BS EN 50502:2015

BSI Standards Publication

Railway applications — Rolling stock — Electric equipment in trolley buses — Safety requirements and current collection systems

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National foreword

This British Standard is the UK implementation of EN 50502:2015. It supersedes DD CLC/TS 50502:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/9/2, Railway Electrotechnical Applications - Rolling st.

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European foreword

This document (EN 50502:2015) has been prepared by CLC/SC 9XB "Electromechanical material on board rolling stock" of the Technical Committee CENELEC TC 9X “Electrical and electronic applications for railways”.

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2016-03-30
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2018-03-30

This document supersedes CLC/TS 50502:2008.

EN 50502:2015 includes the following significant technical changes with respect to CLC/TS 50502:2008:

- Clause 1: a more detailed scope (guided vehicles) in reference to other electric vehicles;
- 5.6.1: insulation resistance and separate source applied voltage tests for voltage band I components is waived with respect to other electric vehicles and with reference to ECE R100;
- Table 5: test voltages for components intended to break a current which are used with open contacts for supplementary or basic insulation;
- 6.4.2: specification of periodical checks additional to insulation resistance tests;
- 6.2.5, Table 6: electrical tests of the insulation of entrance areas are waived, visual inspection is added;
- 6.5: extension of description and test of different leakage detectors;
- A.3: description of special requirements for external insulations;
- A.13, A.14: addition of energy storage systems and fuel cells;
- B.2.4.6: equipment for switch operation of overhead contact line.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

1 Scope

This European Standard applies to electrical systems on board of vehicles of the type trolley bus, as defined in 3.1, fed with a nominal line voltage (U_n) between 600 V d.c. and 750 V d.c.

This European Standard defines the requirements and constructional hints, especially to avoid electrical danger to the public and to staff. Where special requirements are existing for trolley buses, hints are given for mechanical and functional safety as well as for protection against fire.

This European Standard covers vehicles intended for public transport of persons. This Standard applies to:

- trolley buses,
- buses with current rail for guidance in the road surface,
- guided buses with bipolar roof current collector.

This European Standard does not apply to:

a) electric driven vehicles with only internal power supply:
   1) hybrid vehicles,
   2) diesel - electric vehicles,
   3) fuel - cell vehicles,
   4) battery vehicles,
b) vehicles with safe protective bonding:
   1) rubber tyred commuter trains,
   2) guided buses with supply by a separate current rail,
   3) rail guided buses with unipolar roof current collector,
c) vehicles operated outside publicly accessible areas:
   1) electric driven lorries on motorways.

Guidance and current rails are special solutions and at this time are not under standardization like trolley bus current collectors and overhead contact lines (OCL).

It refers mainly to earthed networks, but reference is made also to galvanically insulated networks.

Annex A is related to detailed design features for trolley buses.

Annexes B and C are related to the current collection systems. The detailed scope of these annexes is given in Annex B.

2 Normative references

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

EN 45502 (all parts), *Active implantable medical devices*

EN 45545-5, *Railway applications — Fire protection on railway vehicles — Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles*

EN 50110 (all parts), *Operation of electrical installations*

EN 50110-1:2013, *Operation of electrical installations — Part 1: General requirements*

EN 50119, *Railway applications — Fixed installations — Electric traction overhead contact lines*

EN 50121 (all parts), *Railway applications — Electromagnetic compatibility*

EN 50122-1, *Railway applications — Fixed installations — Electrical safety, earthing and the return circuit — Part 1: Protective provisions against electric shock*

EN 50124-1, *Railway applications — Insulation coordination — Part 1: Basic requirements — Clearances and creepage distances for all electrical and electronic equipment*

EN 50125-1, *Railway applications — Environmental conditions for equipment — Part 1: Rolling stock and on-board equipment*

EN 50153, *Railway applications — Rolling stock – Protective provisions relating to electrical hazards*

EN 50155, *Railway applications — Electronic equipment used on rolling stock*

EN 50163, *Railway applications — Supply voltages of traction systems (IEC 60850)*

EN 50178, *Electronic equipment for use in power installations*

EN 50215:2009, *Railway applications — Rolling stock — Testing of rolling stock on completion of construction and before entry into service*

EN 50264 (all parts), *Railway applications — Railway rolling stock power and control cables having special fire performance*

EN 50272-3, *Safety requirements for secondary batteries and battery installations — Part 3: Traction batteries*

EN 50306 (all parts), *Railway applications — Railway rolling stock cables having special fire performance — Thin wall*

EN 50343, *Railway applications — Rolling stock — Rules for installation of cabling*

CLC/TS 50457 (all parts), *Conductive charging for electric vehicles*

EN 50500, *Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure*

EN 60034 (all parts), *Rotating electrical machines (IEC 60034, all parts)*

EN 60077 (all parts), *Railway applications — Electrical equipment for rolling stock (IEC 60077, all parts)*

EN 60146 (all parts), *Semiconductor converters (IEC 60146, all parts)*

EN 60322, *Railway applications — Electrical equipment for rolling stock — Rules for power resistors of open construction (IEC 60322)*

EN 60349 (all parts), *Electric traction — Rotating electrical machines for rail and road vehicles (IEC 60349, all parts)*

EN 60445, *Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals, conductor terminations and conductors (IEC 60445)*

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

EN 60721-3-5, *Classfication of environmental conditions — Part 3: Classification of groups of environmental parameters and their severities — Section 5: Ground vehicle installations (IEC 60721-3-5)*

EN 61111, *Live working — Electrical insulating matting (IEC 61111)*

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

EN 61373, *Railway applications — Rolling stock equipment — Shock and vibration tests (IEC 61373)*

EN 61557-2, *Electrical safety in low voltage distribution systems up to 1 000V a.c. and 1 500 V d.c. — Equipment for testing, measuring or monitoring of protective measures — Part 2: Insulation resistance (IEC 61557-2)*

EN 61557-8, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. — Equipment for testing, measuring or monitoring of protective measures — Part 8: Insulation monitoring devices for IT systems (IEC 61557-8)*

EN 61851 (all parts), *Electric vehicle conductive charging system (IEC 61851, all parts)*

EN 61881 (all parts), *Railway applications — Rolling stock equipment — Capacitors for power electronics (IEC 61881, all parts)*

EN 62196-1, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles — Part 1: General requirements (IEC 62196-1)*

IEC 60479 (all parts), *Effects of current on human beings and livestock*

ISO 6469-3, *Electrically propelled road vehicles — Safety specifications — Part 3: Protection of persons against electric shock*

ISO 10099, *Pneumatic fluid power — Cylinders — Final examination and acceptance criteria*

ISO 16750-2, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

ISO 16750-3, *Road vehicles — Environental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 23273, *Fuel cell road vehicles — Safety specifications — Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen*

3 Terms and definitions

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

3.1
trolley bus
vehicles with rubber tyres (with limited lateral operating range or guided) without safe protective bonding of the chassis, which operate with an electrical drive in the public area accessible for persons and galvanically externally powered by a supply line (overhead contact line, current rail)

Note 1 to entry: The two poles of the supply line are either both galvanically insulated from earth or one insulated and the other earthed. This can take place at a central point or at every feed (substation).

3.2
current collection system
whole of the components, generally mounted on the vehicle roof, having the task of taking the current from the overhead contact lines to supply the equipment of the vehicle, both in standing and in running conditions

3.3
mass
conductive part of an electrical component which is accessible and which is not energized in normal conditions, but may become energized in fault conditions

Note 1 to entry: The equipment defined in 5.6.1 as normal bus vehicle components are not included in this term.

Note 2 to entry: The conductive parts of the chassis and of the bodywork are defined as the vehicle mass.

3.4
intermediate mass
conductive part between two insulating parts of a double insulated equipment (protection, enclosure, etc.), which shall not be accessible to the public

3.5
basic insulation
insulation for personal safety between the electric parts which are subject to be energized and the intermediate mass, to provide basic protection against electric shock

3.6
supplementary insulation
insulation for personal safety between the intermediate mass and the vehicle mass

3.7
double insulation
insulation comprising both basic insulation and supplementary insulation

Note 1 to entry: According to EN 60077-1 the basic and supplementary insulation may also be interchanged (refer also to Table 5).

3.8
functional insulation
insulation not for personal safety, with lower requirements, that ensures the function of the plant

Note 1 to entry: To some extent, the design is specified in the product standards.

3.9
nominal voltage U_n
designated value for a system to which the general characteristics are referred

3.10
rated voltage range U_{Ne}
voltage range which, together with rated current, defines the use of the equipment and to which the applicable tests and the utilization categories are referred

3.11
highest permanent voltage U_{max1}
maximum voltage value likely to be present indefinitely

3.12
rated insulation voltage U_{Nm}
value to which the dielectric test voltages and the creepage distances are referred and which can in no cases be lower than U_{Ne}

Note 1 to entry: When no value is defined by the purchaser for U_{Nm}, the maximum operating voltage U_{max1}, given by EN 50163 is due to be assumed.

3.13
power frequency withstand voltage U_a
r.m.s. a.c. voltage which does not cause an insulation fault according to specified test conditions

3.14
highest non-permanent voltage U_{max2}
maximum voltage value likely to be present for a limited period of time

3.15
overvoltage
voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

3.16
long term overvoltage
overvoltage higher than U_{max2} lasting typically for more than 20 ms, due to low impedance phenomena, for example a rise in substation primary voltage

3.17
highest long term overvoltage U_{max3}
voltage defined as the highest value of the long term overvoltage for t = 20 ms

3.18
maximum current
maximum current value which the current collection system is able to carry

3.19
maximum speed
maximum speed the vehicle can reach, to be taken into account for the current collection system to guarantee a proper operation of the same

3.20
static contact force
value of force F (see Figure B.8) applied by the slipper on the contact line, as measured with standing vehicle

Note 1 to entry: This value is referred to the mean height of the contact lines (see Figure B.2, dimension “d”), without displacement of the vehicle from the lines axis.

3.21
dewirement
sudden and permanent detachment of the trolley of one or both poles from the overhead contact line(s) with running trolley bus

3.22
overhead contact line
OCL
contact line which is placed above or beside the upper limit of the vehicle gauge and which supplies traction units with electrical energy via roof-mounted current collection equipment

Note 1 to entry: The characteristics of the overhead contact line are due to be made known to the manufacturer, together with the type of service, the environmental conditions and the road profile. Mechanical properties are given in EN 50119, minimum heights are given in EN 50122-1.

3.23
trolley bus displacement from OCL
allowed displacement of the vehicle axis from the longitudinal contact lines axis in both transversal directions as indicated in dimension “g” of Figure B.2

Note 1 to entry: The minimum displacement is referred to the height “d” (see Figure B.2) and represents the allowed excess of the gauge in respect to the gauge normally allowed by the legislation.

3.24
involved parties
- manufacturer: who actually is responsible for the design and the manufacture of the vehicle;
- supplier: who acts as selling partner in a contract;
- purchaser: who acts as purchasing partner in a contract;
- operator: the final entity which is entitled to use the vehicles for public service

3.25
main contactor
remote controlled, two pole circuit breaker to connect/disconnect the entire downstream installation in normal service mode and emergency situations

Note 1 to entry: Design also is possible with a single pole circuit breaker for one polarity combined with a single pole follower contactor for the other polarity or a two pole fuse combined with a two pole follower contactor.

4 Voltages and classification of the voltage bands

4.1 Voltages

4.1.1 General

The voltage definitions used in this European Standard are those of EN 50163 and EN 50124-1, where the following applies to direct voltage networks in compliance with EN 50163.

4.1.2 Operating voltages

The equipment shall operate at voltages of the overhead contact line system specified in EN 50163:

-	U_n	Nominal voltage	600 V	750 V
-	U_{Ne}	Rated voltage range (0.67 U_n to 1.2 U_n)	400 V to 720 V	500 V to 900 V
-	U_{max1}	Maximum permanent voltage	720 V	900 V
-	U_{max2}	Highest non permanent voltage	800 V	1 000 V < 5 min

NOTE In France, Belgium and the United Kingdom different national regulations (EN 50163) apply, which, however, do not apply to trolley buses.

For vehicle wash plants, according to EN 50122-1 the max. allowed voltage is 120 V d.c (Voltage band II). In this case, the vehicle wash plant is not part of the workshop where the max. allowed voltage is 60 V d.c (voltage band I).

4.1.3 Insulation voltages and test voltages

Insulation according to EN 50124-1 shall be designed and tested with reference to the following voltages:

-	U_n	Nominal voltage	600 V	750 V
-	U_{Nm}	Rated insulation voltage ($\geq U_{max1}$)	$\geq$ 720 V	$\geq$ 900 V
-	U_a	Power frequency withstand voltage	refer to Table 5	

4.1.4 Overvoltages

The equipment shall withstand overvoltages of the overhead contact line system specified in EN 50163:

- U_n Nominal voltage 600 V 750 V
- U_{max3} Highest long-term overvoltage 1 270 V 1 270 V

4.2 Classification of the voltage bands

According to EN 50153, the voltage bands applicable to trolley buses are in accordance with Table 1.

Table 1 — Voltage bands for trolley buses

Band	Nominal voltage	
	a.c. V	d.c. V
I	$U_N \leq 25$	$U_N \leq 60$
II	$25 < U_N \leq 50$	$60 < U_N \leq 120$
III	$50 < U_N \leq 1{,}000$	$120 < U_N \leq 1{,}500$

In France different limits apply because of special national conditions.

Table 2 — Voltage bands for France

Band	Nominal voltage	
	a.c. V	d.c. V
I	$U_N \leq 25$	$U_N \leq 60$
II	$25 < U_N \leq 50$	$60 < U_N \leq 120$
III	$50 < U_N \leq 500$	$120 < U_N \leq 750$
IV	$U_N > 500$	$U_N > 750$

In Italy different limits apply because of legal regulations.

Table 3 — Voltage bands for Italy (Decree D.P.R. 547: 1955, Law 191:1974)

Band	Nominal voltage	
	a.c. V	d.c. V
I	$U_N \leq 25$	$U_N \leq 50$
III	$25 < U_N \leq 400$	$50 < U_N \leq 600$
IV	$U_N > 400$	$U_N > 600$

In ISO 6469-3 different limits apply.

Table 4 — Voltage bands for electric plants on road vehicles

Band	Nominal voltage	
	a.c. V	d.c. V
A	$U_N \leq 30$	$U_N \leq 60$
B	$30 < U_N \leq 1\,000$	$60 < U_N \leq 1\,500$

5 Trolley bus construction

5.1 Protection and electrical safety criteria

5.1.1 Protection criteria against direct and indirect contacts

The best criteria and arrangements shall be adopted in the design and in the manufacture of trolley buses to avoid, or at least minimize to a non-dangerous level, all touch voltages and in particular the voltage differential between mass and earth potentials and to detect leakages before the associated voltages reach a dangerous level.

Limit values for touch voltages are specified in EN 50122-1. Limit values for shock currents are specified in the IEC 60479 series.

NOTE Different limit values for touch voltages apply in Switzerland (SR 734.2).

The requirements of EN 50153 shall apply wherever applicable.

Since the highest hazard potential is present when touching the outside of the vehicle, the requirements of EN 50153 of a verifiable double insulation are supplemented by a third insulation in the area of the doors, where passengers would be most likely to come into contact with voltages.

If possible, the double insulation should be designed such that a fault cannot bridge both paths at the same time.

Layout of insulation distances depending on material and degree of pollution is carried out according to EN 50124-1.

