Department of
CONTROL AND COMPUTER ENGINEERING (DAUIN)

Master Degree in Mechatronic Engineering

Feasibility study for the establishment of accredited test/calibration laboratories at TTPU (Polytechnic University of Turin in Tashkent)

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1 Introduction

The main purpose of the thesis is to study the feasibility of calibration and testing laboratories, which will be established at Polytechnic University of Turin in Tashkent (TTPU). Nowadays in Uzbekistan there is a primary laboratory, Uzbek National Institute of Metrology (OZ MMi), and the Uzbek Centre of Accreditation (OZAKK, a full member of ILAC), but there are not yet any accredited secondary laboratories. In March 2023 several meetings with OZ MMi and OZAKK were held at TTPU, traceability issues have been discussed, the reference standards have been selected and the instrumentation for the laboratory was defined. As regards the testing laboratory, several Uzbek companies want to export their products in Europe and to achieve this goal such products must be first tested according to the European standards. The products chosen by Uzbek companies and considered in this project are household appliances and winding wires. The following step consists in selecting the proper International Standards, such as harmonised standards, if duly adopted, gives the presumption of conformity. The standardization is performed by different standardization body with different geographical interests:

WORLD → ISO(not electric)/IEC(electric)→ CISPR(TELECOMM)
EU→ CEN(not electric)/CENELC(electric)/ETSI(TELECOMM)
COUNTRY → DIN/VDE/UNI/CEI/BSI/UL/NF/SASO/SAI GLOBAL...

How to find an harmonised standard? The EU site gives all the information and help manufacturers to find the right standard for the presumption of conformity. Regarding the household appliances, the main standards taken in consideration are the household appliances CEI EN 60335-1 and CEI-EN-IEC-55014-1,2. The first one "recognizes the internationally accepted level of protection against hazards such as electrical, mechanical, thermal, fire and radiation of appliances when operated in normal use taking into account the manufacturer's instructions. It also covers abnormal situations that can be expected in practice and takes into account the way in which electromagnetic phenomena can affect the safe operation of appliances"[1]. The second one deals with the electromagnetic compatibility, Emissions and Immunity for part 1 and part 2. For winding wires, the electrical tests studied are the ones from CEI EN 60851-5, such as Beakdown voltage, Continuity insulation, Pin hole test, and so on. The tables 1 and 2 reports an overview of the required tests.

The tests deeply explained in those standards are studied in order to design the whole facility. In the following chapter the theoretical approach used to choose the instrumentation is explained. The middle chapters describe the tests related to the products and the last chapter deals with the budget prevision of the test facility.

[1] CEI EN 60335-1

Table (1) Household appliances overall tests

Test	**Mechanical**	**Electrical**	**Thermal**
Protection against access to live parts		x	
Power input and current		x	
Heating	x	x	x
Leakage current and electric strength		x	
Transient overvoltages		x	
Moisture resistance			x
Overload protection of transformers and associated circuits		x	
Abnormal operation	x	x	x
Stability and mechanical hazards	x		
Mechanical strength	x		
Construction	x	x	x
Internal wiring	x	x	
Supply connection and external flexible cords	x	x	x
Terminals for external conductors	x		
Provision for earthing		x	
Screws and connections	x	x	
Clearances, creepage distances and solid insulation chapter chapter	x	x	x
Resistance to heat and fire			x
Continuity of insulation	x	x	x
EMC		x	

Table (2) Winding wires overall tests

Test	**Mechanical**	**Electrical**	**Thermal**
Electrical resistance		x	x
Pin hole test		x	x
Breakdown voltage	x	x	x
Continuity of insulation		x	

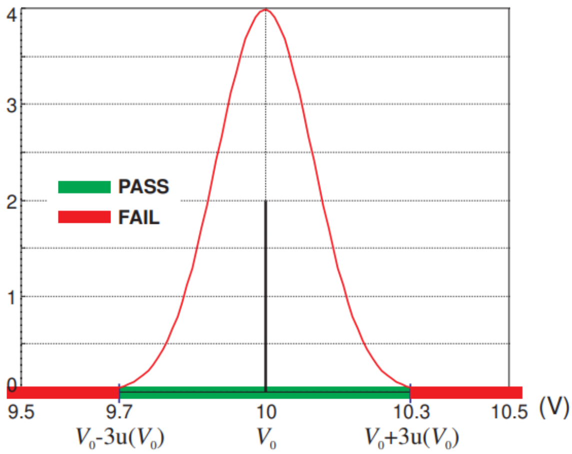


Figure (1) Example of verification of a voltmeter in the ideal situation of input value known without uncertainty.

2 Calibration and conformity verification

In general whenever a quantity, unknown measurand M, has to be measured users have to know the output/input relation (calibration relation[2]) in order to obtain an evaluation of the measurand. Furthermore, the instrumentation indication I is affetced by several factors, such as temperature, humidity, voltage supply, frequency and vibration, so calibration relations valid in different fields of use of the influence quantities are provided. After a certain amount of time, e.g. calibration interval stated by the manufacturer, the calibration relation could be not anymore valid and it must be verified by means of the following operations:

- a set of known values are applied to the instrument input;
- the measurement errors between applied values and indications are compared to the instrument tolerance (maximum admitted errors δI).

If the input values are known without uncertainty and I is not affected by the factors stated before (ideal situation), two main scenarios can arise from the verification procedure (see figure 1):

$E_i = |M_i - I_i|$

- PASS: $E_i < \delta I_i, \forall i$;
- FAIL: $\exists i | E > \delta I_i$;

In a real case I is affected by several factors and the input values have a certain uncertainty, δM_i:

$$\delta M = \pm(A \cdot Reading + B \cdot Range) \tag{1}$$

where the parameters A and B assume different values for the different fields, in table 3 an extract of the uncertainty specifications of a digital multimeter is shown as example.

In this case, besides the pass and fail results discussed previously, other two events are possible, that are:

- False fail: $\exists i | E > \delta I_i$ even though the instrument is conform to its calibration relation
- False pass: $E_i < \delta I_i, \forall i$ even though the calibration relation is not more valid

The probability of these two events decreases as the uncertainty of the reference values M_i decreases. The parameter that is usually employed to express the suitability of a device to act as a reference standard during a verification process is the Test Uncertainty Ratio (TUR), that is defined as:

[2]relationship between the instrumentation indication (output) and the measurand (input).

Table (3) Extract of the uncertainty specifications of a digital multimeter.

Instrumental uncertainty: $\pm(A\% \cdot Reading + B\% \cdot Range)$ V						
Function	Range	24 hours $(23 \pm 1)\ C$; $h < 80\%RH$		90 days $(23 \pm 5)\ C$; $h < 80\%RH$		
		A	B	A	B	
DCV	100 mV	0.003	0.003	0.004	0.004	
	1 V	0.002	0.0006	0.004	0.0007	
	10 V	0.0015	0.0004	0.002	0.0005	

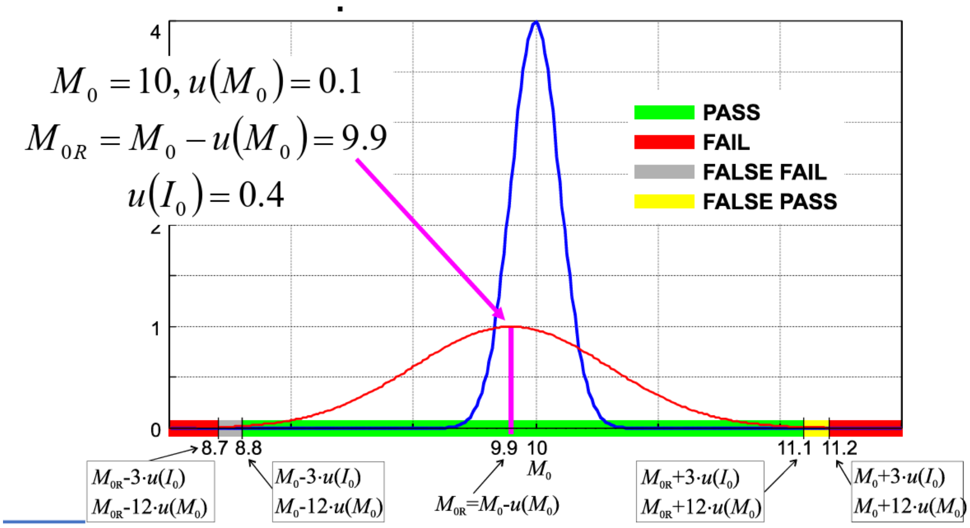


Figure (2) Example of verification of a voltmeter performed by employing a voltage standard whose uncertainty gives a TUR value equal to four

$$TUR_i = \frac{u(I_i)}{u(M_i)} \tag{2}$$

where $u(I_i)$ is the instrumental standard uncertainty corresponding to the generic test point M_i and $u(M_i)$ is the standard uncertainty of the reference value. As shown in figure 2 , M_0 is the nominal reference value, which is generated by a device with standard uncertainty $u(M_0) = 0.1$ V. The actual/real value is assumed to be

$$M_{0R} = M_0 - u(M_0) \tag{3}$$

Also the TUR is assumed to be equal to 4 so, $u(I_0)$ and the maximum admitted error of the instrument under verification are equal to:

$$u(V_0) = 4 \cdot u(M_0) = 0.4 \text{ V} \tag{4}$$

$$3 \cdot u(V_0) = 12 \cdot u(M_0) = 1.2 \text{ V} \tag{5}$$

If the nominal value was the real one the pass event corresponded to $(8.8 \div 11.2\ \ V)$ interval, since M_0 differs from M_0R false fail $(8.7 \div 8.8\ \ V)$ and false pass $(11.1 \div 11.2\ \ V)$ events are present.

The estimation of probability of false event can be applied to choose the suitable instrumentation for the testing laboratory. To assess the conformity of a parameter X to a stated specification, it is necessary to compare the measurement x_0 of the parameter to a tolerance interval or limit, figure 3. Since x is affected by the standard uncertainty $u(x)$, an approach based on the guard-band rule can be implemented to evaluate the false pass probability, i.e. the acceptance limit (or interval) UL-LL, is different than the tolerance limit (or interval), LL-LAL and UAL-UL (see figure 3). The tolerance limit (or interval) and the guard band $(g = k_w \cdot u(x))$ are modified according to the measurement uncertainty

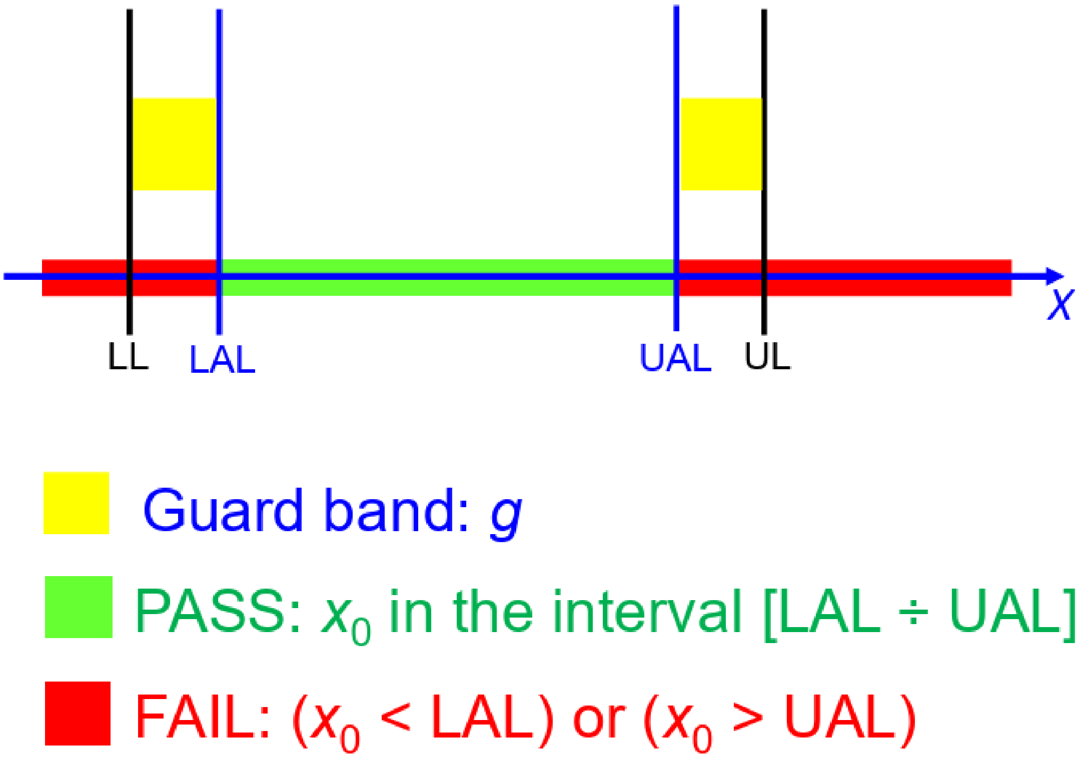


Figure (3) Definition of guard band rule

and the risk of a wrong decision. Eventually the probability of false acceptance (PFA) is evaluated for different values of the guard band.

The algorithm to follow in order to choose an instrument is the following; given those input data:

- required PFA;
- LL-UL;
- $u(x)$;

1. a new PFA is computed given as input $x_0 = (UL - LL)/2$;
   - if $PFA_{new} > PFA_{req}$ then is not possible to ensure PFA_{req}
   - else k_w is evaluated and so $UAL = UL - k_w \cdot u(x)$, $LAL = LL + k_w \cdot u(x)$
2. evaluate PFA using $x_0 = UL$
3. repeat the previous two steps until $PFA \approx PFA_{req}$

A practical example of PFA computation with an acceptance limit is studied in the Leakage current and dielectric strength test at working temperature (section Household appliances).

3 Test methods for household appliances

In this section, all the tests required for the certification of home appliances are described according to the standards CEI EN 60335-1 and CEI-EN-IEC-55014-1,2. For each sub chapter title the related standard section is present on the right inside the brackets. Before explaining the tests some definitions must be given:

"**rated voltage**: voltage assigned to the appliance by the manufacturer.

normal operation: conditions under which the appliance is operated in normal use when it is connected to the supply mains.

electronic circuit: circuit incorporating at least one **electronic component**.

electronic component: part in which conduction is achieved principally by electrons moving through a vacuum, gas or semiconductor [3]

heating appliance: appliance incorporating heating elements but without any motor.

rated power input: power input assigned to the appliance by the manufacturer[4].

combined appliance: appliance incorporating heating elements and motors.

protective impedance: impedance connected between **live parts** and **accessible conductive parts** of **class II** constructions so that the current, in normal use and under likely fault conditions in the appliance, is limited to a safe value.

live part: conductor or conductive part intended to be energized in normal use, including a neutral conductor but, by convention, not a PEN conductor [5].

accessible part: part or surface that can be touched by means of test probe B and probe 18 of IEC 61032, and if the part or surface is metal, any conductive part connected to it [6].

motor-operated appliance: appliance incorporating motors but without any heating element [7].

off position: stable position of a switching device in which the circuit controlled by the switch is disconnected from its supply or, for electronic disconnection, the circuit is de-energized [8].

all-pole disconnection: disconnection of both supply conductors by a single initiating action or, for multi-phase appliances, disconnection of all supply conductors by a single initiating action [9].

basic insulation: insulation applied to **live parts** to provide basic protection against electric shock.

supplementary insulation: independent insulation applied in addition to **basic insulation**, in order to provide protection against electric shock in the event of a failure of **basic insulation**.

protective impedance: impedance connected between live parts and accessible conductive parts of class II constructions so that the current, in normal use and under likely fault conditions in the appliance, is limited to a safe value.

thermal cut-out: device which during abnormal operation limits the temperature of the controlled part by automatically opening the circuit, or by reducing the current, and is constructed so that its setting cannot be altered by the user.

thermostat: temperature-sensing device, the operating temperature of which may be either fixed or adjustable and which during **normal operation** keeps the temperature of the controlled part between certain limits by automatically opening and closing a circuit.

temperature limiter: temperature-sensing device, the operating temperature of which may be either fixed or adjustable and which during **normal operation** operates by opening or closing a circuit when the temperature of the controlled part reaches a pre-determined value[10].

Class 0: electrical shock protection is based only on the main isolation; due to that there is no linking between the conductive approachable parts and a protection conductor embedded inside

[3] Neon indicators are not considered to be **electronic components**.

[4] If no power input is assigned to the appliance, the **rated power input** for **heating appliance** and **combined appliances** is the power input measured when the appliance is supplied at **rated voltage** and operated under **normal operation**

[5] A PEN conductor is a protective earthed neutral conductor combining the functions of both a protective conductor and a neutral conductor.

[6] Accessible non-metallic parts with conductive coatings are considered to be accessible metal parts.

[7] Magnetically driven appliances are considered to be motor-operated appliances.

[8] The **off position** does not imply an **all-pole disconnection.**

[9] For multi-phase appliances, the neutral conductor is not considered to be a supply conductor.

[10] A **temperature limiter** does not make the reverse operation during the normal duty cycle of the appliance. It may or may not require manual resetting.

the electrical plant; in case of main isolation failure the surrounding environment will be in charge for protection [11].

Class 0I: appliance provided with at least basic insulation in all its parts and incorporating an earth terminal, but equipped with a supply cable without a conductor earthed and fitted with a non-earth contact plug

Class I: appliance in which protection against electric shock is not based solely on the main insulation, but also includes an additional safety measure formed by connecting the accessible conductive parts to a protective conductor of earthing which is part of the fixed connections of the installation so that the parts accessible conductors cannot become dangerous in the event of insulation failure principal [12].

Class II: appliance in which protection against electric shock is not based solely on the main isolation, but also on the additional security measures constituted by the double insulation or reinforced insulation [13]; these measures exclude grounding of protection and do not depend on the installation conditions [14].

NOTE 3 if an appliance with all its parts with double insulation or reinforced insulation is provided with grounding arrangements, it is considered **Class I**, or **Class 0I**.

Class III: appliance in which protection against electric shock relies on the power supply coming from a very low safety voltage system and in which they are not generated voltages higher than the very low safety voltage"[15]

3.1 Protection against access to live parts (8)

Appliances shall be constructed and enclosed so that there is adequate protection against accidental contact with live parts. The main purpose of this test is to check if it is possible to touch live parts (or live parts protected only by lacquer, etc see 8.1.1 of CEI EN 60335-1), so the test is failed whenever such situation is possible. Several probes will be used to emulate test finger:

Test probe B and **probe 18 of EN 61032** , see figure 4, with a maximum force of 1N when the DUT is put in all the possible positions. When the probe is not able to dive into the opening both probes are put in straight position and 20 N for **probe B** or 10N for **probe 18**. Those two are applied to appliances from built-in and to appliances installed in a fixed position only after installation.

Test probe 13 of IEC 61032 with a maximum force of 1N through openings in **class 0** appliances, **class II** appliances and **class II constructions**.

For all other type of classes a part from Class II the **test probe 41** of IEC 61032 can be used (1N maximum force).

To all the probes a dynamometer is attached at the end.

How to check if the accessible part is live or not? Two cases are taken in consideration:

[11] **Class 0** appliances either have an insulating material casing which may be wholly or partly the main insulation, or a metal casing separated from live parts by insulation appropriate. If an appliance provided with a casing of insulating material is equipped with a device for grounding ground of the internal parts, it is considered **Class I** or **Class 0I**.

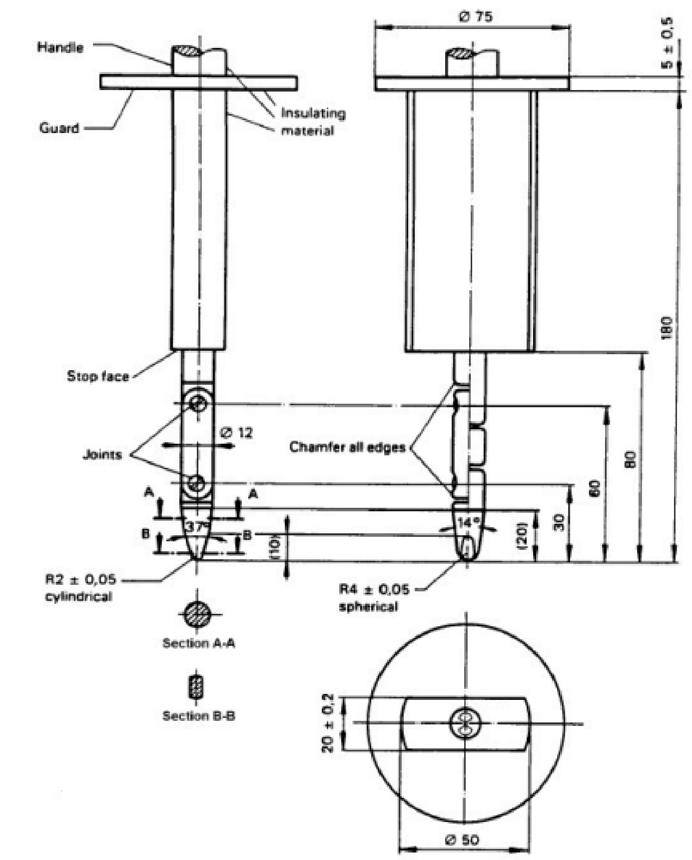
[12] The protective earth conductor must be part of the power cable.

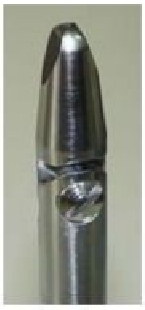
[13] The enclosure of a **Class II** apparatus encapsulated in insulation may constitute wholly or in part supplementary insulation or reinforced insulation.

[14] A device of this kind can be one of the following types:

- luminaire with a durable and practically continuous casing of insulating material which encloses all metal parts, with the exception of small parts such as plates, screws and rivets which are isolated from the metal parts voltage by means of insulation at least equivalent to reinforced insulation; a device of this it is usually called an insulator-encapsulated Class II appliance;
- an apparatus with a practically continuous metal casing and in which twice as much is used everywhere insulation or reinforced insulation; such a device is called a Class II device encapsulated in metal;
- an apparatus which is a combination of an insulator encapsulated Class II apparatus and a metal encapsulated Class II appliance.

[15] CEI EN 60335-1 Terms and definitions





Detail

Figure (4) Test probe B IEC 61032

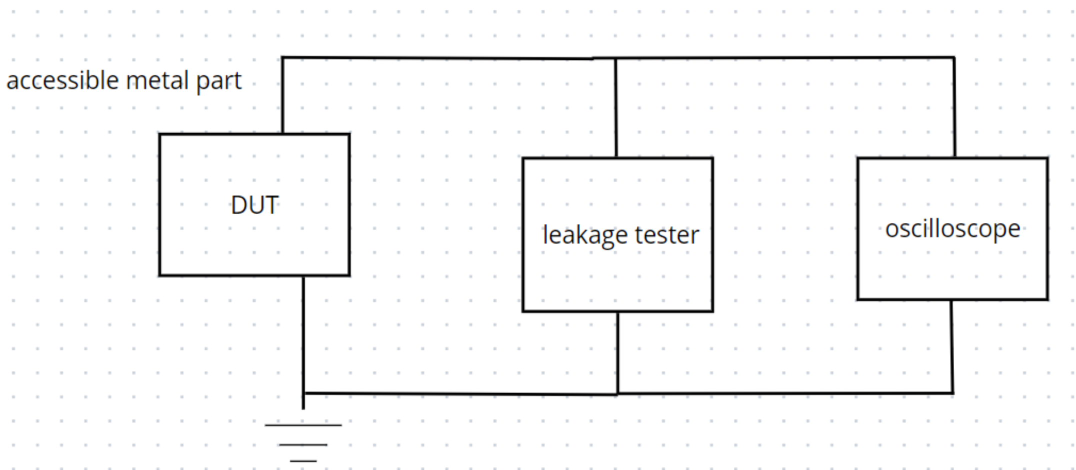


Figure (5) Protection against live part (CEI EN 60335-1, chapter 8), circuit for checking if the part is live or not

1. if there is a protection impedance between such part and the live one (usually Class II appliances have this impedance). The DUT is supplied at rated voltage, the current flowing from the supplier to the part must not exceed:
   - 2 mA (d.c.)
   - if the DUT is supplied at a.c. voltage the current peak must be lower than 0.7 mA and for peak voltage between 42.4 V and 450 V, capacitance must not exceed 0.1 μF;
   The measurements are performed as shown in figure 5 for each pole of the DUT supplier;
     - currents can be measured by using the Associated Research fully automated leakage tester, model 620L;
     - measurements of discharges are taken immediately following the supply interruption. They can be measured by means of an oscilloscope and a probe for currents, a current/time graph will be plotted and by using a specific function the area under the curve is computed.

$$\int_0^t i(t)\,dt = q(t) \tag{6}$$

$$C = \frac{q}{V} \tag{7}$$

2. There is not a protective impedance, the component is supplied with safety extra-low voltage, under the condition that:
   - For AC, the peak voltage does not exceed 42.4 V;
   - For DC, the voltage does not exceed 42.4 V;

The tools needed are summarized in table 4 .

