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Travaux sous tension - Vetements conducteurs pour usage jusqu'a 800 kV de tension nominate en courant alternatif et ±600 kV en courant continu

Live working - Conductive clothing for use at nominal voltage up to 800 kV a.c. and ±600 kV d.c.

International Electrotechnical Commission, 3, rue de Varembe, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone:+41 2291902 11 Telefax:+41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

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LIVE WORKING - CONDUCTIVE CLOTHING FOR USE AT NOMINAL VOLTAGE UP TO 800 kV AC AND ±600 kV DC

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60895 has been prepared by IEC technical committee 78: Live working.

This second edition cancels and replaces the first edition, published in 1987 and constitutes a technical revision of several sections:

- the scope has been extended to cover the use of conductive clothing to ±600 kV d.c.;
- revision of the electrical resistance requirements of the fabrics used in conductive clothing;
- revision of the testing procedures for complete clothing.

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

FDIS	Report on voting
78/469/FDIS	78/478/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 3.

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

• reconfirmed;

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

The contents of the corrigendum of February 2003 have been included in this copy.

INTRODUCTION

This International Standard provides specifications for protective conductive clothing currently being used without incident in live work by qualified electrical workers throughout the world. The adequacy of this clothing is established by its screening efficiency and the electrical resistance of material and component parts of the conductive clothing. Based on resistance measurements carried out by manufacturers and utilities of used clothing being successfully worn in the field, differences of up to 1 000 fold have been reported.

Verification tests have shown that the clothing is equally effective against the electric field existing in the vicinity of installations up to 800 kV a.c. and ±600 kV d.c.

This standard has been prepared according to the requirements of IEC 61477, where applicable.

LIVE WORKING - CONDUCTIVE CLOTHING FOR USE AT NOMINAL VOLTAGE UP TO 800 kV AC AND ±600 kV DC

1 Scope

This International Standard is applicable to conductive clothing, either assembled from component parts or forming a single complete clothing, worn by (electrically) skilled persons during live working (especially bare-hand working) at a nominal power system voltage up to SOOkVa.c. and±600kVd.c.

It is applicable to conductive jackets, trousers, coveralls (one-piece clothing), gloves or mitts, hoods, shoes, overshoe socks and socks.

2 Normative references

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

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

IEC 60050-651:1999, *International Electrotechnical Vocabulary (IEV) - Part 651: Live working*

IEC 60050-826:1982, *International Electrotechnical Vocabulary (IEV) - Chapter 826: Electrical installations of buildings*

I EC 60212:1971, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 60417 (all parts), *Graphical symbols for use on equipment*

IEC 60456:1998, *Clothes washing machines for household use - Methods for measuring the performance*

IEC 60743:2001, *Live working- Terminology for tools, equipment and devices*

IEC 61318/TR2:1994, *Live working - Guidelines for quality assurance plans*

IEC 61477:2001, Live working - *Minimum requirements for the utilization of tools, devices and equipment*

ISO 2859-1:1999, *Sampling procedures for inspection by attributes - Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3175:(all parts), *Textiles - Professional textile cleaning and finishing*

ISO 3290:2001, *Rolling bearings - Balls - Dimensions and tolerances*

ISO 6330:2000, *Textiles - Domestic washing and drying procedures for textile testing*

ISO 9000:2000, *Quality management systems - Fundamentals and vocabulary* ISO

9001:2000, *Quality management systems - Requirements*

ISO 9004:2000, *Quality management systems - Guidelines for performance improvements*

3 Terms and definitions

For the purposes of this International Standard, the following definitions apply.

NOTE Further information on terminology is illustrated in figure 1.

3.1
conductive clothing
clothing made of natural or synthetic material with integral interwoven conductive fibres, or layers, used to provide electrical continuity between all parts of the clothing and a reduction of electric field

[IEC 60743, definition 8.2.7, modified]

3.2
conductive material
material composed of metallic threads or non-metallic conductive substances and natural or synthetic threads closely woven, knitted, or layered

3.3
equipotential bonding lead (bonding lead)
flexible metallic connection used by the worker to connect or disconnect his or her conductive clothing, bucket or screen, to or from another conductive part to create equipotential bonding

NOTE 1 This lead is not an earthing device.

NOTE 2 The means of securing or connecting the lead shall be such that under emergency conditions, for example, a fall, the lead can separate.

[IEV 651-07-07, modified]

3.4
head cover (hood)
part of the clothing, either as a separate item or integrated into a complete garment, that covers the head

3.5
face screen for electrical works
protective device made of conductive, solid, or meshed material

NOTE It provides electrical continuity with the conductive clothing of the worker and a reduction of electric field to the face, or part thereof

[IEC 60743, definition 8.4.3]

3.6
conductive overshoe sock
sock made of conductive material and worn over shoe/boot

3.7 garment
main body of the clothing consisting of jacket and trousers

3.8
component parts
additional elements of the complete clothing such as gloves, socks, head protection, and footwear worn in addition to the main garment and bounded to it

3.9
shielding efficiency
base log 10 of the ratio of a voltage without the conductive clothing to the voltage measured at the spot with conductive clothing

3.10
screening efficiency
per cent ratio of the total current injected into the conductive clothing to the current flowing in the body

3.11
equipotential bonding
electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential

[IEV 826-04-09]

4 Technical requirements

4.1 General

The conductive clothing shall constitute an electrically continuous assembly for the worker.

If press studs, zip fasteners, hooks and eyes or any other method of fastening are used in the assembly of the complete clothing, care should be taken to ensure that the electrical conductivity of the clothing is not impaired.

Bonding lead shall be capable of withstanding anticipated electrical and mechanical stresses.

4.2 Technical requirements for conductive material

The material used to manufacture the conductive clothing shall have the following properties.

NOTE The material used to manufacture the conductive clothing should be resistant to abrasion and to tearing.

4.2.1 Flame retardancy

The material used in conductive clothing shall not ignite and continue to burn when exposed to an ignition source.

4.2.2 Electrical resistance

This quality can be considered as a basic element which determines the current-carrying capability and the spark-discharge properties of the material.

The only direct consequence for a worker of the correct value of electrical resistance is the low potential difference between two points of the cloth in contact with the skin, which is thus an element of comfort.

4.2.3 Current-carrying capability

During the worker's travel to his working position (from the metallic structure of the tower or from the ground in an aerial device) and at the moment of his connection to the live conductor, capacitive currents flow through his clothing. It is necessary for the clothing to be able to conduct them. There shall be no damage to the material.

4.2.4 Shielding and screening efficiencies

The material used for the conductive clothing or the component parts shall attenuate the electric field. The attenuation of the material is determined by shielding efficiency, and that of the conductive clothing by screening efficiency. Shielding and screening efficiencies are defined in 3.9 and 3.10.

These efficiencies shall meet the requirements of this standard.

4.2.5 Requirements to withstand cleaning

To ensure that the efficiency and flame-retardant properties of the conductive clothing do not deteriorate excessively after repeated cleaning, the material shall be subjected to 10 wash-dry cycles in accordance with ISO 6330 and/or 10 dry-cleaning cycles in accordance with ISO 3175. After completion of the 10 washing/cleaning cycles, the shielding efficiency and flame-retardant properties of the material shall still meet the specified requirements.

4.2.6 Spark-discharge protection

To provide protection to the worker from direct spark discharges, the spacing between any individual adjacent conducting components in the conductive material (except for the face screen) shall not exceed 5 mm under all normal wearing conditions including stretching (such as at the elbows or knees).

4.3 Specific requirements for component parts

4.3.1 Conductive gloves, overshoe socks and socks

The maximum resistance value of gloves and overshoe socks or socks, when measured using the specified electrodes, is determined by the manufacturer to meet the bonding requirements of 7.1.

4.3.2 Conductive footwear

The maximum resistance value, when measured using the specified electrodes, is determined by the manufacturer to meet the bonding requirements of 7.1.

