

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**



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**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**

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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- withdrawn,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
		$T_r = 25\text{ °C}$ K	$T_r = 55\text{ °C}$ 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 ($T_r = 25\text{ °C}$) and interior location ($T_r = 55\text{ °C}$).					
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 ($T_r = 25\text{ °C}$) T_k	70 °C ($T_r = 55\text{ °C}$) T_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 $T_r = 25\text{ °C}$ and for interior location with $T_r = 55\text{ °C}$ 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 $T_r = 25\text{ °C}$ (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 ($T_k = 25\text{ °C}$)	70 °C ($T_k = 55\text{ °C}$)
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 $\pm 8\%$.

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.