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Electric road vehicles — Safety specifications —

Part 1:
On-board electrical energy storage

Véhicules routiers électriques — Spécifications de sécurité —

Partie 1: Stockage de l'énergie électrique à bord du véhicule

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 6469 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 6469-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electric road vehicles*.

ISO 6469 consists of the following parts, under the general title *Electric road vehicles — Safety specifications*:

— *Part 1: On-board electrical energy storage*

— *Part 2: Functional safety means and protection against failures*

— *Part 3: Protection of persons against electric hazards*

Annexes A and B of this part of ISO 6469 are for information only.

Electric road vehicles — Safety specifications —

Part 1:
On-board electrical energy storage

1 Scope

This part of ISO 6469 specifies requirements for the on-board electrochemical storage of energy for the propulsion of exclusively battery-powered electric road vehicles (passenger cars and light commercial vehicles) for the purpose of protecting persons and the vehicle environment.

It is applicable only if the maximum working voltage of the on-board electrical circuit is lower than 1 000 V a.c., or 1 500 V d.c. or lower, according to national standards or regulations (e.g. for qualification of service personnel). It does not necessarily apply to assembly, maintenance and repair of these vehicles.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 6469. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 6469 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3864:1984, *Safety colours and safety signs*

ISO 6469-3:2001, *Electric road vehicles — Safety specifications — Part 3: Protection of persons against electric hazards*

ISO 8713:—[1)], *Electric road vehicles — Terminology*

IEC 60417-1:2000, *Graphical symbols for use on equipment — Part 1: Overview and application*

IEC 60417-2:1998, *Graphical symbols for use on equipment — Part 2: Symbol originals*

IEC 60529:1989, *Degree of protection provided by enclosures (IP code)*

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

3 Terms and definitions

For the purposes of this part of ISO 6469, the following terms and definitions apply.

1) To be published.

3.1
battery cell
electrochemical energy storage device, consisting of positive and negative electrodes, and an electrolyte, of which the nominal voltage is the electrochemical couple nominal voltage

[ISO 8713]

3.2
battery module
battery monobloc
grouping of interconnected cells in a single mechanical and electrical unit

[ISO 8713]

3.3
battery pack
single mechanical assembly comprising battery modules and retaining frames or trays, but possibly including other components (e.g. for topping-up and temperature control)

[ISO 8713]

3.4
traction battery
propulsion battery
battery
collection of all traction battery packs which are electrically connected, for the supply of energy to the power train

[ISO 8713]

3.5
battery connection terminal
live part outside the enclosure of the battery pack, intended for transmitting electrical energy

[ISO 8713]

3.6
creepage distance
shortest distance between a live part of a terminal, including any attached conductive fittings, and the electrical chassis, or between two live parts of different electrical potentials, along an insulated surface or surfaces

[ISO 8713]

3.7
conductive part
part capable of conducting electric current

[ISO 8713]

NOTE Although not necessarily electrically energized in normal operating conditions, it may become electrically energized under fault conditions of the basic insulation (see 3.9).

3.8
exposed conductive part
conductive part which can be touched by a test finger according to IPXXB (IEC protection code) as specified in IEC 60529

[ISO 8713]

NOTE This concept is relative to a specific electrical circuit: a live part in one circuit may be an exposed conductive part in another (e.g. the body of a passenger car may be a live part of the auxiliary network but an exposed conductive part of the power circuit).

3.9
live part
conductor or conductive part intended to be electrically energized in normal use

[ISO 8713]

3.10
electrical chassis
conductive parts galvanically connected, whose potential is taken as reference

[ISO 8713]

3.11
direct contact
contact of persons to live parts

[ISO 8713]

3.12
power unit
combination of power control and electric motor

[ISO 8713]

3.13
power system
combination of power unit and the on-board energy source

[ISO 8713]

4 Environmental and operational conditions

The requirements given in this part of ISO 6469 shall be met across the environmental and operational conditions for which the electric vehicle is designed to operate, as specified by the vehicle manufacturer.