4.3.3 Conductive head cover and face screen

A conductive head cover is necessary to provide the worker with a full screening effect.

Further screening protection can be provided by a conductive screen for the face.

If no face screen is provided, protective flaps, conductive visor and the shape of the hood shall ensure face protection. Provision shall be made for an effective and efficient electrical bond between any head cover, screen or face screen and the total garment.

The resistance of the bond shall be checked and meet the requirements of 7.1.

4.4 Marking

Each conductive item shall carry, as a minimum, the following permanent markings:

- name or trade mark of the manufacturer;
- type reference and size (in accordance with ISO standards);
- year of manufacture;
- symbol IEC-60417-5216 - suitable for live working; double triangle (see annex A), attached by sewing, adhesion or other suitable means;
- number of the relevant IEC standard immediately adjacent to the symbol with year of publication (four digits) (IEC 60895:2002).

Markings shall be clearly visible and legible to a person with normal or corrected vision without additional magnification.

4.5 Packaging

The conductive material may become oxidized when stored in the ambient air conditions. The manufactured clothing shall be packaged for shipment in such a way that oxidation is retarded. If the parts of clothing are to be issued by the user separately, individual packaging of parts should be requested by the user. For example, the conductive clothing may be packaged inside an airtight plastic bag with tissue paper protecting the conductive clothing from contact with the plastic bag.

4.6 Manufacturer's instructions

Each piece of the conductive clothing shall come with the manufacturer's instructions for use and care. These instructions shall include, as a minimum, recommendations for cleaning, storage and periodic testing.

5 Type tests of conductive material (specimen)

These tests shall apply to specimens of the material used in the manufacturing of conductive clothing.

5.1 Flame-retardancy test

5.1.1 Principle of test

Ignition of a rectangular test specimen, vertically hung, by a standard ignition source according to prescribed conditions constitutes the principle of the test, which includes the measurement of the burned area and classification of the tested material according to the results.

5.1.2 Test apparatus

The test equipment shall consist of

- a test chamber,
- a specimen holder,
- accessories.

5.1.2.1 Test chamber

The test chamber (see figure 2) shall be made of steel plate not less than 1,5 mm thick. The interior walls of the chamber shall be painted matt black.

The chamber shall be composed of

a) a steel box 570 mm wide x 400 mm deep x 1 000 mm high, with one air vent each in the lower back and front. These air vents shall measure 116 mm in height and 440mm in length;
b) a glass door above the front air vent;
c) a 300 mm x 300 mm steel deflector plate above the top of the chamber, which is penetrated by a 200 mm diameter hole;
d) a support for the test specimen holder (see figure 3a). The lower part of the test specimen holder shall be placed 110 mm above the base of the chamber.

5.1.2.2 Test specimen holder

The test specimen holder (see figures 3a and 3b) shall be composed of

a) a support on which two 5 mm thick bars, spaced 150 mm apart, are fixed;
b) two 5 mm thick holding (removable) bars held on the two fixed bars with clips.

The support and all the bars shall be made of metal.

The size of all bars shall be such that the test specimen is well supported.

5.1.2.3 Accessories

Accessories include

a) a standard ignition linen specimen: whitened, not dressed, composed of 67 % polyester, 33% cotton- 110g/m^2;
b) a clamp;
c) clips;
d) a weighing scale (0,001 g precision);
e) a pattern for test specimen cutting;
f) tracing paper;
g) a mirror of approximately 250 mm x 300 mm, placed in a corner of the chamber, used to observe the burning on the rear of the test specimen.

5.1.3 Test specimens

5.1.3.1 Shape and dimensions

Rectangular test specimens shall have dimensions of 150 mm x 300 mm after being attached to the specimen holder.

For knitted material (for example, socks and gloves) the manufacturer shall provide flat test specimens with the above dimensions.

5.1.3.2 Quantity

The numbers of test specimens required according to the material shall be as follows.

a) Woven material

Tests shall be performed on three test specimens which are cut so that their length is parallel with the warp direction and three test specimens having their length parallel to the weft direction.

b) Knitted material

Three test specimens shall be provided for knitted material unless it is not directionally uniform. In this case, six test specimens shall be provided (three for each direction).

c) Layered material

Three test specimens shall be provided for layered material unless it is not directionally uniform. In this case, six test specimens shall be provided (three for each direction).

5.1.3.3 Preparation of samples

The outlines of the test specimens shall be marked on the material using the pattern set out in 5.1.3.1. The length of each specimen shall be appropriate to the direction specified in the test.

The test specimens shall be cut in such a way that

- the middle point is on a 45° oblique line vis-a-vis the edges of a roll of fabric,
- the sides are parallel with the exterior edges of a roll of material.

The required number of test specimens shall be cut from the material in an area with no visible defects. No specimens shall be taken within 50 mm from the selvage or edge of the material.

5.1.4 Test procedure

For each test specimen, the test procedure shall be as follows.

5.1.4.1 Preparation of standard ignition specimen

Cut a 25 mm x 80 mm strip of polyester cotton (see 5.1.2.3) its length parallel with the warp direction. This textile strip is folded lengthwise to give 25 mm x 20 mm. The ends of the specimen are placed inside the fold (see figure 3c).

5.1.4.2 Clamping standard ignition specimen

The standard ignition specimen shall be clamped in the centre of the lower part of the test specimen. The clamp shall be fixed horizontally, so that

- the standard ignition specimen has two thicknesses on each side of the test specimen,
- the end of the standard ignition specimen is 10 mm lower than the lower part of the test specimen.

5.1.4.3 Test

The test specimen is fixed on the specimen holder, so that the lower part of the test specimen coincides with the lower part of the specimen holder. The standard ignition specimen shall be equidistant from the vertical rods.

The specimen holder is hung vertically in the test chamber.

Apply a flame to the lower part of the standard ignition specimen until it is ignited (about 2 s) and immediately close the door of the test chamber.

The standard ignition specimen shall burn normally for about 25 s to 30 s.

Observe the burning test specimen during the test and note the following:

- points of residual after-glow;
- melting;
- distortion of test specimen;
- smoke.

5.1.4.4 Measurement of burned area

At the end of the test, and after 15 min in atmospheric conditions conforming to code 18 °C to 28 "C/45 % to 75 % of IEC 60212,

- using scissors, remove the completely burned or melted areas,
- lay the damaged test specimen flat on the pattern so that remaining contours coincide with the pattern ones,
- measure the burned area of the test specimen by cutting up and scaling the tracing paper, by planimetry, or by measurement of a geometric area.

5.1.5 Results

The test is considered to be successful if the following conditions are met by each of the speciments

- the burned area of the test specimen is less than, or equal to, 100 cm^2;
- the burned area does not extend to the vertical parts of the specimen holder, nor to the upper edge of the test specimen.

5.2 Electrical resistance test

Standard procedures to determine electrical resistance of material in connection with its antistatic properties are unreliable when the electrical resistance of highly conductive material has to be determined. Indeed, these standard procedures do not take into account the interference of the transition resistance from electrode to test specimen, which is of primary importance when low-resistance test specimens have to be measured.

5.2.1 Test equipment

The following apparatus is needed for the test:

- one alternating current source of power frequency (50 Hz or 60 Hz), or one direct current source, allowing an adjustable and regulated load current of up to 2 A at 30 V;
- one ammeter;
- two contact electrodes, providing a contact surface of 20 mm x 20 mm on both faces of the test specimen. Contact pressure shall be more than 100 kPa (see figure 4);
- two voltage measuring electrodes, such as sewing pins or needles;
- one voltmeter.

5.2.2 Preparation of test specimens

Four material test specimens measuring approximately 200 mm x 20 mm are respectively cut in warp, weft and two perpendicular directions making a 45° angle with warp and weft (see figure 5). No specimens shall be taken within 50 mm from the selvage, or edge of the material.

