IEC 62135-1

Edition 2.0 2015-05

# INTERNATIONAL STANDARD

colour inside

## Resistance welding equipment –
## Part 1: Safety requirements for design, manufacture and installation

IEC 62135-1:2015-05(en)

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## Resistance welding equipment –
## Part 1: Safety requirements for design, manufacture and installation

INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# RESISTANCE WELDING EQUIPMENT –

# Part 1: Safety requirements for design, manufacture and installation

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International Standard IEC 62135-1 has been prepared by IEC technical committee 26: Electric welding.

This second edition cancels and replaces the first edition published in 2008. This edition constitutes a technical revision.

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

– creepage distances for pollution degree 4 are no longer valid (see Table 2);
– insulation requirements for Class II equipment are defined (see Table 3);
– dielectric test voltage interpolation restriction lower limit is changed to 220 V and interpolation for control and welding circuit is clarified (see Table 4);
– maximum temperature for insulation systems are reviewed in accordance with current edition of IEC 60085 (see Table 7);

- marking of terminals is defined (see 10.3);
- table for nominal voltages of supply networks is changed adopting Table B.2 of IEC 60664-1:2007 in place of the Table B.1 values referenced in the previous edition to provide for equipment to be connected to both earthed and unearthed systems. The change impacts the creepage and clearance distance requirements for some supply voltage ratings (see Annex A);
- touch current in fault condition are measurement procedures are clarified (see 6.4.4 and Annex C).
- welding circuit touch current is defined (see 6.2.6);
- touch current in normal condition are clarified and moved in protection against electric shock in normal service (see 6.3.7);
- heating test conditions are clarified (see 7.1.1);
- external surface temperature rise limitation is changed (see 7.3.2).

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

| FDIS | Report on voting |
|---|---|
| 26/558/FDIS | 26/570/RVD |

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The list of all the parts of the IEC 62135 series, under the general title *Resistance welding equipment,* can be found on the IEC website.

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

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

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# RESISTANCE WELDING EQUIPMENT –

# Part 1: Safety requirements for design, manufacture and installation

## 1 Scope

This part of IEC 62135 applies to equipment for resistance welding and allied processes and includes single and multiple welding stations which may be manually or automatically loaded and/or started.

This part of IEC 62135 covers stationary and portable equipment.

This part of IEC 62135 specifies electrical safety requirements for design, manufacture and installation. It does not cover all non-electrical safety requirements (e.g. noise, vibration).

This part of IEC 62135 does not include electromagnetic compatibility (EMC) requirements, which are included in IEC 62135-2.

To comply with this standard, all safety risks involved in loading, feeding, operating and unloading the equipment, where applicable, should be assessed and the requirements of related standards should be observed.

## 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.

IEC 60204-1:2005, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-6, *Low-voltage electrical installations – Part 6: Verification*

IEC 60417-DB:2011[1], *Graphical symbols for use on equipment*

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

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

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

1 “DB” refers to the IEC on-line database.

IEC 60664-3, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

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

ISO 669, *Resistance welding – Resistance welding equipment – Mechanical and electrical requirements*

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 669, IEC 60664-1 and IEC 60204-1, as well as the following, apply.

**3.1**
**equipment for resistance welding and allied processes**
equipment associated with carrying out the processes of resistance welding or allied processes consisting of, for example, power source, electrodes, tooling and associated control equipment

Note 1 to entry: It may be a separate unit or part of a complex machine.

Note 2 to entry: The term "resistance welding equipment" is used in the following text.

**3.2**
**processes allied to resistance welding**
processes carried out on machines comparable to resistance welding equipment considered as allied to resistance welding, for example, resistance brazing, soldering or heating

**3.3**
**type test**
test of one or more devices made to a given design, to check if these devices comply with the requirements of the standard concerned

[SOURCE: IEC 60050-851:2008, 851-12-05]

**3.4**
**routine test**
test made on each individual device during or after manufacture to check if it complies with the requirements of the standard concerned or the criteria specified

[SOURCE: IEC 60050-851:2008, 851-12-06]

**3.5**
**welding circuit**
conductive material through which the welding current is intended to flow

**3.6**
**control circuit**
circuit for the operational control of welding equipment, and/or for protection of the power circuits

**3.7**
**conventional value**
standardized value that is used as a measure of a parameter for the purposes of comparison, calibration, testing, etc.

Note 1 to entry: Conventional values do not necessarily apply during the actual welding process.

**3.8**
**rated value**
value assigned, generally by the manufacturer, for a specified operating condition of a component, device or equipment

**3.9**
**rating**
set of rated values and operating conditions

**3.10**
**hand-held equipment**
resistance welding equipment with built-in or external transformer, which is intended to be held in the hand during use, suspended or not

**3.11**
**portable equipment**
resistance welding equipment that is connected to the mains supply by means of a plug.

**3.12**
**stationary equipment**
resistance welding equipment permanently connected to the mains supply

**3.13**
**material group**
materials are separated into four groups by their comparative tracking index (CTI) values

Note 1 to entry: The groups are as follows:

| | | | | | |
|---|---|---|---|---|---|
| Material group I | 600 | ≤ | CTI | | |
| Material group II | 400 | ≤ | CTI | < | 600 |
| Material group IIIa | 175 | ≤ | CTI | < | 400 |
| Material group IIIb | 100 | ≤ | CTI | < | 175 |

The CTI values above refer to values in accordance with IEC 60112.

Note 2 to entry: For inorganic insulating materials, for example, glass or ceramics, which do not track, creepage distances need not be greater than their associated clearance for the purpose of insulation coordination.

**3.14**
**thermal equilibrium**
state reached when the observed temperature rise of any part of the welding equipment does not exceed 2 K/h

**3.15**
**thermal protection**
system intended to ensure the protection of all or part of the welding equipment against excessive temperatures resulting from certain conditions of thermal overload

Note 1 to entry: It is capable of being reset (either manually or automatically) when the temperature falls to the reset value.

**3.16**
**supply circuit**
**input circuit**
conductive material of the power source through which the supply current is intended to flow

**3.17**
**general visual inspection**
inspection by eye to verify that there are no apparent discrepancies with respect to provisions of the standard concerned

**3.18**
**working voltage**
highest r.m.s. value of the a.c. or d.c. voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

Note 1 to entry: Transients are disregarded.

Note 2 to entry: Both open-circuit conditions and normal operating conditions are taken into account.

## 4 Environmental conditions

Resistance welding equipment intended for indoor use and complying with this standard shall be safe to operate when the following environmental conditions prevail:

a) range of ambient air temperature:
   during operation: 5 °C to 40 °C;
b) relative humidity of the air:
   up to 50 % at 40 °C;
   up to 90 % at 20 °C.
c) ambient air, free from abnormal amounts of dust, acids, corrosive gases or substances etc. other than those generated by the welding process.
d) altitude above sea-level up to 1 000 m;
e) temperature of the cooling medium does not exceed:
   1) in the case of a liquid: 30 °C at the inlet;
   2) in the case of the ambient air: 40 °C.

NOTE Different environmental conditions can be agreed upon between the manufacturer and the purchaser and the resulting welding equipment is marked accordingly. Examples of these conditions are: outdoor use, different altitude, different temperature of cooling medium, high humidity, unusually corrosive fumes, steam, excessive oil vapour, abnormal vibration or shock, excessive dust, unusual sea coast or shipboard conditions.

## 5 Tests

### 5.1 Test condition

The tests shall be carried out on new, dry and completely assembled resistance welding equipment at an ambient air temperature between 10 °C and 40 °C. It is recommended that the thermal tests be carried out at 40 °C. Liquid-cooled resistance welding equipment shall be tested with liquid conditions as specified by the manufacturer.

### 5.2 Measuring instruments

The accuracy of measuring instruments shall be as follows.

a) electrical measuring instruments: class 1 (±1 % of full-scale reading), except for the measurement of insulation resistance and dielectric strength where the accuracy of the instruments is not specified, but shall be taken into account for the measurement;

b) instruments for measuring welding current: class 5;

c) temperature measuring instruments: ±2 K.

### 5.3 Type tests

Unless otherwise specified, the tests in this standard are type tests.

The resistance welding equipment shall be tested with all ancillary equipment fitted that could affect the test results.

All type tests shall be carried out on the same resistance welding equipment except where it is specified that a test may be carried out on another resistance welding equipment.

As a condition of conformity, the type tests given below shall be carried out in the following sequence:

a) general visual inspection, see 3.17;

b) insulation resistance, see 6.2.4 (preliminary check);

c) protection provided by the enclosure, see 6.3.3;

d) insulation resistance, see 6.2.4;

e) dielectric strength, see 6.2.5;

f) general visual inspection, see 3.17.

The other tests included in this standard and not listed here may be carried out in any convenient sequence.

### 5.4 Routine tests

All routine tests shall be carried out on each resistance welding equipment. The following sequence is recommended:

a) general visual inspection, see 3.17;

b) continuity of the protective circuit, see 6.4.7;

c) dielectric strength, see 6.2.5;

d) no-load voltage, see 6.3.2;

e) test to ensure rated minimum and maximum output values in accordance with ISO 669;

f) general visual inspection, see 3.17.

## 6 Protection against electric shock

### 6.1 General

Hazardous-live-parts shall not be accessible and accessible conductive parts shall not be hazardous live

– either under normal conditions (operation in intended use, and absence of a fault); or
– under single-fault conditions.

The requirements for provisions for normal conditions protection are given in 6.3.

The requirements for provisions for fault condition protection are given in 6.4.

## 6.2 Insulation

### 6.2.1 General

The majority of resistance welding equipment falls within overvoltage category III in accordance with IEC 60664-1. All resistance welding equipments shall be designed for use in environmental conditions of pollution degree 3 as a minimum.

Design of liquid cooled equipment shall consider possible condensation which may require different conditions.

Components or subassemblies with clearances or creepage distances corresponding to pollution degree 2 are permitted, if they are completely coated, potted or moulded in accordance with IEC 60664-3.

An equipment designed with insulation based on line-to-neutral voltage values shall be provided with a caution that such equipment shall only be used on a supply system that is either a three-phase, four-wire system with an earthed neutral or a single-phase, three-wire, system with an earthed neutral.

### 6.2.2 Clearances

For basic insulation or supplementary and reinforced insulation, minimum clearances shall be in accordance with IEC 60664-1, as partially summarized in Table 1 for overvoltage category III.

**Table 1 – Minimum clearances for overvoltage category III**

<table>
<tr><th rowspan="3">Voltage[a]</th><th colspan="5">Basic or supplementary insulation</th><th colspan="5">Reinforced insulation</th></tr>
<tr><th rowspan="2">Rated impulse test voltage</th><th rowspan="2">AC test voltage</th><th colspan="3">Pollution degree</th><th rowspan="2">Rated impulse test voltage</th><th rowspan="2">AC test voltage</th><th colspan="3">Pollution degree</th></tr>
<tr><th>2</th><th>3</th><th>4</th><th>2</th><th>3</th><th>4</th></tr>
<tr><th></th><th></th><th></th><th colspan="3">Clearance</th><th></th><th></th><th colspan="3">Clearance</th></tr>
<tr><td>V r.m.s.</td><td>Peak V</td><td>V r.m.s.</td><td colspan="3">mm</td><td>Peak V</td><td>V r.m.s.</td><td colspan="3">mm</td></tr>
<tr><td>50</td><td>800</td><td>566</td><td>0,2</td><td rowspan="2">0,8</td><td rowspan="3">1,6</td><td>1 500</td><td>1 061</td><td>0,5</td><td>0,8</td><td rowspan="2">1,6</td></tr>
<tr><td>100</td><td>1 500</td><td>1 061</td><td>0,5</td><td>2 500</td><td>1 768</td><td colspan="2">1,5</td></tr>
<tr><td>150</td><td>2 500</td><td>1 768</td><td colspan="2">1,5</td><td>4 000</td><td>2 828</td><td colspan="3">3</td></tr>
<tr><td>300</td><td>4 000</td><td>2 828</td><td colspan="3">3</td><td>6 000</td><td>4 243</td><td colspan="3">5,5</td></tr>
<tr><td>600</td><td>6 000</td><td>4 243</td><td colspan="3">5,5</td><td>8 000</td><td>5 657</td><td colspan="3">8</td></tr>
<tr><td>1 000</td><td>8 000</td><td>5 657</td><td colspan="3">8</td><td>12 000</td><td>8 485</td><td colspan="3">14</td></tr>
<tr><td colspan="11">NOTE 1 Values taken from Tables F.1 and F.2 of IEC 60664-1:2007.<br>NOTE 2 For other pollution degrees and overvoltage categories, see IEC 60664-1.</td></tr>
<tr><td colspan="11">[a] See Annex A for voltage value.</td></tr>
</table>

For dimensioning clearances to accessible non-conductive surfaces, such surfaces shall be considered to be covered by metal foil wherever they can be touched by the standard test finger in accordance with IEC 60529.

Clearances shall not be interpolated.

For supply circuit terminals, see Annex B.

Clearances between parts of resistance welding equipment (for example, circuits or components) which are protected by an overvoltage limiting device (for example, oxide varistor) may be rated in accordance with overvoltage category I (see IEC 60664-1).

The values of Table 1 shall also apply to control circuits when separated from the supply circuit, for example, by a transformer.

If the control circuit is connected direct to the supply circuit, the values for the supply voltage shall apply.

*Conformity shall be checked by measurement in accordance with 6.2 of IEC 60664-1:2007 or where this is not possible, by submitting the welding equipment to an impulse test using the voltages given in Table 1.*

For the impulse test, a minimum of three impulses of each polarity at the voltage given in Table 1 are applied with an interval of at least 1 s between impulses using a generator with an output waveform of 1,2/50 μs and an output impedance of less than 500 Ω.

Alternatively, either an a.c. test voltage as given in Table 1 may be applied for three cycles or a ripple free d.c. voltage, the value of which is equal to the impulse voltage, may be applied three times for 10 ms, for each polarity.

The equipment shall withstand the test voltages without any flashover or breakdown.

### 6.2.3 Creepage distances

For basic insulation or supplementary insulation, minimum creepage distances shall be in accordance with IEC 60664-1, as summarized in Table 2.

Creepage distances for reinforced or double insulation shall be twice those determined for basic insulation.

For the purpose of dimensioning creepage distances to accessible surfaces of insulation material, such surfaces shall be considered to be covered by metal foil wherever they can be touched by the standard test finger in accordance with IEC 60529.

Creepage distances are given for the highest rated voltage of each line of Table 2. In the case of a lower rated voltage, interpolation is allowed.

For supply circuit terminals, see Annex B.

The values of Table 2 shall also be applicable to control circuits when separated from the supply circuit by, for example, a transformer.

A creepage distance cannot be less than the associated clearance, so the shortest possible creepage distance is equal to the required clearance.

If the control circuit is connected directly to the supply circuit, the values for the supply voltage shall apply.

*Conformity shall be checked by linear measurement in accordance with 6.2 of IEC 60664-1:2007.*

## Table 2 – Minimum creepage distances

| Working voltage | Creepage distances in millimetres | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Basic or supplementary insulation | | | | | | | | | |
| | Printed wiring material | | Pollution degree | | | | | | | |
| | Pollution degree | | | | | | | | | |
| | 1 | 2 | 1 | 2 | | | 3 | | | |
| | | | | Material group | | | Material group | | | |
| | a | b | a | I | II | III | I | II | III | |
| V r.m.s | mm | mm | mm | mm | mm | mm | mm | mm | mm | |
| 10 | 0,025 | 0,04 | 0,08 | 0,4 | 0,4 | 0,4 | 1 | 1 | 1 | |
| 12,5 | 0,025 | 0,04 | 0,09 | 0,42 | 0,42 | 0,42 | 1,05 | 1,05 | 1,05 | |
| 16 | 0,025 | 0,04 | 0,1 | 0,45 | 0,45 | 0,45 | 1,1 | 1,1 | 1,1 | |
| 20 | 0,025 | 0,04 | 0,11 | 0,48 | 0,48 | 0,48 | 1,2 | 1,2 | 1,2 | |
| 25 | 0,025 | 0,04 | 0,125 | 0,5 | 0,5 | 0,5 | 1,25 | 1,25 | 1,25 | |
| 32 | 0,025 | 0,04 | 0,14 | 0,53 | 0,53 | 0,53 | 1,3 | 1,3 | 1,3 | |
| 40 | 0,025 | 0,04 | 0,16 | 0,56 | 0,8 | 1,1 | 1,4 | 1,6 | 1,8 | |
| 50 | 0,025 | 0,04 | 0,18 | 0,6 | 0,85 | 1,2 | 1,5 | 1,7 | 1,9 | |
| 63 | 0,04 | 0,063 | 0,2 | 0,63 | 0,9 | 1,25 | 1,6 | 1,8 | 2 | |
| 80 | 0,063 | 0,1 | 0,22 | 0,67 | 0,95 | 1,3 | 1,7 | 1,9 | 2,1 | |
| 100 | 0,1 | 0,16 | 0,25 | 0,71 | 1 | 1,4 | 1,8 | 2 | 2,2 | |
| 125 | 0,16 | 0,25 | 0,28 | 0,75 | 1,05 | 1,5 | 1,9 | 2,1 | 2,4 | |
| 160 | 0,25 | 0,4 | 0,32 | 0,8 | 1,1 | 1,6 | 2 | 2,2 | 2,5 | |
| 200 | 0,4 | 0,63 | 0,42 | 1 | 1,4 | 2 | 2,5 | 2,8 | 3,2 | |
| 250 | 0,56 | 1 | 0,56 | 1,25 | 1,8 | 2,5 | 3,2 | 3,6 | 4 | |
| 320 | 0,75 | 1,6 | 0,75 | 1,6 | 2,2 | 3,2 | 4 | 4,5 | 5 | |
| 400 | 1 | 2 | 1 | 2 | 2,8 | 4 | 5 | 5,6 | 6,3 | |
| 500 | 1,3 | 2,5 | 1,3 | 2,5 | 3,6 | 5 | 6,3 | 7,1 | 8 | |
| 630 | 1,8 | 3,2 | 1,8 | 3,2 | 4,5 | 6,3 | 8 | 9 | 10 | |
| 800 | 2,4 | 4 | 2,4 | 4 | 5,6 | 8 | 10 | 11 | 12,5 | |
| 1 000 | 3,2 | 5 | 3,2 | 5 | 7,1 | 10 | 12,5 | 14 | 16 | |
| 1 250 | | | 4,2 | 6,3 | 9 | 12,5 | 16 | 18 | 20 | |
| 1 600 | | | 5,6 | 8 | 11 | 16 | 20 | 22 | 25 | |
| 2 000 | | | 7,5 | 10 | 14 | 20 | 25 | 28 | 32 | |
| 2 500 | | | 10 | 12,5 | 18 | 25 | 32 | 36 | 40 | |
| 3 200 | | | 12,5 | 16 | 22 | 32 | 40 | 45 | 50 | |
| 4 000 | | | 16 | 20 | 28 | 40 | 50 | 56 | 63 | |
| 5 000 | | | 20 | 25 | 36 | 50 | 63 | 71 | 80 | |
| 6 300 | | | 25 | 32 | 45 | 63 | 80 | 90 | 100 | |
| 8 000 | | | 32 | 40 | 56 | 80 | 100 | 110 | 125 | |
| 10 000 | | | 40 | 50 | 71 | 100 | 125 | 140 | 160 | |

NOTE In accordance with IEC 60664-1, the dimensions for creepage distance cannot be specified where permanently conductive pollution is present (Pollution degree 4).