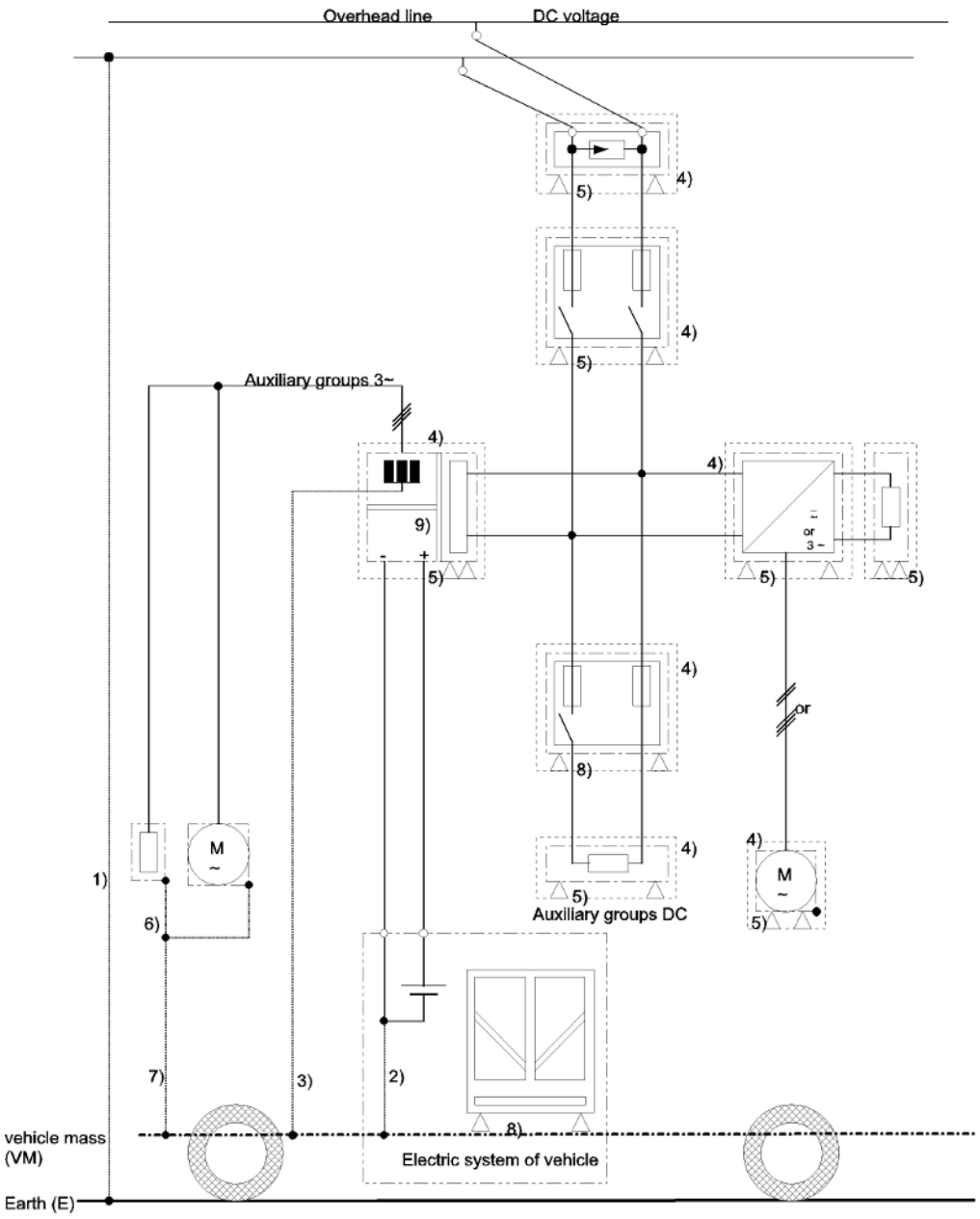
Always make sure for external insulation that part of the insulation remains protected from moisture or dirt. If this is not possible, greater distances and/or other materials shall be selected because of the higher minimum insulation resistances in systems with no protective bonding (see Table 6).

Figure 1 provides an overview of the double insulation requested for this vehicle type in EN 50153 as well as of the third insulation of the doors.

The expansion of the basic insulation to double insulation always applies to all three types of interfaces of the component:

- Supplementary insulation of the mechanical mounting;
- Supplementary insulation of the power supply module;
- Supplementary insulation of the signal interfaces.

The marking by warning signs of installation spaces containing circuits with voltages of bands II and III or power circuits of band I shall comply with EN 50153.



Key:

1) Conducting connection of substation output to earth if applicable

2) Conducting connection of DC- on board power supply to vehicle mass if applicable

3) Conducting connection between neutral point of transformer of static converter and vehicle mass as protective conductor if applicable (see also 7)

4) Protection of direct contact of all intermediate masses (enclosure, roof installation, underfloor installation)

5) Supplementary insulation for implementation of the double insulation. Basic- or functional insulation are represented by enclosures, double insulation of cables is not depicted.

6) Conducting connection of all enclosures of three phase AC loads (protective bonding if applicable).

7) Conducting connection of all enclosures of three phase AC loads and vehicle mass as protective conductor (see also 3)

8) Supplementary insulation of entrance areas (doors, access platforms, push buttons) if applicable

9) Double insulation inside devices (depicted only for static converter)

Figure 1 — Insulation overview — Trolley buses

The insulation resistance of outside insulation as a factor of the atmospheric conditions and vehicles which may have insulation defects may fall short of the limit values for personal safety.

For this reason, measures specified in this paragraph shall be taken independently of the overhead line network configuration (earthed or galvanically isolated).

5.1.2 Steps, stanchions, handrails, slopes and access platforms

To prevent persons entering or leaving the vehicle from sensations of discharge of the vehicle mass exceeding the threshold of perception, entrance areas shall be equipped with insulating materials as protective impedances.

Steps, stanchions and handrails facing all doors shall be insulated from vehicle mass or made of insulating material. Slopes and access platforms for handicapped persons shall be insulated from the vehicle mass.

Entrance areas shall be designed with drip edges at the end of the base plate and with a drain for ingressed water. Direct contact of surface water with other parts of the vehicle mass shall be prevented.

The function of protective impedance of entrance areas shall be ensured by regular cleaning of the entrance areas and visual inspection of material by qualified staff. Detergents shall be chosen to avoid chemical wear of the material.

During visual inspection the material shall be closely examined for any damage that affects the dielectric properties, such as fractures, cracks or pinholes (6.2.5). The dielectric properties of the material shall comply with the requirements for basic insulation in 6.2.

A visual inspection of the cleaned entrance areas is required and is included in the periodic insulation test procedure in 6.4.

5.1.3 Doors and door handles

All doors and relevant accessories, except for control equipment not accessible to the public, shall be insulated from the vehicle mass or made of insulating material.

To provide sufficient creepage distances, plastic door handles or outside sliding doors without handles are recommended.

5.1.4 Cabling

Conduits of cables fed at voltages of band III shall be segregated from those containing cables fed at voltages of bands I and II; band III conduits and trunking shall be easily detectable by means of suitable markings.

In case of double insulation conduits of band III cables being part of different circuits shall be segregated according to EN 50343.

Rescue workers in cities with trolley buses and OCL are specially trained, so special labeling in classic trolley buses with or without auxiliary power supply with diesel engine generator is not required, because the whole system can be switched off. An exception is the cabling of energy storage devices, which shall be labelled orange up to the first circuit breaker[1].

5.1.5 Open door interlocking

Traction equipment shall be provided with an interlock to prevent the vehicle from starting while the vehicle doors are open. This interlock device shall include a push button or a similar padlocked device enabling the driver to by-pass the feature.

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[1] see ECE Regulation No. 100.

5.1.6 Leakage detector

It is recommended, upon agreement between manufacturer and operator and matched with the supply system, to equip trolley buses with an automatic measuring instrument, defined as a leakage detector. Appropriate information shall be provided by the operator.

The device generates an optical/acoustic alarm signal when the insulating resistance between the circuits fed at line voltage and the vehicle mass falls below the permissible limit values. Depending on the type of measuring method, exceeding the permissible touch voltage or the permissible leakage current may also be used as the criterion. The permissible insulation resistance is calculated from the supply voltage according to EN 50163 and the threshold of feeling from the permissible shock current specified in the IEC 60479 series.

When the above mentioned limit values have been reached, the device can open the line contactor and lower the trolley poles automatically when the vehicle is stationary, if this feature is possible and requested by the operator. The vehicle may feature a key switch or a similar sealable device which enables the driver to disable the function, if the operator requests this for emergency mode. If the vehicle has an auxiliary source of energy, it shall be used for the emergency mode.

Since the trolley poles are lowered actively and an opening of the line contactor alone cannot shut down the entire system, safety is implemented only by the protective measure "double insulation" supplemented by the insulation of the entrance areas.

The detection of an insulation resistance value below the permissable limit is considered to be part of preventative maintenance. As a result this will increase the level of safety for passengers above the level that would have been achieved by interventions only at the mandatory intervals (see also A.10).

The leakage detector or at least the relevant acoustic/optical alarm device, if any, shall be mounted at the driving position, in a location easily visible by the driver. An external display can be agreed between operator and manufacturer.

Where required and part of the equipment, the device may feature a means of self-diagnosis and shall meet the resulting safety criteria. In this case, the characteristic shall be accepted by an acknowledged authority.

Since the device itself shall feature a basic and a supplementary insulation since it is interconnected with the system to be monitored, it may cause insulation faults itself. This shall be taken into account especially in the design. For this reason, the device shall be included in the dielectric tests with voltages according to Table 5 as well as in the mandatory periodic test.

5.1.7 Intermediate mass insulation detector

Where a leakage detector is provided, a device suitable to detect the insulation level of the various intermediate masses to the relevant parts, connected to OCL, or to the vehicle mass can be installed for preventative maintenance upon agreement between the manufacturer and the operator. This device can be combined with the leakage detector specified in 5.1.6. The intermediate masses shall be electrically isolated from each other (refer to Table 5).

In exceptional cases and for justified constructional reasons, some intermediate masses for functionally homogeneous equipment may be connected with each other. In this case, the dielectric strength between the intermediate masses according to Table 5 particularly is important.

The leakage detector of the vehicle intermediate masses facilitates preventative maintenance and can thus increase the safety of the passengers.

5.1.8 Capacitors

For capacitors fed with voltages within band III, which may retain charge when they become accessible to direct contact during maintenance, means shall be provided to ensure that there is no risk of electric shock. This may be by means of integral design of discharge circuits, additional circuits or procedure. The implementation shall be agreed between operator and manufacturer.

To achieve the best safety conditions, steps shall be taken to avoid that personnel have access unintentionally to parts with harmful voltages. In this context, the provisions of EN 50153 and of the EN 61881 series shall apply.

5.1.9 Equipotential connections

For insulated circuits of band III that are not directly fed from the contact wire protective measures in compliance with EN 50153 shall be taken.

In the case of articulated trolley buses or connected coaches, these elements of the vehicle shall be electrically interconnected, in order to have vehicle masses at the same potential. These equipotential connections shall be easily found and suitably marked. For the identification of the connections and the equipotential bonding circuit EN 60445 shall be applied.

5.1.10 Electromagnetic compatibility (EMC)

The electrical and electronic equipment on board shall not cause or suffer in the vehicle and in the surrounding ambient interferences of electrical, magnetic or electromagnetic origin at such a level as to endanger the correct operation of the control, calibration, safety, radio-transmission devices etc., due to emissions conducted, induced or radiated.

Field strength limits in the vehicle and in its vicinity shall not exceed the limit values of the EN 45502 series.

As a basis, the EN 50121 series with emission values in compliance with EN 50500 shall apply. For frequencies that were not taken into account in EN 50500 with respect to human exposure the application of 2004/40/EC is recommended.

Interference suppression measures in parallel with individual insulation distances shall not exceed the limit values according to IEC TS 60479-2 for switching processes since these transients become significant in the case of an insulation fault of the supplementary insulation.

Intermediate masses that may feature alternating voltage potentials by capacitive coupling shall be wired such that the limit values according to the IEC 60479 series are not exceeded. These potentials become significant in the case of an insulation fault of the supplementary insulation.

The operator shall also specify the critical frequencies of the existing infrastructure (to operate switches). Interference from other systems (e.g. traffic lights) shall be considered. If necessary an EMC plan shall be drawn up and to be agreed between manufacturer and operator.

5.1.11 Overvoltage protection

To limit atmospheric overvoltages, surge arresters shall be provided in the supply system, which reduce the stress of basic and supplementary insulation. The implementation (at regular intervals on the overhead contact line, at the substations) and the data of the surge arresters shall be provided by the operator.

To limit overvoltages of the supply-system, surge arresters shall be provided on the vehicle, which reduce the stress of the functional insulation. The data of the surge arrestors shall be agreed between vehicle manufacturer and operator.

5.2 Electrical components in band III voltage (high voltage)

5.2.1 General information

The electrical components fed at a voltage of band III and connected to the OCL shall be specifically made for electric traction, suitable for use in trolley bus service, with double insulation to the vehicle mass and both the pole terminals isolated from intermediate mass.

For the electrical and mechanical characteristics the specific standards for the product apply.

5.2.2 Current collection system

See Annex B.

5.2.3 Cables

The cables for the circuits at a voltage of band III shall be of the non-propagating flame type, with low emission of smoke and toxic or corrosive gases. They shall comply with EN 50343 and the EN 50264 and EN 50306 series that are applicable to the use in trolley buses.

Connecting instructions of EN 50343 shall be taken into consideration. Laying of cables shall comply with EN 45545-5.

Especially power cables in passenger compartments or ventilation ducts may only be laid in metal ducts. Cables that cannot be fused (e.g. upstream of the in-line fuse) shall feature double insulation.

5.2.4 Auxiliary groups

The auxiliary groups fed at line voltage, e.g. the auxiliary motors for driving the compressor, the fans, the hydroguide pump, the auxiliary generators, the static converters, and so on, shall have a double insulation in respect to the vehicle mass, independent from the overhead line network configuration (earthed or galvanically insulated).

The equipment supplied through circuits, which are galvanically singly insulated (basic or supplementary insulation) from the line may be mounted without insulation. The basic insulation of this equipment shall fullfill the requirements of basic or supplementary insulation, depending on its function as part of the double insulation.

The equipment supplied through circuits galvanically double insulated from the line may be mounted without insulation. Relevant for the basic insulation of this equipment is the rated voltage of the connected circuit. For the use of industrial devices (electronics, converters, motors) the corresponding industrial standards (the EN 60146 series, EN 50178 and the EN 60034 series) shall be applied.

Protective measures against electrical hazards shall be in compliance with EN 50153.

5.2.5 Heating and ventilation systems

When space heaters or air conditioning equipment, for different uses, contain components supplied by band III voltages, the requirements given in 5.2.4 shall apply. Ventilation ducts, if made of conducting material, shall be connected to the vehicle mass.

In this case, the implementation of the devices and the airflow shall comply with EN 45545-5.

5.3 Electric traction equipment

5.3.1 General information

The electrical traction equipment mainly comprises the traction motor(s), the converter for motoring and braking and the resistor (if fitted, for starting and/or braking).

The control equipment is considered part of the traction equipment from a functional point of view.

5.3.2 Traction motors

For the traction motors the EN 60349 series apply.

The motors shall be arranged to have a double insulation both in respect of the fixing to the vehicle mass and of the connection to the transmission outputs as well as other mechanical (cooling) and electrical interfaces (sensors).

5.3.3 Traction and braking drive

EN 61287-1 applies to the electronic power equipment.

The EN 60077 series applies in case of electromechanical drive.

EN 50155 applies to electronic control equipment.

The equipment shall be installed in body compartments or enclosures, suitably ventilated and accessible only to the personnel maintaining the trolley buses. All the live parts shall have double insulation with respect to the vehicle mass, except for those galvanically insulated from the line voltage, and shall be in any case protected from undue accidental contact when energized. They shall be safeguarded against accidental contact if live.

5.3.4 Starting and braking resistors, resistor for current operated switches

EN 60322 applies to the electrical resistors. They shall be mounted so that the live parts have double insulation relative to the vehicle mass and with suitable barriers or arrangements for protection from undue accidental contacts when energized.

The insulation between live components and the mechanical intermediate frame is only a functional insulation (primary insulation according to EN 60322). Thus, the double insulation requires another intermediate mass insulated from the vehicle mass and the intermediate frame.

When the heat produced by the resistors is used for heating the driver and/or the passenger compartment, the relevant ducts, if made of conducting material, shall be electrically connected to the vehicle mass.

The active parts of the resistors as well as exterior insulators shall be protected by a suitable barrier against flying debris (e.g. leaves) to prevent fire and bridging of insulation distances.

5.4 Power supply independent from OCL

5.4.1 General information

Trolley buses may be equipped with an equipment for running with an auxiliary source of electrical energy, differing from the overhead contact line.

This equipment may be an electro generating thermal engine, a group of batteries or other equivalent means suitable to supply the traction motor(s).

Depending on the power of the independant power supply one can differentiate between emergency power supply to clear the road, auxiliary power supply for restricted service or main power supply. Even if emergency power supplies limit the operation range to the overhead line grid, the thermal capacity of the endurance braking system is relevant for the homologation of the brake system[2].

As far as the control and safety systems are concerned, they can remain in use as in normal running.

5.4.2 Independent power supply and its insulation requirements

All electrical components for specific use for operation in independent running shall have the same characteristics as required for equipment fed at the same voltage band.

For operation on the overhead contact line a facility for energy storage and recovery shall thus feature double insulation. (A.13, A.14).

If every electrical connection between the overhead contact line and the electrical source for independent operation is explicitly broken without having to lower the poles, double insulation is not required. In this case a mechanical or electrical interlock of the switchgear that connects the system to the overhead contact line or the auxiliary power supply suffices. The open contacts of the contactors shall meet meet the requirements for basic or supplementary insulation, depending on the choice of basic and additional insulation for the independent power supply. Because the power connection of the energy source shall be regarded an intermediate potential, an insulation check connection for the power connection shall be agreed between manufacturer and operator.

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[2] see ECE Regulation No. 13.

The equipment under 5.3.1 may be used for feeding the traction motor(s).

It shall be possible to disconnect the independent power supply from the system for maintenance purposes. This may be done by means of switches, fused circuit breakers or electromagnetic switchgear. With engine-driven auxiliary power supplies, it is sufficient to shut down the engine if it can be secured against restarting.

