BRITISH STANDARD

BS EN
60726:2003

Dry-type power transformers

The European Standard EN 60726:2003 has the status of a British Standard

ICS 29.180

National foreword

This British Standard is the official English language version of EN 60726:2003. It was derived by CENELEC from IEC 60726:1982. It supersedes BS 7806:1995 which is withdrawn.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by common modification tags 〚C〉 〈C〛.

The UK participation in its preparation was entrusted to Technical Committee PEL/14, Power transformers, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

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EUROPEAN STANDARD **EN 60726**

NORME EUROPÉENNE

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English version

Dry-type power transformers
(IEC 60726:1982 + A1:1986, modified)

Transformateurs de puissance
de type sec
(CEI 60726:1982 + A1:1986, modifiée)

Trockentransformatoren
(IEC 60726:1982 + A1:1986, modifiziert)

This European Standard was approved by CENELEC on 2002-11-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 60726:2003 E

Foreword

The text of the International Standard IEC 60726:1982 and its amendment 1:1986, prepared by IEC TC 14, Power transformers, together with the common modifications prepared by the Technical Committee CENELEC TC 14, Power transformers, was approved by CENELEC as HD 464 S1 on 1988-06-28.

This Harmonization Document, together with its amendments A1 to A5, was submitted to a formal vote for conversion into a European Standard and was approved by CENELEC as EN 60726 on 2002-11-01and was approved by CENELEC as EN 60726 on 2002-11-01.

This European Standard supersedes HD 464 S1:1988 + A2:1991 + A3:1992 + A4:1995 + A5:2002.

As soon as IEC 60076-11 is endorsed by CENELEC this document will be withdrawn.

The common modifications indicated in this document correspond to those included in HD 464 S1:1988 with additional minor modifications.

The reference of clauses, subclauses, notes, figures and annexes which are in addition to those in IEC 60726 is prefixed with the letter Z.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2003-11-01
- latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	-

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, Annexes A, B, ZA, ZB, ZC and ZE are normative and Annex ZD is informative.
Annexes ZA, ZB, ZC, ZD and ZE have been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60726:1982 and its amendment 1:1986 was approved by CENELEC as a European Standard with agreed common modifications.

CONTENTS

DRY-TYPE POWER TRANSFORMERS

SECTION ONE — GENERAL

1. Scope

This standard applies to dry-type power transformers (including auto-transformers) having values of highest voltage for equipment up to and including 36 kV.

The following small and special dry-type transformers are not covered by this standard:

— single-phase transformers rated at less than 1 kVA and polyphase transformers rated at less than 5 kVA;

[C] — transformers having no windings with rated voltage U_r higher than 1 000 V; [C]

— instrument transformers (covered by IEC Publications 185: Current Transformers, and 186: Voltage Transformers);

— transformers for static convertors (covered by IEC Publications 84: Recommendations for Mercury-arc Convertors, 119: Recommendations for Polycrystalline Semiconductor Rectifier Stacks and Equipment, and 146: Semiconductor Convertors);

— starting transformers;

— testing transformers;

— traction transformers mounted on rolling stock;

— flameproof and mining transformers;

— welding transformers;

— voltage regulating transformers;

— small power transformers in which safety is a special consideration.

[C] NOTE Where IEC standards do not exist for the transformers mentioned above or for other special transformers, this standard may be applicable as a whole or in parts. [C]

With the publication of this standard, the requirements of IEC Publication 76 apply to dry-type transformers only in so far as they are referred to in this standard.

Where reference is made to specific clauses and sub-clauses of various parts of IEC Publication 76, it is to be understood that the editions are as follows:

76-1, 76-2, 76-4, 76-5: 1976.
76-3: 1980.

2. Service conditions

2.1 *Normal service conditions*

This 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 feet).

Note. — For greater altitudes, see Sub-clause 2.2.

b) Temperature of cooling air:

Never exceeding 40 °C and never below:

−25 °C in the case of outdoor transformers;

−5 °C in the case of indoor transformers.

[C] NOTE Both outdoor and indoor dry-type transformers are suitable for transport and storage at ambient temperatures down to −25 °C. [C]

In addition, an ambient air temperature never exceeding the following values:

30 °C average in any one day;

20 °C average in any one year.

Note. — For higher temperatures, see Sub-clause 2.2.

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.

2.2 *Provision for unusual service conditions*

The purchaser shall specify in his enquiry any service conditions not covered by the normal service conditions in Sub-clause 2.1 (see Appendix B).

Supplementary requirements, within defined limits, for the rating and testing of transformers designed for other than normal service conditions listed in Sub-clause 2.1, such as high temperature of cooling air or altitude above 1 000 m (3 300 feet) are given in Sub-clauses 10.2, 10.3 and 11.2.

For temperature conditions outside the limits covered by the supplementary requirements and special operating conditions, for example restricted cooling air circulation, the temperature rise is to be subject to agreement between the manufacturer and the purchaser.

3. Definitions

For the purpose of this standard, the following definitions apply. Other terms used have the meanings ascribed to them in I E C Publications 76-1: Power Transformers, Part 1: General, or 50: International Electrotechnical Vocabulary (I.E.V.).

3.1 *Dry-type transformer*

A transformer in which the core and windings are not immersed in an insulating liquid.

Note. — The cooling of a dry-type transformer may be natural, natural/forced or forced circulation (see Clause 9).

3.1.1 *Encapsulated-winding dry-type transformer*

A dry-type transformer having one or more windings encapsulated with solid insulation.

3.1.2 *Non-encapsulated-winding dry-type transformer*

A dry-type transformer having none of the windings encapsulated with solid insulation.

3.2 *Terms relating to the containment of a dry-type transformer*

3.2.1 *Sealed dry-type transformer*

An air or gas-immersed dry-type transformer within a sealed protective enclosure so constructed that there can be no interchange between its contents and the external atmosphere, i.e. the transformer is non-breathing.

Note. — The gas in a gas-immersed transformer remains in a gaseous state throughout the range of transformer operations.

3.2.2 *Totally enclosed dry-type transformer*

An air immersed dry-type transformer within a protective enclosure so constructed that the ambient air does not circulate to cool the core and windings, but which can breathe to atmosphere.

3.2.3 *Enclosed dry-type transformer*

A dry-type transformer within a protective enclosure so constructed that the ambient air may circulate so as to cool the core and windings directly.

3.2.4 *Non-enclosed dry-type transformer*

A dry-type transformer without a protective enclosure in which the core and windings are cooled by ambient air.

4. Tappings

As in Section One of IEC Publication 76-4: Power Transformers, Part 4: Tappings and Connections, but where tappings are required the preferred tapping range is ±5% in 2.5% steps, i.e. ±2.5%, ±5%, by means of off-circuit [C〉 links to tap-selectors. 〈C]

5. Connections

See Section Two of IEC Publication 76-4.

6. Ability to withstand short circuit

IEC Publication 76-5: Power Transformers, Part 5: Ability to Withstand Short Circuit, applies to the transformers covered by this standard.

SECTION TWO — RATING

7. Rating

7.1 *General*

The manufacturer shall assign ratings to the transformer, which shall be marked on the rating plate (see Clause 8). 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 Three, assuming that the applied voltage is equal to the rated voltage and that the supply is at rated frequency.

7.2 *Rated power*

The rated power shall take into account service conditions corresponding to those specified in Clause 2 and shall be related to the product of rated voltage, rated current and the appropriate phase factor given in Table I.

TABLE I

Phase factors

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

The rated power corresponds to continuous duty; nevertheless, dry-type transformers complying with this standard can be overloaded and guidance on overloads will be given in a future supplement to this standard.

7.3 *Preferred values of rated power*

As Sub-clause 4.3 of IEC Publication 76-1.

7.4 *Operation at higher than rated voltage*

As Sub-clause 4.4 of IEC Publication 76-1.