3.2 Power input and current (10)

Each device has its own rated power input, the following test aims at checking if the power at working temperature is not higher than a certain threshold (see table 5). The measurement must be performed at such conditions:

- all circuits, which can operate simultaneously, in operation;
- the DUT is supplied at rated voltage;
- the appliance functioning under normal operating conditions;

If the power changes during the working cycle, the measure value is computed as the average along a representative time period. The test is carried out at the upper and lower limits of the range for

Table (4) Instrumentation for protection against access to live parts test

Instrument	Main purpose
Associated Research fully automated leakage tester, model 620L	current in the live parts
oscilloscope	voltage and discharges (live parts check)
• Test probe B and probe 18 of EN 61032; • Test probe 13 of IEC 61032; • test probe 41 of IEC 61032;	test finger

Table (5) Power input deviation

Type of appliance	Rated power input	Deviation
All appliances	≤ 25 W	+20%
Heating appliances and combined appliances	> 25 W and ≤ 200 W > 200 W	±10% +5% or 20 W (whichever is the greater) −10%
Motor-operated appliances	> 25 W and ≤ 300 W > 300 W	+20% +15% or 60 W (whichever is the greater)

the devices they carry the indication of one or more nominal voltage ranges, unless the indication of the nominal power refers to the arithmetic mean of the relevant voltage range; in this case, the test is performed with a voltage equal to the arithmetic mean of that field.

The deviation for the Motor-operated appliances is also applied to combined ones if the motor power is 50% higher than the rated power. The maximum allowable deviations apply to both limits of the range for devices that indicate the nominal voltage range whose limits differ by more than 10% from the arithmetic mean of the range itself.

As shown in figure 6 by using a wattmeter the power is measured, the Yokogawa WT300E model has been chosen since its accuracy is compliant with the deviation; ruthless speaking the instrument uncertainty must be lower than one third of the related deviation, if such condition is fulfilled the PFA can be computed.

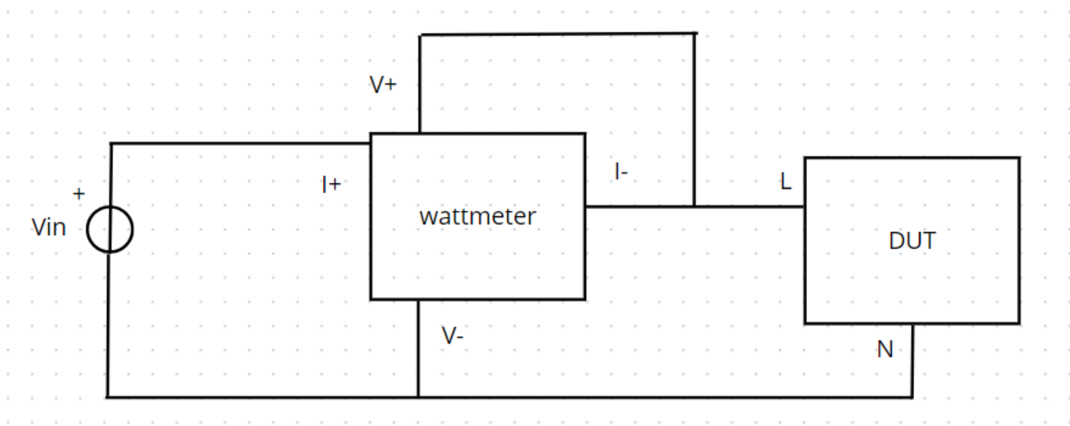


Figure (6) Power input experiment (CEI EN 60335-1, chapter 10): circuit for measuring power by means of a wattmeter

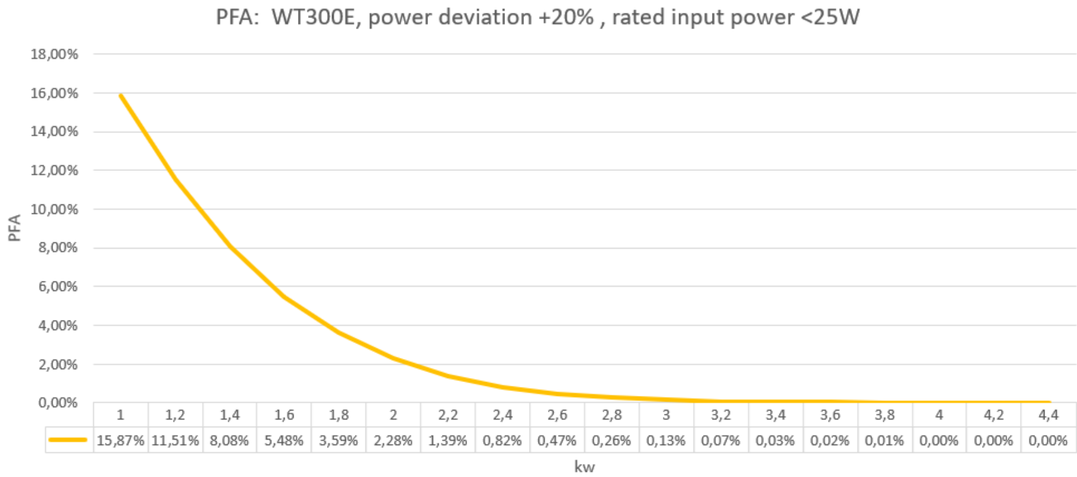


Figure (7) PFA evaluated for different guard bands $g = k_w \cdot u(I_b)$, with $u(I_b)$ corresponding to the uncertainty provided by the wattmeter Yokogawa WT300E model, Power input experiment (CEI EN 60335-1, chapter 10)

Table (6) Current deviation

Type of appliance	**Rated current** A	**Deviation**
All appliances	≤ 0.2	+20%
Heating appliances and combined appliances	> 0.2 and ≤ 1 > 1	±10% +5% or 0.01 A (whichever is the greater) −10%
Motor-operated appliances	> 0.2 and ≤ 1.5 > 1.5	+20% +15% or 0.3 A (whichever is the greater)

Case study: motor-operated appliance with rated power input equal to 100 W so the absorbed power according to table 5 must not exceed $(100 + 20)$ W, 20 W is the admitted deviation (20%). In order to be sure that such threshold is not reached the uncertainty instrument must be lower than one third of the deviation so eventually the absorbed power must not be higher than $(100 + 7)$ W. The WT300E uncertainty in this specific case is equal to 0.058 W then the PFA computation can be performed which consists on collecting several PFA values by changing the k_w factor (figure 7).

The same procedure can be applied to the input current's issue since the wattmeter can measure the current (see table 6).

3.3 Heating (11)

All the devices and the environment must not reach too high temperature while working, in order to check such condition the temperature rise of various parts is determined. The DUT is put in several positions, such as on a test corner, on the floor, along the wall and so on, it depends from their normal condition of use. The overtemperature of the housed part of the cable is determined in most unfavorable point. The temperature rise which are not related to the windings are measured by the thin wired thermocouples, they are set up in a way to not affect the temperature of the part under measurement. In order to measure the test corner walls, ceiling and floors surfaces temperatures the thermocouples are sticked on the back of small discs of copper or blackened brass (15 mm in diameter and 1 mm thick), the front of such disc is put on the panel surfaces. As far as possible, the DUT is put in such way that the thermocouples are able to measure the highest temperatures. The insulation rise temperature is determined on its surfaces on certain points where something wrong might make:

- a short circuit;
- a link between the live part and the metallic accessible part

- bridging of insulation;
- shortening the clearances or creepage distances below the values specified in Clearances, creepage distances and solid insulation chapter chapter.

There are just few items needed:

a dull black-painted plywood approximately 20 mm thick (test corner);
thin wire thermocouples;
small discs of copper or blackened brass, 15 mm in diameter and 1 mm thick;
voltage supplier;

The following equation explains how to compute the temperature rise of a winding (Δt):

$$\Delta t = \frac{R_2 - R_1}{R_1} \cdot (k + t_1) - (t_2 - t_1) \tag{8}$$

Δt: winding's temperature rise;
R_1: resistance at the beginning of the test;;
R_2: resistance at the end of the test;
k: such coefficient depends on the winding material (see chapter 11.3);
t_1: room temperature at the beginning of the test;
t_2: room temperature at the end of the test;

It is recommended that R_2 is determined by making the measurements just after the interruption and then in short intervals in order to plot the R/time graph.

To measure the resistance the Fluke 8846A digital multimeter can be used and to compute the Δt uncertainty the indirect model is used:

$$u^2(\Delta t) = \sum_{i=1}^{N} (\frac{\partial f}{\partial x_i})^2 \cdot u(x_i)^2 + 2 \cdot \sum_{j=1}^{N-1} \sum_{k=j+1}^{N} \frac{\partial f}{\partial x_j} \cdot \frac{\partial f}{\partial x_k} \cdot u(x_j, x_k) \tag{9}$$

so in this specific case:

$$u^2(\Delta t) = (\frac{\partial \Delta t}{\partial R_1})^2 \cdot u^2(R_1) + (\frac{\partial \Delta t}{\partial R_2})^2 \cdot u^2(R_2) + (\frac{\partial \Delta t}{\partial t_1})^2 \cdot u^2(t_1) + (\frac{\partial \Delta t}{\partial t_2})^2 \cdot u^2(t_2) + 2 \cdot \rho(R_1, R_2) \cdot \frac{\partial \Delta t}{\partial R_1} \cdot \frac{\partial \Delta t}{\partial R_2} \cdot u(R_1) \cdot u(R_2) \tag{10}$$

$$u(\Delta t) = \sqrt{u^2(\Delta t)} \tag{11}$$

Case study:

- $R_1 = 1$ kΩ;
- k = 234,5 for copper windings and copper/aluminium windings with an copper content $\geq 85\%$;
- $t_1 = 23°C$;
- $t_2 = 25°C$;
- $U(t) = 0,5°C$;
- $\Delta t_{max} = 75°C$;
- $U(R) = 0,0075\ \Omega$;

So by using all those data the PFA had been computed, see figure 8.

During the test the DUT operates in the worse conditions related to the normal use and the temperature must not exceed the threshold values of table;

- Heating appliances operates at 1.15 times the rated voltage;
- Motor-operated and combined appliances are supplied at the worse condition between 0.94 and 1.06 times the rated voltage;

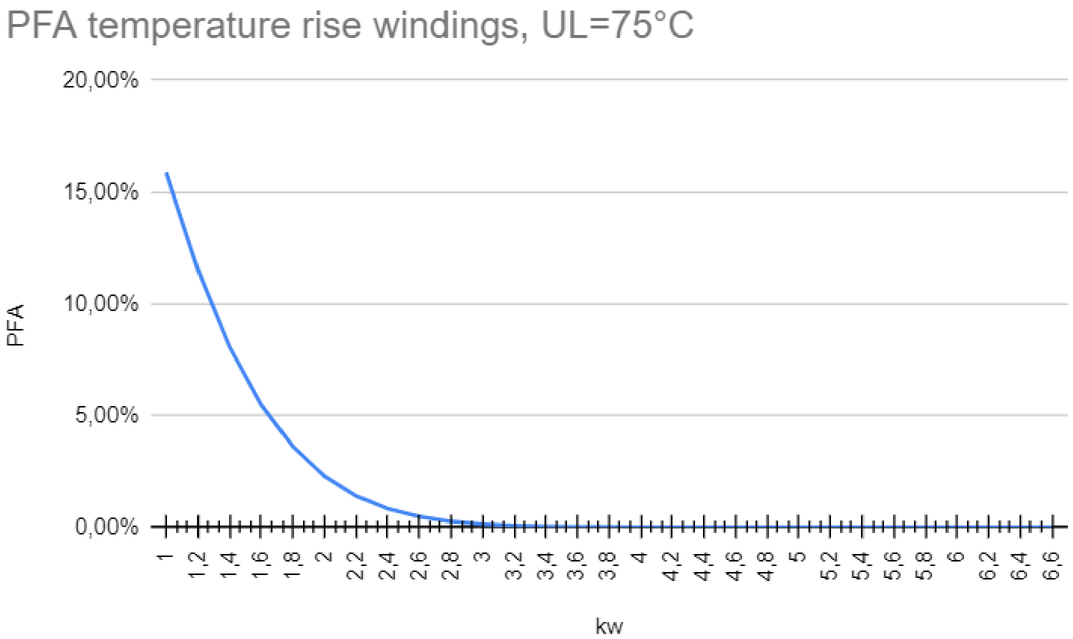


Figure (8) PFA evaluated for different guard bands $g = k_w \cdot u(I_b)$, with $u(I_b)$ corresponding to the uncertainty computed as shown in equation 9, Temperature rise of a winding measurement (CEI EN 60335-1, chapter 11)

If the motor winding temperature rise exceeds the value specified in table 36 or if there are any doubts regarding the thermal classification of the motor insulation, the following test must be performed; Such trial is done on 6 sample engines, it consists on blocking the rotor and making flowing a current into the winding till a certain temperature is reached. Then the leakage current is measured (see the related chapter) and engine will have a 48 hours hygroscopic treatment (see the Cab test explained in chapter Resistance to Moisture). The whole process is repeated 4 times and eventually the insulation system must pass the electric strength test, see Leakage current and electric strength chapter. For more information regarding threshold temperatures and test duration see Table C.1- test condition. The test is passed if there are less than 1 motor damage during the first shift. If one of the six motors is damaged during the other 3 shifts then the left ones must have an extra shift (hygroscopic treatment and then electric strength). The equipment needed is:

- Universal Magnetic Flywheel Lock Key (Chiave Blocca Volano Magnetico Universale);
- thermocouples;
- voltage power supplier
- all the equipment specified in chapters Cab test, Leakage current and electric strength ;

Here is the link for a professional engine test benches https://www.testline.it/it/banchi-prova/ricerca-e-sviluppo/banchi-prova-per-motori-elettrici

3.4 Leakage current and dielectric strength test at working temperature

At the working temperature the leakage current appliances must not exceed the threshold values specified in the table 1 and its dielectric strength must be appropriate, ruthless speaking the short circuit current (Is) and the tripping current (Ir) must not exceed the threshold values of the table 9. First of all, the appliance has to be made working at normal operation for a duration corresponding to the most unfavourable conditions of normal use (the duration of the test may consist of more than one cycle of operation).

- heating appliances work at 1.15 times rated power input.
- motor-operated appliances and combined appliances are supplied at 1,06 times rated voltage

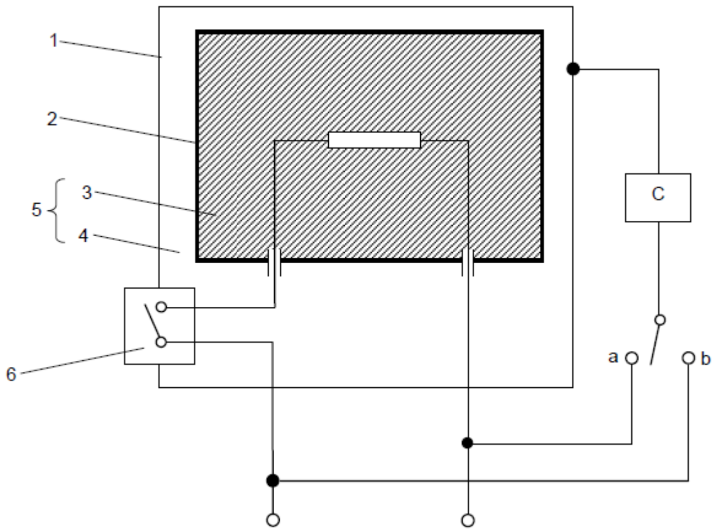


Figure (9) Leakage current test (CEI EN 60335-1, chapter 13): measuring circuit for Class 2 appliances

1. accessible part
2. inaccessible metal part
3. main insulation
4. extra insulation
5. double insulation
6. reinforced insulation

- Three-phase appliances, which according to the instructions for installation are also suitable for single-phase supply, are tested as single-phase appliances with the three circuits connected in parallel.

Before testing, the protective impedance and filters for radio interference must be disconnected.

3.4.1 Single-phase appliances

In order to measure the leakage current, two circuits (see Fig.9 and Fig 10) depending on which class the device belongs can be used. The leakage current is measured by putting the switch in each position a and b, it is measured between each pole of the power supply and the parts accessible metal bonded to a sheet of metal, of an area not exceeding 20 cm 10 cm, which is in contact with the accessible surfaces of the insulating materials. The metal sheet has the largest possible surface area under test, without exceeding the specified size. If its area is less than the surface under test, it is moved to check all parts of the surface. The heat dissipation of the device must not be affected by the metal sheet.

3.4.2 C circuit

For Class 0, II and III equipment, the leakage current is measured by means of the circuit described in Fig. 11 (according to the International Standard IEC 60990). For other appliances a low impedance measuring device able to measure the real effective value of the leakage current can be used. The main purpose of this circuit is to simulate the human touch, ruthless speaking the unweighted touch current I_B must be measured and it can be achieved in several ways; a simple solution could be mounting a circuit as shown in figure 11 and then measuring the voltage across resistor R_B and through that computing I_B:

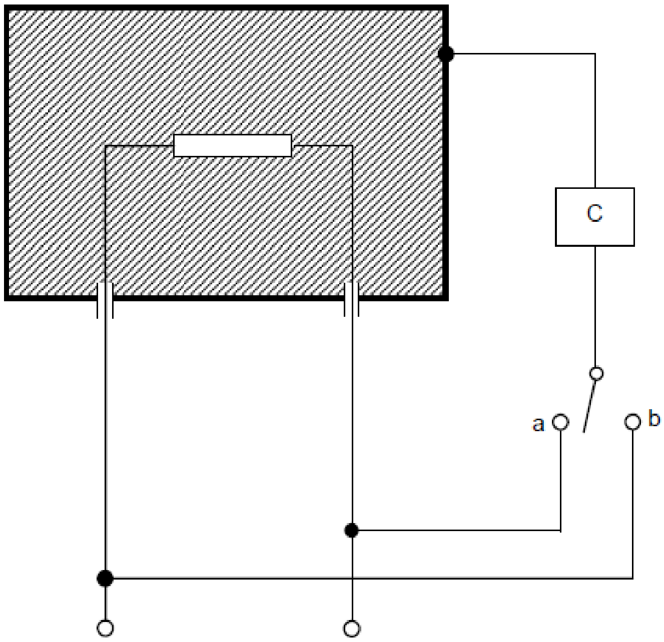


Figure (10) Leakage current test (CEI EN 60335-1, chapter 13): measuring circuit for all classes except from Class II

$$I_B = \frac{U_1}{R_B} \tag{12}$$

Another solution, instead, could be using a device able to simulate such kind of circuit, for example the Associated Research fully automated leakage tester, model 620L. Class 2 appliances, 0.35 mA as threshold voltage, will be taken as a case study in order to evaluate the conformity of such tester; Firstly, a measurement (reading value) done by this instrument, has to be compared to a tolerance limit/interval. Since such measurement is not perfectly known, a decision rule that takes into account measurement uncertainty has to be followed. In this case the reading value, 0.35 mA, coincide with the upper acceptance limit (UAL), by applying a deterministic approach, the absolute uncertainty, δI_B, of the reading value has been computed and then converted to a standard uncertainty, $u(I_B)$. Such uncertainty will be used to calculate the guard band and then the Upper Acceptance Limit, see figure 12. The computations below only aims at explaining the trail to be followed in this specific case.

- g: guard band

Table (7) Threshold leakage current values

Type of appliance	Maximum leakage current value
Class II appliances	0.35 mA (peak value)
Class 0 and **III appliances**	0.7 mA (peak value)
Class 01 appliances	0.5 mA
portable class I appliances	0.75 mA
stationary class I motor-operated appliances	0.35 mA
stationary class I heating appliances	0.75 mA

For combined appliances, the total leakage current may be within the limits specified for heating appliances or motor appliances, by choosing the value greater, but the two limits are not added.
If the device incorporates capacitors and is equipped with a single-pole switch, the measurements are repeated with the switch in the off position[16].
If the appliance incorporates a thermal control device which intervenes during the test of the art. 11, the leakage current is measured immediately before this device opens the circuit[17].

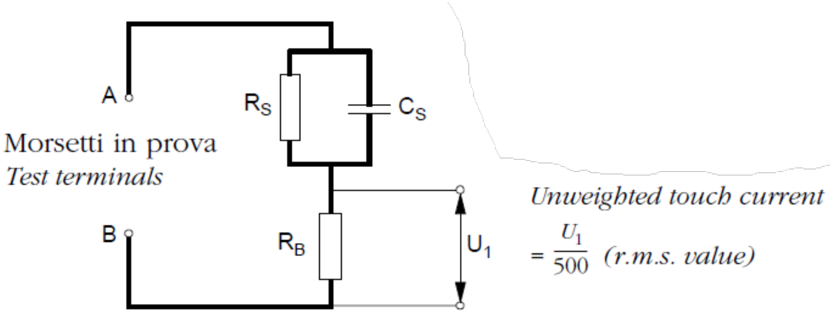


Figure (11) Figure 4 from standard IEC-60990; $R_S = 1500\ \Omega$, $R_B = 500\ \Omega$, $C_S = 0.22\ \mu$F

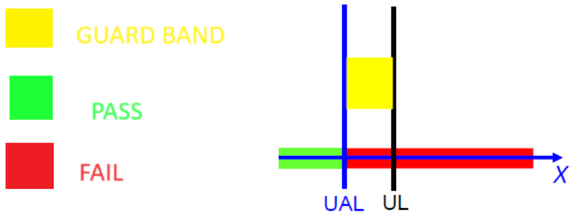


Figure (12) Example of guarda band with only the Upper Acceptance Limit

- k_w: guard band factor

$$\delta I_B = (0.35 \cdot 10^{-3} \cdot 0.1 \cdot 0.35 \cdot 10^{-3} + 2 \cdot 10^{-6})\text{A} \approx 37\ \mu\text{A} \tag{13}$$

$$u(I_B) = \frac{\delta I_B}{\sqrt{3}} = 21.4\ \mu\text{A} \tag{14}$$

$$g = k_w \cdot u(I_B) = (1 \cdot 21.4 \cdot 10^{-6})\ \text{A} \tag{15}$$

$$UAL = UL - g = (0.35 \cdot 10^{-6} - 21.4 \cdot 10^{-6})\ \text{A} \tag{16}$$

$$PFA\_(kw = 1) = 0.158 \tag{17}$$

As shown from figure 13 these elements are really important since they give us information regarding the Gaussian distribution, i.e. where it is centered and how far is from the UL, so it is now possible to compute the area delimited by such curve and the Probability of False Acceptance (PFA), see again figure 13 .