5.5 Electrical components in band II voltage (medium voltage)

5.5.1 General information

The electrical components supplied at a voltage of band II shall be two-pole and insulated from the vehicle mass. They shall be protected by means of fuses or automatic breakers having a suitable breaking capacity and they shall be suitable for the use on trolley buses. When there is the need of having components on the vehicle fed at voltages pertaining to different bands, suitable arrangements shall be taken for an effective electrical segregation.

Protective provisions against electrical hazards shall be according to EN 50153 for insulated supply systems.

5.5.2 Cables

The cables for the circuits at a voltage of band II shall be of the non-propagating flame type, with low emission of smoke and toxic or corrosive gases. They shall comply with EN 50343 and the EN 50264 and EN 50306 series that are applicable to the use in trolley buses.

Connecting instructions of EN 50343 shall be taken into consideration. Laying of cables shall comply with EN 45545-5.

Especially power cables in passenger compartments or ventilation ducts may only be laid in metal ducts. Cables that cannot be fused (e.g. upstream of the in-line fuse) shall feature double insulation.

5.5.3 Separation from other voltage band circuits

The circuits related to the components under 5.5.1, which are mounted on the same structures with cables for voltages of bands I and III, shall be designed for a suitably segregated installation. The connection points, if any, of cables for voltages in band II and apparatus at voltages in bands I and III, shall be carefully designed in respect to distance, mechanical protection and insulation between voltages.

Installation instructions of EN 50343 shall be observed. An identification of the different voltage bands shall be agreed between operator and manufacturer.

5.6 Electrical components in band I voltage (low voltage)

5.6.1 General information

Protective measures against electrical hazards shall be according to EN 50153 for insulated supply systems.

The electrical components supplied in voltage band I are interconnected via additional signal lines and data buses, no distinction between trolley bus components (specifically for trolley buses) and normal bus components (automotive electrical) is made. Because part of the components have no insulated bipolar supply, withstand voltage and insulation resistance tests do not apply to approval.

Trolley bus components with single insulation from the overhead line voltage shall have a bipolar supply and shall be powered by an additional galvanically insulated supply employing the same basic or supplematary insulation like equipment connected to OCL (see Table 5). A test connection for the intermediate potential shall be agreed between operator and manufacturer.

Due to the different mechanical loads of railways and rubber tyred vehicles, ISO 16750-3 instead of EN 61373 shall be used for shock and vibration tests if applicable.

If necessary to install in the vehicle electrical components fed by voltages of different voltage bands, an effective electrical separation shall be ensured.

The cables for the circuits at a voltage of band I for trolley bus components shall be of the non-propagating flame type, with low emission of smoke and toxic or corrosive gases. They shall comply with EN 50343 and the EN 50264 and EN 50306 series that are applicable to these cables for use in trolley buses.

Connecting instructions of EN 50343 shall be taken into consideration. Installation of cables shall comply with EN 45545-5.

Especially power transmission cables in passenger compartments or ventilation ducts may only be laid in metal ducts. Cables for power transmission that cannot be fused (e.g. battery connecting cables upstream of the in-line fuse, when the battery compartment is not additionaly insulated and contains fuse elements) shall feature double insulation according to EN 45545-5.

5.6.2 Separation from other voltage band circuits

Refer to 5.5.3.

6 Checks and tests

6.1 General information

The requirements contained in this clause concern the dielectric tests to be carried out specifically on trolley bus equipment. Test on components are specified in the relevant product standards and applied. Electrical tests, relevant for this European Standard, are to be found in EN 50215:2009 under:

- EN 50215:2009, 8.7 Electrical insulation tests (routine tests);
- EN 50215:2009, 8.7.1 General;
  NOTE Regarding par. 3: verification of double insulation, clearances and creepage distances according to EN 50124-1
- EN 50215:2009, 8.7.2 Voltage withstand test;
  NOTE According to this standard
- EN 50215:2009, 8.7.3 Insulation impedance test;
  NOTE Verification of insulation resistance and insulation monitoring according to this standard
- EN 50215:2009, 8.8 Protective bonding and return circuits tests (routine and safety-related test).

These tests may be conducted alternatively at the vehicle, the device or at a test bench. The testing equipment shall comply with EN 61557-2.

Alternating voltage and direct voltage tests stress the fixed insulations more since voltage of this kind is applied for a much longer time as compared to pulse voltage. Insulation may be damaged by the test. Product standards take this into account by permitting a shorter test period in the case of high AC test voltages or DC test voltages according to EN 50124-1.

Thus, to be able to document the influence of the withstand voltage test on the insulation, it is recommended to perform the insulation resistance measurement according to 4.1.2 before and after the withstand voltage test.

For the routine test, EN 60077-1 also permits test voltages and especially testing periods according to the respective product standard upon agreement between manufacturer and operator. Since the product standards consider the above annotation from EN 50124-1, they shall be given preference for the routine tests to reduce the pre-damage of insulation sections. These deviations are explicitly pointed out in the following text in the relevant passages.

The additional applicable tests on the vehicle according to this Standard are listed in Table 5.

If applicable, the limit value of the leakage current for the individual tests should be specified and logged by the manufacturer.

Checking of the insulation shall preferably be carried out at least every three months. An alternative is an interval of 15 000 km of operation which may be increased to 30 000 km by agreement with the operator, considering the limit firstly encountered between the two given above. These intervals can be shortened in case the pre-alarm device mentioned in A.10 is present and the readings indicate frequent insulation checks are being made.

NOTE In Italy 2 months or 10 000 km apply because of legal prescriptions.

The limit values for the insulation for a new trolley bus, for an overhauled trolley bus and for a trolley bus during normal service are listed in 6.4.

6.2 New trolley-bus

6.2.1 Design and construction verification

The compliance of the vehicle to the requirements of Clause 5 shall be verified, particularly with respect to the insulation of the equipment having voltages in band III, especially those circuits fed by the OCL with double insulation.

The design documents of the electrical part shall list and show the various intermediate masses, on which the electrical tests specified below, shall be carried out.

The design documents of the mechanical part shall specify the dimensions of the clearances and creepage distances and the properties of the insulation materials.

According to EN 50124-1, creepage distances can be checked by measurement only. Only insulation distances, implemented when mounted in the vehicle, need to be measured in compliance with EN 50215 and the impact caused by ageing, weather conditions and deformation due to operation shall be taken into account. For the routine test according to EN 50215, an additional visual inspection suffices.

6.2.2 Separate source applied voltage tests on circuits and components fed at voltages of the band III from the overhead contact line

Circuits and electrical components at the line voltage and those fed at voltages of the band III, with double insulation from the vehicle mass, shall be submitted to voltage tests, carried out on new material when the vehicle is commissioned according to EN 50215.

Other circuits of voltage level III, auxiliary or control circuits of voltage levels II and I that do not feature sufficient insulation based upon the contact line voltage (e.g. that feature insulation for their voltage band and are thus only functional insulation) are assigned to the above-mentioned circuits and shall be tested together with these circuits. The testing of functional insulation is not an integral part of this standard.

The test shall be performed successively from high to low voltage levels/bands. Circuits that have already been tested are not reconnected to the other circuits to prevent repetitive tests and the distortion of insulation resistance measurements due to parallel circuits of insulation resistances.

The test is carried out:

a) after having excluded those components supplied at voltages of band III and that have already been tested ex works, and after having connected together all remaining circuits, belonging to one insulation level of band III. This does not apply to supplementary insulations that are implemented only when mounted on the vehicle between component/device housing and vehicle mass. A list of such components shall be given as well as documentation of a separate test carried out by the manufacturer. These documents may be type test log, routine test log or declaration of conformity (routine tests according to product standards may yield lower values for the item c test period),

b) having connected to earth all remaining circuits and components of the electrical equipment of the trolley bus,

c) by applying a sinusoidal alternating test voltage at a frequency of 50 Hz that increases to the final value U_a within 10 s and keeping this value for a duration of 60 s; U_a is shown in Table 5; the test voltage may also be applied as a direct voltage with the peak value for U_a,

d) by carrying out the test between the above mentioned circuits and components and the intermediate masses connected to the vehicle mass (see Figure 2 a)),

e) by repeating the test between the interconnected intermediate masses and the vehicle mass (see Figure 2 b)); The circuits of voltage level III stay insulated, the connection between the intermediate masses and the remaining circuits is removed,

f) by repeating the test between the intermediate masses insulated from each other (refer to Figure 2 c)).

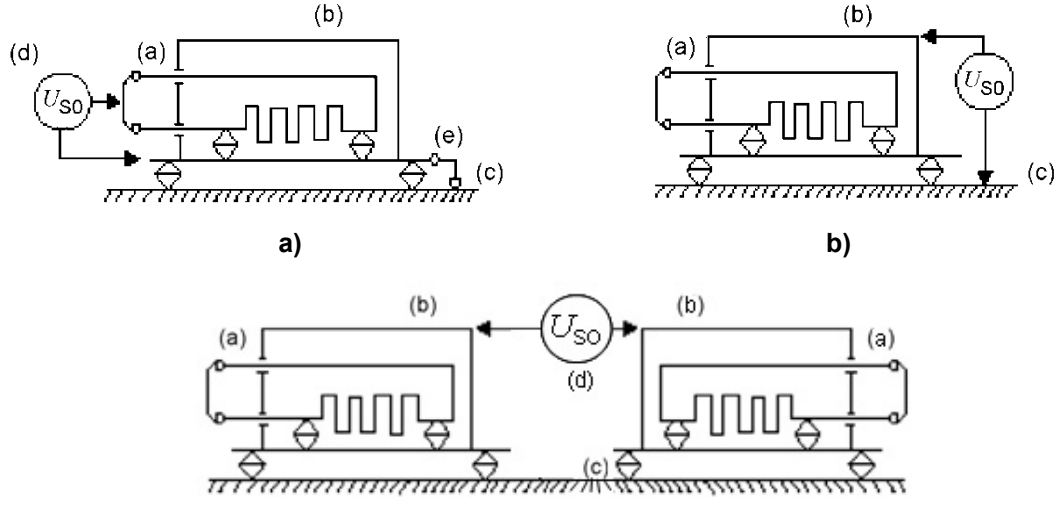
6.2.3 Separate source applied voltage tests on circuits and components fed at voltages of the band III insulated from the overhead contact line

The circuits and the components fed at voltages of band III, but not fed directly by the voltage of the line, featuring single or double insulation from the vehicle mass, shall be tested as specified above, (see Figure 2 d)) at a voltage of U_a (see Table 5), applied between the respective circuits and the vehicle mass.

Connections to the vehicle mass to ensure functions of insulated supply networks that are double insulated from circuits supplied with overhead contact line voltage shall be separated from vehicle mass for this test. These include e.g. in the case of three-phase supply networks the connection from the neutral point of the network to vehicle mass to reduce the line voltages with respect to vehicle mass, to implement an equipotential bonding system with and without leakage current monitoring as well as insulation monitoring.

It is assumed that the values of this double insulation refer to the contact line voltage.

After repair or if the withstand voltage test failed the second test shall be carried out at 85 % of U_a.to reduce the stress by the test for the insulation.



Key

(a)	Circuit or electrical component	(d)	Voltage generator
(b)	Intermediate mass	(e)	Equipotential bonding and grounding
(c)	Vehicle mass		

Figure 2 — Test circuits

6.2.4 Separate source applied voltage tests on circuits and components fed at voltages of the band II

The circuits and the components supplied at voltages of band II shall be submitted to voltage test, on new material, when the vehicle is commissioned according to EN 50215.

It is assumed that the values of these circuits generally feature double insulation from circuits that are supplied with contact line voltage, with reference to the contact line voltage. (Refer also to 6.2.2.)

The test is carried out

a) after having excluded those components supplied at voltages of band II and that have already been tested ex works, and after having connected all remaining circuits belonging to one insulation level of band II. A list of such components as well as the documentation of a separate test carried out by the manufacturer shall be available. These documents may be type test logs, routine test logs or declarations of conformity (routine tests according to product standards may yield lower values for the item c test period),

b) having connected to each other and grounded all remaining circuits and components of the electrical equipment of the trolley bus, supplied on a lower voltage level,

c) by applying a sinusoidal alternating test voltage at a frequency of 50 Hz that increases to the final value U_a within 10 s and keeping this value for a duration of 60 s between the circuits and components specified above and the vehicle mass; the value for U_a is listed in Table 5; the test voltage may also be applied as a direct voltage with the peak value for U_a.

Table 5 — Test voltages U_a based on rated insulation voltage U_{Nm}

Subject	Power withstand voltage U_a V				
	Rated insulation voltage U_{Nm}				
	≤ 36	**> 36 ≤ 60**	**> 60 ≤ 300**	**> 300 ≤ 660**	**> 660 ≤ 1 200**
For components with single insulation, the dielectric test shall be applied between any circuit supplied to a given voltage and the mass, to which all the remaining circuits shall be connected.	750	1 000	1 500	2 500	2 U_{Nm} + 1 500
For components with single insulation which are not connected to the main circuit, the dielectric test shall be applied between any circuit supplied to a given voltage range and the mass, to which all the remaining circuits shall be connected.	750	1 000	2 U_{Nm} + 1 000 with a minimum of 1 500		
For components, 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.	750	1 000	1 500	1,6 U_{Nm} + 1 500	
For components with double insulation, the dielectric test shall be applied: - between intermediate masses connected and the vehicle mass and across each pair of intermediate masses when insulated directly against each other;			1 500	1 500	1,6 U_{Nm} + 500
- between the circuits and the intermediate masses connected to the vehicle mass. Where the main insulation is provided between intermediate masses and vehicle mass, the test voltages shall be reversed.			2 000	2 500	2 U_{Nm} + 1 500
NOTE 1 For electronic equipment with U_{Nm} < 36 V the dielectric test voltage is reduced to 500 V. NOTE 2 Table 5 is an excerpt from EN 60077-1 and is adapted to circuits and components in use on board trolley buses. The tests between the intermediate masses have been added.					
All the voltages may also be applied as rectified ripple voltage if insulation is bridged by means of Y-capacitors or rectifiers in reverse direction.					

6.2.5 Tests of the insulation of entrance areas

The design of the structure and a visual inspection of the entrance areas, together with the test reports or certificates of conformity of the insulating layer (e.g. corresponding to EN 61111), are the criteria for acceptance.

The suitability of materials for insulation of entrance areas regarding dielectric and mechanical properties shall be demonstrated by appropriate documents.

The visual inspection shall be carried out by qualified electricians (defined in EN 50110-1:2013, 3.2.4) During visual inspection the material shall be accurately examined for any damage that affects the dielectric properties, such as fractures, cracks or pinholes.

Adequate clearance and creepage distances (minimum values according to EN 50124-1) shall be confirmed by measurement.

6.2.6 Insulation resistance values for circuits and components supplied at band III voltages from the line voltage

The following insulation resistance measurements shall be effected:

a) between the vehicle mass and all the interconnected circuits and components supplied at the line voltage (see Figure 3 a));

b) between each intermediate mass and all the interconnected circuits supplied at line voltage (see Figure 3 b));

c) between the vehicle mass and each intermediate mass (see Figure 3 c));

d) between each intermediate mass and all other intermediate masses (see Figure 3 d)).