5 Marking

5.1 Battery pack

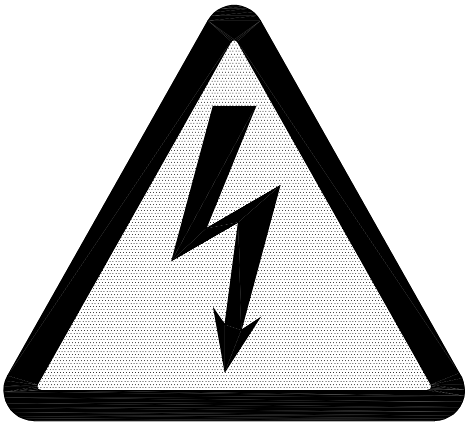
The symbol shown in Figure 1 shall appear near to the battery packs (not applicable for maximum working voltages lower tan 25 V a.c. or 60 V d.c.).

This warning shall be visible when accessing the battery.

5.2 Traction battery type

Prior to the establishment of internationally standardized methods of marking hazardous materials, where present, in the traction battery, national or regional prescriptions can apply, such as those of NFPA 70[1].

Another possible marking is use of the same designation as that indicated on trailers with dangerous goods, as defined in ECE R.105[2].



Symbol (background: yellow; bordering and symbol: black) shall be in accordance with ISO 3864 and IEC 60417K .

Figure 1 — Marking of battery packs

6 Exhaust gas from traction battery

The vehicle manufacturer shall determine the maximum volume flow rate (m^3/h) of potential dangerous gases exhausted by the traction battery

— in the case of normal operation, and

— in the case of a first failure of devices involved in the charging process.

These two values shall determine the ventilation device in the charging room (see applicable national and/or international standards or regulations).

NOTE A proposal for the measurement of hydrogen emissions is under consideration for future standardization.

7 Traction battery requirements

7.1 Insulation resistance of the traction battery

7.1.1 General

Not applicable for maximum working voltages lower than 25 V a.c. or 60 V d.c.

7.1.2 Test method

The measured insulation resistance results in a value which is adequate for safety purposes, but may be lower than the actual physical values.

For the measurement, the traction battery including all its external accessories such as electrical heating and monitoring devices shall be disconnected from the electrical chassis of the vehicle.

Throughout the test, the traction battery shall have an open circuit voltage greater than or equal to its nominal value.

The two poles of the traction battery shall be disconnected from the power unit.

The voltmeter or the measuring device used in this test shall measure d.c. values and have an internal resistance above 10 MΩ.

Measurements shall be performed in three steps, as shown in Figures 2 to 5, at an environmental temperature of (23 ± 5) °C.

If $U_1 > U_1'$ (Figure 4), the value of the insulation R_i shall be calculated by

$$R_i = \frac{(U_1 - U_2)}{U_2} R_0$$

If $U_1 < U_1'$ (Figure 5), the value of the insulation R_i shall be calculated by

$$R_i = \frac{(U_1' - U_2')}{U_2'} R_0$$

This is the standard method of calculation.

Alternatively, the following equation may be used, based on the more detailed calculation given in annex A:

$$R_i = \frac{(U_1 - U_2)}{U_2} R_0 \left(1 + \frac{U_1'}{U_1}\right)$$

$$R_i = \frac{(U_1' - U_2')}{U_2'} R_0 \left(1 + \frac{U_1}{U_1'}\right)$$

7.1.3 Requirement

The insulation resistance R_i, according to the standard method of calculation, divided by the nominal voltage of the traction battery U, shall exceed 100 Ω/V throughout the entire lifetime of the traction battery.