3.4.3 Instrumentation considerations

From the previous computations a k_w equal to 1 was arbitrary chosen but as shown for figure 14, by increasing it the PFA will decrease. So if the client wants a lower risk of false acceptance this device can guarantee it. Furthermore such tester, 620L, could even be calibrated in the TTPU calibration laboratory; as discussed before the sample chosen as multimeter for the calibration laboratory is the DMM Fuke 8588A, by computing the test uncertainty ratio (TUR) it is crystal clear that the DMM Fuke 8588A has an higher accuracy compared to the 620L tester so in order to calibrate such instrument it can even be used a lower quality DMM, such as the Fluke 8846A.

$$u_{DMMFuke8588A} = 0.17\ \mu\text{A} \tag{18}$$

$$TUR = \frac{u(I_B)}{u_{DMMFuke8588A}} = 123 \tag{19}$$

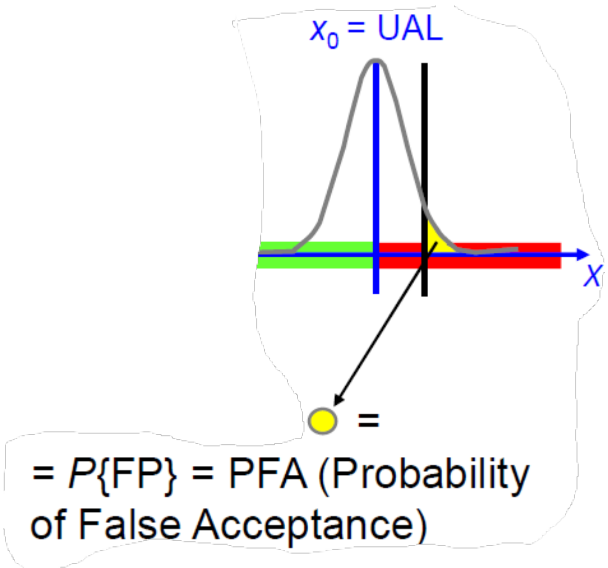


Figure (13) Example of PFA with only the UAL

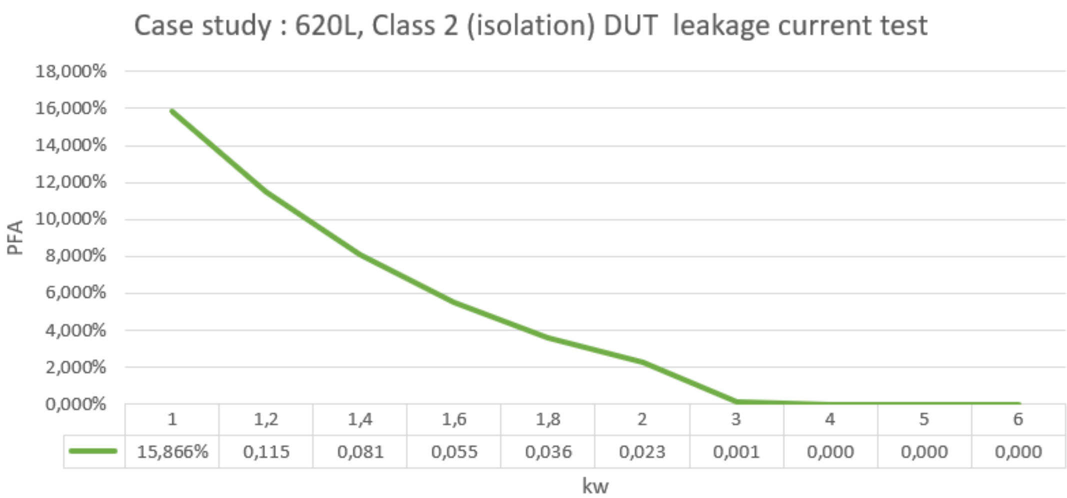


Figure (14) PFA evaluated for different guard bands $g = k_w \cdot u(I_b)$, with $u(I_b)$ corresponding to the uncertainty provided by the Associated Research fully automated leakage tester model 620L (CEI EN 60335-1, chapter 13)

$$u_{DMMFuke8846A} = 0.75\ \mu\text{A} \tag{20}$$

$$TUR = \frac{u(I_B)}{u_{DMMFuke8846A}} = 55 \tag{21}$$

3.4.4 Measuring dielectric strength at operating temperature

In order to perform such a test the appliance is unplugged from the power source, and the insulation is promptly exposed to a voltage with a frequency of 50 Hz or 60 Hz for a duration of 1 minute, according to the International standard IEC 61180-1; "The a.c. test voltage shall be raised uniformly from 0 V to the test voltage value within not more than 5 s. If not specified by the relevant technical committee the test duration at the specified test voltage shall be 60 s and shall be independent of the frequency in the range from 45 Hz to 65 Hz. For routine testing, the tripping current may be adjusted to lower levels. Unless otherwise specified by the relevant technical committee, the requirements of the test are satisfied if no tripping of the test equipment occurs. It is recommended that for safety reasons the current should be reduced to 3mA". The high-voltage source used for the test is to be capable of supplying a short circuit current Is between the output terminals after the output voltage has been adjusted to the appropriate test voltage. The overload release of the circuit is not to be operated by any current below the tripping current I_r. The values of I_s and I_r are given in Table 9 for various high-voltage sources. The test voltage is applied between live parts and accessible parts, non-metallic parts being covered with metal foil. For class II constructions having intermediate metal between live parts and accessible parts, the voltage is applied across the basic insulation and the supplementary insulation.[18]. The values of the test voltages are specified in Table 8. No breakdown shall occur during the test.[19]

3.4.5 Case study

Test voltage $\leq$ 4000 V so I_s must be lower than 200 mA, see table 9. To measure I_s the multimeter Fluke 8846A , which is one of the equipment of the calibration laboratory, can be used. As done for the 620L the computations for the risk of false acceptance are performed. By looking at the figure 15 this multimeter can guarantee a PFA even lower than 0.01%.

As said previously before measuring I_s and I_r a certain voltage must be applied to the DUT so even to the instrumentation used the risk of false acceptance might be computed. The case study is linked to the previous one: reinforced insulation, V_T: 3 kV, the instrument used to apply such voltage is "Generatore di carica elettrostatica CM TINY IQ", also in order to check whether it is applying the right voltage value the Fluke 80K-6 High voltage probe is used, whose accuracy in this case (dc to 500 Hz) is 1%. In this case there is not only the UAL and UL but also the lower limit (LL) and lower acceptance limit (LAL), see figures 3, 16 and the computations below as an arbitrary explanatory example.

$$\delta V_T = (\frac{3 \cdot 10^3}{100} \cdot 1)\text{V} = 30\text{V} \tag{22}$$

$$u(V_T) = \frac{\delta V_T}{\sqrt{3}} = 17.320\text{V} \tag{23}$$

$$g = k_w \cdot u(V_T) = 1 \cdot 17.320\ \text{V} \tag{24}$$

$$UL = 3 \cdot 10^3 + \delta V_T = 3 \cdot 10^3 + 30 = 3030\ \text{V} \tag{25}$$

$$LL = 3 \cdot 10^3 - \delta V_T = 3 \cdot 10^3 - 30 = 2970\ \text{V} \tag{26}$$

[18]Care should be taken to avoid overstressing the components of electronic circuits
[19]Glow discharges without drop in voltage are neglected.

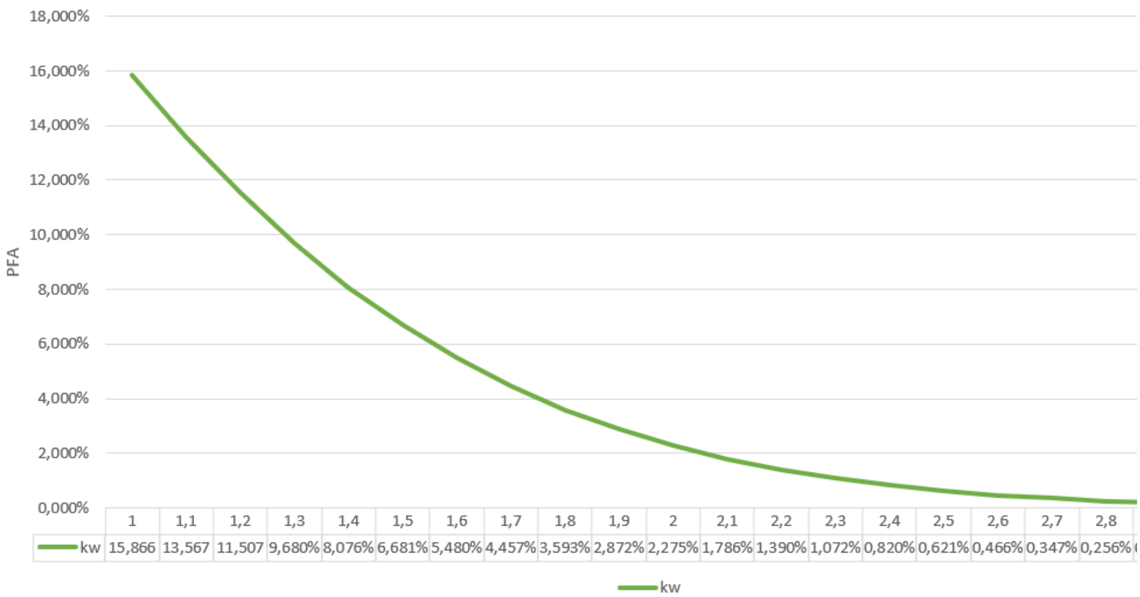


Figure (15) PFA evaluated for different guard bands $g = k_w \cdot u(I_b)$, with $u(I_b)$ corresponding to the uncertainty provided by the multimeter Fluke 8846A, case study :$I_s \leq 200$ mA dielectric strength test (CEI EN 60335-1, chapter 13)

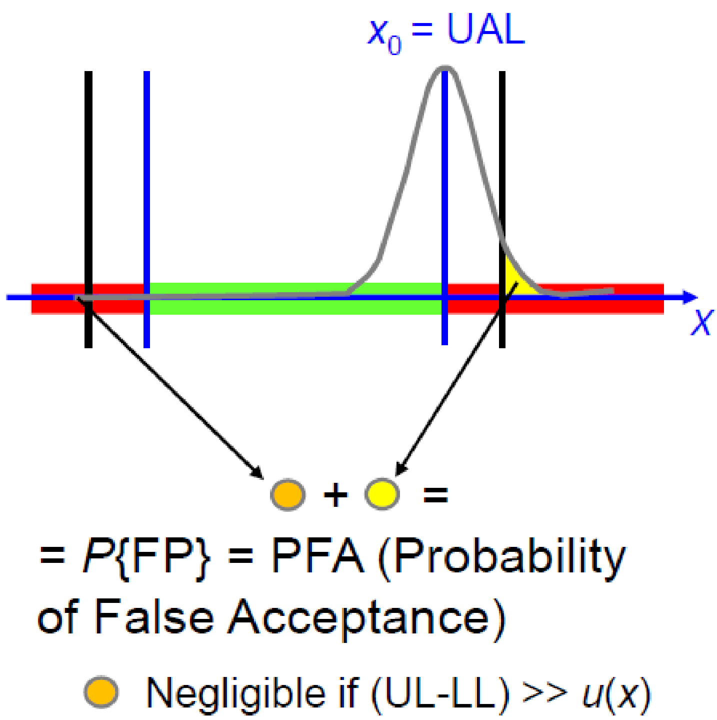


Figure (16) Example of PFA with both UAL and LAL

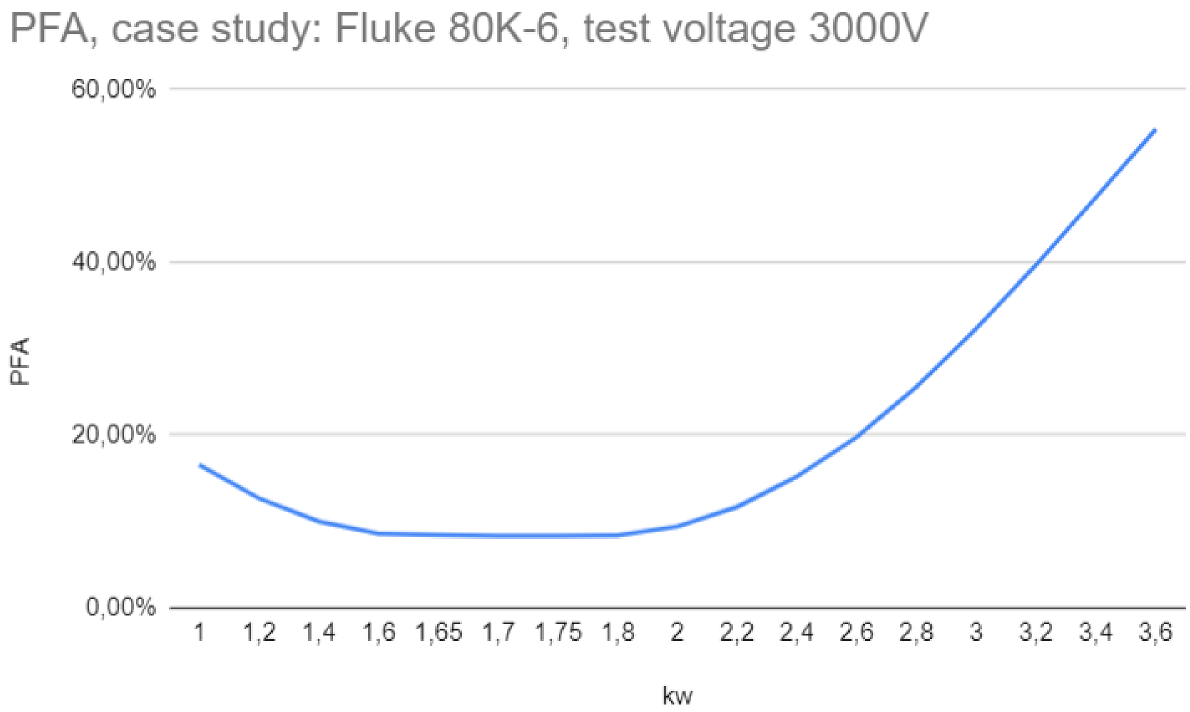


Figure (17) PFA evaluated for different guard bands $g = k_w \cdot u(I_b)$, with $u(I_b)$ corresponding to the uncertainty provided by the Fluke 80K-6, Dielectric strength test (CEI EN 60335-1, chapter 13)

Table (8) Voltage for electric strength test at working temperature

Insulation	Test voltage V			
	Rated voltage[a]			Working voltage (U)
	SELV [20]	$\leq 150V$	$> 150V$ and $\geq 250V$[b]	$> 250V$
Basic insulation	500	1000	1000	$1.2U + 700$
Supplementary insulation		1250	1750	$1.2U + 1450$
Reinforced insulation		2500	3000	$2.4U + 2400$

[a] For multi-phase appliances, the line to neutral or line to earth voltage is used for **rated voltage**. The test voltage for 480 V multi-phase appliances is that specified for a **rated voltage** in the range $> 150V$ and $\geq 250V$.
[b] For appliances having a **rated voltage** $\leq 150V$,these test voltages apply to parts having a **working voltage** $> 150V$ and $\geq 250V$.

$$UAL = UL - g = 3030 - 17.320 = 3012.679 \text{ V} \tag{27}$$

$$LAL = LL + g = 2970 + 17.320 = 2987.321 \text{ V} \tag{28}$$

By looking at the figure 17, the lowest PFA obtained with the Fluke 80K-6 is 8.3%.

3.5 Transient overvoltages (14)

All the devices must resist to the transient over-voltages at which are subjected to. By using the pulse generator specified in the IEC 61180-2, IMPULSE GENERATOR 1,2/50 s, 12 kV (Testing Europe), the DUT clearences in air are subjected to impulse voltage test (for the values see table 6), whose wave form is like the 1.2/50 μs standard impulse (IEC 61180-1), the generator impedance is lower than 42 Ω and the impulse test voltage is applied 3 times for each polarity for at least 1 s interval. To check if there are any flashover an oscilloscope can be used, functional insulation flashovers allowed are if the appliance

Table (9) Characteristics of high-voltage sources

Test voltage V	Minimum current mA	
	I_s	I_r
≤ 4000	200	100
> 4000 and ≤ 10000	80	40
> 10000 and ≤ 20000	40	20

NOTE The currents are calculated on the basis of the short circuit and release energies of $800VA$ and $400VA$ respectively at the upper end of the voltage ranges

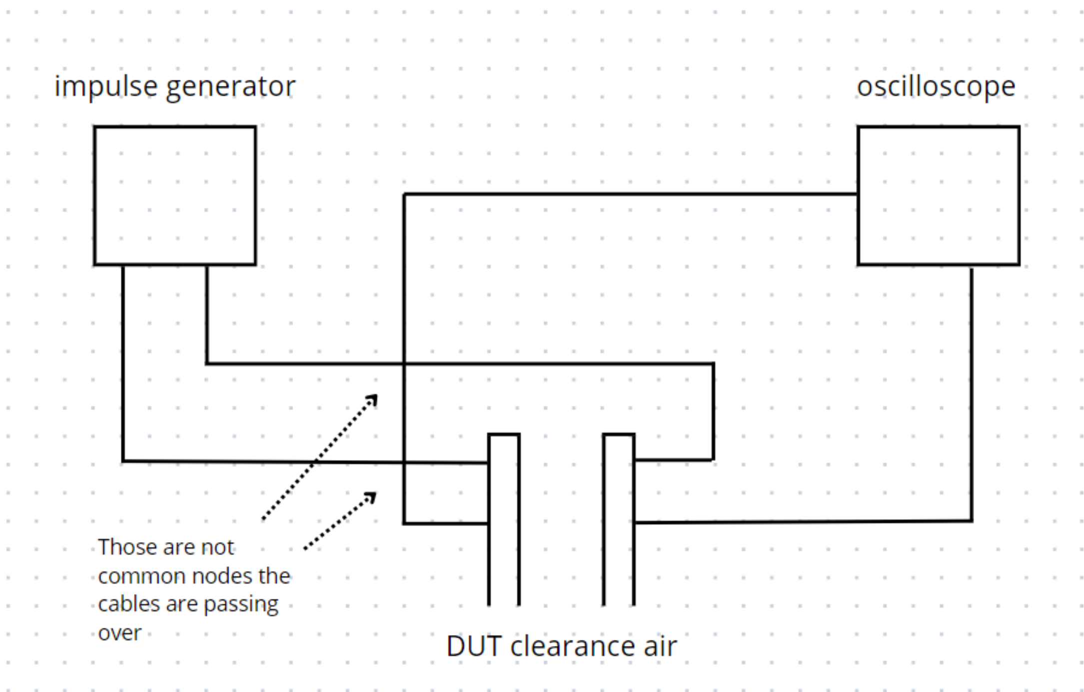


Figure (18) Transient overvoltages (CEI EN 60335-1) impulse voltage test circuit complies with Abnormal operation chapter when the clearance is short-circuited. See figure 18 for the circuit.

3.6 Moisture resistance (15)

The device's shell must guarantee a certain shield degree against humidity according the item class. Before explaining the tests some definitions must be given, each device has its own degree of protection indicated by an IP code, for example IP23CH;

- 2: first characteristic numeral (from 0 to 6 or letter X)
- 3: second characteristic numeral (from 0 to 8 or letter X)
- C: additional letter (A,B,C,D) optional
- H: supplementary letter (H,M,S,W) optional

All the devices considered in those tests have the first characteristic numeral omitted (X) and no additional and supplementary letters. The second characteristic numeral is referred to the ingress of water with harmful effects:

- 0: non protected
- 1: vertically dripping
- 2: dripping (15° tilted)
- 3: spraying
- 4: splashing
- 5: jetting
- 6: powerful jetting
- 7: temporary immersion
- 8: continuous immersion

A part from the IPX0 devices all the others must be tested in the following way;

3.6.1 Test for IPX1 device

A tool which produces a uniform water dropping over the whole enclosure (placed in its normal operating condition) is needed, as shown from figure 19 it has a turntable (1 r/min rotation speed) and the distance between turntable axis and specimen axis is 100 mm . If the enclosure is fixed to a wall or ceiling a wooden board (same dimension of the enclosure surface) is used to emulate the wall. The test lasts for 10 minutes and the flow rate is $1_0^{+0.5}$ mm/ min. The same dripping device is used for testing the IPX2 devices but this time with different flow rate $3_0^{+0.5}$ mm/ min lasting 2.5 min for each position of the tilt, 15° on both sides of the vertical in 2 perpendicular planes, 4 positions in total.

3.6.2 Test for IPX3 and IPX4 devices

As regards those degrees of protection two device can be used to test the DUT, the oscillating tube (figure 20) and the spray nozzle (figure 21);

when the oscillating tube is used the DUT enclosure is put at the centre point of the semicircle and the tube oscillates through a:

- 120° angle for the IPX3 device (5 minutes) then the enclosure is turned on a horizontal angle of 90° and the oscillation continues for other 5 minutes;
- 360° angle for the IPX4 device (10 minutes);

The oscillating tube has spray holes over:

- a 60° arc (IPX3), maximum radius of the oscillating tube is 1600 mm;

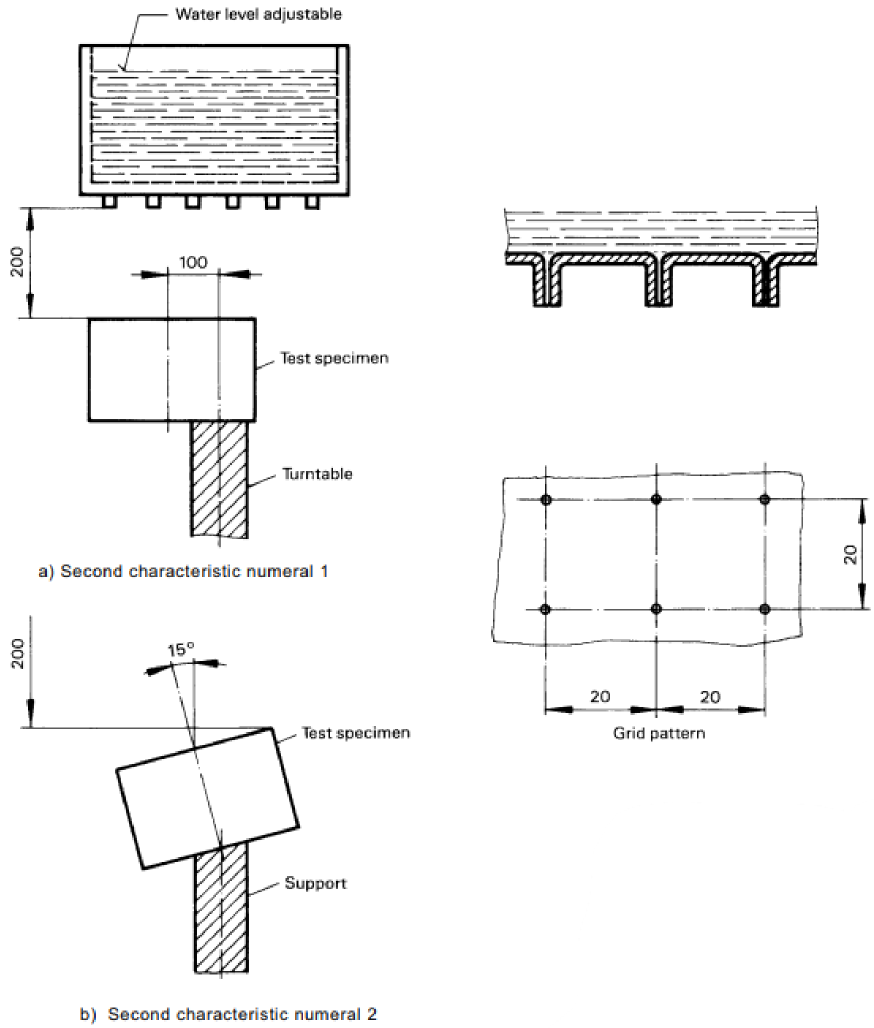


Figure (19) Moisture resistance test (CEI EN 60335-1, chapter 15) drip box for IPX1 device

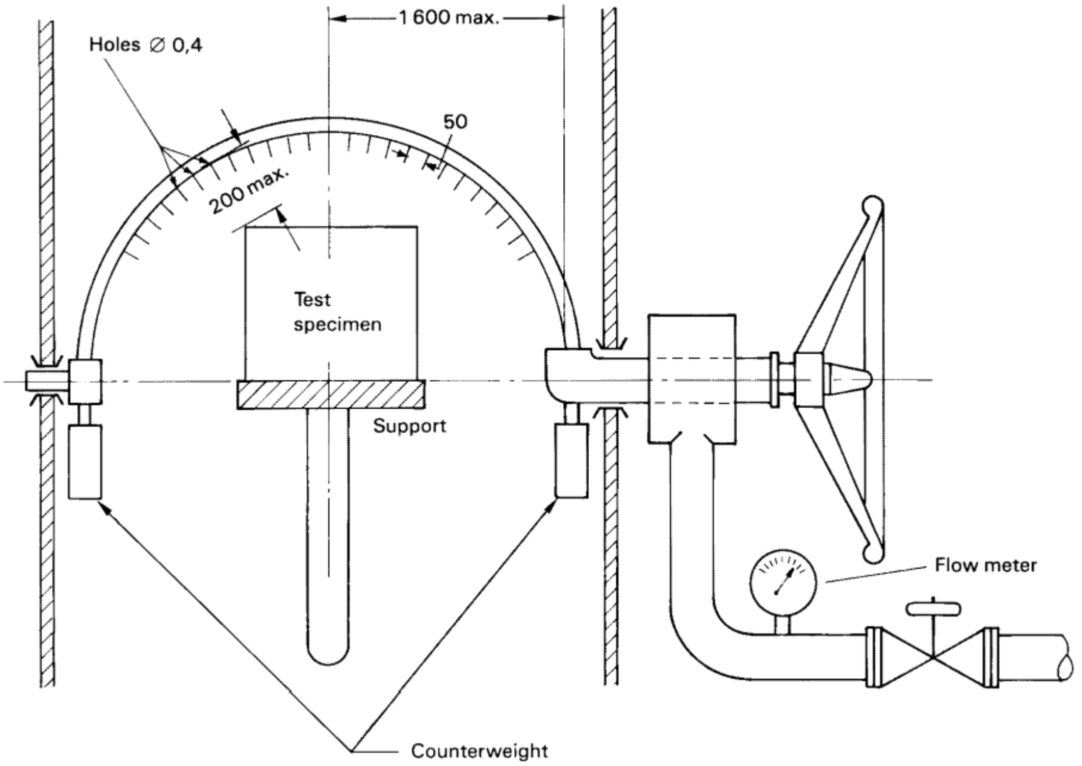


Figure (20) Moisture resistance test (CEI EN 60335-1, chapter 15) oscillating tube IPX3 and IPX4 devices

- a 180° arc

Regarding the flow rate the oscillating tube has a 0.07 l/min ± 5% flow per hole, multiplied by number of holes and the spray nozzle has 10 l/min ± 5% flow, for both IPX3 and IPX4. If for a certain type of DUT is not possible to wet the whole enclosure the spray nozzle is preferable to be used. Water pressure rate will be in range of 50 kPa to 150 kPa. Test duration depends on the enclosure surface 1 min/m^2, it lasts minimum for 5 minutes. If the counterbalanced shield is used then it must be removed.

