IEC 60077-1

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REDLINE VERSION

INTERNATIONAL STANDARD

Railway applications – Electric equipment for rolling stock –
Part 1: General service conditions and general rules

colour inside

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Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RAILWAY APPLICATIONS – ELECTRIC EQUIPMENT FOR ROLLING STOCK –

Part 1: General service conditions and general rules

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60077-1 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition of IEC 60077-1, issued in 1999. It constitutes a technical revision.

This edition includes the following main technical changes with regard to the previous edition:

a) Descriptions regarding insulation coordination, environmental conditions and those of current return and protective bonding are deleted and replaced by references to IEC 62497-1, IEC 62498-1 and IEC 61991, except classes of air temperature, which are copied from Table 2 in IEC 62498-1:2010.
b) Classification of equipment type is introduced.
c) Temperature limits and temperature rise tests are reviewed.
d) Example of lifetime calculation: Annex C (informative) is introduced.

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

FDIS	Report on voting
9/2266/FDIS	9/2278/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 in the IEC 60077 series, published under the general title *Railway applications – Electric equipment for rolling stock*, can be found 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 website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

INTRODUCTION

Although this document specifies the general service conditions and general rules for electric equipment for railway rolling stock, further special details of for certain types of traction electric equipment may be given in other IEC standards. In particular, product standards give further details and the product standards to be part of the traction series are

IEC 60077: *Railway applications – Electric equipment for rolling stock*

IEC 60077 series consists of the following parts:

- Part 1 – General service conditions and general rules
- Part 2 – Electrotechnical components – General rules
- Part 3 – Electrotechnical components – Rules for DC circuit-breakers
- Part 4 – Electrotechnical components – Rules for AC circuit-breakers
- Part 5 – Electrotechnical components – Rules for HV fuses

Although all circuits of power or control electronic equipment connected to battery or contact line voltages, and all circuits comprising switchgear or controlgear are covered by this document, internal circuits of these may be subject to special requirements covered by relevant product standards.

For electric equipment for rolling stock which conforms to an appropriate international standard, including items of industrial equipment, this document, plus the relevant railway equipment product standard for electric equipment where appropriate, specifies only those additional requirements to ensure satisfactory operation on rolling stock.

**RAILWAY APPLICATIONS –
ELECTRIC EQUIPMENT FOR ROLLING STOCK –**

Part 1: General service conditions and general rules

1 Scope ~~and object~~

This part of IEC 60077 specifies the general service conditions and requirements for all electric equipment installed in power circuits, auxiliary circuits, control and indicating circuits etc., on railway rolling stock.

NOTE Some of these rules ~~may~~ can, after agreement between the user and the manufacturer, be used for electrical equipment installed on ~~other~~ vehicles other than railway rolling stock, such as mine locomotives, trolley buses, etc.

The purpose of this document is to harmonize as far as practicable all rules and requirements of a general nature applicable to electric equipment for rolling stock. This is in order to obtain uniformity of requirements and tests throughout the corresponding range of equipment to avoid the need for testing to different standards.

All requirements relating to:

- the environmental stresses expected during the normal service conditions;
- the construction;
- the performance and the associated tests which can be considered as general;

have therefore been gathered in this document together with specific subjects of wide interest and application, for example temperature rise, dielectric properties, etc.

In the event of there being a difference in requirements between this document and a railway rolling stock relevant product standard, then the product standard requirements take precedence.

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 60050(151):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*~~

~~IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*~~

~~IEC 60050(811):1991, *International Electrotechnical Vocabulary (IEV) – Chapter 811: Electric traction*~~

~~IEC 60056:1987, *High-voltage alternating-current circuit-breakers*~~

IEC 60068-2-1~~:1990~~, *Environmental testing – Part 2-1: Tests – Tests A: Cold*

IEC 60068-2-2~~:1974~~, *Environmental testing – Part 2-2: Tests – Tests B: Dry heat*

~~IEC 60068-2-3:1969, *Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state*~~

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-52~~:1996~~, *Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

~~IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*~~

IEC 60085~~:1984~~, *Electrical insulation – Thermal evaluation and ~~classification of electrical insulation~~ designation*

~~IEC 60112:1979, *Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions*~~

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

~~IEC 60364-4-41:1992, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 41: Protection against electric shock*~~

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

IEC 60529~~:1989~~, *Degrees of protection provided by enclosures (IP Code)*

~~IEC/TR 60536:1976, *Classification of electrical and electronic equipment with regard to protection against electric shock*~~

~~IEC 60587:1984, *Test method for evaluating resistance to tracking and erosion of electrical insulating materials used under severe ambient conditions*~~

~~IEC 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*~~

IEC 60721-3-5~~:1997~~, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 5: Ground vehicle installations*

IEC 60850~~:1988~~, *Railway applications – Supply voltages of traction systems*

IEC 61133:~~1992~~ 2016, ~~*Electric traction*~~ *Railway applications – Rolling stock – Testing ~~methods for electric and thermal/electric~~ of rolling stock on completion of construction and before entry into service*

IEC 61373~~:1999~~, *Railway applications – Rolling stock equipment – Shock and vibration tests*

IEC 61991, *Railway applications – Rolling stock – Protective provisions against electrical hazards*

IEC 61992-1, *Railway applications – Fixed installations – DC switchgear – Part 1: General*

IEC 62236-3-2, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

IEC 62497-1, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

IEC 62498-1:2010, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*

3 Terms, definitions and abbreviated terms (see also Annex A)

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 General

3.1.1
rolling stock
~~general term covering~~ all the vehicles with or without motors

Note 1 to entry: Examples of vehicles include a locomotive, a coach and a wagon.

[SOURCE: IEC 60050-811:2017, 811-02-01]

3.1.2
vehicle
~~general term denoting any~~ single item of rolling stock~~, e.g. a locomotive, a coach or a wagon~~

~~[IEV 811-02-02]~~

3.2 Circuits

3.2.1
power circuit
circuit carrying the current of the machines and equipment, such as the converters and traction motors, which transmit the traction output

[SOURCE: IEC 60050-811:2017, 811-25-03]

3.2.2
main circuit
all the conductive parts of a device carrying the current for the function to which this device has been applied

3.2.3
auxiliary circuit, <of a train>
circuit carrying the current of the auxiliaries such as the compressors and fans

[SOURCE: IEC 60050-811:2017, 811-25-05]

3.2.4
control circuit, <of a train>
circuit used to actuate the power or auxiliary equipment

[SOURCE: IEC 60050-811:2017, 811-25-12]

3.2.5
indicating circuit
circuit transmitting a signal indicating or recording whether a particular operating condition exists or not (for example a signal indicating a failure in the electrical equipment)

[SOURCE: IEC 60050-811:2017, 811-25-14]

3.3 Battery supplied equipment

3.3.1
battery
electrochemical system capable of storing in chemical form the electric energy received and which can give it back by reconversion

~~[IEV 811-20-01]~~

3.3.2
battery on float <charge>
secondary battery whose terminals are permanently connected to a source of constant voltage sufficient to maintain the battery approximately fully charged, and which is intended to supply power to an electric circuit, if the normal supply is temporarily interrupted

Note 1 to entry: The battery is absorbing a float charge current in this mode.

[SOURCE: IEC 60050-482:2004, 482-05-35, modified – Note 1 to entry has been added.]

3.3.3
float charge battery system
equipment mostly operated with the battery on float charge

3.3.4
battery off charge system
equipment mostly supplied while the battery is not being charged

3.4 Test categories

3.4.1
type test
~~test of one or more devices made to a certain design to show that the design meets certain specifications~~
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-811:2017, 811-10-04]

3.4.2
routine test
~~a test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria~~
conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-811:2017, 811-10-05]

3.4.3
sampling test
test on a number of devices taken at random from a batch a sample

[SOURCE: IEC 60050-811:2017, 811-10-06]

3.4.4
investigation test
special test of an optional character carried out in order to obtain additional information

[SOURCE: IEC 60050-811:2017, 811-10-07]

3.4.5
exposed conductive part
conductive part which can readily be touched and which is not normally alive, but which may become alive under fault conditions

[SOURCE: IEC 60050-441:1984, 441-11-10, modified – Note has been deleted.]

3.5 Characteristic quantities

3.5.1
limiting value
greatest or smallest admissible value of a quantity in a specification of a component, device, equipment, or system

[IEV 151-04-02]

[SOURCE: IEC 60050-151:2001, 151-16-10, modified – The order of phrases has been changed.]

3.5.2
nominal value
suitable approximate quantity value used to designate or identify a characteristic of a component, device or equipment
value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The nominal value is generally a rounded value.

Note 2 to entry: In this document, the term "nominal" is used only as common practice to designate contact line and battery voltage circuits.

[SOURCE: IEC 60050-811:2017, 811-11-01, modified – Note 2 to entry has been added.]

3.5.3
rated value
quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-811:2017, 811-11-02]

3.6.4
working voltage
highest r.m.s. value of the a.c. voltage or the highest value of the d.c. voltage which may occur (locally) across any insulation at rated supply voltage, transients being disregarded, in open-circuit conditions or under normal operating conditions

NOTE – The working voltage of an internal part of an equipment may be different from the supply voltage, for example if:

– a part of an equipment is considered (after transformer, converter);
– the circuit conductor is not directly connected to the vehicle structure;
– the voltage is a part of supply voltage (components in series);
– secondary insulation or double insulation is considered.

3.5.4
equivalent continuous duty
duty of electrical equipment on rolling stock, which corresponds to the actual service, generally characterized by values of current, voltage, compressed air pressure, etc., which vary with time

Note 1 to entry: The various parts of the equipment are defined by a complete statement of the conditions to be fulfilled. However, it is sometimes sufficient to specify an equivalent duty which corresponds from the point of view of either electrical, mechanical or thermal stresses to the service considered, and is known as being equivalent to the actual service. It is the equivalent continuous duty to which the relevant tests are referred.

3.5.5
equivalent continuous rated current
current corresponding to the equivalent continuous duty

3.6.7
equivalent continuous rated voltage
voltage corresponding to the equivalent continuous duty

3.6 Terms related to lifetime

3.6.1
ageing
change with passage of time of physical, chemical or electrical properties of a component or module under specified operating conditions, which may result in degradation of significant performance characteristics

Note 1 to entry: This entry was numbered 393-18-41 in IEC 60050-393:2003.

[SOURCE: IEC 60050-395:2014, 395-07-100]

3.6.2
endurance
ability to withstand the action of ageing factors

Note 1 to entry: The endurance may be characterized by the results of accelerated ageing tests.

[SOURCE: IEC 60050-212:2010, 212-12-08]

3.6.3
thermal endurance
ability to withstand the action of temperature

[SOURCE: IEC 60050-212:2010, 212-12-09]

3.6.4
durability
ability to perform as required, under given conditions of use and maintenance, until the end of useful life

Note 1 to entry: For the purpose of this document, "durability" is used in order to express the expectancy of the life duration (time or number of operating cycles) which can be performed by the equipment before repair or replacement of parts.

[SOURCE: IEC 60050-192:2015, 192-01-21, modified – Note 1 to entry has been added.]

~~**3.7 Insulations**~~

~~**3.7.1**~~
~~**functional insulation**~~
~~insulation between conductive parts which is necessary only for the proper functioning of the equipment~~

~~**3.7.2**~~
~~**basic insulation**~~
~~insulation of live parts to provide basic protection against electric shock (human safety)~~

~~NOTE – Basic insulation does not necessarily include insulation used exclusively for functional purposes (see 2.1 of IEC 60536).~~

~~**3.7.3**~~
~~**supplementary insulation**~~
~~independent insulation applied in addition to basic insulation, in order to provide protection against electric shock in the event of a failure of basic insulation [IEC 60536, 2.2]~~

~~**3.7.4**~~
~~**reinforced insulation**~~
~~single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant IEC standard [IEC 60536, 2.4]~~

~~NOTE – A single insulation system does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as basic or supplementary insulation.~~

~~**3.7.5**~~
~~**double insulation**~~
~~two-stage insulation, the first being between the live conductors and an intermediate frame and the second between the intermediate frame and the body of the vehicle [IEV 811-27-15]~~

3.7 Abbreviated terms

AC Alternating Current
DC Direct Current
EMC Electromagnetic Compatibility
RMS Root Mean Square value
PD Pollution degree
OV Overvoltage category
VC Voltage Class

4 Classification

This clause is intended to list the characteristics of equipment on which information may be given by the manufacturer and which ~~may not necessarily have to~~ shall be verified by testing where relevant.

~~This clause is not mandatory in product standards which should however leave space for it in order to list, where necessary, classification criteria.~~

Equipment covered by this document is classified, according to the supply source of its control and auxiliary circuits. Details are given in 5.3.3.2.

5 Characteristics of the utilization category

5.1 General

The utilization category of equipment defines the intended application and shall be specified in the relevant product standard; it is characterized by one or more of the following parameters:

- current(s);
- voltage(s);
- frequency(ies);
- air pressure(s).

See also Annex A.

NOTE This list is not exhaustive and can include other parameters as applicable.

5.2 Rated voltages

5.2.1 General

The term rated voltage can generally be related to both the input and output values of equipment. The quantity is assigned generally by the manufacturer.

5.2.2 Rated operational voltage (~~U_e~~ U_r)

The rated operational voltage of equipment is a value of voltage which combined with a rated operational current and rated operational frequency, determines the application of the equipment and to which the relevant tests and the utilization categories are referred.

NOTE Symbol U_e was used in the first edition of IEC 60077-1. U_{Ne} is used in IEC 61992-1.

5.2.3 Rated insulation voltage (~~U_i~~ U_{Nm})

Definition of a rated insulation voltage is given in IEC 62497-1.

The rated insulation voltage is the value of voltage to which ~~dielectric tests~~ rated impulse voltage and creepage distances are referred.

~~In no case shall the maximum value of the working voltage or the rated operational voltage exceed that of the rated insulation voltage.~~

~~The rated insulation voltage is at least equal to the highest r.m.s. value of the voltage existing between electrodes and across the creepage distance for an extended period of time e.g. for a contact line greater than 5 mm. Non-repetitive transient voltages are neglected.~~

When the voltage is not purely of sinusoidal or of continuous form, the RMS or mean value alone cannot be considered to prescribe the rated insulation voltage of the components.

In the absence of any knowledge of the influence on dielectric strength of:

- the ratio between the duration of periodic impulses and their ~~occurrence~~ repetition period;
- the number of impulses during each ~~occurrence~~ burst;
- the voltage rate of rise of the impulse (dv/dt),

it is recommended that this voltage be considered as being equal to the real RMS value, but not less than 70 % of the peak value.

5.2.4 ~~Rated~~ Power-frequency ~~withstand~~ test voltage (~~U_{50}~~ U_a)

The ~~rated~~ power-frequency ~~withstand~~ test voltage is the RMS value of power-frequency sinusoidal voltage which does not cause an insulation failure under specified conditions of test.

U_a is given in IEC 62497-1.

5.2.5 Rated impulse ~~withstand~~ voltage (~~U_{imp}~~ U_{Ni})

~~The rated impulse withstand voltage is the highest peak value of an impulse voltage, of prescribed form and polarity, the equipment is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred (U 1,2/50 µs).~~

~~The rated impulse withstand voltage of the equipment shall be equal to or higher than the values stated for the transient overvoltages occurring in the circuit in which the equipment is fitted.~~

Definition of a rated impulse voltage is given in IEC 62497-1.

The rated impulse voltage is used for determining minimum required clearances and dielectric test voltages.

5.3 Rated voltages for electric equipment

5.3.1 ~~Supply from~~ Equipment supplied by a contact line

The rated operational voltage ~~U_e~~ (U_r) for equipment supplied from the contact line is the ~~greatest~~ highest permanent ~~value~~ voltage (U_{max1}) of the contact line voltage as defined by IEC 60850.

5.3.2 ~~Supply from~~ Equipment supplied by a transformer

The rated operational voltage ~~U_e~~ (U_r) for equipment supplied from a winding of a transformer is equal to the RMS voltage at the terminals of the winding when the transformer primary is supplied at the rated operational voltage. If a second transformer is interposed between the above-mentioned transformer and the equipment, the rated operational voltage ~~U_e~~ (U_r) is equal to the above-mentioned rated operational voltage multiplied by the transformer ratio of the second transformer.

~~**5.2.3 Supply from an independently driven generator/alternator or converter**~~

~~The rated operational voltage U_e for equipment supplied from an independently driven generator/alternator or converter is the greatest limiting voltage of this supply.~~

~~**5.2.4 Supply from a float charged battery**~~

~~The nominal voltage U_n which is only used to designate a battery circuit and the equipment so supplied shall be selected from amongst the following preferred values:~~

~~24 V 48 V 72 V 96 V 110 V~~

~~NOTE 2 – A battery of 26,5 V nominal voltage may be used to supply equipment of 24 V nominal voltage. In this case, compliance with the requirements should be defined by agreement between the manufacturer and the user.~~

~~The rated operational voltage U_e for the equipment supplied from a float charged battery is equal to 1,15 U_n.~~

~~NOTE – This value is considered as being the greatest limiting value of the charging device in normal operation.~~

5.2.5 Supply from a battery

The rated operational voltage U_e of equipment supplied only from a battery is equal to 1,1 U_n. This is the voltage at the terminals of the fully charged battery supplying the equipment with the current at a rating agreed as being appropriate to its type and operating conditions.

NOTE – The battery is used only on discharge i.e. never during charging.

5.3.3 Equipment supplied by DC low voltage sources

5.3.3.1 Nominal voltages

This subclause applies to the equipment supplied from the voltage bands I and band II according to IEC 61991.

The nominal voltage (U_n) is only used to designate the circuits and the equipment and should be selected from the following preferred values:

24 V, 72 V or 110 V

Other voltages may be used upon agreement between the user and the manufacturer.

NOTE These nominal voltage values are given only as standardizing values for the design of the equipment. They should are not be considered as the off-load battery voltage which will be determined as functions of the type of battery, the number of cells and the operating conditions.

5.3.3.2 Voltage ranges

Equipment covered by this document is classified as follows, according to the supply source of its control and auxiliary circuits:

- type VC1: equipment supplied by a float charge battery system;
- type VC2: equipment supplied by a battery off charge system;
- type VC3: equipment not supplied directly by an onboard battery, but supplied by e.g. a generator, alternator or electronic converter.

Table 1 shows the voltage ranges and rated operational voltage (U_r) for control circuit and auxiliary circuit for each equipment type. The values for Type VC3 are valid for a stabilized voltage source.

Table 1 – Voltage ranges for control circuits and auxiliary circuits

Classification	Minimum equipment voltage	Rated operational voltage (U_r)	Maximum equipment voltage
Type VC1	0,7 U_n	1,15 U_n	1,25 U_n
Type VC2	0,7 U_n	1,1 U_n	1,25 U_n
Type VC3	0,85 U_n	1,0 U_n	1,1 U_n

NOTE 1 Basically the battery for Type VC1 equipment is used in charging mode. The voltage can be lower than the float voltage for short periods of time, e.g. before starting the charging equipment, during the battery voltage buildup or during the contact line interruption.

NOTE 2 Basically the battery for Type VC2 equipment is used in discharging mode. The battery voltage will reduce over time.

NOTE 3 The voltage of Type VC3 equipment is not the voltage supplying the generator, alternator or electronic converter itself.

NOTE 4 Voltage range of Type VC1 and Type VC2 is same, but the evolution of the voltage during operation is different regarding the lifetime of the equipment.

NOTE 5 The rated operational voltage is used for calculation of losses, power consumption, temperature rise, etc.

5.4 Rated currents for equipment

5.4.1 Rated operational current (~~I_e~~ I_r)

The rated operational current of equipment is stated by the manufacturer and takes into account the rated operational voltage and rated operational frequency.

5.4.2 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of equipment is the value of short-time withstand current assigned to the equipment by the manufacturer that the equipment can carry without damage~~, under the test conditions specified in the relevant product standard~~.

The rated duration (t_{cw}) of equipment used is the value of the interval of time for which switchgear and controlgear can carry, in the closed position, a current equal to its rated short-time withstand current.

5.5 Rated operational frequency (f_r)

The rated operational frequency of equipment is stated by the manufacturer and takes into account the rated operational voltage.

5.6 Rated air pressure

The rated pressure of the air supply to pneumatic or electro-pneumatic equipment is the greatest limiting value of the range of the regulating device and to which the relevant tests are referred.

6 Product information

6.1 Nature of information

The following information shall be given by the manufacturer for each item of the electric equipment when required by the relevant product standard:

a) identification

- manufacturer's name or trade mark;
- type designation or serial number;
- modification status;
- reference of the relevant product standard, if the manufacturer declares compliance with it.

b) characteristics

The following list is not exhaustive and should be applied as appropriate:

- rated operational voltage(s);
- rated insulation voltage;
- rated impulse ~~withstand~~ voltage;
- rated operational current(s) at the rated operational voltage(s);
- rated operational frequency(ies);
- maximum current consumption or maximum power consumption;
- number of operations for mechanical and electrical durability with reference to the relevant product standard;

– rated performance in overload and/or fault conditions with reference to the relevant product standard;
– IP code in the case of enclosed equipment (according to IEC 60529);
– degree of pollution acceptable for the equipment (according to 7.9);
– rated voltage(s), rated frequency(ies) and rated current(s) of the control circuit(s);
– rated air pressure and pressure variation limits (for equipment with pneumatic control);
– overall dimensions;
– minimum size of the enclosure and, if applicable, data concerning ventilation, to which the rated characteristics apply;
– minimum distance between the equipment and its enclosure;
– minimum distance between the equipment and the metal parts connected to the vehicle structure for equipment which are intended for use without an enclosure;
– weight.

Some of this information may be supplemented by the value of the ambient air temperature at which the equipment was calibrated.

6.2 Marking

All relevant information, as detailed in 6.1, which is to be marked on the equipment, shall be specified in the relevant product standard.

The following markings on the equipment are mandatory:

– manufacturer's name or trade mark,
– type designation,
– serial number or date or code of manufacture.

These are preferably marked on the nameplate, if any, in order to permit the complete data to be obtained from the manufacturer (traceability). The markings shall be indelible and easily legible.

6.3 Instructions for storage, installation, operation and maintenance

The manufacturer shall specify in his documents or catalogues the instructions, if any, for storage, installation, operation and maintenance of the equipment during operation and after a fault.

If necessary, the instructions for the storage, transport, installation and operation of the equipment shall indicate the measures that are of particular importance for the proper and correct installation, commissioning and operation of the equipment.

These documents shall indicate the recommended extent and frequency of maintenance, if any.

~~NOTE~~ ~~All~~ Equipment covered by this document ~~is~~ may not necessarily be designed to be maintained.

7 Normal service conditions

7.1 General

This clause defines environmental conditions stated in IEC 60721-3-5 which are to be considered as normal service conditions unless otherwise defined. In the event of other conditions applying these should be selected from IEC 60721-3-5 if appropriate.

Clause 7 defines service conditions. Some of service conditions are stated in IEC 62498-1:2010 and some others are taken from other stated references. In the event of other environmental conditions applying these should be selected from IEC 62498-1:2010 and, if conditions in IEC 62498-1:2010 are insufficient, those should be selected from IEC 60721-3-5 if appropriate.

The following list is not exhaustive and IEC 62498-1:2010 and IEC 60721-3-5 give further parameters.

The normal service conditions are a combination of environmental, operational and installation conditions.

7.2 Altitude

The altitude at which the equipment is normally to function does not exceed 1 400 m.

The equipment is normally to function in the specified altitude range. Class A1 of altitude range as given in IEC 62498-1:2010 shall apply, unless otherwise specified.

NOTE For installation at higher altitudes, it is necessary to take into account the reduction of the dielectric strength and of the cooling effect of the air. The equipment so used should be designed or used according to an agreement between the user and the manufacturer.

NOTE Regarding the reduction of the cooling effect of the air with altitude, the higher temperature rise at higher altitude is usually compensated by the reduced maximum ambient temperature at higher altitude. Guidance can be found, for example, in 5.1 of IEC TR 60943:1998/ AMD1:2008.

7.3 Temperature

The climatic ambient temperatures are derived from IEC 60721-3-5 class 5K2 which has a range from –25 °C to +40 °C.

Where ambient temperatures lie outside this range, then they shall be agreed between the user and the manufacturer.

Where equipment is surrounded by air at a temperature above ambient air temperature because of enclosure, adjacent heat sources or solar effects, it shall be adequately rated for such elevated temperature.

Usually, a reference temperature T_r = 25 °C is considered as being the permanent temperature for which the effects on the insulating material ageing are equivalent to those of the climatic temperature during the lifetime.

NOTE – Storage temperatures are not considered as normal service conditions unless they have been stated.

7.3.1 Ambient air temperature (T_a)

The determination of temperature-rise limits shall be based on the reference temperature T_r = 25 °C given in 7.3.

The ambient air shall be considered as being that surrounding the device, and will differ according to the location where the device is fitted.

~~For external locations, the ambient air temperature T_a is the reference temperature T_r.~~

The class of ambient temperature, at which the electric equipment will operate, shall be given according to Table 2, unless otherwise specified. Class T1 shall apply, unless otherwise specified.

For internal locations, the ambient air temperature (T_a) is the ~~reference~~ external ambient temperature increased by the air temperature rise due to the localized thermal losses after taking into consideration the normal conditions of cooling.

Table 2 – Classes of air temperatures

Classes (Typical application area)	Air temperature external to vehicle °C	Inside vehicle compartment temperature °C	Inside cubicle temperature °C
T1 (e.g. middle Europe)	–25 +40	–25 +50	–25 +70
T2 (e.g. northern Europe)	–40 +35	–40 +45	–40 +65
T3 (e.g. southern Europe)	–25 +45	–25 +55	–25 +70
T4 (mild climate area in mid-latitude)	–10 +40	–10 +50	–10 +70
T5 (tropical area except desert)	+5 +45	+5 +55	+5 +70
T6 (tropical area in desert)	–20 +55	–20 +65	–20 +75
TX	–40 +50	–40 +60	–40 +75

NOTE 1 This Table is derived from IEC 62498-1:2010, Table 2.

NOTE 2 Storage temperatures are not considered as normal service conditions unless they have been stated.

For each of the various internal parts of the car body, engine compartment, cubicle, box etc. the air temperature rise may be different. When this value is neither specified by a relevant document nor known it shall be considered that it does not exceed 30 K during functioning. ~~The ambient air temperature considered is then T_a = 55 °C (25 °C + 30 K), and thus the maximum temperature expected may be 70 °C (40 °C + 30 K).~~

~~NOTE – If the components used in these internal locations have been designed for T_a = 25 °C, their performance needs to be derated.~~

If the devices are used in a higher average ambient temperature than that designed, their performance needs to be derated.

For altitude class AX in IEC 62498-1:2010, the dependency between altitude and temperature shall be provided by the user through a temperature distribution for each relevant range (e.g. 0 m to 1 000 m and 1 000 m to 2 000 m).

7.3.2 Reference temperature

A reference temperature (T_r) (equivalent continuous surrounding air temperature or cooling medium temperature) is considered as being the permanent temperature for which the effects on material ageing are equivalent to those of the service temperature during the lifetime. It can be used for lifetime and reliability calculation.

a) Either, it shall be taken as 25 °C for exterior location according to Class TR2 of Table 3 in IEC 62498-1:2010, unless otherwise specified;
b) or, it shall be taken as 30 K increase to external reference temperature for interior location unless otherwise specified;
c) or it may be calculated by the manufacturer on the basis of the temperature distribution provided by the purchaser.

NOTE 1 Thermal ageing is an exponential function of temperature (e.g. see IEC 60216 for insulating materials), i.e. the reference temperature is usually higher than the arithmetic mean temperature.

NOTE 2 For interior locations, the temperature distribution depends strongly on the load and the related heat dissipation.

7.4 Humidity

~~The following conditions are derived from IEC 60721-3-5, class 5K2.~~

~~Relative humidity 95 % at 40 C without temperature variation.~~

~~Relative humidity of 95 % associated with rapid variations of temperatures between –25 °C to +30 C, maximum absolute humidity being 30 g/m^3.~~

Humidity is defined in IEC 62498-1:2010, 4.4.

7.5 Biological conditions

Risks of biological attack as defined in IEC 60721-3-5, class 5B2.

7.6 Chemically active substances

Chemically active substances are present as defined in IEC 60721-3-5, class 5C2 for salinity or other chemical substances. Cleaning products shall be specified by the purchaser.

7.7 Mechanically active substances

Mechanically active substances are present as defined in IEC 60721-3-5, class 5S2.

7.8 Vibration and shock

Equipment is submitted to vibration and shock throughout the range of frequencies and acceleration levels experienced in service as required in IEC 61373.

7.9 Exposure to pollution

According to its location the equipment is exposed to various levels of pollution.

~~Pollution must be taken into account in the design of electrical equipments and components, and in particular for clearances and creepages, when the position and orientation are such that deposition of dust, dirt, water etc. is likely to occur in a manner to reduce the clearance and creepage distances.~~

~~Small clearances and creepages can be bridged completely by solid particles, dust and water and therefore minimum clearance and creepage distances are specified. Means may be provided to reduce the influence of pollution on the clearance and creepage under consideration by effective use of enclosure, encapsulation or hermetic sealing.~~

~~The influence of pollution on dielectric performance is classified in four pollution degrees as given below.~~

~~**a) Pollution degree PD1**~~

~~No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.~~

~~NOTE – The use of this pollution degree is not recommended for rolling stock without appropriate sealing such as IP65 according to IEC 60529.~~

~~**b) Pollution degree PD2**~~

~~Normally only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation is to be expected when the equipment is out of operation.~~

~~Example: Location in an enclosure ensuring an efficient protection against pollution, at least equivalent to IP54 according to IEC 60529.~~

~~**c) Pollution degree PD3**~~

~~Conductive pollution or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.~~

~~Example: Indoor location not directly exposed to rain, snow and heavy dust.~~

~~**d) Pollution degree PD4**~~

~~The pollution generates persistent conductivity.~~

~~Example: Outside of vehicles, roofs, underframe, etc.~~

~~NOTE – If the thickness/size of pollution can become significant, the minimum clearance and creepage distances should be raised to a suitable level.~~

Pollution degree (PD) is classified as PD1 to PD4 and shall be taken into account for determining clearance and creepage distances. Details are given in IEC 62497-1.

7.10 Exposure to overvoltages

The electrical equipment is exposed to overvoltages from the external supply network or generated by the equipment itself, for example switching transients, lightning, etc. Their levels are different according to the part of the equipment considered.

~~Overvoltages need to be taken into account in the design of electrical equipment for dimensioning of clearances.~~

~~Four overvoltage categories are used as described below.~~

~~**Overvoltage category OV1**~~

~~Circuits which are protected against external and internal overvoltages and in which only limited overvoltages can occur because~~

~~– they are not directly connected to the contact line,~~

~~– they are being operated internally,~~

~~– they are within an equipment or device.~~

~~**Overvoltage category OV2**~~

~~Circuits which are not directly connected to the contact line and which are protected against overvoltages.~~

Overvoltage category OV3

Circuits which are directly connected to the contact line but with overvoltage protection and are not exposed to atmospheric overvoltages.

