



IEC 60310

Edition 5.0 2026-04

# INTERNATIONAL STANDARD

---

**Railway applications - Transformers and inductors on board rolling stock**

## CONTENTS

FOREWORD .....	5
1 Scope .....	7
2 Normative references .....	7
3 Terms, definitions and abbreviated terms .....	8
3.1 Terms and definitions.....	9
3.1.1 General definitions .....	9
3.1.2 Definitions for transformers.....	11
3.1.3 Definitions for inductors .....	11
3.1.4 Definitions of thermal endurance .....	12
3.1.5 Definitions of thermal endurance calculations .....	12
3.2 Abbreviated terms.....	13
4 Classification .....	13
4.1 General.....	13
4.2 Classification of transformers.....	15
4.3 Classification of inductors .....	16
5 Service conditions .....	16
6 Rated current and load profile .....	16
6.1 Load profile.....	16
6.2 Rated current.....	16
7 Rated voltage and power of transformer windings.....	17
7.1 Rated line-side voltage .....	17
7.2 Rated secondary voltage .....	17
7.3 Rated power of transformer.....	17
8 Transformer tapplings .....	17
9 Cooling.....	17
9.1 Identification of transformers and inductors according to cooling method .....	17
9.2 Arrangement of symbols .....	18
9.2.1 Enclosed transformers and inductors .....	18
9.2.2 Non-enclosed transformers and inductors .....	19
9.2.3 Air cooling .....	19
10 Temperature limits.....	19
10.1 Classification of insulating materials .....	19
10.2 Temperature limits of solid insulation .....	19
10.3 Temperature limits for liquid.....	20
10.4 Temperature limits for other parts .....	21
11 Mechanical design.....	21
12 Fire protection .....	21
13 Rating plates .....	21
13.1 General.....	21
13.2 Rating plates for transformer.....	22
13.3 Rating plates for inductor .....	22
14 Tests .....	22
14.1 Categories of tests.....	22
14.1.1 General .....	22
14.1.2 Type tests.....	23

14.1.3	Routine tests .....	23
14.1.4	Investigation tests.....	23
14.2	List of checks and tests .....	23
14.3	Tolerances.....	25
14.3.1	Tolerances for transformer .....	25
14.3.2	Tolerance for inductors .....	26
14.4	Test items .....	26
14.4.1	Visual checks .....	26
14.4.2	Functional tests .....	26
14.4.3	Mass .....	27
14.4.4	Measurement of winding resistance .....	27
14.4.5	Measurement of voltage ratio, polarities and vector groups.....	28
14.4.6	Measurement of impedance voltages or short-circuit impedances .....	28
14.4.7	Measurement of inductance .....	29
14.4.8	Measurement of no-load primary current and losses .....	32
14.4.9	Measurement of fundamental load losses .....	33
14.4.10	Determination of losses .....	33
14.4.11	Temperature-rise test .....	34
14.4.12	Insulation resistance test .....	39
14.4.13	Dielectric test .....	40
14.4.14	Partial discharge test.....	46
14.4.15	Short-circuit withstand test .....	48
14.4.16	Shock and vibration test .....	51
14.4.17	Vibration test with current flowing .....	52
14.4.18	Voltage Transmission Ratio (VTR).....	53
14.4.19	Noise measurement.....	54
14.4.20	Leakage magnetic flux density measurement.....	54
14.4.21	Electrical frequency response analysis (FRA).....	54
14.4.22	Inrush current measurement.....	54
Annex A (informative) List of items subject to agreement between purchaser and manufacturer, and list of information from purchaser or manufacturer .....		56
A.1	Items subject to agreement between purchaser and manufacturer .....	56
A.1.1	Transformers and inductors .....	56
A.1.2	Transformers .....	57
A.1.3	Inductors .....	58
A.2	Information from purchaser to manufacturer.....	59
A.2.1	Transformers and inductors .....	59
A.2.2	Transformers .....	60
A.2.3	Inductors .....	60
A.3	Information from manufacturer to purchaser.....	60
A.3.1	Transformers and inductors .....	60
A.3.2	Transformers .....	61
A.3.3	Inductors .....	61
Annex B (informative) Thermal ageing and insulation lifetime .....		62
B.1	Insulation lifetime and thermal ageing .....	62
B.2	Special considerations for thermal design and test.....	63
B.2.1	General .....	63
B.2.2	Cooling medium temperature at the external interface .....	63