The tests, to be performed with the conditions shown in 6.2.7 are considered passed when the insulation resistance R, measured in a dry state, satisfies the condition:

$$R \geq 10\ M\Omega$$

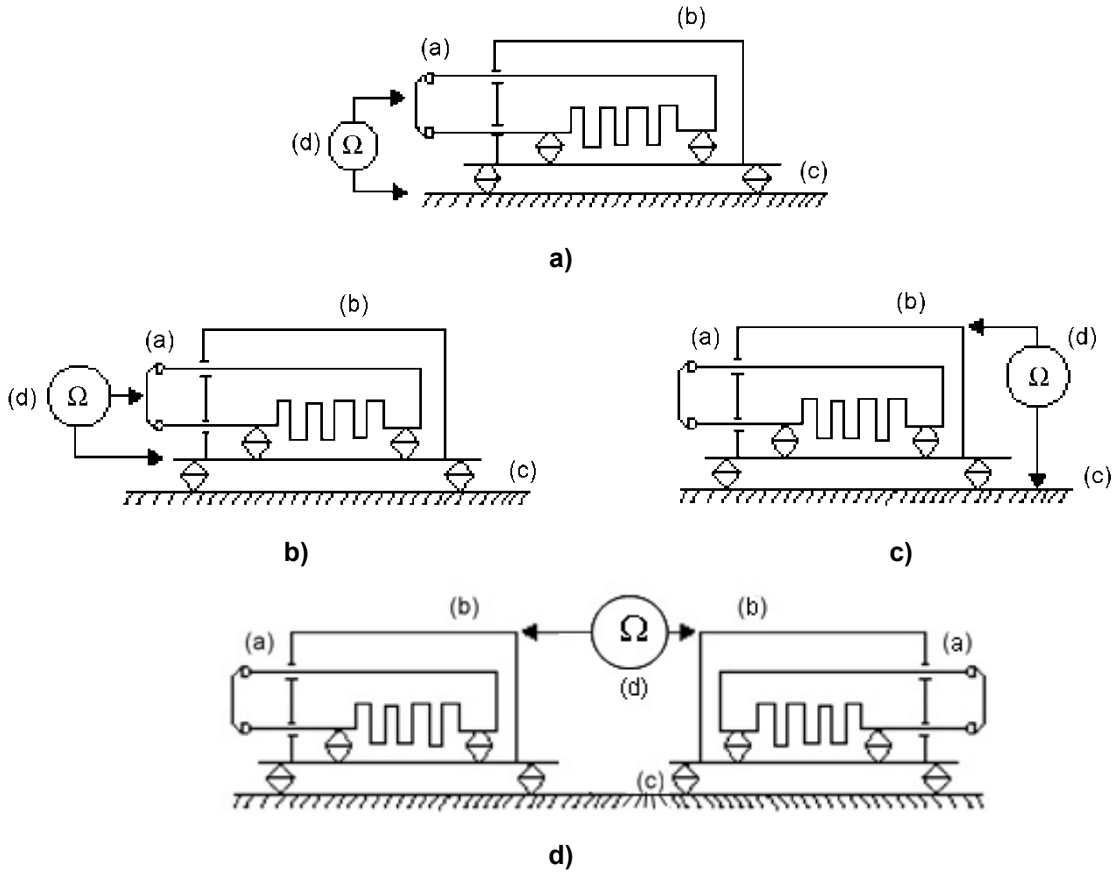
6.2.7 Insulation resistance tests for circuits and components supplied at the line voltage

The insulation tests shall be made with the vehicle dry and also when the vehicle is wet if this is required. Referring to the tests under a) and b) of 6.2.6, all circuits and electrical components shall be connected; therefore, all switches and contactors concerned shall be positioned such that all parts of the electrical installation directly supplied at the line voltage are energized during the test. This can be effected by operating instructions based on the circuit diagrams of the vehicle or (also to facilitate the periodical test) by an integrated test function of the system.

Before testing, the mass connection of the leakage detector (see 5.1.6) shall be removed if the manufacturer of the device specified such for this measurement.

The measurement shall be carried out with a megaohmmeter with a generator (part of the instrument) for 1 000 V d.c.

According to the measurement type the megaohmmeter shall be connected as indicated in Figure 3 a), b), c) or d).



Key

(a)	Circuit or electrical component	(c)	Vehicle mass
(b)	Intermediate mass	(d)	Measuring instrument

Figure 3 — Megaohmmeter connection

6.2.8 Insulation resistance values for circuits and components supplied at band III voltages insulated from the line voltage

These circuits and electrical components shall be submitted to the measurement of the insulation resistance to the vehicle mass even if they are insulated supply networks featuring double insulation from the contact line that are connected to the vehicle mass to ensure functions (refer also to 5.4.2 and 6.2.3). The test is considered passed when the insulation resistance, measured in a dry state, satisfies the following condition:

$$R \geq 10\ M\Omega$$

When an intermediate mass is present for constructional reasons in these installations, the criteria shown in 6.2.6 b) and c) apply. The resistance values for these intermediate masses shall satisfy the above-mentioned condition.

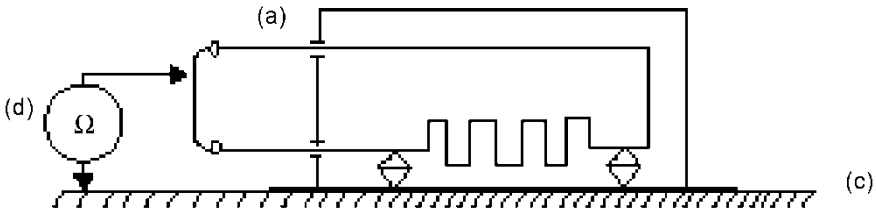
6.2.9 Insulation resistance tests for circuits and components supplied at band III voltages insulated from the line voltage

The insulation tests shall be made with the vehicle dry and also when the vehicle is wet if this is required. All circuits and electrical components shall be connected; therefore all concerned switches and contactors shall be positioned such that all parts of the electrical installation supplied at the voltage of band III are energized during the test. This can be achieved by operating instructions based on the circuit diagrams of the vehicle or (also to facilitate the periodical test) by an integrated test function of the system.

Before testing, the mass connection of the leakage detector (see 5.1.7) shall be removed if the manufacturer of the device specified such for this measurement. In this case a separate periodical test for the leakage detector shall be specified.

The measure shall be carried out with a megaohmmeter with a generator (part of the instrument) for 1 000 V d.c.

The megaohmmeter shall be connected as indicated in Figure 4.



Key

(a) Circuit or electrical component

(c) Vehicle mass

(d) Measuring instrument

Figure 4 — Megaohmmeter connection

When intermediate masses are present, the instrument shall be connected as shown in Figure 3 b) and c).

Depending on the provisions (according to EN 50153), to prevent electrical hazards, if applicable, the insulation resistance test 6.2.9 can be included in the periodical insulation test 6.4.

6.2.10 Insulation resistance values for circuits and components supplied at a voltage of band II

The insulation resistance between the vehicle mass and all the interconnected circuits and components supplied at a voltage of band II shall be measured.

The test is considered passed when the insulation resistance, measured in a dry state, satisfies the following condition:

$R \geq 10\ M\Omega$

6.2.11 Insulation resistance tests for circuits and components supplied at a voltage of band II

The insulation tests shall be made with the vehicle dry and also when the vehicle is wet if this is required. All circuits and electrical components shall be connected; therefore, considering the electrical diagram of the vehicle equipment, all concerned switches and contactors shall be in the position to put all parts of the electrical installation supplied at the voltage of band II energized during the test. This can be achieved by operating instructions based on the circuit diagrams of the vehicle or (also to facilitate the periodical test) by an integrated test function of the system.

Before testing, the mass connection of the leakage detector (see 5.1.7) shall be removed if the manufacturer of the device specified such for this measurement. In this case a separate periodical test for the leakage detector shall be specified.

The measurement shall be carried out with a megaohmmeter with a generator (part of the instrument) for 1 000 V d.c.

The megaohmmeter shall be connected as indicated in Figure 4.

Depending on the provisions (according to EN 50153) to prevent electrical hazards, if applicable, the insulation test can be included in the periodical insulation test.

6.3 Overhauled trolley-bus

6.3.1 Tests and verification of the electrical equipment

Upon new commissioning of the overhauled vehicle, the verifications required under 6.2.1 to 6.2.6 shall be repeated with reduced values of 85 % of U_a.

6.3.2 Measurements and value of the insulation resistance

The insulation tests described in 6.2.7, 6.2.9 and 6.2.11 shall be carried out with reference to the portion of electric installation revised and the voltage band associated.

The tests are considered successful when the insulation resistance is at least 1/3 of the values required for a new vehicle.

6.3.3 Insulation tests

See the requirements in 6.2.7, 6.2.9 and 6.2.11.

6.3.4 Trolley vehicles after minor or maintenance repairs

Depending on the range of repair tests shall be carried out corresponding to the subclauses of 6.3. In particular, for components tested in the workshop on product standards, only the on-board insulations shall be tested. For further tests refer to 6.4.2.

6.4 On-duty trolley-bus (periodical checks)

6.4.1 Insulation decay and provisions required

During service, the insulation can suffer decay, due to several external causes (mud, rain, etc.), gradual wear or fault; this decay, beyond a given limit, shall be revealed by the leakage detector (see 5.1.6). To provide a suitable safety margin of the insulation level of the vehicle two provisions are necessary:

- verifications and periodical checks according to 6.4.2 and 6.4.3. When the verified insulation resistance results are equal to or lower than indicated in Table 6, the vehicle shall be immediately submitted to maintenance before being put in service again;
- verification of the efficiency of the leakage detector, if any, as per 6.5.3. When the verified insulation resistance value results are equal to or lower than what is required in 6.5.2, the vehicle shall be immediately submitted to maintenance before being put in service again.

6.4.2 Periodical checks and tests of the insulation during maintenance

Repairs or modifications to the vehicle shall not result in a reduction of safety relative to its original state. In particular, this concerns:

- creepage distances and clearances,
- protection measures against electric shock,
- protection against ingress of moisture and dust,
- protection measures against mechanical and other hazards,
- the functional sequence of the software, if required.

The qualified electrician responsible for the test shall decide whether additional tests are required to demonstrate that the level of safety has been maintained.

To be observed during the final visual inspection:

- damage of connecting cables;
- damage of insulation;
- proper selection of wires and connectors;
- state of the terminals and wires;
- damage of bend protection and strain relief;
- damage of enclosure and protective covers;

- signs of prohibited manipulation or changes;
- degradation of safety by corrosion or deterioration of materials.

The insulation of the electrical equipment of the vehicle (or a part of the insulation system) should be verified based upon the operator's maintenance plan or following a fault.

These verifications shall be preceded by a visual inspection to check for any deterioration which could prevent operation and reduce safety.

Successively the intermediate masses shall be individually checked using the device under 5.1.7 and, if required, the insulation resistance of the electrical equipment, of the systems or of the sub-systems concerned shall be measured. If available, a specific test board as described in A.9 may be used for this purpose.

6.4.3 Periodical checks and tests of the insulation prescribed by law

The law in some countries prescribes annual visits, checks and tests on the rolling stock. Within the scope of these events, the insulation resistance measurements shall be carried out according to 6.2.7, 6.2.9 and 6.2.11.

Tests are described in 6.2.7, 6.2.9 and 6.2.11 and for the minimum values of the insulation resistance in dry conditions, the following minimum values are recommended:

- for each single insulation $\geq$ 500 kΩ;
- for parallel circuits of all double insulations $\geq$ 1 MΩ (entire vehicle).

Table 6 — Summary of electric tests

Voltage band	New vehicle	Overhauled vehicle	On duty vehicles
Band II	Test voltage U_a based on U_{Nm} (refer to Table 5)	85 % test voltage U_a based on U_{Nm} (refer to Table 5)	
	Insulation R $\geq$ 10 MΩ (Instr. 1 000 V d.c.)	Insulation R $\geq$ 3,3 MΩ (Instr. 1 000 V d.c.)	Insulation $\geq$ 500 kΩ (Instr. 1 000 V d.c.)
Band III	Test voltage U_a based on U_{Nm} (refer to Table 5)	85 % test voltage *Ua* based on U_{Nm} (refer to Table 5)	
	Insulation R $\geq$ 10 MΩ (Instr. 1 000 V d.c.)	Insulation R $\geq$ 3,3 MΩ (Instr. 1 000 V d.c.)	Insulation $\geq$ 500 kΩ (Instr. 1 000 V d.c.)
The manufacturer shall supply for each group of components of the same voltage band, the rated insulation voltage U_{Nm} in order to assess the test voltage U_a given in Table 5.			

6.5 Leakage Detectors (overhaul, definitions, thresholds)

6.5.1 Operating voltages and temperature ranges

The leakage detecting apparatus shall operate correctly in the range of from 0,67 U_n to 1,33 U_n referred to the nominal line voltage (see 4.1.2), specified in EN 50163.

The same applies in the voltage range of 0,70 U_n' to 1,25 U_n', specified in EN 50155, when the apparatus is supplied by the battery of the vehicle network (see 5.6) having the nominal voltage U_n'.

Characteristics of the supply voltage as described in ISO 16750-2 for motor vehicles shall not impact the functionality of the detector.

The temperature range shall comply with EN 50125-1 according to environmental conditions and installation location in the vehicle.

6.5.2 Operation and alarm of the detector

As indicated in 5.1.6, the leakage detector, if any, shall give an alarm signal, optical and acoustical, at the intervention level (threshold) specified in 6.5.3.

To prevent faulty activation at sections, switches and section insulators of the overhead contact line, the device shall not take into consideration short-term reductions in the insulation resistance as well as exceedances of the leakage current or of the touch voltage. For the single monitoring of the vehicle mass (i.e. complete insulation) the time dependent limit values from IEC TS 60479-1 and EN 50122-1 shall apply. If basic and supplementary insulation are independently monitored to identify the need for unscheduled maintenance, longer time limits may be specified by the operator.

If the value falls short of the static limit value, the vehicle shall be immediately removed from service, according to the procedures stated by the operator, for undergoing the verifications and repairs according to 6.4.2.

The following sections show that a leakage detector, similar to other insulated applications, can be used to increase the availability and/or for preventative maintenance. In this case, safety is ensured by the double insulation instead of equipotential bonding/grounding.

6.5.3 Limits and calibration of the detector

6.5.3.1 General

Limit values for perceptual thresholds, pain thresholds and hazard threshold as a function of the leakage current are specified in IEC TS 60479-1 and based upon this the thresholds assuming voltage-dependent transitional and body resistance values as a function of the touch voltage are specified in EN 50122-1.

To prevent accidents caused indirectly by leakage currents or touch voltages (e.g. falling), the static limits of the perceptual thresholds shall be applied for testing.

6.5.3.2 Leakage current monitoring

The static limit value for the leakage current I_F is derived from IEC TS 60479-1 for direct current of 2 mA, for alternating current of 0,5 mA. For higher frequencies IEC 60479-2 applies.

The summation current transformer used for monitoring shall meet extremely high demands due to the high system currents (> 500 A) and low limit values (< 2 mA). Transient events and capacitive coupling may easily cause spurious tripping.

Due to the indeterminate transition resistance to the ground, the fault may be detected in the worst case only when the leakage is caused by a human being. System components on the supply side of the current transformer and the transformer directly are not monitored.

Intermediate masses cannot be monitored using this method.

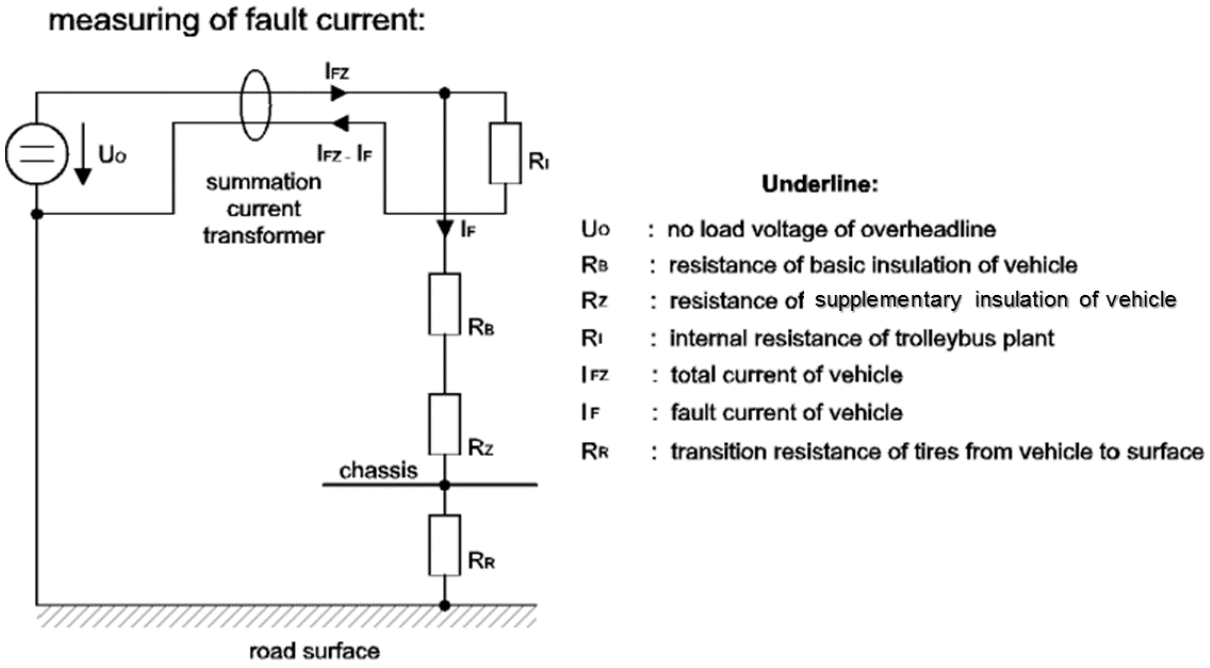


Figure 5 — Leakage current monitoring

6.5.3.3 Insulation resistance monitoring

The static limit value for the minimum insulation resistance R_{min} results from the nominal voltage and the limit value for the leakage current:

R_{min} = U_n / 2 mA with sufficient margin to the limit of 500 kΩ in 6.4.3 for single Insulations.

The insulation resistance is determined by applying a measuring voltage that generates a measurement current. The voltage is applied to the insulation distance via coupling resistances that increase the internal resistance of the measuring instrument.

This monitoring principle can only sense one path or the summary of several paths of basic or supplementary insulations. Bridging the path by means of the coupling resistance, which shall be chosen as small as possible to reduce the measuring time is disadvantageous. Parasitic capacitance or wiring capacitance will increase the response time.

