

Specification for

Power transformers

Co-operating organizations

The Electrical Industry Standards Committee under whose supervision this British Standard was prepared consists of representatives from the following Government departments and scientific and industrial organizations:

Associated Offices' Technical Committee
 Association of Consulting Engineers*
 Association of Mining Electrical and Mechanical Engineers
 Association of Supervising Electrical Engineers
 British Electrical and Allied Manufacturers' Association*
 British Radio Equipment Manufacturers' Association
 British Railways Board
 Crown Agents for Oversea Governments and Administrations
 Department of Employment and Productivity
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 Electric Lamp Industry Council
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 Electrical Contractors' Association (Incorporated)
 Electrical Contractors' Association of Scotland
 Electrical Research Association*
 Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales*
 Electronic Engineering Association
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 Institution of Electrical Engineers
 Ministry of Defence
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 Ministry of Technology (Power)
 Municipal Passenger Transport Association (Incorporated)
 National Inspection Council for Electrical Installation Contracting
 National Physical Laboratory (Ministry of Technology)
 Oil Companies Materials Association
 Post Office
 Public Transport Association (Incorporated)
 South of Scotland Electricity Board

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The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Engineer Surveyors' Association
 London Transport Board
 National Coal Board

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Foreword

This standard makes reference to the following British Standards:

BS 148, *Insulating oil for transformers and switchgear*.

BS 205, *Glossary of terms used in electrical engineering*.

BS 923, *Guide on high-voltage testing techniques. Revision of BS 923:1940. In course of preparation*.

BS 2045, *Preferred numbers*.

BS 2562, *Cable sealing boxes for oil-immersed transformers*.

BS 2757, *Classification of insulating materials for electrical machinery and apparatus on the basis of thermal stability in service*.

BS 2914, *Surge diverters for alternating-current high-voltage power circuits*.

CP 1009, *Maintenance of insulating oil (with special reference to transformers and switchgear)*.

CP 1010, *Guide to loading of oil-immersed transformers to BS 171*.

This revision of BS 171:1959, issued under the authority of the Electrical Industry Standards Committee, is based on the recommendations given in Publication 76¹⁾, second edition, 1967, of the International Electrotechnical Commission. The deviations from the IEC Recommendation are, apart from editorial changes obviously required for the purposes of a British Standard, mainly editorial and minor technical modifications and additions aimed at improving the clarity of the standard. More significant deviations include the following:

35.1, Routine tests. The insulation resistance test is not specified in the IEC Recommendation.

41.9, Temperature correction for cooling of transformers after shut-down. Figure 2A does not appear in the IEC Recommendation.

Clause 45, Full-wave impulse-voltage withstand test (type test). Two additional test methods for low-voltage windings, either of which may be used as an alternative to the method specified in the IEC Recommendation, are detailed in Appendix K.

46.2.3, Voltage applications (impulse-voltage test). The sequence of voltage applications differs from that given in the IEC Recommendation.

Clause 48, Measurement of zero phase-sequence impedance (special test). This test is not referred to in the IEC Recommendation.

Clause 49, Oil, Clause 50, Synthetic insulating liquid, and Clause 51, Provision of fittings. These three clauses are not given in the IEC Recommendation.

Appendix B, Selection of insulation levels. Additional information on system earthing and a further category of system earthing, i.e. neutral-impedance-earthed system (non-effectively earthed) are given in this standard.

Appendix D, Transformer connections. A considerable amount of additional information on designating letters for windings, and connection diagrams is included in this standard. This additional information is similar to that given in BS 171:1959.

Appendix H, Fittings. The information given is similar to that given in BS 171:1959, and is not given in the IEC Recommendation.

Appendix J, Supplementary information concerning high-voltage tests. The information given is similar to that given in BS 171:1959, and is not given in the IEC Recommendation.

¹⁾ IEC Publication 76:1967, "Power transformers". Copies may be obtained from the British Standards Institution, Sales Branch, Newton House, 101–113 Pentonville Road, London, W1Y 4AA.

Appendix K, Impulse-voltage testing of low-voltage windings.

See remarks above on Clause 45.

This British Standard includes a number of appendices which give guidance on the ordering, application and testing of transformers. Particular attention is drawn to the following appendices, which are not cross-referred to elsewhere in the standard:

Appendix A. Information required with enquiry and order.

Appendix C. Calculation of voltage drop (or rise) for a specified load condition.

The following is a list of British Standards which give requirements for certain transformers of types not covered or only partially covered by BS 171.

BS 355, *Mining-type transformers;*

BS 587, *Motor starters and controllers;*

BS 638, *Arc welding plant, equipment and accessories;*

BS 1538, *Intrinsically-safe transformers primarily for bell-signalling circuits;*

BS 1698, *Mercury-arc rectifier equipments;*

BS 2214, *The performance of power transformers (not exceeding 2 kVA rating) for radio and allied electronic equipment;*

BS 2538, *Air cooled flameproof single-phase lighting transformer units supplied from high voltage systems;*

BS 3399, *Transformers for use in ships;*

BS 3535, *Safety isolating transformers for industrial and domestic purposes;*

BS 3938, *Current transformers;*

BS 3941, *Voltage transformers;*

BS 4944, *Reactors, arc-suppression coils and earthing transformers for electric power systems;*

BS 2G 127, *Power and current transformers for use in aircraft electrical power supply systems.*

The foregoing list was correct at the date of publication and will be revised as successive reprints of BS 171 become necessary, but reference should be made to the current British Standards Yearbook for up-to-date information.