Overvoltage category OV4

Circuits which are directly connected to the contact line without any protective device against overvoltages close to the connection point and which may be endangered by lightning or switching overvoltages.

The overvoltage categories can be illustrated by the following explanation.

Rolling stock is generally equipped with overvoltage protection which gives a protection level the value of which is known according to its characteristics. Therefore, it is considered that only the part of the circuit situated upstream of it as far as the current collector and which can be separated by a switchgear or a circuit-breaker, is concerned by conditions of the OV4.

Power circuits without any other protective component than the protective device to reduce overvoltages are considered as having to comply with the conditions of OV3.

Power circuits protected additionally by filters, or inherently protected by components (for example semiconductors) are considered to be OV2 conditions, unless the surge level is well known. When the circuit has galvanic isolation or if there are several successive filters, or components acting as such, separating the circuit from high-power circuits, it is considered as having to comply with the conditions of OV1.

Overvoltage category (OV) is classified as OV1 to OV4.

Details are given in IEC 62497-1.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 Electrical risks

The equipotentiality of conductive parts capable of being touched shall be ensured. Necessary precautions shall be taken to ensure that the equipment does not constitute any risk of electric shock or burning for passengers and personnel due to contact with

– live parts of equipment or an electrical conductor.
– a metal object which has accidentally become live.

Exposed conductive parts (any metallic or other form of conductive material which is not energized except in case of a fault and which may be accessible) shall be bonded to the vehicle body, or constituent parts thereof, either directly or via protective bonding conductors.

All precautions shall be taken to prevent bonding resistance values from increasing with time in particular due to corrosion effects or fatigue.

When the nominal voltage is greater than 60 V d.c. or 25 V a.c., or greater than limits determined in accordance with the legislation of the country in which the equipment is to be used, the live parts of the equipment shall be inaccessible, to direct or indirect contact, by adequate protective provision according to IEC 60364-4-41.

~~If there is a risk of access to dangerous residual charge in capacitors, there shall be a system of discharging it before access is possible to circuits connected to the capacitors.~~

~~The choice of protection (fuses or circuit-breakers) and the electrical resistance of earthing circuits shall be such that no voltage greater than 120 V d.c. or 50 V a.c. can be maintained, between two simultaneously accessible metal parts, in the event of any fault.~~

~~8.1.2 Current return and protective bonding~~

~~8.1.2.1 General~~

~~Circuit design shall ensure that all currents are returned to the source of supply without resulting in any damage or risk of electric shock.~~

~~There shall be at least two separate paths for both current return and protective bonding so that the failure of one path does not cause damage or risk of electric shock. The circuits for protective bonding and current return may be combined. Both paths shall be visible for inspection.~~

~~The connection to the fixed installation shall be made via at least two axle brushes (of two different axles) or two return collector shoes on running or special rails.~~

~~To prevent damage or risk of electric shock, failures in the return current paths shall be detectable by an appropriate means, for example procedure or monitoring device. Paths shall be dimensioned to carry all currents which may flow through them. Consideration shall be given to all currents flowing in the running rails.~~

~~8.1.2.2 Power current return~~

~~Power current return shall be achieved~~

- ~~either by individual connection of all circuits to a busbar insulated from the vehicle body and from any exposed conductive parts and connected itself to the current return collectors, (axle brushes/return collector shoes);~~
- ~~or by connection of all power circuits to the vehicle body which is in turn connected to the current return collectors (axle brushes/return collector shoes).~~

~~The power current return circuits shall not adversely affect the performance of the short-circuit protection system in the event of a fault on the vehicle.~~

~~8.1.2.3 Vehicle grounding~~

~~The vehicle body and its bogie frames shall be connected either to the current return busbar or directly to the current return collectors or, where appropriate (i.e. for low current where no risk of bearing damage is proven), to the axle bearings.~~

~~In protective circuits, it may be necessary to connect the vehicle body structure via resistors or inductors to the current return collectors in order to~~

- ~~offer a circuit with a higher impedance than the current return paths;~~
- ~~limit the current flowing through axle bearings.~~

~~This shall be particularly considered for axle bearings which have no axle brushes.~~

~~8.1.2.4 Rating for protective bonding~~

~~Protective bonding shall be dimensioned to provide adequate strength and current-carrying capacity to ensure that the exposed conductive parts are incapable of causing electric shock~~

~~under failure conditions. The protective bonding connectors shall remain effective under all conditions.~~

8.1.1 Protective provisions against electrical hazards

Protective provisions against electrical hazards shall be made according to IEC 61991.

8.1.2 Batteries

During charge and discharge, the battery compartment may need to be vented in order to ensure that the concentration of hydrogen produced by electrolysis of the water remains below the 4 % threshold.

If needed, it is essential that impediments to air changes are minimized, and the air outlet should lead into the open air. Air inlet and outlet openings shall be located at the best possible location, i.e. in the opposite walls of the enclosure.

Cables between the battery and the downstream fuses shall be as short as possible.

~~8.1.4 Electromagnetic fields (EMC)~~

~~Consideration should be given, in the design and disposition of equipment, to ensure that the electromagnetic fields produced are within any specified limits.~~

8.1.3 Fire protection

Circuits and equipment constituting risks of ignition shall be effectively protected.

Materials shall produce only a small quantity of smoke of minimal opacity and toxicity. (Limits shall be considered.)

Combustible materials shall be kept away from sources of heat. They shall be selected to guarantee good resistance to fire.

To prevent the propagation of fire, special provisions may be specified with regard to installation (fire-break partitions, extinguishers, etc.).

NOTE Requirements of fire protection are different depending on countries, regions.

For example, for European countries EN 45545 series are applicable.

8.1.4 Other risks

Accessible parts which are likely, during normal service, to rise to a temperature in excess of the limits stated in Table 5 shall be protected by a barrier forming an obstacle. The temperature of the barrier shall not exceed the specified limit.

Access to parts continuously in motion (fans, rotating machines, etc.) or to those parts whose unexpected motion is likely to constitute a hazard shall be prevented by suitable barriers giving at least IP20 protection according to IEC 60529.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

All limiting values of supply voltage, air pressure, air temperature, etc., that can influence operation may occur simultaneously. All equipment shall operate satisfactorily in the worst combination of these limiting values. The following requirements apply with the ambient air temperatures defined in 7.3.1.

8.2.1.2 Equipment supplied by a contact line

Equipment which is supplied directly by a contact line shall operate satisfactorily at any value of supply voltage as defined in IEC 60850.

8.2.1.3 ~~Transformer supply system~~ Equipment supplied by a transformer

Equipment which is supplied by a transformer shall operate satisfactorily at any value of supply voltage multiplied by the transformer ratio (or ratios).

~~8.2.1.4 Independantly driven generator, alternator or converter~~

~~Equipment which is supplied either from an independently driven generator/alternator or converter shall operate satisfactorily when energized over the range 0,85 U_e to 1,1 U_e.~~

~~Equipment supplied from a converter shall operate satisfactorily at the relevant value of voltage and frequency from the minimum to the maximum value that the converter is capable of producing.~~

~~Voltage fluctuations lying between 0,7 U_e and 1,25 U_e and not exceeding 1 s shall not cause deviation of function. Voltage fluctuations lying between 0,6 U_e and 1,4 U_e and not exceeding 0,1 s shall not cause damage; equipment may not fully function during these fluctuations.~~

8.2.1.4 Equipment supplied by a float charge~~d~~ battery system (Type VC1)

Equipment~~ which is supplied from a battery on and off float charge~~ shall operate satisfactorily when energized over the~~ range of minimum voltage to maximum~~ voltage range listed in Table 1.

~~The nominal voltage U_n of the equipment is as described in 5.2.4. The minimum and maximum voltages shall relate to the nominal voltage as follows:~~

- ~~Minimum equipment voltage 0,7 U_n~~
- ~~Maximum equipment voltage 1,25 U_n~~

Voltage fluctuations (for example, during start-up of auxiliary equipment or voltage oscillations of battery chargers) lying between 0,6 U_n and 1,4 U_n and not exceeding 0,1 s shall not cause deviation of function.

Voltage fluctuations lying between 1,25 U_n and 1,4 U_n and not exceeding 1 s shall not cause damage; equipment may not fully function during these fluctuations.

In the case of thermal engines, see also 8.2.1.9.

8.2.1.5 Equipment supplied by a battery off charge system (Type VC2)

Equipment which is supplied~~ solely~~ from a battery off charge system is classified as type VC2 and shall operate satisfactorily when energized over the voltage range~~ 0,7 U_n to 1,1 U_n~~ listed in Table 1.

8.2.1.6 Equipment not supplied directly by an onboard battery (Type VC3)

Equipment shall operate satisfactorily when energized over the voltage range listed in Table 1.

Equipment shall operate satisfactorily at the frequency from the minimum to the maximum value that the supply source is capable of producing.

Voltage fluctuations lying between 0,6 U_n and 1,4 U_n and not exceeding 0,1 s shall not cause deviation of function.

Voltage fluctuations lying between 0,7 U_n and 1,25 U_n and not exceeding 1 s shall not cause deviation of function.

8.2.1.7 Traction power supplied by a battery

When the traction power supply voltage is provided by a battery having special arrangements for the correction of voltage variation (i.e. different cell groupings on charge and on discharge), a relaxation of the limits specified in 8.2.1.4 may be allowed by agreement between the user and the manufacturer.

8.2.1.8 Ripple factor

~~The batteries on charge~~ Equipment can receive a pulsating voltage, the DC ripple factor of which, unless otherwise stated, shall be not greater than 5 % calculated from the following formula:

$$\text{DC ripple factor} = \frac{U_{max} - U_{min}}{U_{max} + U_{min}} \times 100$$

where U_{max} and U_{min} are the maximum and minimum values, respectively, of the pulsating voltage.

8.2.1.9 Low battery voltage

Precautions shall be taken to avoid equipment damage due to the reduction and the return to the normal range of the voltage caused by progressive and complete discharge of the battery or by interruption of the supply. At the start-up of thermal engines no mal-operation of equipment shall occur during the whole starting sequence.

8.2.1.10 Air pressure

Pneumatic and electropneumatic equipment shall operate satisfactorily at an air pressure which may vary between the following limits specified by the manufacturer:

– the minimum limiting value which can guarantee to start and maintain the vehicle in service (functioning) when the compressor is momentarily out of service (short supply-voltage interruptions);

– the maximum limiting value, which is the rated air pressure as described in 5.6.

~~In principle,~~ The ratio between the maximum and the minimum value of the air pressure shall not exceed 1,8.

However, in case of failure of the regulating device, the equipment may be supplied at the operating air pressure of the safety valve.

8.2.2 Temperature ~~rise~~ limits

8.2.2.1 General

The temperature ~~rise~~ due to operation of the parts of equipment, and measured during a test carried out at the equivalent continuous rated current or specified currents under the conditions specified in 9.3.2, shall not exceed the ~~values~~ limits stated in Table 3, Table 4 and Table 5.

~~NOTE 1~~ The temperature~~-rise~~ limits given in Table 3, Table 4 and Table 5 apply to equipment tested in new and clean conditions. Different values may be prescribed by product standards for different test conditions.

~~NOTE 2~~ Temperature~~-rise~~ in normal service may differ from the test values, depending on the installation conditions and size of connected conductors.

~~NOTE 3~~ Additional temperature-rise tests in the actual service conditions (intermittent service at different values of current with time) may be made subject to agreement between the manufacturer and the user to ensure that the different overloads will not cause damage to the equipment.

For such tests, the temperature~~-rise~~ limits may be different from those given in Table 3, Table 4 and Table 5 and will be dependent on limit stresses for materials employed.

~~NOTE 4~~ Additional requirements may be necessary to take into account ~~transient~~ limited time thermal stresses due to:

– a ~~momentary insufficient~~ short time of very limited cooling when the equipment starts and stops;
– a reduced efficiency of the cooling system, for example blocked filter, for a specified, small fraction of the total operating time or for a specified, short period for each occurrence.

These ~~specific~~ additional requirements should be adequately specified by the user as a service condition (see 8.2.3).

The determination of temperature rise limits shall be based on the reference temperature ~~T_r = 25 °C~~ (T_r) given in 7.3.2.

8.2.2.2 Main circuit

The main circuit of equipment shall be capable of carrying the rated operational current of the equipment without the temperatures~~-rises~~ exceeding the limits specified in Table 3, Table 4 and Table 5 when tested in accordance with 9.3.2.

NOTE For switchgear, the conventional thermal current defined in IEC 60077-2 is used for temperature rise tests instead of the rated operational current.

8.2.2.3 Control circuits

The equipment shall satisfy the tests specified in 9.3.2 without the temperatures~~-rises~~ exceeding the limits specified in Table 3, Table 4 and Table 5.

8.2.2.4 Auxiliary circuits

Auxiliary circuits of equipment, including auxiliary switches, shall be capable of carrying their rated operational current without the temperatures~~-rises~~ exceeding the limits specified in Table 3, Table 4 and Table 5, when tested in accordance with 9.3.2.

NOTE If an auxiliary circuit forms an integral part of the equipment, it suffices to test it at the same time as the main equipment, but at its actual operational current.

8.2.2.5 Electrical insulating materials and systems

~~The temperature-rise obtained during the tests shall not cause damage to current-carrying parts or adjacent parts of the equipment. In particular, the temperature of the insulating materials shall not exceed the values given by the insulation temperatures index (defined by IEC 60085).~~

The maximum admissible temperature rise is equal to the insulating temperature index decreased by the ambient air temperature determined according to 8.2.2.2. The limits are specified in table 1 which gives examples, for each insulating temperature index, corresponding to the following cases:

– an ambient temperature equal to the reference temperature T_r = 25 °C;

– an ambient air temperature inside a box or a cubicle with an internal temperature-rise of 30 K.

NOTE 1 – Tables 1, 2 and 3 are not applicable to temperature-rise of parts of equipment which are immersed in insulating liquid.

NOTE 2 – The maximum working temperature is to be stated where insulating liquids are used.

8.2.2.5.1 Classification of insulating materials

The insulation life time is defined as the total time between the initial state for which the normal component insulation is considered new and the final state when, due to many factors which are met or occur in normal service, there is a high risk of electrical failure.

The ageing factors are described in IEC 60505, e.g. thermal ageing, dielectric and mechanical stresses (vibration, thermal cycling, etc.), deleterious atmospheres and chemicals, moisture, dirt, radiation, etc.

As temperature is very often the dominating ageing factor, standards have introduced thermal classes (IEC 60085) and methods to characterize thermal endurance properties (IEC 60216-1).

The different classes of solid materials (EIM – Electrical Insulating Material) and systems (EIS – Electrical Insulating System) used for the insulation of electric equipment to which this document applies are defined in IEC 60085 and listed in Table 3.

The thermal class of the solid materials used for the insulation of the windings shall be indicated by the manufacturer.

The thermal class of the solid materials used for the insulation of other parts should be indicated by the manufacturer.

8.2.2.5.2 Temperature limits

The temperature limit of an insulating system for 20 000 h lifetime is equal to the thermal class as listed in Table 3. This limit applies to the hotspot, which sustains the highest speed of thermal ageing. Temperature measurements aim at determining hot spot temperatures.

NOTE 1 The basic principles of insulation lifetime and thermal ageing, leading to thermal classification of insulating materials and systems, and to their temperature limits, are summarized in IEC 60310:2016, Annex B.

Other limits may be adopted by agreement between the user and the manufacturer when certain combinations of insulating materials are used.

A temperature rise limit, equal to the admissible temperature minus the reference temperature in 7.3.2, may be used for testing convenience. Table 3 gives examples of temperature rise limits for given reference temperatures.

For lifetimes longer than 20 000 h, the maximum temperature limit in operation shall be lowered.

For operation and lifetime shorter than 20 000 h, the maximum temperature shall not exceed the limit shown in Table 3.

Lifetime and temperature limits should be calculated, as a minimum for windings, according to the reference temperature stated in 7.3.

NOTE 2 An example of lifetime calculation can be found in Annex C.

NOTE 3 Table 3, Table 4 and Table 5 are not applicable to temperature rise of parts of equipment which are immersed in insulating liquid, for which a guideline can be found in IEC 60310:2016.

Table 3 – Temperature limits of electrical insulating system

~~Thermal class~~	~~Insulation temperature index~~	~~Temperature-rise limits for maximum air ambient temperature of~~	
		~~40 °C (T_a = 25 °C)~~	~~70 °C (T_a = 55 °C)~~
	~~°C~~	~~K~~	~~K~~
~~A~~	~~105~~	~~80~~	~~50~~
~~E~~	~~120~~	~~95~~	~~65~~
~~B~~	~~130~~	~~105~~	~~75~~
~~F~~	~~155~~	~~130~~	~~100~~
~~H~~	~~180~~	~~155~~	~~125~~
~~200~~	~~200~~	~~175~~	~~145~~
~~220~~	~~220~~	~~195~~	~~165~~
~~250~~	~~250~~	~~225~~	~~195~~

~~NOTE 1 – The thermal class normally represents the maximum value of the appropriate annual average temperature. This is the value of the temperature index the number of which is equal to the temperature, expressed in degrees Celsius, deduced from the thermal endurance factor for a given time, normally equal to 20 000 h (see IEC 60085).~~

~~NOTE 2 – The temperature-rise limits are given as an example for exterior location with T_a = 25 °C and for interior location when the air temperature-rise due to the local losses is unknown (see 8.2.2.2).~~

Thermal class of insulating system	**Temperature limits for 20 000 h lifetime**			**Temperature limits for short time operation** [a]	
	Admissible temperature °C (NOTE 1)	**Examples of temperature rise limits for a reference temperature T_r** (NOTE 2)		**General** °C	**Windings** (NOTE 3) °C
		T_r = 25 °C K	**T_r = 55 °C** K		
105(A)	105	80	50	120	130
120(E)	120	95	65	135	145
130(B)	130	105	75	145	155
155(F)	155	130	100	170	180
180(H)	180	155	125	195	205
200(N)	200	175	145	215	225
220(R)	220	195	165	235	245
250	250	225	195	265	No guidance

NOTE 1 This is the value of the temperature index, the number of which is equal to the temperature, expressed in degrees Celsius, derived from the thermal endurance relationship for a given time, normally equal to 20 000 h (see IEC 60216-1).

NOTE 2 The temperature rise limits are given as an example for exterior location (T_r = 25 °C) and interior location (T_r = 55 °C).

NOTE 3 The temperatures listed are according to Table 3 of IEC 60310:2016 for dry-type windings.

Other temperature limits for windings can be found e.g. in IEC 60349 series for traction motors.

[a] Temperature limits applicable to a small fraction of total lifetime, e. g. degraded mode operation.

8.2.2.6 Terminals

The temperature rise of terminals shall not exceed the values stated in Table 4 with the connections specified (bar or type of core, insulation and section) by the manufacturer.

The temperature of terminals shall not cause damage to adjacent parts of the equipment.

Table 4 – Temperature limits of terminals

Terminal material	Maximum temperature °C	Examples of temperature rise limits for maximum air ambient temperature of	
		40 °C (T_r = 25 °C) K	70 °C (T_r = 55 °C) K
Bare copper		60	30
Bare brass		65	35
Tin-plated copper or brass	105 (see NOTE 1)		
Silver-plated or nickel-plated copper or brass		70 (see NOTE 3)	40 (see NOTE 3)
Other metals		(see NOTE 4)	

NOTE 1 The maximum temperature is defined only for tin-plated copper or brass.

NOTE 2 The temperature rise limits are given as examples for exterior location with T_r = 25 °C and for interior location with T_r = 55 °C when the air temperature rise due to the local losses is unknown (see 7.3). These limits apply to a new sample (see 8.2.2.1).

NOTE 3 The terminal temperature rise limit is based on the connection of cables, the temperature index of which is 90 °C. Other values may be necessary if the cable temperature index is different.

NOTE 4 Temperature rise limits are based on service experience or life test but are not to exceed 70 K for T_r = 25 °C (see also NOTE 3).

8.2.2.7 Accessible parts

The temperature ~~rise~~ of accessible parts in normal use of the equipment shall not exceed the values stated in Table 5.

Table 5 applies only for accessible surfaces which are not defined in the other tables in the document.

Table 5 – Temperature limits of accessible parts

Accessible parts	Maximum temperature °C	Examples of temperature rise limits for maximum air ambient temperature of	
		40 °C (T_r = 25 °C) K	70 °C (T_r = 55 °C) K
Manual operating means:			
– metallic	55	15	Not applicable
– non-metallic	65	25	Not applicable
Parts intended to be touched but not hand-held:			
– metallic	70	30	Not recommended
– non-metallic	80	40	10
Parts which need not be touched for normal operation:			
– metallic	80	40	10
– non-metallic	90	50	20
Parts not intended to be touched during normal operation			
Exteriors of enclosure adjacent to cable entries:			
– metallic	80	40	10
– non-metallic	90	50	20
Exteriors of enclosure of equipment, for example resistors		200	
Air issuing from ventilation openings of enclosures of equipment for example resistors		200	

~~NOTE~~ The equipment shall be protected against contact with combustible materials or accidental contacts with personnel. The temperature rise limit of 200 K may be exceeded by agreement between the user and the manufacturer. Guarding and location to prevent danger is the responsibility of the manufacturer fitting the item. The manufacturer shall provide appropriate information, in accordance with 6.3.

8.2.2.8 Other parts

The temperature rise of other live-parts is limited only by safety and damage which could be caused to adjacent parts.

8.2.3 Operation following inactivity

When the rolling stock has been inactive it may take some time to reach its normal operational state. During this time the equipment shall operate but some aspects of the performance may not be fully compliant. Those aspects shall be agreed or specifically defined, if necessary, between the user and the manufacturer.

For example, the temperature of some parts of the equipment may be greater or lower for a short period than the highest or lowest allowable for normal operation.

Nevertheless, such situations shall not cause damage to the equipment itself and shall not cause any hazard to adjacent parts.

Storage conditions are not considered as transient operation and, if outside the normal range, they shall be agreed between the user and the manufacturer.

8.2.4 Electromagnetic compatibility (EMC)

8.2.4.1 General

The EMC requirement has to be given at vehicle level and a particular specification deduced for the equipment.

8.2.4.2 Internal interference

Internal interference can occur for example due to de-energization of inductive coil circuits, or ineffective bonding to the vehicle structure.

Internal radiated interference can occur, for example due to induced radiation from coils or cables affecting electric circuits in the proximity. Coupling may be either capacitive or inductive.

The equipment shall have sufficient immunity against the noise emission of internal interference.

8.2.4.3 External interference

External conducted interference can occur for example, when the harmonic currents in the vehicle power circuits interfere with the signalling currents at related frequencies in the track.

External radiated interference can occur for example when induced radiation from inductors on the vehicle directly interferes either with trackside telecommunication cables or with signalling control coils on the track.

The conducted and radiated interference produced by the equipment shall be lower than the level given in the particular specification.

EMC requirements for rolling stock are given in IEC 62236-3-2 for apparatus.

8.2.5 Acoustic noise emission

The maximum acoustic noise emitted by the equipment shall be specified by the vehicle designer in order to comply with the level required by the user of the whole rolling stock and for the location considered (outside, inside passenger compartment, etc.).

For this, the component manufacturer shall provide, if required, the noise levels emitted by the equipment in the conditions specified.

8.2.6 Dielectric properties (see also annex C)

8.2.6.1 General

Clearance and creepage values are given for

- d.c. equipment operating at no more than its rated insulation voltage between live parts and the vehicle structure, and between the positive and negative poles and between both poles and the vehicle structure in systems where both conductors are insulated;
- a.c. equipment operating at no more than its rated insulation voltage between phases and between each insulated phase and the vehicle structure.

The clearances are determined from the rated impulse withstand voltage for the overvoltage category of the circuits with reference to IEC 60071-1 and IEC 60664-1, taking into account also the exposure to pollution for normal conditions.

For equipment or apparatus, the manufacturer shall declare an impulse voltage which can be withstood (see 8.2.7).

The relation between rated insulation voltage, including the nominal voltage of line supply traction system, and rated impulse withstand voltage for the four overvoltage categories is given in table 4.

The overvoltage categories are used to determine the rated impulse withstand voltage.

For other conditions, higher values may be necessary.

Equivalent or higher clearance values may be used without being verified by impulse withstand test.

When it is foreseen that the pollution may reduce the clearances and creepages, these shall be increased. This is particularly necessary for the clearances and creepages on the exterior of vehicles, for example for roof equipment when the thickness/size of the pollution can become significant.

8.2.6.2 Clearances

8.2.6.2.1 General

The determination of the clearances is based on the expected overvoltage (expressed by the term overvoltage category given in 7.10) and the ambient conditions of the apparatus (expressed by the term pollution degree given in 7.9).

Clearances for rated impulse withstand voltages are given in table 5.

8.2.6.2.2 Functional insulation

Clearances for functional insulation are derived from the rated impulse withstand voltage given in table 4, which shows the preferred values.

Smaller values can be adopted, in particular in the case of homogeneous fields but their compliance to the values stated in table 4 shall be verified by tests on the configurations themselves or on similar configurations.

8.2.6.2.3 Basic and supplementary insulation

Minimum clearances for basic and supplementary insulation are derived from the rated impulse withstand voltage given in table 4, which shows the preferred values.

For human safety reasons smaller values of clearances are not allowed.

8.2.6.2.4 Reinforced insulation

When dimensioning reinforced insulation, 8.2.6.2.3 shall be applied considering that the rated impulse withstand voltage is 1,6 times that required for basic insulation.

For human safety reasons, smaller values of clearances are not allowed.

8.2.6.2.5 Double insulation

When dimensioning double insulation each stage of insulation shall be either basic or functional dependant upon the application.

Table 4 – Determination of rated impulse withstand voltage

Rated insulation voltages U_i (a.c. r.m.s. or d.c.)		Line supply voltages of traction system from IEC 60850		Rated impulse withstand voltages U_{imp} (U 1,2/50 µs)			
				Overvoltage categories			
from	up to	AC	DC	OV1	OV2	OV3	OV4
V	V	V	V	kV	kV	kV	kV
	50 *			0,33	0,5	0,8	1,5
50	100			0,5	0,8	1,5	2,5
100	150			0,8	1,5	2,5	4
150	300			1,5	2,5	4	6
300	660			2,5	4	6	8
660	900		600	4	5	6	10
900	1 200		750	5	6	8	12
1 200	1 600			6	8	10	15
1 600	2 300		1 500	8	10	12	18
2 300	3 000			10	12	15	20
3 000	3 700			12	15		
3 700	4 800		3 000	15	18	25	40
4 800	6 500			20	25		
6 500	8 300	6 250		25	30	40	60
8 300	10 000			30	35		
		15 000				75	95
		25 000				125	170
		50 000				250	300

* To be used only for circuits not subject to switching overvoltages.

Table 5 – Minimum clearances in air

Rated impulse withstand voltages U_{imp} kV	Minimum clearances for pollution degrees mm			
	PD1	PD2	PD3	PD4
0,33	0,01			
0,5	0,04	0,2		
0,8	0,1		0,8	
1,5	0,5			5,5
2,5	1,5			
3	2			
3,5	2,5			6,2
4	3			7
4,5	3,5			8
5	4			8,5
6	5,5			10
8	8			14
10	11			18
12	14			22
15	18			27
18	22			32
20	25			36
25	32			45
30	40			54
40	60			100*
60	90			110
75	120			135
95	160			175
125	210			230
145	260			265
170	310			
200	370			
250	480			
300	600			

* Theoretical value of 72 mm has been replaced by 100 mm as this is the accepted minimum value for 3 kV networks based on practical experience.

8.2.6.3 Creepage

The basis for the determination of creepage is the rated insulation voltage, the environment of the apparatus and the insulation material.

The environmental conditions are given by the pollution degrees as defined in 7.9.

The minimum creepage shall be determined according to tables 6a and 6b.

The shortest creepage distance in each specific case shall be not less than the relevant clearance distance.

~~The quality of the insulation material is determined by the following material groups defined~~

- ~~either by their comparative tracking index (CTI) according to IEC 60112,~~
- ~~or by their class according to IEC 60587~~
  - ~~material group I 600 ≤ CTI or class 1 A 4,5~~
  - ~~material group II 400 ≤ CTI < 600 or class 1 A 3,5~~
  - ~~material group IIIa 175 ≤ CTI < 400 or class 1 A 2,5~~
  - ~~material group IIIb 100 ≤ CTI < 175 or class 1 A 0~~

~~NOTE – Equivalence between both CTI and classes has not been demonstrated.~~

~~Table 6a – Creepages for rated insulation voltages up to 1 000 V~~

Rated insulation voltage U_i V	Creepage distances for pollution degrees mm											
	PD1			PD2			PD3			PD4		
	Material group			Material group			Material group			Material group		
	I	II	III a+b	I	II	III a+b	I	II	III a *	I	II	III a *
10		0,08			0,4			1,0				
12,5		0,09			0,42			1,05				
16		0,1			0,45			1,1			1,6	
20		0,11			0,48			1,2				
25		0,125			0,5			1,25			1,7	
32		0,14			0,53			1,3			1,8	
40		0,16		0,56	0,8	1,1	1,4	1,6	1,8	1,9	2,4	3,0
50		0,18		0,6	0,85	1,2	1,5	1,7	1,9	2,0	2,5	3,2
63		0,2		0,63	0,9	1,25	1,6	1,8	2,0	2,1	2,6	3,4
80		0,22		0,67	0,95	1,3	1,7	1,9	2,1	2,2	2,8	3,6
100		0,25		0,71	1,0	1,4	1,8	2,0	2,2	2,4	3,0	3,8
125		0,28		0,75	1,05	1,5	1,9	2,1	2,4	2,5	3,2	4,0
160		0,32		0,8	1,1	1,6	2,0	2,2	2,5	3,2	4,0	5,0
200		0,42		1,0	1,4	2,0	2,5	2,8	3,2	4,0	5,0	6,3
250		0,56		1,25	1,8	2,5	3,2	3,6	4,0	5,0	6,3	8,0
320		0,75		1,6	2,2	3,2	4,0	4,5	5,0	6,3	8,0	10,0
400		1,0		2,0	2,8	4,0	5,0	5,6	6,3	8,0	10,0	12,5
500		1,3		2,5	3,6	5,0	6,3	7,1	8,0	10,0	12,5	16,0
630		1,8		3,2	4,5	6,3	8,0	9,0	10,0	12,5	16,0	20,0
800		2,4		4,0	5,6	8,0	10,0	11,0	12,5	16,0	20,0	25,0
1000		3,2		5,0	7,1	10,0	12,5	14,0	16,0	20,0	25,0	32,0

NOTE – Materials of group III b are not recommended for pollution degrees PD3 and PD4.

