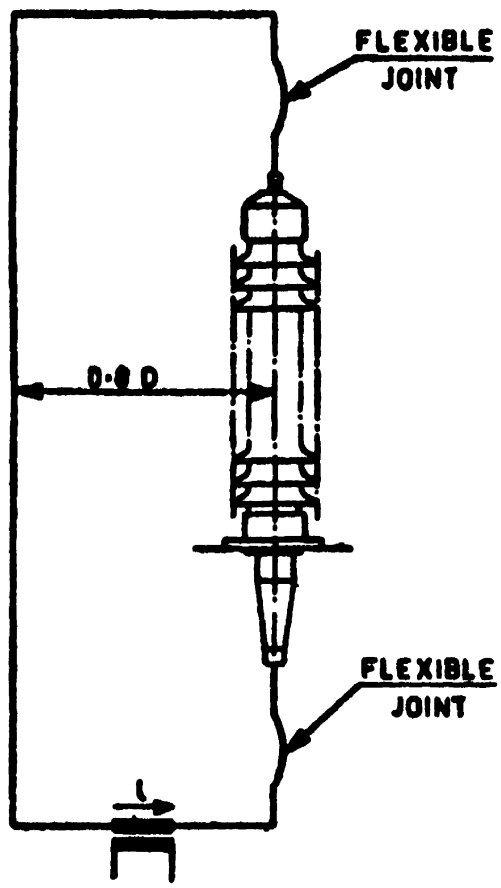
t_{th} = rated duration as specified above, in seconds.

The bushing shall be considered to be able to withstand the minimum value of I_{th} if θ_f does not exceed 180°C.

11.8.2 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 which shall be carried out as given in **11.8.2.1** and **11.8.2.2**.

11.8.2.1 The bushing shall be installed as indicated in Fig. 1. A current of I_{th} and duration of t_{th} in accordance with **5.3** shall be passed through the conductor, the cross-section of which shall correspond with I_N.

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



D = Length of the longest end of the bushing.

FIG. 1 ARRANGEMENT FOR THERMAL AND DYNAMIC CURRENT WITHSTAND TESTS

11.8.2.2 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.

NOTE — This test is not applicable to bushings delivered without conductor.

11.9 Dynamic Current Withstand Test — Under consideration.

11.10 Cantilever Load Withstand Test

11.10.1 This test shall be applicable to bushings of all types.

11.10.2 The test values shall be in accordance with **5.5**.

11.10.3 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 1·0 ± 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 gasketted joint, at the terminal to be tested.

11.10.4 The load shall be applied perpendicular to the axis of the bushing at the mid-point of the terminal for one minute. 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 highest stresses at the critical parts of the bushing in normal operation.

11.10.5 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 routine tests as given in **11.12** and **11.14** without significant change from previous test results.

11.11 Tightness Test on Liquid Filled and Liquid Insulated Bushings

11.11.1 Either of two test methods given in **11.11.1.1** and **11.11.1.2** may be used to check the requirement as given in **11.11.2.**

11.11.1.1 The bushing shall be mounted on a tank filled with oil, maintained at a temperature of 90°C for a period of 12 hours.

11.11.1.2 The bushing shall be placed in a suitably heated enclosure maintained at a temperature of 75°C for 12 hours.

11.11.2 The bushing shall be considered to have passed the test if there is no evidence of leakage of the internal filling at the end of the test.

11.12 Measurement of Dielectric Dissipation Factor (tan δ) and Capacitance at Ambient Temperature

11.12.1 The measurement is only applicable to cast resin insulated, composite and capacitance graded bushings.

NOTE — This measurement is not applicable as a routine test to non-capacitance graded bushings of rated voltage below 52 kV and is carried out only by agreement between the purchaser and the manufacturer.

During this test, the bushing conductor shall not carry current; the measurement shall be made at ambient temperature prevailing at the time of test.

11.12.2 *Measurement of the Dielectric Dissipation Factor (tan δ)* — The measurement of the dielectric dissipation factor (tan δ) shall be made as a function of voltage by means of a Schering bridge or another equivalent method. The measurement of tan δ shall be made at least at:

a) for bushings of $U_N \leq 36$ kV:

$1{\cdot}05\ U_N/\sqrt{3}$ (approximately $0{\cdot}6\ U_N$)

b) for bushings of $U_N \geq 52$ kV:

$0{\cdot}5 - 1{\cdot}05 - 1{\cdot}5\ U_N/\sqrt{3}$ (approximately $0{\cdot}3 - 0{\cdot}6 - 0{\cdot}85\ U_N$).