[a] Material group I, II, IIIa and IIIb.

[b] Material group I, II and IIIa.

### 6.2.4 Insulation resistance

The insulation resistance shall be not less than the values given in Table 3.

**Table 3 – Insulation resistance**

| Measurement[a] | | | Resistance |
|---|---|---|---|
| **Supply circuit** (including control circuits connected to it) with protection provision specified in 6.4.2.2 | to | **welding circuit** (including control circuits connected to it) | 5,0 MΩ |
| **Supply circuit** (including control circuits connected to it) with protection provision different from those specified in 6.4.2.2 | to | **welding circuit** (including control circuits connected to it) | 2,5 MΩ |
| **Control circuits and exposed conductive parts** | to | **all circuits** | 2,5 MΩ |
| **Supply circuit** of Class II equipment | to | **accessible surfaces**[b] | 5,0 MΩ |
| NOTE Due to the design of resistance welding equipment, welding circuit to protective circuit resistance measurement is not required. | | | |

[a] Control circuits are tested together with the circuit to which they are galvanically connected.

[b] For measurement to accessible non-conductive surfaces, such surfaces shall be considered to be covered by metal foil.

Any control or auxiliary circuit connected to the protective conductor terminal shall be considered as an exposed conductive part for the purpose of this test.

*Conformity shall be checked by the stabilized measurement of the insulation resistance without interference suppression or protection capacitors (see 6.4.2.2) by application of a d.c. voltage of 500 V at room temperature.*

During the test, electric components that may be damaged and are not part of the insulation to be tested can be disconnected or short-circuited. Test report shall contain a list of these components with a justification of exclusion by the test.

Test is performed without cooling liquid.

### 6.2.5 Dielectric strength

The insulation shall withstand the following test voltages without any flashover or breakdown:

a) first test of a resistance welding equipment: test voltages given in Table 4;
b) repetition of the test of the same resistance welding equipment: test voltage 80 % of the values given in Table 4.

**Table 4 – Dielectric test voltages**

| **Maximum rated voltage**<br>V r.m.s. | **AC dielectric test voltage**<br>V r.m.s. | | | | |
|---|---|---|---|---|---|
| **Supply[a], welding[b] or control[b] circuits** | **All circuits to exposed conductive parts, supply circuit to all circuits except the welding circuit** | | **All circuits except supply circuit to welding circuit** | **Supply circuit to welding circuit with protection provision different from those specified in 6.4.2.2** | **Supply circuit to welding circuit with protection provision specified in 6.4.2.2** |
| | **Class I equipment** | **Class II equipment** | | | |
| Up to 50 | 250 | 500 | 500 | – | – |
| 220 | 1 100 | 2 200 | 1 100 | 1 100 | 2 200 |
| 450 | 1 875 | 3 750 | 1 875 | 1 875 | 3 750 |
| 700 | 2 500 | 5 000 | 2 500 | 2 500 | 5 000 |
| 1 000 | 2 750 | 5 500 | – | 2 750 | 5 500 |

NOTE 1 The maximum rated voltage is valid for earthed and unearthed systems.

NOTE 2 In this standard the dielectric strength test of control circuits is limited to any circuit that enters or exits the enclosure apart from the supply circuit and the welding circuit.

[a] For intermediate values, interpolation is allowed on all supply networks (supply circuit) operating outside the range of 220 V to 450 V and on all three-phase, three-wire earthed systems without voltage exemption (see Annex A).

[b] For intermediate values, interpolation is allowed on welding and control circuits.

The a.c. test voltage shall be of an approximate sine wave-form with a peak value not exceeding 1,45 times the r.m.s. value, having a frequency of approximately 50 Hz or 60 Hz.

The high-voltage transformer shall deliver the prescribed voltage up to the tripping current. Tripping is regarded as a flashover or a breakdown. The tripping current setting can be selected according to the transformer capacitive dispersion current. The maximum permissible setting of the tripping current shall be 100 mA.

For operator’s safety, the lowest setting of the tripping current (less than or equal to 10 mA) is recommended.

**Alternative test:** A d.c. test voltage of 1,4 times the r.m.s. test voltage may be used.

Components or subassemblies shall not be disconnected or short-circuited unless the conditions of a), b) or c) below are met.

a) The components or subassemblies are designed and tested to relevant standards that specify a voltage lower than the test voltage level of this standard. These components or subassemblies are not connected between supply and welding circuits and their disconnection or short-circuiting does not prevent a part of that circuit from being tested. Example: fan motors and pump motors.

b) The components or subassemblies are completely incorporated within either the supply or the welding circuit and their disconnection does not prevent a part of that circuit from being tested. Example: electronic circuits.

c) Interference suppression networks or protection capacitors between the supply or welding circuit and any exposed conductive part conform to the relevant standards.

Control circuits connected to the protective conductor terminal shall not be disconnected during testing and they are then tested as exposed conductive parts.

The test voltage may be raised to the full value slowly at the discretion of the manufacturer.

Resistance welding equipment incorporating a rectifier shall be tested after assembly of the complete resistance welding equipment, with the power rectifier remaining properly connected to the output circuit of the transformer. Rectifiers, their protective devices and other solid-state electronic components or capacitors, may be short-circuited during the test.

Liquid-cooled equipments shall be tested before being filled with the cooling liquid.

*Conformity shall be checked by application of the test voltage for*

*1) 60 s (type test);*

*2) 5 s (routine test); or*

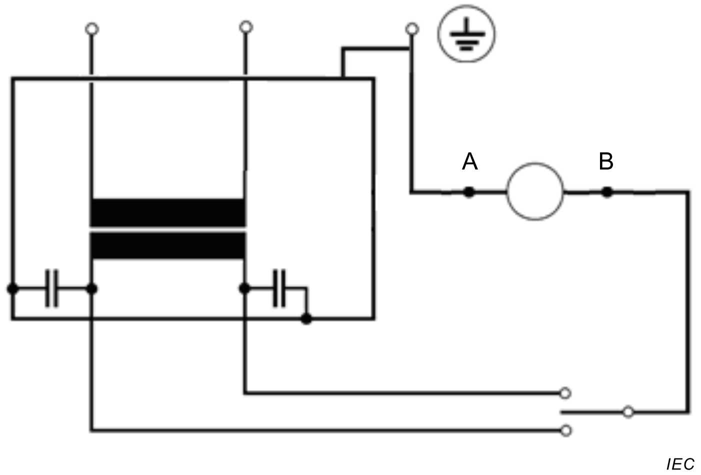
*3) 1 s (routine test with the test voltage increased by 20 %).*

### 6.2.6 Welding circuit touch current

In equipment with welding circuit insulated from the protective conductor the touch current between the welding circuit connections and the protective conductor terminal shall not exceed 14,1 mA peak.

*Conformity shall be checked by visual inspection and measurement of the touch current with a circuit as shown in Figure 1 at the rated supply voltage(s) and no-load condition.*

The measuring network specified in Figure C.1 shall be connected as shown in Figure 1.




**Key**

A, B Measuring network connections

NOTE For class II equipment, use the PE-terminal of earthed supply network.

**Figure 1 – Measurement of welding circuit touch current**

### 6.2.7 Liquid cooling

Coolant-hoses between parts of the input circuit having different polarity shall have a length of at least 0,5 m and a resistance of at least 1 MΩ/m; resistivity of the cooling liquid shall be at least 20 Ωm.

Accessible connections of a cooling-system being in contact with the input circuit shall be provided with a metal part to be connected to the protective conductor.

*Compliance is checked by visual inspection and measurement*.

### 6.3 Protection against electric shock in normal service (direct contact)

#### 6.3.1 General

Protection against electric shock in normal service shall consist of one or more provisions that under normal conditions prevent contact with hazardous-live-parts. These provisions include

- basic insulation;
- barriers or enclosures;
- limitation of voltage;
- limitation of steady-state touch current and charge.

More details may be found in IEC 61140.

#### 6.3.2 Rated no-load voltage at the output

##### 6.3.2.1 General

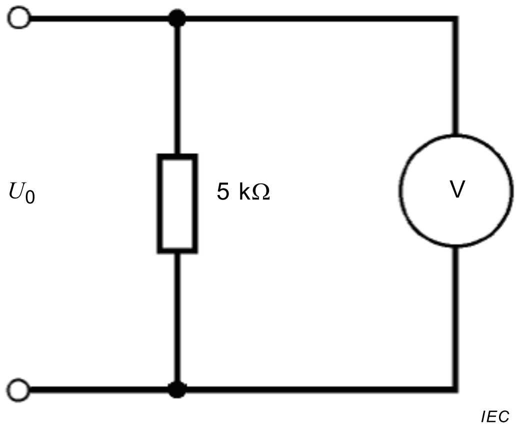
If the welding circuit is accessible during welding process and the welding power source is not fitted with a hazard reducing device in accordance with 6.3.2.3, the rated no-load voltage at the output, at all possible settings, shall not exceed 25 V a.c. r.m.s. or 60 V ripple-free d.c.

If the welding circuit is accessible during welding process and the welding power source is fitted with a hazard reducing device in accordance with 6.3.2.3, the rated no-load voltage at the output, at all possible settings, shall not exceed a.c. 68 V peak and 48 V r.m.s.

*Conformity shall be checked by measurement and by analysis of the circuit and/or by failure.*

##### 6.3.2.2 Measuring circuits

For measuring r.m.s. values, a true r.m.s. meter shall be used together with a resistor of 5 ± 5 % kΩ, connected across the welding circuit terminals as shown in Figure 2.




**Key**

$U_0$ No-load voltage

V True r.m.s. voltmeter

**Figure 2 – Measurement of rms values**

#### 6.3.2.3 Hazard reducing device

##### 6.3.2.3.1 General requirements

A hazard reducing device shall reduce the severity of the electric shock that can originate from no-load voltages exceeding a.c. 25 V.

##### 6.3.2.3.2 Voltage reducing device

A voltage reducing device shall have automatically reduced the rated no-load voltage to a level not exceeding a.c. 25 V. The operating time is 0,1 s.

*Conformity shall be checked by measuring voltage and operating time.*

##### 6.3.2.3.3 Indication of satisfactory operation

A reliable device, for example a signal lamp, shall be provided which indicates that the hazard reducing device is operating satisfactorily. Where a signal lamp is used, it shall light when the voltage has been reduced.

*Conformity shall be checked by visual inspection.*

##### 6.3.2.3.4 Fail to a safe condition

If the hazard reducing device fails to operate in accordance with 6.3.2.3.1, the voltage at the output terminals shall be reduced to a level not exceeding a.c. 25 V and shall not be reset automatically.

Conformity shall be checked by simulating a fault of the hazard reducing device and measuring the time to reach a safe condition after failure of the hazard reducing device.

### 6.3.3 Protection provided by barriers or the enclosure

Barriers or enclosures shall prevent access to hazardous-live-parts by providing an adequate degree of protection against electric shock. Barriers or enclosures shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection, taking account of all relevant influences from the environment and from inside the enclosure.

Resistance welding equipment specifically designed for indoor use shall have a minimum degree of protection of IP20 (except external welding circuit, for example, electrodes) using IEC 60529 test procedures and conditions.

Resistance welding equipment specifically designed for outdoor use shall have a minimum degree of protection of IP23 using IEC 60529 test procedures and conditions.

*Conformity shall be checked as follows.*

Welding equipment shall be subjected to the appropriate water test without being energized. Immediately after the test, the unit shall be moved to a safe environment and subjected to the insulation resistance and dielectric strength tests.

Where the design or construction allows for the removal of barriers, the opening of enclosures or the removal of parts of enclosures, access to hazardous-live-parts shall only be possible

– by the use of a key or tool;
– after isolation of hazardous-live-parts from the supply circuit where the enclosure would no longer provide protection, restoration of the supply shall become possible only after replacement of barriers or parts of enclosures or after the closing of doors;

– where an intermediate barrier still maintains the required degree of protection, such barrier being removable only by the use of a key or tool.

*Conformity shall be checked by visual inspection.*

### 6.3.4 Capacitors

A capacitor provided as part of a resistance welding equipment and connected across supply circuit shall

a) not contain more than 1 l of flammable liquid;

b) be designed not to leak during normal service;

c) be contained within the resistance welding equipment enclosure or other enclosure which conforms to the relevant requirements of this standard.

*Conformity shall be checked by visual inspection.*

Capacitors shall not cause the resistance welding equipment to exhibit hazardous electrical breakdown or present risk of fire in event of a failure.

*Conformity shall be checked by the following test.*

Capacitors are shorted before the equipment is switched on then the resistance welding equipment is operated at no-load at its rated input voltage and with an input supply fuse or circuit-breaker with a value between 120 % and 200 % of those specified in the instruction manual, with all or any of the capacitors shorted until

a) any fuse or overcurrent device in the resistance welding equipment source has operated; or

b) the supply circuit fuse or circuit-breaker has cleared; or

c) the input components of the resistance welding equipment reach a steady-state temperature, not higher than that allowed in 7.3. Any fault of electronic components (for example, primary rectifier) is not meant as a failure criteria for this test.

If any undue heating or melting becomes apparent, the resistance welding equipment shall conform to the requirements of b) and c) of 8.1.

There shall be no leakage of liquid during any of the type tests required by this standard.

For interference suppression capacitors or capacitors having internal fusing or a circuit breaker, this test is not required.

### 6.3.5 Automatic discharge of input capacitors

Each capacitor shall be provided with a means of automatic discharge which shall reduce the voltage across the capacitor to 60 V or less within the time necessary to give access to any current-carrying part connected to the capacitor or an appropriate warning label shall be used. For any plug, which has a voltage due to a capacitor, the access time is considered to be 1 s.

Capacitors having a rated capacitance not exceeding 0,1 μF are not considered to present a risk of electric shock.

*Conformity shall be checked by visual inspection and by the following test.*

The resistance welding equipment shall be tested at its highest rated supply voltage. The resistance welding equipment shall then be disconnected from the supply and the voltages are measured with instruments that do not significantly affect the values being measured.

#### 6.3.6 Protective conductor current under normal condition

The leakage current in the external protective conductor shall not exceed

a) 5 mA rms for plug-connected equipment rated up to and including 32 A;
b) 10 mA rms for plug-connected equipment rated more than 32 A;
c) 10 mA rms for equipment for permanent connection, without special measures for the protective conductor;
d) equipment for permanent connection with a reinforced protective conductor may have a leakage current up to 5 % of the rated input current per phase.

The following shall be provided for reinforced protective conductors:

– a connection terminal designed for the connection of a protective conductor measuring at least 10 $mm^2$ Cu or 16 $mm^2$ Al; or
– a second terminal designed for the connection of a protective conductor of the same cross-section as that of the normal protective conductor.

*Conformity shall be checked under the following conditions.*

The external protective conductor current shall be measured by inserting an ammeter of negligible impedance (for example, 0,5 Ω) in series with the protective conductor. Measurement of the protective conductor is made with the equipment and power distribution system running in all normal operating modes.

#### 6.3.7 Touch current in normal condition

The touch current for accessible conductive surfaces, not connected to the protective circuit, shall not exceed 0,7 mA peak under normal conditions.

Conformity shall be checked using the configurations as shown in Annex C, without simulating any fault and under the following conditions:

a) the resistance welding equipment is:
   – isolated from the ground plane;
   – supplied by the highest rated supply voltage;
b) the welding circuit is in the no-load condition;
c) interference suppression capacitors are not disconnected.

### 6.4 Protection against electric shock in case of a fault condition (indirect contact)

#### 6.4.1 General

##### 6.4.1.1 General safety measures

Protection against indirect contact is intended to prevent hazardous situations due to an insulation fault between live parts and exposed conductive parts.

For each circuit or part of electrical equipment at least one measure shall be applied. Suitable measures for the welding circuit are given in 6.4.2.2 and applicability to different type of equipment is given in 6.4.2.2 to 6.4.2.4.

For each circuit or part of the electrical equipment different from the welding circuit, at least one of the measures in accordance with 6.4.1.2 to 6.4.1.3 shall be applied:

– measures to prevent the occurrence of a touch voltage (6.4.1.2); or
– automatic disconnection of the supply before the time of contact with a touch voltage can become hazardous (6.4.1.3).

Where those recommended measures are not practicable, for example, due to the physical or operational conditions, other measures from IEC 60364-4-41 may be used.

If selected measure(s) necessitate(s) coordination with the type of supply and earthing system, the manufacturer can require power supply earthing system information from the user and design the equipment in accordance with that information (for example, using the enquiry form specified in Annex B of IEC 60204-1:2005).

The manufacturer shall specify in the instruction manual the supply earthing system(s) allowed (for example, TN/TT/IT systems) and the relevant required supply characteristics (for example, fuse, circuit-breaker, and/or RCD rating).

NOTE 1 The risk of harmful physiological effects from a touch voltage depends on the value of the touch voltage and the duration of possible exposure.

NOTE 2 For classes of equipment and protective provisions, see IEC 61140.

#### 6.4.1.2 Prevention of the occurrence of a touch voltage

Measures to prevent the occurrence of a touch voltage include the following:

– provision of class II equipment or by equivalent insulation;
– electrical separation.

Protection by provision of class II equipment or by equivalent insulation is intended to prevent the occurrence of touch voltages on the accessible parts through a fault in the basic insulation. This protection is provided by one or more of the following:

– class II electrical devices or apparatus (double insulation, reinforced insulation or by equivalent insulation in accordance with IEC 61140);
– switchgear and controlgear assemblies having total insulation;
– supplementary or reinforced insulation in accordance with 413.2 of IEC 60364-4-41:2005.

Protection by electrical separation is intended to prevent a touch voltage through contact with exposed conductive parts that can be energized by a fault in the basic insulation of the live parts of that circuit. For this type of protection, the requirements of IEC 60364-4-41 apply.

#### 6.4.1.3 Protection by automatic disconnection of supply

This measure consists of the interruption of one or more of the line conductors by the automatic operation of a protective device in case of a fault. This interruption shall occur within a sufficiently short time to limit the duration of a touch voltage to a time within which the touch voltage is not hazardous. Interruption times are given in IEC 60364-4-41.