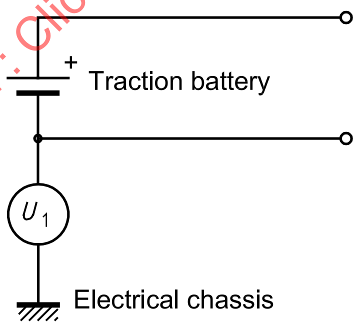


Figure 2 — Step 1: measurement of U_1

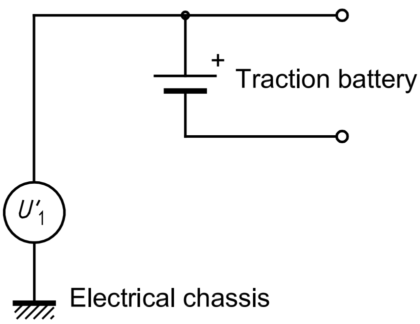
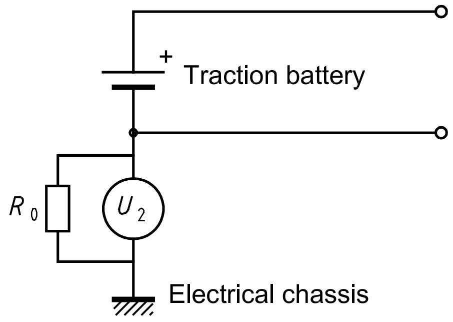
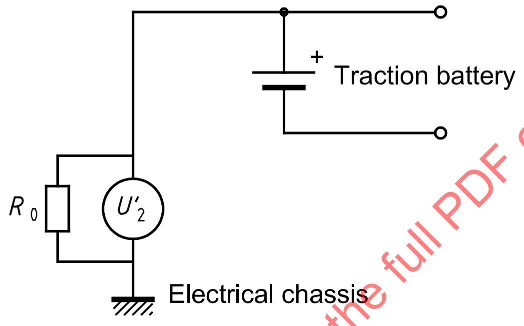


Figure 3 — Step 2: measurement of U_1'



NOTE R_0 is a standard resistance of between 100 Ω/V and 500 Ω/V (referred to the nominal voltage of the traction battery).

Figure 4 — Step 3: measurement of U_2 (if $U_1 > U_1'$)



NOTE R_0 is a standard resistance of between 100 Ω/V and 500 Ω/V (referred to the nominal voltage of the traction battery).

Figure 5 — Step 3: measurement of U_2 (if $U_1 < U_1'$)

7.2 Creepage distance

This subclause deals with an additional leakage current hazard between the connection terminals of a traction battery module, including any conductive fittings attached to them and any conductive parts, due to the risk of electrolyte spillage from leakage under normal operating conditions.

It does not apply to traction batteries, for which electrolyte leakage will not occur under normal operating conditions (e.g. sealed traction batteries). For these batteries, IEC 60664-1 shall apply. The pollution degree shall be suitable for the range of application.

Nor does it apply to maximum working voltages lower than 25 V a.c. or 60 V d.c.

See Figure 6.

If electrolyte leakage can occur it is recommended that the creepage distance be as follows.

a) In the case of a creepage distance between two battery connection terminals:

$$d \geqslant 0{,}25U + 5$$

where

d is the creepage distance measured on the tested traction battery, in millimetres (mm);

U is the nominal voltage between the two battery connection terminals, in volts (V).

b) In the case of a creepage distance between live parts and the electrical chassis:

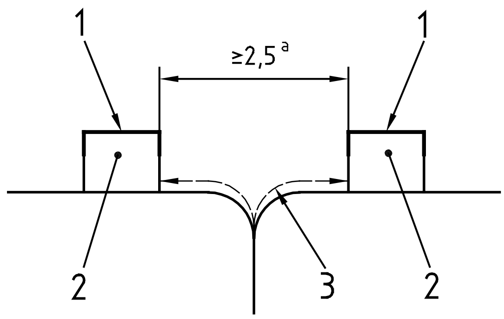
$$d \geqslant 0{,}125U + 5$$

where

d is the creepage distance measured between the live part and the electrical chassis, in millimetres (mm);

U is the nominal voltage between the two battery connection terminals, in volts (V).

Dimensions in millimetres



Key

1 Conductive surface

2 Connector terminal (traction battery module, traction battery pack or traction battery)

3 Creepage distance

[a] Gap between terminals.

Figure 6 — Creepage distance

7.3 Ventilation

7.3.1 General

To prevent explosion, fire or toxicity hazards, the following is applicable when gases can be produced by the traction battery.

— No potentially dangerous accumulation of gas shall be allowed anywhere in the vehicle.

— No potentially dangerous concentration of gas shall be allowed in the passenger compartment or the enclosed load compartment.

Refer to the latest version of applicable national/international standards or regulations for the maximum allowed accumulated quantity of gases.

An example of air flow calculation for hydrogen exhaust is given in annex B.