The overall insulation cannot be sensed directly since the insulation resistance values of the traction substations, of the contact wire and of other vehicles (all switched in parallel) are sensed via the transitional resistance to the ground, which may cause spurious tripping.

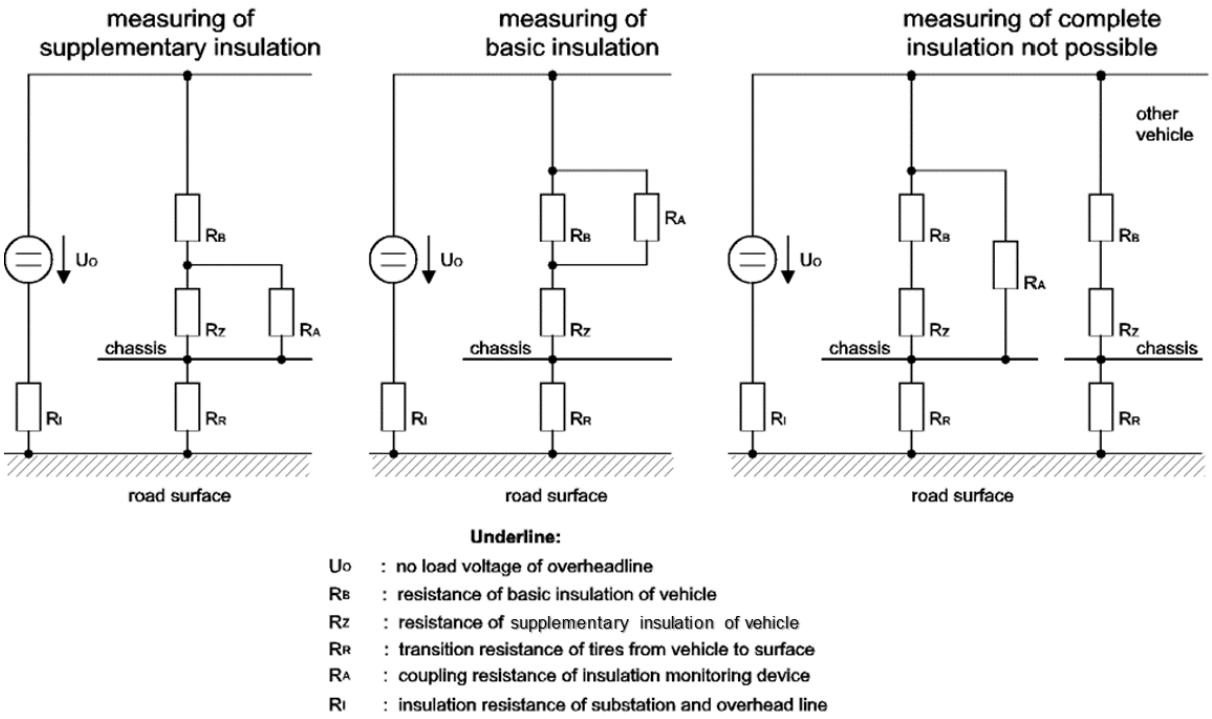


Figure 6 — Insulation resistance monitoring

The individual values of all the basic and supplementary insulation systems shall be acquired. The acquisition time depends on the time constant that is determined by the coupling resistance of the acquisition and the capacity of the basic and supplementary insulation of the measuring point.

To determine the overall insulation, a calculation based on the individual values is required, which requires an addition of all the measurement times.

Switch off or separation of the equipment within the time limits, given by EN 50122-1 or IEC/TS 60479-1 is not possible. (See also 6.5.2.)

6.5.3.4 Touch voltage monitoring

The static limit for touch voltage is taken from EN 50122-1 and is 60V DC or 25V AC.

Since the voltage limit values in EN 50122-1 do not drop below the perceptual threshold under all circumstances, the lower values should be targetted at the response threshold of the touch voltage. The internal resistance of the voltage acquisition shall be choosen according to the leakage current threshold.

If the voltage is measured via electrically conducting sliding wires, the acquisition depends on the contact to ground, its conductivity and transitional resistances connected in parallel (e.g. tyres).

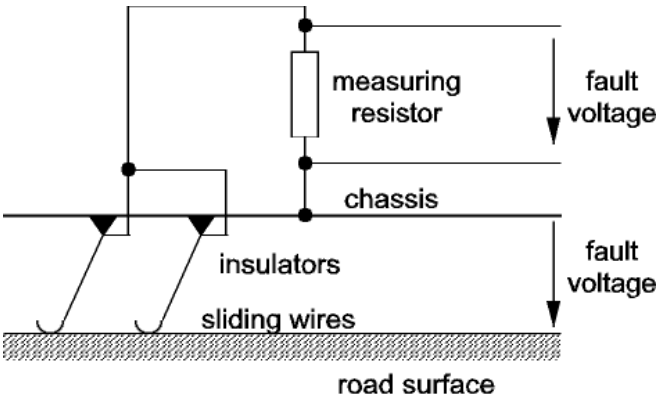


Figure 7 — Touch voltage monitoring with sliding wires

If the voltage is measured indirectly against the grounded pole of the overhead contact line, the voltage between vehicle and ground is increased compared to the measured voltage if the overhead contact line is loaded. This effect is due to the voltage drop on the overhead contact line from the vehicle to the next grounding point.

If the individual segments of the overhead contact line are grounded at each power feed (refer also to Figure 10), this voltage drop is split up in conductor and return conductor and amounts to half the difference between the open-circuit voltage at the power feed and the overhead contact line voltage at the measuring point. Since, according to EN 50163 the maximum voltage drop is 200 V at 600 V and 250 V at 750 V nominal contact line voltage, values increased by 100 V to 125 V are possible. If the open circuit voltage of the power feeds is absolutely identical, the voltage drop can be compensated by means of a controllable voltage source.

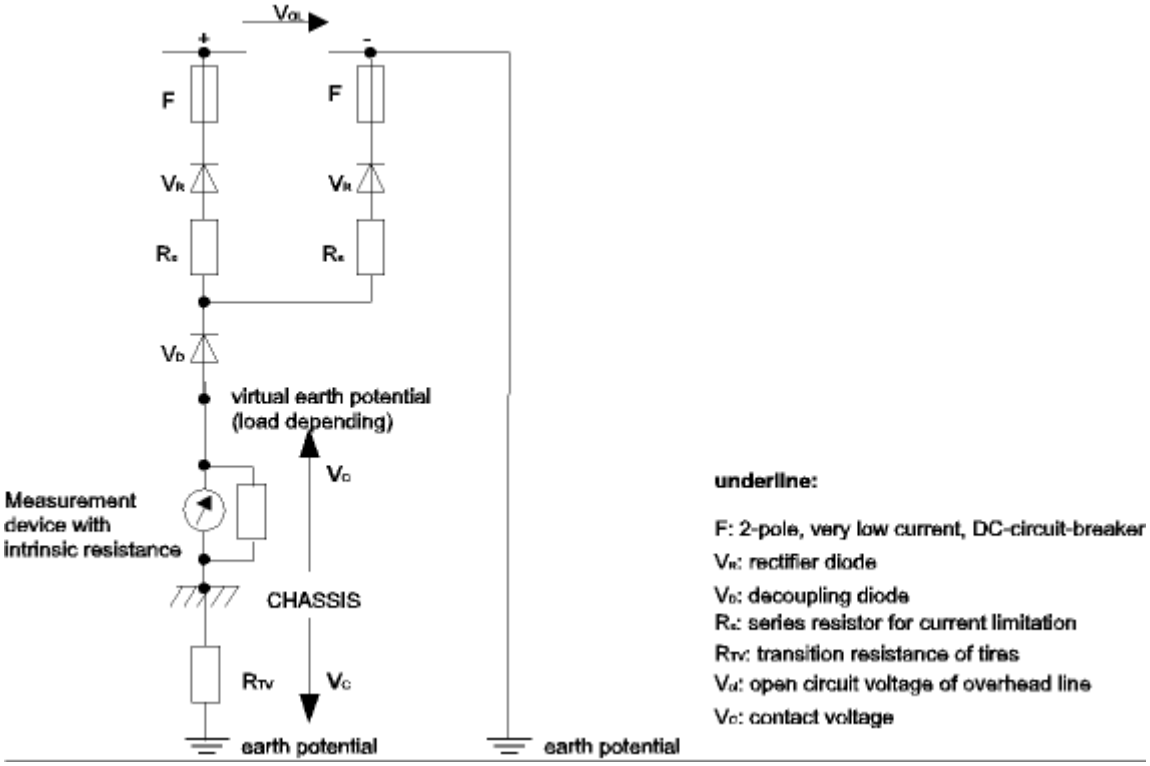


Figure 8 — Touch voltage monitoring with grounded overhead contact line

In case of indirect measurement against the grounded pole, particular importance is attached to the decoupling from the contact line, especially from the ungrounded pole. Additional measures that

prevent the application of a permanent voltage to the vehicle mass, if a decoupling section fails, shall be provided.

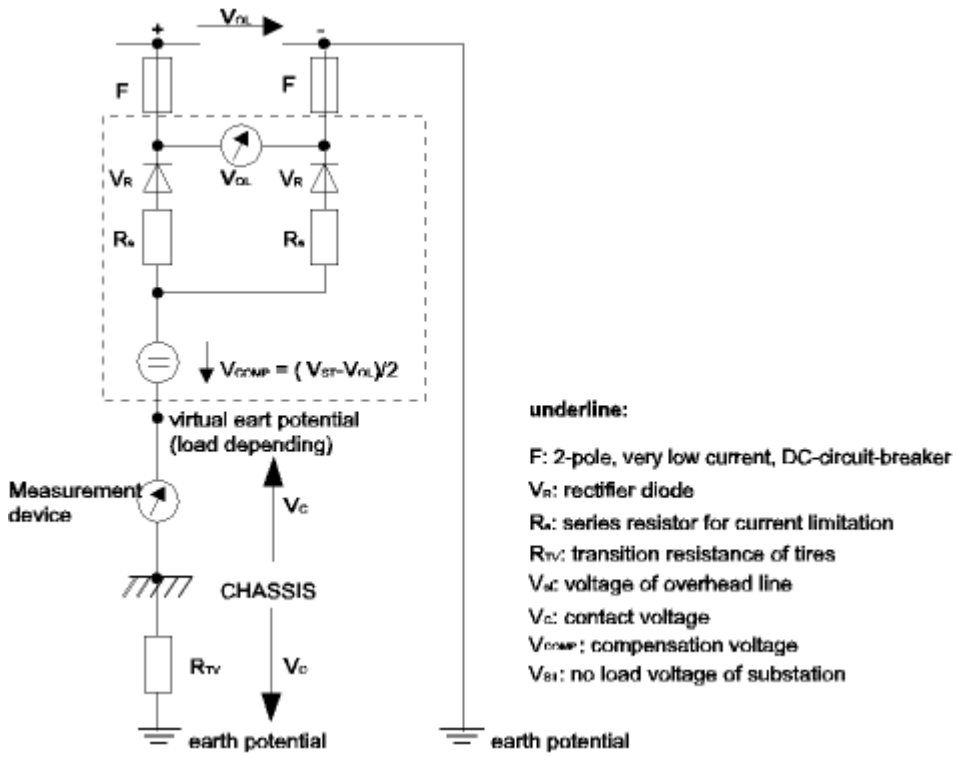
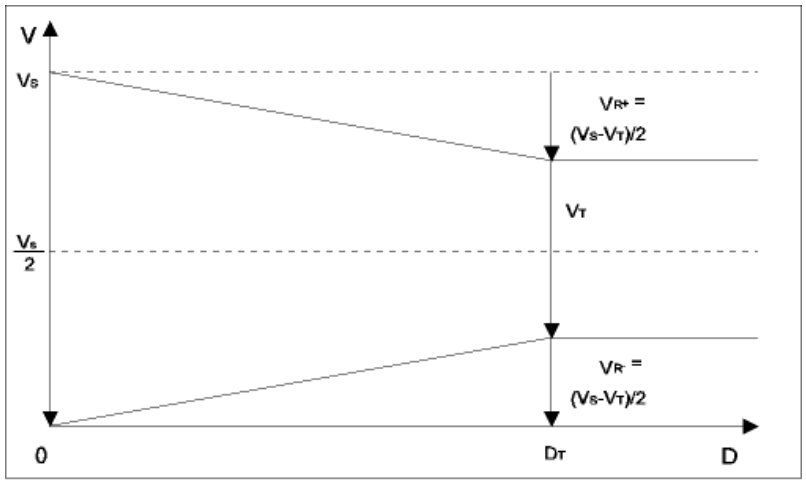


Figure 9 — Compensation of the voltage drop on the grounded overhead contact line

In this case, the internal resistance can be used to limit the potential of the vehicle mass relative to the grounded pole of the contact line. Under certain conditions, the effectiveness of this measure can be increased by compensating for the voltage drop shown in Figure 10 by a voltage controlled voltage source (Figure 9).



underline:

VS : open circuit voltage of substation
VT : line voltage (detected from trolleybus)
VR+ : voltage drop along positve wire
VR- : voltage drop along negative wire
DT : distance of trolleybus to substation

Figure 10 — Voltage development with a load connected to the overhead contact line

If the OCL is grounded at the traction substations and their open circuit voltage is set absolutely identically, this voltage drop can be compensated for by means of a controllable voltage source.

The limits for current, voltage and resistance specified refer to the monitoring of the overall insulation of the vehicle, made up of a parallel circuit of all the double insulations. For the monitoring of all the basic and/or supplementary insulations by monitoring of the intermediate masses described in 5.1.7, other/higher values may be useful and shall be specified by the manufacturer together with the relevant check.

6.5.4 Periodical efficiency checks

6.5.4.1 General

Particular care shall be given to ascertain that the leakage detector, if any, continues to operate and that the calibration remains in the values required in 6.5.2 and the associated voltages and currents.

Such verifications shall be carried out not only with a new or overhauled vehicle, but also periodically in accordance with the maintenance plan of the operator and in any case before putting in service the vehicle after repair work caused by insulation deficiency.

The minimum insulation resistance limits for setting the monitoring are derived from 6.5.3.3: 300 kΩ $\pm$ 45 kΩ.

The maximum leakage current limits are derived from IEC/TS 60479-1: 2 mA $\pm$ 0,3 mA.

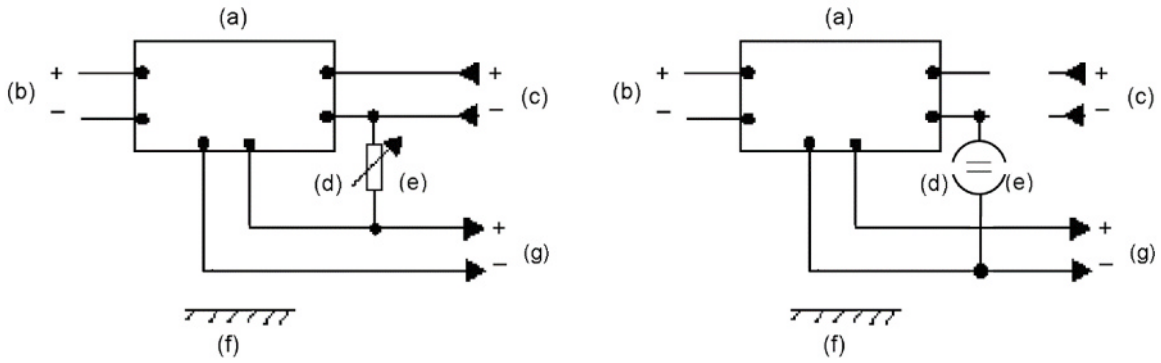
The maximum voltage limits are derived from EN 50122-1: 60 V $\pm$ 9 V.

The measurement tolerance is derived from EN 61557-8 to $\pm$ 15 %.

When checking with line voltage, the pertinent safety regulations shall be observed. The standards of the EN 50110 series shall be used for this purpose.