8. Rating plates

Each transformer shall be provided with a rating plate of weatherproof material, fitted in a visible position, showing the items indicated below. The entries on the plate shall be indelibly marked (i.e. by etching, engraving or stamping).

a) Kind of transformer (see definitions given in Clause 3).

b) Number and year of this standard.

c) Manufacturer's name.

d) Manufacturer's serial number.

e) Year of manufacture.

f) Insulation system temperature and maximum permissible temperature rise for all windings, or for each individual winding, if applicable (see Sub-clause 10.1).

g) Number of phases.

h) Rated power for each kind of cooling.

i) Rated frequency.

j) Rated voltages, including tapping voltages, if any.

k) Rated currents for each kind of cooling.

l) Connection symbol.

m) Impedance voltage at rated current determined according to Sub-clause 8.4 of IEC Publication 76-1.

n) Type of cooling.

o) Type of filling.

p) Operating pressure range.

q) Maximum and minimum absolute pressures for which the enclosure is designed

r) Pressure and temperature of filling medium at the time of sealing.

} applicable only to sealed units.

s) Total mass.

t) Insulation levels.

(The rated withstand voltages for all windings shall appear on the rating plate. The principles of the standard notation are illustrated in Clause 3 of IEC Publication 76-3: Power Transformers, Part 3: Insulation Levels and Dielectric Tests.)

[C] za) Degree or degrees of protection IP in accordance with IEC 60529 when an enclosure is provided.

zb) Statements of environmental, climatic and fire behaviour classes (see Annex B) to which the complete transformer complies, as follows: EX - CX - FX according to Table B.Z1. [C]

SECTION THREE — COOLING METHODS AND TEMPERATURE RISE

9. Identification according to cooling method

9.1 *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 II.

TABLE II

Letter symbols

Kind of cooling medium	Symbol
Air	A
Gas	G
Kind of circulation	
Natural	N
Forced	F

9.2 *Arrangement of symbols*

Transformers without protective enclosures or within enclosures through which the cooling air can circulate are identified by two symbols only for the cooling medium (air) which is in contact with the windings or the surface coating of the windings.

All other transformers shall be identified by four symbols for each cooling method for which a rating is assigned by the manufacturer.

The order in which the symbols are used shall be as given in Table III. Oblique strokes shall be used to separate the group of symbols for different cooling methods for the same piece of equipment.

TABLE III

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 cooling medium	Kind of circulation	Kind of cooling medium	Kind of circulation

For example, the cooling method of a transformer without a protective enclosure or within an enclosure through which the cooling air can circulate and with natural air cooling is designated by:

AN

For a transformer within a protective enclosure through which the cooling air cannot circulate, with natural air cooling inside and outside the enclosure, the designation is:

ANAN

For a transformer in a sealed enclosure with natural nitrogen cooling inside and alternatives of natural or forced air cooling outside the enclosure, the designation is:

GNAN/GNAF

10. Temperature-rise limits

10.1 *Normal temperature-rise limits*

The temperature rises of the windings, core and metal parts of transformers designed for operation at altitudes not exceeding those given in Item *a)* of Sub-clause 2.1 and with external cooling air temperature as described in Item *b)* of Sub-clause 2.1 shall not exceed the limits specified in Table IV when tested in accordance with Clause 21.

The hot spot temperatures given in column 2 are approved for the winding temperature rises specified in column 3 only when used in the insulation of apparatus within the scope of this standard.

Insulating materials may be used separately or in a combination providing that, in any application, each system will not be continuously subjected to a temperature in excess of that for which it is suitable when operating under rated conditions.

Furthermore, the electrical and mechanical properties of the insulated winding must not be impaired by the application of the hot-spot temperature permitted for the specific insulation system.

Note. — In column 2 of Table IV the letters refer to temperature classifications given in IEC Publication 85: Recommendations for the Classification of Materials for the Insulation of Electrical Machinery and Apparatus in Relation to Their Thermal Stability in Service.

TABLE IV

Temperature-rise limits

1	2	3
Part	Insulation system temperature (°C)	Maximum temperature rise (K)
Windings (temperature rise measured by the resistance method)	105 (A) 120 (E) 130 (B) 155 (F) 180 (H) Ⓒ 200 220	60 75 80 100 125 135 150 Ⓒ
Core, metallic parts and adjacent materials		The temperature shall, in no case, reach a value that will damage the core itself, other parts or adjacent materials

10.2 *Reduced temperature rises for transformers designed for high cooling air temperatures or special air cooling conditions*

If the transformer is designed for service where the temperature of the cooling air exceeds one of the maximum values specified in Item *b)* of Sub-clause 2.1 by no more than 10 K, the allowable temperature rises for the windings shall be reduced:

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

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

Where the excess temperature exceeds one of the values specified in Item *b)* of Sub-clause 2.1 by more than 10 K, the allowable temperature rises require an agreement between the manufacturer and the purchaser.

Any site conditions which may either impose restrictions on the cooling air or produce high ambient air temperatures should be stated by the purchaser.

Ⓒ NOTE When a transformer has windings of different insulation system temperatures, the reference temperature relating to the winding having the higher insulation system temperature shall be used.

For some applications, a lower maximum temperature rise may be chosen from values given in column 3 of Table IV.

Reference temperatures for load loss and short-circuit impedance should be in accordance with the newly assigned temperature rises (e.g. it should be possible to specify an unit belonging to class F having a maximum temperature rise of 80 K instead of 100 K). Ⓒ

10.3 *Reduced temperature rises for transformers designed for high altitudes*

Unless otherwise agreed between the manufacturer and the purchaser, for transformers designed for operation at an altitude greater than 1 000 m but tested at normal altitudes, the limits of temperature rise given in Table IV are reduced by the following amounts for each 500 m by which the intended working altitude exceeds 1 000 m:

natural-air-cooled transformers: 2.5%;

forced-air-cooled transformers: 5%.

Note. — If transformers which are designed for operation below 1 000 m are tested at altitudes above 1 000 m, the measured temperature rises are to be reduced by the above-mentioned amounts for each 500 m by which the test altitude exceeds 1 000 m.

SECTION FOUR — INSULATION LEVELS

11. Insulation levels

11.1 *General*

When transformers are intended for general power distribution in public or industrial systems, the insulation levels shall be those given in Table V, List 1 or 2. The choice between Lists 1 and 2 should be made by considering the degree of exposure to lightning and switching overvoltages, the type of system neutral earthing and, where applicable, the type of overvoltage protective device (see IEC Publication 71: Insulation Co-ordination).

However, for application in particular systems where the insulation requirements are lower than in general and where the transformers are not required to be tested with lightning impulse withstand voltages, the power frequency test voltage applied may be below the value specified in Table V where experience has proved this to be permissible. No definite figures are recommended here.

TABLE V

Insulation levels

Highest voltage for equipment U_m (r.m.s.) (kV)	Rated short duration power frequency withstand voltage (r.m.s.) (kV)	Rated lightning impulse withstand voltage (peak value) (kV)	
		List 1	List 2
≤1.1	3	—	—
3.6	10	20	40
7.2	20	40	60
12	28	60	75
17.5	38	75	95
24	50	95	125
36	70	145	170

11.2 *Transformers for use at high altitudes*

When the transformers are specified for operation at altitudes between 1 000 m and 3 000 m above sea-level, but tested at normal altitude, the rated short duration power frequency withstand voltage shall be increased by 6.25% for each 500 m by which the altitude of the installation exceeds 1 000 m.

Note. — The above does not apply to sealed dry-type transformers but special consideration should be given to bushings.

SECTION FIVE — TESTS

12. General requirements for tests

Transformers shall be subjected to tests as specified below.

Tests shall be made at the manufacturer's works, unless otherwise agreed between the manufacturer and the purchaser.

Dielectric tests in accordance with Clauses 17, 18 and 19 shall be made with the transformer at approximately ambient temperature.

All external components and fittings that are likely to affect the performance of the transformer during each test shall be in place.

Tapped windings shall be connected on their principal tapping unless the manufacturer and the purchaser agree otherwise.

The test basis for all characteristics other than insulation is the rated condition, unless the test clause states otherwise.

The reference temperature to which the load loss, impedance voltage and short-circuit impedance are to be corrected shall be the maximum winding temperature rise as given in column 3 of Table IV plus 20 K.

Note. — When a transformer has windings of different insulation system temperatures only one reference temperature is to be used, that is, the one relating to the winding having the higher insulation system temperature.

13. **Measurement of winding resistance** (routine test)

Refer to Sub-clause 8.2 of IEC Publication 76-1.

14. **Measurement of voltage ratio and check of voltage vector relationship** (routine test)

Refer to Sub-clause 8.3 of IEC Publication 76-1.