This measure necessitates co-ordination between

– the type of supply and earthing system;
– the impedance values of the different elements of the protective bonding system;
– the characteristics of the protective devices that detect insulation fault(s);
– the characteristics of fault current (for example, wave shape, frequency content).

Automatic disconnection of the supply of any circuit affected by an insulation fault is intended to prevent a hazardous situation resulting from a touch voltage.

This protective measure comprises both:

– protective bonding of exposed conductive parts;
– and either:

a) overcurrent protective devices for the automatic disconnection of the supply on detection of an insulation fault in TN systems; or
b) residual current protective devices to initiate the automatic disconnection of the supply on detection of an insulation fault from a live part to exposed conductive parts or to earth in TT systems, or
c) insulation monitoring or residual current protective devices to initiate automatic disconnection of IT systems. Except where a protective device is provided to interrupt the supply in the case of the first earth fault, an insulation monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. This insulation monitoring device shall initiate an audible and/or visual signal which shall continue as long as the fault persists.

NOTE In large machines, the provision of an earth fault location system can facilitate maintenance.

Where automatic disconnection is provided in accordance with a), and disconnection within the time specified in IEC 60364-4-41 cannot be assured, supplementary bonding shall be provided to prevent a prospective touch voltage from exceeding 50 V a.c. or 120 V ripple-free d.c. between simultaneously accessible conductive parts.

In the event of failure, the protective device shall operate to isolate the equipment from the power supply within the time specified in IEC 60364-4-41. Depending on the selected provision, the disconnecting device can be incorporated in the equipment by the manufacturer or provided at the installation. The selection of appropriate disconnecting device type and its characteristics is determined from both equipment parameters (fault current characteristics, equipment additional fault loop impedance) and installation parameters (for example, earthing system type, fault loop impedance, earth connection resistance, etc). If the disconnecting device is not incorporated in the equipment but provided at installation, the manufacturer shall specify to the user appropriate information to allow proper selection (for example, required RCD type, maximum earth connection resistance, information on the equipment additional fault loop impedance, etc.).

### 6.4.2 Protective provisions for welding circuit

#### 6.4.2.1 General

To provide protection in the case of failure between input and the output circuits, in contact with the workpieces, one of the provisions described in 6.4.2.2 to 6.4.2.11 shall be adopted. Connection of the protective conductor to the transformer core or frame is required when these parts are accessible by the operator.

The provisions described in 6.4.2.4 to 6.4.2.10 are based on automatic disconnection of the supply (see 6.4.1.3).

If the welding circuit is connected direct to ground (i.e., 6.4.2.4 is applied), execution of the welding process on non-insulated workpieces can generate a current circulation in the protective conductor. Amplitude of this current depends on many factors, for example, including the type of welding current (i.e., a.c. or d.c.), the value of the secondary voltage, the impedance or resistance of the installation protective conductors path where the current circulates. As this stray current can endanger the integrity of the protective conductor, the manufacturer shall inform the user of the equipment under which provisions the equipment is suitable for the welding of non-insulated workpieces without suffering from this danger (for example, installation and verification requirement).

For indirect multi-spot welding with protective provisions according to 6.4.2.3 to 6.4.2.9, the work-piece and backing electrodes shall be insulated from the protective conductor if excessive ground currents likely to endanger the integrity of the protective conductor cannot be avoided.

#### 6.4.2.2 Double or reinforced isolation of the welding circuit

The welding circuit shall be electrically isolated from the supply circuit, and from all other circuits having a voltage higher than the allowable no-load voltage in accordance with 6.3.2 (for example, auxiliary power supply circuits), by double or reinforced insulation in accordance with 6.3.

Between the welding circuit and input circuit (including transformer windings) there shall be insulating material which conforms to the values given in Table 5.

**Table 5 – Minimum distance through insulation**

| **Rated supply voltage** V r.m.s. | | | **Minimum distance through insulation** mm | |
|---|---|---|---|---|
| | | | **Single layer** | **Total of three or more separate layers** |
| Up | to | 440 | 1,3 | 0,35 |
| 441 | to | 690 | 1,5 | 0,4 |
| 691 | to | 1 000 | 2,0 | 0,5 |

NOTE Requirements given in Table 5 are not applicable to equipment with a secondary circuit connected to the protective conductor or where other provisions from 6.4.2.3 to 6.4.2.9 are employed.

If transformer metallic parts are insulated from ground,

– the welding circuit shall be electrically isolated from the transformer metallic parts by double or reinforced insulation in accordance with 6.3 determined by the supply circuit working voltage; or

– the supply circuit shall be electrically isolated from the transformer metallic parts by double or reinforced insulation in accordance with 6.3.

If another circuit is connected to the welding circuit, the power of the other circuit shall be supplied by a safety isolating transformer or equivalent means.

If the welding circuit is not connected to the protective conductor, the touch current between the welding outlets and the protective conductor terminal shall not exceed 14 mA peak.

*Conformity shall be checked by measurement according to 6.2.6.*

#### 6.4.2.3 Metal screen between windings of the supply circuit and the welding circuit

Windings of the supply circuit and the welding circuit shall be insulated by basic insulation to a metal screen between them which is connected to the protective conductor. An example of the structure is shown in Figure 3.

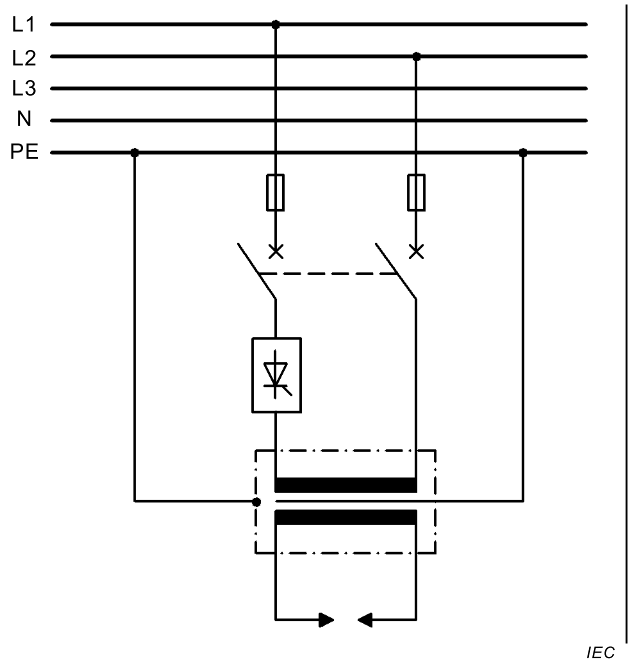



**Figure 3 – Example of metal screen between windings of the supply circuit and the welding circuit**

The thickness of the insulation between each winding and the screen shall be at least half the values given in Table 5.

If transformer metallic parts are insulated from ground,

– the welding circuit shall be electrically isolated from the transformer metallic parts by double or reinforced insulation in accordance with 6.3 determined by the supply-circuit working voltage; or
– the supply circuit shall be electrically isolated from the transformer metallic parts by double or reinforced insulation in accordance with 6.3.

If another circuit is connected to the welding circuit, the power of the other circuit shall be supplied by a safety isolating transformer or equivalent means.

If the welding circuit is not connected to the protective conductor, the leakage current between the welding outlets and the protective conductor terminal shall not exceed 10 mA a.c. r.m.s.

*Conformity shall be checked by visual inspection and by measurement according to 6.4.2.2.*

#### 6.4.2.4 Protective conductor connected direct to welding circuits

If workpieces are not insulated from the protective conductor, the integrity of the mains supply systems protective conductor should observed.

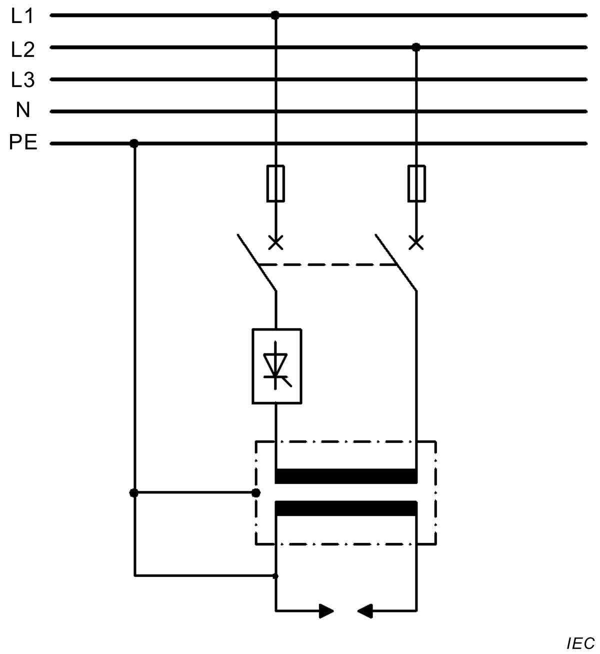



**Figure 4 – Example of protective conductor connected directly to the welding circuit (single-spot, a.c. current equipment)**

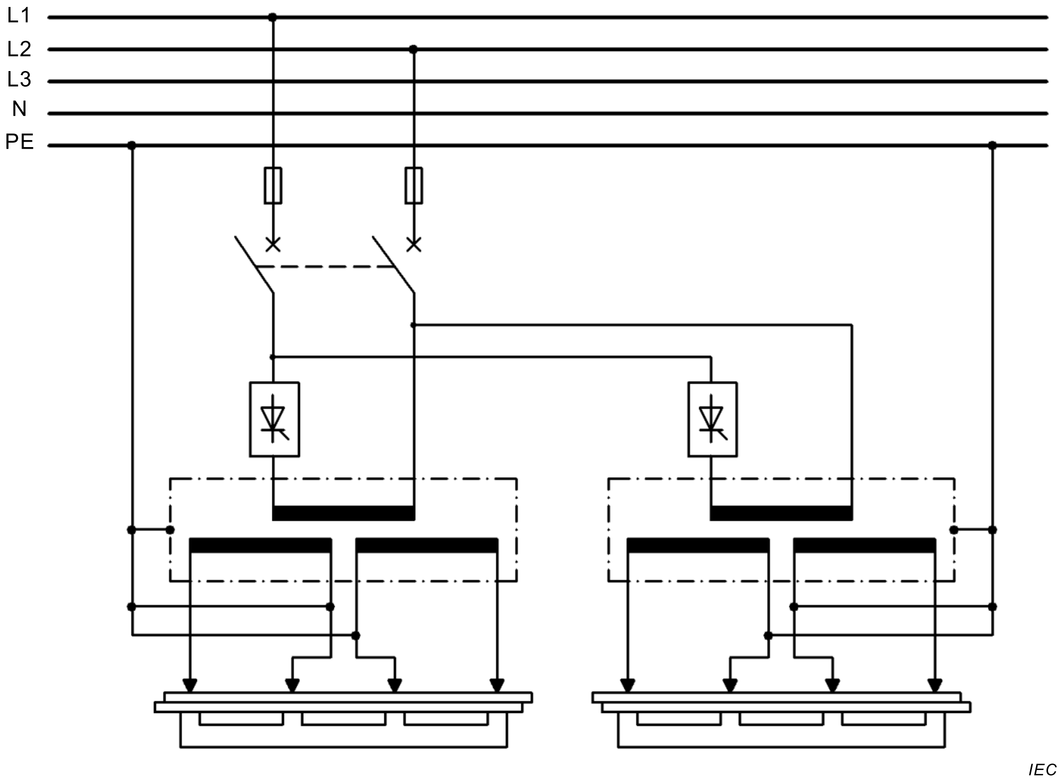
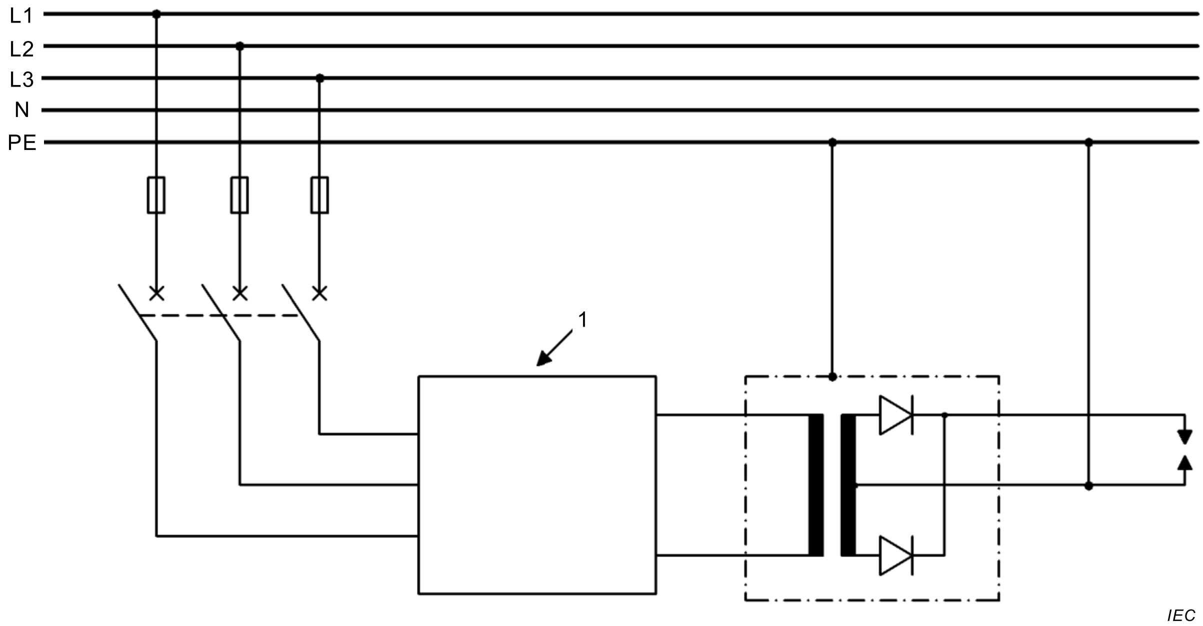



**Figure 5 – Example of protective conductor connected directly to welding circuits (multi-spot, a.c. current equipment)**




**Key**

1 Inverter

**Figure 6 – Example of protective conductor connected directly to welding circuits (medium-frequency equipment)**

Each output circuit including the winding shall be connected direct to the protective conductor according to Figures 4, 5 and 6, unless it causes excessive circulation currents in the protective conductor.

If excessive circulation currents appear, one of the measures complying with 6.4.2.5 to 6.4.2.8 can be used.

*Conformity shall be checked by visual inspection and operation.*

#### 6.4.2.5 Protective conductor connected through impedance

Each output circuit including the winding shall be permanently connected to the protective conductor by an impedance, according to Figure 7, to limit circulation currents.

The impedance shall be so designed that, in the case of failure, the protective device for the input circuit, provided at installation, operates within the time specified in IEC 60364-4-41.

NOTE The impedance while reducing the welding current circulating on the protective conductor under normal conditions also reduces the fault current. While this impedance in TT earthing systems can be negligible, in TN earthing systems the additional impedance can avoid proper operation of overcurrent disconnecting devices (i.e., times specified in IEC 60364-4-41 can be not fulfilled).

The protective impedance device shall withstand the thermal and electric stresses occurring during the failure before the protective device operates.

*Conformity shall be checked by visual inspection and according to IEC 60364-6.*

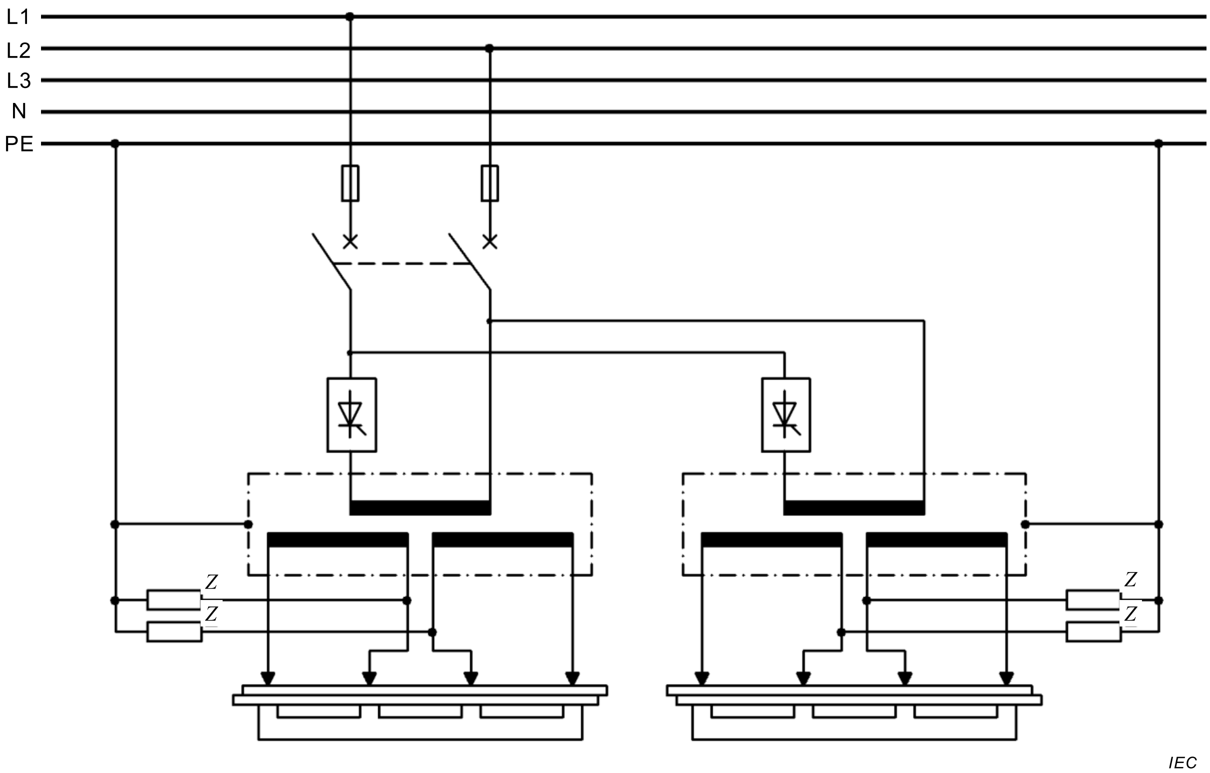



**Figure 7 – Example of protective conductor connected to welding circuits through impedances**

### 6.4.2.6 Protective conductor connected through auto-inductances

Each output circuit including the winding shall be permanently connected to the protective conductor by a saturable auto-inductance, according to Figure 8 or Figure 9, to limit circulation-currents.

The impedance shall be so designed that, in the case of a failure, the protective device for the input circuit, provided at installation, operates within the time specified in IEC 60364-4-41.