With the publication in 1978 of Parts 1, 2, 4 and 5 of the revision of BS 171:1970, the requirements of BS 171:1970 relating to power transformers are superseded by those of the new standard. However, Part 3 of the new standard "Insulation levels and dielectric tests" will not be published for some time as the corresponding part of the revision of IEC Publication 76:1967 has not yet been published. In the meantime the following requirements of BS 171:1970 continue to apply to power transformers:

Section 2. Definitions**4.9, Insulation****Section 7. Insulation levels****20, General****21, Windings with graded insulation****22, Transformers for use at high altitudes****Section 12. Tests****35, General requirements for type, routine and special tests²⁾****42, Application of dielectric tests****43, Induced overvoltage withstand test (routine test)**

²⁾ Only those requirements relating to dielectric tests remain valid.

- 44, Separate source voltage-withstand test (routine test)
- 45, Full wave impulse-voltage withstand test (type test)
- 46, Impulse-voltage withstand test including chopped waves (special test)
- 47, Subsequent dielectric tests
- Appendix B, Selection of insulation levels
- Appendix G, Typical connection diagrams for induced voltage tests on windings with graded insulation
- Appendix J, Supplementary information concerning high-voltage tests
- Appendix K, Impulse-voltage testing of low-voltage windings

Supplementary material relating to power transformers can be found in BS 5953 “*Guide on power transformers*” Part 1 “*Application of power transformers*”, which is identical with IEC Publication 606. Pending the publication of additional supplementary material, the following material from BS 171:1970 remains valid for power transformers for guidance only.

Appendix D, Transformer connections, winding designations, terminal markings and vector diagrams

D.3 Designating letters for windings

D.4 Subscript numbers for winding ends and tappings

Many of the requirements given in BS 171:1970 are called up in BS 4944:1973 “*Reactors, arc-suppression coils and earthing transformers for electric power systems*”. Therefore, BS 171:1970 will remain applicable to equipment covered by BS 4944:1973 as specified in that standard until the latter has been revised to align it with the revision of BS 171:1970. This will follow the revision of IEC Publication 289 “Reactors” which is being prepared by the International Electrotechnical Commission.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to viii, pages 1 to 74, 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.

Section 1. Scope and service conditions

1 Scope

With the publication in 1978 of parts 1, 2, 4 and 5 of the revision of BS 171:1970, the requirements of BS 171:1970 relating to power transformers are superseded by those of the new standard, except for those clauses and appendices listed in the Foreword.

This British Standard specifies power transformers (including auto-transformers). The following small and special transformers are excluded:

Single-phase transformers rated at less than 1 kVA and polyphase transformers rated at less than 2 kVA.

Current transformers.

Voltage transformers.

Constant-current power and lighting transformers.

Testing transformers.

Transformers incorporated in motor starters and controllers.

Induction regulators.

Transformers for use with intrinsically safe apparatus.

Transformers for aircraft purposes.

Transformers for use in ships.

Small power transformers for radio and allied electronic equipment.

Transformers forming part of arc welding plant.

Safety isolating transformers.

Requirements for certain transformers for special applications, such as mining and static convertors, and requirements for reactors, arc-suppression coils and earthing transformers, are covered in so far as reference is made to BS 171 in the relevant British Standards. The requirements of BS 171 may also be applicable, either as a whole or in part, to other special transformers not at present covered by separate British Standards.

NOTE A list of British Standards which give requirements for power transformers of types not covered or only partially covered by BS 171 will be found at the end of the Foreword.

2 Service conditions

This British Standard gives detailed requirements for transformers for use under the following conditions:

a) *Altitude*. A height above sea level not exceeding 1 000 m (3 300 ft) or altitudes in excess of this height above sea level where specified by the purchaser.

NOTE For greater altitudes, see Clause 3.

b) *Temperature of cooling medium*. For water-cooled apparatus, cooling water at a temperature not exceeding 25 °C at the inlet. For air-cooled apparatus, air at a temperature never exceeding 40 °C, or below – 25 °C, unless specially stipulated by the purchaser.

NOTE For higher temperatures, see Clause 3.

In addition, for air-cooled apparatus, the air temperature never exceeds 30 °C average in any one day, and 20 °C average in any one year.

Where a conservator is fitted, the standard capacity covers a range of average oil temperature from – 10 °C to + 80 °C. Where the air temperature is likely to be lower than – 10 °C, the purchaser should state the actual conditions in the enquiry and order. See A.1.1.2 26).

c) *Wave shape of supply voltage*. A supply voltage of which the wave shape is approximately sinusoidal.

d) *Symmetry of polyphase supply voltages*. For polyphase transformers, supply voltages which are approximately symmetrical.

3 Provision for unusual service conditions

Supplementary recommendations are given for the rating and testing of dry-type and oil-immersed type air-cooled transformers designed for use where the cooling air temperatures exceed those given in 2 b) by a limited amount. Supplementary recommendations are also given for all types of transformers designed for use at altitudes in excess of 1 000 m (3 300 ft) above sea level. (See Clauses 18, 19 and 22).

No specific recommendations are given regarding the temperature rises of air-cooled transformers where the temperature of the cooling air exceeds the values given in 2 b) by more than 10 degC or for water-cooled transformers where the temperature of the available cooling water exceeds 25 °C. The special requirements for such transformers are a matter for agreement between the manufacturer and the purchaser.

NOTE For service conditions differing from standard it is recommended that a transformer having a standard temperature rise conforming to BS 171 be used and loaded in accordance with CP 1010³⁾.

Section 2. Definitions

4 Definitions

For the purposes of this British Standard the following definitions apply. Other terms used have the meanings ascribed to them in BS 205⁴⁾.

4.1 General

4.1.1

transformer

a static piece of apparatus which, by electromagnetic induction, transforms alternating voltage and current between two or more windings at the same frequency and usually at different values of voltage and current

4.1.2

auto-transformer

a transformer in which at least two windings have a common part

4.1.3

booster transformer

a transformer of which one winding is intended to be connected in series with a circuit in order to alter its voltage

4.1.4

oil-immersed type transformer

a transformer of which the core and windings are immersed in an oil

NOTE For the purposes of this standard a synthetic insulating liquid, e.g. askarel, is regarded as an oil.