B.2.3	Rated current.....	63
B.2.4	Temperature rise test of a dry-type transformer or inductor.....	64
B.3	Thermal conformity of the insulation system.....	64
B.4	End of life criterion.....	64
Annex C (informative)	Example of thermal endurance calculation to demonstrate the suitability of an insulation system for a specified application .....	65
C.1	Preliminary .....	65
C.2	Example 1 – Temperature limits for a dry-type transformer or inductor.....	65
C.3	Example 2 – Thermal endurance calculation .....	65
C.3.1	General .....	65
C.3.2	Operating conditions to be provided by the purchaser.....	66
C.3.3	Thermal endurance characteristics to be provided by the manufacturer .....	66
C.3.4	Temperature rise test results .....	66
C.3.5	Calculations.....	67
Annex D (informative)	Wet dielectric tests for dry-type transformers and inductors .....	69
D.1	General.....	69
D.2	Wet test 1 (optional type test or optional routine test): short soaking.....	69
D.3	Wet test 2 (investigation test or optional type test): misting.....	70
D.4	Wet test 3 (investigation test): thermal shock – long soaking – misting .....	70
D.4.1	General .....	70
D.4.2	Temperature conditioning .....	70
D.4.3	Thermal shock.....	70
D.4.4	Dielectric test .....	70
D.5	Common test procedure and criteria for wet dielectric tests .....	70
Annex E (informative)	Load profiles .....	72
Annex F (informative)	Background of reference temperature and dielectric test voltage in IEC 60310.....	73
F.1	General.....	73
F.2	Reference temperature .....	73
F.3	Dielectric test voltage .....	73
Bibliography.....		75
Figure 1 – Traction transformer with auxiliary windings fed by AC power supply system .....		14
Figure 2 – Traction transformer without auxiliary windings fed by AC power supply system.....		14
Figure 3 – DC locomotive typical circuit diagram.....		15
Figure 4 – Energy storage system typical circuit diagram.....		15
Figure 5 – Examples of set up for induced voltage withstanding tests .....		43
Figure 6 – Examples of set up for separate source voltage withstanding tests .....		43
Figure 7 – Examples of impulse test connections for traction, inductor and auxiliary transformers .....		44
Figure 8 – Partial discharge test: voltage versus time .....		47
Figure 9 – Configurations for VTR test.....		53
Figure 10 – Example of test circuit.....		55
Table 1 – Letter symbols for cooling method.....		18
Table 2 – Order of symbols.....		18

Table 3 – Temperature limits of solid insulation .....	20
Table 4 – Temperature limits for liquid .....	20
Table 5 – List of checks and tests to be made on transformers or inductors .....	24
Table 6 – Tolerances for transformer .....	25
Table 7 – Tolerances for inductors .....	26
Table 8 – Reference temperatures .....	27
Table 9 – Dielectric test voltage .....	41
Table 10 – Test method of voltage between terminals withstand test .....	45
Table 11 – Partial discharge measurements .....	47
Table C.1 – Temperature limits and expected lifetime for a dry-type transformer or inductor (examples) .....	65
Table C.2 – Load cycle histogram .....	66
Table C.3 – Temperature histogram .....	66
Table C.4 – Temperature rise test results .....	67
Table C.5 – Thermal endurance calculation .....	67
Table C.6 – Equivalent current and temperatures .....	68
Table F.1 – Reference temperatures in IEC 60310:2016 .....	73
Table F.2 – Dielectric test voltage in IEC 60310:2016 .....	74

INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

**Railway applications -  
Transformers and inductors on board rolling stock**

**FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60310 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2016. This edition constitutes a technical revision.

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

- a) typical circuits for transformer and inductors are added;
- b) letter symbols for cooling methods are added;
- c) dielectric test table is modified;
- d) subclauses for the tests of transformers and inductors are restructured;

- e) temperature test for dry type transformer and dry type inductors are separated in different subclauses;
- f) requirements for shock and vibration tests are updated according to IEC 61373:20—.