These test specimens shall be tested successively after a 24 h conditioning using the code 24h/23 °C/50 % of IEC 60212.

5.2.3 Procedure

The test specimen is placed unstretched between the contact electrodes (see figure 4).

The voltage measuring electrodes are threaded through the test specimen at a distance of 100 mm apart (see figure 4).

The electrical circuit is completed (see figure 6). A 0,2 A current is established through the unstretched test specimen.

After 1 min the voltage is measured.

5.2.4 Test results

The voltage measured is proportional to the electrical resistance of the test specimen.

The electrical resistance of a unit square is given by the formula:

$$R_S = R_{measured} \text{ X width/length} = \text{ Uxl / IXL}$$

where

U is the measured voltage, in V;

/ is the width of the test specimen, in mm;

I is the test current, in A;

L is the length of the test specimen, in mm.

Numerical application (R_s in Ω and *U* in V):

$$R_S = \text{U/0,2X20/100}$$

NOTE The specimen resistance should be utilized by the manufacturer to establish the garment resistance limit required in 6.2 for the garment.

The arithmetic mean value of the four electrical values shall be lower than 7 Ω per square. No individual value shall be higher than 10 Q per square.

5.3 Current-carrying capability

This is the test to establish the capacity of the material to carry current without excessive degradation to the material. The test is not to establish a heat comfort level.

5.3.1 Test equipment

The test-set shall be the same as in 5.2.1.

5.3.2 Preparation of test specimens

The preparation shall be the same as in 5.2.2.

5.3.3 Procedure

The procedure shall be as in 5.2.3 except that a 1 A current is established through the test specimen for a duration of 15 min. This current and its time duration are well in excess of anticipated working conditions.

5.3.4 Test results

During the test, there shall be no flame, incandescent point, smoke or carbonization between the contact electrodes.

5.4 Shielding efficiency

Tests carried out in the actual conditions of this standard have shown that shielding efficiency does not depend on test frequency between 50 Hz and 5 kHz. To facilitate testing, 5 kHz is chosen. At this frequency, the test is at least as severe as at 50 Hz or 60 Hz.

5.4.1 Test equipment

The test equipment is composed of the following:

a) one 400 V r.m.s. sine wave voltage generator at 5 kHz;

b) one insulating circular plate 300 mm in diameter;

c) one metallic circular plate 300 mm in diameter with connection clip;

d) one insulating circular plate 400 mm in diameter made from an elastomeric (3,5 ± 0,5) mm thick sheet having a surface hardness between 60° and 65° on the Shore scale;

e) one electrode assembly weighing 3 kg built according to the scheme given in figure 7a and fitted with a 100 kΩ shunt;

f) one measuring device (multimeter or oscilloscope) with constant input impedance greater than, or equal to, 1 MQ, in parallel with a capacitance of 47 pF
than, or equal to, 1 MQ, in parallel with a capacitance of 47 pF maximum;

g) one voltmeter allowing measurement of 400 V r.m.s. at 5 kHz.

5.4.2 Test mounting

The following parts are assembled in the specified order upon a grounded horizontal support (figure 7b):

- circular insulating plate 300 mm in diameter (item b of 5.4.1); - circular metal plate 300 mm in diameter and 3 mm to 5 mm thick (item c of 5.4.1);

- circular elastomeric plate 400 mm in diameter and 3 mm to 5 mm thick (item d of 5.4.1);
- test specimen, minimal dimensions 120 mm x 120 mm;
- electrode assembly (not allowed to pass beyond the edge of test specimen). The thickness of the polyvinyl insulating plate between the electrode and the test specimen shall be 0,8 mm (figure *la).*

5.4.3 Earth connection

The following parts are connected together and earthed:

- frame connection of voltage generator;
- earth connection of electrode assembly;
- frame connection of voltmeter.

5.4.4 Line connection

The following parts are connected together and insulated from earth:

- line connection of voltage generator;
- connection clip of metallic plate 300 mm in diameter;
- line connection of voltmeter.

5.4.5 Test procedure

5.4.5.1 Determination of reference voltage

Without the material specimen, a voltage of 400 V r.m.s. at 5 kHz is applied between the line and earth connections. The voltage is read on the measuring device and noted as £/$_{ref}$.

5.4.5.2 Measuring with test specimen

The test specimen is installed (5.4.2) and the test procedure is carried out in the same way as described in 5.4.5.1. The measured voltage *U* is recorded.

5.4.5.3 Acceptance criteria

Shielding efficiency is given by the formula

$$S£_{dB} = 20 \log_{10}[U_{ref} / U]$$

The shielding efficiency shall be greater than 40 dB.

5.5 Resistance to cleaning

To ensure that the efficiency and flame-retardant properties of the clothing do not deteriorate excessively after repeated cleaning, both of the following procedures (laundering and dry-cleaning) shall be carried out. If the garment can be cleaned by one of the two methods, but not by the other, the manufacturer shall mark the garment accordingly, and only the appropriate method need be used.

5.5.1 Laundering

Material sufficient to conduct flame-resistance testing and shielding efficiency, plus ballast required to make a full load shall be washed in accordance with ISO 6330.

5.5.1.1 Test apparatus

The apparatus and reagents shall have the following specifications.

a) Automatic washing machine capable of being operated under the following conditions:
   - either a top-loading, agitator type with a "normal" agitator speed of (70 ± 5) r/min, or a front-loading machine with a speed of 52 r/min, revolving alternatively in each direction for 12s, with 3 s rest in between,
   - washing time adjustment controllable between 0 min and 15 min, with a tolerance of ±1 min,
   - spin speed: normal (515 ± 5) r/min.

b) Drier of the rotary tumble type having a cylindrical basket approximately 750 mm in diameter and not less than 400 mm in depth, rotating at approximately (50 ± 5) r/min, equipped with means for maintaining a drying temperature of 50 °C to 70 °C measured in the exhaust vent as close as possible to the drying cylinder, and providing a cooling period of 5 min when tumbling at the end of the drying cycle.

c) Commercial detergent not containing bleach. The standard detergent specified in table E.1 of IEC 60456 for a detergent without perborate (type II), can be used in cases of dispute.

d) Dummy load: pieces of undyed spun polypropylene fabric, having a mass of approximately 0,16kg/m^2.

5.5.1.2 Test procedure

Place the test specimens in the washing machine and add sufficient dummy load to make a total dry load of 2 kg. Fill the machine to operate with (40 ± 4) l of water and set the machine to operate at the normal setting (50 °C to 70 °C). If the mass of the test specimen(s) exceeds 2 kg, the amount of water shall be increased proportionately.

Add sufficient household use detergent to provide good running suds and set the machine to wash for 10 min. (If necessary, advance the operation of the machine manually to begin the rinse cycle after 10 min of washing.) Continue until the end of the final spin cycle.

On completion of the final spin cycle, remove the specimens from the machine and place them and the dummy load (if any) in the tumble drier with the temperature of the exhaust from the drum set at 65 °C to 70 °C (for normal material). Operate the drier until the load is dry and continue tumbling, with the heat turned off, for 5 min. Remove the test specimens immediately. One wash-dry cycle will then have been completed.

5.5.2 Dry-cleaning

Material sufficient to conduct flame-resistance testing and shielding efficiency, plus ballast required to make a full load shall be dry-cleaned in accordance with ISO 3175.

5.5.2.1 Test apparatus

The apparatus and reagents shall have the following specifications.

The apparatus shall consist of a cylinder, preferably of metal approximately 330 mm high and 220 mm in diameter (capacity approximately 11 l). The cylinder shall be mounted on an axis inclined at an angle of 50° to the axis of the cylinder when the latter is in a vertical position. 100 % perchlorethylene, dry and free from acid, is used.

5.5.2.2 Test procedure

The material to be tested plus the ballast required, if any, are placed in the cylinder.

The cylinder is filled approximately one-third full with 100 % perchlorethylene, dry and free from acid, and rotated about its axis at a speed of 45 r/min to 50 r/min.