* Linear interpolation between adjacent values is admissible.

Table 6b – Creepages for rated insulation voltages above 1 000 V

Material group	Creepage distances for pollution degrees mm/kV			
	PD1	PD2	PD3	PD4 [2]
I	3,2	5,0	12,5	20,0
II	3,2	7,1	14,0	25,0
NOTE 1 – Materials of groups III are not recommended.				
NOTE 2 – Some d.c. networks require higher values up to 45 mm/kV, based on practical experience.				

8.2.6 Clearances

Guidance for the determination of minimum clearances is given in IEC 62497-1, based on rated impulse voltage (U_{Ni}) obtained by:

– rated insulation voltage (U_{Nm}) and overvoltage category (OV), or
– calculation or measurement of working peak voltage.

8.2.7 Creepage distances

Guidance for the determination of minimum creepage distances is given in IEC 62497-1, based on rated insulation voltage (U_{Nm}), pollution degree (PD) and material group.

8.2.8 Switching overvoltages

Equipment shall not be subjected to switching overvoltages higher than the rated impulse withstand voltage. Also equipment shall not generate switching overvoltages higher than specified in the relevant product standard. In the event of there being no product standard, it shall not generate switching overvoltages higher than the rated impulse withstand voltage.

Equipment having more than one rated operational voltage and/or intended to be used at different transient overvoltage levels shall not generate switching overvoltages higher than the lowest transient overvoltage level at the corresponding rated operational voltage.

8.2.9 Operational performance

The equipment shall be capable of performing its rated duties under conditions corresponding to the specified requirements where relevant.

Specific requirements and test conditions shall be stated in the relevant product standard or test specification agreed between the user and the manufacturer, and may concern:

– the operational performance off-load in order to demonstrate that the equipment meets the operational conditions when energized at the upper and lower limits of supply voltage and/or air pressure specified;
– the operational performance on load during which the equipment shall operate at the specified duty;
– the performance in overload or fault conditions;
– the mechanical and electrical durability.

NOTE – The term "durability" has been chosen, instead of "endurance" or "ageing" in order to express the expectancy of the life duration (time or number of operating cycles) which can be performed by the equipment before repair or replacement of parts. Moreover, the term "endurance" is also commonly used to cover operational performance and it was deemed necessary not to use the term "endurance" in this standard in order to avoid confusion between the two concepts.

The verification of operational performance may be combined in one or several sequences of tests if so stated in the relevant product standard.

8.2.10 Ability to withstand vibration and shock

The equipment shall be capable of withstanding the vibration and shock given by test requirements (see 9.3.5).

9 Tests

9.1 Kinds of tests

9.1.1 General

Tests shall be made to prove compliance with the requirements laid down in this document, where applicable, and in the relevant product standard.

Tests are as follows:

– type tests which shall be made on a representative sample of the equipment;

– routine tests which shall be made on each individual piece of equipment manufactured according to this document, where applicable, and the relevant product standard;

– sampling tests which shall be made if called for in the relevant product standard;

– investigation tests are special tests and shall only be made if required by the manufacturer or the user to test in greater detail any particular aspect of a design.

The tests shall be carried out by the manufacturer at his works or at any suitable laboratory of his choice, before the equipment is mounted on the vehicle.

9.1.2 Type tests

Type tests are intended to verify compliance of the design of a given equipment with this document, where applicable, and with the relevant product standard.

~~These tests may comprise, as appropriate, the verification of~~

~~a) constructional requirements;~~

~~b) performance requirements:~~

- ~~– operating limits;~~
- ~~– temperature-rise;~~
- ~~– dielectric properties;~~
- ~~– operational performance;~~
- ~~– vibration and shock;~~
- ~~– electromagnetic compatibility;~~
- ~~– acoustic noise emission.~~

~~NOTE – The above list is not exhaustive.~~

Written documentation of type tests (proving compliance) shall be made available by the manufacturer.

If these type tests comprise mechanical or electrical durability or performance verifications in overload or fault conditions which may cause damage, they may be carried out on additional specimen(s). However, if this specimen is to be subsequently installed in an operational vehicle, an agreement between the user and the manufacturer shall prescribe its minimum acceptable condition for service.

If they comprise only normal functioning and verification tests without incurring component wear, the tests shall be carried out on one piece of equipment from the order.

9.1.3 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain the proper functioning of the equipment. They shall be made on each individual piece of the equipment including items that are to be subjected to type testing.

~~These tests may comprise, as appropriate, the verification of~~

- ~~visual;~~
- ~~operational;~~
- ~~dielectric;~~
- ~~calibration;~~
- ~~air tightness for pneumatic equipment;~~
- ~~leakage for hydraulic equipment;~~
- ~~measurement of resistance and impedance.~~

~~NOTE – The above list is not exhaustive.~~

Details of the routine tests and the conditions under which they shall be made shall be stated in the relevant clauses of this document and/or the relevant product standard where applicable.

The routine tests shall not cause any damage.

9.1.4 Sampling tests

If engineering and statistical analyses show that routine tests (on each product) are not required, sampling tests may be made instead, if so stated in the relevant product standard. They shall comprise a sequence of tests as for the routine testing.

9.1.5 Investigation tests

~~These are optional tests which may be made to verify specific properties or characteristics of equipment, either on the manufacturer's own initiative, or by agreement between the manufacturer and the user.~~

Investigation tests are special tests of an optional character carried out in order to obtain additional information. As opposed to type tests they are not intended to verify a requirement and consequently they have no acceptance criterion.

An investigation test may be made either on the manufacturer's own initiative or by agreement between the user and the manufacturer.

9.1.6 General test condition

The equipment to be tested shall conform to all functional details with the design which it represents.

Unless otherwise stated in this document or in the relevant product standard:

- tests shall be carried out in the ambient conditions present at the test site;

– each sequence of tests shall be made on equipment in a clean and new condition;

– equipment under test shall be mounted complete either under the conditions prescribed by the manufacturer or under the relevant conditions of installation envisaged on the rolling stock.

The test results shall be within the tolerances stated in the relevant product standard.

9.1.7 Summary of tests

Table 6 is a non exhaustive list of tests which may be appropriate for electric equipment within the scope of this document.

Table 6 – List of tests (as appropriate)

Test item	Type test	Routine test
Verification of constructional requirements	9.2.2	9.2.3
Verification of performance requirements	9.3	
Operating limits and functional tests	9.3.1.1	9.3.1.2
Temperature rise test	9.3.2	-
Dielectric properties	9.3.3	
Verification of clearance and associated solid insulation	9.3.3.2.1	-
Application of test voltage	9.3.3.2.2	-
Verification of creepage distances	9.3.3.2.3	-
Type test for equipment	9.3.3.2.4	-
Power frequency voltage test	-	9.3.3.3
Operational performance capability	9.3.4	
Air-tightness tests for pneumatic equipment	9.3.4.2	
Leakage tests for hydraulic equipment	9.3.4.3.1	9.3.4.3.2
Durability	9.3.4.4	-
Mechanical durability	9.3.4.4.2	-
Electrical durability	9.3.4.4.3	-
Check on the setting and operation of protective equipment and relays (calibration)	-	9.3.4.5
Vibration and shock	9.3.5	-
Electromagnetic compatibility (EMC)	9.3.6	-
Acoustic noise emission	9.3.7	-
Climatic tests	9.3.8	-

9.2 Verification of constructional requirements

9.2.1 General

Unless specific, higher requirements are given in the product standard or different and replacing requirements are given in the customer's specification, the design of equipment and components shall comply with ~~the~~ each applicable requirement~~s~~ given in Clause 8 of this document. This compliance shall be capable of being proven (by visual examination, measurement, etc.) for properties where testing is not appropriate.

9.2.2 Type tests

Verification of compliance with the constructional requirements for the type test may concern:

– protective provisions against electrical ~~risks~~ hazards (8.1.1);
– ~~current return and protective bonding;~~
– ventilation of batteries (8.1.2);
– ~~electromagnetic fields;~~
– fire and smoke protection (8.1.3);
– clearances (8.2.6);
– creepage ~~and clearance~~ distances (8.2.7);
– other risks such as burning risks;
– climatic ~~tests~~ conditions.

NOTE The above list is not exhaustive.

9.2.3 Routine tests

Verification of compliance with the constructional requirements for the routine test concerns:

– visual examination;
– measurement of resistance and impedance.

Measurement of the resistance of windings shall be made on all electro-pneumatic or electromagnetic control devices when cold if the variation of this resistance may affect operation. Typical equipment includes magnet valves, servo-motors, voltage relays and electromagnetic contactors.

The measurements obtained for any given winding, when corrected to a temperature of 20 °C, shall not vary from the specified value or, alternatively, from the mean of the values measured on the first ten units tested. In the absence of a specific product standard, the tolerance shall be ±8 %.

The measurements of resistance are also made when cold on the various resistances inserted in the control, indicating and auxiliary circuits. The allowable tolerances, which vary according to the application, shall be agreed between the parties concerned.

Where correct operation of apparatus in AC circuits depends on the impedance, measurements of resistance shall, if necessary, be accompanied by measurements of impedance carried out with AC at the specified frequency.

The measurement of the main circuit resistance shall be made with a direct current, recording the voltage drop across the terminals. The current chosen for the test shall have a value up to the rated current.

The resistance of any apparatus shall not exceed the limit value fixed by the manufacturer.

9.3 Verification of performance requirements

9.3.1 Operating limits and functional tests

9.3.1.1 Type tests

Operating limits shall be verified as type ~~and routine~~ tests.

~~Type~~ The tests shall be carried out, at both the lowest ambient temperature to which the apparatus can be subjected in service (or at which its correct operation is to be achieved) and at the highest temperature it can attain.

Large items, for example transformers, motors, cubicles, etc., shall only be subject to climatic tests by agreement between the user and the manufacturer.

In the case of electro-magnetic or electro-pneumatic apparatus, the tests consist of checking 20 times in succession, for each relevant combination of minimum and maximum values of temperature, voltage and pressure, that after stabilization of its temperature, the apparatus will operate ~~correctly~~ satisfactorily within the limits of supply voltage and air pressure specified in 8.2.1.

A check shall also be made that the operation of the equipment is still satisfactory when carried out under the most unfavourable combination of voltage, air pressure and temperature obtainable within the limits specified in 8.2.1. In the case of equipment which operates at different frequencies, the test frequency shall be specified.

NOTE In the case of electro-magnetic or electro-pneumatic apparatus, operation when hot at a voltage is considered to be satisfactory if the apparatus when cold operates normally when it is supplied with the current equal to that which would flow through the apparatus after 1 h of operation at the same voltage.

This method is not, however, applicable to apparatus used for preparing the vehicle for service (electro-pneumatic valve for pantographs, machine starting contactors, etc.) since this apparatus ~~must~~ needs to meet special requirements in general.

9.3.1.2 Routine tests

Functional tests shall be performed as routine tests.

Routine tests consist of verifying at ambient temperature the capability of the equipment to operate ~~correctly~~ satisfactorily at the rated supply voltage and air pressure specified in 8.2.1 or at more appropriate values.

9.3.2 Temperature rise test

9.3.2.1 Ambient air temperature

The ambient air temperature shall be recorded during the last quarter of the test period by at least two temperature sensing means, for example thermometers or thermocouples, equally distributed around the equipment at about half its height and at a distance of about 1 m from the equipment. The temperature sensing means shall be protected against air currents, heat radiation and indicating errors due to rapid temperature changes.

During the tests, the ambient air temperature shall be between +10 °C and +40 °C and shall not vary by more than 10 K.

However, if the variation of the ambient air temperature exceeds 3 K, an appropriate correction factor should be applied to the measured temperature of the parts, depending on the thermal time-constant of the equipment.

9.3.2.2 Measurement of the temperature of parts

9.3.2.2.1 General

~~For parts other than coils,~~ The temperature of the different parts shall be measured by suitable temperature sensing means at those points most likely to attain the maximum temperature; these points may be determined during a previous test with a current lower than the test current. These points shall be stated in the report.

Depending on the materials, shape and size of products, and their cooling medium, there may be a significant temperature gradient between the actual hot spot and the location accessible for temperature measurement (such as surface temperature) or the average temperature (e.g. measured indirectly in a coil by DC resistance variation).

In case the maximum temperature cannot be accessed for direct measurement, indirect measurement shall apply.

The temperature sensing means shall not significantly affect the temperature rise. Good thermal conductivity between the temperature sensing means and the surface of the part under test shall be ensured.

The test shall be made for a time sufficient for the temperature rise to reach a steady-state value but not exceeding 8 h. The time depends on the construction and the cooling method of the product. It shall not exceed 8 h unless otherwise agreed. It is assumed that a steady state is reached when the variation does not exceed 1 K per hour unless otherwise agreed.

9.3.2.2.2 Direct temperature measurement method

The temperature is measured directly with a temperature sensor (resistive thermometer, thermocouple, temperature sensitive sticker, infrared camera, etc.).

9.3.2.2.3 Indirect temperature measurement method

The temperature is derived from the measurements of other physical parameters such as voltage, current, resistance, etc.

For example, for electromagnet coils, the method of measuring the temperature by variation of resistance shall is generally be used. Other methods are permitted only if it is impracticable to use the resistance method. This method provides the average temperature of a winding.

The temperature of the coils before beginning the test shall not differ from that of the surrounding medium by more than 3 K.

For copper conductors, The value of the average hot temperature (T_2) of the winding may be obtained from the value of the average cold temperature (T_1) of the winding as a function of the ratio of the hot resistance (R_2) to the cold resistance (R_1) by the following formula:

$$T_2 = \frac{R_2}{R_1}(T_1 + 234{,}5) - 234{,}5$$

$$T_2 = \frac{R_2}{R_1}(T_1 + k) - k$$

where T_1 and T_2 are expressed in degrees Celsius and k is a reciprocal of the temperature coefficient of resistance at 0 °C for the material.

– for copper conductor: 234,5 °C;
– for aluminium conductor: 228,1 °C.

9.3.2.2.4 Calculation method of temperature

In such cases where the hot spot is not accessible, the temperature is measured, either by the indirect method, or by the direct method, at a point close to the hot spot.

The temperature difference between this point and that of the hot spot shall be calculated, as a minimum for windings, when it is relevant to thermal ageing of the insulation system. The calculation is based on data provided by the manufacturer of the equipment.

9.3.2.3 Temperature rise of a part

The temperature rise of a part is the difference between the temperature of the part measured in accordance with 9.3.2.2 and the ambient air temperature measured in accordance with 9.3.2.1.

9.3.2.4 Temperature rise of the main circuit

The equipment shall be mounted as specified in 9.1.6 and shall be protected against abnormal external heating or cooling.

Equipment having an integral enclosure and equipment only intended for use with a specified type of enclosure shall be tested in their enclosures for the rated operational current. No opening giving false ventilation shall be allowed.

For tests with multiphase currents, the current shall be balanced in each phase within ±5 %, and the average of these currents shall be not less than the appropriate test current.

Unless otherwise specified in the relevant product standard, the temperature rise test of the main circuit ~~is made~~ shall be performed at the rated operational current and may be ~~made~~ at any ~~convenient~~ relevant voltage. It may be necessary to take into account the influence of harmonic content in the current waveform when determining temperature rise.

NOTE For switchgear, the conventional thermal current defined in IEC 60077-2 is used for temperature rise tests instead of the rated operational current.

When the heat exchange between the main circuit, the control circuit and the auxiliary circuits may be of significance, the temperature rise tests stated also in 9.3.2.5 to 9.3.2.7 shall be made simultaneously, in so far as this is allowed by the relevant product standard.

Tests on ~~rated~~ DC equipment may be made with an AC supply for convenience of testing but only with the consent of the manufacturer.

At the end of the test, the temperature ~~rise~~ of the different parts of the main circuit shall not exceed the ~~values~~ limits given in 8.2.2.2 unless otherwise specified in the relevant product standard.

~~Depending on the value of the rated operational current, one of the following test connection arrangements shall be used:~~

~~a) for values of test current up to and including 400 A~~

~~– the connections shall be in free air and by single-core copper cables with cross-sections such that the test current is equal to 0,5 times the rated operational current for the cable according to its insulation temperature index;~~

~~b) for values of test current higher than 400 A~~

~~– the connection shall be either two parallel cables with the above requirements, or a single equivalent bare copper conductor specified by the manufacturer.~~

If the temperature rise tests have not been performed in the specified service conditions, additional calculations or tests may be agreed between the user and the manufacturer.

The test connection of cables shall be made according to IEC 61992-1,or for verification for a particular application, with the intended dimensions of connecting conductors.

Details of the test, such as type of supply, number of phases and frequency (where applicable), cross-sections of test connections, etc., shall form part of the test report.

9.3.2.5 Temperature rise of control circuits

The temperature rise tests of control circuits shall be made with the specified current and, in the case of AC, at the rated frequency. Control circuits shall be tested at their rated operational voltage.

Circuits intended for continuous operation shall be tested for a sufficient time for the temperature rise to reach a steady-state value.

Circuits for intermittent duty shall be tested as prescribed in the relevant product standard.

At the end of these tests, the temperature ~~rise~~ of the different parts of the control circuits shall not exceed the ~~values~~ limits given in 8.2.2.3 unless otherwise specified in the relevant product standard.

9.3.2.6 Temperature rise of coils of electromagnets

Coils and electromagnets shall be tested according to the conditions given in 8.2.2.4.

They shall be tested for a sufficient time for the temperature rise to reach a steady-state value.

The temperature shall be measured when thermal equilibrium is reached in both the main circuit and the coil of the electromagnet.

Coils and electromagnets of equipment intended for intermittent duty shall be tested as prescribed in the relevant product standard.

At the end of these tests, the temperature ~~rise~~ of the different parts shall not exceed the ~~values~~ limits given in 8.2.2.4.

9.3.2.7 Temperature rise of auxiliary circuits

The temperature rise tests of auxiliary circuits shall be made under the same conditions as those specified in 9.3.2.4 but may be carried out at any convenient voltage.

At the end of these tests, the temperature ~~rise~~ of the auxiliary circuits shall not exceed the ~~values~~ limits given in 8.2.2.4.

9.3.3 Dielectric properties

9.3.3.1 General conditions

~~The test requirements specified in 9.3.3.2 and 9.3.3.3 apply to equipment for which the manufacturer has declared a value for the rated impulse withstand voltage derived in accordance with 8.2.6.~~

~~For equipment for which this value has not been declared, the test requirements of the relevant product standard shall apply.~~

The equipment to be tested shall be mounted on a metal plate and all exposed conductive parts (frame, etc.) which are connected to the vehicle structure in normal service shall be connected to the metal plate.

Manual actuators of insulating material and integral non-metallic external parts which may be touched during normal operation shall be covered by a metal foil connected to the frame of the mounting plate. The foil shall be applied to all surfaces where these can be touched with the standard test finger.

However, it is not necessary to cover these parts by a metal foil if they are separated from live parts by conductive parts which are connected to the vehicle structure in normal service or if they are double insulated devices or if insulation failure cannot cause any electrical risks higher than 120 V DC or 50 V AC.

During the tests, it may be necessary to disconnect or to short-circuit some parts of the equipment from the electrical stress. This shall be agreed between the user and the manufacturer. If any component or subassembly is not submitted to the dielectric test, its terminals shall be grounded.

9.3.3.2 Type tests

9.3.3.2.1 Verification of clearance and associated solid insulation

Clearances shall be verified by measurement or a dielectric test according to the method described in annex A IEC 62497-1. However, if this method seems inappropriate for a complex equipment, an electrical test according to 9.3.3.2.2 and 9.3.3.2.3 may be used. When clearances of less than those given by tables 4 and 5 are used for functional insulation or when equipment has a rated impulse withstand voltage greater or equal to 30 kV, an impulse test is mandatory. The test value shall be the rated impulse withstand voltage.

For equipment with a rated impulse voltage (U_{Ni}) greater or equal to 30 kV, solid insulation shall be verified by an impulse test at the rated impulse voltage.

NOTE Partial discharge test methods have not been included as they are still under consideration.

9.3.3.2.2 Test voltage

There are three tests that can be used to demonstrate compliance.

a) Verification of clearances by impulse test

The 1,2/50 μs impulse test voltage shall be equal to the value of the rated impulse withstand voltage and shall be applied three times for each polarity at intervals of 1 s minimum.

The test is successful if the test voltage does not collapse.

NOTE For impulse tests associated with nominal voltage equipment of 15 kV, 25 kV or 50 kV, the test method shall be in accordance with IEC 60056.

b) Verification of clearances by power-frequency test

The test voltage shall be equal to the value U_{ac} given in table 7 equivalent to the rated impulse withstand voltage.

The test frequency is 50 Hz ± 10 % or 60 Hz ± 10 %.

The test value shall be reached in 5 s and be maintained for 5 s.

The test is successful if excess leakage current does not flow and the test voltage does not collapse.

c) Verification of clearances by d.c. voltage test

The test voltage shall be equal to the value U_{dc} given in table 7 equivalent to the rated impulse withstand voltage.

The test value shall be reached in 5 s and be maintained for 5 s.

The ripple factor shall not exceed that one given by a three phase bridge (4,2 %).

The test is successful if excess leakage current does not flow and the test voltage does not collapse.

The preferred electric test is an impulse voltage test except when clearances are bridged by capacitances when the d.c. voltage test is preferred.

~~However equipment incorporating overvoltage protection shall be tested with an impulse voltage such that the energy rating of the overvoltage protection shall not be exceeded.~~

~~Provisions may be necessary to avoid damage during the test, especially for electronic equipment.~~

~~There shall be no unintentional disruptive discharge during the tests. An exception is an intentional disruptive discharge, for example by transient overvoltage protection.~~

9.3.3.2.2 Application of test voltage

The test voltage shall be applied as follows with the equipment mounted on a metal plate and prepared as specified in 9.3.3.1:

a) between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the frame or mounting plate, with the contacts in all normal positions of operation;

b) between each pole of the main circuit and the other poles connected together and to the frame or mounting plate, with the contacts in all normal positions of operation;

c) between each control and auxiliary circuit not normally connected to the main circuit and
   - the main circuit,
   - the other control and auxiliary circuits,
   - the exposed conductive parts,
   - the frame or mounting plate,

   which, wherever appropriate, may be connected together;

d) for equipment suitable for isolation, across the poles of the main circuit, the line terminals being connected together and the load terminals connected together.

The test voltage shall be applied between the line and load terminals of the equipment with the contacts in the open position.

9.3.3.2.3 Verification of creepage distances

The shortest creepage distances between phases, between circuit conductors at different voltages and live and exposed conductive parts shall be measured. ~~The~~ Each measured creepage distance ~~with respect to material group and pollution degree~~ shall comply with the minimum requirements of 8.2.7.

The method of measuring creepage~~s~~ distances is given in ~~annex A~~ IEC 62497-1.

~~NOTE – Other tests, under polluted atmosphere (rain, salt moisture, snow) may be specified by the relevant product standard.~~

9.3.3.2.4 Type test for equipment

The method of dielectric test of equipment for routine test in 9.3.3.3 shall apply.

9.3.3.3 Routine tests

9.3.3.3.1 Power frequency voltage test

The power frequency voltage tests shall be carried out on every single piece of equipment. In certain cases to be agreed between the user and the manufacturer, they may also be carried out on equipment connected in groups. For details of tests of equipment when mounted on the vehicle, refer to IEC 61133:2016.

The test voltage at a frequency of 50 Hz or 60 Hz shall be of approximately sinusoidal form.

The method of test is given in IEC 62497-1.

Table 7 – Test voltages for verification of clearances

Clearances mm	U_{imp} kV	U_{ac} kV	U_{dc} kV
0,01	0,33	0,23	0,33
0,04	0,52	0,37	0,52
0,1	0,81	0,5	0,7
0,5	1,55	0,84	1,19
1,5	2,56	1,39	1,97
2,0	3,1	1,69	2,39
2,5	3,6	1,96	2,77
3,0	4,06	2,21	3,13
3,5	4,51	2,45	3,47
4,0	4,93	2,68	3,79
5,5	6,09	3,32	4,69
8,0	7,82	4,26	6,02
11,0	9,95	5,4	7,63
14,0	12,2	6,61	9,35
18,0	15,1	8,17	11,6
22,0	17,8	9,68	13,7
25,0	19,9	10,8	15,3
32,0	24,5	13,3	18,8
40,0	29,5	16,0	22,7
60,0	41,6	22,6	31,9
90,0	58,5	31,7	44,9
120	74,6	40,5	57,2
160	95	51,5	72,9
260	143	77,6	110
310	166	90	127
370	193	104	148
480	240	130	184
600	289	157	222
NOTE – Linear interpolation between adjacent values is admissible.			

9.3.3.3.2 Test voltage and duration

The voltage of the power frequency voltage test (U_a) (kV RMS) based on the rated impulse voltage (U_{Ni}) (kV) of the dielectric test for equipment shall be selected according to IEC 62497-1.

The duration of voltage application is 10 s.

If agreed between the user and the manufacturer the test voltage and duration may be selected according to Annex B.

9.3.3.3.3 Application to groups of equipment before or after mounting

A dielectric test shall be carried out on groups of equipment even if their components have already been tested individually. The This repeated test shall be made at a voltage equal to 0,85 0,80 times the initial test voltage required by the rated insulation voltage of the circuit according to table 8 or table 9 given in IEC 62497-1.

NOTE For testing of rolling stock after completion of construction and before entry into service, IEC 61133:2016 instructs to apply 85 % of the test voltage of the defined test voltage for 1 min. The defined test voltage according to IEC 60077-1 is the repeated test voltage equal to 0,80 times the initial test voltage given in IEC 62497-1.

However, where the circuit contains a mid-point permanently connected to earth, ~~U_i~~ (U_{Nm}) defined in IEC 62497-1 shall be taken to be one-half of the rated insulation voltage which would be taken in the absence of a mid-point connection.

Components which may be damaged during the test, or which can constitute a load for the test voltage, shall be disconnected.

9.3.4 Operational performance capability

9.3.4.1 General

Tests shall be made to verify compliance with the requirements of 8.2.9. Detailed test conditions shall be given in the relevant product standard.

9.3.4.2 Air-tightness tests for pneumatic equipment

Tests shall be made to verify that the leakage of each unit of the pneumatic equipment, cylinder or magnet-valve, does not cause, after the test duration ~~T~~ (t), a reduction of more than 1 % per minute of the air pressure of the vessel ~~V~~ to which this unit has been connected.

The air pressure of the vessel at the beginning of the test shall be equal to the rated air pressure (P) of the unit to be tested.

The cold winding shall be supplied with a current equal to the steady-state current obtained when the winding is supplied at the rated voltage.

The test shall be repeated for every different state of the equipment whether energized or not, if applicable.

The test shall be carried out on a single specimen (air cylinder or magnet-valve) for the type test and may be carried out on no more than 10 identical specimens for the routine test.

For equipment having several air cylinders or magnet-valves which cannot be tested separately, it is sufficient to check that the total leakage is not greater than the sum of the leakages allowable for each unit.

The test duration ~~T~~ (t) is determined with the different parameters as follows:

$$t = \frac{\mathrm{d}P}{P}\frac{100\,V}{(m + 0{,}5\,n)}$$

where:

m is the number of magnet-valves tested;

n is the number of air cylinders supplied during the test;

t is the test duration, expressed in minutes, which shall not be lower than 1 min;

V is the total volume, expressed in cubic decimeters, of the pneumatic circuit comprising the vessel and the air cylinders if any, increased by the pipes' volume if significant. The total volume shall be up to 5 times that of the pneumatic circuit of the equipment tested;

P is the rated air pressure expressed in MPa (1 MPa = 10 bar);

dP is the variation of the air pressure of the vessel at the end of the duration test, expressed in MPa. This variation shall not exceed 0,1 P, but shall be sufficient to be able to quantify it on the air pressure measuring device.

NOTE The choice of the vessel is such that its volume satisfies the conditions for the variation of the air pressure and the test duration.

9.3.4.3 Leakage tests for hydraulic equipment

9.3.4.3.1 Type tests

~~An endurance~~ A durability test of three months duration shall be made on a complete hydraulic equipment operating on a load cycle agreed between the user and the manufacturer to verify that no leaks exist which would either jeopardize the functioning of the equipment or necessitate replenishing the hydraulic fluid.

The duration of the test may be established for a period other than three months after agreement between the user and the manufacturer.

9.3.4.3.2 Routine tests

9.3.4.3.2.1 Cylinders

With the pistons fitted with packing, rings or gaskets there shall be no significant leakage from the cylinder with the maximum load applied externally to the piston rod.

9.3.4.3.2.2 Valves and hydraulic systems

When tested at the maximum rated flow and the maximum rated pressure, the leakage shall not exceed 0,35 % per minute of the maximum flow per ~~100 bars~~ 10 MPa.

9.3.4.4 Durability

9.3.4.4.1 General

Durability tests are type tests intended to verify the number of operating cycles that equipment is likely to be capable of performing without repair or replacement of parts.

The durability tests form the basis of a statistical life estimate, where the manufactured quantities permit this.

9.3.4.4.2 Mechanical durability

During the test, there shall be no voltage or current in the main circuit. The equipment may be lubricated before the test if lubrication is prescribed in the normal service.

The control circuit shall be supplied at its rated voltage and, where applicable, at its rated frequency.

Pneumatic and electro-pneumatic equipment shall be supplied at the rated air pressure.

Manually operated equipment shall be operated as in normal service.

The number of operating cycles shall be not less than that prescribed by the relevant product standard.

For equipment fitted with operating relays or releases (tripping devices), the total number of operations to be performed by such relays or releases shall be stated in the relevant product standard.

Evaluation of test results shall be defined in the relevant product standard.

9.3.4.4.3 Electrical durability

The test conditions are those of 9.3.4.4.2 except that the main circuit is energized according to the requirements of the relevant product standard.

Evaluation of test results shall be defined in the relevant product standard.

9.3.4.5 Check on the setting and operation of protective equipment and relays (calibration)

These checks are routine tests.

Normally, all such equipment shall operate with a tolerance of ±5 % of the maximum setting of their range.

9.3.5 Vibration and shock

Vibration and shock tests shall be carried out according to the relevant method of IEC 61373.

9.3.6 Electromagnetic compatibility (EMC)

~~The railway environment includes electromagnetic fields caused, for example, by radio transmitters, mobile telephones. The electronic equipment of railway vehicles shall offer sufficient immunity against these fields.~~

~~The rolling stock may produce electric, magnetic and electromagnetic fields. These emissions can affect sensitive electronic apparatus, for example radio receivers, televisions, etc., in close proximity to the railway.~~

~~Compatibility between vehicles and signalling equipment shall be especially considered. Depending on the signalling equipment used in the individual case, limits of conducted and radiated emissions of the vehicles shall be taken into account.~~

EMC test methods and criteria for rolling stock are given in IEC 62236-3-2 for apparatus.

