

Power transformers —

Part 2: Temperature rise

The European Standard EN 60076-2:1997 has the status of a British Standard

ICS 29.180

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW



Document Sharing Hub

National foreword

This British Standard is the English language version of EN 60076-2:1997. It supersedes BS 171-2:1978 which will be withdrawn on 1997-09-01. 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.

From 1 January 1997, all IEC publications have the number 60 000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

Cross-references

Attention is drawn to the fact that CEN and CENELEC Standards normally include an annex which lists normative references to international publications with their corresponding European publications. The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or using the “Find” facility of the BSI Standards Electronic Catalogue.

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 and ii, the EN title page, pages 2 to 20, 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.

Amendments issued since publication

Amd. No.	Date	Comments

This British Standard, having been prepared under the direction of the Electrotechnical Sector Board, was published under the authority of the Standards Board and comes into effect on 15 September 1997

© BSI 02-1999

ISBN 0 580 27733 X

Contents

	Page
National foreword	Inside front cover
Foreword	2
Text of EN 60076-2	3

English version

Power transformers Part 2: Temperature rise

(IEC 76-2:1993, modified)

Transformateurs de puissance
Partie 2: Echauffement
(CEI 76-2:1993, modifiée)

Leistungstransformatoren
Teil 2: Übertemperaturen
(IEC 76-2:1993, modifiziert)

This European Standard was approved by CENELEC on 1997-03-11. 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.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

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

© 1997 CENELEC — All rights of exploitation in any form and by any means reserved worldwide for CENELEC members.

Foreword

The text of the International Standard IEC 76-2:1993, prepared by IEC TC 14, Power transformers, together with the common modifications prepared by the Technical Committee CENELEC TC 14 was submitted to the formal vote and was accepted by CENELEC as EN 60076-2 on 1997-03-11.

This European Standard supersedes HD 398.2 S1:1979 and its amendment A1:1988.

Technical differences relate mainly to certain measures to bring the standard in line with actual requirements of User's specifications.

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) 1997-09-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1997-09-01

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

Contents

	Page
Foreword	2
1 Scope	3
2 Normative references	3
3 Identification symbols according to cooling method	3
4 Temperature-rise limits	4
4.1 General	4
4.2 Normal temperature-rise limits at continuous rated power	4
4.3 Modified requirements because of unusual service conditions	5
4.4 Temperature rise during a specified load cycle	4
5 Test of temperature rise	6
5.1 General	6
5.2 Test methods for temperature-rise determination	7
5.3 Determination of oil temperatures	8
5.4 Determination of average winding temperature	9
5.5 Determination of winding temperature before shutdown	9
5.6 Corrections	10
Annex A (informative) Note on oil temperature in transformers with forced oil circulation	11
Annex B (informative) Transient loading — Mathematical model and testing	12
Annex C (informative) Techniques used in temperature-rise testing of oil-immersed transformers	14
Annex ZA (normative) Normative references to international publications with their corresponding European publications	Inside back cover
Figure B.1 — Temperature distribution model	12
Figure C.1 — Graphical extrapolation to ultimate temperature rise	15
Figure C.2 — Evaluation of winding resistance variation after shutdown	17
Figure C.3 — Graphical extrapolation to resistance value at shutdown	18

1 Scope

This part of International Standard IEC 76 identifies transformers according to their cooling methods, defines temperature-rise limits and details the methods of test for temperature-rise measurements. It applies to transformers as defined in the scope of IEC 76-1.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 76. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 76 are encouraged to investigate the possibility of applying the most recent edition of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

IEC 85:1984, *Thermal evaluation and classification of electrical insulation*.

IEC 279:1969, *Measurement of the winding resistance of an a.c. machine during operation at alternating voltage*.

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

IEC 606, *Application guide for power transformers*.

IEC 726:1982, *Dry-type power transformers*.

IEC 905:1987, *Loading guide for dry-type power transformers*.

ISO 2592:1973, *Petroleum products — Determination of flash and fire points — Cleveland open-cup method*.

3 Identification symbols according to cooling method

Transformers shall be identified according to the cooling method employed. For oil-immersed transformers this identification is expressed by a four-letter code as described below. Corresponding codes for dry-type transformers are given in IEC 726.

First letter: Internal cooling medium in contact with the windings:

- O mineral oil or synthetic insulating liquid with fire point^a ≤ 300 °C;
- K insulating liquid with fire point^a > 300 °C;
- L insulating liquid with no measurable fire point.