NOTE The impedance while reducing the welding current circulating on the protective conductor under normal condition also reduces the fault current. While this impedance in TT earthing systems can be negligible, in TN earthing systems the additional impedance can avoid proper operation of overcurrent disconnecting devices (i.e., times specified in IEC 60364-4-41 can be not fulfilled).

The protective impedance device shall withstand the thermal and electric stresses occurring during the failure before the protective device operates.

*Conformity shall be checked by visual inspection and according to IEC 60364-6.*

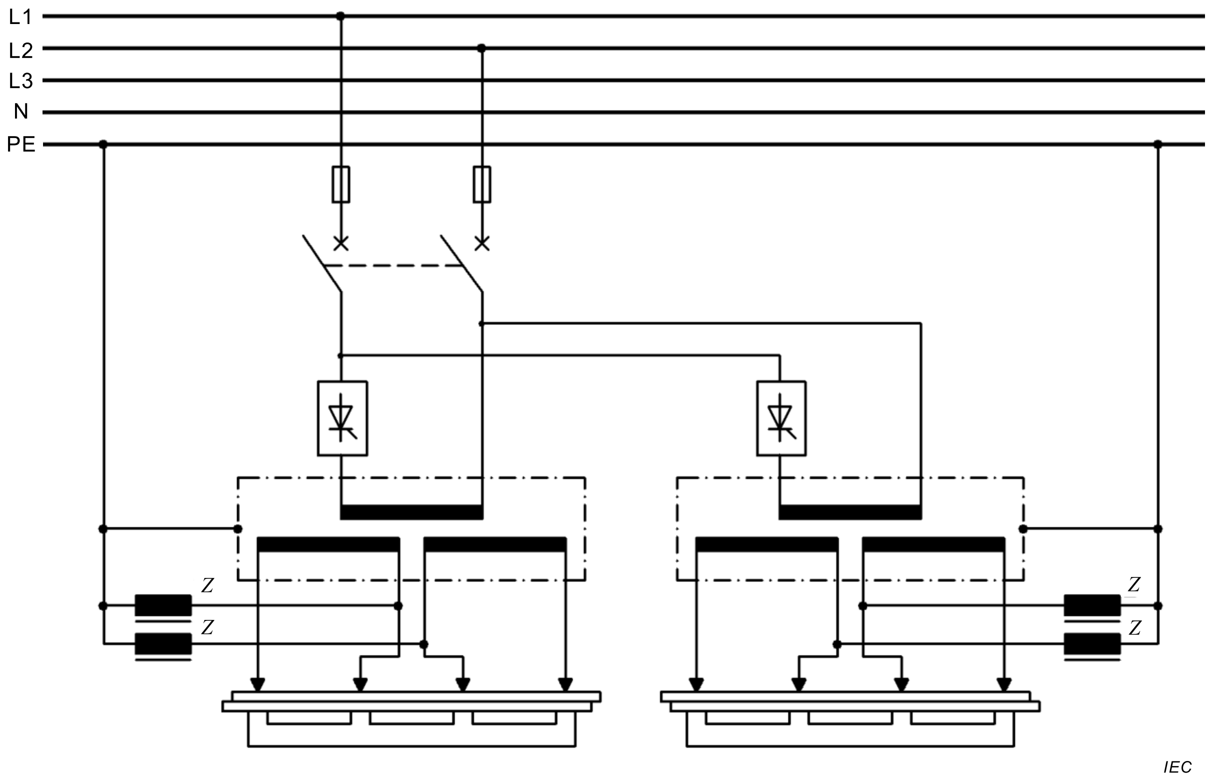



**Figure 8 – Example of protective conductor connected to welding circuits through auto-inductances**

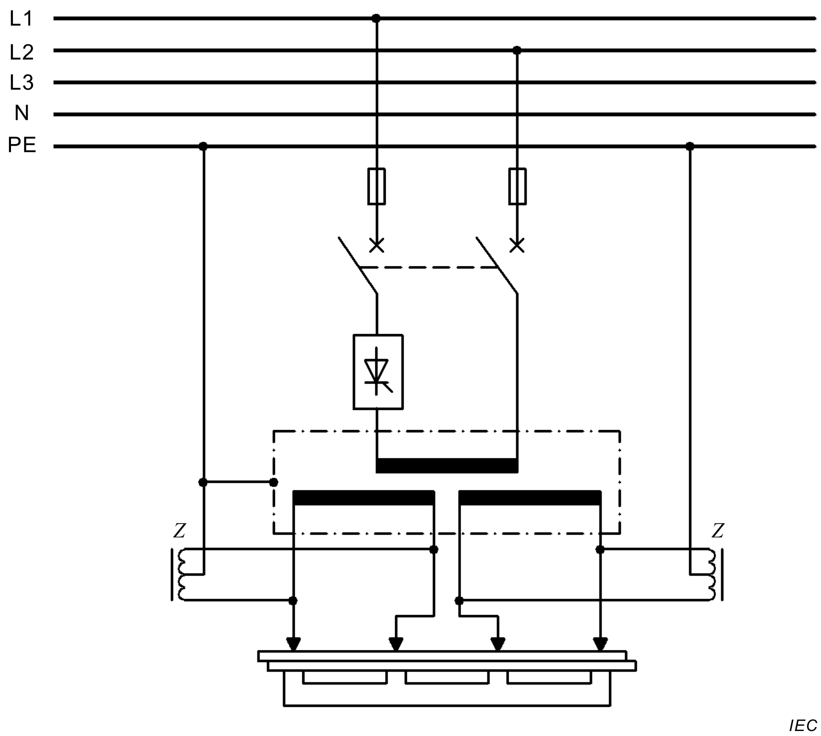



**Figure 9 – Example of protective conductor connected to welding circuits through auto-inductances**

#### 6.4.2.7 Current operated residual current device

Each output winding shall be permanently connected to the protective conductor direct or by means of a suitable resistance according to Figure 10 or Figure 11.

The installed residual current device (RCD) shall be an integral part of the equipment. An additional RCD shall be installed in the supply line.

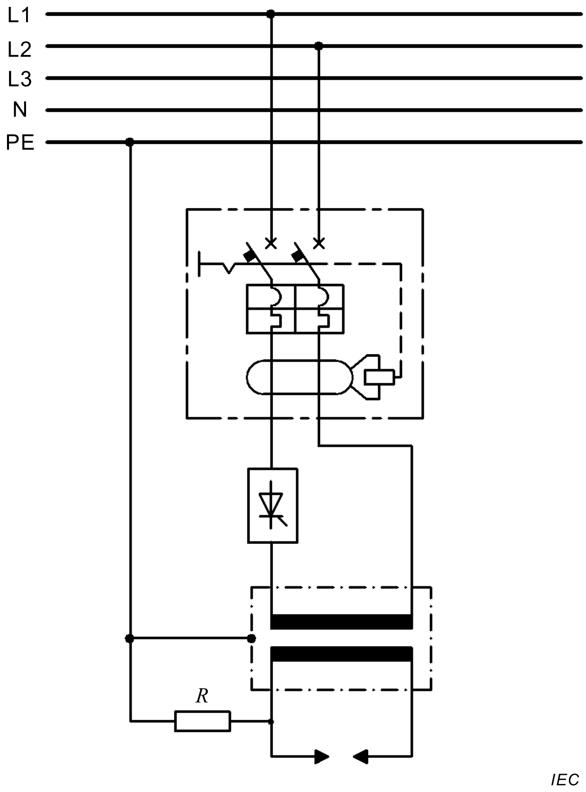
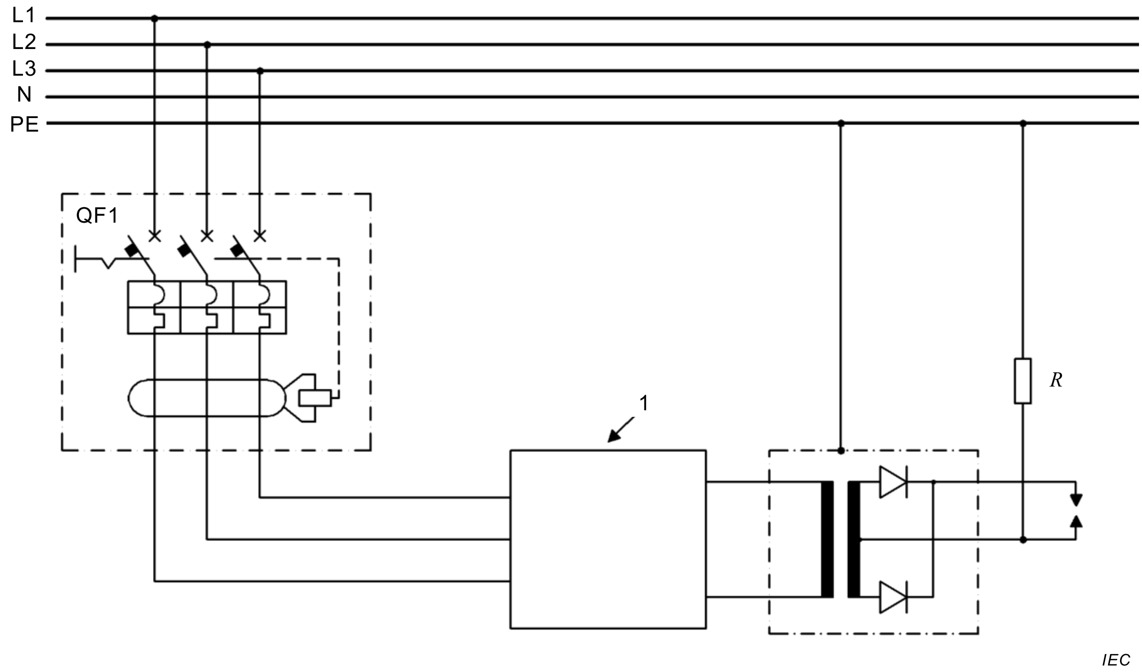



**Figure 10 – Example of current operated RCD (a.c. current equipment)**




**Key**

1 Inverter

**Figure 11 – Example of current operated RCD (medium-frequency equipment)**

RCD type selection shall take care of the possible fault current waveform.

RCD sensitivity selection requires coordination with the installation earth connection; this may be achieved by

– previous measurement in the installation place; or
– requirement in the instruction manual of a maximum allowed value of earth connection resistance; or
– use of a high-sensitivity RCD with a maximum $I_{\Delta n}$ value of 30 mA.

Resistance shall be dimensioned to allow RCD operation for every set-up of the equipment within the time specified in IEC 60364-4-41. The resistance shall withstand the thermal and electric stresses occurring during the failure before the RCD operates.

*Conformity shall be checked by visual inspection and operation.*

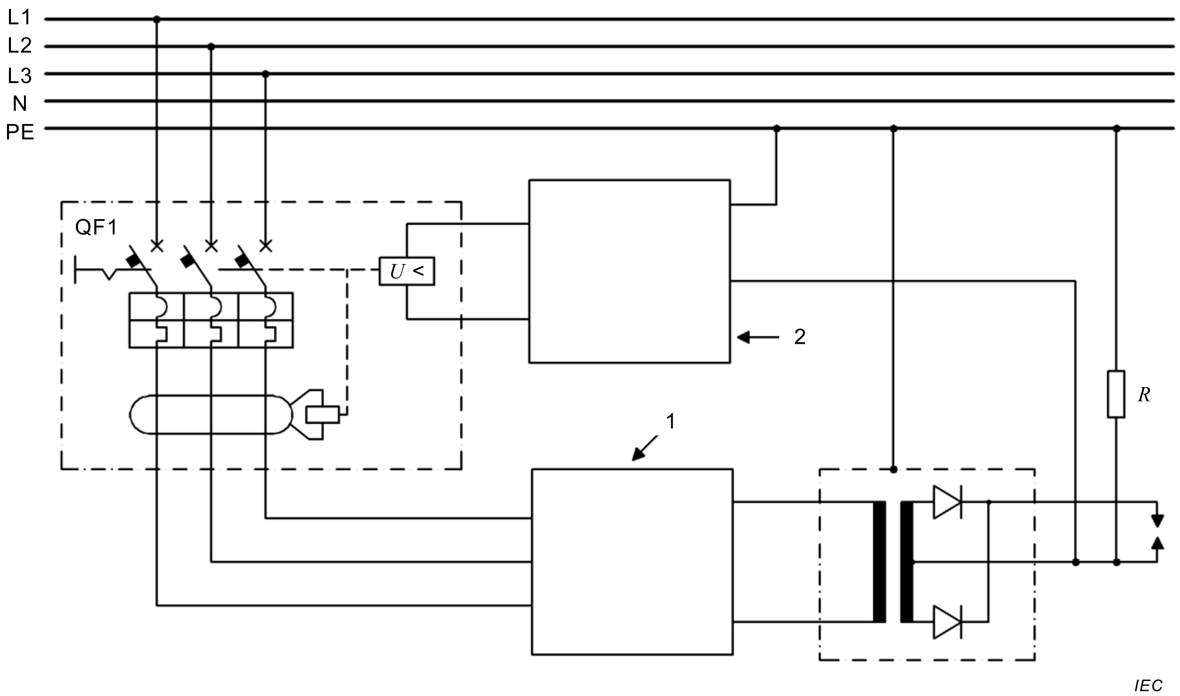
### 6.4.2.8 Current operated residual current device and voltage relay

Safety is provided by both the residual current device and a voltage relay (see Figure 12). The system is suitable for secondary rectified systems.

The installed RCD and voltage relay shall be an integral part of the equipment.

NOTE If rectifiers are used in the input circuit, a d.c. current component can occur in the case of failure. This can be considered when selecting an earth leakage breaker.

*Conformity shall be checked by visual inspection and operation.*




**Key**

1 Inverter

2 Voltage relay

**Figure 12 – Example of current operated residual current device and voltage relay**

RCD type selection shall take care of the possible fault current waveform.

RCD sensitivity selection requires coordination with the installation earth connection; this may be achieved by

- previous measurement in the installation place; or
- requirement in the instruction manual of a maximum allowed value of earth connection resistance; or
- use of a high-sensitivity RCD with a maximum $I_{\Delta n}$ value of 30 mA.

Resistance shall be dimensioned to allow RCD operation for every set-up of the equipment within the time specified in IEC 60364-4-41. The resistance shall withstand the thermal and electric stresses occurring during the failure before the RCD operates.

### 6.4.2.9 Current operated residual current device and safety voltage relay

Safety is provided by both an RCD and a safety voltage relay (see Figure 13).

Each output winding shall be permanently connected to the safety voltage operated relay according to Figure 13. A positive controlled circuit breaker shall be used.

To allow the voltage relay to be safe, it shall be provided with a control circuit assuring the continuity of the connection to the secondary conductor, and assuring detection of possible fault to ground of sensing wires.

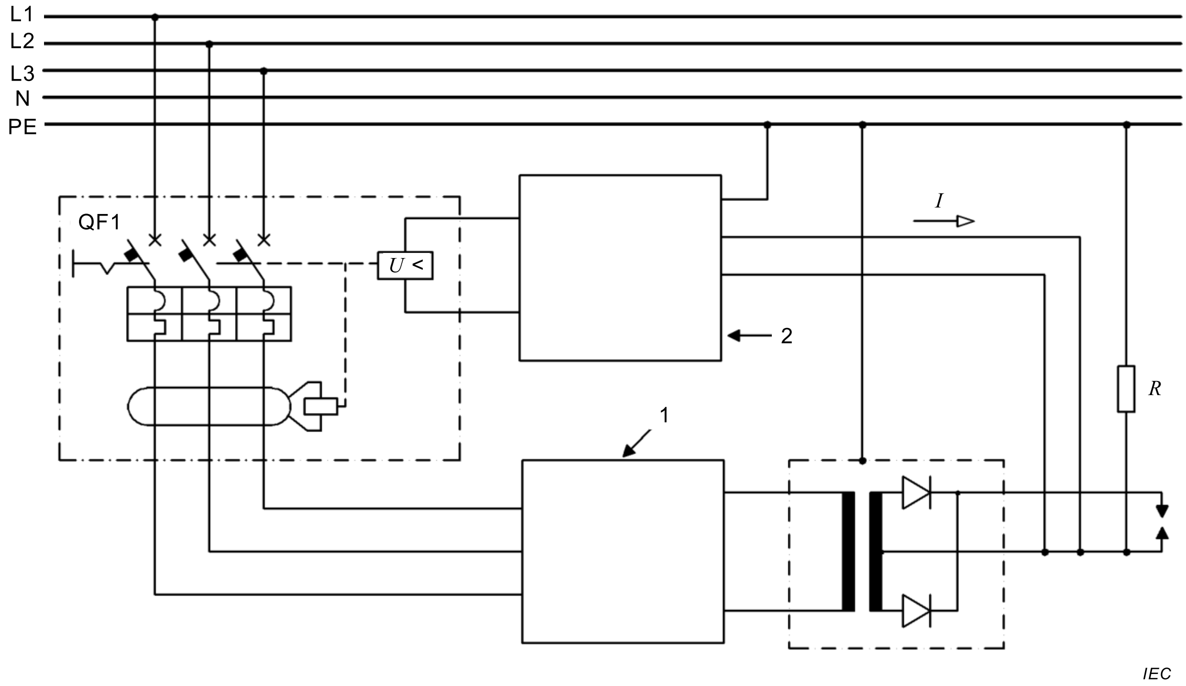
NOTE 1 Example of this type of control circuit is a device injecting a current into a sensing circuit composed of two separate sensing wires, continuously checking the sensing circuit continuity. To ensure correct operation, both sensing wires have to be connected to the same output of the transformer.

Connection to the rectified output is not allowed as a transformer insulation failure may damage the rectifier and avoid correct operation.

The installed RCD and voltage safety relay shall be an integral part of the equipment.

*Conformity shall be checked by visual inspection and operation.*

NOTE 2 If rectifiers are used in the input circuit, a d.c. current component can occur in the case of a failure. This is considered when selecting a residual current device.




**Key**

1 Inverter

2 Safety voltage relay

**Figure 13 – Example of current operated residual current device and safety-voltage relay**

RCD type selection shall take care of the possible fault current waveform.