9.3.7 Acoustic noise emission

If required, acoustic noise tests may be carried out to verify the limits of 8.2.5, as agreed between the user and the manufacturer.

9.3.8 Climatic tests

If required, a series of tests may be carried out to demonstrate the capability of meeting the environmental conditions. The relevant methods of IEC 60068 shall be used and may comprise the following:

- cold — IEC 60068-2-1;
- dry heat — IEC 60068-2-2;
- damp heat steady state — IEC ~~60068-2-3~~ 60068-2-78
  or damp heat cyclic — IEC 60068-2-30;
- salt mist — IEC 60068-2-52.

In addition, other tests may be prescribed by the test document according to the particular environmental conditions defined.

For each test, the particular parameters shall be recorded in the test report.

If applicable an air-tightness test shall be carried out during, and after, exposure to dry heat and cold in accordance with 9.3.4.2.

A new sample shall be used for each test. However, the same sample may be used for several tests if it is declared as new after refurbishment.

Annex A
(normative)

Measurement of creepage distances and clearances

A.1 Basic principles

The widths *X* of grooves specified in examples 1 to 11 basically apply to all examples as a function of pollution as follows:

Pollution degrees	Minimum values of widths *X* of grooves mm
PD1	1,0
PD2	1,5
PD3	2,5
PD4	4,0

The methods of measuring creepage distances and clearances are indicated in the following examples 1 to 11. These examples do not differentiate between gaps and grooves or between types of insulation.

Furthermore:

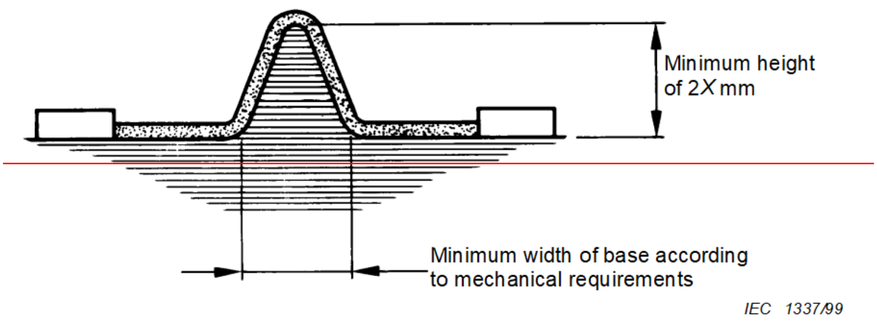
– any corner is assumed to be bridged with an insulating link of a width of *X* mm moved into the most unfavourable position (see example 3);

– where the distance across the top of a groove is *X* mm or more, a creepage distance is measured along the contours of the grooves (see example 2);

– creepage distances and clearances measured between parts moving in relation to each other are measured when these parts are in their most unfavourable positions.

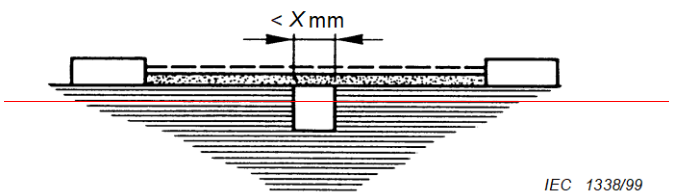
A.2 Use of ribs

Because of their influence on contamination and their better drying-out effect, ribs decrease considerably the formation of leakage current. Creepage distances can therefore be reduced to 0,8 of the required value provided the minimum height of the ribs is 2*X* mm.



~~Figure A.1 – Measurement of ribs~~

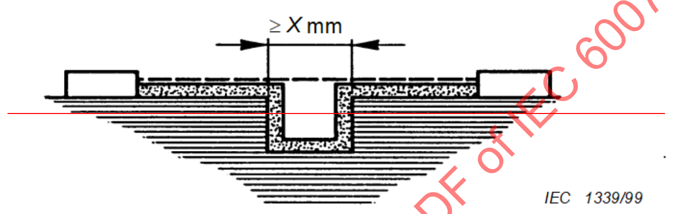
Example 1



Condition: This creepage distance path includes a parallel or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown above.

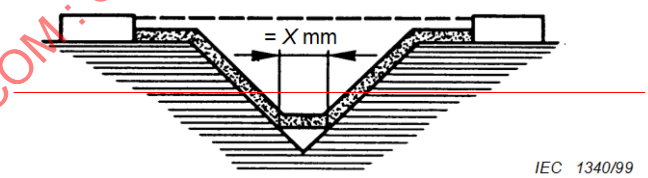
Example 2



Condition: This creepage distance path includes a parallel-sided groove of any depth and of a width equal to or more than X mm.

Rule: Clearance is the "line of sight" distance. The creepage distance path follows the contour of the groove.

Example 3

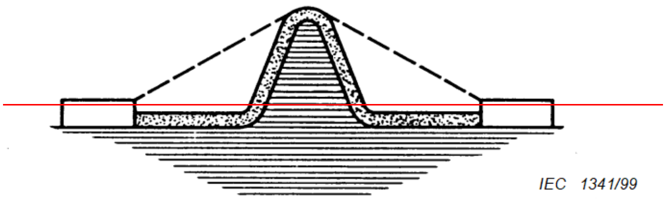


Condition: This creepage distance path includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line of sight" distance. The creepage distance path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

– – – – – Clearance   Creepage distance

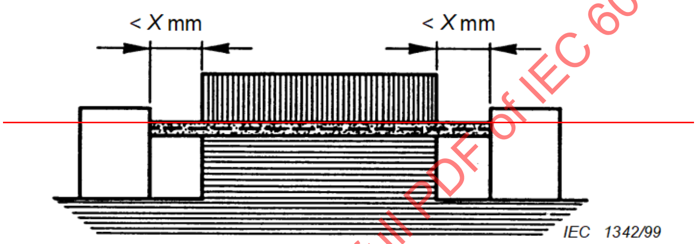
~~Example 4~~



~~Condition: This creepage distance path includes a rib.~~

~~Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib~~

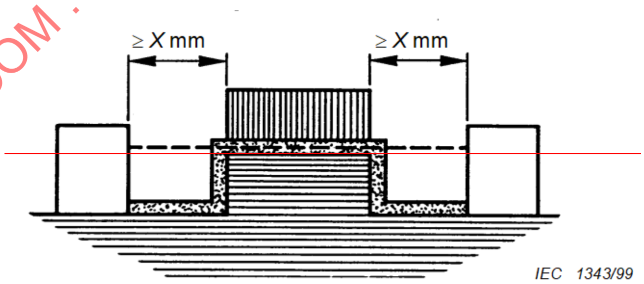
~~Example 5~~



~~Condition: This creepage distance path includes an uncemented joint with grooves less than *X* mm wide on each side.~~

~~Rule: The creepage distance and clearance path is the "line of sight" distance shown above.~~

~~Example 6~~

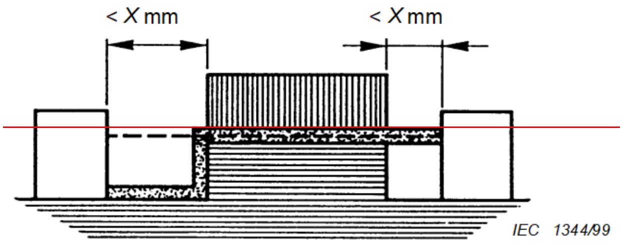


~~Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than *X* mm wide on each side.~~

~~Rule: Clearance is the "line of sight" distance. The creepage distance path follows the contour of the grooves.~~

– – – – – Clearance   Creepage distance

Example 7

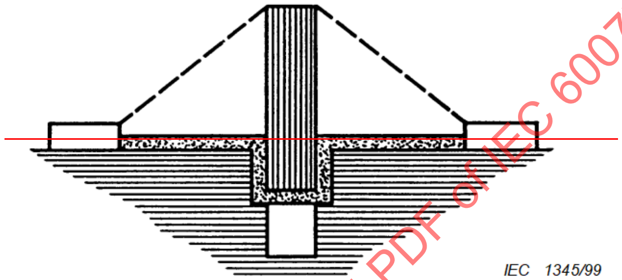


IEC 1344/99

Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage distance paths are as shown above.

Example 8

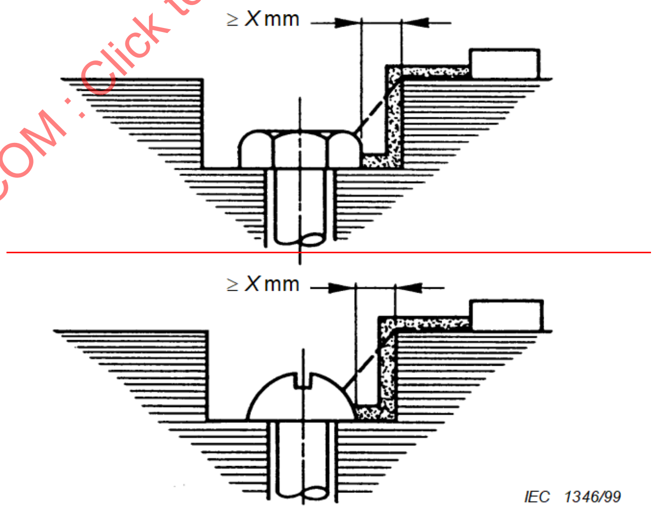


IEC 1345/99

Condition: The creepage distance through the uncemented joint is less than the creepage distance over the barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier.

Example 9



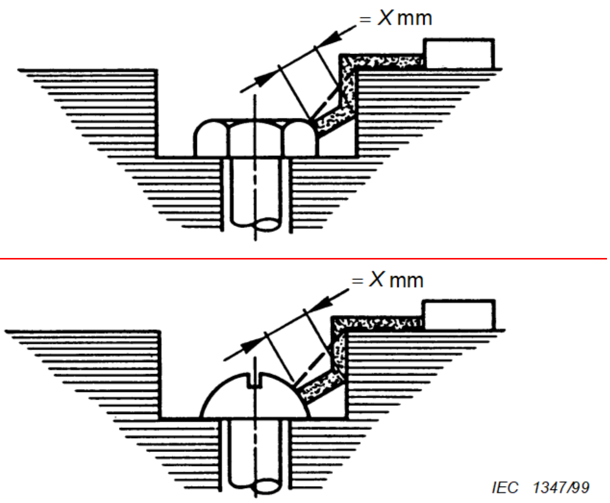
IEC 1346/99

Condition: The gap between the head of the screw and the wall of recess wide enough to be taken into account.

Rule: Clearance and creepage distance paths are as shown above.

- - - - - Clearance Creepage distance

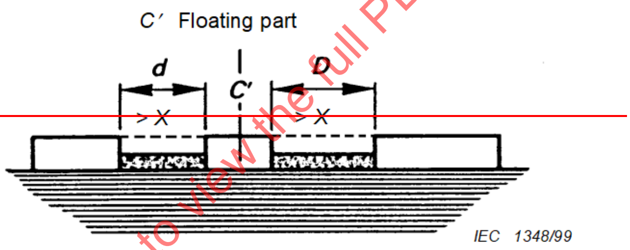
Example 10



Condition: The gap between the head of the screw and the wall of recess too narrow to be taken into account.

Rule: The measurement of creepage distance is from the screw to the wall when the distance is equal to *X* mm.

Example 11



Clearance is *d* + *D* Creepage distance is *d* + *D*

– – – – – – Clearance Creepage distance

Annex A
(informative)

Coordination between definitions

The object of this annex is to clarify the terminology of the definitions and the characteristics.

All terms or expressions in italics are taken from Clauses 3 and 5.

Generally, a quantity can vary within a range that is a gap between two admissible *limiting values*, but to designate or identify this quantity, an approximate value is used; it is the *nominal value* (see Figure A.1).

The greatest value of this range, or maximum value, is chosen to determine the test requirements; it is called the *rated value*.

The smallest is also used as a test value but generally for the operational requirements only.

The use of equipment or a device is defined principally by two values, voltage and current, defined and/or agreed by the manufacturer according to its design; it is a matter of the *rated operational voltage* with the rated frequency, if necessary, and the *rated operational current* (see Figure A.2).

These two rated values are used as references for the tests; they define the *utilization category* (see Figure A.2).

Sometimes when the quantity is derived from a regulating device the greatest value of the range of this regulation may be the *rated operational voltage* even if a larger range is required for operating.

The operational requirements may also take a temporary voltage when the regulation is ineffective into account.

Equipment or a device may have several *utilization categories* (see Figure A.3). It has, in this case, several *rated operational voltages* and *rated operational currents* included in a field voltage/current in which:

– the upper allowable current is that obtained in continuous duty (thermal limit). This limit may be exceeded for a short duration; it is then called an overload current;

– ~~the upper voltage, allowable continuously, is that which has been chosen, associated to the *impulse voltage* level, by the designer to determine the creepages and clearances; it is The *rated insulation voltage*. For the dielectric test, it is the quantity to which the *power frequency withstand voltage* is referred.~~

– the upper continuous allowable voltage is the *rated insulation voltage*, i. e. the voltage which has been chosen for determining the minimum creepage distances and which in turn, together with the overvoltage category, determines the *rated impulse voltage* level. The *rated impulse voltage* determines the minimum clearances and the dielectric test voltage.

~~All operational conditions shall ensure that the~~ The following limitations apply to operational requirements (see Figure A.3):

– *rated operational voltage* should be ~~always~~ lower than the *rated insulation voltage*;

– *transient overvoltages* are always lower than the *rated impulse* ~~*withstand*~~ *voltage* in order to avoid any breakdown;

– *rated operational current* should be ~~always~~ lower than the thermal limit;
– currents in overload condition are not greater than the *rated short-time withstand current*.

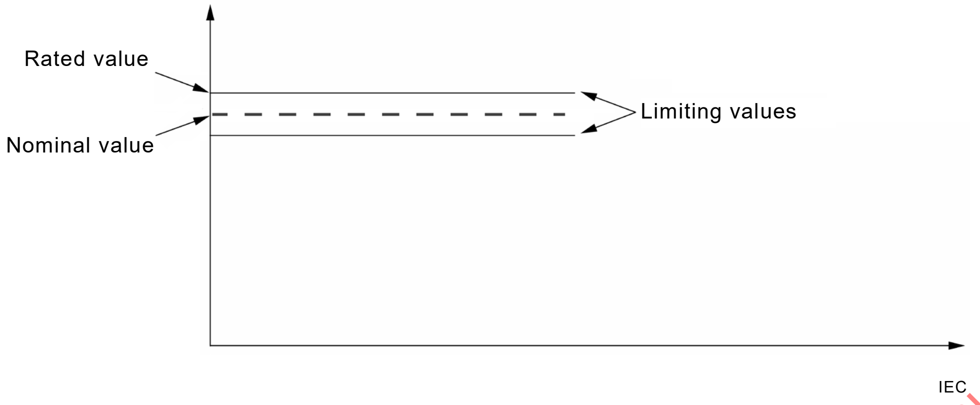


Figure A.1 – Example of relation of limiting values

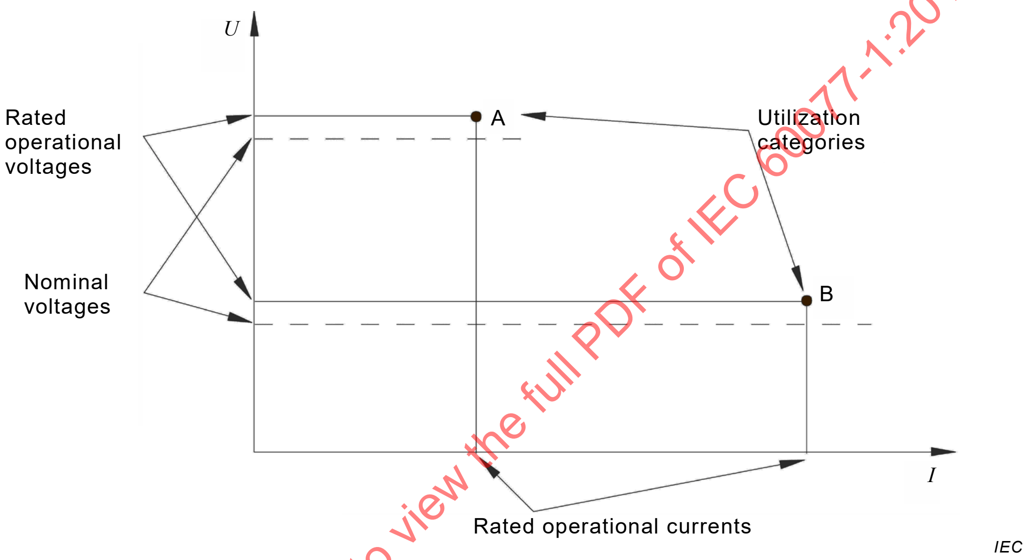


Figure A.2 – Example of utilization category

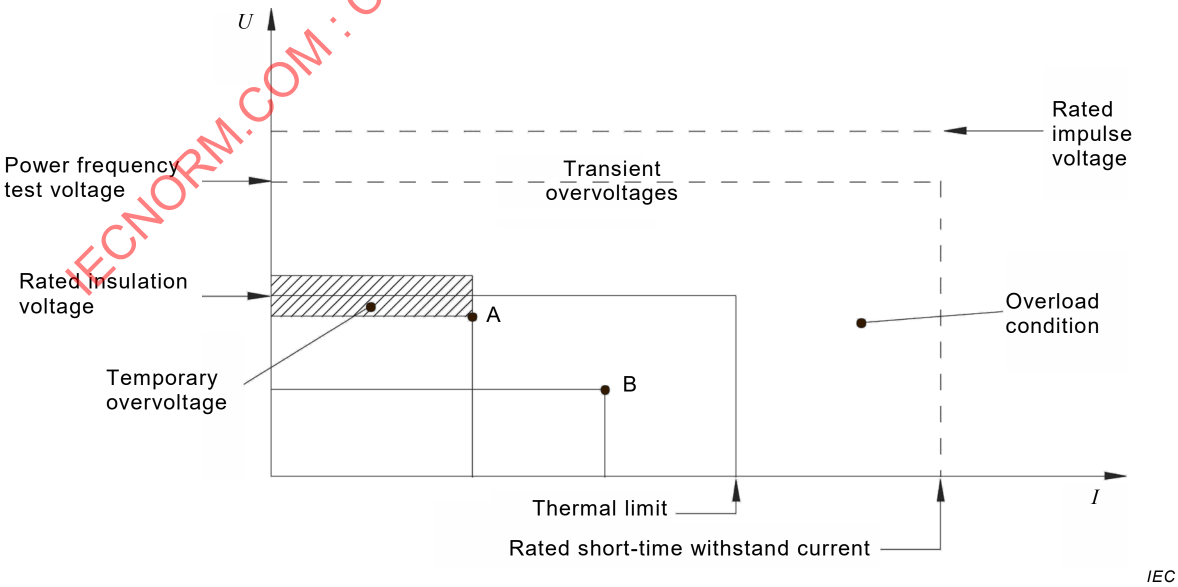


Figure A.3 – Example of coordination of operational conditions

Annex C
(informative)

Clearance and creepage determination

The object of this annex is to give a method and to give some help with the determination of clearances and creepages according to 8.2.6.

That clause gives only minimum values below which the ability to withstand voltage in a rolling stock environment shall be verified by test, but other values are often necessary.

The insulation characteristics of equipment are defined by clearances and creepages. These two parameters depend on the values from which a circuit is characterized from the point of view of its insulation:

– the rated impulse withstand voltage,
– the rated insulation voltage.

Clearances are primarily determined by the impulse voltages which may occur in the circuit either from external cause or by the switching of its own units. The knowledge of these impulse voltages is therefore important but they are not always known.

For equipment or an apparatus the manufacturer shall declare an impulse voltage which can be withstood. Likewise, a circuit shall not generate impulse voltages higher than its impulse withstand voltage.

For these reasons, it is necessary to determine a rated impulse withstand voltage. In electronic circuits it may be possible to know exactly the impulse voltage level. In the same way, the level is known when the impulse voltages which may occur are limited, by an arrester for example. Clearances are then determined by the use of table 5.

In many cases, the level of the expected impulse voltage is unknown. To help the designer, table 4 gives, as a function of the rated insulation voltage, the rated impulse withstand voltage which is unlikely to be exceeded.

The actual clearances can be determined from table 5. The values which are obtained from tables 4 and 5 are the minimum clearances which may be used theoretically.

In practice, the manufacturer with his own experience shall consider a safety factor to apply to clearance. This factor, which takes into account all parameters that may influence the insulation, provides the difference between the values obtained from theoretical consideration and those regarded as necessary for the actual in-service conditions.

These parameters include, for example

– atmospheric conditions (special pollution risks);
– ionized environment;
– local variations in the internal environment;
– quality of installation;
– space occupied by the connections;
– variations in the product quality during the life;
– human safety;

– variations in the equipment manufacturing and maintenance processes;

– ageing in service;

– failure situation and any other exceptional cases;

– etc.

When an electrical test is necessary (see 9.3.3.2.1) to check the clearances, it should be by an impulse withstand voltage test. However, for greater convenience, the power frequency voltage test or the d.c. voltage test can be used, as specified in table 7.

For creepages the values are determined from the rated insulation voltage using tables 6a and 6b. For equipment, the manufacturer shall choose the rated insulation voltage at least equal to rated operational voltage – or the highest rated voltage with a duration shorter than 5 min if in particular cases the interval between such stresses is relevant and if there are several.

If necessary, creepage shall be increased to be at least equal to clearances determined before.

Figure C.1 summarizes the way and the requirements to determine clearances and creepage.

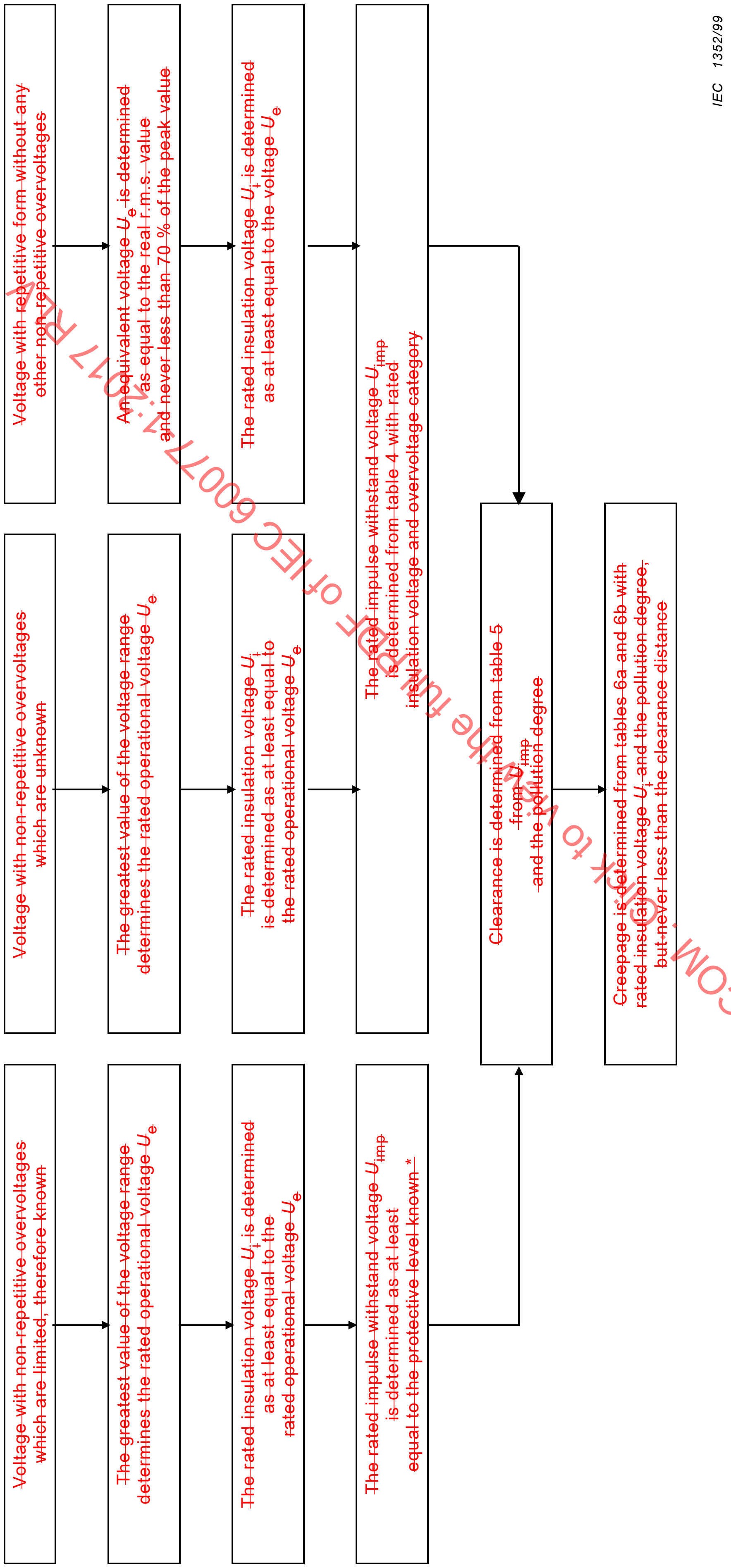


Figure C.1 – Determination of clearance and creep

Annex B
(informative)

Type and routine test of dielectric tests for equipment

B.1 General

This Annex B gives the information about type and routine test method of dielectric tests for equipment described in the first edition of IEC 60077-1.

B.2 General conditions

The tests shall be carried out with the rated power frequency voltage on every single piece of equipment. In certain cases to be agreed between the user and the manufacturer, they may also be carried out on equipment connected in groups. For details of tests of equipment when mounted on the vehicle, refer to IEC 61133.

The test voltage at a frequency of 50 Hz or 60 Hz shall be of approximately sinusoidal form.

The method of test and the RMS values of the test voltage are defined below. The test voltage is applied progressively in 10 s, maintained at the prescribed value during 60 s ± 5 s, and then decreased progressively to zero.

After agreement between the user and the manufacturer, DC voltage may be used; the value of the test voltage is then equal to the peak value of AC voltage required.

NOTE In all formulae giving test voltages, U_{Nm} represents the rated insulation voltage (see 5.2 and Annex A) of the apparatus subject to the test.

These tests may also be required in a type test sequence to verify that equipment has no damage after the test.

B.3 Test voltage

Tests on single pieces of equipment shall be carried out in accordance with the following requirements:

– in Table B.1 for AC and DC rated insulation voltages of no more than 10 000 V;
– in Table B.2 for equipment connected to the AC contact line by the application of the test voltage:
  - between the main circuit or contacts in the closed position and other circuits including earth;
  - and between contacts in the open position.

~~NOTE~~ Aged insulation parts which may be dielectrically tested after refurbishment or repair are not to be tested at more than 1,5 times the rated insulation voltage.

Table B.1 – Dielectric tests on single pieces of equipment

Subject	Rated power frequency voltage (U_a) for rated insulation voltage (U_{Nm}) V					
	Up to 36 [a]	**From 36 to 60**	**From 60 to 300**	**From 300 to 660**	**From 660 to 1 200**	**From 1 200 to 10 000**
For all equipment taken singly, the dielectric test shall be applied between each circuit of a given voltage and the others and earth.	750	1 000	1 500	2 500	2 U_{Nm} + 1 500	2 U_{Nm} + 2 000
For all equipment* intended to break a circuit and taken singly, the dielectric test shall be applied between the input and output sides of the apparatus – with contacts open and arc chutes in position. * Equipment may include more than one item if this is necessary to break the circuit. For all breaking equipment connected in parallel with a resistor, the test voltage shall be limited to 0,75 times the value mentioned, the resistor being disconnected.	750	1 000	1 500	1,6 U_{Nm} + 1 500		
For all equipment taken singly or parts electrically connected to other circuits which are not connected to the power circuit the dielectric test shall be applied between these parts and earth.	750	1 000	2 U_{Nm} + 1 000 with a minimum of 1 500			
For all equipment with double insulation with an intermediate conductive frame[b], the dielectric test shall be applied – between intermediate conductive frame and earth; – between circuit and intermediate conductive frame. Where the main insulation is provided between circuit and intermediate conductive frame insulated from earth, the test voltages are to be reversed.			1 500 1 500	2 500 1 500	2 U_{Nm} + 1 500 1,6 U_{Nm} + 500	2 U_{Nm} + 2 000 1,6 U_{Nm} + 1 000

[a] For electronic equipment having a rated insulation voltage (U_{Nm}) of less than 36 V, the dielectric test voltage is reduced to 500 V.

[b] Definition of double insulation has changed between first edition of IEC 60077-1 and IEC 62497-1. Compared with definition in first edition of IEC 60077-1, double insulation according to IEC 62497-1 does not necessarily imply an intermediate conductive frame.

Table B.2 – Dielectric tests for equipment connected to AC contact line

Nominal voltage of contact supply line AC RMS kV	**Rated power frequency voltage RMS** kV
6,25	20
15	38
25	75
50	130

Annex C
(informative)

Example of thermal endurance calculation to demonstrate the suitability of an insulation system for a specified application

C.1 General

This Annex is just an example for the purpose of understanding the calculation method set up in IEC 60310:2016, Annex B.

It is based on purely indicative thermal endurance characteristics and should not been taken as reference for actual applications if not supported by actual thermal endurance test data.

For easy understanding, the simplified Arrhenius formula (C.1) is used:

$$ECO(h) = 20\,000 \times 2^{\frac{TI - T_{hs}}{HIC}} \quad (C.1)$$

$$CEP(\%) = \frac{AOT}{ECO} \times 100 \quad (C.2)$$

where

ECO is the thermal endurance in continuous operation (in hours);

TI is the temperature index (in degrees Celsius);

T_{hs} is the hot spot temperature (in degrees Celsius);

HIC is the halving interval (in Kelvins);

CEP is the consumed endurance potential (in percent) for a given hot-spot temperature;

AOT is the actual operating time (in hours) the insulating system will operate at the given hot-spot temperature.

C.2 Example 1 – Temperature limits for an electric insulation system

In the examples of Table C.1, two insulation systems of different classes are considered which have a *TI* at the lower limit of their thermal class and with the shown *HIC*.

Table C.1 – Temperature limits and expected lifetime for a dry-type insulation system (examples)

Thermal class	Thermal endurance characteristics for the examples		Short-time operation at maximum hot-spot temperature (NOTE 1)		Continuous operation (210 000 h) (NOTE 2)
	TI	*HIC*	Maximum hot-spot temperature °C	Expected lifetime h	Maximum hot-spot temperature °C
105 (A)	105	6	130	1 100	85
180 (H)	180	11	205	4 100	143

NOTE 1 Column 5 shows the expected lifetime if the insulation system is operated continuously at the maximum hot-spot temperature according to Table 3 for windings. The expected lifetime is calculated for 100 % *CEP*.