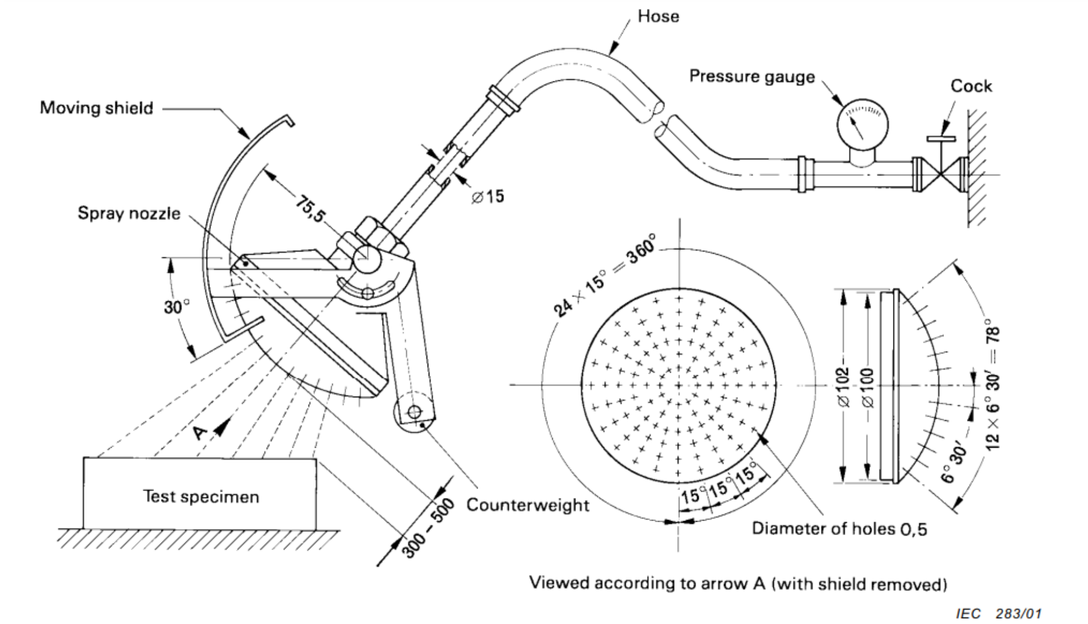
3.6.3 Test for IPX5 and IPX6 devices

As regards those two degrees a spray nozzle, see figure 22, can be used, so the enclosure is sprayed in all the practicable directions with a stream of water. Test conditions are all summarized in table 10.

3.6.4 Test for IPX7 device

This test performed by completely diving the enclosure (in its service position) in water containing 1%NaCl, between 0.15 m and 1 m, those are the test conditions;

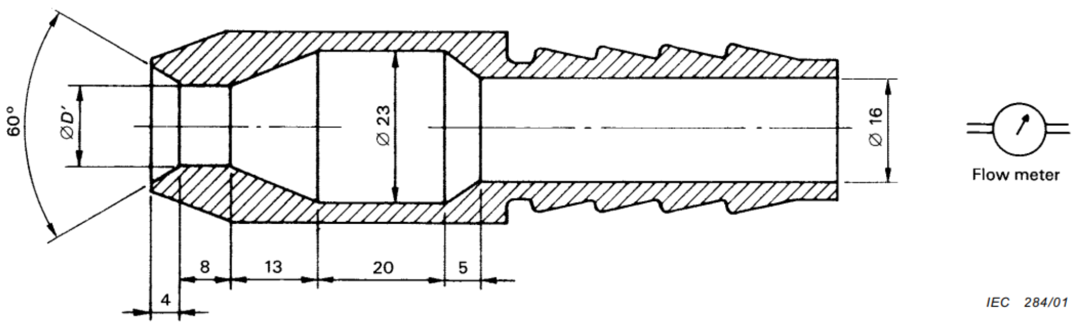
- an enclosure with a eight less than 850 mm must have its lowest point at 1000 mm below the water surface;
- an enclosure with a eight equal or greater than 850 mm must have its highest point at 150 mm below the water surface;
- the test lasts for 30 minutes;
- the temperature difference between water and equipment must not exceed 5 K



Dimensions in millimetres

121 holes of ∅ 0,5;
1 hole at the centre
1 inner circles of 12 holes at 30° pitch
4 outer circles of 24 holes at 15° pitch
Moving shield – Aluminium
Spray nozzle – Brass

Figure (21) Moisture resistance test (CEI EN 60335-1, chapter 15) spray nozzle



Dimensions in millimetres

Figure (22) Moisture resistance test (CEI EN 60335-1, chapter 15) hose nozzle to verify protection against water; D'= 6.3 mm (IPX5), D'=12.5 mm (IPX6)

Table (10) Test conditions for IPX5 and IPX6

	Test conditions	
	IPX5	IPX6
delivery rate	12.5 L/ min ±5%	100 L/ min ±5%
water pressure	to be adjusted to reach the delivery rate	to be adjusted to reach the delivery rate
core of the substantial stream	circle of 40 mm diameter at 2.5 m distance from nozzle	circle of 200 mm diameter at 2.5 m distance from nozzle
test duration per square meter of enclosure surface area likely to be sprayed	1 minute	1 minute
minimum test duration	3 minutes	3 minutes
distance from nozzle to enclosure surface	between 2.5 m and 3 m	between 2.5 m and 3 m

3.6.5 Generic test conditions

During the execution of those tests several conditions must be met;

- Firstly the DUT must not be supplied, all the hand-held appliances are often turn in the must unfavourable positions, also if the device has a cord it must be tested in the most unfavourable position for the cord.
- Appliances normally used on the floor or on a table are placed on a stand non-perforated horizontal tube whose diameter is twice the radius of the swing tube minus 15 cm.
- Appliances normally fixed to a wall and appliances with plugs to be inserted into a power socket they are mounted as in normal use in the center of one wooden board whose dimensions exceed those of the orthogonal projection by 15 cm ± 5 cm of the appliance on the table. The wooden board is placed in the center of the swing tube.
- For IPX3 luminaires, the base of the wall luminaires is placed at the same level as the axis of tube oscillation. For IPX4 fixtures, the horizontal center line of the fixture is aligned with the axis of tube oscillation.
- For appliances normally used on the floor or on a table, the movement is however limited to twice 90° from the vertical for a period of 5 minutes, with the support placed at the level of the tube's oscillation axis.
- If, for wall-mounted appliances, the installation instructions indicate that the appliance must be placed close to floor level and specify a distance, below the device places a table at that distance. The dimensions of the table are larger 15 cm compared to the horizontal projection of the appliance.
- Luminaires that are normally fixed to the ceiling are mounted on the underside of a non-perforated horizontal support that is constructed to keep water out sprayed on its upper surface. The oscillation axis of the tube is located there level with the lower face of the support and is centrally aligned with the appliance. The spray is directed upwards.Regarding IPX4 luminaires, the movement of the tube is limited to two times 90° relative to the vertical for a period of 5 minutes.

Eventually, the DUT must pass the electric strength test (16.3) and after drying the external casing to remove any excess water, a visual examination must confirm the absence of water traces on the insulation that could reduce the air or surface insulation distances below the values specified in Clearances, creepage distances and solid insulation chapter chapter chapter. Regarding the tests explained till now those are the items needed:

- horizontal unperforated support having a diameter of twice the oscillating tube radius minus 15 cm;
- wooden board having dimensions which are 15 cm ± 5 cm in excess of those of the orthogonal projection of the appliance on the board;
- a board with 15 cm more than the horizontal projection of the appliance.

Test to check if the spillage of liquid does not affect the device electrical insulation

Appliances which in normal use are subject to liquid overflow must be constructed in such a way that this overflow does not compromise the electrical insulation. The following test is performed to check such compliance. Set up conditions;

- devices with type X attachment will use the lightest cord with smallest section as specified in table 13
- Appliances incorporating a connector plug are tested with or without a appropriate connector in position, choosing the most unfavorable case.
- separable elements must be removed.

A liquid consisted of water with 1% of NaCl with addition of 15% of the container volume or 0.25 L (highest value is chosen) of the same liquid is continuously dropped for 1 minute. Eventually, the DUT must pass the electric strength test (16.3) and after drying the external casing to remove any excess water, a visual examination must confirm the absence of water traces on the insulation that could reduce the air or surface insulation distances below the values specified in Article 29.

3.6.6 Cab test

The appliances must properly deal with humidity conditions at ordinary usage, in accordance to **IEC 60068-2-78** the Damp heat steady state test is performed to proof it, so a Thermal Cycle Test Chamber is required; for 48 hours the DUT must be put inside it, relative humidity $(93 \pm 3)\%$, air temperature is between 20 °C and 30 °C with 2 K tolerance. Before entering the chamber the DUT must be brought to t_0^{+4} °C. General conditions;

- the DUT before entering the chamber must be kept at environment temperature for 24 hours and then should be introduced in the unpacked, switched-off, ready-for-use state.
- Any cable entries are left open. If there are breakable entrances, one of this is smashed. The separable elements are removed and subjected, where necessary, to the hygroscopic test with the main element.
- Test chamber volume shall be at least five times the total volume of the DUT.
- The DUT during the treatment shall reach temperature stability, the rate of change of temperature allowed is 1 K/ min, over a maximum period of 5 minutes, meanwhile condensation on DUT must not occur and it can be avoided by not increasing the absolute humidity.
- the adjusting time to reach the specified humidity must not exceed 2 hours. The duration of test starts when the specified conditions are met. Eventually a recovery procedure is recommended.
- If it is not possible to put the whole DUT inside the chamber the parts which have the electrical insulation can be tested separately.

Finally the DUT must pass the leakage current and dielectric strength test inside the thermal chamber or the chamber where it reached the specified temperature after mounting all the separable parts.

3.7 Leakage current and electric strength (16)

The device's leakage current must not be too high and its electric strength must have a proper value, see tables 11. Before testing the device few preliminary conditions must be met; the protection impedance must be disconnected from the live part, tests are performed at environment temperature and the DUT must not be supplied by mains. As regards the leakage current an a.c. voltage is applied between live parts and accessible metal parts of the DUT, see figure 23, which are connected to a metal foil (area not exceeding 20 cm · 10 cm).

The voltage test is equal to :

- 1.06 times rated voltage for single pahse devices;
- 1.06 times rated voltage, divided by $\sqrt{3}$ for three-phase devices;

The leakage current must be measured 5s after the application of the test voltage, for threshold values see table 11. Such values are doubled if:

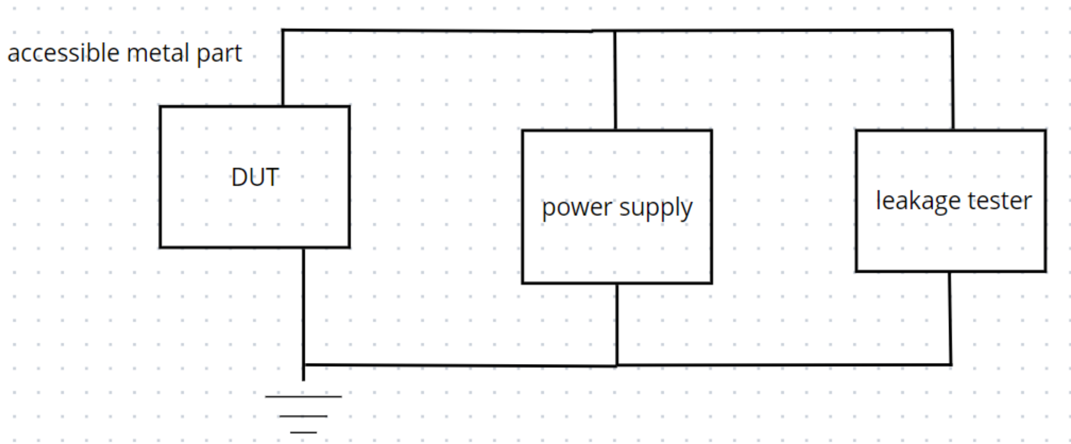


Figure (23) Leakage current test (CEI EN 60335-1, chapter 16) circuit for measuring the leakage current

Table (11) threshold leakage current values

Type of appliance	Maximum leakage current value
Class II appliances	0.25 mA
Class 0, **Class 0I** and **Class III appliances**	0.5 mA
portable class I appliances	0.75 mA
stationary class I motor-operated appliances	0.35 mA
stationary class I heating appliances	0.75 mA or 0.75 mA per kW of rated voltage of the device, the greater value is chosen (maximum 0.5 mA)

- all control devices have one off position in all poles;
- the device does not have any control device other than a thermal interrupter device
- all thermostats, temperature limiters, and energy regulators do not have an 'off' position,
- the device has a filter for radio interference. In this case, the leakage current with the filter disconnected must not exceed the specified limits

Regarding the combined devices the total threshold current can be chosen as the greater value between the ones related to the heating appliances or to the motor-operated appliances, two limits can not be added. Several instruments can be used to measure the leakage current and between all of them the Associated Research fully automated leakage tester, model 620L was chosen. In order to check its state of conformity the following case study is taken into account; Class II appliances, 0.25 mA as threshold value. The PFA had been computed in the most critical situation, read value coincides with the UAL, see figure.

As soon as the leakage current test is finished, the DUT insulation is supplied for 1 minute at 50Hz or 60Hz frequency, for voltage values see table 12 , all the accessible parts are covered by a metal foil. For such voltage values the voltage supply generator for high voltage values till 3000 V, Generatore di carica elettrostatica CM TINY IQ can be used. After that a voltage is applied between the accessible metal parts and the supply cord (covered by a metal foil where the cord is is located in an inlet bushing or it is placed in cable protectors or interlocks of the cable, with screws tightened to two-thirds of the specified torque, see table 14 of CEI EN 60335-1). The testing voltage is:

- 1250 V for Class 0 and Class I devices;
- 1750 V for Class II devices;

There must be no electric discharges during the test. The Associated Research Hypot 3805 can bu used to perform such test, see figure 24 for the sketch. This device supplies the DUT and at the same

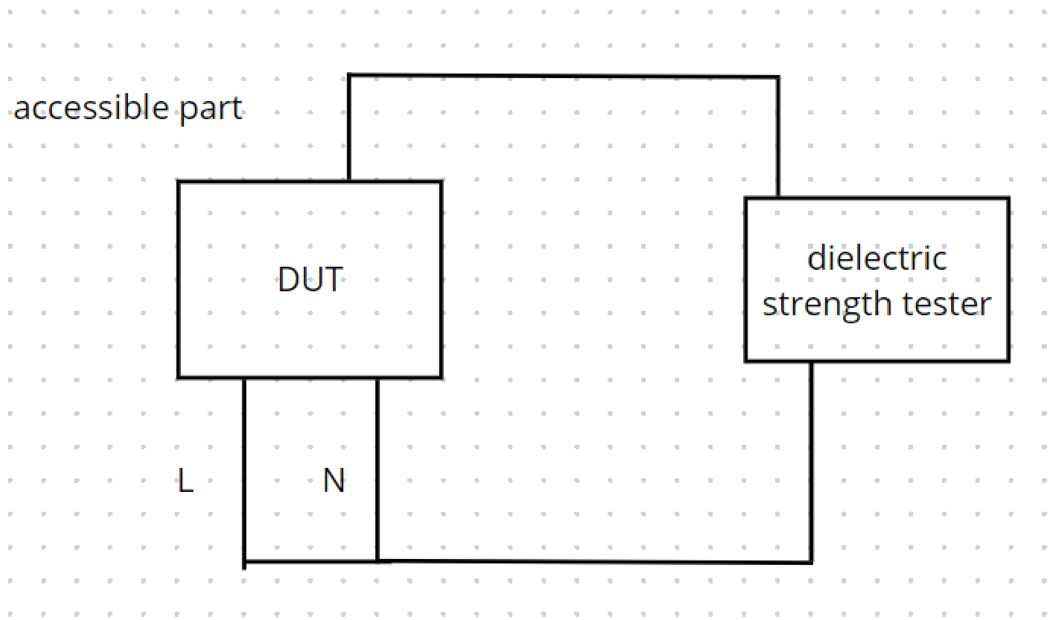


Figure (24) Dielectric strength test (CEI EN 60335-1, chapter 16) circuit for measuring the dielectric strength

Table (12) Voltage for electric strength test

Insulation	Test voltage V			
	Rated voltage[a]			Working voltage (U)
	SELV	$\leq 150V$	$> 150V$ and $\geq 250V$[b]	$> 250V$
Basic insulation[c]	500	1000	1000	$1.2U + 700$
Supplementary insulation[c]		1250	1750	$1.2U + 1450$
Reinforced insulation		2500	3000	$2.4U + 2400$

[a] For multi-phase appliances, the line to neutral or line to earth voltage is used for **rated voltage**. The test voltage for 480 V multi-phase appliances is that specified for a **rated voltage** in the range $> 150V$ and $\geq 250V$.
[b] For appliances having a **rated voltage** $\leq 150V$,these test voltages apply to parts having a **working voltage** $> 150V$ and $\geq 250V$.
c In constructions where basic insulation and supplementary insulation cannot be tested separately, the insulation is subjected to the test voltages specified for reinforced insulation.

time checks if there is any discharges, as soon as the the currents reaches a certain threshold the device stops the test. An adapter box can also bu useful in order to directly plug the DUT to the tester.

3.8 Overload protection of transformers and associated circuits (17)

All the appliances ,in which are embedded circuits supplied by a transfromer, must be built such that, if there is a shortcircuit during ordinary usage, there will not be too high temperatures inside the transformer or inside its circuits. In order to check such compliances the DUT is supplyed at 1.06 or 0.94 its rated voltage (worst case is chosen). The difference between the temperature of the insulation of the conductors of very low voltage circuits safety and its threshold value in table 36 must not exceed 15 K. The temperature of the windings shall not exceed the values of table 15 values. In conclusion those are the tools needed: thermocouples and a voltage supplier.

3.9 Abnormal operation (19)

The devices must be constructed in such a way as to avoid, as much as possible, the risks of fire, mechanical damage that compromises safety, or protection against electric shocks resulting from abnormal or negligent operation. Electronic circuits must be designed and implemented in such a way that a fault condition does not render the device unsafe in terms of electric shocks, fire hazards, mechanical hazards, or dangerous malfunctions. Before delving into the details of the tests some conditions must be given, if not otherwise specified:

- tests are kept going on until:
  - the non-automatic reset thermal interruption device interferes;
  - stead-state condition;

  If a heating part or an intentionally weak part becomes permanently open-circuited, the test is repeated on a second sample. Such test must be completed exactly at the same way unless it is satisfactorily completed in a different way;
- only one abnormal condition is simulated at a time;
- If several tests are performed on the same DUT , those tests are done consecutively after it cooled till environment temperature.
- In the case of combined appliances, tests are conducted with both motors and heating elements running concurrently under typical operating conditions. The relevant tests are applied individually to each motor and heating element.
- If it is specified that a control is short-circuited, it may alternatively be made non-functional instead.
- During and after each test, the temperature of the windings must not exceed the values specified in Table 15. Additionally, any current passing through protective impedance should not surpass the limits defined in chapter "Protection against access to live parts" , definition of live parts. Nonetheless, these constraints do not pertain to fail-safe transformers that adhere to Subclause 15.5 of IEC 61558-1.

Unless stated otherwise, verification of compliance with the tests in this chapter is conducted as follows:

- If a conductor on a printed circuit board becomes disconnected, the appliance is deemed to have passed the specific test, provided that both of the following conditions are met:
  - The substrate material of the printed circuit board endures the test flames, see chapter 19.2.4 of CEI EN 60335-1, according to such conditions :
    * application of the test flame is 30 s ± 1 s.
    * the DUT is positioned in a way that allows the flame to be directed towards a vertical or horizontal edge, as illustrated in the examples provided in Figure 1 (questa figura non presente nella norma IEC 60695-11-5);
    * The flame is administered at a distance of no less than 10 mm from a corner.
    * The test is conducted on a single DUT. Should the DUT fail to pass the test, it can be retested using two additional DUT, both of which must then pass the test.
    * The burning duration (t_b) must not surpass 30 seconds. Nevertheless, for printed circuit boards, the burning duration should not exceed 15 seconds.
  - No slackened conductor shall diminish the clearances or creepage distances between live components and accessible metal parts below the values specified in Clearances, creepage distances and solid insulation chapter chapter.
- During the tests the DUT must not release flames, molten metal, flammable gases or in harmful quantity, overtemperatures must not exceed values in table 13. As soon as the test is finished and the DUT is cooled til environment temperature, adherence to chapter "Protection against access to live parts" must not be compromised, and the appliance must meet the requirements of 20.2 if it remains operable.
- After the insulation, excluding that of class III appliances or class III constructions without live parts, has cooled to about room temperature, it must endure the electrical strength test (for voltage test see table 12). Before such test humidity treatment (must not be performed.

Table (13) Maximum abnormal temperature rise

Part	Temperature rise K
Wooden supports, walls, ceiling and floor of the test corner and wooden cabinets[a]	150
Insulation of the supply cord[a] a without T marking, or with T marking up to 75° C	150
Insulation of the supply cord[a] with T marking above 75° C	T+75
Supplementary insulation and reinforced insulation other than thermoplastic materials[b]	1,5 times the relevant value specified in Table 3

[a] For motor-operated appliances, these temperature rises are not determined.
[b] There is no specific limit for supplementary insulation and reinforced insulation of thermoplastic material. However, the temperature rise has to be determined so that the test of Resistance to heat and fire can be carried out.

- For appliances designed to be submerged or filled with conductive liquid during regular operation, the appliance is submerged or filled with water for 24 hours prior to conducting the electric strength test.
- After a control operation or interruption, the clearances and creepage distances across the functional insulation must pass the electric strength test. The test voltage, however, should be twice the working voltage.
- The appliance must not experience a hazardous malfunction, and protective electronic circuits should not fail if the appliance remains operational. Appliances tested with an electronic switch in the 'off' position or in standby mode, shall not become operational, or if they are activated, they must not lead to a hazardous malfunction either during or after the EMC tests.
- In an appliance with lids or doors controlled by one or more interlocks, it is permissible to release one of the interlocks provided that the following conditions are met:
  - The lid or door does not open automatically when the interlock is released.
  - The appliance will not restart after the cycle in which the interlock was released.