The test specimens are then taken from the cylinder and excess solvent removed from them by convenient means, such as centrifuging or squeezing between layers of white cotton cloth or white blotting paper. They are then laid on a muslin-covered frame or a non-rusting, metal screen. Heavy wrinkles are smoothed out with the hand and the test specimens are allowed to dry at room temperature.

One dry-cleaning cycle will then have been completed.

5.5.3 Acceptability of material

When 10 wash-dry cycles, and/or 10 dry-cleaning cycles, have been completed, the test specimens shall be placed on a flat surface and conditioned to the atmosphere for at least 4 h, and the shielding efficiency (see 5.4.5) and flame-retardancy tests (see 5.1.4) repeated. If the values measured in these tests no longer meet the specified requirements, the material shall be rejected.

6 Type tests of garment

6.1 General

Care shall be taken, if the garment is made up of more than one piece (for example, separate jacket or trousers), to ensure that the method of attachment (bonding) of the individual pieces is electrically continuous. The overlap of the individual component parts shall be such as to ensure that the body of the worker is totally covered.

6.2 Electrical resistance

The electrical resistance shall be measured between the points indicated in 6.2.2. Electrodes shall be at least 50 mm from the edge of the garment or joint location.

Measurements shall be made with the garment mounted on (supported by) a mannequin of non-conductive material (dummy) supporting the garment, to conform to the shape it will assume when worn by the worker, or they may be made with the garment flat on a non-conductive table.

6.2.1 Test procedure

The test shall be made using an adequate a.c. or d.c. source to supply 200 mA for 1 min.

Weights of 2,27 kg shall be applied to each wrist and ankle cuff to maintain "standard" conductive fibre contacts during the test. If weights are not available, sufficient pressure may be achieved by applying pressure with the hand to obtain lowest reading. A working belt shall be secured around the waist to obtain a good contact between the upper and lower portions of a two-piece garment. When a two-piece garment is tested flat on a non-conductive table, the working belt is replaced by a sufficient weight applied over the connection between trousers and jacket, to keep both parts together and to give good electrical contact.

Readings shall be made using electrodes with 25 mm^2 contact area and with adequate pressure. Readings shall include the electrode contact resistance.

Measurements shall be carried out after 1 min of current circulation.

6.2.2 Measurement locations

For all garments, measu**6.2.2 Measurement locations**

a) For all garments, measu rements shall be made between electrodes located approximately 50 mm from the fabric edge.

b) Points to be measured, as appropriate, are as follows:

- right wrist cuff to left wrist cuff;
- right ankle cuff to left ankle cuff;
- each wrist cuff to opposite ankle cuff.

6.2.3 Acceptable values

The garment shall be considered acceptable if the average resistance value measured between these points does not exceed 50 Ω.

When separate items of the garment are purchased, the manufacturer and the customer may agree to measurement points.

7 Type tests of the complete clothing

7.1 Bonding test

All component parts of the conductive clothing intended for use together shall be assembled according to the manufacturer's instructions. The bonding resistance between the garment and any component parts shall not exceed 100 Q.

The measurements required shall be made as specified using the procedure described in 6.2.1. The measurement locations are the following:

- from the wrist of the glove to each jacket wrist cuff;
- each bonding lead to its attachment point on the garment;
- hood, head cover, or face screen, to the neck of the garment or jacket.

Readings may be made using electrodes as described in annex D. However, the readings obtained shall be equal to, or less than, those required. The contact resistance of the electrodes should be included in the above readings.

7.2 Efficiency of conductive clothing

This test shall be carried out at 462 kV r.m.s., which is the maximum phase/earth power frequency voltage for which the clothing is used. The ground shall, as a minimum, be at a distance *D* given by the formula

$$D = U_{test} / 100 + 0{,}5 \quad \text{(with } D \text{ in metres and } L \text{ in kilovoltsj}$$

The mannequin shall be conductive to simulate a human body. It shall be equipped with (see also figure 8)

- a conductive belt placed against the mannequin;

- an insulating suit;

- the complete conductive clothing under test (which includes the face screen or other means to protect the face).

Good insulation between the conductive clothing and the conductive belt worn by the mannequin shall be checked before and after the test.

Direct reading is made on the shielded ammeter of

- the total current $/_1$, flowing between the live electrode and the conductive clothing
  connected to its conductive belt,
- the current $/_2$ flowing between the live electrode and the conductive belt.

The ratio $/_1$ / $/_2$ shall be such that the efficiency coefficient $/_1$ / (I_1+ *I2)* x 100 shall be not less than 99 %.

8 Type test of the component parts

8.1 Conductive gloves and mitts

Two electrodes shall be painted on the glove or mitt using conductive paint having the characteristics described in annex D, or other acceptable electrodes (see annex D and figure 9). The reading shall be recorded.

To provide protection from spark discharges directly to the hand through the material, the spacing between individual adjacent conductive components in the material shall not exceed 5 mm even when the material is stretched with a force of up to 50 N in any direction. No holes are permitted. Spacing can be verified by a visual inspection.

8.2 Conductive overshoe socks and normal socks

An electrode 25 mm long and parallel to the open edge of the overshoe sock or the normal sock and about 5 mm wide shall be painted on the specimen using conductive paint having the characteristics described in annex D, or other agreed-upon electrodes may be used. The sole of the overshoe sock or of the sock shall then be placed on a metal plate and 4 mm diameter nickel stainless steel balls, conforming to ISO 3290, poured into the overshoe sock or into the sock to a depth of 20 mm (see figure 10). The resistance shall then be measured between the electrode and the metal plate. The readings shall be recorded.

8.3 Conductive footwear

The footwear shall be placed on a metal plate and one electrode placed on the inside below the ankle opening. Nickel stainless steel balls 4 mm in diameter, conforming to ISO 3290, shall then be poured in and around the electrode to cover the complete sole to a depth of 20 mm at the heel (see figure 11 a).

The resistance shall then be measured between the metal plate and the electrode according to the procedure and shall be between the range 0 kQ to 10 kΩ.

If straps are used to connect the footwear electrically to the conductive clothing, then the resistance shall be measured between the strap and the metal plate on which the footwear is resting, with the steel balls inside but not connected in the circuit (see figure 11b).

Any metal parts in the footwear larger than 10 cm^2 shall be electrically bonded together during manufacture.

If conductive overshoe socks are used, the resistance of the footwear is not of concern.

NOTE The conductive footwear can be used alone, without complete conductive clothing, for protection against annoying spark discharges when working in an electric field.

8.4 Conductive head cover and face screen

Component parts used for screening the head and face shall meet the resistance and screening requirements and allow for free movement of the head.

9 Routine tests

9.1 Parts of conductive clothing from a single manufacturer

If the different parts of the conductive clothing are provided by a single manufacturer, he shall check each part of the conductive clothing in accordance with clause 6 of this standard for

a) quality as agreed between the customer and the manufacturer,
b) compatibility,
c) electrical continuity,
d) electrical resistance.

The manufacturer shall also check for bonding, according to 7.1.

9.2 Parts of conductive clothing from multiple manufacturers

If the customer buys the different parts of the conductive clothing from different manufacturers, each manufacturer shall check the specific product for

a) general form,
b) electrical resistance.

Recommendation: The customer should verify the compatibility and the electrical continuity (bonding) of the different parts of the complete conductive clothing.

10 Acceptance checks and tests

An acceptance test is a contractual test to prove to the customer that the device meets certain conditions of its specification (see IEV 151-16-23). These tests may be carried out on every unit (routine tests) or on a sample unit (sampling test).

If a customer indicates in his specification that the device shall meet the IEC standard only, the acceptance tests (both routine and sampling) are those listed in this standard.

The customer may, however, if he wishes, ask for additional tests or modify the sampling size but he shall include the information in his specification.