NOTE 2 Column 6 shows the maximum temperature for continuous operation of the insulation system for a specified lifetime of 210 000 h (i.e. 30 years and 7 000 h per year).

C.3 Example 2 – Thermal endurance calculation

C.3.1 General

The example below considers the coil of a magnet valve (type VC1) for a traction application, supplied by a 110 V nominal float charged battery, cooled by natural air convection.

This calculation method may be applied to multiple parameters at the same time or to other parts of components.

It is often possible to split the operation of traction electric equipment into simple equivalent operating conditions thanks to their usually high thermal time constant compared with the running cycle of the railway vehicle.

Annex D in IEC 60310:2016 provides an example of lifetime calculation for a dry-type transformer or inductor.

In the following tables, cells with a white background indicate input data while cells with a grey background indicate output data resulting from calculations.

C.3.2 Operating conditions provided by the purchaser

Total operation hours over lifetime: 194 400 h (30 years at 360 days per year and 18 h per day).

Two main parameters define the winding temperature of the coil: the ambient temperature and the supply voltage of the coil. In this example, for simplicity, the voltage is assumed to be constant and equal to the rated operational voltage (U_r). Then the operation is described by a simplified temperature distribution shown in Table C.2.

Table C.2 – Ambient temperature distribution

Operating conditions	T_{AMB} °C	Voltage V (NOTE)	Operation over lifetime	
			Split %	*AOT* h
Condition 1	40	126,5	40,0	77 760
Condition 2	55		50,0	97 200
Condition 3	65		10,0	19 440
Total			100,0	194 400

NOTE For VC1 type electrical equipment, the battery voltage is usually not constant but regulated by the battery charger with a temperature compensation characteristic which decreases the floating voltage when the battery temperature increases.

C.3.3 Thermal endurance characteristics provided by the manufacturer

– Information about the reference and actually used insulation system according to IEC 60216-5: generic type of materials, test certificates.

– Thermal class, endurance graph (Arrhenius formula constants, ATE or RTE, *HIC*).

In this example, the assessed thermal endurance (ATE) or relative thermal endurance (RTE) index is taken for *TI* in the calculations with the following values:

Class 130 (B) insulation system with *TI* = 130 °C and *HIC* = 9 K.

C.3.4 Temperature rise test results

Table C.3 shows temperature rise test measurements and calculation results. This test provides the winding resistance of the coil (*R*) at a reference temperature (e.g. at 0 °C) and the value of the thermal resistance of the coil (R_{th_avg}).

First, the winding resistance of the coil (*R*) is measured directly and, if necessary, converted to a reference temperature according to 9.3.2.2.3.

Next, the temperature rise test is carried out with direct measurement of ambient air temperature (T_{amb}), voltage (*U*), current (*I*) and hot-spot temperature (T_{hs}). Here, the test is performed at reference temperature T_r = 25 °C and rated operational voltage U_r = 126,5 V. The average winding temperature of the coil (T_{avg}) is derived from the resistance (*R*) variation.

Finally, the other parameters are calculated: power (*P*), temperature rises (ΔT_{avg}, ΔT_{hs}), gradient ($\Delta T_{hs\text{-}avg}$) between hot-spot and average temperatures, and thermal resistance ($R_{th\_avg} = \Delta T_{avg} / P$).

Table C.3 – Temperature rise test results

Comment	T_{amb} °C	*U* V	*I* A	*P* W	*R* Ω	T_{avg} °C	ΔT_{avg} K	R_{th_avg} K/W	T_{hs} °C	$\Delta T_{hs\text{-}avg}$ K	ΔT_{hs} K
R reference	0				779	0					
Test	25	126,5	0,124 9	15,80	1 013	70,5	45,5	2,88	75,5	5,0	50,5

C.3.5 Extrapolations

Table C.4 shows an example of extrapolation, by iterations, of the temperature rise test results at another ambient temperature (corresponding to Condition 1 in Table C.2).

Each iteration is performed as follows:

– starting with the value of the winding resistance of the coil (R) in the previous row of the table;

– calculating the average winding temperature rise of the coil:

$$\Delta T_{avg} = R_{th\_avg} \times P;$$

– recalculating the resistance according to the following formula with k = 234,5 for copper:

$$R_2 = R_1 \times \frac{T_2 + k}{T_1 + k};$$

– and assuming that $\Delta T_{hs\text{-}avg}$ is proportional to ΔT_{avg}.

Table C.4 – Extrapolation to other ambient temperature

Comment	T_{amb}	U	P	ΔT_{avg}	T_{avg}	R	$\Delta T_{hs\text{-}avg}$	ΔT_{hs}	T_{hs}
	°C	V	W	K	°C	Ω	K	K	°C
Test	25	126,5	15,8	45,5	70,5	1 013	5,0	50,5	75,5
Iteration			15,8	45,5	85,5	1 062,4	5,0	50,5	90,5
Iteration			15,1	43,3	83,3	1 055,3	4,8	48,1	88,1
Iteration	40	126,5	15,2	43,6	83,6	1 056,3	4,8	48,4	88,4
Iteration			15,1	43,6	83,6	1 056,1	4,8	48,4	88,4
Condition 1			15,2	43,6	83,6	1 056,2	4,8	48,4	88,4

C.3.6 Lifetime calculation based on thermal endurance

Applying the principles of Table C.4, the temperatures of Table C.5 can be extrapolated for each condition specified in Table C.2.

Using fomula (C.2), the consumed thermal endurance potential (CEP) can then be calculated.

Table C.5 – Lifetime calculation based on thermal endurance

Temperature extrapolations								Thermal endurance calculations			
Comment	T_{amb}	U	P	ΔT_{avg}	T_{avg}	ΔT_{hs}	T_{hs}	Operation over lifetime		Lifetime	
	°C	V	W	K	°C	K	°C	Split %	AOT h	ECO h	CEP %
Test	25	126,5	15,8	45,5	70,5	50,5	75,5			1 334 212	
Condition 1	40		15,2	43,6	83,6	48,4	88,4	40,0	77 760	493 310	15,8
Condition 2	55	126,5	14,5	41,9	96,9	46,4	101,4	50,0	97 200	180 363	53,9
Condition 3	65		14,2	40,8	105,8	45,2	110,2	10,0	19 440	91 692	21,2
Total								100	194 400		90,9

NOTE Because the speed of ageing increases with temperature, although operation in the hottest conditions (Condition 3) is limited to 10 % of the required lifetime, it consumes 21 % of the lifetime potential of the insulation system of the coil. Whereas, operation in the coldest conditions (Condition1), occurring 40 % of lifetime, only consumes 16 %.

The total consumed endurance potential (*CEP*) is less than 100 %: the insulations system of this coil is acceptable, for the specified conditions, from the thermal endurance point of view.

C.3.7 Equivalent continuous duty and rated continuous duty

Applying the principles of Table C.5, it is possible to calculate:

– the available lifetime (*ECO*);

– or the consumption of potential lifetime (*CEP*) after a given operation time (*AOT*);

for continuous operation at any relevant ambient temperature and voltage values as shown in Table C.6 for an equivalent continuous duty and for different rated continuous duties.

Equivalent continuous duty – This calculation aims at determining a single, equivalent, ambient temperature (T_{amb_eq}) and a single, equivalent, voltage (U_{dc_eq}) for continuous operation which consumes the same potential of thermal endurance (approximately, because of the chosen, rounded figures) as the specified application, which corresponds to the actual service. This case is generated from Table C.5 in two steps:

– Step 1: a same temperature (T_{amb_eq}) for each of the voltage conditions is determined, by iterations, which consumes the same overall *CEP* as the specified application.

– Step 2: a same voltage (U_{dc_eq}) for each time slice is then determined by iterations which consumes the same overall *CEP* at the equivalent temperature determined in step 1 (T_{amb_eq}).

Rated continuous duty – Similarly, it is possible to determine many pairs of temperature (T_{amb_rated}) and voltage (U_{dc_rated}) aiming at consuming 100% *CEP* for a given target lifetime (*AOT*), e.g. for the purpose of a catalog.

Table C.6 – Equivalent continuous duty and rated continuous duty

Temperature extrapolations								Thermal endurance calculations		
Comment	T_{amb}	U	P	ΔT_{avg}	T_{avg}	ΔT_{hs}	T_{hs}	Continuous operation	Lifetime	
	°C	V	W	K	°C	K	°C	*AOT* h	*ECO* h	*CEP* %
Test	25	126,5	15,8	45,5	70,5	50,5	75,5		1 334 212	
Equivalent continuous duty	52,5	126,5	14,6	42,1	94,6	46,8	99,3	194 400	213 443	91,1
Rated continuous duty	55	126,5	14,5	41,9	96,9	46,4	101,4	180 000	180 370	99,8

NOTE 180 000 h is another example of lifetime requirement.

Bibliography

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

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 60050-811:1991, *International Electrotechnical Vocabulary (IEV) – Chapter 811: Electric traction*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

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

IEC 60077-2, *Railway applications – Electric equipment for rolling stock – Part 2: Electrotechnical components – Genral rules*

IEC 60077-3, *Railway applications – Electric equipment for rolling stock – Part 3: Electrotechnical components – Rules for d.c. circuit-breakers*

IEC 60077-4, *Railway applications – Electric equipment for rolling stock – Part 4: Electrotechnical components – Rules for a.c. circuit-breakers*

IEC 60077-5, *Railway applications – Electric equipment for rolling stock – Part 5: Electrotechnical components – Rules for HV fuses*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

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

IEC 60310:2016, *Railway applications – Traction transformers and inductors on board rolling stock*

IEC 60322, *Railway applications – Electric equipment for rolling stock – Rules for power resistors of open construction*

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60571, *Railway applications – Electronic equipment used on rolling stock*

IEC 60587, *Electrical insulating materials used under severe ambient conditions – Test methods for evaluating resistance to tracking and erosion*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC TR 60943:1998, *Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals*
IEC TR 60943:1998/AMD1:2008

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 62236-3-1, *Railway applications – Electromagnetic compatibility – Part 3-1: Rolling stock – Train and complete vehicle*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*
IEC 62271-100:2008/AMD1:2012

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

IEC 60077-1

Edition 2.0 2017-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules

Applications ferroviaires – Equipements électriques du matériel roulant – Partie 1: Conditions générales de service et règles générales

IEC 60077-1:2017-07(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

RAILWAY APPLICATIONS – ELECTRIC EQUIPMENT FOR ROLLING STOCK –

Part 1: General service conditions and general rules

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.
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International Standard IEC 60077-1 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition of IEC 60077-1, issued in 1999. It constitutes a technical revision.

This edition includes the following main technical changes with regard to the previous edition:

a) Descriptions regarding insulation coordination, environmental conditions and those of current return and protective bonding are deleted and replaced by references to IEC 62497-1, IEC 62498-1 and IEC 61991, except classes of air temperature, which are copied from Table 2 in IEC 62498-1:2010.
b) Classification of equipment type is introduced.
c) Temperature limits and temperature rise tests are reviewed.

d) Example of lifetime calculation: Annex C (informative) is introduced.

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

FDIS	Report on voting
9/2266/FDIS	9/2278/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 in the IEC 60077 series, published under the general title *Railway applications – Electric equipment for rolling stock*, can be found 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 website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

INTRODUCTION

Although this document specifies the general service conditions and general rules for electric equipment for railway rolling stock, further details for certain types of electric equipment may be given in other IEC standards.

IEC 60077 series consists of the following parts:

- Part 1 – General service conditions and general rules
- Part 2 – Electrotechnical components – General rules
- Part 3 – Electrotechnical components – Rules for DC circuit-breakers
- Part 4 – Electrotechnical components – Rules for AC circuit-breakers
- Part 5 – Electrotechnical components – Rules for HV fuses

Although all circuits of power or control electronic equipment connected to battery or contact line are covered by this document, internal circuits of these may be subject to special requirements covered by relevant product standards.

For electric equipment for rolling stock which conforms to an appropriate international standard, including items of industrial equipment, this document, plus the relevant equipment product standard for electric equipment where appropriate, specifies only those additional requirements to ensure satisfactory operation on rolling stock.

RAILWAY APPLICATIONS – ELECTRIC EQUIPMENT FOR ROLLING STOCK –

Part 1: General service conditions and general rules

1 Scope

This part of IEC 60077 specifies the general service conditions and requirements for all electric equipment installed in power circuits, auxiliary circuits, control and indicating circuits etc., on railway rolling stock.

NOTE Some of these rules can, after agreement between the user and the manufacturer, be used for electrical equipment installed on vehicles other than railway rolling stock, such as mine locomotives, trolley buses, etc.

The purpose of this document is to harmonize as far as practicable all rules and requirements of a general nature applicable to electric equipment for rolling stock. This is in order to obtain uniformity of requirements and tests throughout the corresponding range of equipment to avoid the need for testing to different standards.

All requirements relating to:

- the environmental stresses expected during the normal service conditions;
- the construction;
- the performance and the associated tests which can be considered as general;

have therefore been gathered in this document together with specific subjects of wide interest and application, for example temperature rise, dielectric properties, etc.

In the event of there being a difference in requirements between this document and a railway rolling stock relevant product standard, then the product standard requirements take precedence.

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 60068-2-1, *Environmental testing – Part 2-1: Tests – Tests A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Tests B: Dry heat*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-52, *Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

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 60505, *Evaluation and qualification of electrical insulation systems*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60721-3-5, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 5: Ground vehicle installations*

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

IEC 61133:2016, *Railway applications – Rolling stock – Testing of rolling stock on completion of construction and before entry into service*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

IEC 61991, *Railway applications – Rolling stock – Protective provisions against electrical hazards*

IEC 61992-1, *Railway applications – Fixed installations – DC switchgear – Part 1: General*

IEC 62236-3-2, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

IEC 62497-1, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

IEC 62498-1:2010, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*

3 Terms, definitions and abbreviated terms (see also Annex A)

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 General

3.1.1
rolling stock
all the vehicles with or without motors

Note 1 to entry: Examples of vehicles include a locomotive, a coach and a wagon.

[SOURCE: IEC 60050-811:2017, 811-02-01]

3.1.2
vehicle
single item of rolling stock

3.2 Circuits

3.2.1
power circuit
circuit carrying the current of the machines and equipment, such as the converters and traction motors, which transmit the traction output

[SOURCE: IEC 60050-811:2017, 811-25-03]

3.2.2
main circuit
all the conductive parts of a device carrying the current for the function to which this device has been applied

3.2.3
auxiliary circuit, <of a train>
circuit carrying the current of the auxiliaries such as the compressors and fans

[SOURCE: IEC 60050-811:2017, 811-25-05]

3.2.4
control circuit, <of a train>
circuit used to actuate the power or auxiliary equipment

[SOURCE: IEC 60050-811:2017, 811-25-12]

3.2.5
indicating circuit
circuit transmitting a signal indicating or recording whether a particular operating condition exists or not (for example a signal indicating a failure in the electrical equipment)

[SOURCE: IEC 60050-811:2017, 811-25-14]

3.3 Battery supplied equipment

3.3.1
battery
electrochemical system capable of storing in chemical form the electric energy received and which can give it back by reconversion

3.3.2
battery on float <charge>
secondary battery whose terminals are permanently connected to a source of constant voltage sufficient to maintain the battery approximately fully charged, and which is intended to supply power to an electric circuit, if the normal supply is temporarily interrupted

Note 1 to entry: The battery is absorbing a float charge current in this mode.

[SOURCE: IEC 60050-482:2004, 482-05-35, modified – Note 1 to entry has been added.]

3.3.3
float charge battery system
equipment mostly operated with the battery on float charge

3.3.4
battery off charge system
equipment mostly supplied while the battery is not being charged

3.4 Test categories

3.4.1
type test
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-811:2017, 811-10-04]

3.4.2
routine test
conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-811:2017, 811-10-05]

3.4.3
sampling test
test on a sample

[SOURCE: IEC 60050-811:2017, 811-10-06]

3.4.4
investigation test
special test of an optional character carried out in order to obtain additional information

[SOURCE: IEC 60050-811:2017, 811-10-07]

3.4.5
exposed conductive part
conductive part which can readily be touched and which is not normally alive, but which may become alive under fault conditions

[SOURCE: IEC 60050-441:1984, 441-11-10, modified – Note has been deleted.]

3.5 Characteristic quantities

3.5.1
limiting value
greatest or smallest admissible value of a quantity in a specification of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-10, modified – The order of phrases has been changed.]

3.5.2
nominal value
value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The nominal value is generally a rounded value.

Note 2 to entry: In this document, the term "nominal" is used only as common practice to designate contact line and battery voltage circuits.

[SOURCE: IEC 60050-811:2017, 811-11-01, modified – Note 2 to entry has been added.]

3.5.3
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-811:2017, 811-11-02]

3.5.4
equivalent continuous duty
duty of electrical equipment on rolling stock, which corresponds to the actual service, generally characterized by values of current, voltage, compressed air pressure, etc., which vary with time

Note 1 to entry: The various parts of the equipment are defined by a complete statement of the conditions to be fulfilled. However, it is sometimes sufficient to specify an equivalent duty which corresponds from the point of view of either electrical, mechanical or thermal stresses to the service considered, and is known as being equivalent to the actual service. It is the equivalent continuous duty to which the relevant tests are referred.

3.5.5
equivalent continuous rated current
current corresponding to the equivalent continuous duty

3.6 Terms related to lifetime

3.6.1
ageing
change with passage of time of physical, chemical or electrical properties of a component or module under specified operating conditions, which may result in degradation of significant performance characteristics

Note 1 to entry: This entry was numbered 393-18-41 in IEC 60050-393:2003.

[SOURCE: IEC 60050-395:2014, 395-07-100]

3.6.2
endurance
ability to withstand the action of ageing factors

Note 1 to entry: The endurance may be characterized by the results of accelerated ageing tests.

[SOURCE: IEC 60050-212:2010, 212-12-08]

3.6.3
thermal endurance
ability to withstand the action of temperature

[SOURCE: IEC 60050-212:2010, 212-12-09]

3.6.4
durability
ability to perform as required, under given conditions of use and maintenance, until the end of useful life

Note 1 to entry: For the purpose of this document, "durability" is used in order to express the expectancy of the life duration (time or number of operating cycles) which can be performed by the equipment before repair or replacement of parts.

[SOURCE: IEC 60050-192:2015, 192-01-21, modified – Note 1 to entry has been added.]

3.7 Abbreviated terms

AC	Alternating Current
DC	Direct Current
EMC	Electromagnetic Compatibility
RMS	Root Mean Square value
PD	Pollution degree
OV	Overvoltage category
VC	Voltage Class

4 Classification

This clause is intended to list the characteristics of equipment on which information may be given by the manufacturer and which shall be verified by testing where relevant.

Equipment covered by this document is classified, according to the supply source of its control and auxiliary circuits. Details are given in 5.3.3.2.

5 Characteristics of the utilization category

5.1 General

The utilization category of equipment defines the intended application and shall be specified in the relevant product standard; it is characterized by one or more of the following parameters:

- current(s);
- voltage(s);
- frequency(ies);
- air pressure(s).

See also Annex A.

NOTE This list is not exhaustive and can include other parameters as applicable.

5.2 Rated voltages

5.2.1 General

The term rated voltage can generally be related to both the input and output values of equipment. The quantity is assigned generally by the manufacturer.

5.2.2 Rated operational voltage (U_r)

The rated operational voltage of equipment is a value of voltage which combined with a rated operational current and rated operational frequency, determines the application of the equipment and to which the relevant tests and the utilization categories are referred.

NOTE Symbol U_e was used in the first edition of IEC 60077-1. U_{Ne} is used in IEC 61992-1.

5.2.3 Rated insulation voltage (U_{Nm})

Definition of a rated insulation voltage is given in IEC 62497-1.

The rated insulation voltage is the value of voltage to which rated impulse voltage and creepage distances are referred.

When the voltage is not purely of sinusoidal or of continuous form, the RMS or mean value alone cannot be considered to prescribe the rated insulation voltage of the components.

In the absence of any knowledge of the influence on dielectric strength of:

- the ratio between the duration of periodic impulses and their repetition period;
- the number of impulses during each burst;
- the voltage rate of rise of the impulse (dv/dt),

it is recommended that this voltage be considered as being equal to the real RMS value, but not less than 70 % of the peak value.

5.2.4 Power-frequency test voltage (U_a)

The power-frequency test voltage is the RMS value of power-frequency sinusoidal voltage which does not cause an insulation failure under specified conditions of test.

U_a is given in IEC 62497-1.

5.2.5 Rated impulse voltage (U_{Ni})

Definition of a rated impulse voltage is given in IEC 62497-1.

The rated impulse voltage is used for determining minimum required clearances and dielectric test voltages.

5.3 Rated voltages for electric equipment

5.3.1 Equipment supplied by a contact line

The rated operational voltage (U_r) for equipment supplied from the contact line is the highest permanent voltage (U_{max1}) of the contact line voltage as defined by IEC 60850.

5.3.2 Equipment supplied by a transformer

The rated operational voltage (U_r) for equipment supplied from a winding of a transformer is equal to the RMS voltage at the terminals of the winding when the transformer primary is supplied at the rated operational voltage. If a second transformer is interposed between the above-mentioned transformer and the equipment, the rated operational voltage (U_r) is equal to the above-mentioned rated operational voltage multiplied by the transformer ratio of the second transformer.

5.3.3 Equipment supplied by DC low voltage sources

5.3.3.1 Nominal voltages

This subclause applies to the equipment supplied from the voltage bands I and band II according to IEC 61991.

The nominal voltage (U_n) is only used to designate the circuits and the equipment and should be selected from the following preferred values:

24 V, 72 V or 110 V

Other voltages may be used upon agreement between the user and the manufacturer.

NOTE These nominal voltage values are given only as standardizing values for the design of the equipment. They are not considered as the off-load battery voltage which will be determined as functions of the type of battery, the number of cells and the operating conditions.

5.3.3.2 Voltage ranges

Equipment covered by this document is classified as follows, according to the supply source of its control and auxiliary circuits:

- type VC1: equipment supplied by a float charge battery system;
- type VC2: equipment supplied by a battery off charge system;
- type VC3: equipment not supplied directly by an onboard battery, but supplied by e.g. a generator, alternator or electronic converter.

Table 1 shows the voltage ranges and rated operational voltage (U_r) for control circuit and auxiliary circuit for each equipment type. The values for Type VC3 are valid for a stabilized voltage source.

Table 1 – Voltage ranges for control circuits and auxiliary circuits

Classification	Minimum equipment voltage	Rated operational voltage (U_r)	Maximum equipment voltage
Type VC1	0,7 U_n	1,15 U_n	1,25 U_n
Type VC2	0,7 U_n	1,1 U_n	1,25 U_n
Type VC3	0,85 U_n	1,0 U_n	1,1 U_n

NOTE 1 Basically the battery for Type VC1 equipment is used in charging mode. The voltage can be lower than the float voltage for short periods of time, e.g. before starting the charging equipment, during the battery voltage buildup or during the contact line interruption.

NOTE 2 Basically the battery for Type VC2 equipment is used in discharging mode. The battery voltage will reduce over time.

NOTE 3 The voltage of Type VC3 equipment is not the voltage supplying the generator, alternator or electronic converter itself.

NOTE 4 Voltage range of Type VC1 and Type VC2 is same, but the evolution of the voltage during operation is different regarding the lifetime of the equipment.

NOTE 5 The rated operational voltage is used for calculation of losses, power consumption, temperature rise, etc.

5.4 Rated currents for equipment

5.4.1 Rated operational current (I_r)

The rated operational current of equipment is stated by the manufacturer and takes into account the rated operational voltage and rated operational frequency.

5.4.2 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of equipment is the value of short-time withstand current assigned to the equipment by the manufacturer that the equipment can carry without damage.

The rated duration (t_{cw}) of equipment used is the value of the interval of time for which switchgear and controlgear can carry, in the closed position, a current equal to its rated short-time withstand current.

5.5 Rated operational frequency (f_r)

The rated operational frequency of equipment is stated by the manufacturer and takes into account the rated operational voltage.

5.6 Rated air pressure

The rated pressure of the air supply to pneumatic or electro-pneumatic equipment is the greatest limiting value of the range of the regulating device and to which the relevant tests are referred.

6 Product information

6.1 Nature of information

The following information shall be given by the manufacturer for each item of the electric equipment when required by the relevant product standard:

a) identification

- manufacturer's name or trade mark;
- type designation or serial number;
- modification status;
- reference of the relevant product standard, if the manufacturer declares compliance with it.

b) characteristics

The following list is not exhaustive and should be applied as appropriate:

- rated operational voltage(s);
- rated insulation voltage;
- rated impulse voltage;
- rated operational current(s) at the rated operational voltage(s);
- rated operational frequency(ies);
- maximum current consumption or maximum power consumption;
- number of operations for mechanical and electrical durability with reference to the relevant product standard;
- rated performance in overload and/or fault conditions with reference to the relevant product standard;
- IP code in the case of enclosed equipment (according to IEC 60529);
- degree of pollution acceptable for the equipment (according to 7.9);
- rated voltage(s), rated frequency(ies) and rated current(s) of the control circuit(s);
- rated air pressure and pressure variation limits (for equipment with pneumatic control);
- overall dimensions;
- minimum size of the enclosure and, if applicable, data concerning ventilation, to which the rated characteristics apply;
- minimum distance between the equipment and its enclosure;
- minimum distance between the equipment and the metal parts connected to the vehicle structure for equipment which are intended for use without an enclosure;
- weight.

Some of this information may be supplemented by the value of the ambient air temperature at which the equipment was calibrated.

6.2 Marking

All relevant information, as detailed in 6.1, which is to be marked on the equipment, shall be specified in the relevant product standard.

The following markings on the equipment are mandatory:

- manufacturer's name or trade mark,
- type designation,
- serial number or date or code of manufacture.

These are preferably marked on the nameplate, if any, in order to permit the complete data to be obtained from the manufacturer (traceability). The markings shall be indelible and easily legible.

6.3 Instructions for storage, installation, operation and maintenance

The manufacturer shall specify in his documents or catalogues the instructions, if any, for storage, installation, operation and maintenance of the equipment during operation and after a fault.

If necessary, the instructions for the storage, transport, installation and operation of the equipment shall indicate the measures that are of particular importance for the proper and correct installation, commissioning and operation of the equipment.

These documents shall indicate the recommended extent and frequency of maintenance, if any.

Equipment covered by this document may not necessarily be designed to be maintained.

7 Normal service conditions

7.1 General

Clause 7 defines service conditions. Some of service conditions are stated in IEC 62498-1:2010 and some others are taken from other stated references. In the event of other environmental conditions applying these should be selected from IEC 62498-1:2010 and, if conditions in IEC 62498-1:2010 are insufficient, those should be selected from IEC 60721-3-5 if appropriate.

The following list is not exhaustive and IEC 62498-1:2010 and IEC 60721-3-5 give further parameters.

The normal service conditions are a combination of environmental, operational and installation conditions.

7.2 Altitude

The equipment is normally to function in the specified altitude range. Class A1 of altitude range as given in IEC 62498-1:2010 shall apply, unless otherwise specified.

For installation at higher altitudes, it is necessary to take into account the reduction of the dielectric strength and of the cooling effect of the air. The equipment so used should be designed or used according to an agreement between the user and the manufacturer.

NOTE Regarding the reduction of the cooling effect of the air with altitude, the higher temperature rise at higher altitude is usually compensated by the reduced maximum ambient temperature at higher altitude. Guidance can be found, for example, in 5.1 of IEC TR 60943:1998/ AMD1:2008.

7.3 Temperature

7.3.1 Ambient temperature

The ambient air shall be considered as being that surrounding the device, and will differ according to the location where the device is fitted.

The class of ambient temperature, at which the electric equipment will operate, shall be given according to Table 2, unless otherwise specified. Class T1 shall apply, unless otherwise specified.

For internal locations, the ambient air temperature (T_a) is the external ambient temperature increased by the air temperature rise due to the localized thermal losses after taking into consideration the normal conditions of cooling.

Table 2 – Classes of air temperatures

Classes (Typical application area)	Air temperature external to vehicle °C	Inside vehicle compartment temperature °C	Inside cubicle temperature °C
T1 (e.g. middle Europe)	–25 +40	–25 +50	–25 +70
T2 (e.g. northern Europe)	–40 +35	–40 +45	–40 +65
T3 (e.g. southern Europe)	–25 +45	–25 +55	–25 +70
T4 (mild climate area in mid-latitude)	–10 +40	–10 +50	–10 +70
T5 (tropical area except desert)	+5 +45	+5 +55	+5 +70
T6 (tropical area in desert)	–20 +55	–20 +65	–20 +75
TX	–40 +50	–40 +60	–40 +75

NOTE 1 This Table is derived from IEC 62498-1:2010, Table 2.

NOTE 2 Storage temperatures are not considered as normal service conditions unless they have been stated.

For each of the various internal parts of the car body, engine compartment, cubicle, box, etc., the air temperature rise may be different. When this value is neither specified by a relevant document nor known it shall be considered that it does not exceed 30 K during functioning.

If the devices are used in a higher average ambient temperature than that designed, their performance needs to be derated.

For altitude class AX in IEC 62498-1:2010, the dependency between altitude and temperature shall be provided by the user through a temperature distribution for each relevant range (e.g. 0 m to 1 000 m and 1 000 m to 2 000 m).

7.3.2 Reference temperature

A reference temperature (T_r) (equivalent continuous surrounding air temperature or cooling medium temperature) is considered as being the permanent temperature for which the effects on material ageing are equivalent to those of the service temperature during the lifetime. It can be used for lifetime and reliability calculation.

a) Either, it shall be taken as 25 °C for exterior location according to Class TR2 of Table 3 in IEC 62498-1:2010, unless otherwise specified;

b) or, it shall be taken as 30 K increase to external reference temperature for interior location unless otherwise specified;

c) or it may be calculated by the manufacturer on the basis of the temperature distribution provided by the purchaser.

NOTE 1 Thermal ageing is an exponential function of temperature (e.g. see IEC 60216 for insulating materials), i.e. the reference temperature is usually higher than the arithmetic mean temperature.

NOTE 2 For interior locations, the temperature distribution depends strongly on the load and the related heat dissipation.

7.4 Humidity

Humidity is defined in IEC 62498-1:2010, 4.4.

7.5 Biological conditions

Risks of biological attack as defined in IEC 60721-3-5, class 5B2.

7.6 Chemically active substances

Chemically active substances are present as defined in IEC 60721-3-5, class 5C2 for salinity or other chemical substances. Cleaning products shall be specified by the purchaser.

7.7 Mechanically active substances

Mechanically active substances are present as defined in IEC 60721-3-5, class 5S2.

7.8 Vibration and shock

Equipment is submitted to vibration and shock throughout the range of frequencies and acceleration levels experienced in service as required in IEC 61373.

7.9 Exposure to pollution

According to its location the equipment is exposed to various levels of pollution.