RCD sensitivity selection requires coordination with installation earth connection; this may be achieved by

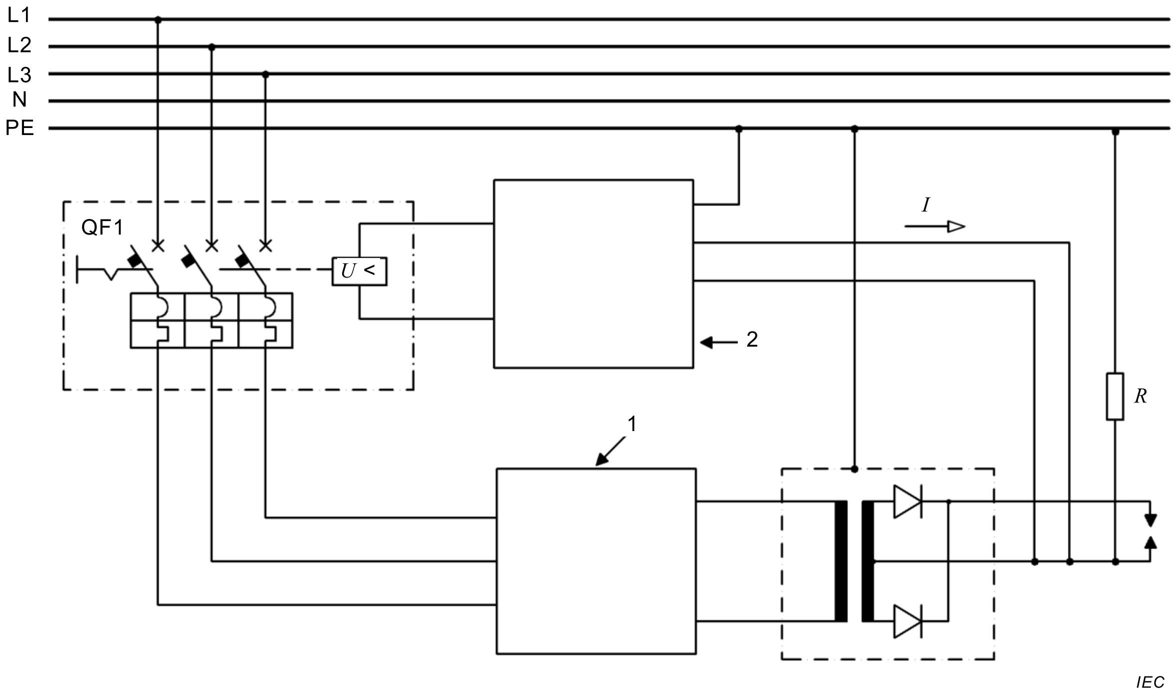
– previous measurement in the installation place; or
– requirement in the instruction manual of a maximum allowed value of earth connection resistance; or
– use of a high-sensitivity RCD with a maximum $I_{\Delta n}$ value of 30 mA.

Resistance shall be dimensioned to allow RCD operation for every set-up of the equipment within the time specified in IEC 60364-4-41. The resistance shall withstand the thermal and electric stresses occurring during the failure before the RCD operates.

#### 6.4.2.10 Safety voltage relay

Safety is provided by a safety voltage relay (see Figure 14).

Each output winding shall be permanently connected to the safety-voltage operated relay according to Figure 14. A positive controlled circuit breaker shall be used.




**Key**

1 Inverter

2 Safety voltage relay

**Figure 14 – Example of safety voltage relay**

To allow the voltage relay to be safe, it shall be provided with a control circuit assuring the continuity of the connection to the secondary conductor, and assuring detecting of possible fault to ground of sensing wires.

NOTE Example of this type of control circuit is a device injecting a current into a sensing circuit composed of two separate sensing wires, continuously checking the sensing circuit continuity. To ensure correct operation, both sensing wires have to be connected to the same output of the transformer.

Connection to the rectified output is not allowed as a transformer insulation failure may damage the rectifier and avoid correct operation.

*Conformity shall be checked by visual inspection and operation.*

### 6.4.2.11 Protective measures restricting access to welding circuit

Access to the welding circuit and other conductive parts that can be in contact with the welding circuit is avoided by protecting devices that

a) prevent access to the welding circuit(s) when the welding transformer(s) failure may be hazardous (for example, are not insulated from supply); and

b) allow supply of the welding transformer only if the protective measures have become effective.

Insulation of the welding transformer supply shall be performed on all phases by monitored contactor or devices with the same safety level.

The control circuit shall fail safe, resulting in the transformer being switched off and preventing reconnection.

NOTE 1 Protective devices are, for example, fixed guards, interlocked movable guards, photoelectric devices, etc.

NOTE 2 This protective provision is usually employed in large equipment, for example, robot installations.

Design shall take care to avoid possible contact with the welding circuit, through the welding pieces or equipment parts, that does not provide an adequate insulation to the welding circuit, for example, by providing equipotential bonding of these parts.

*Conformity shall be checked by visual inspection and operation.*

### 6.4.3 Internal conductors and connections

Internal conductors and connections shall be secured or positioned to prevent accidental loosening, which could cause electrical connection between

a) the input circuit or any other circuit and the welding circuit so that the output voltage could become higher than the allowable no-load voltage;
b) the welding circuit and the protective conductor, enclosure, frame or core (only with the provisions of 6.4.2.2 and 6.4.2.3).

Where insulated conductors pass through metallic parts, they shall be provided with bushings of insulating material and the openings shall be smoothly rounded with a radius of at least 1,5 mm.

Bare conductors shall be so fixed that the clearance and creepage distance from each other and from conductive parts is maintained (see 6.2.2 and 6.2.3).

Conductors of different circuits may be laid side by side, may occupy the same duct (for example, conduit, cable trunking system), or may be in the same multiconductor cable provided that the arrangement does not impair the proper functioning of the respective circuits. Where those circuits operate at different voltages, the conductors shall be separated by suitable barriers or shall be insulated for the highest voltage to which any conductor within the same duct can be subjected.

*Conformity shall be checked by visual inspection and by measurement.*

### 6.4.4 Touch current in fault condition

For class 1 equipment, except for equipment with permanent connection by a reinforced protective conductor in accordance with IEC 61140, the weighted touch current in case of an external protective conductor failure or disconnection shall not exceed:

– 7 mA peak, in case of test on conductive grippable parts,
– 14,1 mA peak, in case of test on conductive non-grippable parts.

*Conformity shall be checked using the configurations as shown in Annex C under the following conditions:*

1) the resistance welding equipment is:
   – isolated from the ground plane;
   – supplied by the highest rated supply voltage;
   – not connected to the protective earth except through measurement components;
2) the welding circuit is in the no-load condition;
3) interference suppression capacitors shall not be disconnected.

### 6.4.5 DC resistance welding equipment operating at mains frequency

For centre-tap and double-star rectifier or bridge rectifier connections operating at a line frequency of 50 Hz or 60 Hz, the provisions specified in 6.4.2.2 to 6.4.2.11 are applicable.

If provisions specified in 6.4.2.4 to 6.4.2.6 are used, ground connection(s) on the output terminal(s) shall be connected to the transformer secondary.

If provisions specified in 6.4.2.7 to 6.4.2.9 are used, resistance connection on the output terminal shall be connected to the transformer secondary.

If provisions specified in 6.4.2.8 to 6.4.2.10 are used, voltage relay connection(s) on the output terminal shall be directly connected to the transformer secondary.

Connection to rectifier diode(s) output terminal is not allowed as transformer insulation failure can cause failure of rectifier diodes.

### 6.4.6 DC resistance welding equipment operating at medium frequency

Provisions described in 6.4.2.2 and 6.4.2.3 are applicable without further requirements.

If provisions specified in 6.4.2.4 to 6.4.2.6 are used, ground connection(s) on the output terminal(s) shall be connected to the transformer secondary. Moreover design shall take care of special conditions as described in 6.4.2.1 and Annex F.

If provisions specified in 6.4.2.7 to 6.4.2.9 are used, resistance connection on the output terminal shall be connected to the transformer secondary. Moreover, design shall take care of special conditions as described in 6.4.2.1 and Annex F.

If provisions specified in 6.4.2.8 to 6.4.2.10 are used, voltage relay connection(s) on the output terminal shall be connected direct to the transformer secondary. Moreover, voltage relay shall be suitable for the inverter output waveform.

Connection to rectifier diode(s) output terminal is not allowed as transformer insulation failure can cause failure of rectifier diodes.

### 6.4.7 Continuity of the protective bonding circuit

The continuity of the protective bonding circuit shall be verified by generating current of at least 10 A at 50 Hz or 60 Hz derived from a PELV source. The tests shall be made between the PE terminal and relevant points which are part of the protective bonding circuit. The test time is 1 s. The measured voltages between the PE terminal and the points of test shall not exceed the values given in Table 6.

**Table 6 – Continuity of the protective bonding circuit**

| **Minimum effective protective conductor cross-sectional area of the branch under test**<br>$mm^2$ | **Maximum measured voltage drop (values are given for a test current of 10 A)**<br>V |
|---|---|
| 1,0 | 3,3 |
| 1,5 | 2,6 |
| 2,5 | 1,9 |
| 4,0 | 1,4 |
| > 6,0 | 1,0 |

### 6.5 Additional user requirements

In special cases a protection against faults of switching devices in the input circuit may be provided. A special agreement between manufacturer and user shall be made in such cases.

### 6.6 Supply voltage

The rated maximum supply voltage shall not exceed

a) 300 V r.m.s. between phase and earth for portable hand-held resistance welding equipment with built-in transformers;

b) 1 000 V r.m.s. between phases for other resistance welding equipment;

unless additional safety provisions are incorporated in the equipment to guarantee the same protection level described in this standard, for example, adequate reaction time and sensitivity of RCD.

*Conformity shall be checked by visual inspection.*

### 6.7 Conductors of the welding circuit

Conductors of the welding circuit may be

a) either rigid, generally bare conductors connected to movable pieces (electrodes, platens) by an appropriate flexible conductor (braided conductors, laminated conductors); or

b) flexible conductors that are especially designed for this use and can be cooled by a cooling liquid (for example, according to ISO 5828, ISO 8205-1 or ISO 8205-2).

## 7 Thermal requirements

### 7.1 Heating test

#### 7.1.1 Test conditions

When placing the measuring devices, the only access permitted shall be through openings with cover plates, inspection doors or easily removable panels provided by the manufacturer. The ventilation in the test area and the measuring devices used shall not interfere with the normal ventilation of the resistance welding equipment or cause abnormal transfer of heat to or from it.

The welding equipment shall be short-circuited according to ISO 669.

The welding equipment is operated at the permanent output current, $I_{2p}$, in one of the following possible operating conditions:

a) with pulsed output current, using a pulse current corresponding to the maximum short-circuit current output ($I_{2cc}$), at the duty factor $X$ calculated to correspond to the permanent output current ($I_{2p}$), by the formula:

$$X = \frac{(I_{2p})^2}{(I_{2cc})^2}$$

or

b) with the permanent output current ($I_{2p}$) at 100 % duty factor.

NOTE 1 Typical resistance welding equipment is operated at a reduced duty factor with high output current. Some welding equipment (i.e. seam welders) are designed to operate at the permanent output current, therefore are tested at this condition.

For liquid cooled equipment the flow rate shall be set up as specified on the rating plate.

In the case of d.c. current equipment operating at medium frequency (inverter equipment), the test shall be carried out at the following operating conditions.

1) a load resistor with a resistance value of 100 μΩ shall be installed between the electrodes. The load resistor dimensions and the applied force shall be the same as specified in ISO 669;
2) equipment welding current adjustment is set up at maximum value;
3) at a welding time according to real operation condition;
4) at the duty factor $X$ corresponding to the permanent output current ($I_{2p}$) considering the equipment output current during the test $I_2$, measured using an integration time equal to the pulse duration calculated by the formula:

$$X = \frac{(I_{2p})^2}{(I_2)^2}$$

NOTE 2 On some types of equipment (i.e. seam welders) the resulting duty factor can be also 100 %.

NOTE 3 As pulse duration setting does not influence the test result it can be freely chosen to match equipment and test instrumentation requirements.

A pulse duration representative of the typical operating condition of the equipment is recommended.

In the case of three-phase d.c. current equipment operating at line frequency (50/60 Hz), the test shall be carried out at the following operating conditions:

– output current is set up to the minimum adjustable value, to obtain the maximum heating condition of the transformers and rectifier; if resulting output current $I_2$ is lower than permanent output current $I_{2p}$, current setup is increased to achieve the permanent current $I_{2p}$;
– at the duty factor $X$ corresponding to the permanent output current ($I_{2p}$) considering the equipment output current during the test $I_2$, measured using an integration time equal to the pulse duration, calculated by the formula:

$$X = \frac{(I_{2p})^2}{(I_2)^2}$$

NOTE 4 On some types of equipment (i.e. seam welders) the resulting duty factor can be also 100 %.

NOTE 5 As pulse duration setting does not influence the test result it can be freely chosen to match equipment and test instrumentation requirements.

A pulse duration representative of the typical operating condition of the equipment is recommended.

NOTE 6 Test setup is valid for both equipment with transformers with delta connected primary windings and with wye connected primary windings.

If the transformer has been tested in accordance with ISO 5826, and the thermal rating of the equipment (permanent output current of the equipment, $I_{2p}$) is lower or equal to the transformer thermal rating, the equipment thermal test can be performed without measuring the transformer temperature rise.

### 7.1.2 Tolerances of the test parameters

During the last 60 min of the heating test in accordance with 7.1.3, the following tolerances shall be met.

a) Output current: ±2 % of the appropriate output current.

b) Cooling liquid flow (if applicable): ±5 % of the rated value.

c) Supply voltage: ±5 % of the appropriate rated supply voltage.

#### 7.1.3 Beginning of the heating test

In the case of embedded or surface temperature sensor, the test may be started without the welding equipment having reached a temperature balance with the ambient air or the cooling liquid.

In the case of resistance measurement the test shall be started only when the temperature difference between cooling liquid inlet and outlet is within 1 K (in the case of liquid-cooled welding equipment).

The temperature of the cooling liquid, $t_1$, is retained as the initial temperature of the winding whose resistance is being measured.

#### 7.1.4 Duration of the test

The heating test shall be carried out until the rate of the temperature rise does not exceed 2 K/h on any component for a period not less than 60 min.

### 7.2 Temperature measurement

#### 7.2.1 Measurements conditions

The temperature shall be determined at the end of the load time of the last cycle as follows.

a) for windings, by surface or embedded temperature sensors or by measurement of the resistance (only input windings);

b) for other parts, by surface temperature sensors.

#### 7.2.2 Surface temperature sensor

The temperature is measured by a temperature sensor applied to accessible surfaces of windings or other parts in accordance with the conditions stipulated below.

NOTE 1 Typical temperature sensors are thermocouples, resistance thermometers, etc.

Bulb thermometers shall not be used for measuring temperatures of windings and surfaces.

Temperature sensors are placed at accessible spots where the maximum temperature is likely to occur. It is advisable to locate the predictable hot spots by means of a preliminary check.

NOTE 2 The size and spread of hot spots in windings depend on the design of the welding equipment.

Efficient heat transmission between the point of measurement and the temperature sensor shall be ensured, and protection shall be provided for the temperature sensor against the effect of air currents and radiation.

#### 7.2.3 Resistance

This method only applies to input windings. The temperature rise of windings is determined by the increase in their resistance and is obtained for copper by the following formula:

$$t_2 - t_a = \frac{(235 + t_1)(R_2 - R_1)}{R_1} + (t_1 - t_a)$$

where

$t_1$ is the temperature of the winding at the moment when $R_1$ is measured (°C);

$t_2$ is the calculated temperature of the winding at the end of the test (°C);

$t_a$ is the ambient air temperature (or the temperature of the cooling liquid) at the end of the test (°C);

$R_1$ is the initial resistance of the winding (Ω);

$R_2$ is the resistance of the winding at the end of the test (Ω).

For aluminium, the number 235 in the above formula is replaced by the number 225.

The temperature $t_1$ shall be within ±3 K of the ambient air temperature.

Recording of measurement results shall be carried out in the following steps, without delay between them:

a) stop of the cooling flow (if applicable),

b) cut off of the current,

c) record of the resistance $R_2$.

### 7.2.4 Embedded temperature sensor

The temperature is measured by thermocouples or other suitable temperature measuring instruments of comparable size embedded at the hottest parts.

When measuring winding and coil temperatures, the thermocouples are applied directly to the conductors and separated from the metallic circuit only by any integrally applied insulation on the conductors themselves.

A thermocouple applied to the hottest point of a single layer winding is considered as embedded.

### 7.2.5 Determination of the ambient temperature ($t_a$)

The ambient air temperature is determined by at least three measuring devices. These are spaced uniformly around the welding equipment, at approximately one-half of its height and 1 m to 2 m from its surface. They are protected from draughts and abnormal heating. The mean value of the temperature readings is adopted as the temperature of the ambient air.

In the case of forced air-cooled welding equipment, the measuring devices are placed where the air enters the cooling system. The mean of the readings taken at equal intervals of time during the last quarter of the duration of the test is adopted as the ambient air temperature.

### 7.2.6 Determination of cooling liquid temperature ($t_a$)

The thermometers shall be placed at the cooling liquid inlet of the welding equipment.

For recording the measurement results the average temperature obtained during the last 60 min of the test shall be taken.

### 7.2.7 Recording of temperatures

Where possible, temperatures are recorded while the equipment is in operation and after shutdown. On those parts where the recording of temperature is not possible while the equipment is in operation, temperatures are taken after shutdown as described below.

Whenever a sufficient time has elapsed between the instant of shutdown and the time of final temperature measurement to permit the temperature to fall, suitable corrections are applied to obtain as nearly as practicable the temperature at the instant of shutdown. This may be done by plotting a curve in accordance with Annex D. A minimum of four temperature readings is taken within 5 min from shutdown. In cases where successive measurements show an increasing temperature after shutdown, the highest value is taken.

## 7.3 Limits of temperature rise

### 7.3.1 Windings

The temperature rise for windings shall not exceed the values given in Table 7, regardless of the method of temperature measurement used, except that the resistance measurement or an embedded temperature sensor shall be used for coils and windings wherever possible.

**Table 7 – Limits of temperature rise for windings**

| Class of insulation | Maximum temperature | Limits of temperature rise for air cooled windings K | | |
|---|---|---|---|---|
| | | Windings | | |
| °C | °C | Surface temperature sensor | Resistance | Embedded temperature sensor |
| 105 (A) | 150 | 55 | 60 | 65 |
| 120 (E) | 165 | 70 | 75 | 80 |
| 130 (B) | 175 | 75 | 80 | 90 |
| 155 (F) | 190 | 95 | 105 | 115 |
| 180 (H) | 210 | 115 | 125 | 140 |
| 200 (N) | 230 | 130 | 145 | 160 |
| 220 (R) | 250 | 150 | 160 | 180 |

NOTE 1 Surface temperature sensor means that the temperature is measured with non-embedded sensors at the hottest accessible spot of the outer surface of the windings.

NOTE 2 Normally, the temperature at the surface is the lowest. The temperature determined by resistance measurement gives the average between all temperatures occurring in a winding. The highest temperature occurring in the windings (hot spot) can be measured by embedded temperature sensors.

NOTE 3 Other classes of insulation having higher values than those given in this table are available (see IEC 60085).

NOTE 4 In case of liquid cooled windings the limit of temperature rise is increased by 10 K.