7.3.2 Measurements and requirements

7.3.2.1 Hydrogen when charging the traction battery from the mains

To ensure that no critical level of hydrogen inflammability is reached when charging the traction battery from the mains, and until internationally accepted test methods are developed, the following method for the measurement of hydrogen concentration is recommended.

a) The hydrogen concentration shall be measured around the gas exhaust within an area specified by the vehicle manufacturer.

b) No potential ignition source (see Note 1) shall be located within the gas exhaust area specified.

c) During the measurement, the recorded values of hydrogen concentrations shall be

- less than 1 % by volume at normal charging operation, and
- less than 2 % by volume or according to national standards or regulations in the case of a first failure (see Note 2) during charging operation.

NOTE 1 Potential ignition sources are

- electrical contacts,
- brake pads,
- fuse links,
- electrostatic discharges,
- contact brushes,
- cigarettes, open flames, lights, etc.

NOTE 2 A first failure can be

- a failing ventilation device (inside the vehicle),
- damage to the charger,
- release of traction battery connection terminal,
- disconnection of exhaust gas tubing, etc.

7.3.2.2 Hydrogen when driving the vehicle

When driving the vehicle, and until internationally accepted test methods are developed, measurement of the hydrogen concentration is recommended inside the vehicle.

During the measurement, the recorded values of hydrogen concentration shall be

- less than 1 % by volume at normal driving operation, and
- less than 2 % by volume or according to national standards or regulations in the case of first failure during driving.

7.3.2.3 Measurement and requirements for other gases

Measurement and requirements for other gases will be specified in a future revision of this part of ISO 6469.

7.4 Hazardous substances

Under normal conditions, no hazardous substances shall escape from the traction battery in potentially dangerous quantities.

In the event of an accident or other failure condition where higher quantities may be released, the consequences of this shall be reduced to a minimum. Special care shall be taken in respect of the passenger compartment.

8 Traction battery over-current interruption

8.1 Function

A traction battery over-current interruption device shall open the traction battery circuit under conditions specified by the vehicle manufacturer.

8.2 Requirements

The traction battery over-current interruption device shall be able to open the electrical circuit or circuits connected to the terminals of the traction battery pack in the cases of

— an over-current specified by the vehicle manufacturer, and

— a short-circuit within the circuits connected to the traction battery.

The traction battery over-current interruption device shall operate in all cases of failure, including a failure of the on-board energy source.

The response time of the traction battery over-current interruption device shall be selected by the vehicle manufacturer to prevent dangerous effects for persons, vehicle and environment.

9 Specific on-board energy storage crash requirements

9.1 General

Any crash tests performed shall be in accordance with the test requirements of applicable national and/or international standards or regulations.

9.2 Protection of occupants

In a crash, the following requirements and those of 7.4 shall be met.

a) If the traction battery or traction battery packs is/are located outside the passenger compartment, no traction battery or traction battery pack components (battery modules, electrolyte) shall penetrate into the passenger compartment.

b) If the traction battery or traction battery packs is/are located inside the passenger compartment, movement of the traction battery or traction battery packs shall be limited to ensure the safety of the occupants.

c) For aqueous batteries, not more than 5 l of electrolyte shall be spilled during tests according to 9.1.

d) No spilled electrolyte shall enter the passenger compartment during and after tests according to 9.1.

9.3 Protection of a third party

The traction battery, traction battery packs and their components (traction battery modules, electrolyte) shall not be ejected from the vehicle due to a crash corresponding to the tests according to 9.1.

9.4 Protection against short-circuit

In case of a crash corresponding to the tests according to 9.1, the power system shall be protected against effects of a short-circuit. Traction battery over-current interruption devices according to clause 8 may be used to meet this requirement.

10 Safety of the traction battery in the case of a roll-over

In the case of a roll-over of the vehicle, the traction battery shall fulfil the requirements of clause 9.

Annex A
(informative)

Derivation of traction battery insulation resistance calculation

A.1 General

It has been noted that the calculation of the traction battery insulation resistance in 7.1.2 can be in error by a factor of two, i.e. the calculated value can be only one half the true value.