NOTE — It is recommended to carry out measurements at a voltage between 2·5 kV and 10 kV as a reference value for measurements carried out later when the bushing is in operation.

11.12.3 *Maximum Values of tan* δ — The maximum values of tan δ, measured at $1{\cdot}05\ U_N/\sqrt{3}$ shall be as follows:

a) *Capacitance graded bushings:*

— oil impregnated paper	0·007
— resin bonded paper	0·015
— resin impregnated paper	0·015
— cast resin	0·015
— insulating gas	0·010
— composite and other	*see* Note

b) *Non-capacitance graded bushings:*

— cast resin	0·02
— composite and other	*see* Note

NOTE — The manufacturer shall indicate the maximum values of tan δ for composite and other bushings.

11.12.4 *Permissible Values for Increase of tan* δ *on Capacitance Graded Bushings* — The permissible values for increase of tan δ of bushings mentioned under 11.12.3(a) shall be as follows:

From $0{\cdot}5$ to $1{\cdot}05\ U_N/\sqrt{3}$: *Max* 0·001

From $0{\cdot}5$ to $1{\cdot}50\ U_N/\sqrt{3}$: *Max* 0·003

11.12.5 *Measurement of Capacitance*— The capacitance of the bushing shall be measured at $1{\cdot}05\ U_N/\sqrt{3}$. The capacitance measured at the end of the series of type and routine dielectric tests should not differ by more than the amount attributable to the puncture of one layer.

NOTE — In some cases, it may be necessary to wait several hours before repeating the capacitance measurement at the end of the series of dielectric type and routine tests.

11.13 Dry Power Frequency Voltage Withstand Test

11.13.1 The test shall be applicable to bushings of all types except gas insulated bushings.

NOTE — The dry power frequency voltage withstand test may be carried out as a type test only on gas insulated bushings 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 provided the insulating envelope of the bushing has been subjected to an adequate electrical test (for example, wall test of the porcelain) before assembly.

11.13.2 The test duration shall be one minute.

11.13.3 The values of dry power frequency withstand voltage shall be as given in Table 1.

11.13.4 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 bushings shall be considered to have passed the test.

11.14 Measurement of Partial Discharge Quantity

11.14.1 The tests shall be carried out on bushings of various types as given below. Test shall be made in accordance with IS : 6209-1982*.

Type of Bushing Insulation	*Discharge Quantity in* $10^{-12}C$	
	At $1{\cdot}05\ U_N/\sqrt{3}$	At $1{\cdot}5U_N/\sqrt{3}$
Oil and resin impregnated paper	10	10
Resin bonded paper	100	250
Cast insulation (*see* Note 6)	10	—
Gas	10	10
Composite	*See* Note 7	

NOTE 1 — On resin bonded paper bushings with metallic layers, the discharge quantity at $1{\cdot}05\ U_N/\sqrt{3}$ should not exceed 300×10^{-12} C and at $1{\cdot}5\ U_N/\sqrt{3}$ it should be agreed upon between the manufacturer and the user.

NOTE 2 — The values at $1{\cdot}5\ U_N/\sqrt{3}$ apply only to bushings for use on transformers or reactors.

NOTE 3 — When measuring partial discharges by means of meters giving the quadratic rate, expressed in coulomb square per second, the minimum measurable discharge quantity shall be ten times smaller than the permissible quantity.

*Methods for partial discharge measurements (*first revision*).

The maximum permissible values of the partial discharge quantity on descending voltage with reference to the terminals shall be agreed between the purchaser and the manufacturer except for resin bonded paper capacitance graded bushings for which the values shall be as follows :

Type of Layer	*Quadratic Rate in C²/s*	
	$1{\cdot}05\ U_N/\sqrt{3}$	$1{\cdot}5\ U_N/\sqrt{3}$
Non-metallic	10 to 18	10 to 16
Metallic	10 to 16	10 to 15

NOTE 4 — 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 permissible value, as well as the minimum measurable value, shall be agreed between the purchaser and the supplier.

NOTE 5 — The measurement may be carried out as a type test only on gas insulated bushings 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 provided the insulation envelope of the bushing has been subjected to an adequate electrical test (for example, wall test of the porcelain) before assembly.