3.9.1 Appliances with heating components - tests

Regarding devices with heating components those are the tests to be performed:

- same test conditions of "Heating" chapter but with less heat dissipation. The voltage supply needed for the test is the one which can guarantee 0.85 times the power of the rated power during normal operating conditions. Such voltage is kept for the whole test.
- the previous test is repeated but the voltage supply is such that the power is 1.24 the rated one.
- if such appliances have a control devices that limits the temperature, such devices are short-circuited in turn and the DUT is tested as specified in the "heating" chapter.
- the previous test is again repeated to Class 0I and Class I devices with tubulars heating elements under sheath or embedded. The controls are not directly short-circuited. Instead, one end of the element is linked to the heating element's sheath. This procedure is replicated by reversing the polarity of the power supply to the appliance and connecting the other end of the element to the sheath. The test is omitted for appliances designed for permanent connection to fixed wiring and for those where a complete disconnection of all poles occurs during the previous test . For appliances equipped with a neutral, the test is conducted with the neutral connected to the sheath.
- if the device has also PTC heating element it is supplied at rated voltage the steady state conditions are reached. Then the working voltage is augmented by 5% and it will keep on working till steady state conditions. The voltage is again increased till the 1.15 times the working voltage is reached or the PTC elements does not yield.

3.9.2 Appliances with embedded motors - tests

Devices with embedded motors must follow such tests:

- Test conditions: if the locked rotor torque is lower than the full-load torque the rotor is blocked otherwise the movable parts are blocked. The DUT works till stall conditions. If a device has more than one motor the test is performed on each motor. Devices with capacitors inside the windings are made working wiht blocked rotor and by putting the capacitors into open circuit one at a time. Unless the capacitor are compliant to the P2 of IEC 60252-1 the test is repeated Short-circuiting the capacitors one at a time. For each test appliances with timer or programmer are supplied at rated voltage for a period which is equal to the maximum allowed one by the timer or programmer. Other devices are also supplied at rated voltage but for a period of :
  - 30 s if:
    - are portable devices;
    - in order to keep them on a hand or a foot must be used;
    - the load is constantly hand-applied;
  - 5 minutes for devices operating under surveillance;
  - till reaching steady state conditions;

  For threshold values see table 15.
- One phase of appliances with multi-phase motors is intentionally disconnected. The appliance is subsequently run under typical conditions, receiving power at its rated voltage for the duration outlined in the previous test.
- The overload operation test is performed to:
  - devices remotely or automatically controlled or that can operate continuously;
  - combined devices (to which is applicable what is written in 30.2.3 subchapter) which employ electronic circuit-based overload protection devices for safeguarding the motor windings;

  The DUT works at normal operating conditions and supplied at rated voltage till steady-state condition. Then the load is increased such that the current flowing inside the windings increases also by 10% after that the device works till reaching steady-state condition. Eventually, the load is again increased and the test is repeated till the activation of the protection device or the motor blocks. During the test the temperature of the windings must not exceed such values:
  - 140 ° C, for Class 105 (A);
  - 155 ° C, for Class 120 (E);
  - 165 ° C, for Class 130 (B);
  - 180 ° C, for Class 155 (F);
  - 200 ° C, for Class 180 (H);
  - 220 ° C, for Class 200 (N);
  - 240 ° C, for Class 220 (R);
  - 270 ° C, for Class 250;
- The devices with embedded series motor are made working at the least load and supplied at 1.3 times the rated voltage for 1 minute. During such test the parts must not be taken out from the DUT.

3.9.3 Appliances with electronic circuits - tests

As regards the devices with electronic circuits the compliance is verified by assessing the specified fault conditions unless those conditions are both verified:

- the electronic circuit is low power circuit;
- Safeguards against electric shock, fire risks, mechanical hazards, or potentially dangerous malfunctions in other components of the appliance are not contingent on the proper operation of the electronic circuit;

In order to check if the circuit is a low power one the following test is performed; the DUT is supplied at rated voltage and variable resistor, set at its maximum value, is mounted as shown in figure. Then the resistor is decreased till the maximum power is absorbed. The closest points to the supplier, where 15 W is the maximum power the resistor could absorb for a 5 s period, are called low power points. The part of the circuit which is further than the low power points to the supplier is defined as low power circuit. Measurements are done by using one pole of the supplier, the one which lead to lower number

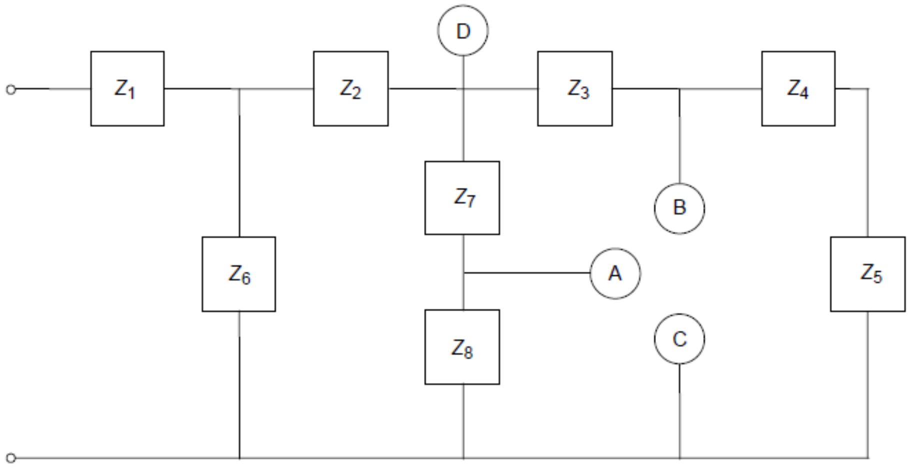


Figure (25) Example of an electronic circuit with low-power points. D is a point farthest from the supply source where the maximum power delivered to external load exceeds 15 W. A and B are points closest to the supply source where the maximum power delivered to external load does not exceed 15 W. These are low-power points. Points A and B are separately short-circuited to C. The fault conditions a) to g) are applied individually to Z1, Z2, Z3, Z6 and Z7, where applicable.

of lower power points. In order to determine such points is better to start from the points closer to the supplier. The power absorbed by the variable resistor is measured by a wattmeter.

Fault conditions:

- a Functional insulation may experience a short circuit if clearances or creepage distances fall below the values outlined in Clearances, creepage distances and solid insulation chapter chapter chapter;
- b open circuit at the terminals of any component;
- c short circuit of capacitors, unless they comply with IEC 60384-14;
- d A short circuit between any two terminals of an electronic component, excluding an integrated circuit, is considered. It's worth noting that this fault condition doesn't apply to the two circuits of an optocoupler;
- e failure of triacs in the diode mode;
- f Excluding components like thyristors and triacs, potential failures of microprocessors and integrated circuits are examined. Every conceivable output signal is taken into account in the event of a fault within the component. If it can be demonstrated that a specific output signal is improbable, then the corresponding fault is not taken into consideration; this condition can be related to encapsulated components and similar ones if the circuit can't be evaluated in another way.
- g Malfunction of an electronic power switching device in a partial turn-on mode, resulting in a loss of gate (or base) control. This mode can be simulated by disconnecting the gate (or base) terminal of the electronic power switching device and connecting an external adjustable power supply between the gate (or base) terminal and the source (or emitter) terminal of the device. The power supply is then adjusted to achieve a current level that won't cause damage to the electronic power switching device but will create the most demanding testing conditions. Examples of electronic power switching devices include field-effect transistors (FETs and MOSFETs) as well as bipolar transistors (including IGBTs).

If for each of the fault conditions the safety of the device depends from the right working of a miniature fuse compliant with IEC 60127, each test is repeated by substituting the fuse with an amperometer. If the measured current:

- is not higher than 2.1 times the rated current of the fuse the circuit is not well protected and the test is done with the shorten fuse;

- is at least 2.75 times the rated current of the fuse, the circuit is well protected;
- is between 2.1 and 2,75 the rated current, the fuse is shorten and the test is done:
  - for either the specified duration or 30 minutes, whichever is shorter, in the case of quick-acting fuse-links;
  - for either the specified duration or 2 minutes, whichever is shorter, for time-delay fuse-links;

  If there is any doubt regarding the current, the maximum resistance of the fuse is considered.

Test for PTC resistors Positive temperature coefficient resistors are not bridged when operated within the manufacturer's specified parameters. However, PTC-S thermistors are bridged unless they adhere to IEC 60738-1. Furthermore, each low-power circuit is bridged by linking the low-power terminal to the positive terminal of the power source from which the measurements were taken. In order to simulate such fault conditions the DUT is made working at the conditions specified in chapter 11 but supplied at rated voltage. The duration of the test for each fault condition is:

- a period equal to the worst conditions during ordinary usage but only for one working cycle and only if the fault can't be detected by the user, such as a change in temperature;
- as specified in the stall conditions if the fault can be detected by a user, for example when the motor of a sewing machine stops.
- till reaching the steady state conditions as regards circuit constantly supplied by mains, stand-by circuits;

However, the test is finished whenever there is a non-automatic re-arming interruption of the power supply within the device.

Test for Devices with a programmable component: Devices with a programmable component are conceived for this test provided that resuming operation at any stage in the operational cycle following an interruption caused by a dip in the supply voltage does not pose a risk. Before starting the test the batteries must be taken out and also other components in charge to supply the programmable component whenever there are drops in the supply voltage, interruptions, and fluctuations. The DUT is supplied at rated voltage and works at normal operating conditions. After 60 s the voltage is reduced till the device stops answering to user commands or the parts ruled by the programmable one stops working. Such voltage supply values is recorded. Again the DUT is supplied at rated voltage and works at normal operating conditions, then the voltage is reduced till the a values which is 10% less than the recorder one, such values is kept for 60 s. Eventually, the voltage is brought till the rated value. The rate at which the power supply voltage decreases and increases should be around 10 V/s . The DUT must either continue normal operation from the same point in its operating cycle where the voltage decrease happened, or it may require manual intervention to restart.

3.9.4 EMC test

The aim of this chapter is not to describe the EMC test procedures, instrumentation and so on but to outline the severity and conditions of such tests, for more details see table 14. The related EMC tests are described in the last chapter. Test conditions:

- Appliances equipped with a mechanism that achieves an 'off' state through electronic disconnection, or a device capable of entering standby mode is tested while supplied at rated voltage and at 'off' or standby mode.
- Devices with protective electronic circuit are tested after all the tests of this chapter a part from:
  - first test of the heating appliances;
  - test for devices with PTC heating element;
  - test for devices with protective electronic circuit that gets activated to assure the conformity with chapter "Abnormal operation";

  If such devices during the test of stall condition are tested for a period of 30 s or 5 minutes must not follow EMC tests.
- During tests the protection devices are switched off unless they have surge suppressors.

Table (14) EMC tests conditions

Test	Test conditions
Electrostatic discharge immunity test	-test level 4; -10 positive discharges and 10 negative discharges for each point;
Radiated, radio-frequency, electromagnetic field immunity test	-test level 3; -frequency ranges tested : 80 MHz-1000 MHz and 1.4 GHz and 2 GHz;
Electrical fast transient/burst immunity test	-test level 3 with repetition rate of 5 kHz (for signal and control lines) or -test level 4 with repetition rate of 5 kHz for the power supply lines; -2 minutes burst for each polarity;
Surge immunity test	• 5 impulses for each polarity; – Test level 3 for line to line coupling mode and 2 Ω impedance generator or – Test level 4 for line-to-earth coupling mode and 12 Ω impedance generator; • grounded heating elements in Class I appliances are disconnected[a]; • if the DUT has surge arresters incorporating spark gaps, test repeated at 95% (level) flashover voltage;
Immunity to conducted disturbances, induced by radio-frequency fields	• Test level 3; • frequency between 0.15 MHz and 80 MHz ;
Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase	class 3 voltage dips[b];
Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current more than 16 A per phase	class 3 voltage dips[c];
Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests	Test level 2 (table 11[d]), frequency steps according to Table 10[d];

[a] if a feedback system depends on it an artificial network may be needed.
[b] The values listed in Table 1 and Table 2 of IEC 61000-4-11 are implemented precisely at the zero crossing of the supply voltage;
[c] The values listed in Table 1 and Table 2 of IEC 61000-4-34 are implemented precisely at the zero crossing of the supply voltage;
[d] IEC 61000-4-13;

Table (15) Maximum winding temperature

Type of appliance	Temperature ° C							
	Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)	Class 200 (N)	Class 220 (R)	Class 250
Appliances other than those operated until steady conditions are established	200	215	225	240	260	280	300	330
Appliances operated until steady conditions are established								
if impedance protected	150	165	175	190	210	230	250	280
if protected by a protective device								
· during the first hour, maximum value	200	215	225	240	260	280	300	330
· after the first hour, maximum value	175	190	200	215	235	255	275	305
· after the first hour, arithmetic average	150	165	175	190	210	230	250	280

Appliances with relay appliances selector - tests: Appliances are subjected to the conditions outlined in chapter "Heating". Any contactor or relay contact that operates under these conditions is bridged. If a relay or contactor with multiple contacts is utilized, all contacts are bridged simultaneously. However, any relay or contactor solely responsible for ensuring the appliance is powered for regular use, and doesn't have other operational functions during normal use, is not bridged. If multiple relays or contactors operate in chapter "Heating", each one is bridged in succession. For appliances equipped with a mains voltage selector switch, set the switch to the lowest rated voltage position and apply the highest rated voltage value.

3.10 Stability and mechanical hazards (20)

3.10.1 Stability

Appliances designed for use on surfaces like floors or tables, excluding fixed and hand-held appliances, must possess sufficient stability. In order to check such conformity the following test is performed. Test conditions;

- Appliances equipped with an appliance inlet should be fitted with a suitable connector and flexible cord;
- When the appliance is not connected to the mains, it is positioned in any typical usage orientation on a surface inclined at 10° to the horizontal, with the supply cord positioned in the most disadvantageous manner on the inclined surface. If any part of the appliance makes contact with the horizontal support surface while tilted at 10° , the appliance is placed on a flat support and tilted in the least favorable direction by 10°;
- Appliances equipped with doors are tested in the position that yields the most unfavorable result, whether the doors are open or closed;
- Appliances designed for user-filling with liquid during normal use are tested both when empty and when filled with the highest specified quantity of water, up to the capacity indicated in the instructions, whichever represents the most challenging condition;

The DUT must not overturn. The test is conducted again on appliances with heating elements, this time with the inclination angle increased to 15° . If the appliance tips over in one or more positions,

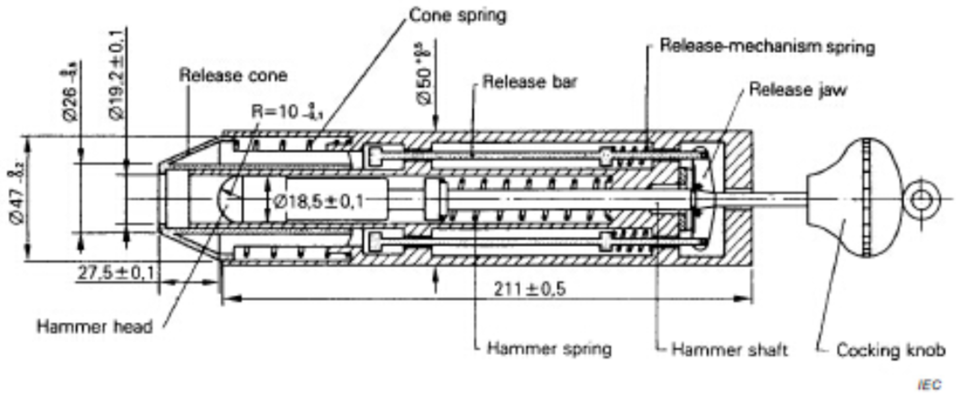


Figure (26)   Mechanical strength test (CEI EN 60335-1, chapter 21) Spring hammer

it undergoes the tests specified in Heating chapter in each of these overturned positions. Temperatures must not exceed threshold values specified in table 13.

3.10.2 Mechanical hazards

The movable components of appliances must, to the extent feasible while still allowing the appliance to function, be positioned or enclosed to offer sufficient protection against personal injury during regular use. This stipulation does not pertain to components of an appliance that must necessarily remain exposed in order for the appliance to perform its intended function, for example the needle of a sewing machine, tools of kitchen machines or the blade of an electrical knife. Conformity is assessed through visual inspection, the tests outlined in ehb test, and employing:

- A test probe akin to test probe B of EN 61032, but featuring a circular stop face measuring 50 mm in diameter, in lieu of a non-circular face. This is applied with a force of 5 N, after removing any accessories and detachable covers;
- Test probe 18 of EN 61032, applied with a force of 2.5 N to the fully assembled appliance.

For appliances equipped with movable devices, such as those designed for adjusting belt tension, the test using the probe is conducted with these devices set to their most unfavorable position within their adjustable range. If needed, belts are taken off. It must not be possible to come into contact with hazardous moving parts using this test probe. Instrumentation needed:

- test probe B of EN 61032 but featuring a circular stop face measuring 50 mm in diameter;
- dynamometer;
- Test probe 18 of EN 61032;
- all the instrumentation needed for heating test and ehb test;

3.11 Mechanical strength (21)

3.11.1 Ehb test

Appliances must possess sufficient mechanical durability and be designed to endure the kind of rough handling that can reasonably be anticipated during normal use. To verify that the DUT is subjected to blows according to the Ehb of IEC 60068-2-75. The main tool of this test is the spring hammer which consist of 3 parts: the body, the striking element and the release system, see figure 26.

When it is used in a position different from the horizontal one the energy is affected by ΔE, which is positive when applied downward and vice-versa.

$\Delta E = 10 \cdot m \cdot d \cdot \sin \alpha$

- m : mass of the striking element, kilograms;
- d : travel of striking element, meters;
- α : angle of the axis of the striking element with the horizontal;

The appliance is firmly secured, and three impacts with an energy of 0.5 J are administered to every susceptible point on the enclosure. If required, the impacts are also directed at handles, levers, knobs, and similar components, as well as signal lamps and their protective covers. This applies only if the lamps or covers extend from the enclosure by over 10 mm or if their surface area surpasses 4 cm^2. Lamps and their covers inside the appliance are only subjected to testing if they are prone to damage during regular use. Following the test, the appliance must exhibit no damage that could hinder compliance with CEI EN 60335-1 standard. Additionally, compliance with Protection against live parts, Resistance against moisture, and Clearances, creepage distances and solid insulation chapter chapter chapter should not be compromised. In cases of uncertainty, supplementary insulation and reinforced insulation are subjected to the electric strength test.

3.11.2 Resistance to penetration of sharp objects

Exposed portions of solid insulation must possess adequate strength to resist penetration by sharp objects. Conformity is verified by conducting the insulation test specified below, unless the supplementary insulation is at least 1 mm thick, and the reinforced insulation is at least 2 mm thick. The insulation is brought to the temperature recorded during the test outlined in Heating chapter. A hardened steel pin, having a conical tip with an angle of 40°, and a rounded tip with a radius of 0.25 mm $\pm$ 0.02 mm, is used to scratch the surface of the insulation. The pin is held at an angle ranging from 80° to 85° to the horizontal, and it is loaded in a way that applies a force of 10 N $\pm$ 0.5 N along its axis. The scratches are created by moving the pin along the surface of the insulation at a speed of about 20 mm/s. Two parallel scratches are made, spaced far enough apart to ensure they do not affect each other. Their combined length covers roughly 25% of the insulation's total length. Additionally, two similar scratches are made at a 90° angle to the first pair, without intersecting them. Next, the test fingernail shown in figure 27 is pressed against the scratched surface with a force of about 10 N. There should be no additional damage, such as material separation. Following this, the insulation must successfully pass the electric strength test. Subsequently, the hardened steel pin is pressed perpendicular to the surface with a force of 30 N $\pm$ 0.5 N on an unscratched area. The insulation must then pass the electric strength test , with the pin still in place and functioning as one of the electrodes. In conclusion those are the tools needed:

- hardened steel pin;
- dynamometer;
- test fingernail;
- spring hammer;
- all the instrumentation needed for electric strength test, heating test, protection against live parts and moisture resistance tests;

3.12 Construction (22)

Several checks must be done on the DUT in order to verify if it was properly designed and mounted, many of those are verified through visual inspection, such as: appliances must not feature any jagged or sharp edges, except those essential for the operation of the appliance, which could pose a risk to the user in typical use or during user maintenance. Additionally, pointed tips of self-tapping screws or other fasteners should be positioned in a way that makes it improbable for them to be touched by the user during normal use or maintenance. For more details regarding the others visual inspection tests see chapter 22 of the CEI EN 60335-1 standard. The other tests which are not simply verified through visual inspection are all taken in consideration in chis chapter.

1. (22.3) Appliances equipped with pins for insertion into socket-outlets must not exert excessive force on these outlets. The mechanisms for holding the pins must be able to withstand the forces they

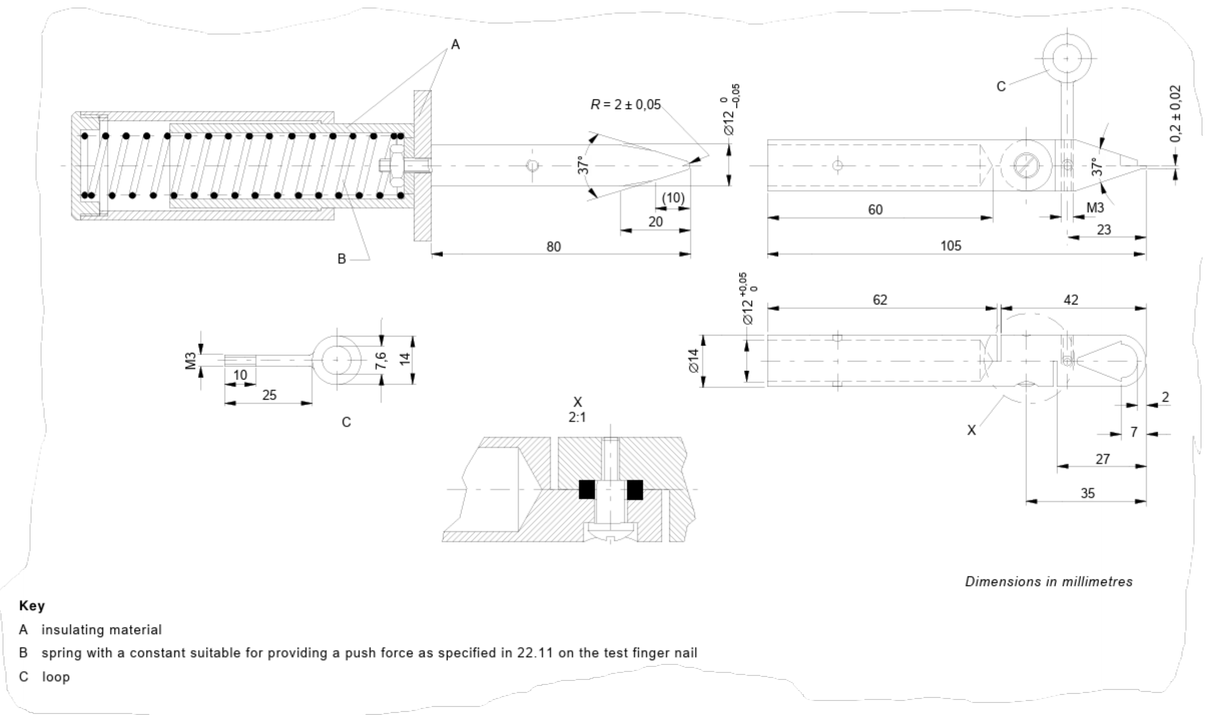


Figure (27) Mechanical strength test (CEI EN 60335-1, chapter 21) finger nail test

are expected to encounter during regular use. Conformity is assessed by inserting the pins of the appliance into a socket-outlet without an earthing contact. The socket-outlet is equipped with a horizontal pivot located 8 mm behind the engagement face of the socket-outlet and in alignment with the contact tubes. The torque needed to keep the engagement face of the socket-outlet in the vertical plane must not exceed 0.25 Nm. A fresh sample of the appliance is securely held to ensure the pin retention remains unaffected. The appliance is then positioned in a heating cabinet at a temperature of 70° C ± 2° C for a duration of 1 hour. Subsequently, the appliance is taken out of the heating cabinet, and a pull force of 50 N is promptly applied to each pin along their longitudinal axes for 1 minute. Once the appliance has returned to room temperature, the pins must not have shifted by more than 1 mm. Each pin is sequentially exposed to a torque of 0.4 Nm, applied for 1 minute in both directions. The pins should not rotate, unless such rotation does not hinder compliance with this standard. Tools needed:

- socket-outlet without an earthing contact;
- Torque meter;
- laboraotry stove

2. (22.5) Appliances designed for connection to the mains via a plug must be constructed in a way that eliminates the risk of electric shock from charged capacitors with a rated capacitance exceeding 0.1 μF when the plug pins are touched during normal use. Conformity is verified through the following test. The DUT is powered at its rated voltage. Subsequently, any switches are turned off, and the appliance is disconnected from the mains at the moment of the voltage peak. One second after disconnection, the voltage between the plug pins is measured using an instrument that has minimal impact on the measured value. This voltage should not surpass 34 V. A suitable device for carrying out this test (ad hoc) is the Residual voltage meter.
3. (22.6) Appliances must be designed to prevent any compromise of their electrical insulation due to water condensation on cold surfaces or from liquid leakage originating from containers, hoses, couplings, and similar components of the appliance. In the case of class II appliances and class II constructions, the electrical insulation should remain unaffected even if a hose ruptures or a seal leaks. Compliance is assessed through visual inspection and, if there are uncertainties, through the subsequent test. Colored water solution drops are administered using a syringe to internal parts of the appliance where liquid leakage might transpire and potentially impact electrical insulation. The appliance is either in operation or at rest, depending on which condition is more disadvantageous.