No part shall be allowed to reach any temperature that will damage another part even though that part might conform to the requirements in Table 7.

Further, for tests at other than 100 % duty cycle (duty factor), the temperature occurring during any full cycle shall not exceed the maximum temperatures given in Table 7.

*Conformity shall be checked by measurement in accordance with 7.2.*

### 7.3.2 External surfaces

External surface temperature rise limitation is required to avoid risks of burning deriving from contact of hot surfaces with unprotected skin. As different conditions of skin contact apply with different equipment (or part of equipment) types, different limits values are given for different types of equipment.

NOTE 1 Hand-held equipment are designed to be held during operation (i.e. portable welders), hand-guided equipment are designed to be manually moved by the operator but are sustained by appropriate systems (i.e. suspended guns), fixed equipment are not held by the operator during operation (i.e. standard stationary equipment).

The temperature rise for external surfaces that can be touched during equipment operation shall not exceed the values given in Tables 8, 9, and 10.

NOTE 2 Surfaces of automatic equipment (for example, robot equipment) can be inaccessible during equipment operation, but accessible during service. In such a case, additional risk assessment is typically performed.

**Table 8 – Limits of temperature rise for external surfaces of hand-held equipment**

| External surface | Maximum temperature rise<br>K | Burn threshold for contact period [a]<br>s |
|---|---|---|
| Uncoated metal enclosures | 18 | 4 |
| Painted metal enclosures | 22 | 4 |
| Plastic enclosures | 36 | 4 |
| Uncoated metal buttons | 20 | 4 |
| Painted metal buttons | 24 | 4 |
| Plastic buttons | 40 | 4 |
| Metal handles | 11 | 60 |
| Plastic handles | 20 | 60 |
| [a] Informative values in accordance with ISO 13732-1. | | |

**Table 9 – Limits of temperature rise for external surfaces of hand-guided equipment**

| External surface | Maximum temperature rise<br>K | Burn threshold for contact period [a]<br>s |
|---|---|---|
| Uncoated metal enclosures | 29 | 1 |
| Painted metal enclosures | 39 | 1 |
| Plastic enclosures | 53 | 1 |
| Uncoated metal buttons | 20 | 4 |
| Painted metal buttons | 24 | 4 |
| Plastic buttons | 40 | 4 |
| Metal handles | 11 | 60 |
| Plastic handles | 20 | 60 |
| [a] Informative values in accordance with ISO 13732-1. | | |

**Table 10 – Limits of temperature rise for external surfaces of fixed equipment**

| External surface | Maximum temperature rise<br>K | Burn threshold for contact period [a]<br>s |
|---|---|---|
| Uncoated metal enclosures | 33 | 0,5 |
| Painted metal enclosures | 45 | 0,5 |
| Plastic enclosures | 59 | 0,5 |
| Uncoated metal buttons | 20 | 4 |
| Painted metal buttons | 24 | 4 |
| Plastic buttons | 40 | 4 |
| [a] Informative values in accordance with ISO 13732-1. | | |

As some types of equipment are composed of a fixed part (i.e. a power supply) and a hand-held or hand-guided part (i.e. a welding gun), each part shall be tested according the relevant table.

Required values are based on environmental conditions given in Clause 4, if different environmental conditions are agreed between the manufacturer and the purchaser the values have to be reconsidered.

NOTE 3 Maximum temperature rise are defined for a maximum ambient temperature of 40 °C. For example, equipment designed for operation up to 45 °C values are reduced by 5 K.

The limits of Tables 8, 9 and 10 may be exceeded for electrodes as deliberately heated as an integral part of the functioning of the product.

The limits of Tables 8, 9 and 10 may be exceeded for surfaces that are not handles or buttons and are marked with the symbol given in 7.4.2.

The limits of Tables 8, 9 and 10 may be exceeded for surfaces that are located or guarded to prevent unintentional contact during normal operation in accordance with 7.4.3.

*Conformity shall be checked by measurement in accordance with 7.2 and visual inspection.*

### 7.3.3 Other components

The maximum temperature of other components shall not exceed their rated maximum temperature, in accordance with the relevant standard. Difference between the temperature of the cooling medium of the component and its maximum value shall be considered.

Rectifier sets can be used in the input or output circuit. The temperature reached by the rectifier elements during the heating test shall not exceed those specified by the manufacturer of the rectifier elements.

NOTE Attention is drawn to the intermittent duty characteristic of rectifier elements.

*Conformity shall be checked by temperature measurement during the heating test.*

## 7.4 Protection from thermal hazards in normal service (direct contact)

### 7.4.1 General

Protection from thermal hazards in normal service shall consist of one or more provisions including:

– identification of hot surfaces;
– thermal insulation;
– barriers;
– supplemental cooling.

### 7.4.2 Identification of hot surfaces

Where the temperature of a surfaces exceeds the limits of temperature rise given in Tables 8, 9 and 10 by less than 15 K the surface shall be visibly marked and labelled as a hot surface using symbol IEC 60417-5041:

If the above symbol is used on the equipment, the manufacturer shall include in product documentation information regarding required personal thermal protection devices.

### 7.4.3 Protection provided by insulation or other barriers

Where barriers are provided to prevent contact to hot surfaces, the barrier shall have sufficient mechanical strength, stability and durability to maintain the specified protection, taking into account all relevant influences from the environment.

### 7.4.4 Protection provided by supplemental cooling

Where supplemental cooling is provided to limit the surface temperature, means shall be provided to remove the source of heat and prevent operation in the event of a failure of the cooling system.

## 8 Abnormal operation

### 8.1 General requirements

Resistance welding equipment shall not suffer hazardous electrical breakdown or constitute a fire risk under the conditions of operation of 8.2 to 8.4. These tests are conducted disregarding temperature of any part, or the continued proper functioning of the resistance welding equipment. The only criterion is the continued safety of the resistance welding equipment.

Resistance welding equipment, protected internally by, for example, a circuit-breaker or thermal protection, meets this requirement provided the protection device operates before an unsafe condition occurs.

*Conformity shall be checked by the following tests.*

a) Starting from the cold state, the resistance welding equipment is operated in accordance with 8.2 to 8.4.
b) During the test, the resistance welding equipment shall not emit flames, molten metal or other materials.
c) Following the test and within 5 min, the resistance welding equipment shall be capable of withstanding a dielectric test in accordance with 6.2.5 b).

### 8.2 Stalled fan test

Resistance welding equipment, which relies on motor-driven fan(s) for conformity with the tests of Clause 7, is operated at rated supply voltage for a period of 4 h while the fan motor(s) is(are) stalled or disabled, at the test conditions of 7.1.

NOTE The intention of this test is to run the equipment with the fan stationary. The fan can be blocked mechanically or disconnected.

### 8.3 Cooling system failure

Resistance welding equipment, which relies on liquid cooling system for conformity with the tests of Clause 7, is operated at rated supply voltage for a period of 30 min while the cooling system is disabled, at the test conditions of 7.1.

### 8.4 Overload test

The resistance welding equipment is operated at 1,2 times the thermal current, in accordance with 7.1.1.

The test is performed

a) until the equipment thermal protection operates, or for a maximum time of 4 h (for equipment with thermal protection); or
b) for a maximum time of 4 h (for equipment without thermal protection).

## 9 Provisions against mechanical hazards

### 9.1 General

Due to the nature of the process, the shape and size of resistance welding electrodes in contact with the work-piece and the electrode force, approach rate and displacement all differ widely from application to application. This also applies to the electrode support system and associated tooling.

Therefore, detailed protection measures cannot be given in this standard but all mechanical risks shall be shown to have been addressed. To conform to this standard, equipment shall comply with the risk analysis and minimum requirements set out in this standard.

Equipment where electrode motion is manually operated does not require risk analysis. This equipment is:

– manual operated butt welders;
– mechanical operated rocker arm welders;
– manual operated welding guns.

### 9.2 Risk analysis

#### 9.2.1 General

Apply the procedures outlined in ISO 12100 for identifying hazards and estimating and evaluating risks during relevant phases of the resistance welding equipment life cycle, and for the elimination of hazards or sufficient risk reduction.

As some equipment is ready for use in the delivery state, while other equipment requires further adaptation to the performed process by the customer or final user, the requirements for risk analysis differ for different situations.

#### 9.2.2 Ready-to-use equipment as in delivery state

When welding equipment allows several uses depending on interchangeable tools, and the tools are provided by the manufacturer together with the equipment, this equipment shall be considered ready for use.

The manufacturer shall perform a risk analysis and include safe use in the instruction manual.

The user shall operate the equipment in accordance with the manufacturer’s instructions.

#### 9.2.3 Equipment not ready to use as in delivery state

In the case of resistance welding equipment allowing several uses depending on interchangeable tools not provided by equipment manufacturer (for example, projection welding equipment), the manufacturer shall perform the risk analysis on all reasonably expected conditions given by the use of the tools fitted on the equipment and provisions taken by the manufacturer (for example, two hands safety device, connection ports for light barriers) and

– specify the essential characteristics of tools which may be fitted to the machinery (for example, maximum mass or dimensions requirements);
– include safe use in the instruction manual;
– include a requirement in the instruction handbook to perform an additional risk analysis of the equipment fitted with the interchangeable tool.

Risk deriving from user design tools shall be covered by user risk analysis and measures.

#### 9.2.4 Equipment not ready for use and designed to be incorporated in more complex equipment

In case of equipment not ready for use and intended to be incorporated in other more complex equipment, the manufacturer shall perform limited risk analysis and provide to the integrator (i.e., the manufacturer of the equipment where the component is incorporated) information on which risks have been established and by which measures they have been countered (for example, categories of related control circuits, list of possible hazards already eliminated).

Completion of risk analysis is the task of the integrator.

NOTE Examples of this equipment are robot guns, welding groups with or without control circuitry, equipment similar to complete ones but without start of cycle devices.

### 9.3 Measures

#### 9.3.1 Minimum measures

All equipment shall be provided with the following features as a minimum:

a) emergency stop device

   The following exceptions apply:

   – machines in which an emergency stop device would not lessen the risk, either because it would not reduce the stopping time or because it would not enable the special measures required to deal with the risk to be taken;
   – hand-held portable machines and hand-guided machines;
   – equipment intended to be incorporated in a more complex equipment provided with a connection port, or information on how to realize this function;

b) a restart preventer in the case of power failure and emergency stop operation; this does not apply to equipment intended to be incorporated in a more complex equipment;

c) protection in the case of pneumatic/hydraulic supply system failure which may create a mechanical hazard.

#### 9.3.2 Additional measures

The following measures shall be taken by the manufacturer or customer in accordance with the specification of supply and intended use, where applicable:

– means of releasing trapped parts or persons;
– for projection welding equipment only, a mechanical detent for movable electrode system with a mass exceeding 5 kg or other system having the same safety level (needed for safe maintenance or tooling change);
– device(s) to separately isolate all sources of energy supply (i.e., electric, pneumatic, hydraulic); risk related to operation of these devices shall be addressed (i.e. effects of stored energy);
– control systems category design following risk analysis result;

– any other protection means considered necessary and appropriate (see Annex E).

Realization responsibility in accordance with 9.2.

## 9.4 Conformity of components

Components which due to failure may increase the risk of a hazard, shall comply with the requirements of this standard or with the requirements of the relevant IEC/ISO standards.

Performance level, appropriate to the hazard, shall be chosen in accordance with ISO 13849-1.

NOTE 1 An IEC component standard is considered relevant only if the component in question falls within its scope.

Evaluation and testing of components shall be carried out as follows.

a) A component certified by a recognized testing authority for compliance with the requirements of a standard harmonized with the relevant IEC component standard shall be checked for correct application and used in accordance with its rating. It shall be subjected to the applicable tests of this standard as part of the equipment with the exception of those tests which are part of the relevant IEC component standard.
b) A component which is not certified for compliance with a relevant standard as above, shall be checked for correct application and used in accordance with its specified rating. It shall be subjected to the tests required by this standard, as part of the equipment, and to the applicable tests required by the component standard, under the conditions arising in the equipment.

   NOTE 2 The applicable test for compliance with a component standard is, in general, carried out separately. The number of test samples is, in general, the same as that required in the component standard.

c) Where no relevant component standard exists, or where components are used in circuits not in accordance with their specified ratings, the components shall be tested under the conditions arising in the equipment. The number of samples required for test is, in general, the same as that required by an equivalent standard.

## 9.5 Starting for manual operated equipment

It shall be possible to start the resistance welding equipment only by voluntary actuation of a device provided for the purpose. When the work-piece is too big to allow the operator’s hands to reach the electrode working area or it is held with both hands, or the operator needs to use both hands to hold or operate the equipment, the cycle may be started by means of

– a foot pedal;
– a single-hand button or similar.

When it is not possible to hold or load the work-piece without any risks, it is necessary to provide adequate protections according to the work to be done. Example of protections are:

– adjust the distance between the electrodes to the minimum value (5 mm to 10 mm);
– movable or immovable safety guards (for example, grids or screens);
– safety devices without contact (for example, photoelectric), this device may as well start the cycle;
– presence detector with contact.

If no protections can be used, the cycle has to be started by means of

– concomitant push buttons.

Where equipment has several starting controls and the operators can therefore put each other in danger, additional devices (for example, enabling devices or selectors allowing only one part of the starting mechanism to be actuated at any one time) shall be fitted to rule out such risks.

# 10 Instructions and markings

## 10.1 Instructions

Each resistance welding equipment shall be delivered with instructions which shall include the following (as applicable):

a) general description;

b) lifting and storage instructions, for example, by fork lift or crane;

c) correct methods of handling and precautions to be taken;

d) an explanation for all indications, markings and graphical symbols;

e) information for selection and connection to the supply network (for example, suitable earthing system(s) TT/TN/IT, fuse, circuit-breaker and/or RCD rating);

f) correct operational use relating to the resistance welding equipment (for example, cooling requirement, location, device, indicators);

g) welding capability, mechanical characteristics, limitations of duty and explanation of thermal protection if relevant;

h) limitations of use (for example, environmental conditions);

i) basic guidelines regarding protection against personal hazards for operators and persons in the work area (for example, fumes, noise, hot metal and sparks, EMF);

j) maintenance (preventive and routine instructions);

k) adequate circuit diagram together with a list of essential parts;

l) information on auxiliary outlets (for example, plug for lighting or electric tools);

m) installation and commissioning;

n) information that the manufacturer’s instructions cover the equipment in the as-delivery state, and of the necessity to perform risk analysis on the user’s responsibility if he does not respect the manufacturer’s instructions.

Other useful information may also be given, for example, the class of insulation, pollution degree, efficiency, degree of protection provided by the enclosure, etc.

*Conformity shall be checked by reading the instructions.*

## 10.2 Markings

Each resistance welding equipment shall be clearly and indelibly marked as defined in ISO 669 (rating plate).

## 10.3 Marking of terminals

The terminal for the external protective conductor shall be marked with the symbol ⏚ (IEC 60417-5019).

Optionally the following may be added:

a) the letters: **PE**

or

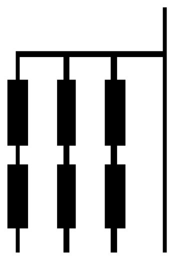
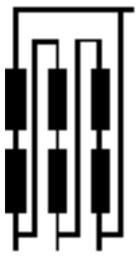
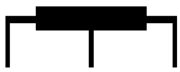
b) the twin colours: green and yellow.

Additionally, three-phase equipment terminals shall be clearly marked in accordance with IEC 60445 or other relevant component standards. The identifying marking notation shall be located on or adjacent to the corresponding terminal.

*Conformity shall be checked by visual inspection.*

# Annex A
(informative)

## Nominal voltages of supply networks

| Voltage line-to-neutral derived from nominal voltages a.c. or d.c. up to and including | Nominal voltages presently in the world | | | |
|---|---|---|---|---|
| | **Three-phase four-wire systems**<br>**with earthed neutral**<br>E  | **Three-phase three-wire systems**<br>**Earthed or unearthed**<br>(E)  | **Single-phase two-wire systems**<br>**a.c. or d.c.**<br> | **Single-phase three-wire systems**<br>**a.c. or d.c.**<br> (E) |
| V | V | V | V | V |
| 50 | | | 12,5 24<br>25 30<br>42 48 | 30-60 |
| 100 | 66/115 | 66 | 60 | |
| 150 | 120/208[a],<br>127/220 | 115, 120, 127 | 100[b],<br>110, 120 | 100-200[b],<br>110-220,<br>120-240 |
| 300 | 220/380, 230/400,<br>240/415, 260/440,<br>277/480 | 200[b], 220,<br>230, 240,<br>260, 277 | 220 | 220-440 |
| 600 | 347/600, 380/660,<br>400/690, 417/720,<br>480/830 | 347, 380, 400,<br>415, 440, 480,<br>500, 577, 600 | 480 | 480-960 |
| 1 000 | – | 660,<br>690, 720,<br>830, 1 000 | 1 000 | – |

NOTE 1 Values taken from Table B.2 of IEC 60664-1:2007.

NOTE 2 "E" means "earthed".

[a] Common practice of the United States of America and Canada.

[b] Common practice of Japan.

# Annex B
(normative)

# Construction of supply circuit terminals

## B.1 Size of terminals

The terminals shall be dimensioned in accordance with the maximum permanent input current $I_{1p}$ and it shall be possible to connect flexible conductors with cross-sectional areas as given in Table B.1. These values are based on wire rated at 60 °C.

**Table B.1 – Range of conductor dimensions to be accepted by the supply circuit terminals**

| Input permanent current<br>A | Range of cross-sectional area of the conductor<br>$mm^2$ |
|---|---|
| 10 | 1,5 to 2,5 |
| 16 | 1,5 to 4 |
| 25 | 2,5 to 6 |
| 35 | 4 to 10 |
| 50 | 6 to 16 |
| 63 | 10 to 25 |
| 80 | 16 to 35 |
| 100 | 25 to 50 |
| 125 | 35 to 70 |
| 160 | 50 to 95 |
| 200 | 70 to 120 |
| 250 | 95 to 150 |
| 315 | 120 to 240 |
| 400 | 150 to 300 |

Alternative cross-section ranges are permitted if the manufacturer indicates in the instructions the type and size of wire to be used.

*Conformity shall be checked by calculation and measurement.*

## B.2 Spacings between supply circuit terminals

Terminals shall be designed as follows.

The spacing between the supply terminals shall be not less than the values specified in Table B.2. Barriers or means for retaining all the conductor strands (for example, pressure type connectors) shall prevent strands of conductors, or lugs from contacting strands of conductors, or lugs connected to adjacent terminals, and shall maintain the spacing provided.