The text of this International Standard is based on the following documents:

Draft	Report on voting
9/3296/FDIS	9/3322/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://www.iec.ch/publications).

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

## 1 Scope

This document specifies the terms and definitions, classification, service conditions, characteristics and test methods for transformers and inductors on board rolling stock.

This document is applicable to traction and auxiliary power transformers installed on board rolling stock and to the various types of power inductors inserted in the traction and auxiliary circuits of rolling stock, of dry or liquid-immersed design.

This document is also applicable to the traction transformers of three-phase AC line-side powered vehicles and to the transformers inserted in the single-phase or polyphase auxiliary circuits of vehicles, after agreement between purchaser and manufacturer.

This document does not apply to instrument transformers, transformers of a rated output below 1 kVA single-phase or 5 kVA poly-phase, and inductors of a rated output below 1 kVAR single-phase or 5 kVAR poly-phase on board rolling stock.

This document does not cover accessories such as tap changers, resistors, heat exchangers, fans, etc., intended for mounting on transformers or inductors, which are tested separately according to the relevant rules.

NOTE Items requiring agreement between the delivery parties and items of supplementary information and specification particulars to be provided by the ordering party or manufacturer are given in Annex A.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60076-1:2011, *Power transformers - Part 1: General*

IEC 60076-2, *Power transformers - Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-3, *Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5, *Power transformers - Part 5: Ability to withstand short circuit*

IEC 60076-6:2007, *Power transformers - Part 6: Reactors*

IEC 60076-10, *Power transformers - Part 10: Determination of sound levels*

IEC 60076-12:2008, *Power transformers - Part 12: Loading guide for dry-type transformers*

IEC 60076-18, *Power transformers - Part 18: Measurement of frequency response*

IEC 60296, *Fluids for electrotechnical applications - Mineral insulating oils for electrical equipment*

IEC 60836, *Specifications for unused silicone insulating liquids for electrotechnical purposes*

IEC 60850, *Railway applications - Supply voltages of traction systems*

## Bibliography

IEC 60050-151:2001, *International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices*

IEC 60050-212:2010, *International Electrotechnical Vocabulary (IEV) - Part 212: Electrical insulating solids, liquids and gases*

IEC 60050-411:1996/AMD1:2007, *International Electrotechnical Vocabulary (IEV) - Part 411: Rotating machinery*

IEC 60050-421, *International Electrotechnical Vocabulary - Part 421: Power transformers and reactors*

IEC 60050-426:2020, *International Electrotechnical Vocabulary (IEV) - Part 426: Explosive atmospheres*

IEC 60050-811, *International Electrotechnical Vocabulary (IEV) - Part 811: Electric traction*

IEC 60060-1, *High-voltage test techniques - Part 1: General terminology and test requirements*

IEC 60060-2, *High-voltage test techniques - Part 2: Measuring systems*

IEC 60076-4, *Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors*

IEC 60076-7, *Power transformers - Part 7: Loading guide for mineral-oil-immersed power transformers*

IEC 60076-11:2018, *Power transformers - Part 11: Dry-type transformers*

IEC 60076-14, *Power transformers - Part 14: Liquid-immersed power transformers using high-temperature insulation materials*

IEC 60077-1, *Railway applications - Electric equipment for rolling stock - Part 1: General service conditions and general rules*

IEC 60085, *Electrical insulation - Thermal evaluation and designation*

IEC 60216-1, *Electrical insulating materials - Thermal endurance properties - Part 1: Ageing procedures and evaluation of test results*

IEC 60216-5, *Electrical insulating materials - Thermal endurance properties - Part 5: Determination of relative temperature index (RTI) of an insulating material*

IEC 60270, *High-voltage test techniques - Charge-based measurement of partial discharges*

IEC 60505, *Evaluation and qualification of electrical insulation systems*

IEC 61287-1, *Railway applications - Power converters installed on board rolling stock - Part 1: Characteristics and test methods*

EN 45545 (all parts), *Railway applications - Fire protection on railway vehicles*

IEEE C 57.12.91, *IEEE Standard Test Code for Dry-Type Distribution and Power Transformers*