6.5.4.2 Checking the leakage current monitoring

For checking purposes, an appropriate current source or a settable resistor, in connection with the system, if applicable, can be used together with the line voltage. The monitor shall respond at a leakage current of 2 mA against ground that is located on the vehicle side behind the point of measurement.



a) Test with variable resistor **b) Test with current source**

Key

(a)	Leakage detector	(d)	Connect different poles up- and downstream of the device with the variable resistor Connect equal poles up- and downstream with current source
(b)	Battery voltage	(e)	R_{min} = variable leakage resistance externally applied
(c)	Line voltage	(f)	Vehicle mass
(g)	Outgoing line to the vehicle downstream of the measurement		

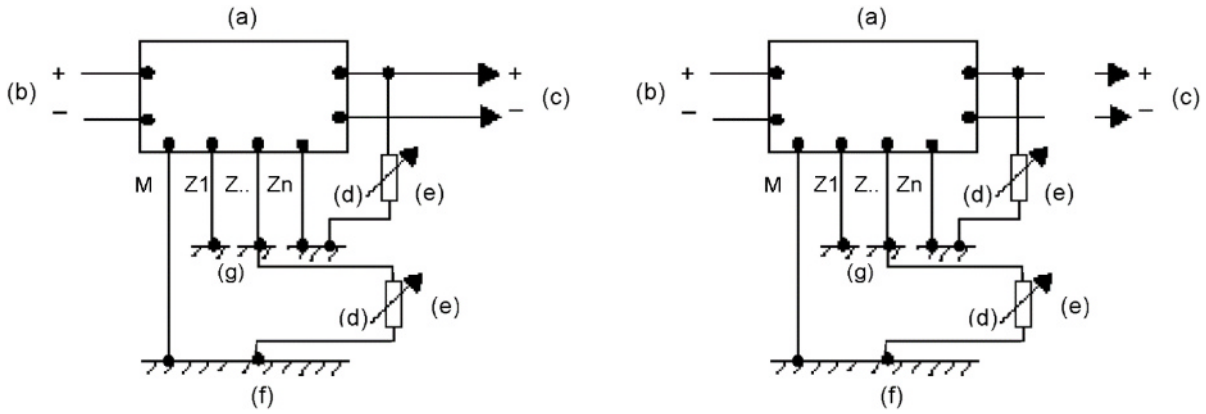
Figure 11 — Function check of the leakage current monitoring

To establish more safety during the test, the test should be carried out with the current source without connection to the overhead line. Figure 11 a) only serves for clarification.

The test is successfully passed, when the device responds at 2 mA $\pm$ 0,3 mA.

6.5.4.3 Check of the Insulation resistance monitoring

For checking purposes, settable resistances (also without connection of the system with the line voltage) can be used. Apart from the individual measurements between the contact line and the intermediate mass and the intermediate mass and the vehicle mass (Figure 12), the overall insulation shall be checked by connecting the resistors simultaneously to an intermediate mass Z. The monitoring shall then respond to the minimum value of the overall insulation defined above.



a) Test with overhead line voltage **b) Test without overhead line voltage**

Key

(a)	Leakage detector	(d)	Connect intermediate mass connectors Z1 … Zn with the measurement resistors
(b)	Battery voltage	(e)	R_{min} = variable resistor externally applied
(c)	Line voltage	(f)	Vehicle mass
(g)	Intermediate mass		

Figure 12 — Function check of the insulation resistance monitor

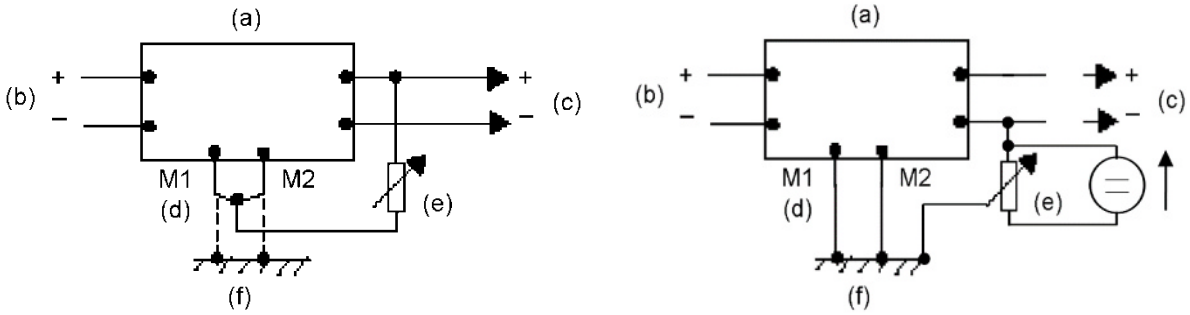
To establish more safety during the test, the test should be carried out without connection to the overhead line. Figure 12 a) only serves for clarification.

The test is successfully passed, when the device responds at 300 kΩ ± 45 kΩ.

6.5.4.4 Checking the touch voltage monitor

For checking purposes, an appropriate voltage source or a settable resistor in connection with the line voltage can be used. If the transitional resistance to ground cannot be increased by means of insulating mats to the extent that the measurement is falsified, the connection of the measuring instrument to the vehicle mass shall be disconnected for the check.

Criteria for the function check with a grounded supply of the test setup and the overhead line voltage as the driving voltage are shown in Figure 13.



a) Test with overhead line voltage **b) Test without overhead line voltage**

Key

(a) Leakage detector (d) where applicable disconnect the measurement connections M1/M2 from the vehicle mass and short-circuit them

(b) Battery voltage (e) R_{min} = variable resistor externally applied between + and the measurement connections

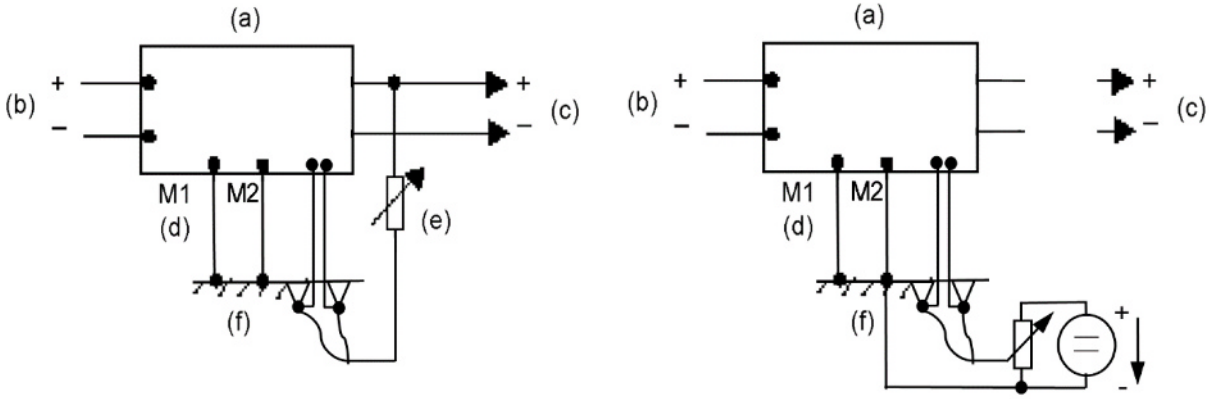
external test voltage source applied between - and vehicle mass

(c) Line voltage (f) Vehicle mass

Figure 13 — Function check of the touch voltage monitor with test against the positive of overhead line or external voltage source

To establish more safety during the test, the test should be carried out with an external voltage source without connection to the overhead line. Figure 13 a) only serves for clarification.

The test is successfully passed, when the device responds at 60 V ± 9 V.



a) Test with overhead line voltage **b) Test without overhead line voltage**

Key

(a) Leakage detector (d) where applicable disconnect the measurement connections M1/M2 from the vehicle mass and short-circuit them

(b) Battery voltage (e) R_{min} = variable resistor externally applied between + and sliding wires external test voltage source applied between sliding wires and vehicle mass

(c) Line voltage (f) Vehicle mass

Figure 14 — Function check of the touch voltage monitor with test against the positive of overhead line or external voltage source

To establish more safety during the test, the test should be carried out with an external voltage source without connection to the overhead line. Figure 14 a) only serves for clarification.

The test is successfully passed, when the device responds at 60 V ± 9 V.

Annex A
(normative)

Constructional detailed provisions

A.1 General information

Considering the specific characteristics of a trolley bus vehicle, it is considered necessary to recall the following points, which shall be carefully considered during the design and manufacture.

A.2 Attachment of the current collection system and other components

Large components and their mounting parts shall be designed to withstand the load as specified by the vehicle manufacturer. Without information, the requirements shall comply with EN 61373 and ISO 16750-3 if applicable.

The current collection system and the poles to the base shall be fitted and secured in order to prevent disconnection or loss of parts, taking into account shocks due to dewirements of the trolley.

A.3 Insulations

The insulating covers, the interposed insulations, clearance in air and the protection against water penetration shall be adequately designed and maintained. The design of insulation distances is detailed in EN 50124-1.

EN 50124-1 provides only minimum values for creepage distances regarding the voltage stress on insulation. Layout of creepage distances according to EN 50124-1 without additional measures may result in unacceptable insulation resistances resulting in high leakage currents.

For outdoor use on systems without a protecting earth conductor, the manufacturer shall design appropriate creepage distances regarding the environmental data given by the operator, to ensure compliance with the minimum insulation resistance values given in Table 6.

The approval is achieved by visual inspection and measurement of the length of clearances and creepage distances.

The design of insulation systems shall consider carefully pollution degree, form and material. Insulators with grooves, drip edges or installed in environmental protected locations or made of silicone shall be preferred. For protection of insulation in the lower part of the vehicle splash protection shall be provided to prevent water film formation. A combination of covers and mud flaps to the wheel houses shall be provided.

Insulation in air ducts, in particular in electric warm-air heaters is susceptible to pollution and with high air moisture their insulation resistance easily tends to fall below the limits given in Table 6. Therefore their cleaning shall be included in the maintenance plan (also for reasons of fire safety).

Positioning of external air intakes shall carefully consider the amount of pollution. Water separators with subsequent filtering shall be provided.

A.4 Ventilation

The compartments housing contactors or switching devices which may produce an arc during breaking shall be adequately ventilated to avoid accumulation of ionized air. The same precautions shall be used for compartments containing batteries.

Installation spaces for electronic components, having at least a protection degree of IP54 according to EN 60529, are necessary to be separated from ventilated installation spaces.

A.5 Accessibility

The arrangement of the individual equipment and of cabling shall be designed taking into account the need of accessibility and inspection: the cables shall not create an obstacle to access parts to be calibrated or subject to wear and tear.

A.6 Location of the main circuit breaker

Mounting of the main protection equipment shall ensure that, particularly under fault conditions, the circuit breaker arc does not reach flammable parts. In particular mounting in the passenger compartment is not allowed.

A.7 Income and outlet points of cables

The income and outlet points through the vehicle body and from the conduits under the chassis shall be protected against penetration of water or mud and against the formation of moisture. Degrees of protection and the relevant tests are described in EN 60529. The aging of sealing materials and gaskets shall be considered.

A.8 Cabling

Particular care shall be given to the routing, anchoring location and spans of cables, to avoid that they work loose or abrade due to vibrations, considering, if any, passages in proximity to metallic edges. Installation instructions of EN 50343 shall be observed.

A.9 Test terminal board

In order to facilitate the checks and measurements of the electrical insulation, it is advisable to provide a terminal board, on the vehicle, to which all intermediate masses and other components, requiring verification, are connected. This terminal board may be part of the insulation monitoring device according to 5.16 or 5.17.The design shall be agreed between operator and manufacturer.

A.10 Insulation leakage pre-alarm

To give an early indication of insulation deterioration, particularly in the presence of adverse climatic conditions, it is suggested that an insulation leakage pre-alarm be fitted. This device will measure the insulation resistance and will have a threshold of pre-alarm at a value to be agreed with the operator. This device may be considered a complement of the terminal board under A.9 or of the device under 5.1.6.

A.11 Equipment connected to different voltage band circuits

In case of connection to circuits supplied with band I and II voltages, having components supplied with band III voltages, particular attention shall be given to the integrity of terminals and clearances for the cabling. If necessary, additional clamps and protections shall be added, suitable to avoid contact between different voltage bands, even in case of detachment of the terminals.

For double insulations, in addition to the requirements of EN 50153, one cause shall not lead to the deterioration of the basic insulation and the supplementary insulation at the same time.

A.12 Segregation of band III circuits

The compartments containing electrical components at band III voltages, placed inside the vehicle, shall be sucurely closed and protected from unauthorized access. Warning signs in compliance with EN 50153 shall be mounted on the cover of these compartments.

Referring to EN 60529 within the passenger or the luggage compartment protection degree IPXXD applies. In areas other than the roof protection degree IPXXB applies. On the roof no protection is required, because of protection by distance according to EN 50153.

A.13 Batteries and other energy storage devices

When operation of the vehicle with or without overhead contact line is planned with batteries or other energy storage devices such as capacitors and flywheel storage devices, these devices should be selected among those commonly used in traction and road vehicles (ECE Regulation No. 100, ISO 6469-1 and ISO 6469-3).

Depending on the mode of operation of the energy storage system, the need of a double insulation shall be verified. Where, during operation (loading or unloading), there is no galvanic isolation from the overhead line, supplementary insulation shall be retrofitted in the mechanical structure as well as for the voltage supply and the signal interfaces of the control electronics.

A galvanically isolated charger and a galvanically separable connection of the traction circuit with an isolating contactor according to 5.4.2 is recommended. This increases crash safety and allows battery systems only with basic insulation (battery bus standard).

The selection of energy storage devices shall be made taking into consideration the safety of personnel and passengers and, by the European Standards applying to the kind of energy storage device selected shall apply. (Refer also to EN 50272-3, the EN 61881 series, EN 60077-1 and EN 62196-1).

Special attention shall be paid to additional hazards in the case of an accident. Chemical and thermal effects due to leakage and short-circuits in the energy storage device shall be taken into account. The partitioning in units with rated voltages < 120 V by use of additional isolation contactors is recommended. The probability of energy release and the energy released will be reduced as well as the possible touch voltage being reduced to acceptable values.

If applicable, unloading devices shall correspond to EN 50153 and the EN 61881 series. Corresponding warning signs in compliance with EN 50272-3 shall be additionally affixed. The handling of capacitors is described in the EN 61881 series, that of batteries in EN 50272-3.

General handling instructions are specified in EN 50110-1.

Recommendations for external charging systems of energy storage devices are specified in ECE Regulation No. 100, EN 62196-1, and the EN 61851 and CLC/TS 50457 series.

A.14 Fuel cells

In respect of the electrical safety, fuel cells can be considered auxiliary power supplies. The vehicle standards ISO 23273 shall apply[3].

These specify general requirements for electrical systems, especially there are differences in electric shock protection and the voltage bands. Because in fuel cell vehicles, all components of the.voltage bands II and III are normally connected galvanically with the traction circuit, in this context, voltage bands II and III are combined as stated in ISO 6469-3.

A.15 Environmental conditions

The ambient temperature range shall be specified by the operator and the operating temperature range according to EN 50125-1 shall be determined by the manufacturer.

More environmental conditions can be specified by the operator and the operating conditions according to EN 60721-3-5 shall be determined by the manufacturer.

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[3] see also ECE Regulation No. 100.

Annex B
(normative)

Trolley buses – Current collection system for overhead contact lines

B.1 Scope

This annex applies to trolley buses and provides a product standard complementary to EN 50119.

It defines the main characteristics of the current collection system for overhead contact lines, with a rated voltage between 600 V d.c. and 750 V d.c., which is mounted on the roof of the trolley bus (for limit values, refer to 4.1.2).

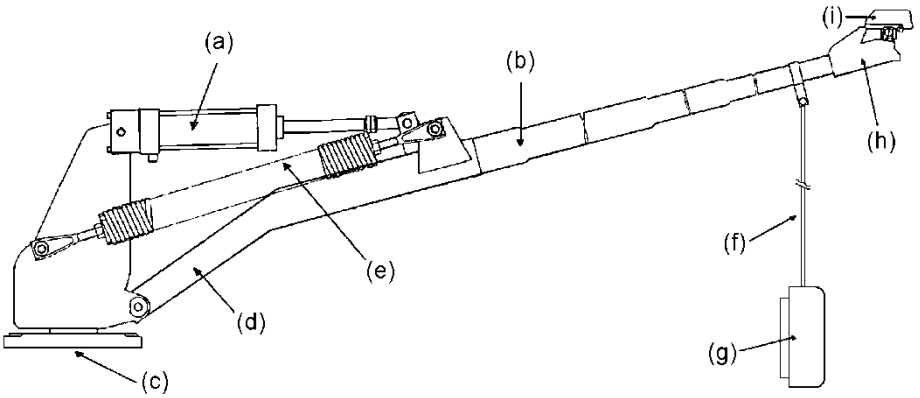
This annex covers mainly automatic lowering and raising of the trolley poles. Nevertheless this annex may be used also for manually operated trolley pole systems for those parts which are not specifically intended for automatic raising and lowering.

B.2 General Characteristics

B.2.1 General information

The typical fundamental parts of the current collection system, in their most common arrangement with actuators for vertical movements are shown in Figure B.1 and listed below the figure. Other actuators for horizontal movements can be added (refer also to B.2.3.5).