Following this test, a visual inspection must confirm the absence of any liquid traces on windings or insulation, which could lead to a decrease in creepage distances below the values stipulated in 29.2 chapter of CEI EN 60335-1. Instrumentation needed:
   - syringe;
   - coloured water;
4. (22.11) Non-removable components designed to guard against access to live parts, moisture, or contact with moving parts must be securely affixed and capable of withstanding the mechanical stress experienced during regular use. Snap-in devices used to secure such components should have a clearly identifiable locked position. The fastening capabilities of snap-in devices used in components likely to be removed during installation or servicing must be dependable. Compliance with these requirements is assessed through the following tests which is administered to all components that are prone to detachment, regardless of whether they are secured with screws, rivets, or similar means. Preparatory steps for the test:
   - Components that may be taken off during installation or maintenance are dismantled and reassembled ten times prior to conducting the test;
   - The test is conducted at room temperature. Nevertheless, if adherence to the standard could be influenced by the temperature of the appliance, the test is also conducted promptly after the appliance has been operated under the conditions outlined in Heating chapter.

   The DUT is subjected to:
   - a force which is steadily applied for 10 seconds in the direction that is deemed most unfavorable for parts susceptible to weakness. The applied force is as follows:
     - push force, 50 N, test probe 11 of IEC 61032 is needed;
     - pull force:
       * If the shape of the part is such that the fingertips cannot easily slip off, a force of 50 N is applied.
       * If the projection of the part being gripped is less than 10 mm in the direction of removal, a force of 30 N is applied.

     Such force is applied using an appropriate tool, like a suction cup, to ensure the test results remain unaffected. While the force is being exerted, the test fingernail depicted in Figure 7 is inserted into any opening or seam with a force of 10 N. The fingernail is then slid sideways with a force of 10 N, but it is not twisted or used as a lever. If the shape of the part makes it unlikely for an axial pull to occur, the pull force is omitted. Instead, the test fingernail is inserted into any aperture or joint with a force of 10 N. Subsequently, it is pulled for 10 seconds using the loop with a force of 30 N in the direction of removal.
   - If the part is susceptible to twisting, the following torque is applied simultaneously with the push or pull force:
     - 2 Nm for major dimensions up to 50 mm;
     - 4 Nm for major dimensions exceeding 50 mm;

     This torque is also applied when the test fingernail is pulled using the loop. If the projection of the gripped part is less than 10 mm, the torque is reduced by 50%.

   Components must stay securely in the locked position and should not come loose. Those are the required tools:
   - test probe 11 IEC 61032;
   - test finger nail, see figure;
   - Mechanical Force Gauge;
   - Torque meter;
5. (22.12) Handles, knobs, grips, levers, and similar components must be securely attached in a manner that prevents them from becoming loose during regular use, especially in cases where loosening could lead to a hazard. If these components are employed to indicate the position of switches or similar elements, they must not be capable of being affixed incorrectly, particularly if doing so could lead to a hazard. Conformity is verified through visual inspection, manual testing, and attempting to remove the part by applying an axial force of:
   - 15 N, if an axial pull is improbable in regular use.
   - 30 N, if an axial pull is likely in normal use.

   This force is sustained for 1 minute. A Mechanical Force Gauge is needed.

6. (22.13) Appliances must be designed in a way that, during regular use, when handles are gripped, it is improbable that the operator's hand comes into contact with parts experiencing a temperature rise surpassing the value indicated in Table 3 for handles held for short durations in normal use. Adherence to this requirement is assessed through visual inspection and, if deemed necessary, by measuring the temperature rise. So the instrumentation needed is the same as in Heating chapter.
7. Automatic cord reels must be designed in a way that prevents:
   - Excessive abrasion or damage to the sheath of the flexible cord;
   - Breakage of conductor strands;
   - Excessive wear of contacts;

   This compliance is verified through the following test, which is conducted without passing current through the flexible cord. Two-thirds of the cord's length is unwound. If the retractable length of the cord is less than 225 cm, 75 cm of the cord is left on the reel. Another 75 cm length of the cord is then unwound and pulled in a manner that causes the most significant abrasion to the sheath, considering the typical position of use of the appliance. At the point where the cord exits the appliance, there is an angle of approximately 60 between the cord's axis during the test and its axis when it is unwound without substantial resistance. The cord is allowed to rewind on the reel. If the cord does not retract at a 60 angle, the angle is adjusted to the maximum that permits proper retraction. The test is conducted 6,000 times, at a rate of about 30 times per minute or at the maximum rate permitted by the design of the cord reel, if it is lower. Following this test, both the cord and cord reel undergo an inspection. In cases of uncertainty, the cord is subjected to the electric strength test. This involves applying a test voltage of 1,000 V between the conductors of the cord, which are connected together, and a metal foil wrapped around the cord.
   - 30times/Min Household Appliance Test Equipment For Automatic Cord Reels Endurance Test
   - Generatore di carica elettrostatica CM TINY IQ;
   - all the instrumentation of the elecrtic strength test;
8. Metal components that carry current and other metal parts, the corrosion of which could pose a hazard, must be corrosion-resistant under typical usage conditions. Compliance is confirmed by ensuring that following the tests outlined in Abnormal operation chapter, the pertinent parts exhibit no indications of corrosion.
9. (22.32) Supplementary and reinforced insulation must be designed or shielded in a way that prevents the accumulation of pollutants caused by wear of internal appliance components from decreasing clearances or creepage distances below the values specified in Clearances, creepage distances and solid insulation chapter chapter chapter.

   In cases where natural or synthetic rubber is employed as supplementary insulation, it must either be resistant to aging or positioned and sized in a manner that ensures creepage distances are not reduced below the values specified in 29.2 chapter of CEI EN 60335-1, even if cracks develop.

   Materials like loosely sintered ceramic, similar substances, or loose beads are not acceptable for use as either supplementary or reinforced insulation. Two test are performed:
   (a) If the rubber component needs to withstand the effects of aging, it is suspended without restraint inside an oxygen bomb, which has a capacity that is at least ten times greater than the volume of the part. The bomb is filled with oxygen that is no less than 97% pure, at a pressure of 2.1 MPa with a tolerance of ± 0.07 MPa, and is held at a temperature of $70C$ with a tolerance of $\pm 1C$. The component is left inside the bomb for a duration of 96 hours. Following this period, it is taken out and left at room temperature away from direct sunlight for a minimum of 16 hours. Afterward, the component is inspected, and it should exhibit no visible cracks to the naked eye.
   (b) In situations where there is uncertainty, the following test is conducted to ascertain if the ceramic material is adequately sintered:
   The ceramic material is fractured into fragments, which are then submerged in a solution containing 1 gram of fuchsine in every 100 grams of methylated spirit. This solution is maintained at a pressure not less than 15 MPa for a duration such that the product of the test duration in hours and the test pressure in megapascals is approximately 180.

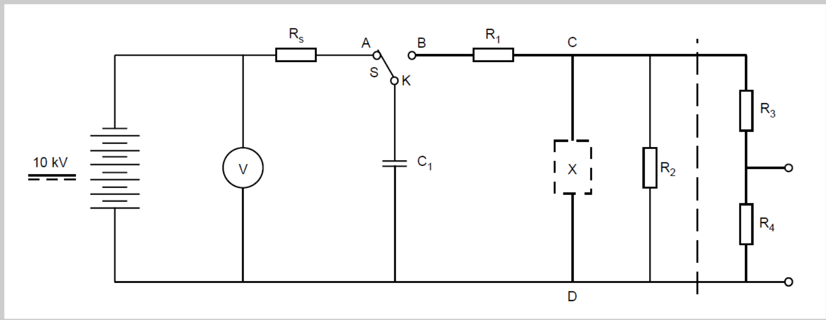


Figure (28) surge test circuit

Subsequently, the fragments are taken out of the solution, rinsed, dried, and further broken into smaller pieces. The freshly fractured surfaces are inspected, and they must not display any trace of dye discernible to the naked eye.

Those are the tools required:

- 820420670mm 2.4KW Heater Oxygen Bomb Ageing Tester;
- oxygen at 97% pure;
- AC380V 3KW Fuchsine Solution Pressure Tester For Ceramic Material;
- solution containing 1 g of fuchsine in each 100 g of methylated spirit;

10. (22.34) The shafts of operating knobs, handles, levers, and similar parts should not carry any electric current unless the shaft becomes inaccessible when the part is removed.
    Compliance with this requirement is verified through visual inspection and by using the test probe as outlined in Protection against live part chapter after the part has been removed, even if tools are used for removal.
11. (22.35) For constructions other than class III, handles, levers, and knobs that are held or operated in normal use must not become electrically charged in the event of basic insulation failure. If these metal handles, levers, or knobs have shafts or fixtures that could potentially become charged in the event of a basic insulation failure, they must be sufficiently covered with insulating material or their accessible parts must be isolated from their shafts or fixtures with supplementary insulation. The compliance is verified through visual inspection and, if needed, by conducting the appropriate tests.
    Insulating material that covers metal handles, levers, and knobs must pass the electric strength test specified for supplementary insulation, as outlined in the electronic strength chapter.
12. (22.42) Protective impedance shall comprise a minimum of two distinct components. If any one of these components is either short-circuited or open-circuited, the values specified in the part of the Protection against live parts, explaining how to check if it is a live part or not shall not be exceeded.
    - Resistors are tested on 10 samples, before starting the test the DUT is subjected to the damp heat test according to IEC 60068-2-3 (withdrawn), severity 21 days. For resistors connected between HAZARDOUS LIVE parts and ACCESSIBLE conductive parts, as well as for resistors bridging contact gaps of MAINS switches, each of the 10 specimens is subjected to 50 discharges at a maximum rate of 12 per minute. These discharges originate from a 1 nF capacitor charged to 10 kV in a test circuit as illustrated in figure 28. Following this test, the resistance value should not deviate by more than 20% from the value measured prior to the damp heat test. No failures are permitted.
13. (22.47) Appliances designed for connection to the water mains must be able to withstand the water pressure typically encountered in regular use. This compliance is assessed by connecting the appliance to a water supply with a static pressure equal to twice the maximum inlet water pressure or 1.2 MPa, whichever is greater, for a duration of 5 minutes. There should be no signs of leakage from any part, including any inlet water hose. The only tool needed is a manometer to measure water pressure.

14. (22.48) Appliances designed for connection to the water mains must be constructed in a way that prevents the backflow of non-potable water into the water mains. Two tests are performed to verify such conformity:
   (a) The DUT works for 5000 cycles. In each cycle there is a 3 seconds of water flowing inside it another 3 seconds period without stream. The water has a pressure of 0.2 MPa and its temperature is :
      - 15° C ± 5° C for Dynamic flow prevention devices supplied at cold water;
      - 65° C ± 5° C for Dynamic flow prevention devices supplied at hot water;
      - 65° C ± 5° C for Dynamic flow prevention devices if the entrance is not marked;

      Such test is repeated for 10 times sometimes with a 48 hours rest period. Before each test the Dynamic flow prevention devices is checked in order to be sure if the mobile parts works properly when the water flows through them.
   (b) After the first test is performed the backsiphonage test is followed, The pipes and hoses from the inlet valve to the backflow prevention device are dried. Then, a clear hose with an internal diameter at least as large as the inlet hose is attached to the appliance, replacing the original hose-set. The opposite end of this clear hose is connected, using the shortest available tubing, to a vacuum pump. The appliance is filled to the critical water level using a separate water supply, and this water level is maintained during the entire test. A negative pressure of 65 kPa 15 kPa is applied for a minimum of 5 seconds. This pressure is measured as close to the appliance as feasible. The magnetic valve is held in the open position through a separate electrical power supply.For appliances equipped with multiple hose-sets, the inlets are tested one by one. No water should have entered the transparent hose. The cross-sectional area of the connection to the vacuum pump must be adequate to ensure unrestricted airflow. This last test is performed at such conditions:
      - The test is conducted with movable parts positioned individually in their most unfavorable position.
      - After removable parts have been taken off;
      - after simulating damage to movable parts, including their supports or guides, one at a time.

      Only one of these three conditions is applied at any one time. The instrumentation needed is:
      - manometer for water pressure;
      - transparent tube;

3.13 Internal wiring (23)

1. (23.3) Parts of an appliance that have relative movement during normal use or maintenance should not impose excessive stress on electrical connections and internal conductors, including those ensuring grounding continuity. Flexible metallic tubes should not harm the insulation of the conductors they contain. Open-coil springs are not suitable for wire protection. If a coiled spring with touching turns is utilized, there must be sufficient insulating material in addition to the conductor insulation. Compliance is verified through visual examination and the subsequent test. If flexing occurs in normal use, the appliance is positioned in its typical usage stance and supplied with rated voltage for normal operation. The movable part is oscillated back and forth, causing the conductor to flex through the maximum angle permitted by the design, at a rate of 30 cycles per minute. The total number of flexing cycles is then recorded:
   - 10 000, for conductors flexed during normal use;
   - 100, for conductors flexed during user maintenance;

   The appliance must not sustain damage that compromises its compliance with this standard, and it should remain suitable for continued use. Specifically:
   - the wiring and its connections must endure the electric strength test outlined in 16.3. During this test, the voltage is lowered to 1,000 V and applied solely between live parts and accessible metal components.
   - Furthermore, no more than 10% of the strands in any conductor of the internal wiring, connecting the main part of the appliance to the movable part, should be broken. However, if

Table (16) Dimensions of cables and conduits

Number of conductors including earthing conductors	Maximum overall dimension	
	Cable	Conduit[a]
2	13,0	16,0 (23,0)
3	14	16,0 (23,0)
4	14,5	20,0 (23,0)
5	15,5	20,0 (29,0)

[a] The dimensions in parentheses are for use in USA and Canada.

the wiring powers circuits that use no more than 15 W, then up to 30% of the strands may be broken.

So in conclusion the required instrumentation is :

- 30times/Min Household Appliance Test Equipment For Automatic Cord Reels Endurance Test;
- all the tools needed in the electric strength test;

2. (23.5) The insulation of internal wiring exposed to the supply mains voltage must be able to withstand the electrical stress it will encounter in regular use. Compliance is verified in the following manner: The basic insulation should be electrically equivalent to the basic insulation of cords in accordance with IEC 60227 or IEC 60245, or it should pass the specified electric strength test. A voltage of 2,000 V is applied for 15 minutes between the conductor and the metal foil wrapped around the insulation. No breakdown should occur. In order to perform such test an oscilloscope to check if there are any flashovers and a Generatore di carica elettrostatica CM TINY IQ are required.

3.14 Supply connection and external flexible cords (25)

1. (25.2) Appliances, except for fixed appliances designed for multiple power sources, should not have more than one way to connect to the mains. Fixed appliances for multiple power sources may have multiple connection points, as long as the associated circuits are sufficiently insulated from one another. Compliance is verified through visual examination and a subsequent test. A voltage of 1.250 V with a mostly sinusoidal waveform and a frequency of either 50 Hz or 60 Hz is applied for a duration of 1 minute across each supply mains connection point. Throughout this test, no electrical breakdown should occur. So items needed for this test are a voltage generator and an oscilloscope.
2. (25.4) For appliances designed for permanent connection to the fixed wiring and with a rated current not exceeding 16 A, the cable and conduit entries must be compatible with cables or conduits with a maximum overall dimension as specified in Table 16. Conduit entries, cable entries, and knock-outs must be designed or positioned in a way that when conduits or cables are introduced, it does not result in clearances or creepage distances falling below the values specified in Clearances, creepage distances and solid insulation chapter chapter. To measure such dimensions a micro meter screw gauge is needed.
3. (25.7) The supply cords for appliances, excluding class III appliances, should fall under one of the following categories:
   - Rubber sheathed cords. These cords must possess at least the properties of standard durable rubber sheathed cords (identified by the code designation 60245 IEC 53). It's worth noting that these cords are not suitable for outdoor use or situations where they may be exposed to substantial amounts of ultraviolet radiation.
   - Supply cords for appliances can also be of the polychloroprene sheathed type. These cords should meet the minimum requirements specified for standard polychloroprene sheathed cords (identified by the code designation 60245 IEC 57).
   - Supply cords for appliances can also be of the cross-linked polyvinyl chloride sheathed type. These cords should meet the minimum requirements specified for cross-linked polyvinyl chloride sheathed cords (identified by the code designation 60245 IEC 88).

Table (17) Minimum cross-sectional area of conductors

Rated current of appliance A	**Nominal cross-sectional area** mm^2
- ≤ 0.2	Tinsel cord[a]
> 0.2 and ≤ 3	0.5[a]
> 3 and ≤ 6	0.75
> 6 and ≤ 10	1,0 (0,75)[b]
> 10 and ≤ 16	1,5 (1,0)[b]
> 16 and ≤ 25	2.5
> 25 and ≤ 32	4
> 32 and ≤ 40	6
> 40 and ≤ 63	10

NOTE For supply cords supplied with multi-phase appliances, the nominal cross-sectional area of the conductors is based on the maximum cross-sectional area of the conductors per phase at the supply cord connection to the appliance terminals.

[a] These cords may only be used if their length does not exceed 2 m between the point where the cord or cord guard enters the appliance and the entry to the plug.

[b] Cords having the cross-sectional areas indicated in the parentheses may be used for portable appliances if their length does not exceed 2 m.

- Polyvinyl chloride sheathed. These cords should not be used in situations where they might come into contact with metal parts that experience a temperature rise greater than 75 K during the test specified in Heating chapter. Depending on the mass of the appliance, the cords should meet the requirements for either "light polyvinyl chloride sheathed cord" (code designation 60227 IEC 52) for appliances weighing up to 3 kg, or "ordinary polyvinyl chloride sheathed cord" (code designation 60227 IEC 53) for other appliances.
- Heat resistant polyvinyl chloride sheathed. These cords should not be used for type X attachment, unless they have been specially prepared. Depending on the mass of the appliance, the cords should meet the requirements for either "heat-resistant light polyvinyl chloride sheathed cord" (code designation 60227 IEC 56) for appliances weighing up to 3 kg, or "heat-resistant polyvinyl chloride sheathed cord" (code designation 60227 IEC 57) for other appliances.
- Halogen-free thermoplastic compound sheathed. The cords should meet the requirements for "halogen-free thermoplastic compound sheathed cords." For appliances weighing up to 3 kg, the code designations should be H03Z1Z1H2-F or H03Z1Z1-F. For other appliances, the code designations should be H05Z1Z1H2-F or H05Z1Z1-F.
- Cross-linked halogen-free compound sheathed. Understood. The cords should meet the specifications for "cross-linked halogen-free compound sheathed cords" with the code designation H07ZZ-F.

For class III appliances, the compliance regarding the insulation of supply cords is verified through inspection, measurement, and, in the case of class III appliances that contain live parts, a specific test. A voltage of 500 V is applied for 2 minutes between the conductor and the metal foil wrapped around the insulation, with the insulation being at the temperature measured during the test of Heating chapter. There should be no breakdown during this test. A voltage supplier, metal foil and an oscilloscope are required.

4. (25.8) The conductors of supply cords should have a nominal cross-sectional area that is equal to or greater than what is specified in Table 17. To verify such dimension a micro meter gauge screw is required
5. (25.14) Appliances equipped with a supply cord and designed to be moved while in operation must be constructed in a way that adequately protects the supply cord from excessive flexing at the point where it enters the appliance. Compliance is verified through the following test, conducted on a device equipped with an oscillating component, as depicted in Figure 29. The section of the appliance containing the inlet opening is affixed to the oscillating component. When the supply cord is positioned at the midpoint of its movement, the axis of the cord where it enters the cord

Table (18) Pull force and torque

Mass of appliance kg	**Pull force** N	**Torque** Nm
≤ 1	30	0.1
> 0.1 and ≤ 4	60	0.25
> 4	100	0.35

guard or inlet is vertical and aligns with the axis of oscillation. Additionally, the flat cords' primary axis should be parallel to the axis of oscillation.
The cord is subjected to a load according to the following criteria:

- 10 N for cords with a nominal cross-sectional area greater than 0.75 mm^2.
- 5 N for cords with other cross-sectional areas.

The distance X, as illustrated in Figure 29, is set to ensure that when the oscillating member moves through its entire range, the cord and load experience minimal lateral movement. The oscillating member is pivoted through an angle of 90° (45° on each side of the vertical), with 20,000 flexings for type Z attachments and 10,000 for other attachments. This is done at a rate of 60 flexes per minute. The cord and its associated parts are rotated by 90° after completing half the designated number of flexes, unless a flat cord is utilized. Throughout the test, the conductors are supplied with the rated voltage and loaded with the rated current of the appliance. No current is passed through the earthing conductor. The test must not lead to:

- A short circuit between the conductors causing a current exceeding twice the rated current of the appliance.
- More than 10% of the strands of any conductor breaking.
- Separation of the conductor from its terminal.
- Loosening of any cord guard.
- Damage to the cord or cord guard that could compromise compliance with this standard.
- Broken strands piercing the insulation and becoming accessible.

To perform the test such equipment is sold on the market Test Equipment Power Cord Flexing Test Apparatus of Adjustable Bend Angle.

6. (25.15) Appliances furnished with a supply cord and those meant for permanent connection to fixed wiring using a flexible cord must feature a cord anchorage. This anchorage serves to alleviate stress on conductors, encompassing any twisting at the terminals, and provides protection for the insulation of the conductors against abrasion. Additionally, it should not be feasible to push the cord into the appliance to an extent where the cord or internal components of the appliance could be damaged. This procedure ensures compliance through inspection, manual testing, and the following set of tests:
   1 A mark is made on the cord, roughly 20 mm from the cord anchorage or another suitable point, while it's subjected to the specified pull force according to Table 18.
   2 The cord is then pulled in the most unfavorable direction, without any abrupt jerks, for 1 second using the specified force. This test is repeated 25 times.
   3 Except for automatic cord reels, the cord is subjected to a torque applied as close to the appliance as possible. The torque value is defined in Table 18 and is maintained for 1 minute.