15. **Measurement of impedance voltage (principal tapping), short-circuit impedance and load loss** (routine test)

Refer to Sub-clause 8.4 of IEC Publication 76-1.

16. **Measurement of no-load loss and current** (routine test)

Refer to Sub-clause 8.5 of IEC Publication 76-1.

17. **Separate-source voltage withstand test** (routine test)

Refer to Clause 10 of IEC Publication 76-3.

The test voltage shall be in accordance with Table V (Sub-clause 11.1) for the specified insulation level of the transformer, if no other value has been agreed upon by the manufacturer and purchaser.

The full test voltage shall be applied for 60 s between the winding under test and all the remaining windings, core, frame and transformer enclosure, connected to earth.

18. **Induced overvoltage withstand test** (routine test)

Refer to Sub-clauses 11.1 and 11.2 of IEC Publication 76-3.

The test voltage shall be twice the value corresponding to the rated voltage across an untapped winding of the transformer.

The duration of the test at full voltage shall be 60 s for any test frequency up to and including twice the rated frequency.

When the test frequency exceeds twice the rated frequency, the duration of the test shall be:

$$120 \cdot \frac{\text{rated frequency}}{\text{test frequency}} \text{ seconds}$$

but not less than 15 s.

19. **Lightning impulse test** (type test)

Refer to Clause 12 of IEC Publication 76-3.

The test voltage shall be in accordance with List 1 or List 2 of Table V (Sub-clause 11.1), for the specified insulation level of the transformer.

The test impulse shall be a full standard lightning impulse:

$$1.2 \pm 30\%/50 \pm 20\% \ \mu s$$

The test voltage shall normally be of negative polarity. The test sequence per line terminal shall be one calibration impulse at a voltage between 50% and 75% of the full voltage followed by three impulses at full voltage.

By agreement between the manufacturer and the purchaser at the time of the enquiry, tests may be made with positive polarity, but in this case sudden changes of polarity have to be avoided.

Note. — In dry-type transformers, the lightning impulse test can give rise to capacitive partial discharges in the air which do not endanger the insulation. These partial discharges lead to changes in the current waveform, whilst the voltage waveform varies only slightly or not at all. [C] Taking into account the above statement, slight deviations in current wave-form are not reasons for rejection. [C]

[C] 20 Partial discharge measurement

20.1 General

Partial discharge measurements shall be performed on all dry-type transformers. Measurement shall be made in accordance with IEC 60270 and IEC 60076-3, Annex A.

The partial discharge measurement shall be performed on transformer windings having $U_m \geq 3{,}6$ kV.

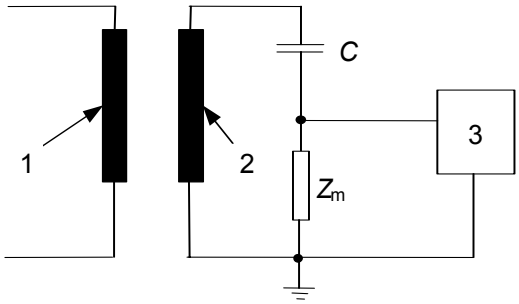
20.2 Basic measuring circuit (typical only)

A basic measuring circuit for the partial discharge test is shown in Figure 1, Figure 2, Figure Z1 and Figure Z2.

In the figures a partial discharge-free capacitor, C (having a capacitance value large in comparison with the calibration generator capacitance, C_0) in series with a detection impedance, Z_m, is connected to each of the high-voltage terminals. [C]

〈C〉 20.3 Calibration of the measuring circuit

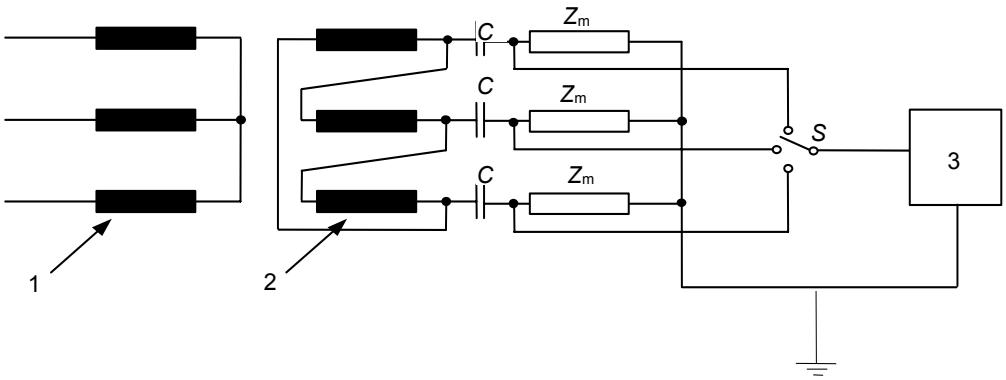
Attenuation of the discharge pulses occurs both within the windings and in the measuring circuit. Calibration is carried out as described IEC 60076-3, Annex A, by injecting simulated discharge pulses from a standard discharge calibrator at the transformer terminals. The repetition rate of calibration pulses should be of the order of twice the frequency of the excitation voltage.



Key

1 is the low-voltage winding
2 is the high-voltage winding
3 is the measuring instrument

Figure 1 – Basic measuring circuit for the partial discharge test for a single-phase transformer



Key

1 is the low-voltage winding
2 is the high-voltage winding, delta or star connected
3 is the measuring instrument

Figure 2 – Basic measuring circuit for the partial discharge test for a three-phase transformer 〈C〉

[C] 20.4 Voltage application

The partial discharge measurement shall be carried out after all dielectric tests are completed. The low-voltage winding shall be supplied from a three-phase or single-phase source, depending on whether the transformer itself is three-phase or single-phase. The voltage shall be as nearly sinusoidal as possible and of a frequency suitably increased above the rated frequency to avoid excessive excitation current during the test. The procedure shall be as in 20.4.1 or 20.4.2.

20.4.1 Three-phase transformers

Routine test

The following test shall be performed on all dry type transformers.

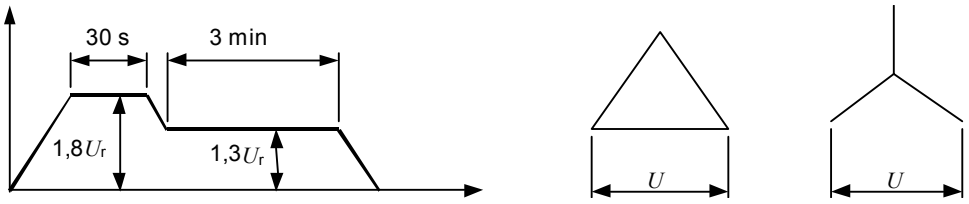


Figure Z1 – Voltage application for partial discharge test

A phase-to-phase pre-stress voltage of 1,8 U_r shall be induced for 30 s where U_r is the rated voltage, followed without interruption by a phase-to-phase voltage of 1,3 U_r for 3 min, during which the partial discharge shall be measured.

Additional procedure test

This additional test is for transformers connected to systems which are isolated or earthed through a high value impedance and which can continue to be operated under a single phase line-to-earth fault condition. The test shall be performed when specified by the customer. [C]

[C]

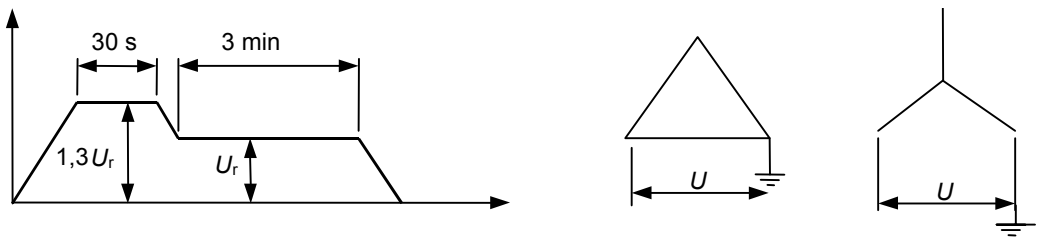


Figure Z2 – Additional procedure test – Voltage application for partial discharge test

A phase-to-phase voltage of 1,3 U_r shall be induced for 30 s, with one line terminal earthed, followed without interruption by a phase-to-phase voltage of U_r for 3 min during which the partial discharge shall be measured. This test shall be repeated with another line terminal earthed.