The customer may wish to witness the tests, have someone witness them or simply accept the results of the tests as carried out by the manufacturer. He may also specify that the tests be carried out in an independent laboratory of his choosing or even in his own laboratory.
Further, the customer may specify additional tests or larger sampling sampling sizes when he is purchasing from a new manufacturer.

11 Modification

Before carrying out any modification of any characteristic after the purchase agreement has been made, whether specified herein or not, the manufacturer shall obtain the agreement of the customer.

Any modification of the conductive clothing may require new type tests, in whole or in part (if the degree of modification so justifies), as well as a change in clothing reference literature.

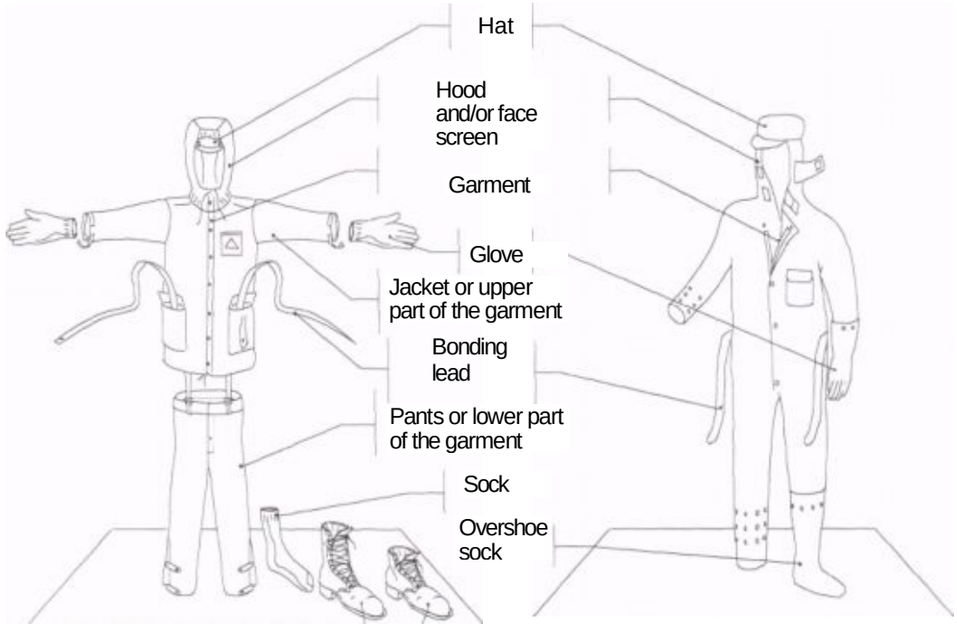


Figure 1 - Example of general arrangement of complete conductive clothing

(see clause 3)

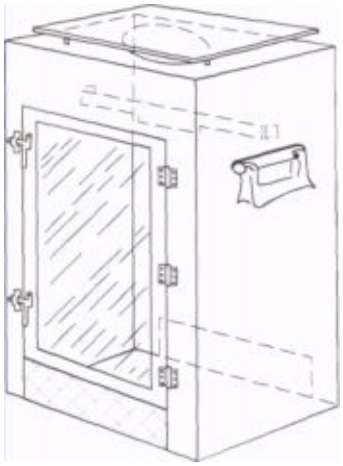
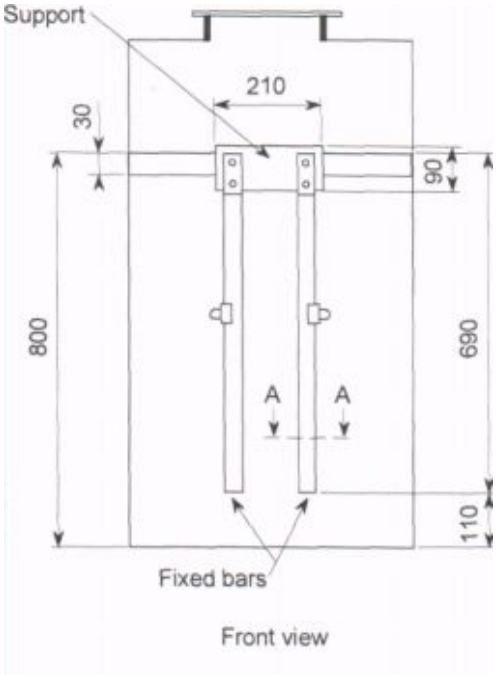


Figure 2 - Flame-retardancy test - Test chamber (see 5.1)



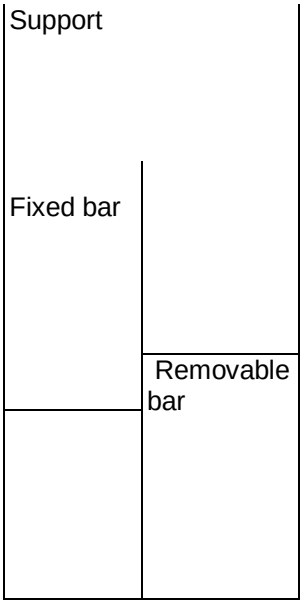


Figure 3a -Support for the test specimen holder

Fastener

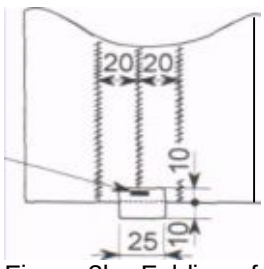
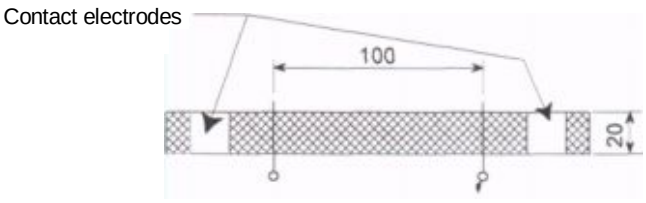


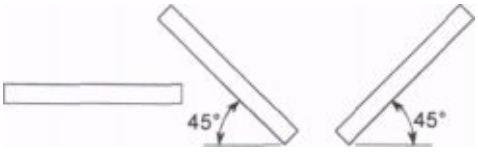
Figure 3b - Folding of the ignition specimen

Figure 3 - Flame-retardancy-test - Specimen holder and support (see 5.1)



Top view

Figure 4 - Electrical resistance test - Test set-up (see 5.2.3)



Weft

IEC 2065/02
Dimensions in millimetres

Figure 5 - Orientation of test specimens for electrical resistance and current-carrying capability tests (see 5.2.2)

