IEC 60076-2

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Power transformers –
Part 2: Temperature rise for liquid-immersed transformers

Transformateurs de puissance –
Partie 2: Echauffement des transformateurs immergés dans le liquide

IEC 60076-2:2011

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FOREWORD

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International Standard IEC 60076-2 has been prepared by IEC technical committee 14: Power transformers.

This third edition cancels and replaces the second edition published in 1993. It is a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the standard is applicable only to liquid immersed transformers;
b) the winding hot-spot temperature rise limit was introduced among the prescriptions;
c) the modalities for the temperature rise test were improved in relation to the new thermal requirements;
d) five informative annexes were added in order to facilitate the standard application.

The text of this standard is based on the following documents:

FDIS	Report on voting
14/669/FDIS	14/676/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60076 series can be found, under the general title *Power transformers*, on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,
- replaced by a revised edition, or
- amended.

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POWER TRANSFORMERS –

Part 2: Temperature rise for liquid-immersed transformers

1 Scope

This part of IEC 60076 applies to liquid-immersed transformers, identifies power transformers according to their cooling methods, defines temperature rise limits and gives the methods for temperature rise tests.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-8:1997, *Power transformers – Part 8: Application guide*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 61181:2007, *Mineral oil-filled electrical equipment – Application of dissolved gas analysis (DGA) to factory tests on electrical equipment*

IEC Guide 115:2007, *Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60076-1 and the following apply.

3.1
external cooling medium
the medium external to the transformer cooling system (air or water) into which the heat produced by the transformer losses is transferred

3.2
internal cooling medium
the liquid in contact with the windings and other transformer parts by means of which the heat produced by the losses is transferred to the external cooling medium

NOTE The liquid can be mineral oil or other natural and synthetic liquid.

3.3
temperature rise
the difference between the temperature of the part under consideration (for example, the average winding temperature) and the temperature of the external cooling medium

3.4
top-liquid temperature
θ_o
the temperature of the insulating liquid at the top of the tank, representative of top-liquid in the cooling flow stream

3.5
top-liquid temperature rise
$\Delta\theta_o$
the temperature difference between the top-liquid temperature and the external cooling medium temperature

3.6
bottom-liquid temperature
θ_b
the temperature of the insulating liquid as measured at the height of the bottom of the windings or to the liquid flowing from the liquid cooling equipment

3.7
bottom-liquid temperature rise
$\Delta\theta_b$
the difference between the bottom-liquid temperature and the external cooling medium temperature

3.8
average liquid temperature
θ_{om}
the average temperature of the top-liquid and bottom liquid temperatures

3.9
average liquid temperature rise
$\Delta\theta_{om}$
the difference between the average liquid temperature and the external cooling medium temperature

3.10
average winding temperature
θ_w
the winding temperature determined at the end of temperature rise test from the measurement of winding d.c. resistance

3.11
average winding temperature rise
$\Delta\theta_w$
the difference between the average winding temperature and the external cooling medium temperature

3.12
average winding gradient
g
the difference between the average winding temperature and the average insulating liquid temperature

3.13
hot-spot winding temperature
θ_h
the hottest temperature of winding conductors in contact with solid insulation or insulating liquid

3.14
hot-spot winding temperature rise
$\Delta\theta_h$
the difference between hot-spot winding temperature and the external cooling medium temperature

3.15
hot-spot factor
H
a dimensionless factor to estimate the local increase of the winding gradient due to the increase of additional loss and variation in the liquid flow stream

NOTE *H* factor is obtained by the product of the *Q* and *S* factors (see 3.16 and 3.17).

3.16
***Q* factor**
a dimensionless factor to estimate the increase of the average winding gradient due to the local increase of the additional loss

3.17
***S* factor**
a dimensionless factor to estimate the local increase of the average winding gradient due to the variation in the liquid flow stream

3.18
thermally upgraded paper
cellulose-based paper which has been chemically modified to reduce the rate at which the paper decomposes

A paper is considered as thermally upgraded if it meets the life criteria of the 50 % retention in tensile strength after 65 000 h in a sealed tube at 110 °C or any other time/temperature combination given by the equation:

$$\text{Time (h)} = 65\,000\,e^{\left(\frac{15\,000}{\theta_h + 273} - \frac{15\,000}{110 + 273}\right)} \qquad (1)$$

NOTE 1 Ageing effects are reduced either by partial elimination of water forming agents or by inhibiting the formation of water through the use of stabilizing agents.

NOTE 2 See IEC 60076-7, for an alternative test method based on the nitrogen content.

4 Cooling methods

4.1 Identification symbols

Transformers shall be identified according to the cooling method employed. For liquid-immersed transformers, this identification is expressed by a four-letter code as described below.

First letter: Internal cooling medium:

- O: mineral oil or synthetic insulating liquid with fire point ≤ 300 °C;

- K: insulating liquid with fire point > 300 °C;
- L: insulating liquid with no measurable fire point.

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 1 In this standard, the use of insulating liquids K and L is considered only for safety and environmental reasons.

NOTE 2 In a transformer designated as having forced directed insulating liquid circulation (second code letter D), the rate of liquid 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 liquid 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 liquid.

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

4.2 Transformers with alternative cooling methods

A transformer may be specified with alternative cooling methods. In this case, the specification and the rating plate shall then carry information about the power values at which the transformer fulfils the temperature rise limits when these alternatives apply, see IEC 60076-1.

The power value for the alternative cooling methods with the highest cooling capacity is the rated power of the transformer (or of an individual winding of a multi-winding transformer, see IEC 60076-1). The alternatives cooling methods are conventionally listed in rising order of cooling capacity.

Examples:

- ONAN/ONAF. The transformer has a set of fans which may be put into service as desired at high loading. The insulating liquid 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 rated power under natural cooling (for example, in case of failure or reduction of auxiliary power).

5 Normal cooling conditions

5.1 Air-cooled transformers

Normal ambient temperature limits for power transformers are given in IEC 60076-1.