NOTE 6 — On cast insulation bushings, the discharge quantity at $1{\cdot}05\ U_N$ must not exceed 100 pC.

NOTE 7 — Composite bushings shall be subjected to partial discharge test only when agreed between the purchaser and the supplier. The maximum permissible values of the discharge quantity shall also be subjected to agreement between the purchaser and the supplier.

11.14.2 Unless otherwise stated, the elements of the test circuit shall be chosen so that:

a) the background noise quantity does not exceed 50 percent of the specified permissible discharge quantity.

b) the sensitivity of the measuring circuit itself is such as to detect 20 percent or less of the specified permissible discharge quantity.

11.14.3 The measurement shall be made at $1{\cdot}05\ U_N/\sqrt{3}$ (approx $0{\cdot}6\ U_N$) and/or at $1{\cdot}5\ U_N/\sqrt{3}$, depending on the type of bushing insulation as given below, on ascending voltage and again on descending voltage after the voltage has been raised to at least U_N.

11.15 Tests of Tap Insulation

11.15.1 The following power frequency voltage withstand test with respect to earth shall be applicable to all taps. The test duration shall be one minute.

Test tap (*see* **2.33**)	At least 2 kV
Voltage tap (*see* **2.34**)	2 times the rated voltage of the voltage tap but at least 2 kV

Before and after the power frequency voltage withstand test on voltage taps, the capacitance with respect to earth shall be measured at rated voltage.

11.15.2 After the power frequency voltage withstand test, the capacitance with respect to earth shall be measured at 0·5 kV at least on all test taps.

11.15.3 After the power frequency voltage withstand test on test taps on transformer bushings, the capacitance with respect to earth and dielectric dissipation factor shall be measured at 0·5 kV at least and the results shall be in accordance with **9.3**.

11.16 Pressure Test of Gas Filled and Gas Insulated Bushings

11.16.1 The test shall be applicable only to gas filled and gas insulated bushings.

11.16.2 The bushing, complete as for normal operation, shall be filled with gas or liquid at the choice of the manufacturer.

11.16.3 A test pressure 1·5 times the maximum operating gauge pressure $\pm$ 0·1 bar shall be produced inside the bushing and maintained for 15 minutes at ambient temperature.

11.16.4 The bushing shall be considered to have passed the test if there is no evidence of mechanical damage such as deformation and rupture.

NOTE 1 — In case of bushings of which the insulating envelope is of porcelain and intended to be under pressure in operation, the porcelain shall be tested alone, before assembly, at a pressure not less than 3 times the maximum operating gauge pressure.

NOTE 2 — The pressure test requirements of gas filled equipment are at present under consideration

11.17 Tightness Test on Gas Filled and Gas Insulated Bushings

11.17.1 The test shall be applicable to gas filled and gas insulated bushings.

11.17.2 The bushing shall be assembled as for normal service and filled with the gas specified at maximum operation pressure (*see* **2.28**) at ambient temperature.

The bushing shall be considered to have successfully passed the test if the leakage observed (*see* **2.29**) is equal to or lower than the value agreed upon between the purchaser and the manufacturer.

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

11.18 Pressure Test on Liquid Filled and Liquid Insulated Bushings — The pressure test for leakage of internal filling is applicable only to bushings defined in **2.2** and **2.3** except for those bushings of which the liquid filling has a viscosity equal to or above 5×10^{-4} m^2/s at 20°C. Any one of the two alternative test procedures given in **11.18.1** and **11.18.2** may be used at the choice of the supplier.

NOTE — If the design of the bushing is such that the tests as specified below are impracticable, the test procedure shall be subject to agreement between the purchaser and the manufacturer.

11.18.1 *Test with Oil or Insulating Liquid at Ambient Temperature* — The bushing complete as for normal service shall be filled to the normal level with oil or insulating liquid of the quality specified by the manufacturer. The bushings shall be placed in air at ambient temperature of not less than 10°C. The temperature of the oil or insulating liquid shall be ambient temperature.

The following testing pressure shall be produced inside the bushings and maintained for at least 12 hours:

a) For bushings operating at a pressure above the atmospheric pressure between 0·6 and 2 bar	To be tested at a pressure of $1{\cdot}0 \pm 0{\cdot}1$ bar above the maximum operating pressure
b) For bushings operating at a pressure above the atmospheric pressure between 0 and 0·6 bar	To be tested at a pressure of $1{\cdot}0 \pm 0{\cdot}1$ bar above atmospheric pressure

The bushing shall be considered to be effectively sealed if there is no evidence of leakage of oil or insulating liquid.