4.1.5

dry-type transformer

a transformer of which the core and windings are not immersed in an insulating liquid

4.1.6

sealed transformer

a transformer which is non-breathing, i.e. so sealed that there can be no physical or chemical interchange between its contents and the external atmosphere

sealed transformers fall into two categories:

- a) a transformer in which the total volume of oil, gas, air, or any combination remains constant over the temperature range;
- b) a transformer in which the total volume of oil, gas, air, or any combination varies over the temperature range, this variation being accommodated by a sealed flexible container.

³⁾ CP 1010, "Guide to loading of oil-immersed transformers to BS 171". (The 1959 edition of CP 1010 will be revised in conformity with the Loading Guide soon to be published by the IEC.)

⁴⁾ BS 205, "Glossary of terms used in electrical engineering".

4.2 Terminals and neutral point

4.2.1

terminal

a conducting element intended for connecting a winding to external conductors

4.2.2

line terminal

a terminal intended for connection to a line conductor of a system

4.2.3

neutral terminal

this is defined as:

- a) *For polyphase transformers*, the terminal connected to the neutral point of a star-connected or zigzag-connected winding.
- b) *For single-phase transformers*, the terminal intended for connection to a neutral point of a system.

4.2.4

neutral point

either:

- a) The common point of the star in a polyphase system.
- b) The point of a symmetrical system which is normally at zero potential.

4.2.5

corresponding terminals

terminals of different windings of a transformer, marked with the same letter or corresponding symbol in different characters

4.3 Windings

4.3.1

winding

the assembly of turns forming an electrical circuit associated with one of the voltages assigned to the transformer

NOTE 1 For a polyphase transformer the “winding” is the combination of the phase-windings (see 4.3.2).

NOTE 2 For an auto-transformer the common part of the windings is called the “common winding”; the other part is called the “series winding”.

NOTE 3 For a booster transformer the winding intended to be connected in series with a circuit is called the “series winding”; the other is called the “energizing winding”.

4.3.2

phase-winding

the assembly of turns forming one phase of a polyphase winding

NOTE The term “phase-winding” should not be used for identifying the assembly of coils on a certain leg.

4.3.3

high-voltage winding⁵⁾

the winding for the highest rated voltage

4.3.4

low-voltage winding⁵⁾

the winding for the lowest rated voltage

NOTE For a booster transformer the winding having the lower rated voltage may be that having the higher insulation level.

4.3.5

intermediate-voltage winding⁵⁾

a winding of a multi-winding transformer whose rated voltage is intermediate between the highest and lowest rated voltages

⁵⁾ A winding which receives the active power from the supply system in service conditions can be designated a “primary”, that which delivers the active power to the load circuit a “secondary”.

4.3.6**auxiliary winding**

a winding intended only for a load small compared with the rated power of the transformer

4.3.7**stabilizing winding**

a supplementary delta-connected winding, especially provided on star-star or star-zigzag connected transformers to decrease the zero-sequence impedance of the star-connected winding (see 4.7.5)

NOTE 1 Decrease of this impedance may be necessary, for example, to reduce the magnitude of third-harmonic voltages or to stabilize voltages to the neutral.

NOTE 2 A winding is regarded as a stabilizing winding if its terminals are not brought out for connection to an external circuit. However, one or two points of the winding which are intended to form the same corner point of the delta may be brought out, for example, for earthing. For a 3-phase transformer, if other points of the winding are brought out, the winding should be regarded as an auxiliary winding as defined in 4.3.6.

4.4 Rating**4.4.1****rating**

those numerical values assigned to the quantities which define the operation of the transformer in the conditions specified in this British Standard and on which the manufacturer's guarantees and the tests are based

4.4.2**rated quantities**

quantities (voltage, current, etc.) the numerical values of which define the rating

NOTE 1 Unless otherwise specified rated quantities are related to principal tapplings (see 4.5.1). For quantities related to other tapplings, see 4.5 and Section 4.

NOTE 2 Voltages and currents are always expressed by their r.m.s. values, unless otherwise specified.

4.4.3**rating plate**

a plate fixed to a transformer, giving its rated and other essential data

NOTE The rated and other data to be given on the rating plate are specified in Section 9.

4.4.4**rated voltage of a winding**

the voltage assigned to be applied, or developed at no-load, between the line terminals of a winding of a polyphase transformer or between the terminals of a winding of a single-phase transformer

NOTE 1 The rated voltages of all windings appear simultaneously at no-load when the voltage applied to one of them has its rated value.

NOTE 2 For single-phase transformers intended to be associated in a 3-phase bank, the voltage of a winding intended to be connected in star is indicated by a fraction, in which the numerator is the line-to-line voltage and the denominator is $\sqrt{3}$, for example:

$$\frac{430}{\sqrt{3}} \text{ V}$$

The same applies to series windings of booster transformers

4.4.5**rated voltage ratio**

the ratio of the rated voltage of a winding to the rated voltage of another winding associated with a lower or equal rated voltage

4.4.6**rated frequency**

the frequency at which the transformer is designed to operate

4.4.7**rated power**

a conventional value of apparent power (in kVA or MVA), establishing a basis for the design, the manufacturer's guarantees and the tests, determining a well-defined value for the rated current that may be carried with rated voltage applied, under the conditions specified in this British Standard

NOTE 1 Both windings of a two-winding transformer have the same rated power, which by definition is the rated power of the transformer.

NOTE 2 For multi-winding transformers the rated power for each of the windings should be stated.

NOTE 3 With constant rated voltage applied to one of the windings, the apparent power that can actually be delivered by (one of) the other winding(s) loaded with its rated current will deviate from the rated power of the latter winding by an amount depending on the corresponding voltage drop (or rise) (see 4.7.4). This apparent power is equal to the product of the actual voltage on load of the latter winding, the rated current (see 4.4.8) related to that winding and the appropriate phase factor (see Table 1).