20.4.2 Single-phase transformers

For single-phase transformers U_r shall be the line-to-line or line-to-neutral voltage as appropriate. The voltage application shall be as for a three phase transformer.

Three-phase transformers comprising of three single-phase transformers shall be tested as for three-phase transformers.

20.5 Partial discharge acceptance levels

The maximum level of partial discharges shall be 10 pC.

NOTE Special considerations should be given to transformers fitted with ancillary equipment, for example, surge arrestors. [C]

21. Temperature-rise test (type test)

Refer to Sub-clauses 3.1.1, 3.1.2, 3.1.3, 3.3, 3.9.1, 3.9.2 and 3.9.3 of IEC Publication 76-2: Power Transformers, Part 2: Temperature Rise.

21.1 *Methods of loading*

At the choice of the manufacturer, any of the following methods may be applied.

21.1.1 *Direct loading method**

One winding, preferably the inner winding, of the transformer is excited at rated voltage with the other connected to a suitable load such that rated currents flow in both windings.

21.1.2 *Back-to-back method**

This is the preferred method, applicable when there are two similar transformers available.

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* The duration of the test may be reduced by exciting the core for a period of time (preferably not less than 12 h) prior to the application of test current to the windings.

Two transformers, one of which is the transformer under test, are connected in parallel, and preferably the inner windings are excited at the rated voltage of the transformer under test. By means of different voltage ratios or an injected voltage, the rated current is made to flow in the transformer under test.

21.1.3 *Simulated load method (by agreement between the manufacturer and purchaser)*

This method is used for an enclosed or non-enclosed dry-type unit with natural air cooling, when only the transformer under test is available, or when there is a similar transformer available but there are limitations on the test equipment.

Temperature tests are made by utilizing the rises obtained on two tests, one with no-load loss only, and one with load losses only, i.e., short-circuit run.

The no-load test, at rated voltage, is continued until steady-state conditions are obtained; individual winding temperature rises, $\Delta\theta_e$, are then measured.

The short-circuit run with rated current flowing in one winding and the other winding short-circuited is started immediately following the no-load run, and continued until steady-state conditions are obtained when the individual winding temperature rises, $\Delta\theta_c$, are measured.

The total winding rise, $\Delta\theta_c'$, of each winding, with rated current in the winding and normal excitation of the core, is calculated by the following formula:

$$\Delta\theta_c' = \Delta\theta_c \left[1 + \left(\frac{\Delta\theta_e}{\Delta\theta_c}\right)^{1.25}\right]^{0.8}$$

Note. — For other types of transformer, modifications to the formula may be necessary.

21.2 *Winding temperature-rise correction for reduced current*

When the input test current I_t is below the rated value of current I_N, but not less than 90% I_N, of the temperature rises, $\Delta\theta_t$, of the windings, shall be measured by the resistance method when steady-state conditions have been reached, and corrected to rated load conditions, $\Delta\theta_N$, by the formula:

$$\Delta\theta_N = \Delta\theta_t \left[\frac{I_N}{I_t}\right]^q$$

The value of q shall be taken as:

AN transformers: 1.6;

AF transformers: 1.8.

[C] NOTE For other cooling methods, the value of q shall be agreed between the manufacturer and the purchaser. [C]

21.3 *Determination of constant temperature conditions*

The ultimate temperature rise is reached when the temperature rise becomes constant; this is considered to have been achieved when the temperature rise does not vary by more than 2% of the permissible temperature rise per hour or 2 K per hour, whichever is the smaller.

For the purpose of determining when constant temperature conditions have been achieved, thermocouples or thermometers shall be applied to the following surfaces:

— Enclosed and non-enclosed units: centre of top yoke and as close as practicable to the innermost low-voltage winding conductors at the top of the winding, the measurement being on the centre leg of a three-phase unit.

— Sealed and totally enclosed units: centre of top cover surface and centre of one side of enclosure surface.

22. **Measurement of sound level** (special test)

Refer to IEC Publication 551: Measurement of Transformer and Reactor Sound Levels.

When a transformer is for operation within an enclosure supplied by the purchaser, sound measurements of the transformer core and coils may be carried out at the manufacturer's works without the enclosure.

The measuring distance is 0.3 m unless, for safety reasons, 1 m is chosen.

23. **Short-circuit test** (special test)

Short-circuit tests shall be as specified in IEC Publication 76-5.

Note. — References to gas relays and tanks in Sub-clause 2.2.6 of IEC Publication 76-5 are not applicable to dry-type transformers.

[C] Z1 Thermal shock test (special test)

Refer to Annex ZB.

Z2 Environmental test (special test)

Refer to Annex ZA.

Z3 Fire test (special test)

Refer to Annex ZC. [C]

24. **Tolerances**

Tolerances shall be as specified in Table III (Clause 7) of IEC Publication 76-1.

[C] SECTION SIX – ENCLOSURES AND SAFETY REQUIREMENTS [C]

25. **Degrees of protection provided by enclosures**

The design of an enclosure will be dependent upon the location and environmental conditions in which the transformer is installed. The screens and openings provided for the air circulation shall comply with IEC Publication 529: Classification of Degrees of Protection Provided by Enclosures.

⟨C⟩ Z4 Protection against direct contact

Transformers in which constructive features do not provide for protection against direct contact, shall be supplied with a visible element (warning plate or special mark) indicating the danger, according to national rules.

Z5 Earthing terminal

Transformers shall be fitted with an earth terminal which shall be permanently connected to all exposed metallic conductive non-live parts and which provides for the connection to a protective conductor. ⟨C⟩

⟨C⟩ SECTION SEVEN – MISCELLANEOUS

30 Electromagnetic compatibility (EMC)

Dry-type transformers shall be considered as passive elements in respect to emission of, and immunity to, electromagnetic disturbances.

NOTE 1 Report R014-001 describes electromagnetic aspects of transformers and provides some methods of evaluating electric and magnetic fields related to the connections.

NOTE 2 Passive elements are not liable to cause electromagnetic disturbances and their performance is not liable to be affected by such disturbances. ⟨C⟩

APPENDIX A

INFORMATION REQUIRED WITH ENQUIRY AND ORDER

A1. **Rating and general data**

A1.1 *Normal*

The following information shall be given in all cases:

1) Particulars of the specifications to be complied with.
2) Kind of transformer (see Clause 3).
3) Single or polyphase units.
4) Number of phases in system.
5) Frequency.
6) Information as to whether an enclosure is required or not. If it is, the degree of protection of the enclosure (see Clause 25). Information on the gas, if required, to fill the enclosure.
7) Method of cooling.
8) Indoor or outdoor installation.
9) Rated power (in kVA).
10) Rated voltage (for each winding).
11) State whether tappings are required, and if so, whether off-circuit tap-changers or links are required.
12) Highest voltage for equipment, U_m, (for each winding).
13) Insulation level, i.e. values of test voltage at power frequency and, if required, lightning impulse for which each winding is to be designed (see IEC Publication 76-3).
14) Connection symbol.
15) Impedance voltage at rated current, if specific value is required.
16) Neutral terminals if required (for each winding).
17) Method of system earthing (for each winding).
18) Any peculiarities of installation, for example space limitations, difficulty of maintenance, storage conditions, etc.
19) Any other appropriate information, for example site conditions, duty for which the transformer is required, system overvoltages, etc.
20) Details of fittings required and an indication of the side from which meters, rating plates, etc., should be readable.

A1.2 *Special*

21) Whether a lightning impulse test is required.
22) Altitude above sea level, if in excess of 1 000 m (see Sub-clauses 10.3 and 11.2).
23) Temperature of cooling air if above or below values given in Item *b)* of Sub-clause 2.1 (see Sub-clause 10.2).

24) Whether the transformer is to be directly connected to other apparatus which may affect short-circuit conditions.

25) Whether unbalanced loading is anticipated and if so, details thereof.

26) Details of intended regular cyclic overloading.

27) Connections required ex works in the case of a transformer having alternative winding connections.

28) Which special tests (see Section Five) are required, and for each of these tests the relevant acceptance conditions (levels, limits, etc.).