11.18.2 *Test with Compressed Gas* — The bushing. complete as for normal service, shall be filled with air or any suitable gas maintained at a pressure of $1{\cdot}0 \pm 0{\cdot}1$ bar above the maximum operating pressure. The bushings shall be in air at an ambient temperature of not less than 10°C. The duration of the test shall be 15 minutes.

The bushing shall be considered effectively sealed if there is no evidence of leakage of gas.

11.19 Tightness Test at Flange or Other Fixing Device

11.19.1 The test shall be applicable to all bushings of indoor-immersed, outdoor-immersed and completely immersed types, intended to be used as an integral part of an apparatus, such as switchgear or transformer, where the bushings contribute to the sealing of the complete apparatus.

11.19.2 The bushing shall be assembled as far as necessary for the test. The end for immersion shall be mounted on a tank as for normal operation. The tank shall be filled with air or any suitable gas at a gauge pressure of $1{\cdot}5 \pm 0{\cdot}1$ bar and maintained for 15 minutes.

11.19.3 The bushing shall be considered to have passed the test if there is no evidence of leakage.

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

The test may be omitted for transformer and circuit breaker bushings, fitted with a one-piece metal flange, provided the flange has been subjected to a preliminary tightness test and the bushing has been tested according to **11.11** (for example, oil impregnated paper bushings) or **11.17** if the end to be immersed does not include any gaskets.

12. INFORMATION TO BE FURNISHED WITH ENQUIRIES AND ORDERS

12.1 The information given in Appendix C shall be furnished when enquiring or ordering bushings conforming to this standard.

APPENDIX A

(*Clauses* 3.1 *and* 11.1.4)

CORRECTION OF TEST VOLTAGE FOR ATMOSPHERIC CONDITIONS

A-1. GENERAL

A-1.1 Variations in barometric pressure and humidity of the atmosphere cause variation in electric strength of air and hence also in flashover voltage of bushings exposed to air; flashover and puncture strength are not significantly affected by these changes under oil.

A-2. CORRECTION FACTORS

A-2.1 When the atmospheric conditions in the neighbourhood of the bushing during the test differ from the reference conditions, adjustments should be made to correct the test voltages by the application of air density correction factor, k_d, and humidity correction factor, k_h, as given below [*see also* IS : 2071 (Part 1)-1974*] for bushings for which the electrode configuration of rod-plane gap is valid:

Clause Reference	*Test*	*Correction of Test Voltage*
11.3	Wet power frequency voltage withstand test	Multiply by k_d
11.4	Dry lightning impulse voltage withstand test	Multiply by k_d/k_h in the conditions indicated in A-2.2
11.5	Dry switching impulse voltage withstand test	Multiply by k_d/k_h in the conditions indicated in A-2.2
11.5	Wet switching impulse voltage withstand test	Multiply by k_d in the conditions indicated in A-2.2
11.6	Thermal stability test	None
11.12	Measurement of dielectric dissipation factor and capacitance	None
11.13	Dry power frequency voltage withstand test	None
11.14	Measurement of partial discharge quantity	None
11.15	Tests of tap insulation	None

A-2.2 In case of impulse test 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 greater than 1, the correction applies to both polarities but if the correction factor is greater than 1·05, the

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purchaser and the manufacturer shall agree as to whether the test shall or shall not be continued.

NOTE 1 — As the dielectric routine tests (*see* 11.2.3) are intended to check the internal insulation only, it is permissible practice to screen the external metal parts of the bushing during these tests.

NOTE 2 — 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.

NOTE 3 — Normally transformer bushings are tested in vertical position; other test arrangements must be agreed between the purchaser and the supplier.

NOTE 4 — The angle of mounting of the bushing for the wet power frequency voltage withstand test may be the subject of special agreement between the purchaser and the supplier. In certain cases, it may be necessary to extend the voltage range above that specified in 11.3.

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

The purchaser may use the bushing for a simulation test to prove the adequacy of the operating arrangement.

On request the supplier should be willing to carry out such a simulation test, possibly, in conjunction with the type test of the bushing itself.