4.4.8

rated current

the current, flowing through a line terminal of a winding, derived by dividing the rated power of the winding by the rated voltage of the winding and by an appropriate phase factor (see Table 1)

NOTE 1 If the delta or other polygon connection is made externally by linking the terminals of two phase-windings in pairs, this current corresponds to the value obtained for the pair of terminals thus connected.

NOTE 2 For single-phase transformers intended to be associated in a 3-phase bank, the current of a winding intended to be connected in delta is indicated by a fraction, in which the numerator is the corresponding line current and the denominator is $\sqrt{3}$, for example:

$$\frac{500}{\sqrt{3}} \text{ A}$$

4.5 Tappings

4.5.1

principal tapping

the tapping to which the rating of a tapped winding is related

NOTE For the choice of this tapping, see Clause 10.

4.5.2

tapping quantities

quantities related to tappings other than the principal tapping

4.5.3

tapping power

a conventional value of apparent power of a winding which, when the tapped winding is connected on the tapping concerned and when the appropriate voltages applied or developed have the values corresponding to no-load, determines the current which may be carried through a line terminal of this winding

NOTE The appropriate voltages depend on the category of voltage variation (see Clause 11 and 14.2).

4.5.4

tapping voltage

the value of the voltage developed at no-load between the line terminals of a tapped polyphase winding, or between the terminals of a tapped single-phase winding, connected on the corresponding tapping, when rated voltage is applied to the other winding which, if tapped, is connected on its principal tapping

4.5.5

step voltage

the difference between the tapping voltages of two adjacent tappings

NOTE It may be given as a percentage of the rated voltage.

4.5.6

plus tapping

a tapping so located in a tapped winding as to introduce into this winding a greater number of effective turns than those corresponding to the principal tapping

4.5.7

minus tapping

a tapping so located in a tapped winding as to introduce into this winding fewer, effective turns than those corresponding to the principal tapping

4.5.8**tapping range**

the total tapping range of a tapped winding consists of the plus and minus tapping ranges, which are the differences between its highest and lowest tapping voltages, on the one hand, and its rated voltage on the other hand, usually expressed as a plus and a minus percentage of that rated voltage

4.5.9**tapping current**

the maximum permissible current through a line terminal of a tapped winding when connected on the tapping concerned

4.5.10**voltage variation range**

the range of the variable (no-load) voltages at the line terminals of a tapped or an untapped winding

4.6 Losses and no-load current**4.6.1****no-load loss**

the active power absorbed when rated voltage at rated frequency is applied to the terminals of one of the windings, the other winding(s) being open-circuited

4.6.2**no-load current**

the current flowing through a line terminal of a winding when rated voltage is applied at rated frequency, the other winding(s) being open-circuited

NOTE 1 The no-load current of a winding is often expressed as a percentage of the rated current of the same winding. For multi-winding transformers this percentage is referred to the winding with the highest rated power.

NOTE 2 For polyphase transformers the no-load currents through the different line terminals may be unequal. If, in this case, the values of the different no-load currents are not given separately the no-load current is assumed to be the arithmetic mean value of these currents.

4.6.3**load loss**

this is defined as:

- a) *Of two-winding transformers*, the active power absorbed at rated frequency when rated current is flowing through the line terminal(s) of one of the windings, the terminals of the other winding being short-circuited. The value is related to the reference temperature shown in Table 15.
- b) *Of multi-winding transformers, related to a certain combination of two windings*, the active power absorbed at rated frequency when a current flows through the line terminal(s) of one of the windings of the combination, corresponding to the smaller of the rated power values of both windings of that combination, the terminals of the other winding of the combination being short-circuited and the remaining winding(s) being open-circuited. The various values for the different combinations are related to the reference temperature shown in Table 15.

4.6.4**total losses**

the sum of the no-load loss and the load loss

NOTE 1 For multi-winding transformers the total losses refer to a specified loading combination.

NOTE 2 The losses in auxiliary plant are not included in the total losses. They should be stated separately.

4.7 Impedance voltage and voltage drop**4.7.1****impedance voltage at rated current**

this is defined as:

- a) *Of two-winding transformers*, the voltage required to be applied at rated frequency to the line terminals of a winding of a polyphase transformer or to the terminals of a winding of a single-phase transformer to cause the rated current to flow through these terminals when the terminals of the other winding are short-circuited. The value is related to the reference temperature shown in Table 15.

b) *Of multi-winding transformers, related to a certain combination of two windings*, the voltage required to be applied at rated frequency to the line terminals of one of the windings of the combination for a polyphase transformer or to the terminals of such a winding for a single-phase transformer to cause a current to flow through these terminals corresponding to the smaller of the rated power values of both windings of that combination, the terminals of the other winding of the combination being short-circuited and the remaining winding(s) being open-circuited. The various values for the different combinations are related to the reference temperature shown in Table 15.

NOTE 1 [Applicable to both a) and b).] The rated impedance voltage is usually expressed as a percentage of the rated voltage of the winding to which the voltage is applied.

NOTE 2 [Applicable to b) only.] In order to simplify certain calculations it may be convenient to recalculate the impedance voltages of the various combinations in terms of the same rated power.

NOTE 3 Where in this standard the expression "impedance voltage" is used in a general sense, it means a quantity similar to the impedance voltage at rated current but possibly related to other values of current and/or to connections to tapings other than the principal tapping.

4.7.2

resistance voltage

the component of an impedance voltage in phase with the current

NOTE See Note 3 to 4.7.1.

4.7.3

reactance voltage

the component of an impedance voltage in quadrature with the current

NOTE See Note 3 to 4.7.1.

4.7.4

voltage drop (or rise) (regulation) for a specified load condition

the difference between the rated voltage of a winding and the voltage developed at a specified load and power factor, the voltage supplied to (one of) the other winding(s) being at its rated value. It is generally expressed as a percentage of the rated voltage of the former winding

NOTE For multi-winding transformers the voltage drop (or rise) depends not only on the load and power factor of the winding itself but also on the load and power factor of the other windings.