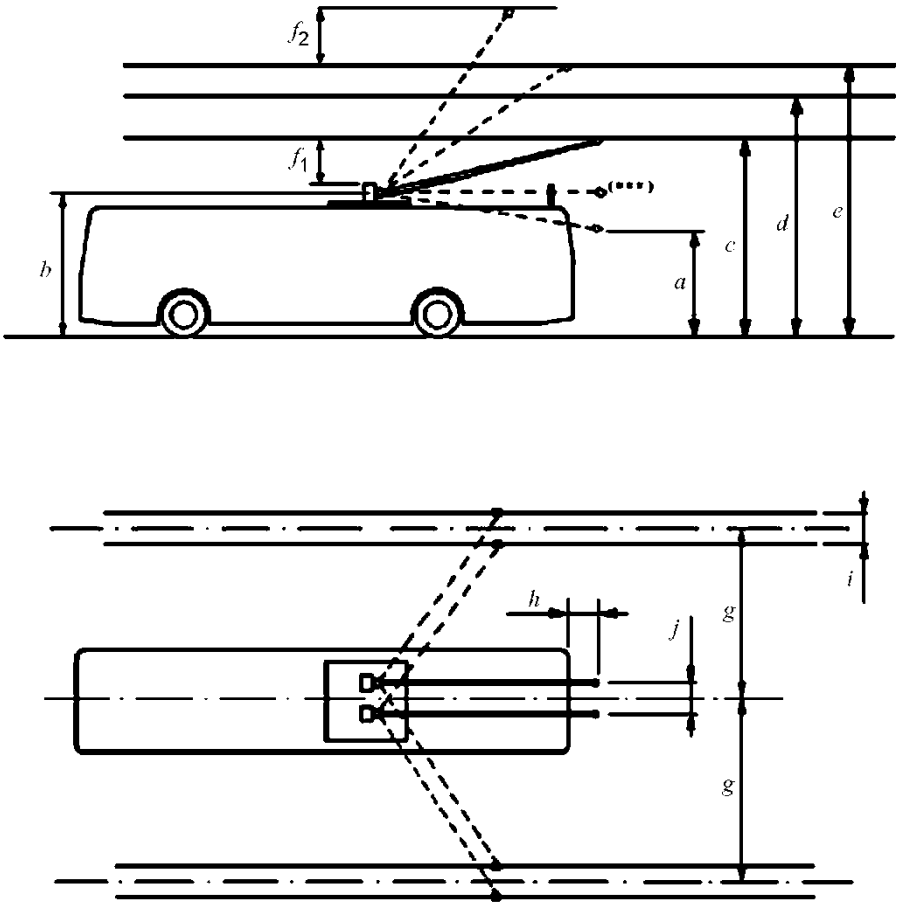
The dimensional characteristics of the system, as well as the limit geometry of the trolley bus are given in Figure B.2.



Key

(a)	actuator	(d)	pole foot	(g)	winding device.
(b)	pole	(e)	raising spring	(h)	current collector head
(c)	base support	(f)	rope	(i)	trolley

Figure B.1 — General characteristics of a typical current collector



Dimensions in mm

Minimum height from ground [a]	Height of pivot [b]	Height from ground of the overhead contact line (corresponding to EN 50122-1 for AC 1 000 V or DC 1 500 V)			Safety distance under *c*	Safety distance over *e*	Minimum displacement of the vehicle at height *d* [c]		Maximum protruding of pole system [d]	OCL gauge
		min.[e]	nom.	max. [e]			*g*			
a	***b***	***c***	***d***	***e***	f_1	f_2	g_1	g_2	***h***	***i***
To be agreed	3 100 ÷ 3 500	Preferred 4 700	5 500 to 5 600	Preferred 6 500	≥ 200	≤ 800	4 500	4 000	≤ 1 200	600 ÷ 700

[a] Due to statutory provisions, the minimum height above the roadway is 2,7 m.
In Switzerland, the minimum height shall still permit change of the carbon brushes standing next to the vehicle.
In all cases, the procedure shall be determined by the operator. Attention shall be paid on signs for hot surfaces and the need to ensure no voltage conditions.

[b] The distance b of the pivot from ground (vertical rotation) is to be intended for any load condition of the vehicle.

[c] g_1 and g_2 are respectively referred to trolley pole systems long 6 200 mm and 5 500 mm.

[d] Trolley pole locked in stand still position.

[e] Minimum and maximum heights of existing systems may undercut / exceed these values.
(Values between 3 400 mm and 7 200 mm are known.)

Figure B.2 — Preferred excursion of trolley poles versus distances of overhead contact lines to ground

B.2.2 Trolley pole system

B.2.2.1 General

The part of the equipment, including all components required for the connection to the overhead contact lines and the moving parts that make the connection. The length of the pole assembly is the distance between the vertical axis of rotation on the base support and the vertical rotation axis of the trolley, as measured with locked down poles in lowered position, as shown in Figure B.2. It is mainly composed of the following devices.

B.2.2.2 Base support

The base support, together with the pole foot is the rotation centre of the system, allowing lateral displacements of the vehicle, in respect to the OCL axis, and height variations of "d", as shown in Figure B.2. It is fastened on the mounting frame (see Figure B.2).

With basic insulation between the pole foot and the pole (also refer to B.2.2.3), the base support shall be electrically isolated from the mounting frame or, as an alternative, the mounting frame shall be electrically insulated from the vehicle mass. In either case, the base support is an intermediate mass and should feature a connector for the terminal board according to A.9.

Without basic insulation between the pole foot and the pole (also refer to B.2.2.3), the base support shall be electrically isolated from the mounting frame and the mounting frame shall be electrically isolated from the vehicle mass. In this case, the mounting frame is an intermediate mass (refer also to B.2.4.2) and should feature a connector for the terminal board according to A.9.

Dimensional requirements for mounting the base support on the mounting frame are given in Figures B.3 and B.4.

B.2.2.3 Pole

Tube structure, generally metallic or of materials of equivalent strength, with various diameters, having one end fitted on the pole foot, and the other end supporting the current collector head.

The pole may be bent near the trolley head.

In Italy the pole ends shall be provided with red and white stripes of reflecting material (Figure B.7).

The pole shall be insulated from the base support and from the pole foot. Alternatively the support base may be double insulated and the pole not insulated. In such a case the direct contact with the vehicle roof shall be prevented by means of insulated mechanical stops.

The pole foot shall allow at least ± 55° of rotation on the horizontal plane.

When the pole is used as the electrical connection, it shall be covered by an insulation sufficient to grant a functional insulation, to prevent shorts of the OCL in case of dewirement.

The manufacturer shall declare (among other constructional data) the maximum allowable force $\vec{F}_P$ applied to the free end of the pole, when it is engaged with a mechnical stop and there is no risk of permanent deformation.

B.2.2.4 Current collector head

B.2.2.4.1 General

Support structure allowing the trolley to rotate both vertically and horizontally.

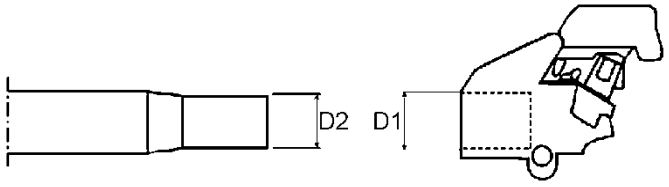
It shall allow a ± 55° rotation on the horizontal plane and a ± 20° (minimum) on the vertical plane, in any case suitable to keep the trolley horizontal both at the minimum and maximum height of the line, in order to avoid abnormal wear at the edges of the slipper.

The current collector head shall have a smoothed profile to avoid catching the line components, so damaging the same.

If applicable, the manufacturer of the head shall declare the maximum allowable force $\vec{F}_t$ in the direction of the pole supported by the current collector head in case of engagement to the OCL. Beyond said force the current collector head or parts of it shall slip off the pole.

A device suitable to limit consequences of the collector head slipping off the pole shall be provided.

Figure B.3 shows the usual diameter D1, D2 of the fit between the collector head and the pole in millimeters.



D1, D2	18	25	38

Figure B.3 — Example of fit of pole and the head

Figure B.4 shows the usual hole spacing and hole diameter of the fit between mounting frame and base support in millimeters.

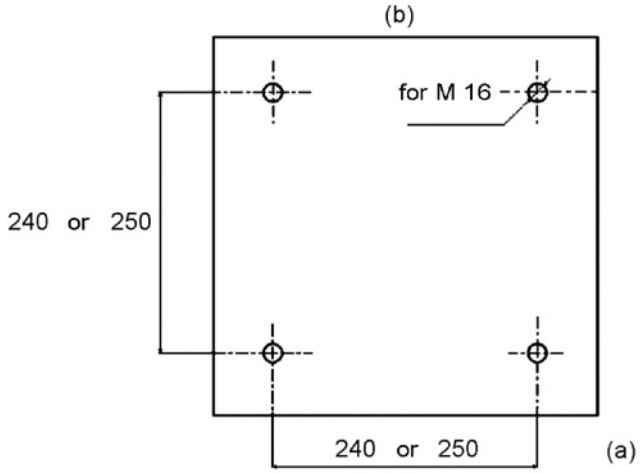


Figure B.4 — Example of fit of mounting frame with the base support

B.2.2.4.2 Trolley

Metallic support to the slipper; in some conditions it is in direct contact with some components of the fixed installation (switches, crossings, bends, etc.) slipping on the same; Figure B.5 shows the detail of this situation.

The material used shall have a hardness selected to optimize wear and tear of the trolley and the fixed installation. It shall withstand the electrical and mechanical stresses occurring when passing switches and crossings and in case of dewirement.

It shall allow an easy and quick replacement of the slipper, the fit ensuring a correct positioning in all operating conditions. Its dimensions shall allow smooth transitions at discontinuities of the OCL such as passive switches and its moulded depth shall be adapted to the suspension of the OCL.

Suitable low-resistance links shall be provided for the electrical connection between the pole end and the trolley. The same shall ensure the maximum moving freedom of the trolley.

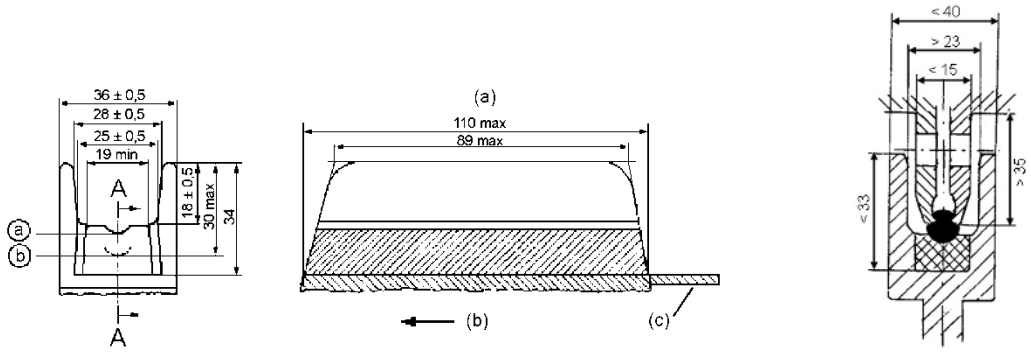
B.2.2.4.3 Slipper

Consumable element, described in Figures B.5 and B.6, providing the direct contact with the OCL, through which the current necessary for supplying the electrical equipment on board the trolley bus and the electric braking (in case of energy recovery scheme) flows.

The selection of the correct slipper type shall consider the characteristics of the environment, of the operation and of the fixed installation.

These requirements may be disregarded when specific requirements of the operator are given due to previous installations.

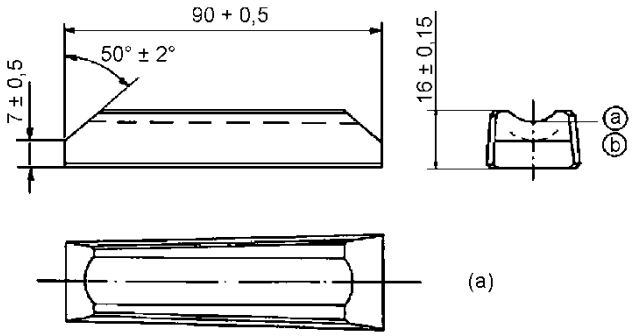
For maintenance the head may consist of individual parts (bottom and side panels, arc runner).



Key

ⓐ	slipping plane with new slipper	(a)	section A – A
ⓑ	slipping plane with slipper worn out	(b)	forward motion
		(c)	arc runner

Figure B.5 – Typical trolley



The dimensions (in millimetres) shall be such to guarantee the correct fit to the trolley.

The following characteristics shall be agreed between manufacturer and operator:

- type of material: e.g. carbon (hard or amorphous), electrographite;
- max. current for any contact point;
- specific resistance;
- max. admitted temperatures;
- shore hardness;
- density;
- flexural strength.

Figure B.6 — Typical slipper

B.2.2.5 Electrical connecting cables

The cables between the current collector head and the vehicle equipment shall be suitable for use on trolley buses and have specific electromechanical characteristics for this application with its mechanical and environmental stresses. (EN 50343)

B.2.2.6 Raising spring

The raising spring or, alternatively, an equivalent device, shall ensure, statically and dynamically and in the various height conditions of the overhead contact line that the force $\vec{F}_r$ applied by the slipper to the line is as constant as possible, without significant difference from the contact force indicated.

The spring shall be adjustable to obtain values of $\vec{F}_r$ at least between 80 N and 150 N. The adjusting device shall be easily operated.

B.2.2.7 Operating system of trolley poles

B.2.2.7.1 General

This may be required for lowering and raising the poles. It may have three configurations:

- automatic lowering, manual raising through the operating and guiding devices in B.2.3,
- automatic lowering and raising,
- manual actuation of raising and/or lowering poles.

It shall lower the poles, or at least give a signal on the drivers desk, in case of the following events:

- loss of supply voltage,

- failure of the relevant electronic equipment,
- insufficient air pressure.

B.2.2.7.2 Moving the system through automatic lowering and manual raising

The main components for allowing this movement are:

B.2.2.7.2.1 Actuator.

It is a pneumatic cylinder, or an equivalent device, which performs lowering the trolley pole. The device is automatically controlled by the device in B.2.2.7.2.2 in case of:

- dewirement and/or other emergency condition requiring safe positioning of the poles,
- lowering the poles following a control signal actuated from the driving desk for standing vehicle.

B.2.2.7.2.2 Control-command device.

It is the device, if any, responsible for the lowering of the trolley poles, which, in case of dewirement, shall occur as quickly as possible.

The device is supplied with a nominal voltage of band I and its operation shall be correctly performed with the supply voltage in the range 0,7 to 1,25 U_{Ne}. Short time below or exceeding the values according to EN 50155 shall not impair the functionality.

B.2.2.7.3 Moving the system through automatic lowering and raising

In case this configuration is used, suitable guides may be mounted on the OCL to facilitate the engagement of the trolley during raising.

The main components for allowing this movement are:

B.2.2.7.3.1 Actuator.

It is a pneumatic cylinder, or an equivalent device, which performs raising and lowering the trolley pole.

The device is automatically controlled by the device in B.2.2.7.3.2 in case of:

- of dewirement and/or other emergency condition requiring safe positioning of the poles,
- lowering or raising the poles following a control signal actuated from the driving desk for standing vehicle.

B.2.2.7.3.2 Control-command device.

For lowering the trolley poles, see B.2.2.7.2.2.

For raising the trolley poles, the device shall control the correct positioning of the current collector head on the OCL and avoid damage of the fixed installation.

The device is supplied with a nominal voltage of band I and its operation shall be correctly performed with the supply voltage in the range (0,7 to 1,25) U_{Ne}. Short time below or exceeding the values according to EN 50155 shall not impair the functionality.

B.2.3 Recovering and actuating mechanisms

B.2.3.1 General

They shall be adequately dimensioned from a mechanical point of view and, when necessary, have electrical insulation characteristics suitable to ensure safety for the personnel driving or maintaining the vehicle in all operation conditions.

B.2.3.2 Rope

If any, is the connection and operating element for pole manual operation.

Three types of ropes are identified:

- **Operating rope:** is the portion of rope that is wound on the winding device; its length shall be determined taking into account the height of the OCL and the lateral displacement admitted for the vehicle.

  The operating rope shall feature a rated break point that prevents damage to objects on the curbside when the rope gets caught on them during a dewirement. The breaking force shall be adapted to the operating force.

  If the operating rope is used for automatically retracting the poles in case of a dewirement (e.g. mechanical, pneumatic or electrical winding mechanisms such as in B.2.3.4), the probability of getting caught is reduced by permanent rope tension. In that case a rated break point could impair the retraction and can be omitted.

- **Pole rope:** is the short rope between the operating rope and the pole head if applicable.

  Its presence is required to provide the necessary electrical insulation as necessary for the operating personnel.

  It may be replaced by suitable insulating means, which, however, shall not cause damage to persons or goods in case of dropping due to breakage of the rope.

  Operating rope and pole rope shall have a breaking load not less than 10 kN.

- **Safety rope:** is a very short piece of rope which retains the current collector head in case of becoming detached from the pole.

  The breaking load shall be suitable for the weight of the trolley head.

B.2.3.3 Manual operating pole and other auxiliary equipment

Tool made of insulating material for the manual operation of the pole in case of necessity. If ropes are not attached, this tool is mandatory and is carried in the vehicle.

B.2.3.4 Trolley pole retriever

Rope winding device used with a rope operating system of trolley poles (B.2.2.7), it is the device for collecting and housing the necessary rope length.