Pollution degree (PD) is classified as PD1 to PD4 and shall be taken into account for determining clearance and creepage distances. Details are given in IEC 62497-1.

7.10 Exposure to overvoltages

The electrical equipment is exposed to overvoltages from the external supply network or generated by the equipment itself, for example switching transients, lightning, etc. Their levels are different according to the part of the equipment considered.

Overvoltage category (OV) is classified as OV1 to OV4.

Details are given in IEC 62497-1.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 Protective provisions against electrical hazards

Protective provisions against electrical hazards shall be made according to IEC 61991.

8.1.2 Batteries

During charge and discharge, the battery compartment may need to be vented in order to ensure that the concentration of hydrogen produced by electrolysis of the water remains below the 4 % threshold.

If needed, it is essential that impediments to air changes are minimized, and the air outlet should lead into the open air. Air inlet and outlet openings shall be located at the best possible location, i.e. in the opposite walls of the enclosure.

Cables between the battery and the downstream fuses shall be as short as possible.

8.1.3 Fire protection

Circuits and equipment constituting risks of ignition shall be effectively protected.

Materials shall produce only a small quantity of smoke of minimal opacity and toxicity. (Limits shall be considered.)

Combustible materials shall be kept away from sources of heat. They shall be selected to guarantee good resistance to fire.

To prevent the propagation of fire, special provisions may be specified with regard to installation (fire-break partitions, extinguishers, etc.).

NOTE Requirements of fire protection are different depending on countries, regions.

For example, for European countries EN 45545 series are applicable.

8.1.4 Other risks

Accessible parts which are likely, during normal service, to rise to a temperature in excess of the limits stated in Table 5 shall be protected by a barrier forming an obstacle. The temperature of the barrier shall not exceed the specified limit.

Access to parts continuously in motion (fans, rotating machines, etc.) or to those parts whose unexpected motion is likely to constitute a hazard shall be prevented by suitable barriers giving at least IP20 protection according to IEC 60529.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

All limiting values of supply voltage, air pressure, air temperature, etc., that can influence operation may occur simultaneously. All equipment shall operate satisfactorily in the worst combination of these limiting values. The following requirements apply with the ambient air temperatures defined in 7.3.1.

8.2.1.2 Equipment supplied by a contact line

Equipment which is supplied directly by a contact line shall operate satisfactorily at any value of supply voltage as defined in IEC 60850.

8.2.1.3 Equipment supplied by a transformer

Equipment which is supplied by a transformer shall operate satisfactorily at any value of supply voltage multiplied by the transformer ratio (or ratios).

8.2.1.4 Equipment supplied by a float charge battery system (Type VC1)

Equipment shall operate satisfactorily when energized over the voltage range listed in Table 1.

Voltage fluctuations (for example, during start-up of auxiliary equipment or voltage oscillations of battery chargers) lying between 0,6 U_n and 1,4 U_n and not exceeding 0,1 s shall not cause deviation of function.

Voltage fluctuations lying between 1,25 U_n and 1,4 U_n and not exceeding 1 s shall not cause damage; equipment may not fully function during these fluctuations.

In the case of thermal engines, see also 8.2.1.9.

8.2.1.5 Equipment supplied by a battery off charge system (Type VC2)

Equipment which is supplied from a battery off charge system is classified as type VC2 and shall operate satisfactorily when energized over the voltage range listed in Table 1.

8.2.1.6 Equipment not supplied directly by an onboard battery (Type VC3)

Equipment shall operate satisfactorily when energized over the voltage range listed in Table 1.

Equipment shall operate satisfactorily at the frequency from the minimum to the maximum value that the supply source is capable of producing.

Voltage fluctuations lying between 0,6 U_n and 1,4 U_n and not exceeding 0,1 s shall not cause deviation of function.

Voltage fluctuations lying between 0,7 U_n and 1,25 U_n and not exceeding 1 s shall not cause deviation of function.

8.2.1.7 Traction power supplied by a battery

When the traction power supply voltage is provided by a battery having special arrangements for the correction of voltage variation (i.e. different cell groupings on charge and on discharge), a relaxation of the limits specified in 8.2.1.4 may be allowed by agreement between the user and the manufacturer.

8.2.1.8 Ripple factor

Equipment can receive a pulsating voltage, the DC ripple factor of which, unless otherwise stated, shall be not greater than 5 % calculated from the following formula:

$$\text{DC ripple factor} = \frac{U_{max} - U_{min}}{U_{max} + U_{min}} \times 100$$

where U_{max} and U_{min} are the maximum and minimum values, respectively, of the pulsating voltage.

8.2.1.9 Low battery voltage

Precautions shall be taken to avoid equipment damage due to the reduction and the return to the normal range of the voltage caused by progressive and complete discharge of the battery or by interruption of the supply. At the start-up of thermal engines no mal-operation of equipment shall occur during the whole starting sequence.

8.2.1.10 Air pressure

Pneumatic and electropneumatic equipment shall operate satisfactorily at an air pressure which may vary between the following limits specified by the manufacturer:

– the minimum limiting value which can guarantee to start and maintain the vehicle in service (functioning) when the compressor is momentarily out of service (short supply-voltage interruptions);
– the maximum limiting value, which is the rated air pressure as described in 5.6.

The ratio between the maximum and the minimum value of the air pressure shall not exceed 1,8.

However, in case of failure of the regulating device, the equipment may be supplied at the operating air pressure of the safety valve.

8.2.2 Temperature limits

8.2.2.1 General

The temperature due to operation of the parts of equipment, and measured during a test carried out at the equivalent continuous rated current or specified currents under the conditions specified in 9.3.2, shall not exceed the limits stated in Table 3, Table 4 and Table 5.

The temperature limits given in Table 3, Table 4 and Table 5 apply to equipment tested in new and clean conditions. Different values may be prescribed by product standards for different test conditions.

Temperature in normal service may differ from the test values, depending on the installation conditions and size of connected conductors.

Additional temperature-rise tests in the actual service conditions (intermittent service at different values of current with time) may be made subject to agreement between the manufacturer and the user to ensure that the different overloads will not cause damage to the equipment.

For such tests, the temperature limits may be different from those given in Table 3, Table 4 and Table 5 and will be dependent on limit stresses for materials employed.

Additional requirements may be necessary to take into account limited time thermal stresses due to:

– a short time of very limited cooling when the equipment starts and stops;
– a reduced efficiency of the cooling system, for example blocked filter, for a specified, small fraction of the total operating time or for a specified, short period for each occurrence.

These additional requirements should be adequately specified by the user as a service condition (see 8.2.3).

The determination of temperature rise limits shall be based on the reference temperature (T_r) given in 7.3.2.

8.2.2.2 Main circuit

The main circuit of equipment shall be capable of carrying the rated operational current of the equipment without the temperatures exceeding the limits specified in Table 3, Table 4 and Table 5 when tested in accordance with 9.3.2.

NOTE For switchgear, the conventional thermal current defined in IEC 60077-2 is used for temperature rise tests instead of the rated operational current.

8.2.2.3 Control circuits

The equipment shall satisfy the tests specified in 9.3.2 without the temperatures exceeding the limits specified in Table 3, Table 4 and Table 5.

8.2.2.4 Auxiliary circuits

Auxiliary circuits of equipment, including auxiliary switches, shall be capable of carrying their rated operational current without the temperatures exceeding the limits specified in Table 3, Table 4 and Table 5, when tested in accordance with 9.3.2.

NOTE If an auxiliary circuit forms an integral part of the equipment, it suffices to test it at the same time as the main equipment, but at its actual operational current.

8.2.2.5 Electrical insulating materials and systems

8.2.2.5.1 Classification of insulating materials

The insulation life time is defined as the total time between the initial state for which the normal component insulation is considered new and the final state when, due to many factors which are met or occur in normal service, there is a high risk of electrical failure.

The ageing factors are described in IEC 60505, e.g. thermal ageing, dielectric and mechanical stresses (vibration, thermal cycling, etc.), deleterious atmospheres and chemicals, moisture, dirt, radiation, etc.

As temperature is very often the dominating ageing factor, standards have introduced thermal classes (IEC 60085) and methods to characterize thermal endurance properties (IEC 60216-1).

The different classes of solid materials (EIM – Electrical Insulating Material) and systems (EIS – Electrical Insulating System) used for the insulation of electric equipment to which this document applies are defined in IEC 60085 and listed in Table 3.

The thermal class of the solid materials used for the insulation of the windings shall be indicated by the manufacturer.

The thermal class of the solid materials used for the insulation of other parts should be indicated by the manufacturer.

8.2.2.5.2 Temperature limits

The temperature limit of an insulating system for 20 000 h lifetime is equal to the thermal class as listed in Table 3. This limit applies to the hotspot, which sustains the highest speed of thermal ageing. Temperature measurements aim at determining hot spot temperatures.

NOTE 1 The basic principles of insulation lifetime and thermal ageing, leading to thermal classification of insulating materials and systems, and to their temperature limits, are summarized in IEC 60310:2016, Annex B.

Other limits may be adopted by agreement between the user and the manufacturer when certain combinations of insulating materials are used.

A temperature rise limit, equal to the admissible temperature minus the reference temperature in 7.3.2, may be used for testing convenience. Table 3 gives examples of temperature rise limits for given reference temperatures.

For lifetimes longer than 20 000 h, the maximum temperature limit in operation shall be lowered.

For operation and lifetime shorter than 20 000 h, the maximum temperature shall not exceed the limit shown in Table 3.

Lifetime and temperature limits should be calculated, as a minimum for windings, according to the reference temperature stated in 7.3.

NOTE 2 An example of lifetime calculation can be found in Annex C.

NOTE 3 Table 3, Table 4 and Table 5 are not applicable to temperature rise of parts of equipment which are immersed in insulating liquid, for which a guideline can be found in IEC 60310:2016.

Table 3 – Temperature limits of electrical insulating system

Thermal class of insulating system	Temperature limits for 20 000 h lifetime			Temperature limits for short time operation [a]	
	Admissible temperature °C (NOTE 1)	Examples of temperature rise limits for a reference temperature T_r (NOTE 2)		General °C	Windings (NOTE 3) °C
		T_r = 25 °C K	T_r = 55 °C K		
105(A)	105	80	50	120	130
120(E)	120	95	65	135	145
130(B)	130	105	75	145	155
155(F)	155	130	100	170	180
180(H)	180	155	125	195	205
200(N)	200	175	145	215	225
220(R)	220	195	165	235	245
250	250	225	195	265	No guidance

NOTE 1 This is the value of the temperature index, the number of which is equal to the temperature, expressed in degrees Celsius, derived from the thermal endurance relationship for a given time, normally equal to 20 000 h (see IEC 60216-1).

NOTE 2 The temperature rise limits are given as an example for exterior location (T_r = 25 °C) and interior location (T_r = 55 °C).

NOTE 3 The temperatures listed are according to Table 3 of IEC 60310:2016 for dry-type windings.

Other temperature limits for windings can be found e.g. in IEC 60349 series for traction motors.

[a] Temperature limits applicable to a small fraction of total lifetime, e. g. degraded mode operation.

8.2.2.6 Terminals

The temperature rise of terminals shall not exceed the values stated in Table 4 with the connections specified (bar or type of core, insulation and section) by the manufacturer.

The temperature of terminals shall not cause damage to adjacent parts of the equipment.

Table 4 – Temperature limits of terminals

Terminal material	Maximum temperature °C	Examples of temperature rise limits for maximum air ambient temperature of	
		40 °C (T_r = 25 °C) K	70 °C (T_r = 55 °C) K
Bare copper	105 (see NOTE 1)	60	30
Bare brass		65	35
Tin-plated copper or brass			
Silver-plated or nickel-plated copper or brass		70 (see NOTE 3)	40 (see NOTE 3)
Other metals		(see NOTE 4)	

NOTE 1 The maximum temperature is defined only for tin-plated copper or brass.

NOTE 2 The temperature rise limits are given as examples for exterior location with T_r = 25 °C and for interior location with T_r = 55 °C when the air temperature rise due to the local losses is unknown (see 7.3). These limits apply to a new sample (see 8.2.2.1).

NOTE 3 The terminal temperature rise limit is based on the connection of cables, the temperature index of which is 90 °C. Other values may be necessary if the cable temperature index is different.

NOTE 4 Temperature rise limits are based on service experience or life test but are not to exceed 70 K for T_r = 25 °C (see also NOTE 3).

8.2.2.7 Accessible parts

The temperature of accessible parts in normal use of the equipment shall not exceed the values stated in Table 5.

Table 5 applies only for accessible surfaces which are not defined in the other tables in the document.

Table 5 – Temperature limits of accessible parts

Accessible parts	Maximum temperature °C	Examples of temperature rise limits for maximum air ambient temperature of 40 °C (T_r = 25 °C) K	70 °C (T_r = 55 °C) K
Manual operating means:			
– metallic	55	15	Not applicable
– non-metallic	65	25	Not applicable
Parts intended to be touched but not hand-held:			
– metallic	70	30	Not recommended
– non-metallic	80	40	10
Parts which need not be touched for normal operation:			
– metallic	80	40	10
– non-metallic	90	50	20
Parts not intended to be touched during normal operation Exteriors of enclosure adjacent to cable entries:			
– metallic	80	40	10
– non-metallic	90	50	20
Exteriors of enclosure of equipment, for example resistors		200	
Air issuing from ventilation openings of enclosures of equipment for example resistors		200	

The equipment shall be protected against contact with combustible materials or accidental contacts with personnel. The temperature rise limit of 200 K may be exceeded by agreement between the user and the manufacturer. Guarding and location to prevent danger is the responsibility of the manufacturer fitting the item. The manufacturer shall provide appropriate information, in accordance with 6.3.

8.2.2.8 Other parts

The temperature rise of other live-parts is limited only by safety and damage which could be caused to adjacent parts.

8.2.3 Operation following inactivity

When the rolling stock has been inactive it may take some time to reach its normal operational state. During this time the equipment shall operate but some aspects of the performance may not be fully compliant. Those aspects shall be agreed or specifically defined, if necessary, between the user and the manufacturer.

For example, the temperature of some parts of the equipment may be greater or lower for a short period than the highest or lowest allowable for normal operation.

Nevertheless, such situations shall not cause damage to the equipment itself and shall not cause any hazard to adjacent parts.

Storage conditions are not considered as transient operation and, if outside the normal range, they shall be agreed between the user and the manufacturer.

8.2.4 Electromagnetic compatibility (EMC)

EMC requirements for rolling stock are given in IEC 62236-3-2 for apparatus.

8.2.5 Acoustic noise emission

The maximum acoustic noise emitted by the equipment shall be specified by the vehicle designer in order to comply with the level required by the user of the whole rolling stock and for the location considered (outside, inside passenger compartment, etc.).

For this, the component manufacturer shall provide, if required, the noise levels emitted by the equipment in the conditions specified.

8.2.6 Clearances

Guidance for the determination of minimum clearances is given in IEC 62497-1, based on rated impulse voltage (U_{Ni}) obtained by:

– rated insulation voltage (U_{Nm}) and overvoltage category (OV), or
– calculation or measurement of working peak voltage.

8.2.7 Creepage distances

Guidance for the determination of minimum creepage distances is given in IEC 62497-1, based on rated insulation voltage (U_{Nm}), pollution degree (PD) and material group.

8.2.8 Switching overvoltages

Equipment shall not be subjected to switching overvoltages higher than the rated impulse voltage. Also equipment shall not generate switching overvoltages higher than specified in the relevant product standard. In the event of there being no product standard, it shall not generate switching overvoltages higher than the rated impulse voltage.

Equipment having more than one rated operational voltage and/or intended to be used at different transient overvoltage levels shall not generate switching overvoltages higher than the lowest transient overvoltage level at the corresponding rated operational voltage.

8.2.9 Operational performance

The equipment shall be capable of performing its rated duties under conditions corresponding to the specified requirements where relevant.

Specific requirements and test conditions shall be stated in the relevant product standard or test specification agreed between the user and the manufacturer, and may concern:

– the operational performance off-load in order to demonstrate that the equipment meets the operational conditions when energized at the upper and lower limits of supply voltage and/or air pressure specified;
– the operational performance on load during which the equipment shall operate at the specified duty;
– the performance in overload or fault conditions;
– the mechanical and electrical durability.

The verification of operational performance may be combined in one or several sequences of tests if so stated in the relevant product standard.

8.2.10 Ability to withstand vibration and shock

The equipment shall be capable of withstanding the vibration and shock given by test requirements (see 9.3.5).

9 Tests

9.1 Kinds of tests

9.1.1 General

Tests shall be made to prove compliance with the requirements laid down in this document, where applicable, and in the relevant product standard.

Tests are as follows:

– type tests which shall be made on a representative sample of the equipment;

– routine tests which shall be made on each individual piece of equipment manufactured according to this document, where applicable, and the relevant product standard;

– sampling tests which shall be made if called for in the relevant product standard;

– investigation tests are special tests and shall only be made if required by the manufacturer or the user to test in greater detail any particular aspect of a design.

The tests shall be carried out by the manufacturer at his works or at any suitable laboratory of his choice, before the equipment is mounted on the vehicle.

9.1.2 Type tests

Type tests are intended to verify compliance of the design of a given equipment with this document, where applicable, and with the relevant product standard.

Written documentation of type tests (proving compliance) shall be made available by the manufacturer.

If these type tests comprise mechanical or electrical durability or performance verifications in overload or fault conditions which may cause damage, they may be carried out on additional specimen(s). However, if this specimen is to be subsequently installed in an operational vehicle, an agreement between the user and the manufacturer shall prescribe its minimum acceptable condition for service.

If they comprise only normal functioning and verification tests without incurring component wear, the tests shall be carried out on one piece of equipment from the order.

9.1.3 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain the proper functioning of the equipment. They shall be made on each individual piece of the equipment including items that are to be subjected to type testing.

Details of the routine tests and the conditions under which they shall be made shall be stated in the relevant clauses of this document and/or the relevant product standard where applicable.

The routine tests shall not cause any damage.

9.1.4 Sampling tests

If engineering and statistical analyses show that routine tests (on each product) are not required, sampling tests may be made instead, if so stated in the relevant product standard. They shall comprise a sequence of tests as for the routine testing.

9.1.5 Investigation tests

Investigation tests are special tests of an optional character carried out in order to obtain additional information. As opposed to type tests they are not intended to verify a requirement and consequently they have no acceptance criterion.

An investigation test may be made either on the manufacturer's own initiative or by agreement between the user and the manufacturer.

9.1.6 General test condition

The equipment to be tested shall conform to all functional details with the design which it represents.

Unless otherwise stated in this document or in the relevant product standard:

– tests shall be carried out in the ambient conditions present at the test site;
– each sequence of tests shall be made on equipment in a clean and new condition;
– equipment under test shall be mounted complete either under the conditions prescribed by the manufacturer or under the relevant conditions of installation envisaged on the rolling stock.

The test results shall be within the tolerances stated in the relevant product standard.

9.1.7 Summary of tests

Table 6 is a non exhaustive list of tests which may be appropriate for electric equipment within the scope of this document.

Table 6 – List of tests (as appropriate)

Test item	Type test	Routine test
Verification of constructional requirements	9.2.2	9.2.3
Verification of performance requirements	9.3	
Operating limits and functional tests	9.3.1.1	9.3.1.2
Temperature rise test	9.3.2	-
Dielectric properties	9.3.3	
Verification of clearance and associated solid insulation	9.3.3.2.1	-
Application of test voltage	9.3.3.2.2	-
Verification of creepage distances	9.3.3.2.3	-
Type test for equipment	9.3.3.2.4	-
Power frequency voltage test	-	9.3.3.3
Operational performance capability	9.3.4	
Air-tightness tests for pneumatic equipment	9.3.4.2	
Leakage tests for hydraulic equipment	9.3.4.3.1	9.3.4.3.2
Durability	9.3.4.4	-
Mechanical durability	9.3.4.4.2	-
Electrical durability	9.3.4.4.3	-
Check on the setting and operation of protective equipment and relays (calibration)	-	9.3.4.5
Vibration and shock	9.3.5	-
Electromagnetic compatibility (EMC)	9.3.6	-
Acoustic noise emission	9.3.7	-
Climatic tests	9.3.8	-

9.2 Verification of constructional requirements

9.2.1 General

Unless specific, higher requirements are given in the product standard or different and replacing requirements are given in the customer's specification, the design of equipment and components shall comply with each applicable requirement given in Clause 8 of this document. This compliance shall be capable of being proven (by visual examination, measurement, etc.) for properties where testing is not appropriate.

9.2.2 Type tests

Verification of compliance with the constructional requirements for the type test may concern:

– protective provisions against electrical hazards (8.1.1);
– ventilation of batteries (8.1.2);
– fire and smoke protection (8.1.3);
– clearances (8.2.6);
– creepage distances (8.2.7);
– other risks such as burning risks;
– climatic conditions.

NOTE The above list is not exhaustive.

9.2.3 Routine tests

Verification of compliance with the constructional requirements for the routine test concerns:

– visual examination;
– measurement of resistance and impedance.

Measurement of the resistance of windings shall be made on all electro-pneumatic or electro-magnetic control devices when cold if the variation of this resistance may affect operation. Typical equipment includes magnet valves, servo-motors, voltage relays and electromagnetic contactors.

The measurements obtained for any given winding, when corrected to a temperature of 20 °C, shall not vary from the specified value or, alternatively, from the mean of the values measured on the first ten units tested. In the absence of a specific product standard, the tolerance shall be ±8 %.

The measurements of resistance are also made when cold on the various resistances inserted in the control, indicating and auxiliary circuits. The allowable tolerances, which vary according to the application, shall be agreed between the parties concerned.

Where correct operation of apparatus in AC circuits depends on the impedance, measurements of resistance shall, if necessary, be accompanied by measurements of impedance carried out with AC at the specified frequency.

The measurement of the main circuit resistance shall be made with a direct current, recording the voltage drop across the terminals. The current chosen for the test shall have a value up to the rated current.

The resistance of any apparatus shall not exceed the limit value fixed by the manufacturer.

9.3 Verification of performance requirements

9.3.1 Operating limits and functional tests

9.3.1.1 Type tests

Operating limits shall be verified as type tests.

The tests shall be carried out, at both the lowest ambient temperature to which the apparatus can be subjected in service (or at which its correct operation is to be achieved) and at the highest temperature it can attain.

Large items, for example transformers, motors, cubicles, etc., shall only be subject to climatic tests by agreement between the user and the manufacturer.

In the case of electro-magnetic or electro-pneumatic apparatus, the tests consist of checking 20 times in succession, for each relevant combination of minimum and maximum values of temperature, voltage and pressure, that after stabilization of its temperature, the apparatus will operate satisfactorily within the limits of supply voltage and air pressure specified in 8.2.1.

A check shall also be made that the operation of the equipment is still satisfactory when carried out under the most unfavourable combination of voltage, air pressure and temperature obtainable within the limits specified in 8.2.1. In the case of equipment which operates at different frequencies, the test frequency shall be specified.

NOTE In the case of electro-magnetic or electro-pneumatic apparatus, operation when hot at a voltage is considered to be satisfactory if the apparatus when cold operates normally when it is supplied with the current equal to that which would flow through the apparatus after 1 h of operation at the same voltage.

This method is not, however, applicable to apparatus used for preparing the vehicle for service (electro-pneumatic valve for pantographs, machine starting contactors, etc.) since this apparatus needs to meet special requirements in general.

9.3.1.2 Routine tests

Functional tests shall be performed as routine tests.

Routine tests consist of verifying at ambient temperature the capability of the equipment to operate satisfactorily at the rated supply voltage and air pressure specified in 8.2.1 or at more appropriate values.

9.3.2 Temperature rise test

9.3.2.1 Ambient air temperature

The ambient air temperature shall be recorded during the last quarter of the test period by at least two temperature sensing means, for example thermometers or thermocouples, equally distributed around the equipment at about half its height and at a distance of about 1 m from the equipment. The temperature sensing means shall be protected against air currents, heat radiation and indicating errors due to rapid temperature changes.

During the tests, the ambient air temperature shall be between +10 °C and +40 °C and shall not vary by more than 10 K.

However, if the variation of the ambient air temperature exceeds 3 K, an appropriate correction factor should be applied to the measured temperature of the parts, depending on the thermal time-constant of the equipment.

9.3.2.2 Measurement of the temperature of parts

9.3.2.2.1 General

The temperature of the different parts shall be measured by suitable temperature sensing means at those points most likely to attain the maximum temperature; these points may be determined during a previous test with a current lower than the test current. These points shall be stated in the report.

Depending on the materials, shape and size of products, and their cooling medium, there may be a significant temperature gradient between the actual hot spot and the location accessible for temperature measurement (such as surface temperature) or the average temperature (e.g. measured indirectly in a coil by DC resistance variation).

In case the maximum temperature cannot be accessed for direct measurement, indirect measurement shall apply.

The temperature sensing means shall not significantly affect the temperature rise. Good thermal conductivity between the temperature sensing means and the part under test shall be ensured.

The test shall be made for a time sufficient for the temperature rise to reach a steady-state value. The time depends on the construction and the cooling method of the product. It shall not exceed 8 h unless otherwise agreed. It is assumed that a steady state is reached when the variation does not exceed 1 K per hour unless otherwise agreed.

9.3.2.2.2 Direct temperature measurement method

The temperature is measured directly with a temperature sensor (resistive thermometer, thermocouple, temperature sensitive sticker, infrared camera, etc.).

9.3.2.2.3 Indirect temperature measurement method

The temperature is derived from the measurements of other physical parameters such as voltage, current, resistance, etc.

For example, for electromagnet coils, the method of measuring the temperature by variation of resistance is generally used. This method provides the average temperature of a winding.

The temperature of the coils before beginning the test shall not differ from that of the surrounding medium by more than 3 K.

The value of the average hot temperature (T_2) of the winding may be obtained from the value of the average cold temperature (T_1) of the winding as a function of the ratio of the hot resistance (R_2) to the cold resistance (R_1) by the following formula:

$$T_2 = \frac{R_2}{R_1}(T_1 + k) - k$$

where T_1 and T_2 are expressed in degrees Celsius and k is a reciprocal of the temperature coefficient of resistance at 0 °C for the material:

– for copper conductor: 234,5 °C;
– for aluminium conductor: 228,1 °C.

9.3.2.2.4 Calculation method of temperature

In such cases where the hot spot is not accessible, the temperature is measured, either by the indirect method, or by the direct method, at a point close to the hot spot.

The temperature difference between this point and that of the hot spot shall be calculated, as a minimum for windings, when it is relevant to thermal ageing of the insulation system. The calculation is based on data provided by the manufacturer of the equipment.

9.3.2.3 Temperature rise of a part

The temperature rise of a part is the difference between the temperature of the part measured in accordance with 9.3.2.2 and the ambient air temperature measured in accordance with 9.3.2.1.

9.3.2.4 Temperature rise of the main circuit

The equipment shall be mounted as specified in 9.1.6 and shall be protected against abnormal external heating or cooling.

Equipment having an integral enclosure and equipment only intended for use with a specified type of enclosure shall be tested in their enclosures for the rated operational current. No opening giving false ventilation shall be allowed.

For tests with multiphase currents, the current shall be balanced in each phase within ±5 %, and the average of these currents shall be not less than the appropriate test current.

Unless otherwise specified in the relevant product standard, the temperature rise test of the main circuit shall be performed at the rated operational current and may be at any relevant voltage. It may be necessary to take into account the influence of harmonic content in the current waveform when determining temperature rise.

NOTE For switchgear, the conventional thermal current defined in IEC 60077-2 is used for temperature rise tests instead of the rated operational current.

When the heat exchange between the main circuit, the control circuit and the auxiliary circuits may be of significance, the temperature rise tests stated also in 9.3.2.5 to 9.3.2.7 shall be made simultaneously, in so far as this is allowed by the relevant product standard.

Tests on DC equipment may be made with an AC supply for convenience of testing but only with the consent of the manufacturer.

At the end of the test, the temperature of the different parts of the main circuit shall not exceed the limits given in 8.2.2.2 unless otherwise specified in the relevant product standard.

If the temperature rise tests have not been performed in the specified service conditions, additional calculations or tests may be agreed between the user and the manufacturer.

The test connection of cables shall be made according to IEC 61992-1,or for verification for a particular application, with the intended dimensions of connecting conductors.

Details of the test, such as type of supply, number of phases and frequency (where applicable), cross-sections of test connections, etc., shall form part of the test report.

9.3.2.5 Temperature rise of control circuits

The temperature rise tests of control circuits shall be made with the specified current and, in the case of AC, at the rated frequency. Control circuits shall be tested at their rated operational voltage.

Circuits intended for continuous operation shall be tested for a sufficient time for the temperature rise to reach a steady-state value.

Circuits for intermittent duty shall be tested as prescribed in the relevant product standard.

At the end of these tests, the temperature of the different parts of the control circuits shall not exceed the limits given in 8.2.2.3 unless otherwise specified in the relevant product standard.

9.3.2.6 Temperature rise of coils of electromagnets

Coils and electromagnets shall be tested according to the conditions given in 8.2.2.4.

They shall be tested for a sufficient time for the temperature rise to reach a steady-state value.

The temperature shall be measured when thermal equilibrium is reached in both the main circuit and the coil of the electromagnet.

Coils and electromagnets of equipment intended for intermittent duty shall be tested as prescribed in the relevant product standard.

At the end of these tests, the temperature of the different parts shall not exceed the limits given in 8.2.2.4.

9.3.2.7 Temperature rise of auxiliary circuits

The temperature rise tests of auxiliary circuits shall be made under the same conditions as those specified in 9.3.2.4 but may be carried out at any convenient voltage.

At the end of these tests, the temperature of the auxiliary circuits shall not exceed the limits given in 8.2.2.4.

9.3.3 Dielectric properties

9.3.3.1 General conditions

The equipment to be tested shall be mounted on a metal plate and all exposed conductive parts (frame, etc.) which are connected to the vehicle structure in normal service shall be connected to the metal plate.

Manual actuators of insulating material and integral non-metallic external parts which may be touched during normal operation shall be covered by a metal foil connected to the frame of the mounting plate. The foil shall be applied to all surfaces where these can be touched with the standard test finger.

However, it is not necessary to cover these parts by a metal foil if they are separated from live parts by conductive parts which are connected to the vehicle structure in normal service or if they are double insulated devices or if insulation failure cannot cause any electrical risks higher than 120 V DC or 50 V AC.

During the tests, it may be necessary to disconnect or to short-circuit some parts of the equipment from the electrical stress. This shall be agreed between the user and the manufacturer. If any component or subassembly is not submitted to the dielectric test, its terminals shall be grounded.

9.3.3.2 Type tests

9.3.3.2.1 Verification of clearance and associated solid insulation

Clearances shall be verified by measurement or a dielectric test according to the method described in IEC 62497-1.

For equipment with a rated impulse voltage (U_{Ni}) greater or equal to 30 kV, solid insulation shall be verified by an impulse test at the rated impulse voltage.