4.7.5

zero-sequence impedance

the impedance, expressed in ohms per phase at rated frequency, between the line terminals of a polyphase star or zigzag-connected winding connected together and its neutral terminal

NOTE 1 The zero-sequence impedance may have several values, because it depends not only on the method of connection of the winding itself but also on the way in which the other windings and their terminals are connected.

NOTE 2 The zero-sequence impedance is often dependent on the value of the current.

4.8 Temperature rise

4.8.1

temperature rise

the difference between the temperature of the part under consideration and, for air-cooled transformers, the temperature of the cooling air; for water-cooled transformers, the temperature of the water at the intake of the cooling equipment

4.9 Insulation

4.9.1

insulation level

that combination of voltage values (both power-frequency and impulse) which characterizes the insulation of each of the windings and their associated parts with regard to capability of withstanding dielectric stresses

NOTE The insulation level is generally expressed by the value of both the power-frequency test voltage and the full-wave impulse test voltage, but for windings not designed for impulse testing it is expressed by the power-frequency test voltage only.

4.9.2

uniformly-insulated winding

a winding in which the insulation to earth is at all points designed to withstand the separate-source power-frequency test voltage appropriate to the line end

4.9.3

graded-insulated winding

a winding in which the insulation to earth is graded from the amount at the line end to a smaller amount at the neutral end

NOTE Such a winding therefore will withstand a separate-source power-frequency test voltage of a value appropriate only to the insulation level of the neutral end.

4.9.4

exposed installation

an installation in which the transformer is exposed to overvoltages of atmospheric origin

NOTE Such installations are usually connected to overhead transmissions lines, either directly or through a short length of cable.

4.9.5

non-exposed installation

an installation in which the transformer is not exposed to overvoltages of atmospheric origin

NOTE Such installations are usually connected to cable networks.

4.9.6

system nominal voltage

the r.m.s. line-to-line voltage by which a system is designated

NOTE This voltage is not necessarily the same as the rated voltage of the winding of the transformer connected to the system.

4.9.7

system highest voltage

the highest r.m.s. line-to-line voltage that can be maintained under normal operating conditions at any time and at any point on the system

NOTE 1 It excludes temporary voltage variations due to fault conditions or the sudden disconnection of large loads.

NOTE 2 The open-circuit voltage of certain tapplings may exceed the system highest voltage. See Appendix B.

4.10 Connections

4.10.1

star connection

the winding connection so arranged that one end of each of the phase-windings of a polyphase transformer or of each of the windings for the same rated voltage of single-phase transformers associated in a polyphase bank is connected to a common point (the neutral point) and the other end to its appropriate line terminal

4.10.2

delta connection

the winding connection so arranged that the phase-windings of a 3-phase transformer or the windings for the same rated voltage of single-phase transformers associated in a 3-phase bank are connected in series to form a closed-circuit

4.10.3

open-delta connection

the winding connection in which the phase-windings of a 3-phase transformer or the windings for the same rated voltage of single-phase transformers associated in a 3-phase bank are connected in series without closing one corner of the delta

4.10.4

zigzag or interconnected-star connection

the winding connection in star of the phase-windings of a polyphase transformer, each one of which is made up of parts in which phase-displaced voltages are induced

4.10.5

open windings

phase-windings of a polyphase transformer which are not interconnected within the transformer

NOTE The terminal arrangement frequently used on generator transformers where all phase ends are brought out through terminals and appropriate terminals are then linked to form a closed-circuit is deemed to be a delta connection, as defined in 4.10.2.

4.10.6**phase displacement**

the angular difference between the vectors representing the voltages between the neutral point (real or imaginary) and the corresponding terminals of two windings, a positive-sequence voltage system being applied to the high-voltage terminals following each other in alphabetical sequence if they are lettered or in numerical sequence if they are numbered. The vectors are assumed to rotate in a counter-clockwise sense the phase displacement is expressed as the hour number, shown on a clock whose large (minute) hand is pointing at 12 and coincides with the vector of the voltage between the neutral point (real or imaginary) and the high-voltage line terminal, and whose small (hour) hand coincides with the vector of the voltage between the neutral point (real or imaginary) and the corresponding low-voltage or intermediate voltage terminal

4.10.7**vector-group symbol**

a conventional notation indicating the respective connections of the high-voltage, intermediate voltage (if any) and low-voltage windings and their relative phase displacement(s) expressed as clock-hour figure(s)

4.11 Kinds of tests**4.11.1****acceptance tests**

those tests which demonstrate to the satisfaction of the purchaser that the transformer complies with the specification

4.11.2**routine test**

a test to which each individual transformer is subjected

4.11.3**type test**

a test made on a transformer which is representative of other transformers, to demonstrate that these transformers comply with specified requirements not covered by routine tests

NOTE A transformer is considered to be representative of others if it is fully identical in rating and construction, but the type test is also considered valid if it is made on a transformer which has minor deviations of rating or other characteristics. If the test is an acceptance test, these deviations should be subject to agreement between the manufacturer and the purchaser.

4.11.4**special test**

a test other than a type test or a routine test, agreed by the manufacturer and the purchaser and applicable only to one or more transformers of a particular contract

Section 3. Rating**5 General**

The manufacturer shall ascribe ratings to the transformer which shall be marked on the rating plate (see Section 9). These ratings shall be such that the transformer can deliver its rated current under steady loading conditions without exceeding the limits of temperature rise specified in Section 6, assuming that the applied voltage is equal to the rated voltage and that the supply is at rated frequency.

6 Rated power

The rated power so assigned shall take into account service conditions corresponding to those specified in Section 1 and shall be related to the product of rated voltage, rated current and the appropriate phase factor given in Table 1.