The winding device may be additionally equipped with mechanical or electromechanical equipment for the recovery of the poles in case of dewirement. In this case measures shall be taken to prevent accidents when the rope is retracted, especially when deploying the poles manually.

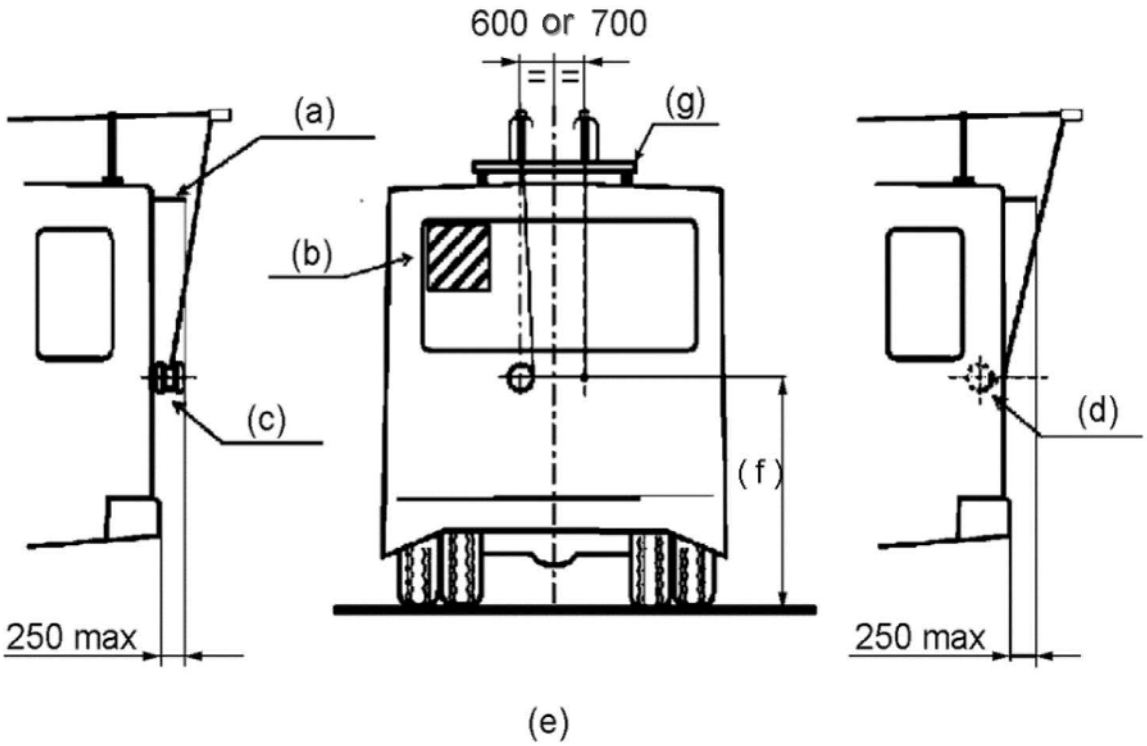
Dimensions (in millimeters) and location are indicated in Figure B.7.

The manufacturer shall utilize a rope force which allows a reliable collection of the rope as well as a minimum of influence on the contact force within the heights and excursions given in Figure B.2. In this context, the type of rope excursion limiting device and the rope force shall be coordinated such that when the poles are lowered in the case of a dewirement, loops of the rope are not formed.

B.2.3.5 Automatic aligning device

An automatic aligning device shall be provided, if required, for automatically aligning the trolley poles, parallel to the major vehicle axis. This device shall operate, when the poles are lowered by the actuator in B.2.2.7.

In addition, this device may be used for maintaining the trolley poles alignment during automatic deployment.



Key

(a) rope excursion limiting device

(b) indicating panel for protruding loads (required in Italy)

(c) type A winding device

(d) type B winding device

(e) to be agreed between manufacturer and operator

(f) to be agreed between purchaser and supplier

(g) locking equipment

The rear projection for type A winding device and rope excursion limiting device shall be not more than 0,25 m.

In Italy the pole ends shall be provided with red and white stripes. In Italy the indicating panel shall have a minimum surface of 0,25 m^2 and shall be fitted on the rear of the vehicle. In Italy the tape A winding devices shall be provided with red and white stripes of reflecting material.

Figure B.7 — Devices (if any) for recovering and excursion limiting of pole ropes position, overall dimensions and signalling

B.2.4 Additional elements

B.2.4.1 General

These elements complete the installation of the trolley poles on the roof, for a correct use.

B.2.4.2 Mounting frame

The mounting frame is the structure mounted on the vehicle roof to fix the support base. It shall be able to withstand the stresses due to dewirements and the possibility to get entangled with components of the fixed installation.

Therefore the connection system to the OCL shall be designed together with the general design of the trolley bus.

The mounting frame may be mounted on dampers against vibrations, considering however that dampers are not considered as electrically insulating elements.

If the support base is insulated from the mounting frame, the latter shall feature devices that hold the current collector on the roof if the insulators of the support base are damaged.

If the pole (B.2.2.3) is not insulated from the pole base or baseframe, the mounting frame shall be designed with insulation from the roof. In this case, the mounting frame is an intermediate mass (refer also to B.2.2.2) and should feature a connector for the terminal board according to A.9. On the roof, there shall be devices that hold the current collector on the roof if the insulators of the support base are damaged.

If the support base is not insulated from the roof, it shall be equipped with electrical equipotential bonding to the vehicle mass.

B.2.4.3 Pole displacement limiters

If required suitable arrangements shall be used to avoid the possibility that the current collector head can reach a height from ground to be agreed between supplier and purchaser (Figure B.2), also in dynamic conditions. These may be part of the vehicle roof or of the support frame and shall feature an insulation to the vehicle roof.

To comply with the requirements of higher displacement to permit the change of carbon brushes on the road, the displacement limiters may be discontinued in one place on each side of the vehicle. The exact procedure shall be agreed between manufacturer and operator and to be adopted by the operator in an operational arrangement.

B.2.4.4 Rope excursion limiting device

This device, mounted on the back wall of the vehicle, shall limit the rope length (when this feature is provided) to avoid exceeding the limit gauge of the vehicle particularly for lateral displacement.

Passage of vehicles 4 m high shall be ensured both by the road marking, location of the OCL and the design of the rope excursion limiting device. For this purpose, it may be necessary for the rope excursion limiting device to keep the rope far within the limit gauge of the vehicle. Critical positions and critical dimensions shall be provided by the operator.

B.2.4.5 Locking equipment for the poles

This equipment shall lock down, in a way easily visible from ground, the poles on the vehicle roof. Locking may be manually or automatically operated. In case of automatic locking a signal shall appear on the driving desk.

This locking equipment shall be insulated like the support base for cases where one pole is interlocked and the other one is on the overhead line.

B.2.4.6 Equipment for control of OCL switch operation

This equipment allows control of electromechanically operated OCL switches. Signal transmission of common OCL switches is carried out with:

- line current of vehicle by resistors for switch operation,
- electromagnetic waves (radio frequency, microwaves, infrared) over antennas on the roof or on the end of the pole,
- induction loops in the road surface.

Control and display elements are located on the drivers desk.

Antennas at the end of the pole shall have double insulation to control and display elements in case of an uninsulated pole. When the pole is insulated from OCL, a single insulation is sufficient. Insulation shall meet the conditions of 6.2.2 and 6.2.6.

The design of the switches is described in EN 50119.

B.3 Marking

The following system components shall be permanently marked:

- support base, together with actuating, control and command devices;
- winding device.

This marking shall allow to identify:

- the manufacturer,
- the serial number,
- the component type.

The other components may be identified through the above mentioned criteria.

B.4 Checks and tests

B.4.1 Test categories

B.4.1.1 General

Three categories of tests are required:

- type tests,
- routine tests,
- functional tests.

The required tests are listed in Table B.1.

Table B.1 — Summary of tests and checks

Subclause	Subject	Type test	Routine test	Functional test
B.4.2.1	Visual inspection		X	
B.4.2.2	Weighing	X		
B.4.2.3	Dimensional checks		X	
B.4.2.3.2	Displacement of pole system			X
B.4.2.3.3	Minimum height of the poles from ground			X
B.4.2.4	Identification		X	
B.4.3.1	Contact force			X
B.4.3.2	Collector head operation when reversing			X
B.4.3.4	Climatic tests	X		
B.4.3.5	Air tightness test of the pneumatic cylinder	X		
B.4.3.6	Air tightness test of the pneumatic system			X
B.4.3.7	Check on the detachment of the current collector head	X		
B.4.3.8.1	Withstand voltage test		X	
B.4.3.8.2	Measure of the insulation resistance			X
B.4.3.9	Impact and vibration test	X		

B.4.1.2 Type tests

The type tests are intended to assess the conformity of the complete system to the technical characteristics and to the performance of the complete vehicle; they shall follow a sampling plan and the purchaser and the supplier shall state the criteria for acceptance.

When the design or the manufacturing techniques are changed after the tests, the influence of such modifications on the system performance shall be evaluated and the purchaser and the supplier shall agree the need for the repetition of one or more type tests.

B.4.1.3 Routine tests

Routine tests shall be carried out on all the production components. For some components, the purchaser and the supplier may agree to perform the tests on samples.

B.4.1.4 Functional tests

Functional tests require the erection of the complete system on board the trolley bus, and where necessary the availabilty of the operator´s fixed installation.

B.4.2 General checks

B.4.2.1 Visual inspection (routine test)

The current collection system, before being completely assembled with all components foreseen in the design, shall be carefully inspected; it shall show no physical defects and the various materials shall have the indication of the surface treatment received, according to the design or to particular requirements of the operator.

B.4.2.2 Weighing (type test)

Masses shall be verified to be in accordance with the characteristics declared by the manufacturer when tendering the complete system and the various components, except for those components which are definitively in the scope of the vehicle manufacturer.

B.4.2.3 Dimensional checks (routine test)

B.4.2.3.1 General

The dimensions and relevant tolerances given in the manufacturing drawings (and part of the contractual documentation) shall be verified.

B.4.2.3.2 Displacement of the pole system (functional test)

Once the pole system has been completely mounted on the trolley bus, the compliance with the dimensions given in Figure B.2 shall be verified. When purchaser and supplier agree for the need of the check, this verification shall be carried out in dynamic conditions.

B.4.2.3.3 Minimum height of the poles from ground (functional test)

For the static verification, the pole is manually lowered down to the lower limit allowed by the limiting device under B.2.4.3; this test shall be repeated for both poles and for different positions within distance “g” given in Figure B.2, but protruding the vehicle lateral walls.

The measured height over ground shall not be less than the stated dimension “a” of Figure B.2.

For the verification simulating dynamic conditions, in order to avoid damage to the poles, in the less favourable position obtained with static test, 90 % of the force $\vec{F}_P$ (B.2.2.3) declared by the manufacturer shall be vertically applied.

In these conditions too, distance “a” of Figure B.2 shall be respected.

B.4.2.4 Identification (routine test)

The component marking (see B.3) shall be verified.

B.4.3 Functional checks

B.4.3.1 Contact force (functional check)

The contact force $\vec{F}_r$ (B.2.2.6) in axis at nominal height of OCL with rope attached shall be declared by the manufacturer and verified with the vehicle completely assembled.

B.4.3.2 Collector head operation when reversing (functional test))

The correct behaviour of the system, particularly in respect to the current collector head and its components, shall be verified during reverse movement of the vehicle, on a straight path without switches or intersections and at a speed agreed between manufacturer and operator (5 km/h preferred).

B.4.3.3 Lowering (functional test)

A dewirement at every height "*c-d-e*" of Figure B.2 and at the displacement "g" indicated in Figure B.2 shall be simulated. The time delay between the moment the pole is released and the time it reaches 0,1 m below its initial height shall be measured. Contact to parts of the roof shall be prevented to avoid damage of pole or equipment.

This time delay shall not exceed 2 s.

Thereafter, the current collector head shall further lower at least 0,2 m below the minimum OCL level, given by EN 50122-1.

B.4.3.4 Climatic tests (type test)

These tests are intended to check the correct operation of the components at different temperature and humidity conditions. When the operator does not specify special values, these tests shall be performed at temperatures of – 25 °C and + 45 °C with relative humidity of 95 % at 40 °C according to EN 50125-1, temperature class T3, without temperature variations.

B.4.3.5 Air tightness test of the pneumatic cylinders (type test))

All pneumatic cylinders of the actuator (see B.2.2.7.2.1), shall be submitted to an air tightness test at ambient temperature. The test shall be carried in accordance with ISO 10099.

B.4.3.6 Air tightness test of the pneumatic system (functional test)

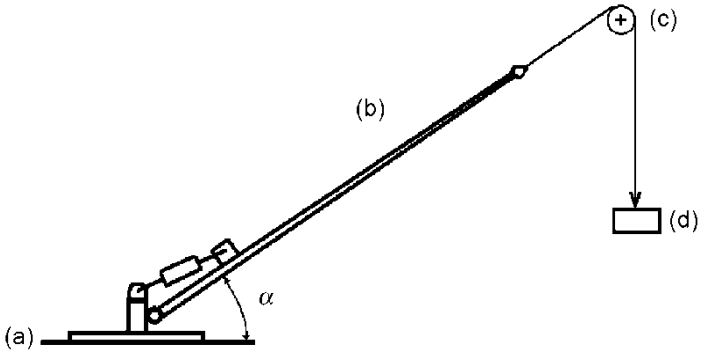
A tightness test shall be carried out on the pneumatic plant of the current collecting system. The test shall be made as agreed between operator and manufacturer.

B.4.3.7 Check on the detachment of of the current collector head (type test)

The test, if required, shall be made with a pole system completely assembled, at normal ambient temperature and with the pole positioned to form an angle α corresponding to that formed by the pole system when mounted on the vehicle and in contact with OCL at the height "d" shown in Figure B.2. A force $\vec{F}_t$ shall be gradually applied as shown in Figure B.8.

At the end of the test, the current collector head shall detach at the declared force, with a tolerance of $\pm$ 10 %, and no deformations, breakages or other faults of any component, with particular attention to the connection components and to the safety rope.

Purchaser and supplier may agree further specific tests.



Key

(a) base support (c) pulley

(b) Pole (d) $\vec{F}_t$

Figure B.8 — Scheme of the verification of the detachment the current collector head

B.4.3.8 Electrical Tests

B.4.3.8.1 Power frequency withstand voltage test (routine test)

A 50Hz a.c voltage is applied which is gradually increased to U_a r.m.s over 10 s and then maintained for 60 s. The value of U_a is given in Table 5.

B.4.3.8.2 Measure of the insulation resistance (functional test)

With the current collection assembly completely mounted on a vehicle roof, the insulation resistance is measured according to the requirement of this Standard. Limits are given in Table 6.

B.4.3.9 Shock and vibration tests (type test)

Due to the different mechanical loads of railways and rubber tyred vehicles, ISO 16750-3 instead of EN 61373 shall be used for shock and vibration tests if applicable.

B.5 Inspections

In accordance with EN ISO 9001 inspections may be required, according to the requirements of the contract.

B.6 Electromagnetic compatibility

The system described in this Standard shall comply with the requirements of the EN 50121 series.

Annex C
(normative)

Constructional requirements for current collection systems

C.1 General information

In view of the importance of the current collection system described in this Standard, both in respect to the mobile part (vehicle) and to the fixed installation (OCL and supports), the following points shall be particularly cared by the designer of the vehicle and the manufacturers of the various parts.

C.2 Material of the trolley poles

The poles can be made of materials suitable to be straightened cold, to facilitate maintenance. Other materials like aluminium or glass fibre reinforced plastic also may be used.

C.3 Current connections

The best current conduction shall be achieved between the current collector head and the electric cable, avoiding phenomena such as sticking of the head on the pole end, due to galvanic migration of material.

C.4 Joints

Lubrication of the articulated joint shall not be necessary: e.g. suitable antifriction linings shall be used.

C.5 Cable insulation

The ends of the electric cable, which may be affected by water, shall be suitably protected to avoid the ingress of water between the core and the cover of the cable.

C.6 Abnormal line height

The operation of the equipment described in this Standard shall be assured even in case the height of OCL from ground is lower than the distance “c” shown in Figure B.2.

Annex D
(informative)

Open door interlocking

The following requirements of ECE Regulation No. 107 should be met:

- 7.6.5.1.8: the doors shall be prevented from opening if the vehicle moves at a speed higher than 5 km/h;
- 7.6.5.8: a starting prevention device, if fitted, shall be effective only at speeds of less than 5 km/h and shall be incapable of operation above that speed;
- 7.6.5.9: if the vehicle is not fitted with a starting prevention device, an audible warning to the driver shall be activated if the vehicle is driven away from rest when any power-operated service door is not fully closed; this audible warning shall be activated at a speed exceeding 5 km/h for doors complying with the requirements of 7.6.5.6.1.2.3.

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