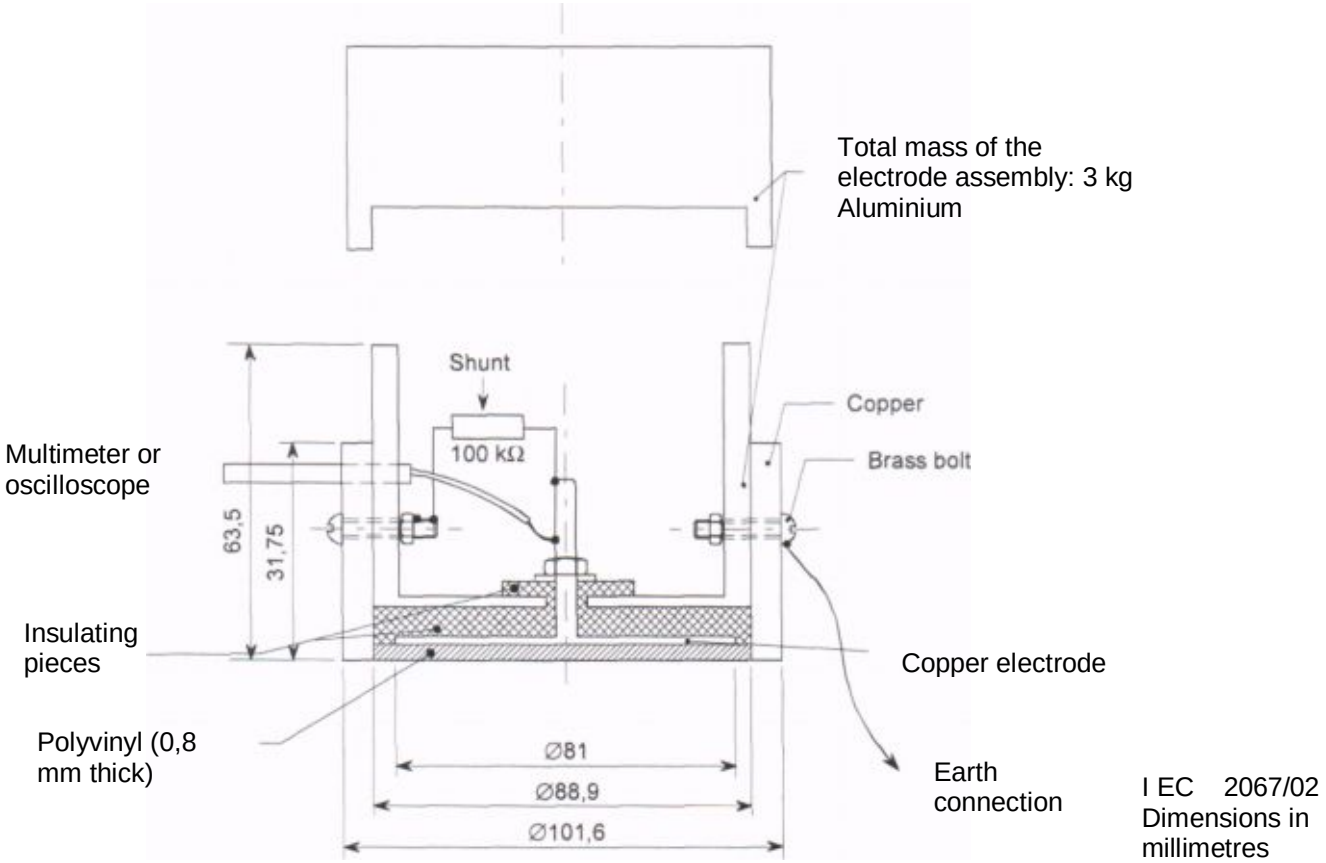


Figure 7a - Electrode assembly

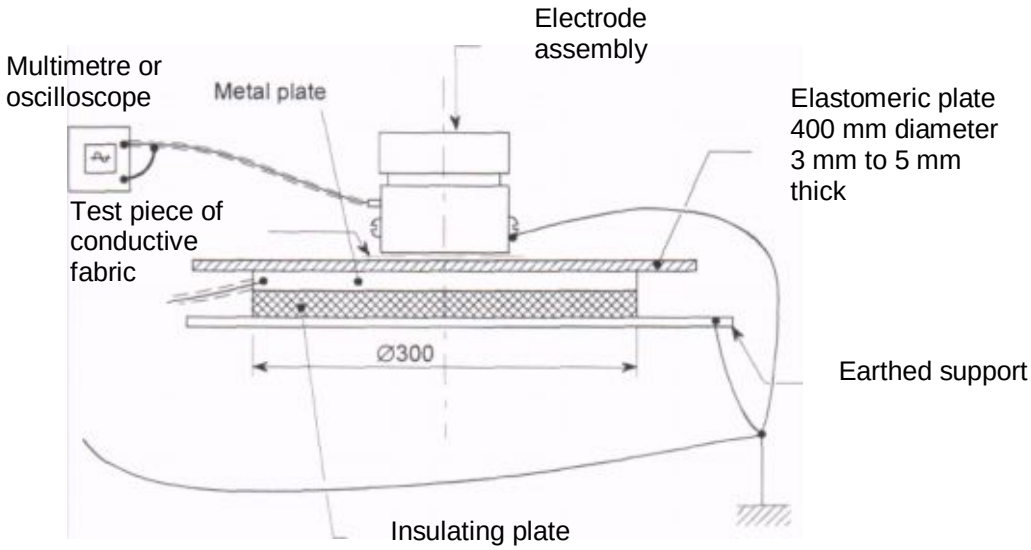
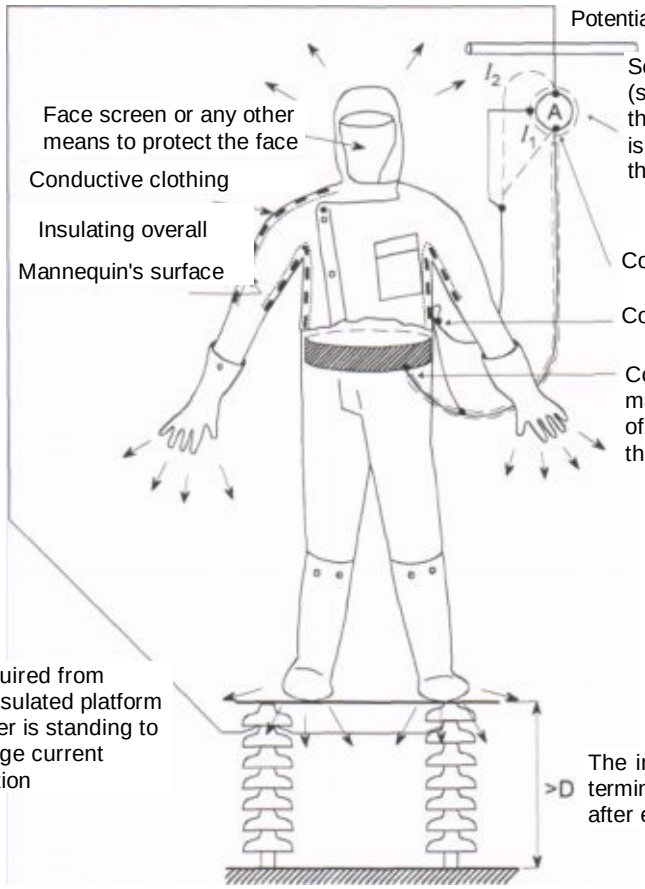


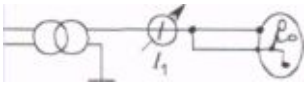
Figure 7b - Test set-up

Figure 7 - Shielding efficiency (see 5.4)

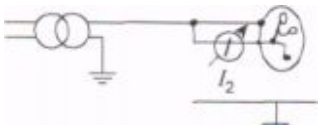
Position for measuring I_t: The current measured is the total charging current; it is the current to which the electrical worker would be exposed if he were not wearing a conductive clothing.

Position for measuring I_1: The charging current of the conductive clothing by-passes the micro-ammeter and the current measured is that which passes into the electrical worker only.