NOTE Partial discharge test methods have not been included as they are still under consideration.

9.3.3.2.2 Application of test voltage

The test voltage shall be applied as follows with the equipment mounted on a metal plate and prepared as specified in 9.3.3.1:

a) between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the frame or mounting plate, with the contacts in all normal positions of operation;

b) between each pole of the main circuit and the other poles connected together and to the frame or mounting plate, with the contacts in all normal positions of operation;

c) between each control and auxiliary circuit not normally connected to the main circuit and

  – the main circuit,
  – the other control and auxiliary circuits,
  – the exposed conductive parts,
  – the frame or mounting plate,

  which, wherever appropriate, may be connected together;

d) for equipment suitable for isolation, across the poles of the main circuit, the line terminals being connected together and the load terminals connected together.

The test voltage shall be applied between the line and load terminals of the equipment with the contacts in the open position.

9.3.3.2.3 Verification of creepage distances

The shortest creepage distances between phases, between circuit conductors at different voltages and live and exposed conductive parts shall be measured. Each measured creepage distance shall comply with the minimum requirements of 8.2.7.

The method of measuring creepage distances is given in IEC 62497-1.

9.3.3.2.4 Type test for equipment

The method of dielectric test of equipment for routine test in 9.3.3.3 shall apply.

9.3.3.3 Routine tests

9.3.3.3.1 Power frequency voltage test

The power frequency voltage tests shall be carried out on every single piece of equipment. In certain cases to be agreed between the user and the manufacturer, they may also be carried out on equipment connected in groups. For details of tests of equipment when mounted on the vehicle, refer to IEC 61133:2016.

The test voltage at a frequency of 50 Hz or 60 Hz shall be of approximately sinusoidal form.

The method of test is given in IEC 62497-1.

9.3.3.3.2 Test voltage and duration

The voltage of the power frequency voltage test (U_a) (kV RMS) based on the rated impulse voltage (U_{Ni}) (kV) of the dielectric test for equipment shall be selected according to IEC 62497-1.

The duration of voltage application is 10 s.

If agreed between the user and the manufacturer the test voltage and duration may be selected according to Annex B.

9.3.3.3.3 Application to groups of equipment before or after mounting

A dielectric test shall be carried out on groups of equipment even if their components have already been tested individually. This repeated test shall be made at a voltage equal to 0,80 times the initial test voltage given in IEC 62497-1.

NOTE For testing of rolling stock after completion of construction and before entry into service, IEC 61133:2016 instructs to apply 85 % of the test voltage of the defined test voltage for 1 min. The defined test voltage according to IEC 60077-1 is the repeated test voltage equal to 0,80 times the initial test voltage given in IEC 62497-1.

However, where the circuit contains a mid-point permanently connected to earth, (U_{Nm}) defined in IEC 62497-1 shall be taken to be one-half of the rated insulation voltage which would be taken in the absence of a mid-point connection.

Components which may be damaged during the test, or which can constitute a load for the test voltage, shall be disconnected.

9.3.4 Operational performance capability

9.3.4.1 General

Tests shall be made to verify compliance with the requirements of 8.2.9. Detailed test conditions shall be given in the relevant product standard.

9.3.4.2 Air-tightness tests for pneumatic equipment

Tests shall be made to verify that the leakage of each unit of the pneumatic equipment, cylinder or magnet-valve, does not cause, after the test duration (t), a reduction of more than 1 % per minute of the air pressure of the vessel to which this unit has been connected.

The air pressure of the vessel at the beginning of the test shall be equal to the rated air pressure (P) of the unit to be tested.

The cold winding shall be supplied with a current equal to the steady-state current obtained when the winding is supplied at the rated voltage.

The test shall be repeated for every different state of the equipment whether energized or not, if applicable.

The test shall be carried out on a single specimen (air cylinder or magnet-valve) for the type test and may be carried out on no more than 10 identical specimens for the routine test.

For equipment having several air cylinders or magnet-valves which cannot be tested separately, it is sufficient to check that the total leakage is not greater than the sum of the leakages allowable for each unit.

The test duration (t) is determined with the different parameters as follows:

$$t = \frac{\mathrm{d}P}{P} \frac{100\,V}{(m + 0{,}5\,n)}$$

where:

- m is the number of magnet-valves tested;
- n is the number of air cylinders supplied during the test;
- t is the test duration, expressed in minutes, which shall not be lower than 1 min;
- V is the total volume, expressed in cubic decimeters, of the pneumatic circuit comprising the vessel and the air cylinders if any, increased by the pipes' volume if significant. The total volume shall be up to 5 times that of the pneumatic circuit of the equipment tested;
- P is the rated air pressure expressed in MPa (1 MPa = 10 bar);
- $\mathrm{d}P$ is the variation of the air pressure of the vessel at the end of the duration test, expressed in MPa. This variation shall not exceed 0,1 P, but shall be sufficient to be able to quantify it on the air pressure measuring device.

NOTE The choice of the vessel is such that its volume satisfies the conditions for the variation of the air pressure and the test duration.

9.3.4.3 Leakage tests for hydraulic equipment

9.3.4.3.1 Type tests

A durability test of three months duration shall be made on a complete hydraulic equipment operating on a load cycle agreed between the user and the manufacturer to verify that no leaks exist which would either jeopardize the functioning of the equipment or necessitate replenishing the hydraulic fluid.

The duration of the test may be established for a period other than three months after agreement between the user and the manufacturer.

9.3.4.3.2 Routine tests

9.3.4.3.2.1 Cylinders

With the pistons fitted with packing, rings or gaskets there shall be no significant leakage from the cylinder with the maximum load applied externally to the piston rod.

9.3.4.3.2.2 Valves and hydraulic systems

When tested at the maximum rated flow and the maximum rated pressure, the leakage shall not exceed 0,35 % per minute of the maximum flow per 10 MPa.

9.3.4.4 Durability

9.3.4.4.1 General

Durability tests are type tests intended to verify the number of operating cycles that equipment is likely to be capable of performing without repair or replacement of parts.

The durability tests form the basis of a statistical life estimate, where the manufactured quantities permit this.

9.3.4.4.2 Mechanical durability

During the test, there shall be no voltage or current in the main circuit. The equipment may be lubricated before the test if lubrication is prescribed in the normal service.

The control circuit shall be supplied at its rated voltage and, where applicable, at its rated frequency.

Pneumatic and electro-pneumatic equipment shall be supplied at the rated air pressure.

Manually operated equipment shall be operated as in normal service.

The number of operating cycles shall be not less than that prescribed by the relevant product standard.

For equipment fitted with operating relays or releases (tripping devices), the total number of operations to be performed by such relays or releases shall be stated in the relevant product standard.

Evaluation of test results shall be defined in the relevant product standard.

9.3.4.4.3 Electrical durability

The test conditions are those of 9.3.4.4.2 except that the main circuit is energized according to the requirements of the relevant product standard.

Evaluation of test results shall be defined in the relevant product standard.

9.3.4.5 Check on the setting and operation of protective equipment and relays (calibration)

These checks are routine tests.

Normally, all such equipment shall operate with a tolerance of ±5 % of the maximum setting of their range.

9.3.5 Vibration and shock

Vibration and shock tests shall be carried out according to the relevant method of IEC 61373.

9.3.6 Electromagnetic compatibility (EMC)

EMC test methods and criteria for rolling stock are given in IEC 62236-3-2 for apparatus.

9.3.7 Acoustic noise emission

If required, acoustic noise tests may be carried out to verify the limits of 8.2.5, as agreed between the user and the manufacturer.

9.3.8 Climatic tests

If required, a series of tests may be carried out to demonstrate the capability of meeting the environmental conditions. The relevant methods of IEC 60068 shall be used and may comprise the following:

– cold	IEC 60068-2-1;
– dry heat	IEC 60068-2-2;
– damp heat steady state	IEC 60068-2-78
or damp heat cyclic	IEC 60068-2-30;
– salt mist	IEC 60068-2-52.

In addition, other tests may be prescribed by the test document according to the particular environmental conditions defined.

For each test, the particular parameters shall be recorded in the test report.

If applicable an air-tightness test shall be carried out during, and after, exposure to dry heat and cold in accordance with 9.3.4.2.

A new sample shall be used for each test. However, the same sample may be used for several tests if it is declared as new after refurbishment.

Annex A
(informative)

Coordination between definitions

The object of this annex is to clarify the terminology of the definitions and the characteristics.

All terms or expressions in italics are taken from Clauses 3 and 5.

Generally, a quantity can vary within a range that is a gap between two admissible *limiting values*, but to designate or identify this quantity, an approximate value is used; it is the *nominal value* (see Figure A.1).

The greatest value of this range, or maximum value, is chosen to determine the test requirements; it is called the *rated value*.

The smallest is also used as a test value but generally for the operational requirements only.

The use of equipment or a device is defined principally by two values, voltage and current, defined and/or agreed by the manufacturer according to its design; it is a matter of the *rated operational voltage* with the rated frequency, if necessary, and the *rated operational current* (see Figure A.2).

These two rated values are used as references for the tests; they define the *utilization category* (see Figure A.2).

Sometimes when the quantity is derived from a regulating device the greatest value of the range of this regulation may be the *rated operational voltage* even if a larger range is required for operating.

The operational requirements may also take a temporary voltage when the regulation is ineffective into account.

Equipment or a device may have several *utilization categories* (see Figure A.3). It has, in this case, several *rated operational voltages* and *rated operational currents* included in a field voltage/current in which:

– the upper allowable current is that obtained in continuous duty (thermal limit). This limit may be exceeded for a short duration; it is then called an overload current;
– the upper continuous allowable voltage is the *rated insulation voltage*, i. e. the voltage which has been chosen for determining the minimum creepage distances and which in turn, together with the overvoltage category, determines the *rated impulse voltage* level. The *rated impulse voltage* determines the minimum clearances and the dielectric test voltage.

The following limitations apply to operational requirements (see Figure A.3):

– *rated operational voltage* should be lower than the *rated insulation voltage*;
– *transient overvoltages* are always lower than the *rated impulse voltage* in order to avoid any breakdown;
– *rated operational current* should be lower than the thermal limit;
– currents in overload condition are not greater than the *rated short-time withstand current*.

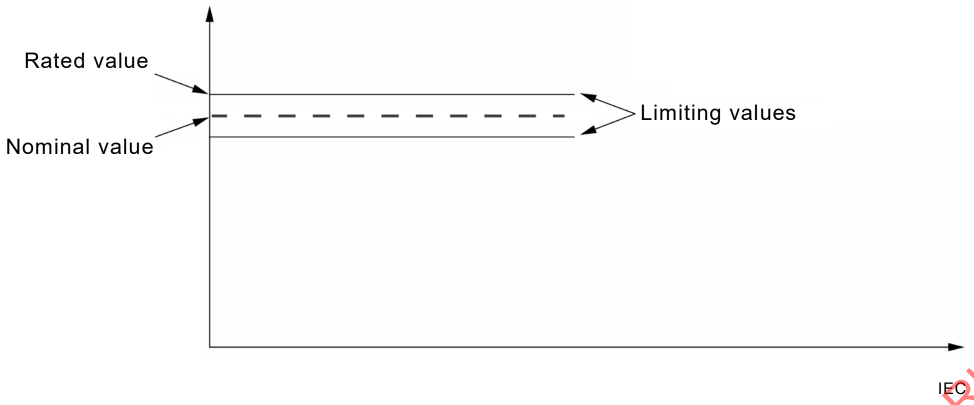

Figure A.1 – Example of relation of limiting values

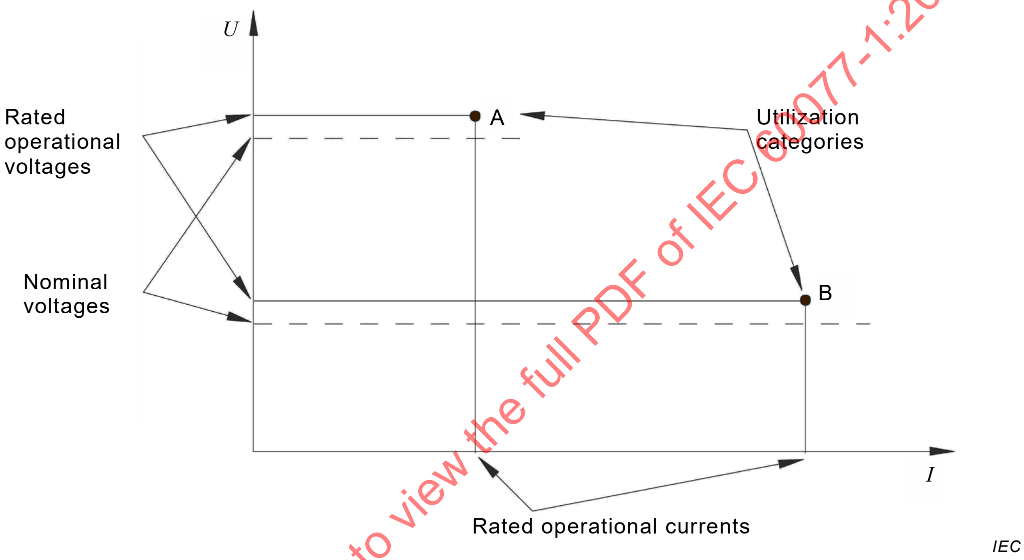

Figure A.2 – Example of utilization category

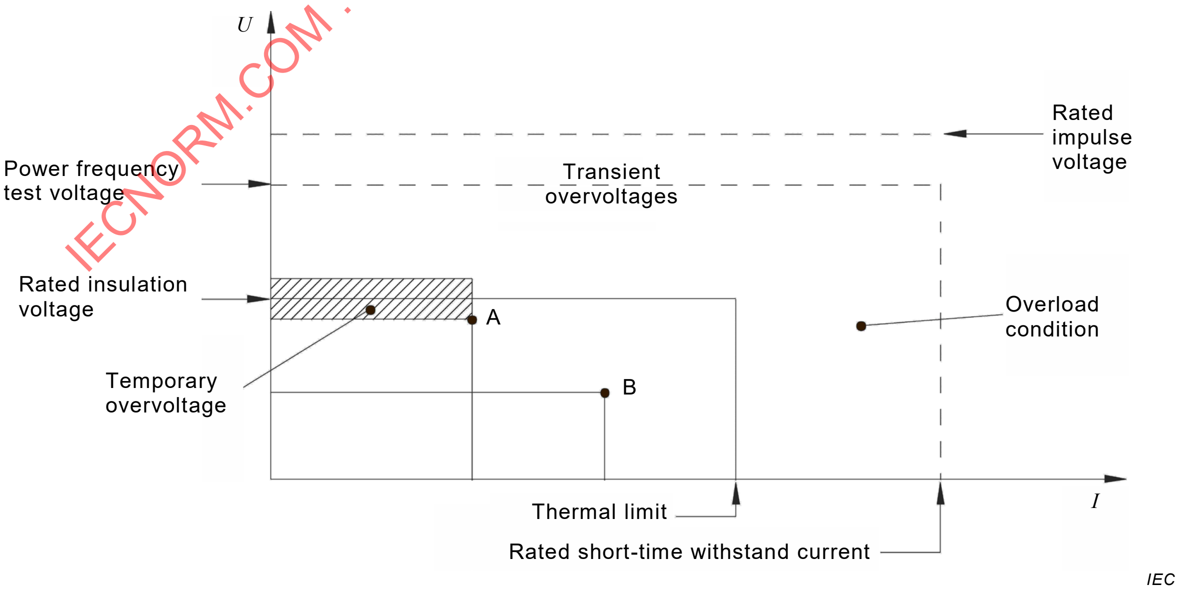

Figure A.3 – Example of coordination of operational conditions

Annex B
(informative)

Type and routine test of dielectric tests for equipment

B.1 General

This Annex B gives the information about type and routine test method of dielectric tests for equipment described in the first edition of IEC 60077-1.

B.2 General conditions

The tests shall be carried out with the rated power frequency voltage on every single piece of equipment. In certain cases to be agreed between the user and the manufacturer, they may also be carried out on equipment connected in groups. For details of tests of equipment when mounted on the vehicle, refer to IEC 61133.

The test voltage at a frequency of 50 Hz or 60 Hz shall be of approximately sinusoidal form.

The method of test and the RMS values of the test voltage are defined below. The test voltage is applied progressively in 10 s, maintained at the prescribed value during 60 s ± 5 s, and then decreased progressively to zero.

After agreement between the user and the manufacturer, DC voltage may be used; the value of the test voltage is then equal to the peak value of AC voltage required.

NOTE In all formulae giving test voltages, U_{Nm} represents the rated insulation voltage (see 5.2 and Annex A) of the apparatus subject to the test.

These tests may also be required in a type test sequence to verify that equipment has no damage after the test.

B.3 Test voltage

Tests on single pieces of equipment shall be carried out in accordance with the following requirements:

– in Table B.1 for AC and DC rated insulation voltages of no more than 10 000 V;
– in Table B.2 for equipment connected to the AC contact line by the application of the test voltage:
  • between the main circuit or contacts in the closed position and other circuits including earth;
  • and between contacts in the open position.

Aged insulation parts which may be dielectrically tested after refurbishment or repair are not to be tested at more than 1,5 times the rated insulation voltage.

Table B.1 – Dielectric tests on single pieces of equipment

Subject	Rated power frequency voltage (U_a) for rated insulation voltage (U_{Nm}) V					
	Up to 36 [a]	**From 36 to 60**	**From 60 to 300**	**From 300 to 660**	**From 660 to 1 200**	**From 1 200 to 10 000**
For all equipment taken singly, the dielectric test shall be applied between each circuit of a given voltage and the others and earth.	750	1 000	1 500	2 500	2 U_{Nm} + 1 500	2 U_{Nm} + 2 000
For all equipment* intended to break a circuit and taken singly, the dielectric test shall be applied between the input and output sides of the apparatus – with contacts open and arc chutes in position. * Equipment may include more than one item if this is necessary to break the circuit. For all breaking equipment connected in parallel with a resistor, the test voltage shall be limited to 0,75 times the value mentioned, the resistor being disconnected.	750	1 000	1 500	1,6 U_{Nm} + 1 500		
For all equipment taken singly or parts electrically connected to other circuits which are not connected to the power circuit the dielectric test shall be applied between these parts and earth.	750	1 000	2 U_{Nm} + 1 000 with a minimum of 1 500			
For all equipment with double insulation with an intermediate conductive frame[b], the dielectric test shall be applied						
– between intermediate conductive frame and earth;			1 500	2 500	2 U_{Nm} + 1 500	2 U_{Nm} + 2 000
– between circuit and intermediate conductive frame.			1 500	1 500	1,6 U_{Nm} + 500	1,6 U_{Nm} + 1 000
Where the main insulation is provided between circuit and intermediate conductive frame insulated from earth, the test voltages are to be reversed.						

[a] For electronic equipment having a rated insulation voltage (U_{Nm}) of less than 36 V, the dielectric test voltage is reduced to 500 V.

[b] Definition of double insulation has changed between first edition of IEC 60077-1 and IEC 62497-1. Compared with definition in first edition of IEC 60077-1, double insulation according to IEC 62497-1 does not necessarily imply an intermediate conductive frame.

Table B.2 – Dielectric tests for equipment connected to AC contact line

Nominal voltage of contact supply line AC RMS kV	**Rated power frequency voltage RMS** kV
6,25	20
15	38
25	75
50	130

Annex C
(informative)

Example of thermal endurance calculation to demonstrate the suitability of an insulation system for a specified application

C.1 General

This Annex is just an example for the purpose of understanding the calculation method set up in IEC 60310:2016, Annex B.

It is based on purely indicative thermal endurance characteristics and should not been taken as reference for actual applications if not supported by actual thermal endurance test data.

For easy understanding, the simplified Arrhenius formula (C.1) is used:

$$ECO(h) = 20\,000 \times 2^{\frac{TI - T_{hs}}{HIC}} \quad \text{(C.1)}$$

$$CEP(\%) = \frac{AOT}{ECO} \times 100 \quad \text{(C.2)}$$

where

ECO is the thermal endurance in continuous operation (in hours);

TI is the temperature index (in degrees Celsius);

T_{hs} is the hot spot temperature (in degrees Celsius);

HIC is the halving interval (in Kelvins);

CEP is the consumed endurance potential (in percent) for a given hot-spot temperature;

AOT is the actual operating time (in hours) the insulating system will operate at the given hot-spot temperature.

C.2 Example 1 – Temperature limits for an electric insulation system

In the examples of Table C.1, two insulation systems of different classes are considered which have a TI at the lower limit of their thermal class and with the shown HIC.

Table C.1 – Temperature limits and expected lifetime for a dry-type insulation system (examples)

Thermal class	Thermal endurance characteristics for the examples		Short-time operation at maximum hot-spot temperature (NOTE 1)		Continuous operation (210 000 h) (NOTE 2)
	TI	*HIC*	Maximum hot-spot temperature °C	Expected lifetime h	Maximum hot-spot temperature °C
105 (A)	105	6	130	1 100	85
180 (H)	180	11	205	4 100	143

NOTE 1 Column 5 shows the expected lifetime if the insulation system is operated continuously at the maximum hot-spot temperature according to Table 3 for windings. The expected lifetime is calculated for 100 % *CEP*.

NOTE 2 Column 6 shows the maximum temperature for continuous operation of the insulation system for a specified lifetime of 210 000 h (i.e. 30 years and 7 000 h per year).

C.3 Example 2 – Thermal endurance calculation

C.3.1 General

The example below considers the coil of a magnet valve (type VC1) for a traction application, supplied by a 110 V nominal float charged battery, cooled by natural air convection.

This calculation method may be applied to multiple parameters at the same time or to other parts of components.

It is often possible to split the operation of traction electric equipment into simple equivalent operating conditions thanks to their usually high thermal time constant compared with the running cycle of the railway vehicle.

Annex D in IEC 60310:2016 provides an example of lifetime calculation for a dry-type transformer or inductor.

In the following tables, cells with a white background indicate input data while cells with a grey background indicate output data resulting from calculations.

C.3.2 Operating conditions provided by the purchaser

Total operation hours over lifetime: 194 400 h (30 years at 360 days per year and 18 h per day).

Two main parameters define the winding temperature of the coil: the ambient temperature and the supply voltage of the coil. In this example, for simplicity, the voltage is assumed to be constant and equal to the rated operational voltage (U_r). Then the operation is described by a simplified temperature distribution shown in Table C.2.

Table C.2 – Ambient temperature distribution

Operating conditions	T_{AMB} °C	Voltage V (NOTE)	Operation over lifetime	
			Split %	AOT h
Condition 1	40	126,5	40,0	77 760
Condition 2	55		50,0	97 200
Condition 3	65		10,0	19 440
Total			100,0	194 400

NOTE For VC1 type electrical equipment, the battery voltage is usually not constant but regulated by the battery charger with a temperature compensation characteristic which decreases the floating voltage when the battery temperature increases.

C.3.3 Thermal endurance characteristics provided by the manufacturer

– Information about the reference and actually used insulation system according to IEC 60216-5: generic type of materials, test certificates.

– Thermal class, endurance graph (Arrhenius formula constants, ATE or RTE, HIC).

In this example, the assessed thermal endurance (ATE) or relative thermal endurance (RTE) index is taken for TI in the calculations with the following values:

Class 130 (B) insulation system with TI = 130 °C and HIC = 9 K.

C.3.4 Temperature rise test results

Table C.3 shows temperature rise test measurements and calculation results. This test provides the winding resistance of the coil (R) at a reference temperature (e.g. at 0 °C) and the value of the thermal resistance of the coil (R_{th_avg}).

First, the winding resistance of the coil (R) is measured directly and, if necessary, converted to a reference temperature according to 9.3.2.2.3.

Next, the temperature rise test is carried out with direct measurement of ambient air temperature (T_{amb}), voltage (U), current (I) and hot-spot temperature (T_{hs}). Here, the test is performed at reference temperature T_r = 25 °C and rated operational voltage U_r = 126,5 V. The average winding temperature of the coil (T_{avg}) is derived from the resistance (R) variation.

Finally, the other parameters are calculated: power (P), temperature rises (ΔT_{avg}, ΔT_{hs}), gradient ($\Delta T_{hs\text{-}avg}$) between hot-spot and average temperatures, and thermal resistance ($R_{th\_avg} = \Delta T_{avg} / P$).

Table C.3 – Temperature rise test results

Comment	T_{amb} °C	U V	I A	P W	R Ω	T_{avg} °C	ΔT_{avg} K	R_{th_avg} K/W	T_{hs} °C	$\Delta T_{hs\text{-}avg}$ K	ΔT_{hs} K
R reference	0				779	0					
Test	25	126,5	0,124 9	15,80	1 013	70,5	45,5	2,88	75,5	5,0	50,5

C.3.5 Extrapolations

Table C.4 shows an example of extrapolation, by iterations, of the temperature rise test results at another ambient temperature (corresponding to Condition 1 in Table C.2).

Each iteration is performed as follows:

– starting with the value of the winding resistance of the coil (R) in the previous row of the table;

– calculating the average winding temperature rise of the coil:

$$\Delta T_{avg} = R_{th\_avg} \times P;$$

– recalculating the resistance according to the following formula with k = 234,5 for copper:

$$R_2 = R_1 \times \frac{T_2 + k}{T_1 + k};$$

– and assuming that $\Delta T_{hs\text{-}avg}$ is proportional to ΔT_{avg}.

Table C.4 – Extrapolation to other ambient temperature

Comment	T_{amb} °C	U V	P W	ΔT_{avg} K	T_{avg} °C	R Ω	$\Delta T_{hs\text{-}avg}$ K	ΔT_{hs} K	T_{hs} °C
Test	25	126,5	15,8	45,5	70,5	1 013	5,0	50,5	75,5
Iteration			15,8	45,5	85,5	1 062,4	5,0	50,5	90,5
Iteration			15,1	43,3	83,3	1 055,3	4,8	48,1	88,1
Iteration	40	126,5	15,2	43,6	83,6	1 056,3	4,8	48,4	88,4
Iteration			15,1	43,6	83,6	1 056,1	4,8	48,4	88,4
Condition 1			15,2	43,6	83,6	1 056,2	4,8	48,4	88,4

C.3.6 Lifetime calculation based on thermal endurance

Applying the principles of Table C.4, the temperatures of Table C.5 can be extrapolated for each condition specified in Table C.2.

Using fomula (C.2), the consumed thermal endurance potential (CEP) can then be calculated.

Table C.5 – Lifetime calculation based on thermal endurance

Temperature extrapolations								Thermal endurance calculations			
Comment	T_{amb}	U	P	ΔT_{avg}	T_{avg}	ΔT_{hs}	T_{hs}	Operation over lifetime		Lifetime	
	°C	V	W	K	°C	K	°C	Split %	AOT h	ECO h	CEP %
Test	25	126,5	15,8	45,5	70,5	50,5	75,5			1 334 212	
Condition 1	40		15,2	43,6	83,6	48,4	88,4	40,0	77 760	493 310	15,8
Condition 2	55	126,5	14,5	41,9	96,9	46,4	101,4	50,0	97 200	180 363	53,9
Condition 3	65		14,2	40,8	105,8	45,2	110,2	10,0	19 440	91 692	21,2
Total								100	194 400		90,9

NOTE Because the speed of ageing increases with temperature, although operation in the hottest conditions (Condition 3) is limited to 10 % of the required lifetime, it consumes 21 % of the lifetime potential of the insulation system of the coil. Whereas, operation in the coldest conditions (Condition1), occurring 40 % of lifetime, only consumes 16 %.

The total consumed endurance potential (*CEP*) is less than 100 %: the insulations system of this coil is acceptable, for the specified conditions, from the thermal endurance point of view.

C.3.7 Equivalent continuous duty and rated continuous duty

Applying the principles of Table C.5, it is possible to calculate:

– the available lifetime (*ECO*);

– or the consumption of potential lifetime (*CEP*) after a given operation time (*AOT*);

for continuous operation at any relevant ambient temperature and voltage values as shown in Table C.6 for an equivalent continuous duty and for different rated continuous duties.

Equivalent continuous duty – This calculation aims at determining a single, equivalent, ambient temperature (T_{amb_eq}) and a single, equivalent, voltage (U_{dc_eq}) for continuous operation which consumes the same potential of thermal endurance (approximately, because of the chosen, rounded figures) as the specified application, which corresponds to the actual service. This case is generated from Table C.5 in two steps:

– Step 1: a same temperature (T_{amb_eq}) for each of the voltage conditions is determined, by iterations, which consumes the same overall *CEP* as the specified application.

– Step 2: a same voltage (U_{dc_eq}) for each time slice is then determined by iterations which consumes the same overall *CEP* at the equivalent temperature determined in step 1 (T_{amb_eq}).

Rated continuous duty – Similarly, it is possible to determine many pairs of temperature (T_{amb_rated}) and voltage (U_{dc_rated}) aiming at consuming 100% *CEP* for a given target lifetime (*AOT*), e.g. for the purpose of a catalog.

Table C.6 – Equivalent continuous duty and rated continuous duty

Comment	Temperature extrapolations							Thermal endurance calculations		
	T_{amb}	U	P	ΔT_{avg}	T_{avg}	ΔT_{hs}	T_{hs}	Continuous operation	Lifetime	
	°C	V	W	K	°C	K	°C	*AOT* h	*ECO* h	*CEP* %
Test	25	126,5	15,8	45,5	70,5	50,5	75,5		1 334 212	
Equivalent continuous duty	52,5	126,5	14,6	42,1	94,6	46,8	99,3	194 400	213 443	91,1
Rated continuous duty	55	126,5	14,5	41,9	96,9	46,4	101,4	180 000	180 370	99,8

NOTE 180 000 h is another example of lifetime requirement.

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPLICATIONS FERROVIAIRES – ÉQUIPEMENTS ÉLECTRIQUES DU MATÉRIEL ROULANT –

Partie 1: Conditions générales de service et règles générales

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La Norme internationale IEC 60077-1 a été établie par le comité d'études 9 de l'IEC: Matériels et systèmes électriques ferroviaires.

Cette deuxième édition annule et remplace la première édition de l'IEC 60077-1 publiée en 1999. Elle constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) Suppression et remplacement des descriptions concernant la coordination de l'isolement, les conditions d'environnement et celles du retour de courant et de la mise à la masse par des références à l'IEC 62497-1, l'IEC 62498-1 et l'IEC 61991, à l'exception des classes de température ambiante, qui sont tirées du Tableau 2 de l'IEC 62498-1:2010.

b) Introduction d’une classification de type d’équipement.

c) Révision des températures limites et des essais d'échauffement.

d) Introduction d’un exemple de calcul de durée de vie à l’Annexe C (informative).