Table 1 — Phase factors

Number of phases	Phase factor
1	1
2	$\frac{2}{\sqrt{3}}$
3	$\sqrt{3}$

NOTE 1 The rated power assigned here corresponds to continuous duty. Conditions for other duties should be the subject of an agreement between the manufacturer and the purchaser.

NOTE 2 Although the rating is related to the rated voltage the transformer should be capable of delivering its rated current at an applied voltage 5 % higher than the rated voltage.

7 Preferred values of rated power

Preferred values of rated power for 3-phase transformers are listed in Table 2, but compliance with this British Standard does not require the adoption of only the values given in that table. The values should, however, be adopted whenever possible. They are in the R10 series given in BS 2045⁶⁾.

Table 2 — Preferred values of rated power for 3-phase transformers

kVA	kVA	kVA
5	31.5	200
6.3	40	250
8	50	315
10	63	400
12.5	80	500
16	100	630
20	125	800
25	160	1 000, etc.

Section 4. Tappings

NOTE 1 In specifications and on rating plates only no-load voltages should be mentioned. The purchaser when drafting his enquiry may derive these no-load values from voltages on load by a rough estimation of the voltage drop (or rise), which can be checked afterwards when exact values of this drop (or rise) are known.

NOTE 2 The asterisk (*) added to "voltage" in this section and in Appendix F means that for a voltage not applied to, but developed at, the terminals no-load condition is implied.

NOTE 3 In Clauses 11–14 of this section only the case (the most common in practice) of transformers which have only one winding provided with voltage variation tappings is envisaged.

8 General

Transformers are not provided with tappings unless specifically required. When tappings are required it shall be stated if they are intended for off-circuit or for on-load tap-changing.

9 Off-circuit tappings

If off-circuit tap-changing is specified but the tapping range and the step voltages are not stated, standard values of ± 5 % for the tapping range and of 2.5 % for the step voltages are assumed.

10 Principal tapping

Unless otherwise specified, the principal tapping (see 4.5.1) is taken to correspond with the mean tapping position if the number of tapping positions is odd or, if this number is even, that one of the two middle tapping positions which is associated with the higher number of effective turns on the tapped winding.

⁶⁾ BS 2045, "Preferred numbers".

11 Categories of voltage variation

With respect to the influence of voltage variation on several characteristics of a transformer having tappings inserted in only one winding, three categories of voltage variation should be distinguished:

- a) *Constant-flux voltage variation* (C.F.V.V.). Voltage⁷⁾ substantially constant at the untapped winding(s) and variable at the tapped winding. This type of voltage variation is associated with a constant voltage⁷⁾ per turn and, consequently, with a constant magnetic flux (at no-load).
- b) *Variable-flux voltage variation* (V.F.V.V.). Voltage⁷⁾ substantially constant at the tapped winding and variable at the untapped winding(s). This type of voltage variation is associated with a variable voltage⁷⁾ per turn and, consequently, with a variable magnetic flux (at no-load).
- c) *Mixed voltage variation* (M.V.V.). Voltage⁷⁾ variable at the tapped winding and at the untapped winding(s). For a given constant value of the voltage⁷⁾ at the untapped winding(s), the voltage variation is associated with a constant magnetic flux (at no-load) but, when passing from this value to another one, with a variable magnetic flux (at no-load).

NOTE 1 The purchaser should specify which category of voltage variation is wanted. If nothing is specified the manufacturer chooses a certain category. The category of voltage variation applied should be clearly indicated, using the symbols C.F.V.V., V.F.V.V. or M.V.V. given above. If nothing is indicated category C.F.V.V. is assumed to be applied.

NOTE 2 For transformers of category C.F.V.V. a variation of the magnetic flux (at no-load) up to 5 % is permissible. If this value is not exceeded the regulation is considered to be C.F.V.V.

NOTE 3 If a transformer, designed under one category, should be used under another category, certain operating limitations should be recognized. If a transformer is destined for service conditions according to more than one category it should be designed to meet the most onerous conditions of magnetic flux and load current.

NOTE 4 For examples of specifying transformers for the different categories of voltage variation, see Appendix F.

12 Specification of voltage conditions

If a tapped or untapped winding is to be designed for a variable voltage⁷⁾, the voltage variation range (see 4.5.10) shall be specified.

The voltage variation range of a winding is indicated either by showing its rated voltage, followed by the extreme plus and minus voltage⁷⁾ variations expressed as percentages of that rated voltage, or by showing, in a decreasing order, the values of its extreme voltages⁷⁾ and of its rated voltage.

NOTE 1 Certain intermediate values of voltages required by the purchaser may be incompatible with the design. In this case the manufacturer should provide the purchaser with information on the values which can be obtained in practice.

NOTE 2 Percentages are indicated as follows:

if the range contains equal plus and minus components (e.g. a %), by: $\pm a$ %;

if the components are unequal (e.g. $+a$ % and $-b$ %), by: $+a$ % $-b$ %;

if there is only a plus or only a minus component (e.g. only $+a$ % or only $-b$ %), by: $+a$ % or by $-b$ % respectively

It should be quite clearly indicated which of the values is related to the rated voltage (e.g. by underlining this value).

In the case of untapped windings, all values, whether of percentages or voltages, should be put between parentheses (round brackets), values of rated voltages excepted.

For category M.V.V. it is advisable to specify those combinations of the variable voltages⁷⁾ that are required simultaneously in both the tapped and the untapped windings, which determine the extreme values of the ratio. If these combinations are not specified it is to be assumed that the extreme values of the voltage ratio should cover all the combinations of voltages up to the opposite limits of the voltage variation ranges of the windings.

13 Tapping range

The tapping range (see 4.5.8) to be provided for the tapped winding is determined by the specified voltage variation range(s) (and if necessary by the limits of combinations of variable voltages⁷⁾ as mentioned in Clause 12).