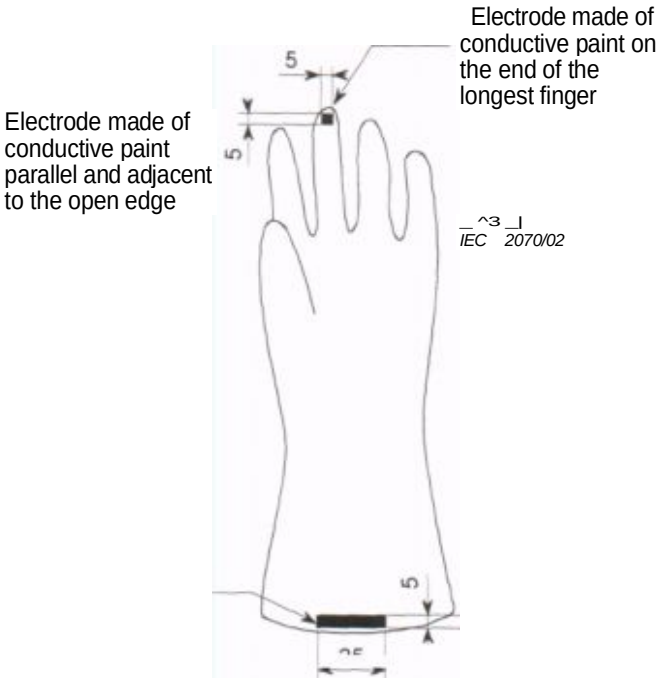
Electrical worker + conductive clothing



Electrical worker only

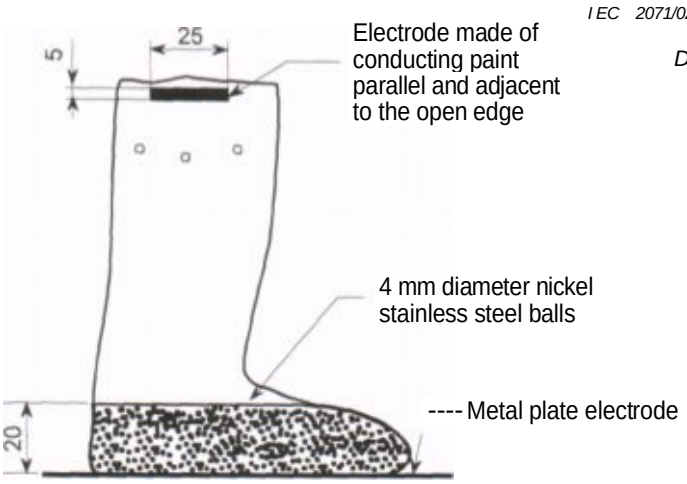
/EC 2069/02

Figure 8 - Efficiency of conductive clothing (see 7.2)



Dimensions in millimetres

Figure 9 - Electrical resistance test - Conductive gloves and mitts (see 8.1)



Dimensions in millimetres

Figure 10 - Electrical resistance test - Conductive overshoe socks and normal socks (see 8.2)

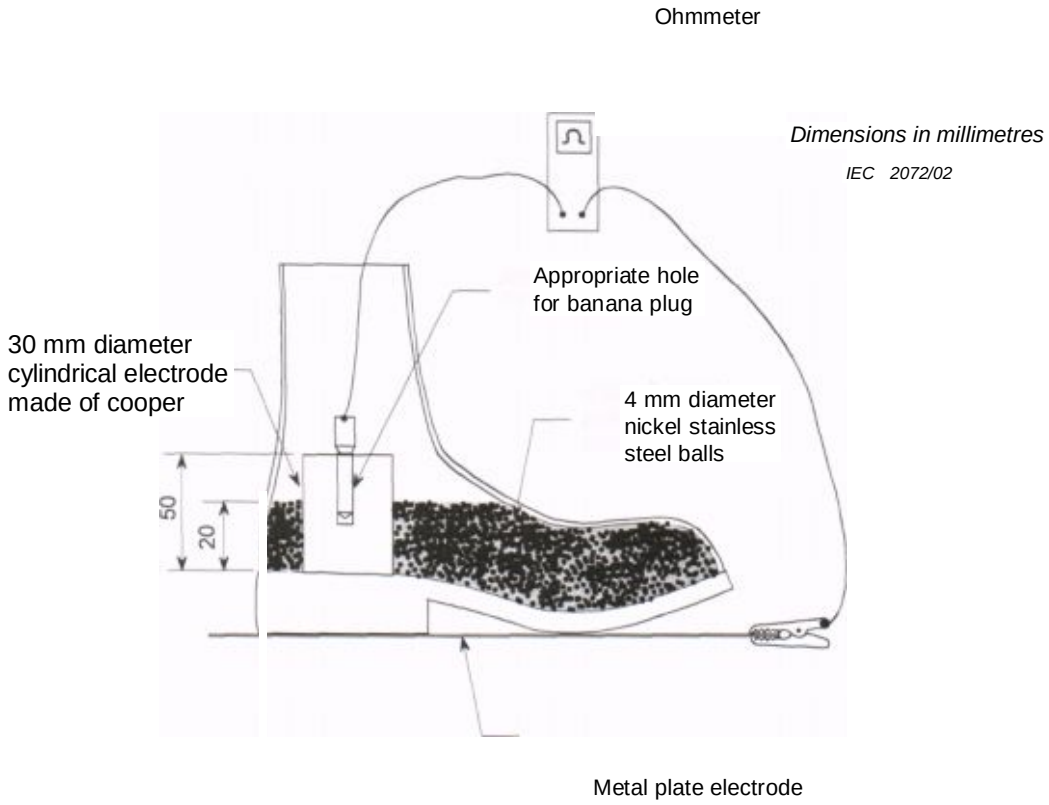


Figure 11a - Footwear without straps

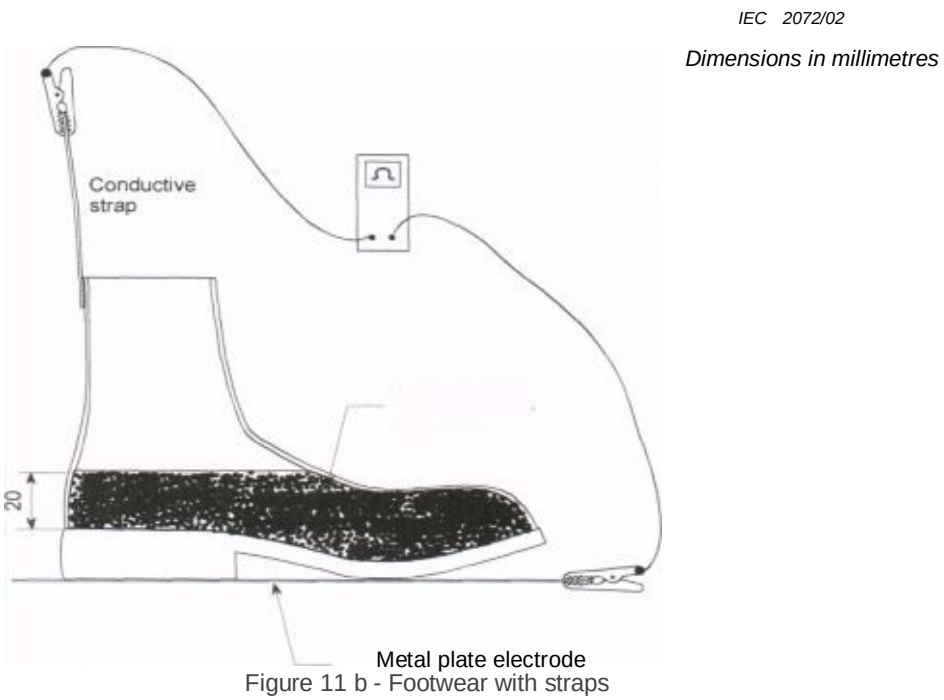


Figure 11 b - Footwear with straps

Figure 11 - Electrical resistance test - Conductive footwear (see 8.3)

Annex A
(normative)

Suitable for live working
(double triangle) (IEC-60417-5216)

/EC *2074/02*

Annex B
(normative)

Classification of tests

B.1 Tests on conductive material

Table B.1 gives the list of tests to be carried out on the conductive material.

Table B.1 - List of tests to be carried out on the conductive material

Description of tests	Requirement subclause	Test subclause	Type of defect	Type of test		
				Type	Routine	Sampling
Flame retardancy	4.2.1	5.1	Critical	X		
Electrical resistance	4.2.2	5.2	Critical	X		
Current-carrying capability	4.2.3	5.3	Critical	X		
Shielding efficiency	4.2.4	5.4	Critical	X		
Resistance to cleaning	4.2.5	5.5	Major	X		

B.2 Tests on the conductive garment

Table B.2 gives the list of tests to be carried out on the conductive garment.