A2. Parallel operation

If parallel operation with existing transformers is required, this should be stated and the following information given concerning the existing transformers:

a) Rated power.

b) Rated voltage ratio.

c) Voltage ratios corresponding to tappings other than the principal tapping.

d) Load loss at rated current on the principal tapping, corrected to the appropriate reference temperature.

e) Impedance voltage at rated current (on the principal tapping).

f) Short-circuit impedances, at least on the extreme tappings, if the tapping range of the tapped winding exceeds $\pm 5\%$.

g) Diagram of connections, or connection symbol, or both.

APPENDIX B

[C] Climatic, environmental and fire behaviour classes

B.1 Environmental and climatic classes

Environmental conditions for dry-type transformers are identified in terms of humidity, condensation, pollution and ambient temperature [1].

With regard to humidity, condensation and pollution, three different environmental classes are defined.

Class E0 — No condensation occurs on the transformers and pollution is negligible. This is commonly achieved in a clean, dry indoor installation.

Class E1 — Occasional condensation can occur on the transformer (e.g. when the transformer is de-energised).
Limited pollution is possible.

Class E2 — Frequent condensation or heavy pollution or combination of both.

Special tests according to the procedure of Annex ZA shall prove suitability to E1 or E2 classes.

With regard to the minimum ambient temperature to which the transformer can be exposed, the following climatic classes are defined.

Class C1 — The transformer is suitable for operation at ambient temperature not below –5 °C but may be exposed during transport and storage to ambient temperatures down to –25 °C.

Class C2 — The transformer is suitable for operation, transport and storage at ambient temperatures down to –25 °C.

Special tests according to the procedure of Annex ZB shall prove suitability to C1 or C2 classes.

NOTE Transformers for outdoor operation should normally be provided with an enclosure or be given other suitable protection. [C]

B2. Enclosed or non-enclosed non-encapsulated-winding dry-type transformers are normally designed for installation indoors in dry locations. They will, however, operate successfully where the humidity is high providing precautions are taken to keep them dry if they are shut down for long periods.

[1] These are important not only during service but also during storage before installation.

[C] B.Z1 Fire behaviour classes

Two fire behaviour classes are defined:

Class F0 Unspecified fire performance. Except for the characteristics inherent in the design of the transformer, no special measures are taken to limit flammability.

Class F1 Transformers subject to fire hazard. Restricted flammability is required. The emission of toxic substances and opaque smokes shall be minimised.

Special tests according to the procedure of Annex ZC shall prove suitability to class F1.

B.Z2 Test criteria for climatic, environmental and fire behaviour classes

When a transformer is declared as suitable for a combination of climatic, environmental and fire behaviour classes, those tests which prove compliance with these classes shall be carried out on the same transformer in the sequence given in Table B.Z1.

The tests specified in Annex ZA, Annex ZB and Annex ZC are carried out as specified in the respective Annexes, on one transformer being representative of a certain design type.

Table B.Z1

Classes		Climatic		Environmental			Fire behaviour	
Tests	**Clauses**	**C1**	**C2**	**E0**	**E1**	**E2**	**F0**	**F1**
1. Thermal shock at –5 °C	ZB.2	YES	NO	—	—	—	—	—
2. Thermal shock at –25 °C	ZB.3	NO	YES	—	—	—	—	—
3. Condensation test	ZA.2.1	—	—	NO	YES	NO	—	—
4. Condensation and humidity penetration test	ZA.2.2	—	—	NO	NO	YES	—	—
5. Fire behaviour test	ZC.2; ZC.3	—	—	—	—	—	NO	YES

[C]

Annex ZA
(normative)

Special tests for environmental classes

ZA.1 General

The test laid down in Annex ZA allows to determine the suitability of transformers for environmental classes as defined by B.1 in Annex B. For the test sequence, see B.Z2.

If not otherwise specified, the tests shall be performed on one transformer completely assembled, fitted with its accessories (relevant for the test).

The tests are not required for sealed transformers.

The transformer and its accessories shall be new and clean without any additional surface treatment of the insulating parts.

Validity of the test:

The validity of the results of a climatic test carried out on a transformer can be extended to other transformers based on the same design criteria, such as

- same conceptual design (encapsulated or impregnated type, winding type, …),
- same maximum temperature-rise for the windings (according to Table IV of this document),
- same conducting materials,
- same main insulating materials.

ZA.2 Testing procedure

ZA.2.1 Class E1 transformers

This test is a condensation test.

The transformer shall be placed in a test chamber in which temperature and humidity are kept under control.

The volume of the chamber shall be at least five times that of the rectangular box circumscribing the transformer. The clearances from any part of the transformer to walls, ceiling and spraying nozzles shall be not less than the smallest phase-to-phase clearance between live parts of the transformer and not less than 0,15 m.

The temperature of the air in the test chamber shall be such as to ensure condensation on the transformer.

The relative humidity in the chamber shall be maintained above 93 %. This may be achieved by periodically or continuously atomising a suitable amount of water.

The conductivity of the water shall be in the range of 0,1 S/m to 0,3 S/m.

The position of the mechanical atomisers shall be chosen in such a way that the transformer is not directly sprayed.

No water shall drop from the ceiling upon the transformer under test.

The transformer shall be kept in air having a relative humidity above 93 % for not less than 6 h, without being energised.

Within 5 min thereafter the transformer shall be submitted to a test with induced voltage as specified below. Preferably this test should be made in the test chamber.

Transformers with windings intended for connection to system which are solidly earthed or earthed through a low impedance:

The transformer shall be energised at a voltage of 1,1 times the rated voltage for a period of 15 min.

Transformers with windings intended for connection to systems which are isolated or earthed through a considerable impedance:

The transformer shall be submitted to a test with induced voltage for 3 successive periods of 5 min during which each high voltage terminal in turn is connected to earth and a voltage of 1,1 times the rated voltage appears between the other terminals and earth. In the latter case, the three-phase test can be replaced by single-phase tests with the two non-earthed phase terminals being interconnected.

During the voltage application no flashover shall occur and visual inspection shall not show any serious tracking.

ZA.2.2 Class E2 transformers

The test procedure includes a condensation test and a humidity penetration test.

The condensation test shall be the same as described under ZA.2.1 for class E1 transformers, except for the conductivity of water which shall be in the range of 0,5 S/m to 1,5 S/m.

At the beginning of the humidity penetration test, the transformer shall be in a dry condition.

It shall be installed in a de-energised condition and held in the climatic chamber for 144 h. The temperature of the climatic chamber shall be held at (50 ± 3) °C and the relative humidity held at (90 ± 5)%. At the end of this period and after 3 h in normal ambient conditions at the latest, the transformer shall be subjected to the separate-source and induced voltage tests, but at voltages reduced to 80 % of the standardised values. There should be neither flashover nor breakdown during the dielectric tests and visual inspection shall not show any serious tracking.

Annex ZB
(normative)

Special tests for climatic classes

ZB.1 Thermal shock test (special test)

The test laid down in Annex ZB allows to determine the suitability of transformers for climatic classes as defined by B.1. For the test sequence, see B.Z2.

Validity of the test:

The validity of the results of a climatic test carried out on a transformer can be extended to other transformers based on the same design criteria, such as

- same conceptual design (encapsulated or impregnated type, winding type, …),
- same maximum temperature-rise for the windings (according to Table IV of this document),
- same conducting materials,
- same main insulating materials.

ZB.2 Thermal shock test for C1 class transformers

ZB.2.1 Test modalities

The test shall be carried out on a complete transformer [1)] without enclosure, if any.

The transformer shall be placed in a test chamber.

The ambient temperature in the chamber shall be measured at least at 3 points located at 0,1 m from the external surface and at half height of the test object. The mean values of the readings shall be taken as reference air temperature.

Then the following test procedure shall be applied:

a) the air temperature in the test chamber shall be gradually decreased to (–25 ± 3) °C in 8 h and then maintained at this value for 12 h at least;

b) the temperature shall then be gradually increased up to (–5 ± 3) °C in about 4 h. This temperature shall be maintained for 12 h at least;

[1)] By agreement between supplier and purchaser, the test may be carried out on all coils removed from the core. The final dielectric checks should be carried out after reassembling the tested coil on the unit.

c) a thermal shock shall then be performed by applying a current equal to twice the rated current to the winding under test.