A review determined that this difference was due to the assumption embedded in the procedure that only a single insulation resistance "fault" will exist from traction battery to vehicle chassis (i.e. ground). The review concluded that this assumption was conservative but not necessarily true. Subsequently, it was noted that vehicles in the real world will have finite resistance from both terminals of the traction battery to ground, even in the absence of an actual fault. If these resistances are equal or nearly so (which may occur in the absence of failures), the effective insulation resistance will be twice the value calculated in 7.1.2. Thus the calculated value of insulation resistance may be in error, and this error could lead to an erroneous conclusion that the vehicle has insufficient insulation.

A.2 Derivation of traction battery insulation resistance

7.1.3 specifies a minimum level of traction battery insulation resistance of 100 Ω/V (referred to the nominal voltage of the traction battery).

This value was chosen with the following intentions.

The worst-case leakage current resulting if a person or other object completes an external circuit between the traction battery system (or "high voltage" circuit) and ground will not exceed 2 mA, as the threshold of perception below a human being has no physical sensation (see IEC 60479-1[3]).

The effective traction battery insulation resistance is thus implicitly defined as

> "that resistance that corresponds to the worst case current that would flow if a short circuit were arbitrarily introduced from some point in the traction battery circuit to ground".

This definition is reasonable if compared to the obvious cases.

a) If the traction battery is perfectly insulated, shorting any point to ground causes no current flow, thus the insulation resistance is "infinite".

b) If the traction battery is already shorted to chassis at one end, the current which would flow through an external circuit to ground is limited only by the external resistance, and the insulation resistance is zero.

c) If there are equal leakage resistances from both traction battery terminals, shorting one end externally would result in a current determined by the resistance at the other end, which is thus the insulation resistance.

Real traction batteries do, in fact, have finite resistance from both terminals to ground. (They may also have leakage paths from points within the traction battery to ground. However, such internal resistances tend to lower the maximum voltage to ground which is accessible in an external circuit, and are not treated here.) The insulation resistance equations in 7.1.2 are derived here using a circuit model which includes resistances from both ends of the traction battery as shown in Figures 2 to 5 and A.1 and A.2. These have been designated as R_{i1} and R_{i2}, because in general they cannot be assumed to be equal. (This is particularly true in the event that a fault occurs.) For the circuit shown in Figure A.1, the insulation resistance is necessarily equal to the smaller of R_{i1} and R_{i2}, because the smaller of the two resistances would allow higher current to flow through the external circuit connected from the opposite end of the traction battery to ground.