The tapping range is usually made up of a number of step voltages (see 4.5.5).

The number of tapping positions required should be mentioned in the specification.

⁷⁾ See Note 2 at the beginning of this section.

For the different categories of voltage variation the relation between the tapping range to be provided and the voltage variation range(s) required is as follows:

C.F.V.V. The tapping range is identical with the voltage variation range, because both are related to the tapped winding.

V.F.V.V. The tapping range (of the tapped winding) is not identical with the voltage variation range or ranges (of the untapped winding or windings), but can be derived directly from them (see **F.2**).

M.V.V. The tapping range (of the tapped winding) is not identical with the voltage variation ranges (of the tapped and untapped windings), but can be derived from the extreme value of the ratio required, determined according to Clause **12** (see **F.3**).

NOTE 1 Certain modifications of the voltage variation range(s) may be desirable in order to obtain a tapping range compatible with an appropriate design. Such modifications are subject to agreement between the manufacturer and the purchaser. (See **F.2.1**.)

NOTE 2 For categories V.F.V.V. and M.V.V., where the tapping range is not identical with the voltage variation range(s), it is recommended that only the voltage variation range(s) be mentioned in a specification or on a rating plate. The addition of tapping voltages, which generally do not correspond to actual voltages, or of the tapping range may give rise to confusion. For category M.V.V., however, more explicit information as mentioned in Appendix F is required.

14 Tapping quantities

14.1 Temperature rise. It is recognized that the transformer may not completely meet the relevant temperature rise limits at full rated power when connected on certain tapplings other than the principal tapping. Unless otherwise specified this condition is assumed to be satisfactory with a tapping range not exceeding $\pm 5\%$, but if this range exceeds this value the tapping power of the transformer relative to connection on certain tapplings other than the principal tapping shall be specified.

14.2 Tapping power. The value of the tapping power (for both tapped and untapped windings) related to the connection of the tapped winding on a certain tapping is valid for the following appropriate voltages (see **4.5.3**).

C.F.V.V. Rated voltage at the untapped winding(s), and the tapping voltage of the tapping concerned at the tapped winding.

V.F.V.V. Rated voltage at the tapped winding, and the variable voltage⁸⁾ at the untapped winding(s), specified for the tapping connection concerned.

M.V.V. The combination of the variable voltages⁸⁾ at the terminals of the windings, specified for the tapping connection concerned.

NOTE For the various combinations of voltages⁸⁾ specified for the same tapping connection different values for the tapping power may be specified (see Appendix F).

14.3 Currents. The values of the currents through the line terminals of tapped and untapped windings, relative to a certain tapping connection, are always derived from the values of the corresponding tapping power of the transformer by dividing by the appropriate voltage⁸⁾ relative to the winding concerned (see **14.2**) and by an appropriate phase factor (see Table 1).

14.4 Load loss and impedance voltage. If the tapping range exceeds $\pm 5\%$, it shall be subject to agreement between the manufacturer and the purchaser for which tapping connections, in addition to that on the principal tapping, values for load loss and impedance voltage should be stated by the manufacturer, and what tolerances should be applied.

The value of the current for which such quantities are valid and the base for the percentage value of the impedance voltage should be clearly stated.

14.5 No-load loss. For categories V.F.V.V. and M.V.V. it shall be subject to agreement between the manufacturer and the purchaser for which tapping connections and corresponding voltages, in addition to those on the principal tapping, and values for no-load loss should be stated by the manufacturer, and what tolerances should be applied.

14.6 Auto-transformers and booster transformers. For auto-transformers and booster transformers with tapped windings, the specification of values for load losses and impedance voltages and, as far as categories V.F.V.V. or M.V.V. are implied, for no-load losses, and of the tolerances to be applied, shall always be subject to agreement between the manufacturer and the purchaser, independent of the voltage variation range.

⁸⁾ See Note 2 at the beginning of this section.

Section 5. Identification according to cooling method

15 Identification symbols

Transformers shall be identified according to the cooling method employed. Letter symbols for use in connection with each cooling method shall be as given in Table 3.

Table 3 — Letter symbols

Kind of cooling medium	Symbol
Mineral oil	O
Synthetic insulating liquid	L
Gas	G
Water	W
Air	A
Solid insulant	S
Kind of circulation	
Natural	N
Forced	F

16 Arrangement of symbols

With the exception of dry-type transformers in protective enclosures, for which the symbols shall be “AN” or “AF” as appropriate, transformers shall be identified by four symbols for each cooling method for which a rating is assigned by the manufacturer. An oblique stroke shall be used to separate each group of symbols. The order in which the symbols are used shall be as given in Table 4.

Table 4 — Order of symbols

1st letter	2nd letter	3rd letter	4th letter
Indicating the cooling medium that is in contact with the windings		Indicating the cooling medium that is in contact with the external cooling system	
Kind of medium	Kind of circulation	Kind of medium	Kind of circulation

For example, an oil-immersed transformer with forced oil and air circulation would be designated “OFAF”, whereas a dry-type transformer with cooling fans would be designated “AF”. For oil-immersed transformers in which the alternatives of natural or forced cooling are possible, typical designations are:

ONAN/ONAF

ONAN/OFAF

NOTE The identification system specified in Clauses 15 and 16 differs somewhat from that specified in BS 17:1959. The following examples show some equivalent designations in accordance with the two editions of the British Standard.

BS 171:1970: designation, OFAF AF ONAN/ONAF ONAN/OFAF OFWF

BS 172:1959: designation, OFB AB ON/OB ON/OFB OFW

Section 6. Limits of temperature rise

17 Temperature rise limits

The temperature rises of the windings, cores and oil of transformers designed for operation at altitudes not exceeding those given in 2 a) and with cooling medium temperatures as described in 2 b) shall not exceed the limits specified in Table 5 and Table 6, when tested in accordance with Clause 41.