   Throughout the tests, the cord must remain undamaged and exhibit no significant strain at the terminals. After applying the pull force, the cord should not have shifted longitudinally by more than 2 mm. The device sold on the market for this test is 20mm Torque Arm Cord Anchorage Strain And Twist Tester Machine.
7. (25.16) Cord restraints for type X connections must be designed and positioned in a way that:
   - the cord can be readily replaced;
   - the method of strain relief and prevention of twisting is evident;
   - they are compatible with various types of supply cords that may be connected, unless the cord is specially prepared;
   - the cord must not come into contact with the clamping screws of the cord anchorage, provided these screws are accessible, unless they are insulated from accessible metal parts by supplementary insulation;
   - the cord is not secured by a metal screw that directly presses against it;

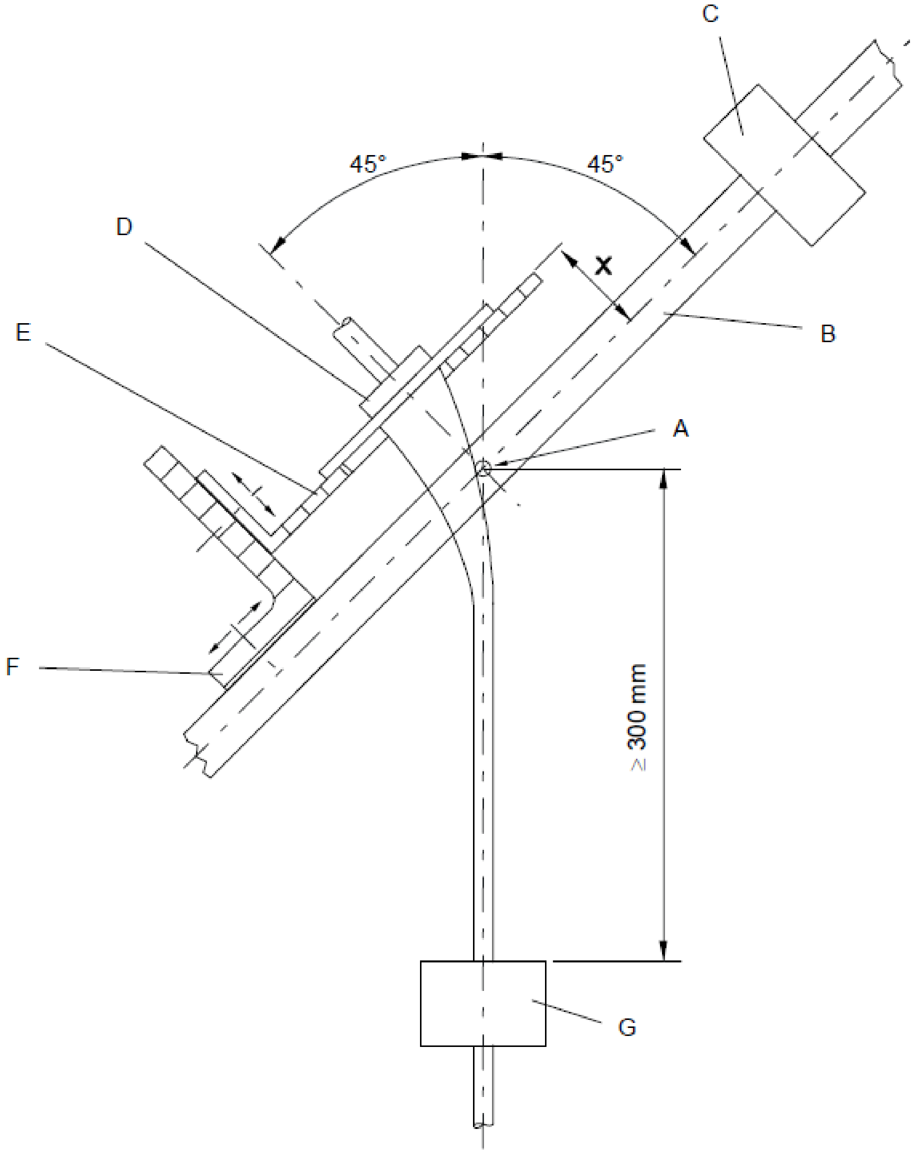


Figure (29) Flexing test apparatus;
A axis of oscillation
B oscillating frame
C counterweight
D sample
E adjustable carrier plate
F adjustable bracket
G load

- At least one component of the cord anchorage is firmly attached to the appliance, unless it is integral to a specially designed cord.
- Screws that need to be manipulated during cord replacement should not secure any other component. However, exceptions apply if:
  - After removing the screws, or if the component is repositioned incorrectly, the appliance becomes inoperable or visibly incomplete.
  - The parts intended to be secured by them cannot be detached without the use of a tool during cord replacement.
- If labyrinths can be bypassed, the test specified in the previous test must still be passed.
- For Class 0, Class 0I, and Class I appliances, the cord anchorage components are made of insulating material or have an insulating lining. This is unless a failure of the cord insulation does not result in exposed metal parts becoming live.
- For Class II appliances, the cord anchorage components are made of insulating material. If they are made of metal, they must be insulated from accessible metal parts by supplementary insulation.

Compliance is verified through visual inspection and the test specified previously, under the following conditions:

1 Tests are conducted first with the lightest acceptable cord of the smallest cross-sectional area as indicated in Table 31. Subsequently, the next heavier cord type with the largest specified cross-sectional area is used. If the appliance is equipped with a specially prepared cord, this cord is used for testing.

2 The conductors are inserted into the terminals, and the terminal screws are tightened enough to prevent the conductors from easily shifting position. The clamping screws of the cord anchorage are tightened to two-thirds of the specified torque in 28.1.

(a) Screws made of insulating material, which directly contact the cord, are fastened with two-thirds of the specified torque in column I of Table 32. The length of the slot in the screw head is considered as the nominal diameter of the screw.

(b) Following the test, the conductors must not have shifted by more than 1 mm within the terminals.

8. (25.17) For Y and Z type connections, the cable fastening devices must be appropriate. Compliance is verified through the previous test, using the cable provided with the appliance.
9. (25.21) The space for connecting supply cords with type X attachment or fixed wiring must be designed to meet the following criteria:
   - Allow for easy verification of correct positioning and connection of the supply conductors before installing any cover.
   - Enable the installation of any cover without posing a risk of damaging the conductors or their insulation.
   - For portable appliances, prevent any uninsulated end of a conductor, if it were to become detached from the terminal, from making contact with accessible metal parts.

   For portable appliances, compliance is further assessed through the following test, unless they are equipped with pillar terminals and the supply cord is securely clamped within 30 mm of them. This test is conducted after fitting cables or flexible cords with the largest cross-sectional area specified in Table 31. The clamping screws or nuts are individually loosened. A force of 2 N is then applied to the conductor in any direction near the terminal. The uninsulated end of the conductor must not make contact with accessible metal parts. To do such test a gauge meter is required.
10. (25.23) Interconnection cords must meet the same criteria as the supply cord, with the following exceptions:
    - The conductor's cross-sectional area is determined based on the maximum current it carries during the test considered in Heating chapter, not the appliance's rated current.
    - The insulation thickness of the conductor may be reduced if the conductor's voltage is lower than the rated voltage.

    Compliance is verified through inspection, measurement, and, if needed, additional tests, like the electric strength test.
11. (25.25) The dimensions of pins of appliances that are inserted into socket-outlets shall be compatible with the dimensions of the relevant socket-outlet. Dimensions of the pins and engagement face are

to be in accordance with the dimensions of the relevant plug listed in IEC/TR 60083. Compliance is checked by measurement.

3.15 Terminals for external conductors (26)

1. (26.2) Appliances with type X attachment, excluding those with a specially prepared cord, as well as appliances designed for cable connections in fixed wiring, must be equipped with terminals for making connections using screws, nuts, or similar mechanisms, unless the connections are soldered. These screws and nuts should not serve to secure any other component, though they may also secure internal conductors if arranged to prevent displacement during the fitting of supply conductors.
   If soldered connections are employed, the conductor must be positioned or secured in a way that does not solely rely on soldering for its stability. However, soldering alone may be acceptable if barriers are in place to prevent reductions in clearances or creepage distances between live parts and other metal components, even if the conductor becomes loose at the soldered joint. Compliance is assessed through visual inspection and measurements.
2. (26.3) Terminals designed for type X attachment and those intended for connecting fixed wiring cables must be constructed in a way that they securely grip the conductor between metal surfaces, applying adequate pressure for good contact without causing any damage to the conductor.The terminals must be secured in a manner that, when the clamping mechanism is either tightened or loosened, the terminal remains firmly in place. This requirement does not apply if the terminals are secured with two screws, or if they are fixed with one screw in a recess in such a way that there is minimal movement. Additionally, if the terminals are not subjected to torsion during normal use and are secured by a self-hardening resin, they are exempt from this condition.
   It's important to note that terminals may be prevented from loosening by other suitable means. The use of a sealing compound alone, without additional locking measures, is not considered sufficient. Moreover, during the tightening or loosening process:
   - The internal wiring should not be subjected to stress.
   - Clearances and creepage distances must not be reduced below the values specified in Clearances, creepage distances and solid insulation chapter chapter.

   Compliance is verified through visual inspection and by conducting the following test: Screws and nuts are cycled through tightening and loosening five times using an appropriate screwdriver or spanner. The tightening torque should align with the corresponding column in Table 19, two-thirds of the torque specified. A fresh conductor end is employed every time the screw or nut is loosened.
   - Column I is relevant for screws that lack heads or, if the screw, when tightened, does not extend beyond the hole. It also applies to other screws that cannot be tightened using a screwdriver with a blade wider than the screw's diameter.
   - Column II pertains to nuts of mantle clamping units that are tightened using a screwdriver.
   - Column III is intended for other screws of clamping units that are tightened using a screwdriver.
   - Column IV is for screws and nuts, excluding nuts of mantle clamping units, which are fastened using tools other than a screwdriver.
   - Column V is for nuts of mantle clamping units that are fastened using tools other than a screwdriver.
   - This means that for screws with hexagonal heads and a slot, if the values in columns III and IV are different, the test is conducted twice:
     - On a set of three specimens, applying the torque specified in column IV.
     - On another set of three specimens, applying the torque specified in column III using a screwdriver.

     If the values in columns III and IV are the same, only the test with the screwdriver is conducted.

   Screws and nuts used for clamping conductors must have a metric ISO thread or a thread with a pitch and mechanical strength comparable to that of the ISO standard. The specified nominal diameter for mantle clamping units refers to the slotted stud. The test screwdriver's blade shape should match the head of the screws being tested. Additionally, screws and nuts should not be tightened abruptly or with jerking motions.

Table (19) Relationship between torque and nominal diameter of thread

Nominal diameter of thread mm	**Torque** Nm				
	I	**II**	**III**	**IV**	**V**
≤ 1.6	0,05	-	0,1	0,1	-
> 1.6 and ≤ 2	0,1	-	0,2	0,2	-
> 2 and ≤ 2.8	0,2	-	0,4	0,4	-
> 2.8 and ≤ 3	0,25	-	0,5	0,5	-
> 3 and ≤ 3.2	0,3	-	0,6	0,6	-
> 3.2 and ≤ 3.6	0,4	-	0,8	0,8	-
> 3.6 and ≤ 4.1	0,7	1,2	1,2	1,2	1,2
> 4.1 and ≤ 4.7	0,8	1,2	1,8	1,8	1,8
> 4.7 and ≤ 5.3	0,8	1,4	2	2	2
> 5.3 and ≤ 6	1,2	1,8	2,5	3	3
> 6 and ≤ 8	2,5	2,5	3,5	6	4
> 8 and ≤ 10	-	3,5	4	10	6
> 10 and ≤ 12	-	4	-	-	8
> 12 and ≤ 15	-	5	-	-	10

Following the test, the conductors should not exhibit any deep or sharp indentations. In order to carry it out a torque screwdrivers is needed.

3. (26.4) Terminals intended for type X attachment, with the exception of specially prepared type X attachments, and those designed for connecting fixed wiring cables, should not necessitate any specific preparation of the conductor, like soldering individual strands, using cable lugs, eyelets, or similar means. They must be designed or positioned in a way that prevents the conductor from slipping out when clamping screws or nuts are secured. Verification of compliance involves visually inspecting the terminals and conductors after conducting the previous test.
4. (26.5) Terminals designed for type X attachment must be positioned or protected in a manner that prevents any individual wire of a stranded conductor from inadvertently making contact with other parts, which could lead to a potential danger, when the conductors are being installed. This compliance is verified through visual inspection and a subsequent test. A segment of insulation, 8 mm in length, is removed from the end of a flexible conductor with a specified nominal cross-sectional area (refer to Table 11). One wire from the stranded conductor is left free, while the remaining wires are fully inserted and securely clamped in the terminal. The free wire is gently bent in all possible directions, avoiding sharp bends around any obstructions, without stripping the insulation back further.
   It's important to note that this test also applies to earthing conductors. The outcome must ensure that there is no contact between live parts and accessible metal components. Additionally, for class II constructions, there should be no contact between live parts and metal elements that are only separated from accessible metal parts by supplementary insulation.
5. (26.6) Terminals designated for type X attachment and for linking cables to fixed wiring must accommodate conductors with the nominal cross-sectional areas specified in Table 31. However, in the case of a specially prepared cord being used, the terminals need only be suitable for connecting that specific cord. Compliance is assessed through visual examination, measurements, and by installing cables or cords with both the smallest and largest cross-sectional areas as specified.
6. (26.10) Terminals with screw clamping and screwless terminals must not be utilized for connecting the conductors of flat twin tinsel cords unless the ends of the conductors are equipped with appropriate means for use with screw terminals. This compliance is verified through visual inspection and subjecting the connection to a 5 N pull force, by using a dynamometer. Following the test, the connection must exhibit no damage that could compromise compliance with this standard.

3.16 Provision for earthing (27)

1. (27.5) The link between the earthing terminal or contact and grounded metal components should exhibit minimal electrical resistance. If the clearances of basic insulation in a protective extra-low

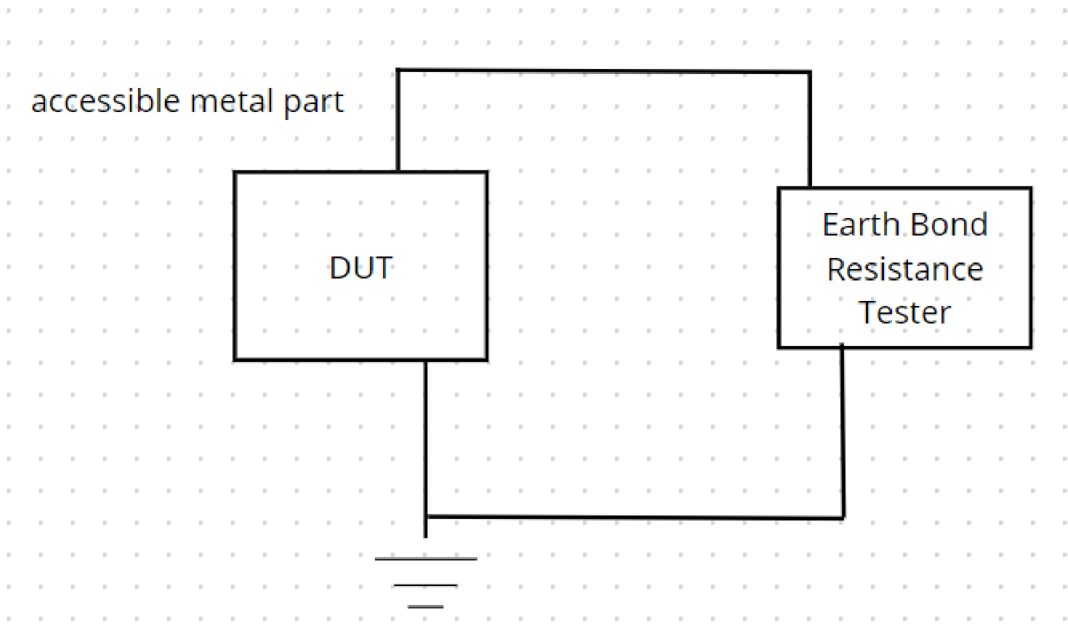


Figure (30) Provisioning for earthing (CEI EN 60335-1): Earth Bond Resistance Teste circuit

voltage circuit are determined by the rated voltage of the appliance, this criterion does not pertain to connections ensuring earthing continuity in the protective extra-low voltage circuit. Compliance is verified through the following procedure. A current sourced from a system with a no-load voltage not surpassing 12 V (whether alternating or direct current) and equal to 1.5 times the rated current of the appliance or 25 A, whichever is greater, is directed between the earthing terminal or contact and each of the accessible metal components, one after the other. The voltage reduction from the earthing terminal of the appliance or the earthing contact of the appliance's inlet to the accessible metal part is gauged. The resistance, derived from this current and voltage drop, must not exceed 0.1 Ω. The Earth Bond Resistance Tester can be used to perform the test, see figure 30.

2. (27.6) The printed conductors on printed circuit boards are not permitted to serve as the sole means of ensuring earthing continuity in hand-held appliances. However, they may be utilized for this purpose in other appliances, provided that at least two separate tracks with independent soldering points are employed, and the appliance meets the requirements of the previous test for each circuit.

3.17 Screws and connections (28)

Any fixings, electrical connections, or components responsible for providing earthing continuity must be capable of withstanding the mechanical stresses encountered during normal use, as their failure could potentially jeopardize compliance with this standard. Compliance is assessed through visual inspection and a subsequent test. Screws and nuts are subjected to testing if they meet any of the following criteria:

- They are utilized for electrical connections.
- They are employed for connections ensuring earthing continuity, unless a minimum of two screws or nuts are utilized.
- They are anticipated to be tightened:
  - During user-performed maintenance.
  - When substituting a supply cord featuring a type X attachment.
  - During installation.

The screws or nuts are securely fastened and loosened without abrupt movements:

- 10 cycles for screws interacting with an insulating material thread.

- 5 cycles for nuts and other screws. Screws engaged with an insulating material thread are fully extracted and reinserted in each cycle.

During the examination of terminal screws and nuts, a cable or flexible cord with the maximum cross-sectional area indicated in Table 31 is inserted into the terminal. It is adjusted before each tightening. The test is performed using an appropriate screwdriver, spanner, or key, applying a torque as specified in Table 32. Column I is relevant for metal screws without heads if the screw does not extend beyond the hole when it is tightened. Column II applies to:

- Other metal screws and nuts.
- Screws made of insulating material with the following characteristics:
  - Having a hexagonal head with a dimension across flats that exceeds the overall thread diameter.
  - Featuring a cylindrical head and a socket for a key, where the socket's cross-corner dimension exceeds the overall thread diameter.
  - Having a head with a slot or cross-slots, where the length of the slot exceeds 1.5 times the overall thread diameter.

Column III applies to other screws made of insulating material. No damage that would hinder the continued use of the fixings or connections should occur. The main tool needed for this test is a Torque screwdriver.

3.18 Clearances, creepage distances and solid insulation chapter chapter (29)

Appliances must be designed with clearances, creepage distances, and solid insulation sufficient to withstand the expected electrical stresses placed on the appliance. To verify such conformity the following tests are performed.

3.18.1 Clearances

1. The specified clearances, as outlined in Table 21 and considering the rated impulse voltage for the respective overvoltage categories in Table 20, must be maintained. This is unless, for both basic and functional insulation, they meet the requirements of the impulse voltage test described in Transient overvoltages chapter. However, if the construction of the apparatus is such that clearances could potentially be compromised due to factors like wear, distortion, movement of parts, or during assembly, the clearances for rated impulse voltages of 1500 V and higher are extended by 0.5 mm, and the impulse voltage test is not applicable. Compliance is verified through visual inspection and precise measurements. Components, like hexagonal nuts susceptible to various tightening positions during assembly, and movable parts, are positioned in their most critical configuration. An applied force is exerted on exposed conductors (excluding those of heating elements) and accessible surfaces to simulate conditions that might diminish clearances during the measurement process.The force applied is:
   - 2 N for exposed conductors.
   - 30 N for accessible surfaces.

   This force is administered using test probe B of IEC 61032. Openings are assumed to be covered with a flat piece of metal.
2. Basic insulation clearances must be robust enough to endure the anticipated overvoltages that may arise during normal operation, factoring in the rated impulse voltage. The criteria outlined in table 21, or the impulse voltage test specified in Transient overvoltages chapter, are pertinent in this evaluation.
3. Clearances for supplementary insulation must meet or exceed those outlined for basic insulation in 21. This is verified through measurement to ensure compliance.
4. The clearances required for reinforced insulation must be equal to or greater than those specified for basic insulation in Table 21, using the next highest step for rated impulse voltage as a reference

Table (20) Rated impulse voltage- Appliances are in overvoltage category II.

Rated voltage V	**Rated impulse voltage** V **Overvoltage category**		
	I	**II**	**III**
≤ 50	330	500	800
> 50 and ≤ 150	800	1500	2500
> 150 and ≤ 300	1500	2500	4000

NOTE 1 For multi-phase appliances, the line to neutral or line to earth voltage is used for rated voltage.
NOTE 2 The values are based on the assumption that the appliance will not generate higher overvoltages than those specified. If higher overvoltages are generated, the clearances have to be increased accordingly.

Table (21) Minimum clearances

Rated impulse voltage V	**Minimum clearance**[a] mm
330	0,5[b,c,d]
500	0,5[b,c,d]
800	0,5[b,c,d]
1500	0,5[c]
2500	1,5
4000	3
6000	5,5
8000	8
10000	11

[a] The distances specified apply only to clearances in air.
[b] The smaller clearances specified in IEC 60664-1 have not been adopted for practical reasons, such as mass-production tolerances.
[c] This value is increased to 0.8 mm for pollution degree 3.
[d] For tracks of printed circuit boards this value is reduced to 0.2 mm for pollution degree 1 and pollution degree 2.

Table (22) Examples of clearances, figure 31

Type of insulation	Clearance
Basic insulation	L_1A
	L_1D
	L_2F
Functional insulation	L_1L_2
Supplementary insulation	DE
	FG
Reinforced insulation	L_1K
	L_1J
	L_2I
	L_1C

point. Compliance is verified through measurement. In the case of double insulation, where there is no intermediate conductive part between the basic insulation and supplementary insulation, clearances are assessed between live parts and accessible surfaces, treating the insulation system as reinforced insulation, as illustrated in figure 31.

5. The clearances required for functional insulation are determined by considering the largest values from:
   - Table 21, using the rated impulse voltage as a reference.
   - Table F.7a in IEC 60664-1, taking into account the steady-state voltage or recurring peak voltage anticipated to be present across it, provided the frequency of the steady-state voltage or recurring peak voltage does not surpass 30 kHz.
   - Clause 4 of IEC 60664-4, considering the steady-state voltage or recurring peak voltage expected to occur across it, if the frequency of the steady-state voltage or recurring peak voltage exceeds 30 kHz.

   If the values specified in Table 21 are the most critical, the impulse voltage test outlined in Transient overvoltages chapter can be conducted as an alternative, unless the microenvironment is classified as pollution degree 3 or if the construction is such that the distances could be influenced by wear, distortion, movement of parts, or during assembly.Clearances are not explicitly defined if the appliance adheres to the provisions of Abnormal operation chpater with functional insulation short-circuited. Lacquered conductors of windings are treated as if they were bare conductors. However, clearances at crossover points are excluded from measurement. In the case of PTC heating elements, the clearance between their surfaces may be reduced to 1 mm. Compliance is verified through measurement and, if required, by conducting a test.
6. For appliances operating at voltages higher than their rated voltage, such as on the secondary side of a step-up transformer, or in the presence of a resonant voltage, the clearances required for basic insulation are determined based on the following criteria:
   1 Table 21, using the rated impulse voltage as a reference.
   2 Table F.7a in IEC 60664-1, taking into account the steady-state voltage or recurring peak voltage anticipated to be present across it, provided the frequency of the steady-state voltage or recurring peak voltage does not surpass 30 kHz.
   3 Clause 4 of IEC 60664-4, considering the steady-state voltage or recurring peak voltage expected to occur across it, if the frequency of the steady-state voltage or recurring peak voltage exceeds 30 kHz.

   If the clearances are chosen according to the:
   - 2 or 3 option then the clearances for supplementary insulation must be equal to or greater than those specified for basic insulation.
   - 2 option then the clearances for reinforced insulation must be designed according to the dimensions specified in Table F.7a to endure 160% of the withstand voltage necessary for basic insulation.
   - 3 option then The clearances for reinforced insulation must be twice the value needed for basic insulation.

If the secondary winding of a step-down transformer is grounded, or if there is a grounded screen between the primary and secondary windings, the clearances for basic insulation on the secondary side must be no less than those indicated in table 21, with the next lower step for rated impulse voltage as a reference. For circuits supplied with a voltage lower than the rated voltage, such as on the secondary side of a transformer, clearances for functional insulation are determined based on the working voltage, which is considered as the rated voltage in table 20. The verification is conducted through measurements.

3.18.2 creepage distances

Appliances must be designed with creepage distances that meet the requirements for the working voltage, considering the material group and pollution degree. Pollution degree 2 is the default classification. However, under the following conditions:

- If measures are in place to safeguard the insulation, then pollution degree 1 applies.
- In cases where the insulation is exposed to conductive pollution, pollution degree 3 is applicable.