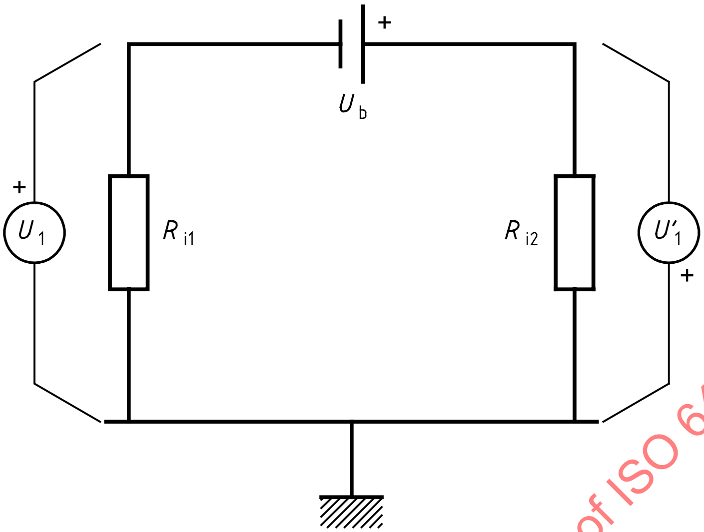


Figure A.1 — Resistances between traction battery and ground

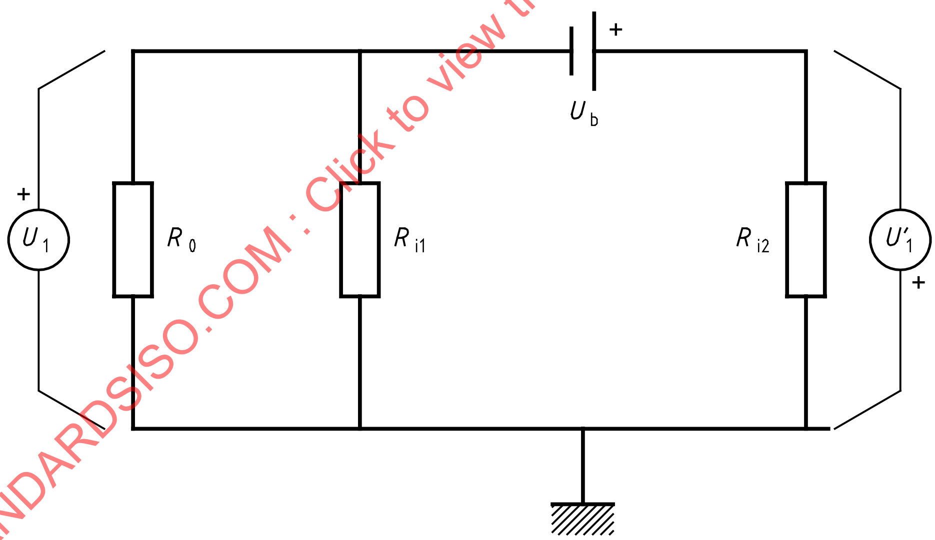


Figure A.2 — Case where $U_1 \geqslant U'_1$

The values of R_{i1} and R_{i2} can be derived using the same measurements specified in 7.1.2, provided the following assumptions are made.

a) Initial voltage measurements U_1 and U'_1 are made with the meter connected as shown in Figure A.1, so that both U_1 and U'_1 are positive. (This is not actually necessary, but it somewhat simplifies the algebra by avoiding the need to use absolute values.)

b) The sum of U_1 and U'_1 is equal to traction battery voltage U_b. The calculations may not be valid in any event, if this is not true, because insulation resistance comparable to the high meter resistance (or the traction battery string is no longer intact) is implied.

c) Meter resistance is sufficiently high that it can be neglected. (This is generally assumed, and the 10 MΩ requirement assures it.)

Given these assumptions, the procedure now addresses two cases, where either

1) U_1 is greater than or equal to U_1', or

2) U_1' is greater than U_1.

Because of the symmetry of the circuit, the resulting equations are also symmetric and only one of the two cases needs to be considered here.

For case 1) ($U_1 \geqslant U_1'$), the procedure then inserts a known resistance, R_0, between the negative side of the traction battery and ground. This is shown in Figure A.2.

A third measurement, U_2, is then made with the known resistance in the circuit. The value of insulation resistance can now be determined from the values of the three measurements and the known resistance. Note that the value of insulation resistance is the value of R_{i2}, because $U_1 \geqslant U_1'$ necessarily means $R_{i1} \geqslant R_{i2}$.

Skipping over the somewhat tedious derivation, the resulting value for insulation resistance is found to be

$$R_{i2} = R_0 \left(1 + \frac{U_1'}{U_1}\right) \frac{U_1 - U_2}{U_2}$$

Note that if $U_1 \gg U_1'$, which corresponds to the "single fault" assumption in the calculation of 7.1.2, in the limit this equation reduces to the one specified:

$$R_i = R_0 \frac{U_1 - U_2}{U_2}$$

Further, if the two resistances R_{i1} and R_{i2} are equal (the case where an actual fault does not exist), then U_1 and U_1' are also equal and the equation reduces to

$$R_i = 2R_0 \frac{U_1 - U_2}{U_2}$$

In the general case, the true value of insulation resistance may lie somewhere between these two values.

In summary, generalizing the insulation resistance calculations in 7.1.2 as is done for case 1 and case 2, below, is appropriate for the following reasons.

a) It avoids the possibility that a vehicle with marginal but adequate isolation resistance might fail the test because the equations are not quite accurate.

b) It accounts for both the conditions where no fault has occurred (where the resistances from both ends of the traction battery are likely to be similar) and the case where an actual fault results in a much lower resistance from one end of the traction battery to ground.

c) It requires only one new assumption ($U_1 + U_1' = U_b$), which is loosely assumed by the procedure already. (The equations should still work if this is only approximately true).

The resulting equations would be as follows.

Case 1 ($U_1 \geqslant U_1'$):

$$R_i = \left(1 + \frac{U_1'}{U_1}\right) \frac{U_1 - U_2}{U_2} R_0$$