^a "Cleveland open-cup" test method, see ISO 2592.

Second letter: Circulation mechanism for internal cooling medium:

- N *natural* thermosiphon flow through cooling equipment and in windings;
- F *forced* circulation through cooling equipment, thermosiphon flow in windings;
- D forced circulation through cooling equipment, *directed* from the cooling equipment into at least the main windings.

Third letter: External cooling medium:

- A air;
- W water.

Fourth letter: Circulation mechanism for external cooling medium:

- N natural convection;
- F forced circulation (fans, pumps).

NOTE In a transformer designated as having forced directed oil circulation (second code letter D), the rate of oil flow through the main windings is determined by the pumps and is not, in principle, determined by the loading. A minor fraction of the flow of oil through the cooling equipment may be directed as a controlled bypass to provide cooling for core and other parts outside the main windings. Regulating windings and/or other windings having relatively low power may also have non-directed circulation of bypass oil.

In a transformer with forced, non-directed cooling, on the other hand (second code letter F), the rates of flow of oil through all the windings are variable with the loading, and not directly related to the pumped flow through the cooling equipment.

A transformer may be specified with alternative cooling methods. The specification and the nameplate shall then carry information about the power figures at which the transformer fulfils the temperature-rise limitations when these alternatives apply, see 7.1 m) of IEC 76-1. The power figure for the alternative with the highest cooling capacity is the rated power of the transformer (or of an individual winding of a multi-winding transformer, unless otherwise agreed between manufacturer and purchaser, see 4.1 of IEC 76-1). The alternatives are conventionally listed in rising order of cooling capacity.

Examples:

ONAN/ONAF. The transformer has a set of fans which may be put in service as desired at high loading. The oil circulation is by thermosiphon effect only — in both cases.

ONAN/OFAF. The transformer has cooling equipment with pumps and fans but is also specified with a reduced power-carrying capacity under natural cooling (for example, in case of failure of auxiliary power).

4 Temperature-rise limits

4.1 General

Temperature-rise limitations for transformers are specified according to different options.

— A set of requirements apply which refer to continuous rated power. These requirements are given in 4.2.

— When explicitly specified, an additional set of requirements is imposed which is related to a specified loading cycle. This procedure is described in 4.4. It is applicable mainly to large system transformers for which emergency loading conditions deserve particular attention, and should not be regularly used for small and medium-size standardized transformers.

It is assumed throughout this part of IEC 76 that the service temperatures of different parts of a transformer can each be described as the sum of a cooling medium temperature (ambient air or cooling water) and a temperature rise of the transformer part.

The cooling medium temperature and the altitude (with regard to cooling air density) are characteristic of the installation site. When normal service conditions in these respects prevail, see 1.2 of IEC 76-1, then normal values of temperature rise for the transformer will result in allowable service temperatures.

The values of temperature rise are characteristics of the transformer which are subject to guarantees and to tests under specified conditions. Normal temperature-rise limits apply unless the enquiry and contract indicate “unusual service conditions”. In such cases the limits of temperature rise shall be modified as indicated in 4.3.

Additional temperature-rise tests, as agreed between the manufacturer and the purchaser, may be carried out on transformers having guaranteed ratings related to different cooling conditions, e.g. ONAN/ONAF, to verify the efficiencies of alternative cooling arrangements.

No plus tolerance is permitted on temperature-rise limits.

4.2 Normal temperature-rise limits at continuous rated power

When a transformer has a tapped winding with a tapping range exceeding $\pm 5\%$ then the temperature-rise limits shall apply to every tapping at the appropriate tapping power, tapping voltage and tapping current, see 5.6 of IEC 76-1. The load losses are different for different tappings and sometimes also the no-load losses, namely within tapping ranges where variable flux voltage variation is specified.

If a temperature-rise type test is to be made on such a transformer it will, unless otherwise specified, be carried out on the “maximum current tapping”, see 5.3 of IEC 76-1.

NOTE In a separate-winding transformer, the maximum current tapping is normally the tapping with the highest load loss. In an auto-transformer with tappings, the choice of tapping for the temperature-rise test will be dependent on how the tappings are arranged.

For a multi-winding transformer, the temperature-rise requirements refer to rated power in all windings simultaneously if the rated power of one winding is equal to the sum of the rated powers of the other windings. If this is not the case, one or more particular loading combinations have to be selected and specified for the temperature-rise test, see 5.2.3.