**Table B.2 – Spacing between supply circuit terminals**

| Range of voltage V r.m.s. | Minimum spacing between live parts mm | |
|---|---|---|
| | With barrier | Without barrier |
| Up to 150 | 6,3 | 12,5 |
| 151 to 300 | | |
| 301 to 600 | 9,5 | 25 |
| 601 to 1 000 | | |

The clearances in Table 1 may be used, when barriers envelop the insulation of the supply circuit conductors and prevent strands of conductors from reducing the clearances.

*Conformity shall be checked by measurement of the spacings as in IEC 60664-1.*

## B.3 Connections at the terminals

Connections at the terminals shall be made by means of screws, nuts or other equivalent means.

The terminal screws or nuts shall not be used to secure other parts or to connect other conductors.

*Conformity shall be checked by visual inspection.*

## B.4 Construction of the terminals

Conductors or their lugs shall be clamped between metallic parts and shall not be able to escape when the clamping means are tightened.

Live parts that can turn and reduce the spacing shall not rely on friction between mounting surfaces to prevent turning. A suitable lock washer, properly applied, shall be acceptable. Leads or busbars that are secured by other means need not have a lock washer.

Iron or steel, plain or plated, shall not be used for current-carrying parts.

*Conformity shall be checked by visual inspection and by the temporary connection of conductors with the minimum and maximum cross-sectional area specified.*

## B.5 Fixing of the terminals

The terminals shall be securely fixed so that they cannot work loose when the clamping means are tightened or loosened. Further, if friction alone is relied on to prevent turning or shifting of the terminals on the supporting surface, the spacings shall not be reduced below the values of Table B.2 by shifting or turning. A pressure terminal connector need not be prevented from turning provided no spacings less than those required result when the terminals are turned 30° towards each other, or towards other uninsulated parts of opposite polarity, or towards grounded metal parts.

*Conformity shall be checked by visual inspection and by tightening and loosening 10 times the clamping means holding a conductor of the maximum cross-sectional area specified.*

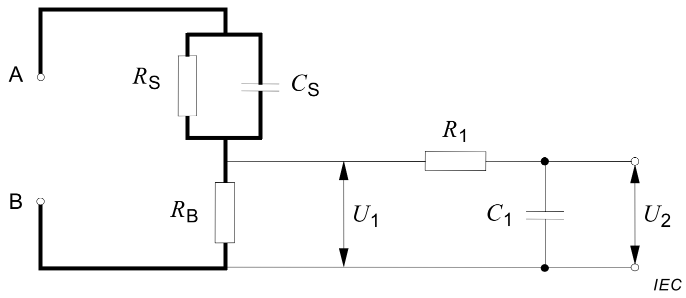
The test shall be repeated using a conductor of the minimum cross-sectional area specified.

# Annex C
(normative)

## Touch current measurement in fault condition

For measuring the touch current in fault condition, the measuring network in accordance with Figure C.1 and the appropriate configurations in Figures C.2 and C.3 shall be used with an appropriate measuring device.

Caution! An expert shall perform this test. The protective conductor is disabled for this test.




**Key**

| | | | |
|---|---|---|---|
| A, B | Test terminals | $C_S$ | 0,22 µF |
| $R_S$ | 1 500 Ω | $R_1$ | 10 000 Ω |
| $R_B$ | 500 Ω | $C_1$ | 0,022 µF |
| $U_1$ | r.m.s. voltage | $U_2$ | peak voltage |

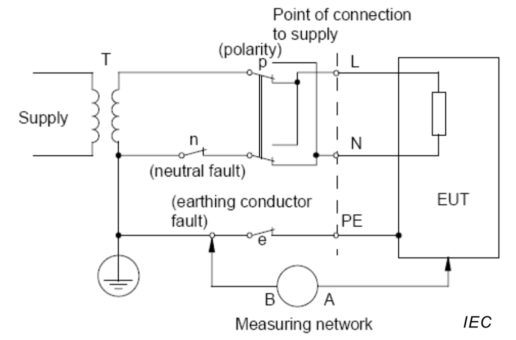
Weighted touch current (perception/reaction) $= \frac{U_2}{500}$ (peak value)

**Figure C.1 – Measuring network for weighted touch current**

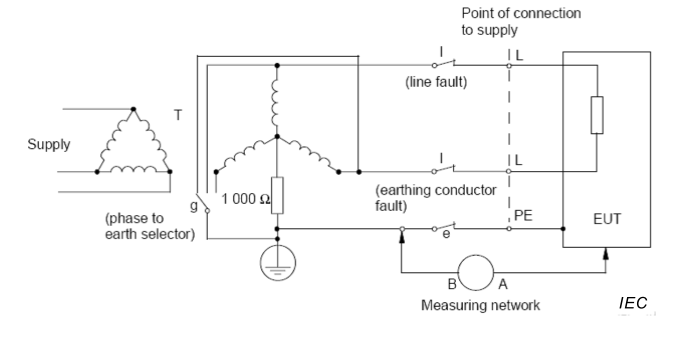
For three-phase equipment, touch current in fault condition is measured with the switches (l) and (n) in the closed position and switch (e) in the open position. The measurement is then repeated with each of the switches (l) and (n) opened one by one, with the other switches closed, except switch (e). The measurements are similar for single-phase equipment, except that they shall be repeated for each position of the polarity switch (p). Diagrams for touch current measurement with switches are shown in Figures C.2 and C.3.

The manufacturer shall identify the configuration (TN, TT, star IT, etc.) to which its equipment is intended to be connected in its final application. The equipment under test shall be tested to those identified configurations or the worst-case configuration.

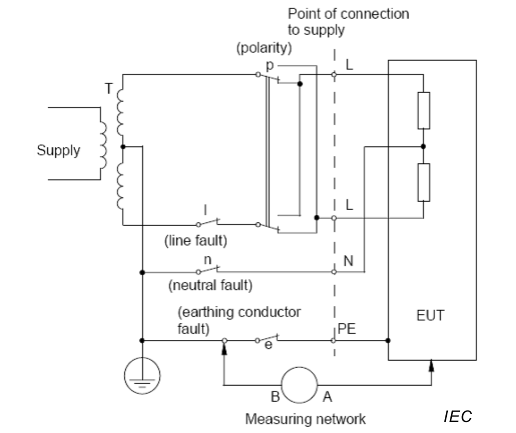
The use of isolating transformer (T) is optional. When not used, safety precautions shall be taken to protect the test operator from any hazardous voltage on the enclosure and other accessible conductive parts of the equipment.



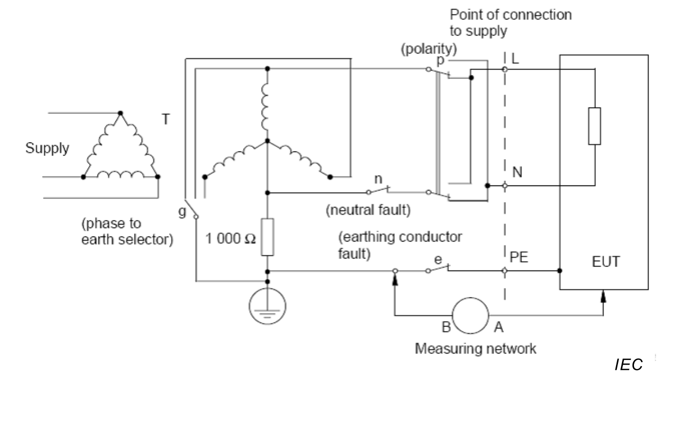

a) single phase equipment on
star TN or TT system




b) single phase equipment connected
line-to-line on star TN or TT system

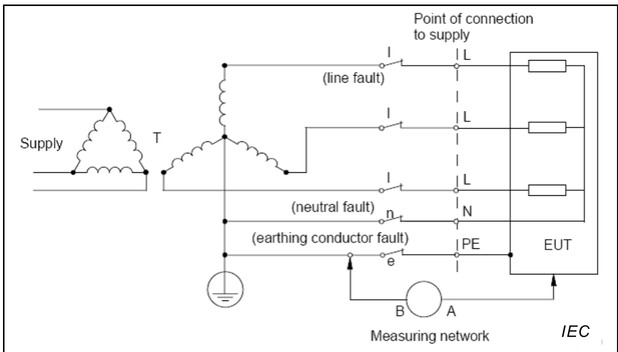



c) single phase equipment on
centre- earthed TN or TT system

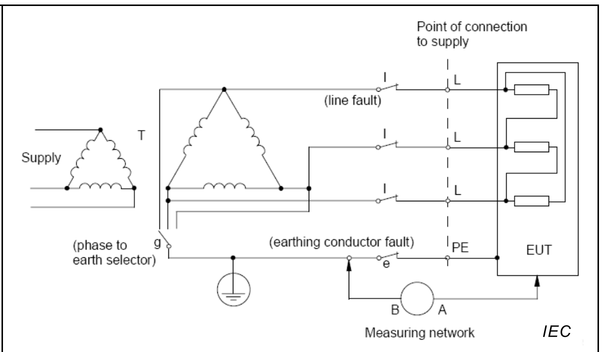



d) single phase equipment connected
line-to-neutral on star IT system

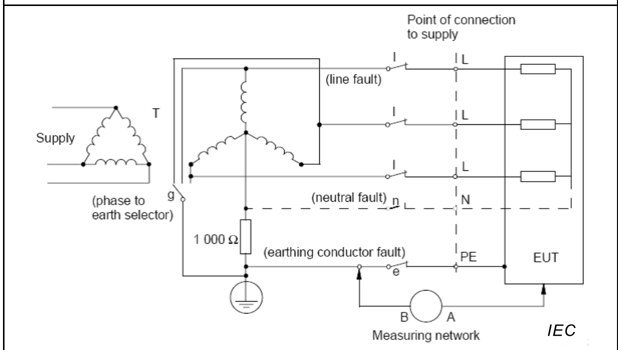
**Figure C.2 – Diagram for touch current measurement on fault condition at operating temperature for single-phase connection of appliances other than those of class II**



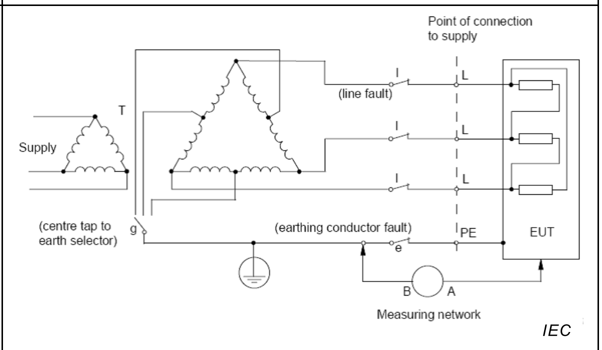

a) three-phase equipment on
star TN or TT system




b) three-phase equipment on unearthed
three-phase three-line system




c) three-phase equipment
on star IT system




d) three-phase equipment on earthed
centred three-phase three-line system

**Figure C.3 – Diagram for touch current measurement on fault condition for three-phase four-wire system connection of appliances other than those of class II**

# Annex D
(informative)

## Extrapolation of temperature to time of shutdown

When the temperature at the instant of shutdown cannot be recorded, it is necessary to use an extrapolation to obtain this temperature. The procedure for such extrapolation is as follows:

a) the time is marked at the instant of shutdown;

b) successive temperature readings are taken, and the elapsed time from shutdown noted for each;

c) a minimum of four readings is taken for each temperature to be extrapolated;

d) using logarithmic/linear graph paper, the readings are plotted so that the temperature is against the logarithmic scale, and the time from shutdown against the linear scale. A straight line extending back to $t = 0$ will give the extrapolated temperature at shutdown.

**Alternative**

A mathematical regression analysis can be used as an alternative to the graphical method. If a linear regression is chosen, then the logarithms of the temperatures are used with the linear values of the reading times from the instant of shutdown. The regression analysis is solved for the time $t = 0$ and the antilogarithm taken to find the true temperature.

# Annex E
(informative)

# Example of risk analysis and safety level requirement

## E.1 General

This annex describes possible mechanical hazards on resistance welding equipment. Corresponding to the type of equipment, hazards vary. The hazards are evaluated on the basis of ISO 14121-1 and ISO 13849-1 and examples given for measures to be taken. These measures should be looked upon as one possible solution out of many.

Hazards due to sparks and splatters are not dealt with in this annex.

## E.2 Monitored hazards

The following hazards on resistance welding equipment are monitored:

a) squeezing of parts of the body between the electrodes or electrode wheels;
b) squeezing of parts of the body between upper and lower platen;
c) squeezing by accidentally dropping of tools from upper platen or the clamping device;
d) squeezing between work piece and clamping device;
e) squeezing by retraction of electrode wheels.

## E.3 General measures

The following general measures are taken:

a) reduced closing or clamping speed (for example, 10 mm/s).
b) reduced opening gap between tools or electrodes or clamping devices.
c) force reduction until gap is closed to an extent where no part of the body can enter (i.e., 6 mm between work piece and clamping device).
d) necessity to hold welding gun or work piece with both hands.

## E.4 Typical hazards by type of equipment

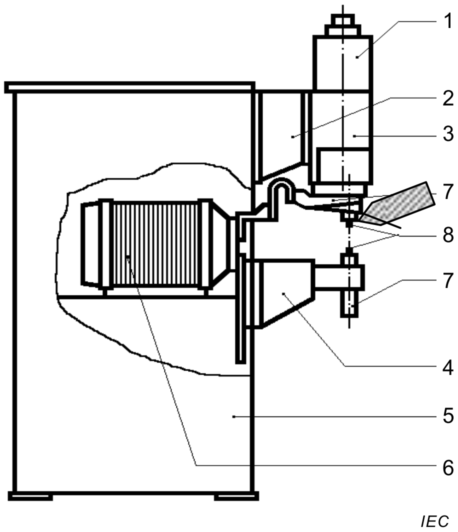
### E.4.1 General

Hazardous areas are indicated by means of an arrow (see Figures E.1 to E.5). Machine elements are identified by the following numbering.

| | | | | | |
|---|---|---|---|---|---|
| 1 | force generation system | 6 | transformer | 11 | electrode wheel |
| 2 | upper arm | 7 | electrode holder | 12 | handle |
| 3 | welding head | 8 | electrode | 13 | finger deflector |
| 4 | lower arm | 9 | platen | 14 | guiding protective bar |
| 5 | frame | 10 | wheel head | | |

### E.4.2 Spot welding

#### E.4.2.1 Mounted machine




NOTE Numbers are defined in E.4.1.

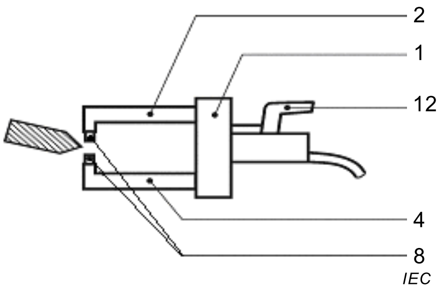
**Figure E.1 – Structure of a mounted machine**

Hazard 2a

Result of risk evaluation category B or 1.

Additional measures, where applicable: operated by one or two push-button(s), light barrier

#### E.4.2.2 Hand-held welding gun




NOTE Numbers are defined in E.4.1.

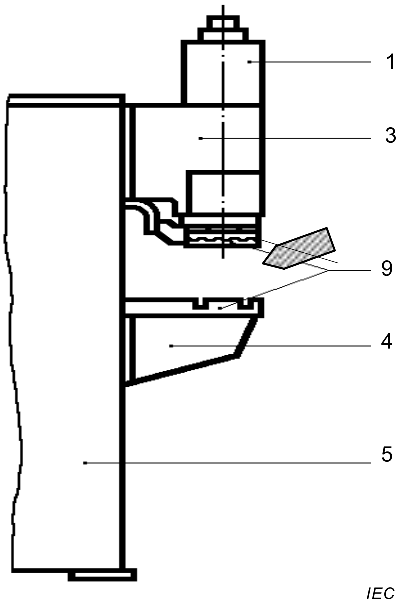
**Figure E.2 – Structure of a hand-held welding gun**

Hazard 2a whilst maintaining or changing electrodes

Result of risk evaluation: category B

Additional measures where applicable: trigger lock for work on electrodes

### E.4.3 Projection welding




NOTE Numbers are defined in E.4.1.

**Figure E.3 – Structure of projection welding machinery**

Hazard: 2a, 2b, 2c, 2d

Result risk evaluation

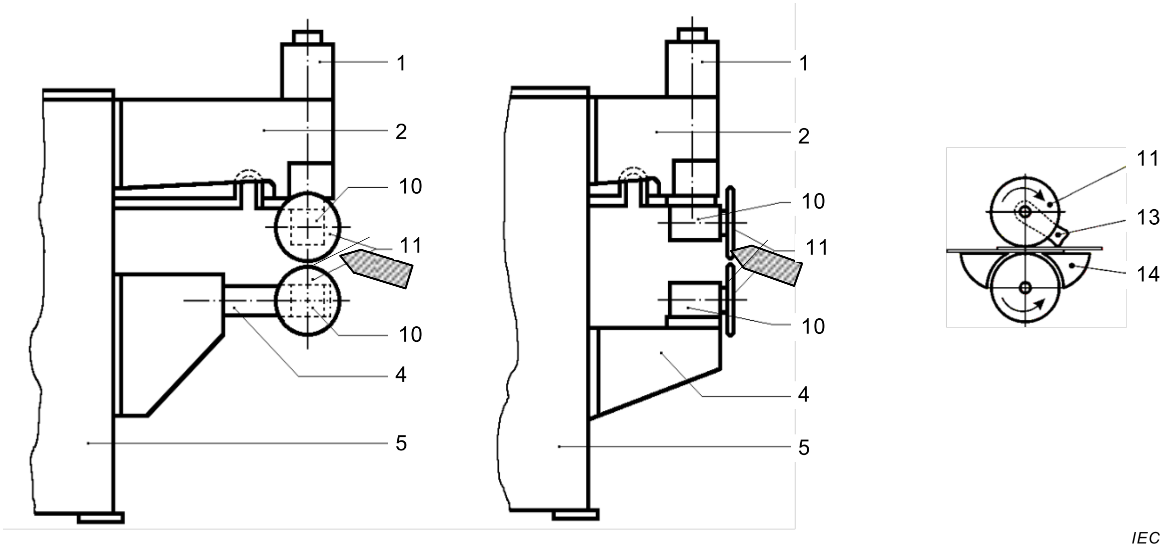
Category 3 or possibly 2 at small tool weight and/or low welding force (due to severity of possible injury).

Additional measures:

Operation start by two push buttons, self-supervising, light barrier self-supervising, movable protection shield.

On this equipment a special protection system for the set-up mode may be necessary.

### E.4.4 Seam welding




NOTE Numbers are defined in E.4.1.