For multi-winding transformers the temperature rise of the top oil refers to the specified loading combination for which the total losses are highest. Individual winding temperature rises shall be considered relative to that specified loading combination which is the most severe for the particular winding under consideration.

Table 5 — Temperature rise limits for dry-type transformers

1	2	3	4
Part	Cooling method	Temperature class	Temperature rise
Windings (measured by resistance)	Air, natural or forced	A E B F H C	degC 60 75 80 100 125 150 ^a
Cores and other parts ^b : a) adjacent to windings b) not adjacent to windings	All	—	a) Same values as for windings ^c b) a value that will not adversely affect insulating parts that may be in contact with the windings

NOTE Insulating materials may be used separately or in combination, provided that in any application each material will not be subjected to a temperature in excess of that for which it is suitable, if operated under rated conditions. Six of the temperature classes listed in BS 2757, “Classification of insulating materials for electrical machinery and apparatus on the basis of thermal stability in service”, are recognized for dry-type transformers. These are A, E, B, F, H and C.

^a For certain insulating materials temperature rises in excess of 150 degC may be adopted by agreement between the manufacturer and the purchaser.

^b Surface temperature measured by thermometer, thermocouple or other agreed means.

^c This means the same temperature as adjacent winding.

Table 6 — Temperature rise limits for oil-immersed type transformers

1	2	3	4
Part	Cooling method	Oil circulation	Temperature rise
Windings — temperature Class A (measured by resistance)	Natural air Forced air Water (internal coolers)	Natural	degC 65
	Forced air Water (external coolers)	Forced	65
Top oil (measured by thermometer)	—	—	60, when the transformer is sealed or equipped with a conservator 55, when the transformer is not so sealed or equipped
Cores and other parts	—	—	The temperature in no case to reach a value that will injure the core itself or adjacent materials

18 Reduced temperature rises for transformers designed for high cooling medium temperatures

If the transformer is designed for service where the temperature of the cooling medium exceeds one of the maximum values shown in 2 b) by not more than 10 degC, the allowable temperature rises for the windings, cores and oil shall be reduced:

by 5 degC if the excess temperature is less than or equal to 5 degC;

by 10 degC if the excess temperature is greater than 5 degC and less than or equal to 10 degC.

19 Reduced temperature rises for transformers designed for high altitudes

For air-cooled transformers designed for operation at an altitude greater than 1 000 m (3 300 ft) but tested at normal altitudes, the limits of temperature rise given in Table 5 and Table 6 are reduced by the following amounts for each 500 m (1 650 ft) by which the intended working altitude exceeds 1 000 m (3 300 ft):

oil-immersed, natural-air-cooled transformers	2.0 %
dry-type, natural-air-cooled transformers	2.5 %
oil-immersed, forced-air-cooled transformers	3.0 %
dry-type, forced-air-cooled transformers	5.0 %

NOTE 1 These reductions in temperature rise limits are not applicable to water-cooled transformers.

NOTE 2 An additional or modified rating plate is required, see Clause 31.

NOTE 3 Selection of a transformer with standard rating and temperature rise limits in accordance with Table 6, for operation in accordance with CP 1010, "Guide to loading of oil-immersed transformers to BS 171", is preferable to the selection of a transformer with a special rating. The 1959 edition of CP 1010 will be revised in conformity with the Loading Guide soon to be published by the IEC.

Section 7. Insulation levels

20 General

The insulation levels for dry-type transformers⁹⁾ and, in oil-immersed type transformers, those of the windings and connected parts which are not designed for impulse-voltage testing, shall be those given in Table 7. For oil-immersed type transformers the insulation levels of windings and connected parts which are designed for impulse-voltage testing shall be those given in Table 8. (See Appendix B.)

NOTE For transformers with a high-voltage winding tested according to Table 8 and a low-voltage winding rated at 1.1 kV or less, the appropriate test voltage for the low-voltage winding is selected from Table 7.

Table 7 — Insulation levels for windings and connected parts not designed for impulse-voltage tests

System highest voltage	Insulation level (power-frequency test voltage)
kV r.m.s.	kV r.m.s.
Less than 1.1	2.5
1.1	3
3.6	8
7.2	15
12	25
17.5	36

⁹⁾ Impulse-voltage tests are not as yet specified for dry-type transformers. Such transformers are not intended for use in exposed installations. (See B.4.)

Table 8 — Insulation levels for windings and connected parts designed for impulse-voltage tests

Series I (based on current practice other than in North America)

System highest voltage	Insulation level			
	Impulse test voltage		Power-frequency test voltage	
	Standard 1	Standard 2	Standard 2	Standard 2
kV r.m.s.	kV peak		kV r.m.s.	
3.6	45		16	
7.2	60		22	
12	75		28	
17.5	95		38	
24	125		50	
36	170		70	
52	250		95	
72.5	325		140	
100	450	380	185	150
123	550	450	230	185
145	650	550	275	230
170	750	650	325	275
245	1 050	900	460	395
300	—	1 050	—	460
362	—	1 175	—	510
420	—	1 425	—	630

Series II (based on current practice in North America)

System highest voltage	Insulation level		
	Impulse test voltage		Power-frequency test voltage
kV r.m.s.	kV peak		kV r.m.s.
	500 kVA and below	Above 500 kVA	
2.75	45	60	15
5.5	60	75	19
9.52	75	95	26
15.5	95	110	34
25.8		150	50
38.0		200	70
48.3		250	95
72.5		350	140
Above 72.5 the values of Series I are applicable			

NOTE 1 Values for Series II are applicable only to the internal insulation of oil-immersed transformers.

NOTE 2 With reference to Series II, single-phase transformers for system highest voltages between terminals of 9.52 kV and below are designed for both star and delta connection and are insulated for the test voltage corresponding to the star connection. The test voltages for such transformers when operated delta-connected are therefore one step higher than needed for their system highest voltage.