Table B.2 - List of tests to be carried out on the conductive garment

Description of tests	**Requirement subclause**	**Test subclause**	**Type of defect**	**Type of test**		
				Type	**Routine**	**Sampling**
Electrical resistance	**4.2.2**	**6.2**	**Major**	**X**	**X**	
Marking	**4.4**		**Major**	**X**		**X**
Packaging	**4.5**		**Minor**	**X**		**X**
Manufacturer's instructions	**4.6**		**Major**	**X**		**X**

B.3 Tests on the conductive component parts

Table B.3 gives the list of tests to be carried out on the conductive component parts.

Table B.3 - List of tests to be carried out on the component parts

Description of tests	Requirement subclause	Test subclause	Type of defect	Type of test		
				Type	Routine	Sampling
Electrical resistance of gloves and mitts	4.3.1	8.1.1	Minor	X		X
Spark discharge protection of gloves and mitts	4.2.6	8.1	Minor	X		X
Electrical resistance of overshoe socks and socks	4.3.1	8.2	Minor	X		X
Electrical resistance of conductive footwear	4.3.2	8.3	Minor	X		X
Electrical resistance of conductive head cover	4.3.3	8.4	Minor	X		X
Marking	4.4		Major	X		X
Packaging	4.5		Minor	X		X
Manufacturer's instructions	4.6		Major	X		X

B.4 Tests on the complete clothing

Table B.4 gives the list of tests to be carried out on the conductive complete clothing.

Table B.4 - List of tests to be carried out on the complete clothing

Description of tests	Requirement subclause	Test subclause	Type of defect	Type of test		
				Type	Routine	Sampling
Bonding test	4.1	7.1	Critical	X	X"	
Efficiency	4.2.4	7.2	Critical	X		X

[a] This routine test is carried out when the different parts of the complete clothing are provided by a single manufacturer.

Annex C
(normative)

Sampling procedure

C.1 General

The sampling procedure for this product does not follow in its entirety the sampling procedure developed in ISO 2859-1. The product covered by this standard does not lend itself to the application of the above-mentioned standard due to its nature.

The sampling procedure used in conjunction with this standard has been specially developed on the basis of the quality assurance practice of the ISO 9000 series. When those requirements (ISO 9000) are not followed, the procedure of this annex is applicable.

C.2 Classification of defects

Defects are classified as critical, major or minor (see clause 2 of IEC 61318). Annex B gives the defect classification for the tests retained for the sampling procedure.

C.3 General sampling plan

Sampling tests shall be made under the responsibility of the manufacturer who shall make their results available to the customer. The sampling plan and the acceptable quality level shall be in accordance with AQL 10 in IEC 61318, as indicated in table C.1 below.

Table C.1 - Sampling plan (AQL 10)

Lot or batch size	Sampling size	Acceptance criterion "	Rejection criterion "
2 to 5	2	0	1
6 to 10	3	0	1
11 to 90	5	1	2
91 to 150	8	2	3
151 to 3 200	13	3	4
3 201 to 35 000	20	5	6
[a] Maximum allowable number of defectives. [b] Rejected if the number of defectives is equal to, or greater than, this number.			

C.4 Procedure when testing is carried out in a laboratory other than the manufacturer's

Testing procedures shall follow the requirements of this standard.

Annex D
(informative)

Electrodes for determining electrical resistance properties of material specimen and garments

D.1 General

The type of electrode used to determine the electrical resistance of the material specimen is that specified and described in figure 4. The potential electrodes are to be threaded through the specimen as indicated in figure 4.

For conductive clothing the electrodes may be of different design but must have a contact area of at least 25 mm^2 and have a contact pressure of 100 kPa. The voltage drop due to the electrode contact shall be included in the measurement.

The type of electrodes does not significantly influence the overall reading. Crabclaws, clips or pads affixed to the material may be used. The contact surface shall be at least 25 mm^2 and the contact pressure shall be 100 kPa, required to reduce the contact resistance and obtain the lowest reading.

D.2 Conductive paint

Conductive paint may provide the lowest contact resistance as it soaks into the fabric. If paint is used, it should meet the following criteria:

- colloidal silver paint is recommended;
- before a conductive paint is used as an electrode material, it should be established that the solvent in the paint does not attack the material so as to change its electrical properties.

Annex E
(informative)

Recommendations for the in-service care, maintenance and periodic testing of conductive clothing and component parts

E.1 Care, storage and repair

E.1.1 Care

The integrity of the conductive clothing is essential. It is the responsibility of the worker to exercise extreme care while wearing and handling the conductive clothing. Tears, holes and other deformities should be repaired according to accepted practice as described in E.1.4.

E.1.2 Storage

Conductive clothing, and component parts should be stored in a dustproof breathable container, such as a canvas or vinyl bag or briefcase. The container should be breathable in order to allow any moisture in the conductive clothing to dry, rather than turn mouldy. The storage container should be easily identified and stored in a location safe from heat, moisture and damage from other stored items. Care should be taken in transport. Conductive clothing should not be stored when made damp by perspiration or other moisture.

E.1.3 Cleaning

The manufacturer's cleaning instructions should be followed. In general, the conductive clothing may be washed by hand or in an automatic washer with a detergent and no other additives (bleach, etc.) and may be dried in an automatic dryer on low heat or air-dried.

The life of the conductive clothing may be prolonged by hand washing with mild detergent and air-dried. Conductive clothing that is heavily soiled with grease, oil or other heavy contaminants should be dry cleaned.

E.1.4 Patching and repair

Snags and rips can be sewn with flame-retardant thread. Holes can be repaired by using a patch of the conductive clothing material and by stitching a 2,54 cm overlap with flame-retardant thread.

NOTE When conductive clothing is damaged beyond repair and needs to be retired from service, it is recommended that it be returned to the manufacturer along with a complete history of its use and care, in order to provide a database for future review.

Socks and gloves are not repairable.

E.2 Inspection before use

E.2.1 General

Before each day's use, a visual inspection should be made of the complete conductive clothing to ensure that all component parts fit together.

Zip fasteners, metal press-studs, metal hooks and eyes (gallow straps or suspenders) should be checked to ensure that they are correctly inserted and making a good contact. The stitching should be examined to ensure that it is continuous and that two or more pieces, when joined, stay in good contact.

Adjustable self-gripping devices may be used to eliminate the need for metal fasteners.

E.2.2 Conductive clothing

Conductive clothing should be carefully examined by the wearer to be sure it is not damaged and that the bonding leads are secure.

E.2.3 Conductive boots and leg straps

The straps between the conductive boots and the calf should be inspected for breaks that would disrupt electrical continuity. They should be replaced if they are judged inadequate.

The soles of the boots should be kept clean and free from dirt and contaminants.

E.2.4 Conductive socks and gloves

Conductive socks and gloves should be inspected for damage.

E.3 Non-destructive periodic testing

E.3.1 General

Conductive clothing should be tested for resistance, either on a mannequin or flat, on a non-conductive table. A weight of 2,27 kg should be used at each wrist and ankle cuff to provide for proper and repeatable contact between fibres within the material. The resistance may be measured using either an a.c. source with current and voltage meters, or with d.c. source and digital multimeter to read the resistance directly. Digital multimeters provide adequate sensitivity and accuracy for these measurements.

E.3.2 Test frequency

Testing is recommended at least every five years, or after five washings, whichever comes first.

E.3.3 Resistance test

When worn, conductive clothing should register continuity between any two extremities of the material. The required actual ohmic value will depend upon the electric field in which the worker will be exposed. New material will meet the limits set in the text: 50 Q for the conductive clothing and a maximum of 100 Q for the component bonding when tested according to this standard.

If the in-service test exceeds three times the original manufacturer's test values, the use of the conductive clothing should be investigated.

The garment test should be performed as given in clause 6 and bonding test as given in 7.1.

E.3.4 Record keeping

A complete chronological record of the conductive clothing used, its condition and test results should be retained so that the user can establish his own replacement parameters based on the specific tasks, use of the conductive clothing and care given the garment and component parts.