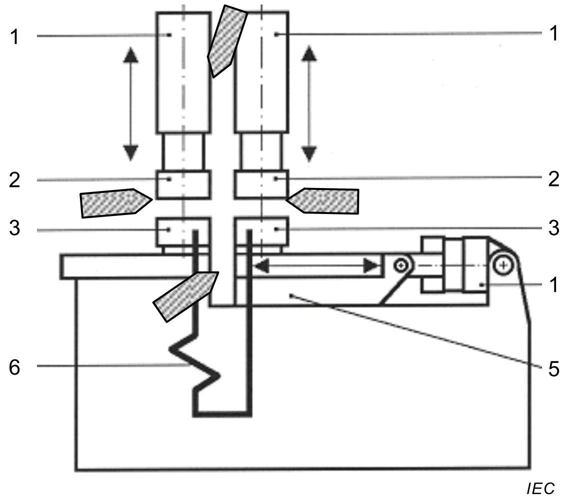
**Figure E.4 – Structure of seam welding machinery**

Hazard 2a, 2e

Result of risk evaluation: category 2 or 3.

Additional measures: installation of a movable (up and down) finger deflector (13) on the retracting side (held in position by its own weight) and a guiding protective bar (14).

### E.4.5 Butt welding




NOTE Numbers are defined in E.4.1.

**Figure E.5 – Structure of butt welding machinery**

Hazard 2c, 2d

Result of risk evaluation: category 2 or 3.

Additional measures: operation start by means of two push-buttons, light barrier, movable shield.

# Annex F
(informative)

# Indirect contact protection in resistance welding equipment

## F.1 Protection against indirect contact by automatic disconnection of the supply

### F.1.1 General

Protection against indirect contact prevent risk arising when a person touches a metal part of the equipment (exposed conductive part) with an insulation fault. The following Figures F.1 to F.3 explain in principal possible protective measures against electric shock.

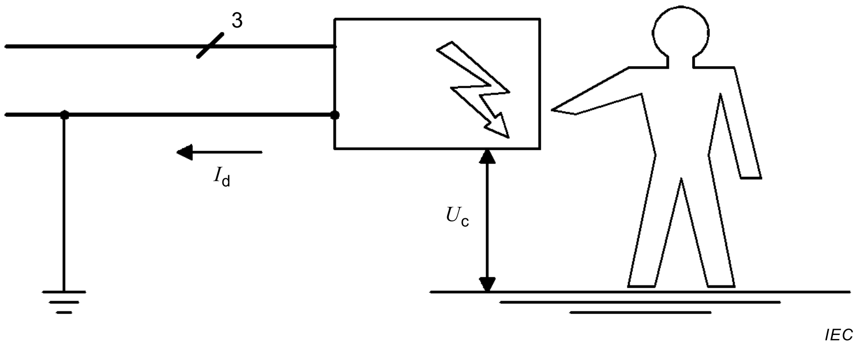



**Figure F.1 – Principle illustration of insulation fault**

Automatic disconnection of the supply is the most common solution used for protection against indirect contact. It is achieved by the removal of a touch voltage, appearing on the occurrence of an insulation fault, before the time of contact with a touch voltage can become hazardous.

Maximum disconnecting time for installations are defined by IEC 60364-4-41.

The type of disconnection device is selected depending on the type of earthing system of the installation. IEC 60364-4-41 describes the main earthing systems and defines their protection rules; in this annex only TN an TT systems are considered.

In TN and TT systems, an insulation fault between a live conductor and the equipment exposed conductive parts caused current flow to earth. In both cases, the touch voltage usually exceeds the maximum permissible values and requires an automatic disconnection of supply.

This protection provision requires the presence of a protective bonding circuit, connected to all exposed conductive parts that allow detection of the fault.

### F.1.2 TN system

The neutral point of the voltage source (supply transformer) is earthed and the equipment protective conductor is connected direct to it.

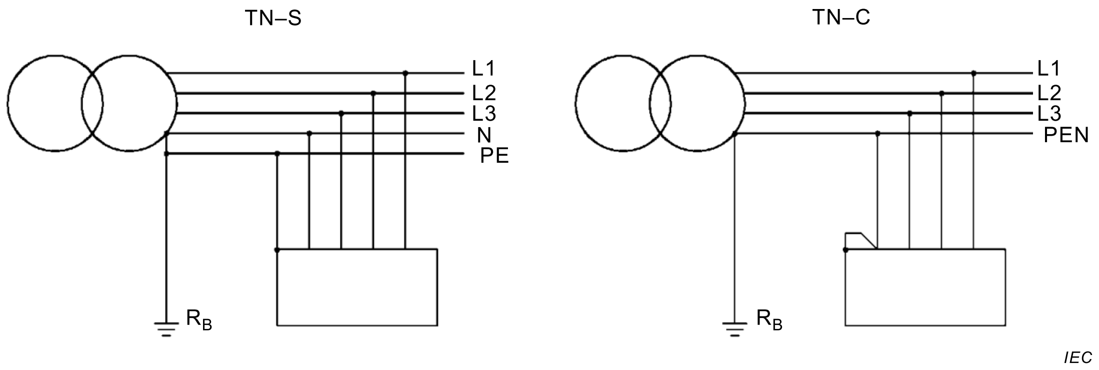



**Figure F.2 – Illustrations of TN systems**

Two main types of TN system exist:

– TN-S where equipment exposed conductive parts are connected to the voltage source earthed neutral by PE (protective conductor and neutral are separate);
– TN-C where equipment exposed conductive parts are connected to the earthed neutral by PEN (protective conductor combined with the neutral conductor).

In the TN system, the fault current is equivalent to a short circuit. The current is high as limited only by the fault-loop impedance; therefore, the circuit can be disconnected by an overcurrent protective device (circuit-breaker thermal or magnetic protection, fuses).

For circuits which supply class I hand-held equipment or portable equipment, the maximum disconnecting time is 0,4 s (for equipment operating on network having a nominal voltage to earth of 230 V).

An higher disconnection time up to 5 s is permitted for stationary equipment under special conditions.

The ability of an overcurrent protective device to provide protection for indirect contact is verified at the installation design stage by calculating the fault currents for all the distribution circuits and verifying that the disconnection device operate in a sufficient time with that current.

If due to long cables or low conductor cross-section the fault current is too low to properly operate the overcurrent protection device, an additional RCD is used.

This RCD may be separate residual current device or be combined with circuit-breakers.

This solution is not applicable in installation with a TN-C earthing system, where the protective conductor and the neutral one are the same.

### F.1.3 TT systems

The neutral point of the voltage source (supply transformer) is earthed by an electrode separate from that used for the equipment.

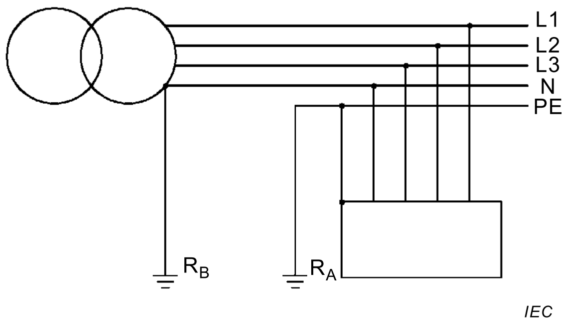



**Figure F.3 – Illustrations of TT systems**

In the TT system, the fault current is low as limited by the earth resistance, so cannot be detected and cleared by standard overcurrent protective devices. Therefore, different disconnection devices are provided in the installation, usually an RCD.

IEC 60364-4-41 specifies that the ability of an RCD to provide protection for indirect contact is assured selecting an RCD sensitivity lower that a value derived from measured installation earth connection resistance ($R_a$), by the formula:

$$I_{\Delta n} \leq \frac{50}{R_a}$$

This assures sufficient protection as the device operates with a fault current generating a 50 V touch voltage. A fault with a lower current will generate a touch voltage lower than 50 V, a fault with higher current will be detected and insulated by RCD in a shorter time.

RCDs have a tripping time that is defined by IEC standards and related to the ratio between the fault current and the sensitivity value.

IEC 60364-4-41 requires that de-energizing by the RCDs shall occur in less than 1 s.

The tripping times of RCDs are generally lower than those required in the majority of situations.

In order to increase availability of electrical power, the use of several RCDs ensures time and current discrimination on tripping.

## F.2 Automatic disconnection of supply in single phase a.c. current equipment

### F.2.1 TN system

As described above, overcurrent protective device are usually used as disconnecting device for indirect contact protection.

Resistance welding equipment are characterized by very high instantaneous current compared to the continuous equivalent current. Therefore high setting of circuit-breaker trip current or use of delayed fuses (type aM) are required, while fuses used in installation for short-circuit protection are usually of gG type.

The installation design shall take care of this providing sufficient low fault loop impedence to assure that the circuit-breaker or fuses operate in case of fault within the specified time (for example, using supply and PE cables with a sufficient cross-section).

If the required conditions cannot be met, an additional residual current device is used (apart from installation with a TN-C earthing system). In this situation, the following considerations regarding use of RCD in TT systems apply.

### F.2.2 TT systems

As described above, residual-current devices are usually used as disconnecting devices for indirect contact protection.

The operation capability of an RCD depends on the fault current waveform. IEC 60755 defines three types of RCD depending on the characteristics of the fault current.

In the case of fault between the input circuit and the welding circuit in typical single-phase a.c. equipment, the fault current is sinusoidal; therefore types AC, A and B RCDs are appropriate.

Anyway, other circuit faults can generate a different fault waveform that requires a different RCD selection.

Only the manufacturer knows the possible fault current waveform of its equipment and can incorporate the device in the equipment or specify which type of RCD is capable of assuring proper operation.

## F.3 Automatic disconnection of supply in d.c. current equipment operating at medium frequency (inverter equipment)

### F.3.1 TN system

All the considerations above for a.c. single-phase equipment apply also to d.c. current equipment operating at medium frequency; moreover, other important factors have to be considered.

The most common fault is between the inverter output to ground, typically by a fault in the welding transformer insulation. This type of fault requires additional consideration described below.

The touch voltage in case of fault is higher than in network frequency fault as the protective conductor impedance is higher at the inverter frequency (typically 1 kHz to 20 kHz).

The fault current may be limited in time by the inverter as it is present only when the equipment execute the welding process (i.e., when the welding transformer is supplied).

Additionally, it has to be considered that the fault current amplitude may be limited by

– the current supplied by the inverter may be electronically limited to a maximum permissible value (for example, by the welding current adjustment);
– the protective conductor impedance (it is higher than 50 Hz impedance value as the fault current have frequency components of 1 kHz to 20 kHz).

These fault current times and amplitude limitations can avoid the circuit-breaker or fuse operation in case of fault.

It shall also be considered that the reduction of the fault current time and magnitude correspond to a reduced touch voltage therefore to a reduced risk.

The inverter can provide a protection against short circuits between phases at the output that interrupt the supply of current to the transformer. In TN systems this device does not protect persons against indirect contact under all circumstances. In fact, the impedance of the fault at the inverter frequency may limit the current to a value that is below the inverter's protection threshold.

### F.3.2 TT systems

#### F.3.2.1 General

As described above, residual-current device are usually used as disconnecting device for indirect contact protection.

In the case of fault between the input circuit and the welding circuit of typical inverter equipment, the fault current is non-sinusoidal. It is composed of the inverter switching frequency and the d.c. bus voltage to ground frequency (typically 1 000 Hz and 150 Hz).

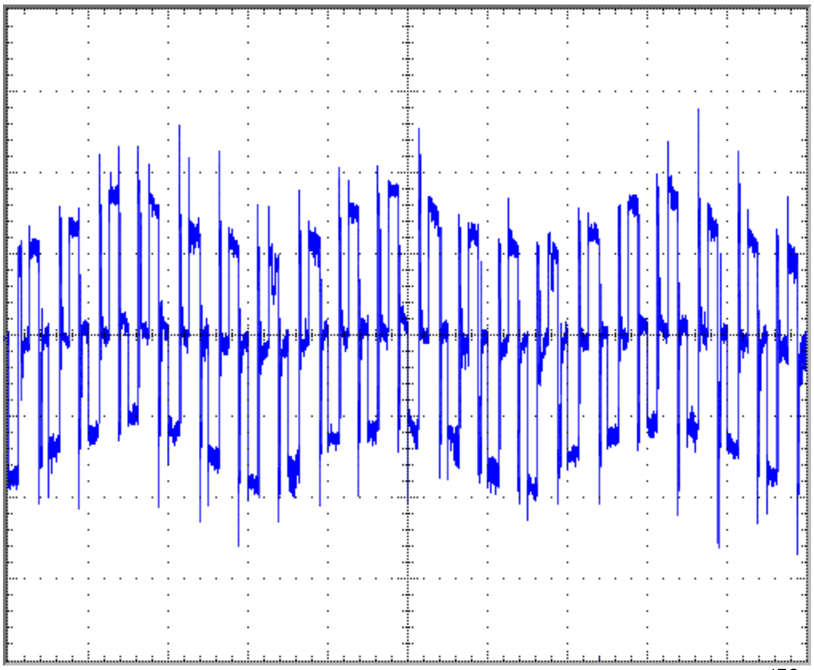



**Figure F.4 – Typical fault current**

Frequency content of the fault current depends on many factors, including inverter switching frequency, type of inverter input stage and equipment welding current adjustment.

The complex shape of the fault current (see Figure F.4) requires the use of a type A or B RCD suitable for the frequency content of the fault current.

Anyway other circuit faults generate different fault waveforms that can require different RCD selection; for example, d.c. bus to earth fault generates a fault current that requires type B RCD.

Only the manufacturer knows the possible fault current waveform of its equipment (i.e., its frequency content) and can incorporate the device in the equipment or specify which type of RCD is capable of assuring proper operation.

The inverter can provide a protection against short circuits between phases at the output that interrupt the supply of current to the transformer. In TT systems this device does not protect persons against indirect contact as the impedance of the fault at the inverter frequency is very high and limit the current to a value that is far below the inverter's protection threshold (the fault current may be of a few amps).

### F.3.2.2 RCD sensitivity, break time and operating frequency

The patho-physiological effects of electrical current flowing in the body depend on its magnitude and duration. RCD are typically designed for network frequency operation and provide current related operating time that are defined by IEC standards based on patho-physiological effects.

RCD sensitivity is expressed as the rated residual operating current, $I_{\Delta n}$. Preferred values have been defined by IEC, making it possible to divide RCDs into three groups according to their $I_{\Delta n}$ value:

– high sensitivity (HS): 6 mA – 10 mA – 30 mA;

– medium sensitivity (MS): 0,1 A – 0,3 A – 0,5 A – 1 A;

– low sensitivity (LS): 3 A –10 A – 30 A.

High sensitivity (HS) is most often used for additional direct-contact protection. The other sensitivities (MS and LS) are usually used for protection against indirect contacts. RCD are also used in installations for fire protection and protection of the equipment.

When the RCD is used for protection against indirect contact, its sensitivity is not directly related to current flowing into the body but selected according to installation earth connection resistance.

The current flowing through the human body depends mainly on environmental conditions and on the touch voltage.

The current flowing through the human body is influenced also by the frequency, as the body impedance is highly frequency dependant.

When an RCD is used for indirect contact protection, it has to disconnect the supply within a time that is related to the prospective touch voltage. The reference curves used by IEC 60364-4-41 are derived from IEC 60479 series together with an explanation of the derivation of the requirements.

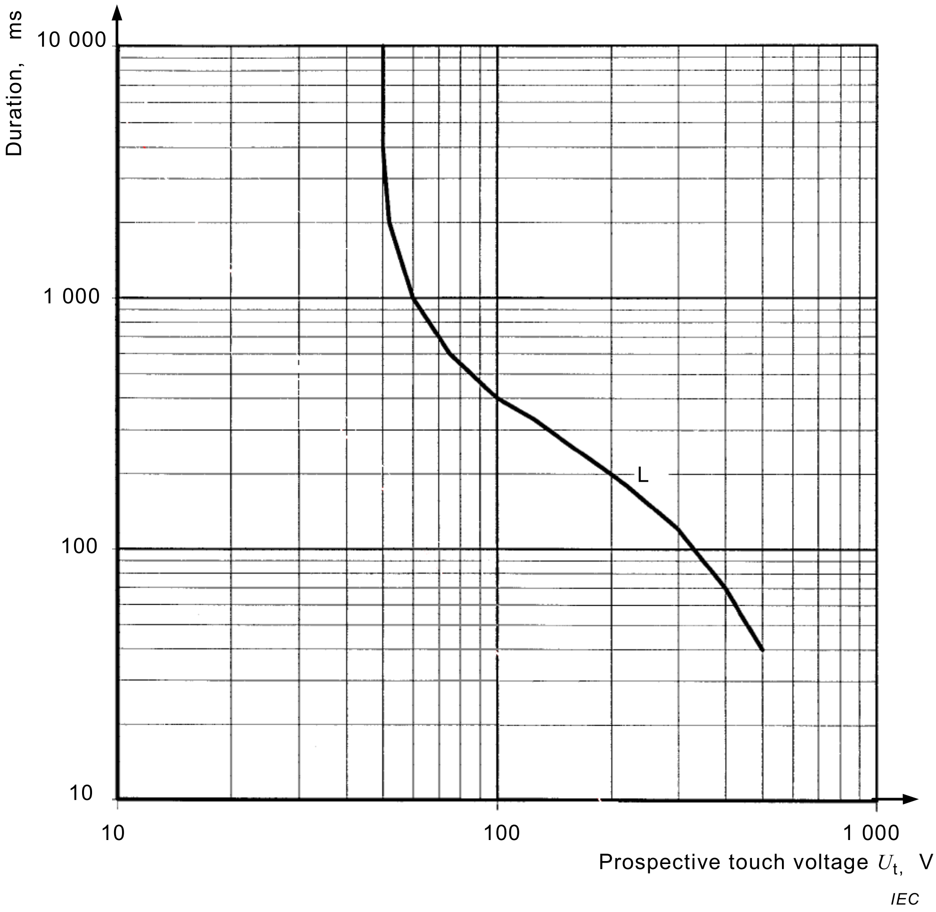



**Figure F.5 – Time-to-voltage reference curve**

IEC 60364-4-41 provides means of compliance based on the selection of RCD sensitivity corresponding to a fault current generating a 50 V touch voltage and allowing a maximum disconnection time of 1 s. This satisfies the requirement for any value of touch voltage and fault current. Time-to-voltage reference curve is shown in Figure F.5

In order to prevent undesired tripping, an RCD may be protected against high-frequency currents with low-pass filters; therefore, an RCD device may present low sensitivity (or increased break time) to fault currents on inverter resistance welding equipment. The frequency content of the fault current is, therefore, a most important factor.

Standards specify that type B RCD shall operate with frequencies up to 1 kHz; therefore, the use of this device satisfies the requirement for inverter resistance welding equipment operating up to 1 kHz.

The ability of other RCD types or equipment operating at higher frequencies shall be verified case by case as different RCDs present different sensitivity and operation time.

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[2] This publication was withdrawn.

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