The current shall be maintained until the winding under test reaches a mean temperature corresponding to the maximum temperature rise, according to Table IV of this document, plus 40 °C (maximum ambient temperature under normal service conditions).

The mean temperature reached by the windings shall be determined by resistance variation.

The thermal shock should be performed by applying one of the three following alternative methods:

1. With d.c. supply

The prescribed thermal shock shall be performed by applying a d.c. current of the specified value to the winding to be tested.

In case of multiphase transformers, the test current should be applied to all phase coils connected in series.

The monitoring of the winding mean temperature along the test duration can be made directly by the volt-ampere method measuring the test current and the relevant voltage drop.

NOTE 1 For putting the coils in series it may be necessary to remove the winding connections.

2. With a.c. supply

The prescribed thermal shock shall be performed by applying an a.c. current of the specified value to the winding to be tested, with the other winding(s) short-circuited. In case of multiphase transformers, a symmetrical system of currents should be applied.

The monitoring of the winding mean temperature along the test duration should be performed in d.c. by superposing the measuring current and the a.c. test current, or by some other equivalent method.

3. With a.c. supply (alternative method)

The prescribed thermal shock shall be performed by applying an a.c. current of the specified value to the winding to be tested, with the other winding(s) short-circuited. In case of multiphase transformers, a symmetrical system of currents should be applied.

The temperature in each of the windings is monitored by readings of temperature sensors fixed near the bottom and top of the winding surface. The sensors are calibrated by a calibration test with twice the rated current carried out at normal ambient temperature before the actual test.

The calibration is made by comparing the sensor readings with the winding temperature rise as measured by change in winding resistance. In this way, the sensor reading corresponding to an average winding temperature according to Table IV plus 40 °C is determined. The same sensor reading shall be obtained in the test, which starts at low ambient temperature.

NOTE 2 Care shall be taken to prevent that some winding be thermally overstressed because of the different thermal transient behaviour of the transformer parts.

d) After the thermal shock, the transformer shall be brought back to a temperature of (25 ± 10) °C.

ZB.2.2 Test criteria

At least 12 h after the end of thermal shock test, the transformer shall be submitted to the dielectric routine tests (separate-source and induced over-voltage withstand tests) as specified in this document, in accordance with the insulation level of the windings, but at voltages reduced to 80 % of the standard values.

In addition, for encapsulated transformers, partial discharge measurements shall be carried out according to Clause 20 of the present document. The test voltage shall not exceed the test voltage of the reduced induced over-voltage withstand test (160 % of the rated value) and the measured values shall not exceed the one prescribed for routine tests.

On visual inspection, the windings shall show no visible abnormality, such as cracks and slits.

ZB.3 Thermal shock test for C2 class transformers

ZB.3.1 Test modalities

The test modalities are the same as in ZB.2.1 with the following modification:

Step b) is deleted in order to carry out thermal shock test from –25 °C.

ZB.3.2 Test criteria

The test criteria are the same described in ZB.2.2.

Annex ZC
(normative)

Special tests to prove suitability to fire behaviour class F1

ZC.1 General

To optimise the behaviour of a transformer it is necessary to minimise its emission of toxic substances and opaque smoke in the event of burning. The use of halogenic materials should be avoided. Checking of corrosive and harmful gases emission shall be made according to ZC.2.

Moreover, the transformer shall not contribute significantly to the thermal energy of an external fire. The fire behaviour shall be assessed by the test procedure ZC.3.

ZC.2 Checking of corrosive and harmful gases emission

The emission of corrosive and harmful gases shall be checked on small quantities of the combustible materials present in the transformer.

Only such material is taken into account, which makes more than 5 % of weight of non-metallic materials in a complete transformer.

In principle, the tests should be able to detect the presence of components such as hydrogen chloride (HCl), hydrogen cyanide (HCN), hydrogen bromide (HBr), hydrogen fluoride (HF), sulfur dioxide (SO_2), formaldehyde (HCOH).

The details of test procedures and acceptable limits may be agreed between purchaser and manufacturer unless specified in European or national regulations.

ZC.3 Fire test

ZC.3.1 Test object

The test is carried out on one complete phase of a transformer comprising HV and LV coils, core leg and insulation components, without enclosure, if any.

The core leg may be replaced by material of approximately similar dimensions and thermal behaviour as the original core leg. The yoke will not be considered.

The outer coil diameter of circular or non-circular windings to be tested shall be between 400 mm and 500 mm of a standard transformer.

NOTE Windings with larger or smaller dimensions may be tested by agreement.

ZC.3.2 Validity of the test

The validity of the results of a fire test carried out on a transformer can be extended to other transformers based on the same design criteria, such as

- same conceptual design (encapsulated or impregnated type, winding type, …),
- same maximum temperature rise for the windings (according to Table IV of this document),
- same conducting materials,
- same main insulating materials.

ZC.3.3 Testing installation

a) Test chamber

The test chamber is based on the one related to cables described in Figure 1 of IEC 60332-3. The walls are made of heat resistant steel with a thickness of 1,5 mm to 2,0 mm, thermally insulated, so as to give a heat transfer of approximatively 0,7 W/m²K. A fire resistant window should be fitted if possible.

The main dimensions of the tested chamber (see Figure ZC.1) are

- height: from 3,5 m to 4,0 m,
- width: 1 m,
- depth: 2 m.

The chamber shall be equipped with a chimney of approximatively 0,5 m inner diameter and an air-inlet duct of approximatively 0,35 m inner diameter. The difference in level between the air inlet into the test-chamber and the gas outlet at the chimney shall be approximatively 9 m. The air is admitted under the test chamber through a grating (0,40 × 0,80) m and escapes through an opening of approximatively 0,3 m² into the chimney.

Within the chimney there shall be a measuring section of 0,5 m diameter and a length of at least 0,6 m, the lower end of which is situated 1,5 m to 2,0 m above the level of the roof of the test-chamber.

Within the air-inlet duct there shall be a measuring section of 0,35 m diameter and a length of at least 0,4 m in a distance of at least 1 m to the air inlet into the test chamber and to the air-inlet to the duct.

A throttle valve shall be provided in the chimney and/or in the air inlet unless forced airflow is provided. The test-chamber should be built in such a way that the influence of wind on the amount of entering air is negligible.

b) Ignition sources (see Figure ZC.2)

The main source of heat is ethyl alcohol (caloric value 27 MJ/kg) burning in a container which may be subdivided by concentric rings. The outer diameter of the container in use shall be at least 100 mm larger than the external diameter of the outer coil. The inner diameter of the container shall be at least 40 mm smaller than the inner diameter of the inner coil.

The initial level of the alcohol in the container shall be (30 ± 1) mm which corresponds to a burning time of approximatively 20 min.

A second source of heat is a vertically placed flat radiant electrical panel, approximatively 0,8 m in height and 0,5 m in width, made up of heating resistors totalling 24 kW with an adjustable power source to maintain the panel at 750 °C. A hemicylindrical metal shield, 0,9 m in diameter and 1,2 m in height, shall be placed opposite the panel.

NOTE When testing windings with an outer dimension larger than 500 mm, the shield may be omitted.

ZC.3.4 Quantities to be measured and measuring devices

ZC.3.4.1 Temperatures

The following temperatures shall be measured by means of thermocouples or equivalent devices:

- air inlet;
- air outlet;
- surface of LV-coil at top (optional);
- surface of HV-coil at top (optional);
- core leg or part simulating it, at bottom and top (optional);
- duct between core and LV-coil in the middle (optional);
- duct between LV- and HV-coil in the middle (optional).

NOTE The location of the measuring sensors on the test object is indicated in Figure ZC.2.

ZC.3.4.2 Other quantities to be measured

- Transmission of visible light in the measuring section; this measurement shall be carried out along an optical path through the smoke of at least 500 mm.

  NOTE The measured transmission factor being X and the actual length of the optical path being p (expressed in m), the value of the transmission factor referred to a 1 m path is: $\tau = X^{1/p}$.

- Air flow rate in the air inlet
- Gas rate in the chimney (optional)

ZC.3.5 Calibration of the test chamber without test object

The chamber shall be calibrated after energising the radiant panel with 24 kW constant for not less than 40 min.