APPENDIX B

(*Clause* 11.3.2)

HIGH VOLTAGE TESTS

B-1. CONDITION OF BUSHINGS DURING DIELECTRIC AND THERMAL TESTS

B-1.1 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.

B-1.2 Test tappings and voltage tappings shall be either earthed or held near earth potential.

B-1.3 Liquid filled and liquid insulated bushings shall be filled to the normal level with insulating liquid of the quality specified by the supplier.

B-1.4 Gas filled and gas insulated bushings shall be filled with the type of gas specified by the manufacturer and raised to the minimum operating density of insulating gas. The density may be expressed as the pressure 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 to correspond with the required density.

Bushings according to **2.16, 2.17** and **2.18** shall normally be immersed in an immersion medium which is as similar as possible to that used in normal operation except for the following:

a) Bushing for which the immersion medium is gas, the immersion medium may be replaced by oil for the dielectric routine tests, by agreement between the supplier and the purchaser.

b) Bushings for which the immersion medium is neither oil nor gas, the immersion medium may be replaced by oil or gas for all dielectric and thermal tests by agreement between the supplier and the purchaser.

B-1.5 The applicable atmospheric conditions for dielectric and thermal tests are given in IS : 2071 (Part 1)-1974*.

APPENDIX C

(*Clause* 12.1)

INFORMATION TO BE FURNISHED WITH ENQUIRIES AND ORDERS

C-1. ENUMERATION OF CHARACTERISTICS

C-1.1 When specifying, the purchaser should furnish as much of the following information as necessary and any additional information needed to determine clearly the required characteristics:

a) *Application* — Application, including type of apparatus for which the bushing is intended and the relevant Indian Standard. Attention

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should be drawn to any features (including tests) of the complete apparatus which may affect the design of the bushing.

b) *Classification* — The classification of bushings shall be as given in 2.2 to 2.18.

c) *Ratings*

i) Rated voltage (U_N) (*see* 2.19);

ii) Rated phase-to-earth voltage (*see* 2.20);

iii) Standard insulation level (*see* 9);

iv) Rated current (I_N) (*see* 2.21);

v) Rated thermal current I_{th} and rated duration t_{th}, if deviating from the values indicated in 5.3;

vi) Rated frequency (*see* 2.25);

vii) Rated density of insulating gas (*see* 2.26) (relevant only to bushings according to 2.4 and 2.5 when the gas of the equipment is in communication with that of the bushing);

viii) Cantilever withstand load, if exceeding the value indicated in 5.5; and

ix) Maximum value of test tap capacitance, if lower than the value indicated in 9.2.

d) *Operating Conditions*

i) Temporary overvoltages, if applicable (*see* 6.1);

ii) Altitude, if exceeding 1 000 metres (*see* 6.3) (relevant only to bushings according to 2.13 to 2.17);

iii) Class of minimum ambient air temperature (*see* 6.4) (relevant only to bushings according to 2.13 to 2.17);

iv) Type of immersion medium (relevant only to bushings according to 2.16 to 2.18);

v) Minimum level of immersion medium (relevant only to bushings according to 2.16 to 2.18);

vi) Maximum operating pressure of immersion media (relevant only to bushings according to 2.16 to 2.18);

vii) Type of insulating gas (relevant only to bushings according to 2.4 and 2.5 when the gas of the equipment is in communication with that of the bushing);

viii) Minimum operating density of insulating gas (*see* 2.27) (relevant only to bushings according to 2.4 and 2.5 when the gas of the equipment is in communication with that of the bushing);

ix) Maximum operating pressure (*see* 2.28) (relevant only to bushings according to 2.4 and 2.5 when the gas of the equipment is in communication with that of the bushing);

x) Angle of mounting (*see* 6.2);

xi) Minimum specific creepage distance (*see* 7) (relevant only to bushings according to 2.14, 2.15 and 2.17); and

xii) Unusual climatic conditions.

e) *Design*

i) For bushings supplied without a conductor the diameter, type (cable, solid or hollow stem), material and position of the conductor with which the bushing will be fitted in service;

ii) Particular dimensional requirements, if any;

iii) Test tap or voltage tap, if required (*see* 2.33, 2.34 and 2.35);

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

v) General information concerning the position of the bushing in relation to the earthed parts of the apparatus for which the bushing is intended;

vi) Whether protective gaps are to be fitted or not;

vii) Special requirements for corrosion protection of metallic parts; and

viii) Oil level in central tube of bushing.

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