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
9/2266/FDIS	9/2278/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60077, publiées sous le titre général *Applications ferroviaires – Équipements électriques du matériel roulant*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l’IEC sous «http://webstore.iec.ch» dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

INTRODUCTION

Bien que le présent document spécifie les conditions générales de service et les règles générales pour les équipements électriques du matériel roulant, d'autres détails propres à certains types d'équipements électriques peuvent être donnés dans d'autres normes IEC.

La série de normes IEC 60077 comprend les parties suivantes:

- Partie 1: Conditions générales de service et règles générales
- Partie 2: Composants électrotechniques – Règles générales
- Partie 3: Composants électrotechniques – Règles pour disjoncteurs à courant continu
- Partie 4: Composants électrotechniques – Règles pour disjoncteurs à courant monophasé
- Partie 5: Composants électrotechniques – Règles pour les fusibles à haute tension

Bien que l'ensemble des circuits des équipements électroniques de puissance ou de commande alimentés à partir des tensions de l'accumulateur ou de la ligne de contact soient couverts par le présent document, leurs circuits internes peuvent être assujettis aux exigences des normes de produit correspondantes.

Pour les équipements électriques du matériel roulant, y compris les éléments de matériel industriel, qui répondent à une norme internationale propre, le présent document et, le cas échéant, la norme de produit d'équipement électrique spécifient seulement les exigences complémentaires pour assurer un service satisfaisant sur le matériel roulant.

APPLICATIONS FERROVIAIRES – ÉQUIPEMENTS ÉLECTRIQUES DU MATÉRIEL ROULANT –

Partie 1: Conditions générales de service et règles générales

1 Domaine d'application

La présente partie de l'IEC 60077 spécifie les conditions générales de service et les exigences pour l'ensemble de l'équipement électrique installé dans les circuits de puissance, les circuits auxiliaires, les circuits de commande, les circuits de signalisation et de surveillance, etc., sur le matériel roulant ferroviaire.

NOTE Après accord entre utilisateur et fabricant, certaines règles peuvent être utilisées pour l'équipement électrique installé sur des véhicules autres que ceux du matériel roulant ferroviaire, tels que les locomotives de mine, trolleybus, etc.

Le présent document a pour objet d'harmoniser dans la mesure du possible l'ensemble des règles et des exigences de caractère général applicables aux équipements électriques du matériel roulant; cela de manière à uniformiser les exigences et les essais de la gamme complète des matériels correspondants et à éviter d'avoir à effectuer des essais suivant des normes différentes.

L'ensemble des exigences relatives

- aux contraintes dues à l'environnement dans les conditions normales d'utilisation;
- à la construction;
- aux performances et aux essais correspondants qui peuvent être considérés comme généraux;

ont donc été rassemblées dans le présent document avec les sujets d'intérêt et d'application d'ordre général comme les échauffements, les propriétés diélectriques, etc.

Dans l'éventualité où une différence existerait entre les exigences du présent document et une norme de produit pertinente, les exigences de la norme de produit prévaudraient.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-1, *Essais d'environnement – Partie 2-1: Essais – Essais A: froid*

IEC 60068-2-2, *Essais d'environnement – Partie 2-2: Essais – Essais B: chaleur sèche*

IEC 60068-2-30, *Essais d'environnement – Partie 2-30: Essais – Essai Db: Essai cyclique de chaleur humide (cycle de 12 h + 12 h)*

IEC 60068-2-52, *Essais d'environnement – Partie 2-52: Essais – Essai Kb: Brouillard salin, essai cyclique (solution de chlorure de sodium)*

IEC 60068-2-78, *Essais d'environnement – Partie 2-78: Essais – Essais Cab: Chaleur humide, essai continu*

IEC 60085, *Isolation électrique – Evaluation et désignation thermiques*

IEC 60216-1, *Matériaux isolants électriques – Propriétés d'endurance thermique – Partie 1: Méthodes de vieillissement et évaluation des résultats d'essai*

IEC 60505, *Evaluation et qualification des systèmes d'isolation électrique*

IEC 60529, *Degrés de protection procurés par les enveloppes (code IP)*

IEC 60721-3-5, *Classification des conditions d'environnement – Partie 3: Classification des groupements des agents d'environnement et de leurs sévérités – Section 5: Installations des véhicules terrestres*

IEC 60850, *Applications ferroviaires – Tensions d'alimentation des réseaux de traction*

IEC 61133:2016, *Applications ferroviaires – Matériel roulant – Essais sur matériel roulant après achèvement et avant mise en service*

IEC 61373, *Applications ferroviaires – Matériel roulant – Essais de chocs et vibrations*

IEC 61991, *Applications ferroviaires – Matériel roulant – Dispositions de protection contre les dangers électriques*

IEC 61992-1, *Applications ferroviaires – Installations fixes – Appareillage à courant continu – Partie 1: Généralités*

IEC 62236-3-2, *Applications ferroviaires – Compatibilité électromagnétique – Partie 3-2: Matériel roulant – Appareils*

IEC 62497-1, *Applications ferroviaires – Coordination de l'isolement – Partie 1: Exigences fondamentales – Distances d'isolement dans l'air et lignes de fuite pour tout matériel électrique et électronique*

IEC 62498-1:2010, *Applications ferroviaires – Conditions d'environnement pour le matériel – Partie 1: Equipement embarqué du matériel roulant*

3 Termes, définitions et termes abrégés (voir également l'Annexe A)

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC entretiennent des bases de données terminologiques pour l'usage de la normalisation aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1 Généralités

3.1.1
matériel roulant
ensemble des véhicules, motorisés ou non

Note 1 à l'article: Cela inclut, par exemple, une locomotive, une voiture ou un wagon.

[SOURCE: IEC 60050-811:2017, 811-02-01]

3.1.2
véhicule
élément de matériel roulant

3.2 Circuits

3.2.1
circuit de puissance
circuit parcouru par le courant des machines et appareils, tels que les convertisseurs et les moteurs de traction, qui transmet la puissance de traction

[SOURCE: IEC 60050-811:2017, 811-25-03]

3.2.2
circuit principal
ensemble des parties conductrices d'un équipement parcouru par le courant de la fonction à laquelle cet équipement est destiné

3.2.3
circuit auxiliaire, <d'un train>
circuit parcouru par le courant des appareils auxiliaires tels que les compresseurs et les ventilateurs

[SOURCE: IEC 60050-811:2017, 811-25-05]

3.2.4
circuit de commande, <d'un train>
circuit servant à mettre en action des équipements de puissance ou des auxiliaires

[SOURCE: IEC 60050-811:2017, 811-25-12]

3.2.5
circuit de signalisation et de surveillance
circuit transmettant un signal indiquant si certaines conditions de fonctionnement existent ou non, ou les enregistrant (par exemple un signal indiquant la défaillance de l'équipement électrique)

[SOURCE: IEC 60050-811:2017, 811-25-14]

3.3 Matériel alimenté par accumulateur

3.3.1
accumulateur (électrique)
système électrochimique capable d'accumuler, sous forme chimique, l'énergie électrique reçue et de la restituer par transformation inverse

3.3.2
batterie flottante <charge>
batterie d'accumulateurs dont les bornes sont connectées en permanence à une source de tension constante suffisante pour maintenir la batterie approximativement à charge complète, et qui est destinée à fournir de l'énergie à un circuit électrique lorsque l'alimentation normale est interrompue

Note 1 à l'article: L'accumulateur absorbe un courrent «en floating» dans ce mode.

[SOURCE: IEC 60050-482:2004, 482-05-35, modifié – La Note 1 a été ajoutée.]

3.3.3
système d'accumulateur «en floating»
matériel principalement exploité avec l'accumulateur «en floating»

3.3.4
système d'accumulateur hors charge
matériel principalement alimenté alors que l'accumulateur n'est pas en charge

3.4 Catégories d'essais

3.4.1
essai de type
essai de conformité effectué sur une ou plusieurs entités représentatives de la production

[SOURCE: IEC 60050-811:2017, 811-10-04]

3.4.2
essai individuel de série
essai de conformité effectué sur chaque entité en cours ou en fin de fabrication

[SOURCE: IEC 60050-811:2017, 811-10-05]

3.4.3
essai sur prélèvement
essai effectué sur un échantillon

[SOURCE: IEC 60050-811:2017, 811-10-06]

3.4.4
essai d'investigation
essai spécial de caractère facultatif qui est effectué en vue d'obtenir des informations complémentaires

[SOURCE: IEC 60050-811:2017, 811-10-07]

3.4.5
partie conductrice accessible
partie conductrice, susceptible d'être touchée directement, qui n'est pas normalement sous tension mais qui peut le devenir en cas de défaut

[SOURCE: IEC 60050-441:1984, 441-11-10, modifié – La Note a été supprimée.]

3.5 Grandeurs caractéristiques

3.5.1
valeur limite
plus grande ou la plus petite valeur admissible d'une grandeur dans une spécification d'un composant, dispositif, matériel ou système

[SOURCE: IEC 60050-151:2001, 151-16-10, modifié – L'ordre de la phrase a été modifié.]

3.5.2
valeur nominale
valeur d'une grandeur, utilisée pour dénommer et identifier un composant, un dispositif, un matériel ou un système

Note 1 à l'article: La valeur nominale est généralement une valeur arrondie.

Note 2 à l'article: Dans le présent document, l'expression «valeur nominale» n'est utilisée, conformément à la pratique, que pour désigner les circuits de la tension d'alimentation de la ligne de contact et des accumulateurs.

[SOURCE: IEC 60050-811:2017, 811-11-01, modifié – La Note 2 à l'article a été ajoutée.]

3.5.3
valeur assignée
valeur d'une grandeur, utilisée à des fins de spécification, correspondant à un ensemble spécifié de conditions de fonctionnement d'un composant, dispositif, matériel ou système

[SOURCE: IEC 60050-811:2017, 811-11-02]

3.5.4
régime permanent équivalent
régime du matériel électrique du matériel roulant, correspondant au fonctionnement réel, généralement caractérisé par des valeurs de courant, de tension, de pression d'air comprimé, etc., qui varient dans le temps

Note 1 à l'article: Les différentes parties du matériel sont définies par l'énoncé complet des conditions à satisfaire. Cependant, il est parfois suffisant de spécifier le régime permanent équivalent qui correspond du point de vue des contraintes électriques, mécaniques ou thermiques au service considéré et qui est reconnu comme étant équivalent au service réel. C'est le régime permanent équivalent auquel les essais se réfèrent.

3.5.5
courant permanent équivalent assigné
courant correspondant au régime permanent équivalent

3.6 Termes liés à la durée de vie

3.6.1
vieillissement
modification dans le temps des propriétés physiques, chimiques et électriques d'un composant ou d'un module, dans un domaine de fonctionnement prévu à la conception, qui peut entraîner une dégradation significative des caractéristiques de performances

Note 1 à l'article: Cet article était numéroté 393-18-41 dans la CEI 60050-393:2003.

[SOURCE: IEC 60050-395:2014, 395-07-100]

3.6.2
endurance
aptitude à résister à l'action des facteurs de vieillissement

Note 1 à l'article: L'endurance peut être caractérisée par les résultats d'essais de vieillissement accéléré.

[SOURCE: IEC 60050-212:2010, 212-12-08]

3.6.3
endurance thermique
aptitude à résister à l'action de la température

[SOURCE: IEC 60050-212:2010, 212-12-09]

3.6.4
durabilité
aptitude à fonctionner tel que requis, dans des conditions données d'utilisation et de maintenance, jusqu'à la fin de la vie utile

Note 1 à l'article: Pour les besoins du present document, "durabilité" est utilisé afin d'exprimer l'estimation de la durée de vie (temps ou nombre de cycles de fonctionnement) qui peut être réalisée par l'équipement avant réparation ou remplacement de parties.

[SOURCE: IEC 60050-192:2015, 192-01-21, modifié – La Note 1 à l'article a été ajoutée.]

3.7 Termes abrégés

CA Courant alternatif

CC Courant continu

CEM Compatibilité électromagnétique

RMS Valeur efficace *(*Root Mean Square value*)*

PD Degré de pollution *(*Pollution degree*)*

OV Catégorie de surtension *(*Overvoltage category*)*

VC Classe de tension *(*Voltage Class*)*

4 Classification

Cet article est destiné à énumérer les caractéristiques d'un matériel sur lesquelles le fabricant peut donner des informations, et qui doivent être vérifiées par des essais si nécessaire.

Les équipements couverts par le présent document sont classés selon la source d'alimentation de leurs circuits de commande et auxiliaires. Les détails sont donnés en 5.3.3.2.

5 Caractéristiques de la catégorie d'emploi

5.1 Généralités

La catégorie d'emploi d'un matériel définit l'application à laquelle il est destiné et doit être spécifiée dans la norme de produit correspondante; elle est caractérisée par une ou plusieurs des grandeurs suivantes:

- courant(s);
- tension(s);
- fréquence(s);
- pression(s).

Voir également Annexe A.

NOTE Cette liste n'est pas exhaustive et, le cas échéant, peut inclure d'autres grandeurs applicables.

5.2 Tensions assignées

5.2.1 Généralités

Généralement, le terme de tension assignée peut être affecté à la valeur d'entrée comme à celle de sortie d'un matériel. La valeur est généralement fixée par le fabricant.

5.2.2 Tension assignée d'emploi (U_r)

La tension assignée d'emploi d'un matériel est une valeur qui, combinée avec un courant assigné d'emploi et une fréquence assignée d'emploi, détermine l'emploi du matériel, et à laquelle se rapportent les essais correspondants et la catégorie d'emploi.

NOTE La tension assignée d'emploi était symbolisée par U_e dans la première édition de l'IEC 60077-1. Elle est symbolisée par U_{Ne} dans l'IEC 61992-1.

5.2.3 Tension assignée d'isolement (U_{Nm})

La définition de la tension assignée d'isolement est donnée dans l'IEC 62497-1.

La tension assignée d'isolement d'un matériel est la valeur de tension à laquelle on se réfère pour les essais de tension assignée de choc et pour les lignes de fuite.

Lorsque la tension n'est pas strictement sinusoïdale ou continue, la valeur efficace ou moyenne seule ne peut pas suffire pour prescrire la tension assignée d'isolement.

En l'absence de connaissances de l'influence possible sur la contrainte diélectrique:

- du rapport entre la durée des impulsions périodiques et leur période de répétition;
- du nombre d'impulsions durant occurence;
- du front de l'impulsion (dv/dt);

il est recommandé de choisir cette tension comme étant égale à la valeur efficace réelle sans être inférieure à 70 % de la valeur de crête.

5.2.4 Essai de tension de fréquence industrielle (U_a)

L'essai de tension de fréquence industrielle est la valeur efficace d'une tension sinusoïdale qui ne provoque pas de défaut d'isolement dans des conditions d'essai spécifiées.

U_a est spécifié dans l'IEC 62497-1.

5.2.5 Tension assignée de choc (U_{Ni})

La définition de la tension assignée de choc est donnée dans l'IEC 62497-1.

La tension assignée de choc est utilisée pour déterminée les exigences minimum des distances d'isolement et des tensions d'essais diélectriques.

5.3 Tensions assignées des équipements électriques

5.3.1 Matériel alimenté à partir d'une ligne de contact

La tension assignée d'emploi (U_r) pour un matériel alimenté par la ligne de contact correspond à la tension (U_{max1}) permanente la plus élevée de la ligne de contact, définie par l'IEC 60850.

5.3.2 Matériel alimenté à partir d'un transformateur

La tension assignée d'emploi (U_r) pour un matériel alimenté par un enroulement de transformateur est égale à la tension efficace aux bornes de l'enroulement alors que l'enroulement primaire est alimenté à la tension assignée d'emploi. Si un second transformateur est interposé entre le transformateur et le matériel, la tension assignée d'emploi (U_r) est égale à la tension assignée ci-dessus multipliée par le rapport de transformation du second transformateur.

5.3.3 Matériel alimenté à partir de sources basse tension à courant continu

5.3.3.1 Tensions nominales

Ce paragraphe s'applique pour le matériel alimenté selon la classe de tension I et la classe de tension II définies dans l'IEC 61991.

La tension nominale (U_n) est utilisée uniquement pour désigner les circuits et le matériel, et il convient qu'elle soit sélectionnée parmi les valeurs préférentielles suivantes:

24 V, 72 V, ou 110 V.

D'autres tensions peuvent être utilisées après accord entre l'utilisateur et le fabricant.

NOTE Ces valeurs de tension nominale sont données uniquement comme valeurs normalisées pour la conception des matériels. Elles ne sont pas considérées en tant que tension à vide de l'accumulateur qui sera déterminée en fonction des types d'accumulateur, du nombre d'éléments et des conditions d'emploi.

5.3.3.2 Plages de tension

Un matériel couvert par le présent document est classé comme suit, selon la source d'alimentation de ses circuits auxiliaires de commande.

- Type VC1: materiel alimenté par un système d'accumulateur «en floating»;
- Type VC2: materiel alimenté par un système d'accumulateur hors charge;
- Type VC3: materiel non alimenté directement par un système d'accumulateur à bord, mais alimenté par exemple par une génératrice, un alternateur ou un convertisseur électronique.

Le Tableau 1 montre les plages de tensions et les tensions assignées d'emploi (U_r) pour les circuits auxiliaires de commande pour chaque type de matériel. Les valeurs pour le Type VC3 sont valables pour une source de tension stabilisée.

Tableau 1 – Plages de tension pour les circuits auxiliaires de commande

Classification	Tension minimale du matériel	Tension assignée d'emploi (U_r)	Tension maximale du matériel
Type VC1	0,7 U_n	1,15 U_n	1,25 U_n
Type VC2	0,7 U_n	1,1 U_n	1,25 U_n
Type VC3	0,85 U_n	1,0 U_n	1,1 U_n

NOTE 1 Fondamentalement, la batterie pour l'équipement de Type VC1 est utilisée en mode de charge. La tension peut être inférieure à la tension flottante pour de courtes périodes, par exemple avant le démarrage de l'équipement de charge, pendant l'accumulation de tension de la batterie, ou en cas d'interruption de la ligne de contact.

NOTE 2 Fondamentalement, la batterie pour l'équipement de Type VC2 est utilisée en mode de décharge. La tension de la batterie va diminuer progressivement.

NOTE 3 La tension pour l'équipement de Type VC3 n'est pas la tension qui alimente le générateur, l'alternateur ou le convertisseur électronique lui-même.

NOTE 4 La plage de tension du Type VC1 et VC2 est la même, mais l'évolution de la tension en fonctionnement diffère selon la durée de vie de l'équipement.

NOTE 5 La tension assignée d'emploi est utilisée dans le calcul des pertes thermiques, de la consommation de puissance, de l'échauffement, etc.

5.4 Courants assignés du matériel

5.4.1 Courant assigné d'emploi (I_r)

Le courant assigné d'emploi du matériel est défini par le fabricant et tient compte de la tension assignée d'emploi et de la fréquence assignée d'emploi.

5.4.2 Courant assigné de courte durée admissible (I_{cw})

Le courant assigné de courte durée admissible du matériel est la valeur du courant de courte durée admissible, assignée au matériel par le fabricant, que ce matériel peut supporter sans dommage.

La durée assignée (t_{cw}) du matériel utilisé est la valeur de l'intervalle de temps pendant lequel un appareillage peut supporter, en position fermée, un courant égal à son courant assigné de courte durée admissible.

5.5 Fréquence assignée d'emploi (f_r)

La fréquence assignée d'emploi du matériel est définie par le fabricant et tient compte de la tension assignée d'emploi.

5.6 Pression assignée

La valeur assignée de la pression d'alimentation d'un matériel pneumatique ou électropneumatique est la valeur limite supérieure de la plage du régulateur de pression et à laquelle les essais correspondants se réfèrent.

6 Informations sur le produit

6.1 Nature de l'information

Les informations suivantes doivent être données par le fabricant pour chaque partie d'un matériel électrique, si la norme de produit correspondante le spécifie:

a) identification
   - nom ou sigle du fabricant;
   - désignation du type ou numéro de série;
   - indice de modification;
   - référence à la norme de produit correspondante, si le fabricant déclare la conformité du produit.

b) caractéristiques

   La liste suivante n'est pas exhaustive et ses termes s'appliquent lorsqu'ils sont appropriés.
   - tension(s) assignée(s) d'emploi;
   - tension assignée d'isolement;
   - tension assignée de choc;
   - courant(s) assigné(s) d'emploi à la (aux) tension(s) assignée(s) d'emploi;
   - fréquence(s) assignée(s) d'emploi;
   - consommation maximale de courant ou consommation maximale de puissance;
   - nombres de manœuvres des durabilités mécanique et électrique selon la norme de produit correspondante;
   - performances assignées en surcharge et/ou en régime dégradé selon la norme de produit correspondante;
   - code IP dans le cas d'un matériel sous enveloppe (selon l'IEC 60529);
   - degré de pollution acceptable pour le matériel (selon 7.9);
   - tension(s), fréquence(s) et courant(s) assigné(s) du ou des circuits de commande;
   - pression assignée et limites de variation de la pression (pour le matériel à commande pneumatique);
   - dimensions extérieures;

– taille minimale de l'enveloppe et, selon les cas, données concernant la ventilation, auxquelles se rapportent les caractéristiques assignées;
– distance minimale entre le matériel et son enveloppe;
– distance minimale entre le matériel et les parties métalliques reliées à la masse du véhicule pour le matériel utilisé sans enveloppe;
– masse.

Certaines de ces informations peuvent être complétées par la valeur de la température ambiante pour laquelle le matériel a été déterminé.

6.2 Marquage

Toute information appropriée à marquer sur le matériel, parmi celles listées en 6.1, doit être spécifiée dans la norme de produit correspondante.

Sur le matériel, les marquages suivants sont obligatoires:

– nom ou sigle du fabricant;
– désignation du type;
– numéro de série ou date ou code du fabricant.

Ces informations sont marquées de préférence sur la plaque d'identification lorsqu'elle existe, pour fournir toutes les données nécessaires (traçabilité). Les marquages doivent être indélébiles et facilement lisibles.

6.3 Instructions pour le stockage, l'installation, le fonctionnement et l'entretien

Le fabricant doit spécifier dans ses documents ou catalogues les instructions, si nécessaire, pour le stockage, l'installation, le fonctionnement et l'entretien du matériel durant le fonctionnement et après une défaillance.

Si nécessaire, les instructions pour le stockage, le transport, l'installation et le fonctionnement du matériel doivent indiquer les mesures particulièrement importantes pour une installation, une mise en service et un fonctionnement corrects du matériel.

Ces documents doivent indiquer la consistance et la fréquence des opérations d'entretien recommandées, le cas échéant.

Le matériel couvert par le présent document n’est pas obligatoirement conçu pour être entretenu.

7 Conditions normales de service

7.1 Généralités

L’Article 7 fixe les conditions de service. Certaines conditions de service sont énoncées dans l'IEC 62498-1:2010 et d’autres sont issues d’autres références mentionnées. Dans le cas où d'autres conditions environnementales s'appliquent, il convient de les sélectionner dans l’IEC 62498-1:2010 et, si les conditions dans l’IEC 62498-1:2010 sont insuffisantes, elles doivent être sélectionnées dans l’IEC 60721-3-5 si elles sont appropriées.

La liste suivante n'est pas exhaustive, et l'IEC 62498-1:2010 ainsi que l'IEC 60721-3-5 fournissent des données complémentaires.

Les conditions normales de service sont une combinaison de conditions d'environnement, de fonctionnement et d'installation.

7.2 Altitude

Le matériel est supposé fonctionner normalement dans la plage d'altitude spécifiée. La classe A1 de plage d'altitude, spécifiée dans l'IEC 62498-1:2010, doit être appliquée, sauf spécification contraire.

Pour des installations à plus haute altitude, il est nécessaire de tenir compte de la réduction de la contrainte diélectrique et de l'effet de refroidissement de l'air. Il convient de concevoir ou d'utiliser le matériel ainsi employé après accord entre l'utilisateur et le fabricant.

NOTE En ce qui concerne la réduction de l'effet de refroidissement de l'air avec l'altitude, l'élévation plus haute des températures à plus haute altitude est généralement compensée par la température ambiante maximale réduite à plus haute altitude. Des orientations sont disponibles, par exemple en 5.1 de l'IEC TR 60943:1998/AMD1:2008.

7.3 Température

7.3.1 Température ambiante

L'air ambiant doit être considéré comme étant celui qui environne le matériel; il différera selon l'emplacement où est monté ce matériel.

La classe de température ambiante à laquelle le matériel électrique fonctionnera doit être déterminée conformément au Tableau 2, sauf spécification contraire. La classe T1 doit être appliquée, sauf spécification contraire.

Pour les emplacements intérieurs, la température ambiante (T_a) est la température ambiante extérieure augmentée de la valeur de l'échauffement de l'air produit par les pertes thermiques locales, dans les conditions normales de refroidissement.

Tableau 2 – Classes de températures ambiantes

Classes (Zone d'application type)	Température ambiante à l'extérieur du véhicule °C	Température à l'intérieur d'un compartiment du véhicule °C	Température à l'intérieur d'un bloc d'appareillage °C
T1 (par ex., Europe centrale)	–25 +40	–25 +50	–25 +70
T2 (par ex., Europe du Nord)	–40 +35	–40 +45	–40 +65
T3 (par ex., Europe du Sud)	–25 +45	–25 +55	–25 +70
T4 (région tempérée aux latitudes moyennes)	–10 +40	–10 +50	–10 +70
T5 (région tropicale sauf désert)	+5 +45	+5 +55	+5 +70
T6 (région tropicale dans un désert)	–20 +55	–20 +65	–20 +75
TX	–40 +50	–40 +60	–40 +75

NOTE 1 Ce tableau est dérivé de l'IEC 62498-1:2010, Tableau 2.

NOTE 2 Les températures de stockage ne sont pas considérées comme des conditions normales de service, à moins qu'elles aient été notifiées.

Pour chacun des emplacements à l'intérieur de la caisse, d'un compartiment moteur, d'un bloc d'appareillage, d'un coffre, etc., cet échauffement de l'air peut être différent. Lorsque cette valeur n'est ni spécifiée par un document approprié ni connue, elle doit être considérée comme n'excédant pas 30 K pendant le fonctionnement.

Si les matériels sont utilisés à des températures ambiantes moyennes supérieures à celles prévues, il est nécessaire de réduire leurs performances.

Pour la classe d'altitude AX donnée dans l'IEC 62498-1:2010, l'utilisateur doit fournir la relation de dépendance entre altitude et température en spécifiant la distribution de température pour chaque plage pertinente (par exemple, de 0 m à 1 000 m et de 1 000 m à 2 000 m).

7.3.2 Température de référence

Une température de référence (T_r) (température ambiante constante équivalente, ou température de milieu de refroidissement) est considérée comme étant la température pour laquelle les effets sur le vieillissement du matériau sont équivalents à ceux de la température de service pendant la durée de vie. Elle peut être utilisée pour le calcul de la durée de vie et de la fiabilité.

a) Soit elle doit être fixée à 25 °C pour un emplacement extérieur conformément à la classe TR2 du Tableau 3 de l'IEC 62498-1:2010, sauf spécification contraire;
b) ou à la température de référence extérieure augmentée de 30 K pour un emplacement intérieur sauf spécification contraire;
c) soit elle peut être calculée par le fabricant sur la base de la distribution de température fournie par l'acheteur.

NOTE 1 Le vieillissement thermique est une fonction exponentielle de la température (par ex., voir IEC 60216 pour les matériaux isolants); en d'autres termes, la température de référence est habituellement supérieure à la moyenne arithmétique de la température.

NOTE 2 Pour un emplacement intérieur, la distribution de température dépend fortement de la charge et de la dissipation de la chaleur liée.

7.4 Humidité

L'humidité est définie dans l'IEC 62498-1:2010, 4.4.

7.5 Conditions biologiques

Les risques d'attaques biologiques sont définis dans l'IEC 60721-3-5, classe 5B2.

7.6 Substances chimiquement actives

Présence de substances chimiquement actives comme défini dans l'IEC 60721-3-5, classe 5C2 pour la salinité ou d'autres substances chimiques. Les produits de nettoyage doivent être spécifiés par l'acheteur.

7.7 Substances mécaniquement actives

Présence de substances mécaniquement actives comme défini dans l'IEC 60721-3-5, classe 5S2.

7.8 Vibrations et chocs

Le matériel est soumis aux vibrations et aux chocs dans la gamme de fréquences et de niveaux d'accélération présents en service conformément à l'IEC 61373.

7.9 Exposition à la pollution

Selon son emplacement, le matériel est exposé à une pollution plus ou moins importante.

Le degré de pollution (PD) est classé de PD1 à PD4 et doit être pris en compte lors de la détermination des distances d'isolement et des lignes de fuite. De plus amples détails sont donnés dans l'IEC 62497-1.

7.10 Exposition aux surtensions

Le matériel électrique est exposé aux surtensions provenant de la ligne de contact ou générées par le matériel lui-même, par exemple les transitoires de coupure, les chocs de foudre, etc. Leurs niveaux sont différents selon la partie du matériel considérée.

La catégorie de surtensions (OV) est classée de OV1 à OV4.

De plus amples détails sont donnés dans l'IEC 62497-1.

8 Exigences relatives à la construction et au fonctionnement

8.1 Exigences relatives à la construction

8.1.1 Risques électriques

Des dispositions de protection contre les risques électriques doivent être prises conformément à l'IEC 61991.

8.1.2 Accumulateurs

Pendant la charge et la décharge, les accumulateurs peuvent nécessiter d'être aérés afin de garantir que la concentration d'hydrogène produite par l'électrolyse de l'eau reste inférieure au seuil de 4 %.

Si nécessaire, il est essentiel que tout obstacle au renouvellement de l'air soit réduit au minimum et que l'ouverture débouche en plein air. Les entrées et sorties d'air doivent être situées aux meilleurs emplacements, c'est-à-dire sur les parois opposées de l'enveloppe.

Le câblage entre l'accumulateur et les coupe-circuits doit être aussi court que possible.

8.1.3 Protection contre le feu

Les circuits et les matériels comportant des risques d'inflammation doivent être efficacement protégés.

Les matériaux ne doivent produire qu'une faible quantité de fumée d'opacité et de toxicité minimales. (Les limites doivent être déterminées.)

Les matériaux combustibles doivent être installés loin des sources de chaleur. Ils doivent être choisis de façon à garantir une bonne résistance au feu.

Pour limiter la propagation du feu, des prescriptions spéciales peuvent être spécifiées en tenant compte de l'installation (cloisons coupe-feu, extincteurs, etc.).

NOTE Les exigences en matière de protection contre le feu diffèrent d'un pays à l'autre et d'une région à l'autre.

Par exemple, pour les pays européens, la série EN 45545 est applicable.

8.1.4 Autres risques

Les parties accessibles qui sont susceptibles, en service normal, d'être portées à une température supérieure aux limites du Tableau 5 doivent être protégées par un écran formant obstacle. La température de l'écran ne doit pas dépasser la limite spécifiée.