The air-flow rate measured in the inlet section, shall be adjusted in such a way that in steady state conditions it will be 0,21 m³/s ± 15 %.

When the testing installation is based on natural airflow, the flow-rate may be modified by acting on the throttle valve or equivalent device.

In case of testing installations operating with forced air the flow-rate may be adjusted by acting on the fan system.

NOTE More adjustments may be needed to obtain the required air-flow-rate in steady-state conditions.

ZC.3.6 Test modality

The test object shall be installed in the test chamber as indicated in Figure ZC.2 respecting the following conditions:

- the distance between the radiant panel and the outer winding surface shall be approximatively 175 mm;

- the initial level of alcohol in the container shall be approximatively 40 mm under the transformer winding level;

  NOTE In some cases, agreement between purchaser and manufacturer is necessary depending upon the design of the test object.

- the hemicylindrical metal shield shall be opposite to the heating panel and concentric with the test object;

- the temperature in the test chamber, of the inlet air, and of the test object at the beginning of the test shall be between 15 °C and 30 °C;

- the container is filled with alcohol just before starting (in practice, within 5 min).

The test starts at the moment the alcohol is ignited and the radiant panel (24 kW) switched on.

The radiant panel shall be switched off 40 min later.

The quantities listed in ZC.3.4.1 and ZC.3.4.2 shall be recorded for at least 60 min from the beginning of the test, i.e. for the total duration of the test.

The test object shall be weighed before and after the test with an accuracy of ± 0,5 % or better. The material representing the core leg and the coils with insulation parts may be weighed separately.

Measurements made in conformity with this standard tend to result in certain deviations of reproducibility. By testing similar transformer coils in different – or even more in the same – laboratories, deviations up to 10 % were found, due to different climatic conditions for example.

By agreement between manufacturer and purchaser, further tests may be performed on the remaining coils of the same transformer, if the measurements exceed limits by no more than 10 %.

ZC.3.7 Test report

The test report shall contain the following information:

- result of the test performed on samples of material (if required by the user);

- total calculated weight and thermal energy of burnable materials (if possible) and measured weight of the tested object;

- result of the test-chamber calibration (air flow-rate, temperatures in the measuring sections, adjustment of the throttle valve or gas extraction system, etc.);

- full description of the method of carrying out the test, including the time periods during which alcohol burns and electrical energy is applied;

- loss of weight of burnable materials during the test (accuracy of ± 10 %) and calculated heat release (MJ) (if possible);

- temperatures recorded throughout the test at intervals of 2 min or less, starting from the beginning of the test (ignition of the alcohol);

- visible light transmitted in the measuring section continuously recorded throughout the test (in %);

- inlet airflow rate throughout the test, measured at intervals of 2 min or less in the measuring section (m^3/s);

- visible fire behaviour of the object under test.

ZC.3.8 Criteria for evaluating the test results

The test object shall be considered to have passed the test if it meets the following criteria:

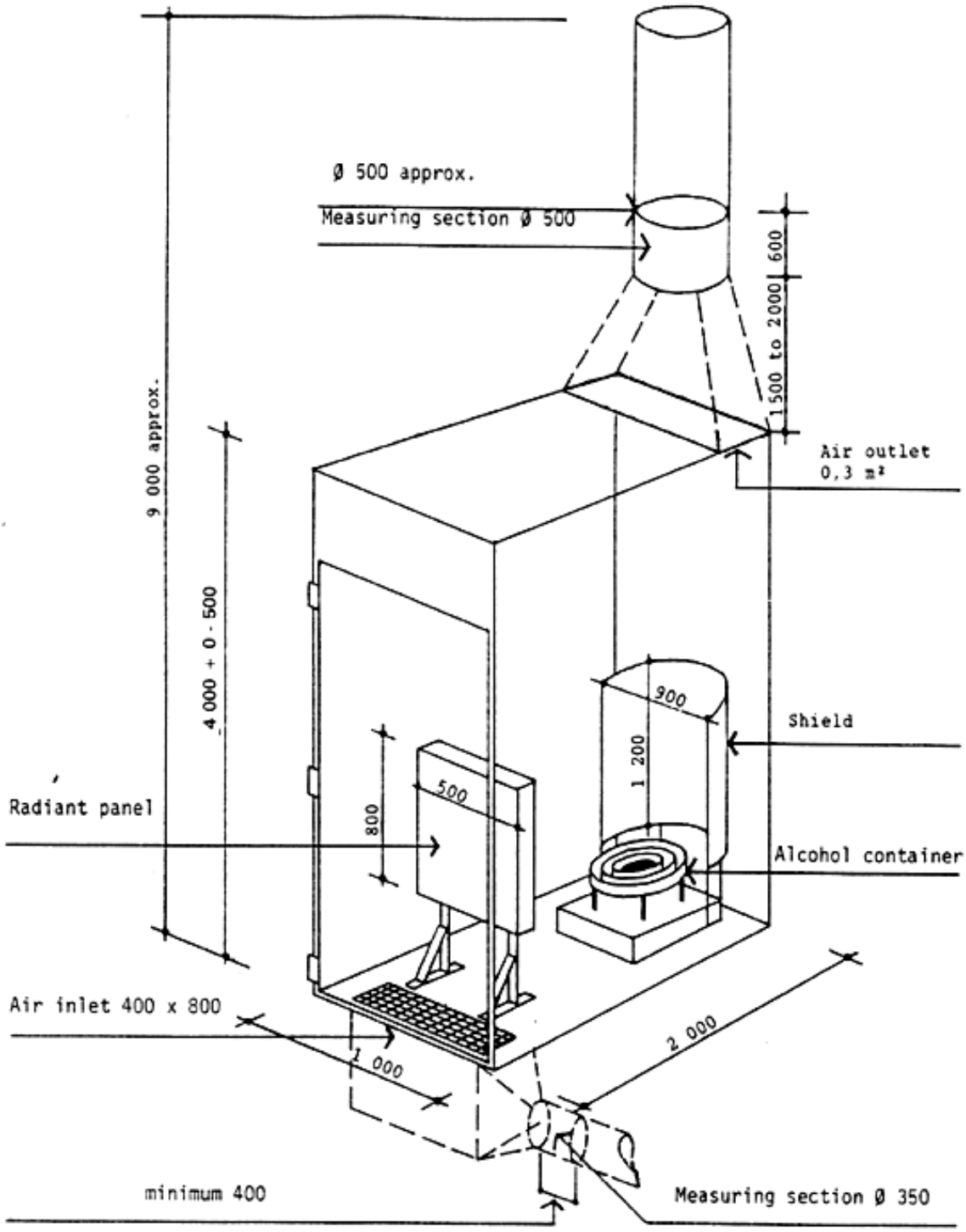
- the temperature rise above ambient of the gases in the measuring section in the chimney shall not exceed 420 K throughout the test;

- the temperature rise above ambient of the gases in the measuring section in the chimney shall not exceed 140 K 5 min after the radiant panel is switched off (45 min after the beginning of the test), and it shall decrease when measured over time periods of 10 min;

- the temperature rise of the gases in the measuring section in the chimney shall not exceed 80 K after 60 min from the beginning of the test. These conditions are assumed to demonstrate the self-extinction of the fire;

  NOTE A higher temperature rise may be allowed if the stored thermal energy prevents the temperature drop with natural airflow.

- the arithmetic mean of the optical transmission factor of light in the measuring section, referred to an optical path through smoke of 1 m, between 20 min and 60 min after the beginning of the test shall be not less than 20 % (indicative).



(dimensions in mm)

Figure ZC.1 – Test chamber

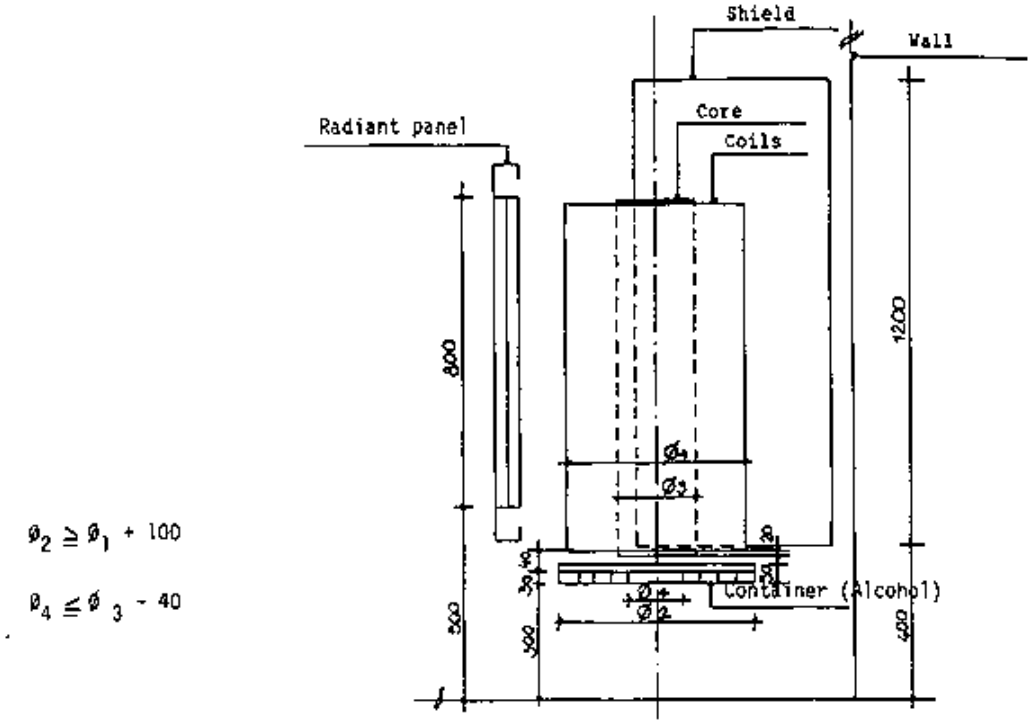


Figure ZC.2a

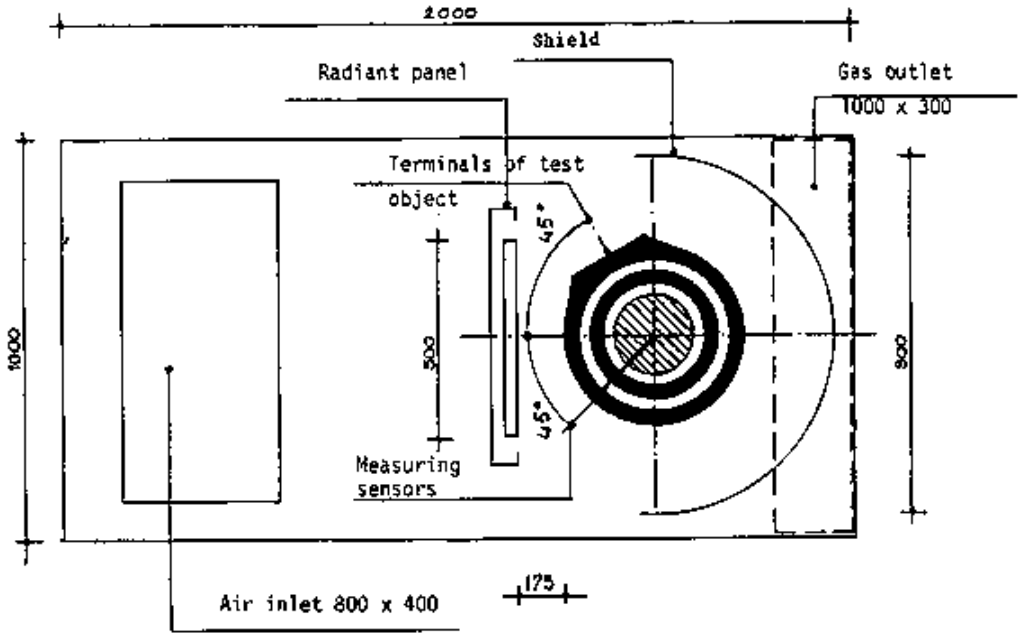


Figure ZC.2b

(dimensions in mm)

Figure ZC.2 – Ignition sources – Details

Annex ZD
(informative)

Installation and safety of a dry-type transformer

ZD.1 Manuals

Instruction manuals concerning installation requirements, transport requirements, erection, maintenance and operation should be given to the purchaser by the supplier, in particular for the supply of a prototype for a given purchaser. Unless otherwise specified in the contract, it is considered a good practice to transmit these manuals in advance, in order to enable the purchaser to check the correctness of the installation and the steps taken to organise transport and erection, if applicable.

ZD.2 Installation

ZD.2.1 General

Safety in the transformer use can be considered from different points of view:

- intrinsic safety of the transformer in order to be free from dangerous events arising from internal failure;
- safety deriving from steps taken in the installation precautions against unavoidable events;
- limitation of consequences of external events.

National laws and regulations impose in several countries the steps to be taken to improve safety in b) and c) above.

HD 637 S1 and national standards specify installation requirements to be observed.

NOTE National laws and regulations prevail on the contents of this informative annex.

The following subclauses give some examples on the steps to be taken both by the supplier and the purchaser to assure an acceptable degree of safety.

ZD.2.2 Intrinsic safety

The fulfilment of the requirements contained in this standard gives the necessary reliability against dangerous failures inside the transformer. For main fittings the relevant standards are applicable. Manufacturer's instruction on loading capabilities should be followed and loading guides are available in national standards.

The following particular points may be applicable:

- insulation levels and tests;
- maximum heat generation resulting from the guaranteed losses and tested;
- maximum temperature in service;

- systematic maintenance of the transformer, its accessories and protection. The manual should address these points;
- the manual should give guidance on condition based maintenance;
- use of an F1 class transformer in case of danger of fire (external or internal).

ZD.2.3 Installation precautions

Installation precautions are given in national laws and regulations, in national standards and in HD 637.

Installation designers should consider the following, non exhaustive, list of points:

- the cooling system should be sufficient to keep the temperature of the ambient air below the specified maximum limits;
- adequate protection against transient overvoltages generated by the system or by lightning;
- the overcurrent protection and inherent short-circuit withstand capability of the transformer;
- other protections on the transformer (contacts on temperature indicating devices, etc.) and in the installation (relays, fuses, etc.);
- risk and consequences of and precaution against fire with origin in the transformer itself or origin at other place;
- restricted access to avoid contact with live parts or hot parts and to limit the presence of persons in the case of failure;
- limitation of the noise emission outside the installation;
- for busbars or cables, control of the emission of the magnetic field may be necessary;
- provision to prevent ambient air contamination;
- to prevent generation and accumulation gases.

Annex ZE
(normative)

Normative references to international publications with their corresponding European publications

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

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

Publication	Year	Title	EN/HD	Year
IEC 60050	1979	International Electrotechnical Vocabulary	-	-
IEC 60071	Series	Insulation co-ordination	EN 60071	
IEC 60076-1 (mod)		Power transformers Part 1: General	EN 60076-1	
IEC 60076-2 (mod)		Part 2: Temperature rise	EN 60076-2	
IEC 60076-3		Part 3: Insulation levels, dielectric tests and external clearances in air	EN 60076-3	
IEC 60076-5		Part 5: Ability to withstand short circuit	EN 60076-5	
IEC 60270		High-voltage test techniques - Partial discharge measurements	EN 60270	
IEC 60529		Degrees of protection provided by enclosures (IP Code)	EN 60529	
IEC 60551		Determination of transformer and reactor sound levels	[1)]	

[1)] IEC 60551 is replaced by IEC 60076-10 which has been harmonized as EN 60076-10.

Bibliography

IEC 60084 [1)]		Recommendations for mercury-arc convertors		
IEC 60085	1984	Thermal evaluation and classification of electrical insulation	HD 566 S1	1990
IEC 60119	1960	Recommendation for polycrystalline semiconductor rectifier stacks and equipment		
IEC 60146	Series	Semiconductor convertors	EN 60146	Series
IEC 60185 (mod)	1987 [2)]	Current transformers		
IEC 60186 (mod)	1987 [3)]	Voltage transformers		

1) Withdrawn.

2) Replaced by IEC 60044-1:1996; has been harmonized as EN 60044-1 (IEC mod.).

3) Partially replaced by IEC 60044-2:1997; has been harmonized as EN 60044-2 (IEC mod.).

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