The verification is conducted through measurements. Components, like hexagonal nuts susceptible to various tightening positions during assembly, and movable parts, are positioned in their most critical configuration. An applied force is exerted on exposed conductors (excluding those of heating elements) and accessible surfaces to simulate conditions that might diminish clearances during the measurement process.The force applied is:

- 2 N for exposed conductors.
- 30 N for accessible surfaces.

This force is administered using test probe B of IEC 61032.

1 Creepage distances for basic insulation must meet or exceed the values specified in table 33. However, if the working voltage is periodic and has a frequency exceeding 30 kHz, the creepage distances must also be assessed according to Table 2 of IEC 60664-4. These values take precedence if they surpass the figures in table 33. With the exception of pollution degree 1, if the Transient overvoltages test has been employed to verify a specific clearance, the corresponding creepage distance must not fall below the minimum dimension specified for the clearance in Table 21. The verification is conducted through measurements.

2 Creepage distances for supplementary insulation must meet at least the specifications set for basic insulation, as outlined in table 33 or Table 2 of IEC 60664-4, depending on the applicable standard. Notes 1 and 2 of table 33 do not apply. The verification is conducted through measurements.

3 Creepage distances for reinforced insulation must be at least twice the values specified for basic insulation in table 33 or Table 2 of IEC 60664-4, as applicable. Notes 1 and 2 of table 33 do not apply. The verification is conducted through measurements.

4 Creepage distances for functional insulation must be no less than the values specified in table 34. However, if the working voltage is periodic and has a frequency exceeding 30 kHz, creepage distances should also be determined according to Table 2 of IEC 60664-4. These values should be used if they exceed those in table 34. Creepage distances may be reduced if the appliance complies with Abnormal operation chapter with the functional insulation short-circuited.The verification is conducted through measurements.

3.18.3 Solid insulation

Supplementary insulation and reinforced insulation must possess a thickness or consist of a suitable number of layers to endure the electrical stresses anticipated during the operation of the appliance. The verification is conducted:

- through measurements; The insulation must have a minimum thickness of:
  - 1 mm for supplementary insulation.

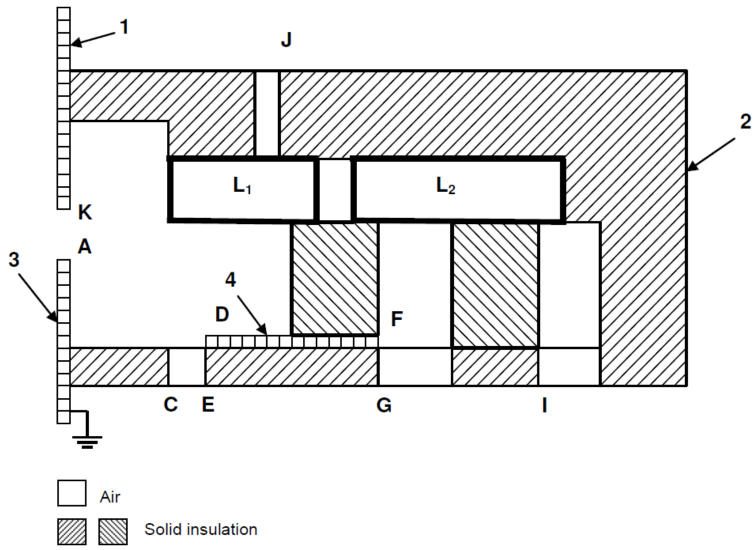


Figure (31)
(a) accessible unearthed metal part
(b) enclosure
(c) accessible earthed metal part
(d) inaccessible unearthed metal part

The live parts L_1 and L_2 are isolated from one another and are partly enclosed by a plastic casing with openings. They are also partially surrounded by air and come into contact with solid insulation. An inaccessible metal component is integrated within the structure. Additionally, there are two metal covers, with one of them being grounded.

If the clearances L_1D or L_2F satisfy the clearance criteria for reinforced insulation, the clearances DE or FG of supplementary insulation are not assessed.

– 2 mm for reinforced insulation.

or

- by the following condition; every individual layer of material must pass the electric strength test for supplementary insulation. Supplementary insulation should comprise a minimum of two layers of material, while reinforced insulation should have a minimum of three layers. Provided the insulation is composed of multiple distinct layers, excluding natural mica or similar flaky materials. Or
- by assessment of the thermal quality of the material, in conjunction with an electric strength test; the insulation is exposed to the dry heat test Bb as per IEC 60068-2-2, maintaining a temperature 50 K higher than the maximum temperature rise observed in the test related to Abnormal operation chapter, for a duration of 48 hours. Following this, the insulation undergoes the electric strength test at the conditioned temperature. Subsequently, the test is repeated after the insulation has cooled down to room temperature. Should the temperature rise of the insulation in the Abnormal operation chapter tests fall within the limits specified in Table 3, the IEC 60068-2-2 test is not required. Also the accessible portions of reinforced insulation, when composed of a single layer, must meet the minimum thickness requirements outlined in Table 23.
  The appliance must be designed to ensure that, in cases where there's a risk of damaging the insulation during installation, the insulation can withstand the scratch and penetration test outlined in Mechanical strength chapter, second test.
- as specified in Subclause 6.3 of IEC 60664-4 for insulation that is exposed to any periodic voltage with a frequency exceeding 30 kHz.

Table (23) Minimum thickness for accessible parts of reinforced insulation consisting of a single layer

Rated voltage V	**Minimum thickness of single layers used for accessible parts of reinforced insulation** mm		
	Overvoltage category		
	I	**II**	**III**
≤ 50	0,01	0,04	0,1
> 50 and ≤ 150	0,1	0,3	0,6
> 150 and ≤ 300	0,3	0,6	1,2

3.18.4 Coated printed circuit boards

If coatings are applied to printed circuit boards for safeguarding the microenvironment (type 1 protection) or for supplying basic insulation (type 2 protection), the following tests are performed.

1. Scratch-resistance test, only for type 2 protection, scratches shall be created across five pairs of conducting parts and the intervening separations at points where the insulation will face the highest electric field strength between conductors. The protective layers shall be scratched using a hardened steel pin. The end of the pin shall be cone-shaped with an angle of 40°. The tip should be rounded and polished, with a radius of 0.25 mm ± 0.02 mm. The pin must be loaded so that the force applied along its axis is 10 N ± 0.5 0 5. The scratches shall be created by drawing the pin along the surface in a direction perpendicular to the edges of the conductor of the protective layer, at a speed of approximately 20 mm/s, as illustrated in Figure 32. A minimum of five scratches shall be made, with each scratch being at least 5 mm apart and at least 5 mm away from the edges.
   The device used to carry out this test is a Scratch Tester.
2. Test conditioning:

3.19 Resistance to heat and fire (30)

3.19.1 Ball pressure test

External components made of non-metallic materials, as well as insulating components supporting live elements, including connections, and thermoplastic components providing supplementary or reinforced insulation, must possess adequate heat resistance. This is essential to prevent any deterioration that could lead to non-compliance with this standard. It's important to note that this requirement does not extend to the insulation or protective covering of flexible cords or internal wiring. The relevant component is subjected to the ball pressure test according to IEC 60695-10-2 to verify compliance. To perform the test a sample with such features is needed, if obtaining it directly from the product:

- The upper and lower surfaces must be approximately parallel.
- The thickness should be a minimum of 2.5 mm.
- The sample should either be a square plane with a side length of at least 10 mm, or a circular plane with a diameter of at least 10 mm.

If it is not feasible to extract it from the product:

- Utilize a piece of the same material as the test sample.
- The thickness of this material piece should be within the range of 3.0 mm ± 0.5 mm.
- It should also have a square plane with a side length of at least 10 mm, or a circular plane with a diameter of at least 10 mm.

The sample test is placed in a tool, ball pressure test device see figure, a weight which applies a force of 20 N by using a sphere of 5 mm. Then the whole assembly is put in a oven for one hour,the test is conducted at a temperature of 40 °C ± 2 °C, in addition to the maximum temperature rise established during the test of Heating chapter. However, this temperature shall not be less than:

- 75 °C ± 2 °C, for external parts;

- 125 °C ± 2 °C, for parts supporting live parts.

Once the sample it has cooled, the imprint left on its surface is measured. If the imprint is less than 2 mm the test is considered as passed. However, for parts made of thermoplastic material providing supplementary insulation or reinforced insulation, the test is conducted at a temperature of 25 °C ± 2 °C, in addition to the maximum temperature rise determined during the tests of Abnormal operating chapter, if this value is higher.

3.19.2 Glow wire test

Non-metallic components must demonstrate resistance to ignition and the spread of fire.

This requirement does not extend to parts with a mass below 0.5 g, which are considered insignificant. However, if multiple insignificant parts are located within 3 mm of each other, and there's a potential for them to collectively propagate flames originating inside the appliance, then they must still meet the fire resistance criterion.

Additionally, decorative trims, knobs, and similar components that are unlikely to catch fire or spread flames originating inside the appliance are exempt from this requirement. The tests are conducted on non-metallic components that have been detached from the appliance. During the glow-wire test, these parts are positioned in the same way they would be in regular use. These tests are not conducted on wire insulation. To perform the glow wire test this is the full equipment:

- The glow-wire is constructed using nickel/chromium wire, with a composition of more than 77% nickel and 20 ± 1%chromium. It possesses a total diameter of 4.00 mm ± 0.07 mm prior to bending. The specific measurements for the glow-wire loop can be found in Figure . The test setup should be constructed to ensure that the glow-wire remains in a horizontal position and exerts a force of 0.95 N ± 0.1 N onto the test specimen while the glow-wire is being applied. This force should be sustained when either the glow-wire or the test specimen is moved horizontally towards the other. The depth of penetration of the glow-wire tip into and through the test specimen should not exceed 7.00 mm ± 0.5 mm. The test apparatus must be designed in a manner that allows any burning or glowing particles that fall from the test specimen to descend unimpeded onto the designated surface.
- Temperature measuring system: the temperature at the tip of the glow-wire must be gauged using a mineral-insulated, metal-sheathed fine-wire thermocouple with an insulated junction. This thermocouple should possess an overall nominal diameter of 1.0 mm. Its wires should be capable of sustained operation at temperatures reaching up to 960° C (e.g., chromel/alumel for Type K or NiCrSi/NiSi for Type N). The welded junction point should be positioned inside the sheath as close to the tip as feasible. The sheath itself should be crafted from a metal capable of withstanding continuous operation at a temperature of at least 1.05° C.
- Specified layer: To assess the potential fire spread, such as from burning or glowing particles falling from the test specimen, a designated layer is positioned beneath it. Unless stated otherwise, a single layer of wrapping tissue is placed on a smooth, flat wooden board with a minimum thickness of 10 mm. This layer should be in close contact with the upper surface of the board. The distance from where the glow-wire touches the test specimen to this layer should be 200 mm ± 5 mm.
- Test chamber: the equipment should be operated in an environment free from drafts, with ample volume to ensure that:
  1. Oxygen depletion during the test doesn't notably impact the outcome.
  2. The test specimen can be positioned at least 100 mm away from any surface.

Prior to testing, the wooden board and wrapping tissue must be kept in an environment with a temperature ranging from 15° C to 35° C and a relative humidity between 45% and 75% for at least 24 hours. The tip of the glow-wire is smoothly brought into contact with the test specimen for precisely 30 seconds. It's recommended to approach and withdraw at a speed of 10 to 25 m/s. However, the approach speed should be slowed to near zero upon contact to prevent excessive impact forces (over 1.05 N). If the material melts away from the glow-wire, it should not remain in contact with the test specimen. After the specified time, the glow-wire and the test specimen are slowly separated to prevent further heating and air movement that could affect the test outcome. The penetration of the glow-wire's tip into and through the test specimen must not exceed 7 mm $\pm$ 0.5 mm. The DUT must be positioned according to the following positions:

- If the test specimen is a component where surrounding materials and distances are not known, the specified layer should be positioned 200 mm $\pm$ 5 mm below the point of contact with the glow-wire.
- If the test specimen is a complete free-standing equipment, it is placed in its normal position of use on the specified layer as described in IEC 6 0695-2-10 extending for at least 100 mm outside the base of the equipment in all directions.
- If the test specimen is a complete, freestanding piece of equipment, it should be positioned in its usual operating orientation on the specified layer . This layer should extend at least 100 mm beyond the equipment's base in all directions.
- If the test specimen is a complete wall-mounted equipment, it should be securely fixed in its regular operating position, positioned 200 mm $\pm$ 5 mm above the specified layer. The test specimen is deemed to have successfully passed the GWEPT test if the following conditions are satisfied:
  - there is no ignition, or
  - all of the following situations apply when ignition has occurred:
    * flames or glowingcombustion of the DUT extinguish within 30 s after removal of the glow-wire, i.e. $t_R \leq 30$ s; and
    * the specified layer placed underneath the DUT does not ignite

Test generalities:

- Parts made of non-metallic material undergo the glow-wire test specified in IEC 60695-2-11, conducted at 550 °C. However, components composed of material classified with a glow-wire flammability index (GWFI) as per IEC 60695-2-12, which is a minimum of 550 °C, are exempt from the glow-wire test.
- If the GWFI is not available for a sample with a thickness within $\pm$0.1 mm of the relevant part, then the test sample should have a thickness equal to one of these values: 0.4 mm $\pm$ 0.05 mm, 0.75 mm $\pm$ 0.1 mm, 1, 5 mm $\pm$ 0.1 mm, 3 mm $\pm$ 0.2 mm and 6 mm $\pm$ 0.4 mm
  the nearest preferred value that is no thicker than the relevant part is chosen.
- The glow-wire test is also not conducted on parts of material classified at least as HB40 (Devo dare la definizione?) according to IEC 60695-11-10, provided that the test sample used for the classification was no thicker than the relevant part of the appliance.

Test for appliances that are operated while attended:

- Parts made of non-metallic material that support current-carrying connections and parts of non-metallic material at a 3 mm distance of such connections are tested using the glow-wire test at such severity:
  - 750 °C, for connections that carry a current exceeding 0,5 A during normal operation.
  - 650 °C, for other connections.

  Where a non-metallic material is within a 3 mm distance of a current-carrying connection, but is shielded from direct contact with the connection by a different material the test is conducted at the appropriate test severity with the tip of the glow-wire applied to the shielding material that separates it from the current-carrying connection, ensuring that the shielded material is in place and not in direct contact with the glow-wire.
- However, the glow-wire test is not performed on:
  - parts of material having the GWFI at least:
    * 750 °C, for connections that carry a current exceeding 0.5 A during normal operation.
    * 650 °C, for other connections.
  - small parts that:
    * consist of material with a glow-wire flammability index (GWFI) of at least 750 °C, or 650 °C as applicable, or
    * comply with the Needle-flame test described in the last subsection.

        * They should consist of material classified as V-0 or V-1 according to IEC 60695-11-10, ensuring that the test sample used for classification is no thicker than the relevant part of the appliance.
    - hand-held appliances;
    - These are appliances that require manual or foot-operated activation to remain in the switched-on state.
    - These are components that provide support for welded connections, as well as components located within 3 mm of these connections.
    - parts supporting connections in low-power circuits described in Abnormal operation chapter and parts within a distance of 3 mm of these connections;
    - These refer to connections that have been soldered onto printed circuit boards and components located within 3 mm of these soldered connections.
    - These are referring to the soldered connections on small electronic components like diodes, transistors, resistors, inductors, integrated circuits, and capacitors that are not directly connected to the mains power supply. It also includes parts located within 3 mm of these connections.

Test for appliances that are operated while unattended, the test is not performed when:

- These are components that provide support for welded connections, as well as components located within 3 mm of these connections.
- parts supporting connections in low-power circuits described in Abnormal operation chapter and parts within a distance of 3 mm of these connections;
- These refer to connections that have been soldered onto printed circuit boards and components located within 3 mm of these soldered connections.
- These are referring to the soldered connections on small electronic components like diodes, transistors, resistors, inductors, integrated circuits, and capacitors that are not directly connected to the mains power supply. It also includes parts located within 3 mm of these connections.

Before explaining all the details of the test conditions 2 cases must distinguished:

1. In this context, "small parts" refer to components that are relatively small in size. Parts made of non-metallic material that support connections carrying a current greater than 0.2 A under normal operation, as well as non-metallic parts (excluding small parts) within 3 mm of such connections, are tested using the glow-wire test according to IEC 60695-2-11, with a test severity of 850 °C. When non-metallic material is located within 3 mm of a current-carrying connection but is shielded from direct contact with the connection by another material, the glow-wire test in accordance with IEC 60695-2-11 is conducted. In this test, the tip of the glow-wire is applied to the interposed shielding material, with the shielded material in its usual position, rather than directly onto the shielded material. This ensures a more accurate assessment of the insulation's fire-resistant properties in practical conditions. However this test is not performed on parts having a GWFI of at least 850 °C. If the GWFI is not available for a sample with a thickness within ±0.1 mm of the relevant part, then the test sample should have a thickness equal to one of these values: 0.4 mm ± 0.05 mm, 0.75 mm ± 0.1 mm, 1,5 mm ± 0.1 mm, 3 mm ± 0.2 mm and 6 mm ± 0.4 mm
   the nearest preferred value that is no thicker than the relevant part is chosen.
2. Non-metallic material components that support electrical connections and those within 3 mm proximity of these connections are subjected to the glow-wire test according to IEC 60695-2-11, at such severity:
   - 750 °C, for connections that carry a current exceeding 0.2 A during normal operation.
   - 650 °C, for other connections.

   If a non-metallic material is within 3 mm of a current-carrying connection but is shielded by another material, the glow-wire test specified in IEC 60695-2-11 is conducted. In this test, the tip of the glow-wire is applied to the intervening shielding material, with the shielded material in its normal position, rather than directly to the shielded material itself. However such test is not performed on:
   - parts of material that meet one or both of the following classifications:
     - GWIT according to IEC 60695-2-13 of at least;

        * 775 °C for connections that conduct a current exceeding 0.2 A during regular operation,
        * 675 °C, for other connections.
    - GWIT according to IEC 60695-2-12 of at least;
        * 750 °C for connections that conduct a current exceeding 0.2 A during regular operation,
        * 650 °C, for other connections.
- small parts that :
    - have a material with GWIT of at least 775 °C or 675 °C as appropriate, or
    - have a material with GWIT of at least 750 °C or 650 °C as appropriate, or
    - comply with the needle-flame test described in the last subsection.
    - The material may be classified as V-0 or V-1 according to IEC 60695-11-10, provided that the test sample used for the classification was no thicker than the relevant part of the appliance.

The needle-flame test (NTF) is performed on such materials, but before explaining it those are the cases when it is not applicable:

- on printed circuit boards of low-power circuits described in Abnormal operation chapter.
- on the printed circuit boards in:
    - A metal enclosure that contains or confines flames or burning droplets.
    - hand-held appliances,
    - Appliances that require manual or foot-operated continuous operation.
    - Appliances that are continuously operated or loaded by hand.
- on a base material classified as V-0 according to IEC 60695-11-10 or VTM-0 according to ISO 9773, provided that the test sample used for the classification was no thicker than the printed circuit board.

The test is performed according to the IEC 60695-11-5 with a slight modification (annex E of IEC 60335-1). On the market there are several testers with the whole apparatus compliant with the IEC 60695-11-5, see figure. Those are the main items of the test apparatus:

- Burner: a tube of at least 35 mm with a bore of 0.5 mm $\pm$ 0.1 mm, outer diameter not exceeding 0.9 mm. It is supplied with propane or butane gas having at least 95% purity.
- Flame: overall height is 12 mm $\pm$ 1 mm, see figure 51 for the burner position.
- Chamber: inside volume 0.5 mm^3, it shall proved a draught-free environment and it shall permit observation of the test in progress. It must have an extraction device to remove products of combustion.

The duration of application of the test flame is 30 s $\pm$ 1 s. Before the test starts the DUT and the tissue-covered wooden board must stay for 24 hours at:

- temperature: between 15° C and 35° C;
- relative humidity: between 45% and 75%;

Test conditions :

- temperature: between 15° C and 35° C;
- relative humidity: $\leq$ 75%;

The DUT is positioned to allow the flame to be applied either to a vertical or horizontal edge, as illustrated in the examples provided in Figure 51. The flame must be located such that its tip is in contact with the tip of DUT. If the DUT is positioned vertically above the flame a space of 8 mm $\pm$ 1 mm must be kept between the center of top of the burner and the remaining portion of DUT. If the DUT is positioned horizontally from the flame this time a space of 5 mm $\pm$ 1 mm must be kept. If possible, the flame is applied at least 10 mm from a corner. The test is passed if:

- no ignition is present on the specified layer and after removing the flame there is no flame and no glowing on the DUT.

- flames or glowing of the DUT extinguish in 30 seconds after the removal of the test flame. The surrounding parts have not burnt away completely and no ignition is present on the specified layer.
- The burning duration must not exceed 30 seconds. However, for printed circuit boards, it must not exceed 15 seconds.

3.20 EMC tests

3.20.1 Electrostatic discharge immunity test

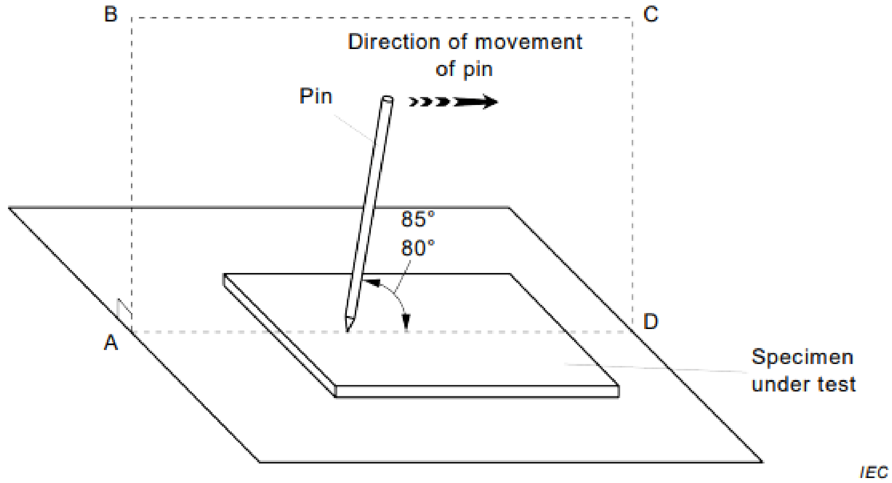
The test consists of applying 20 discharges (10 positive polarity and 10 negative polarity) to each selected point of the DUT. For household appliances 8 kV for air discharge and 4 kV regarding contact discharge. Generally the test can be applied in two different manners:

- contact discharge to conductive surfaces and coupling planes;
- air discharge at insulating surfaces;

Contact discharge is the preferred method of testing. Air discharges should be employed in cases where contact discharge cannot be applied. For both cases the same ESD generator is used but with different discharge electrodes, see figure 33. Unless specified otherwise in the generic, product-specific, or product-family standards, electrostatic discharges should be administered solely to the points and surfaces of the Equipment Under Test (EUT) accessible to individuals during routine use. The subsequent exemptions are applicable (i.e., discharges are not administered to these items):

- Points and surfaces that are exclusively accessible during maintenance are exempt. In such instances, specific electrostatic discharge (ESD) mitigation procedures should be outlined in the accompanying documentation.
- Excluded from electrostatic discharge (ESD) application are points and surfaces exclusively accessible during service by the end-user. Examples of such rarely accessed points include battery contacts during battery replacement, a cassette in a telephone answering machine, etc.
- Excluded from electrostatic discharge (ESD) application are points and surfaces of equipment that become inaccessible after fixed installation or following the instructions for use. This includes areas such as the bottom and/or wall side of equipment or regions behind fitted connectors.
- For coaxial and multi-pin connectors with a metallic connector shell, contact discharges should only be applied to the metallic shell. Contacts within a non-conductive (e.g., plastic) connector that are accessible shall be tested using the air-discharge test with the rounded tip finger on the ESD generator.
- ESD-sensitive contacts or other accessible parts, crucial for functional reasons, and labeled with an ESD warning (e.g., RF inputs for measurement, receiving, or communication functions) are exempt from direct electrostatic discharges.

An initial value of 1 second is recommended for the time interval between successive single discharges.The ESD generator should be held perpendicular, whenever possible, to the surface to which the discharge is applied, as this enhances the repeatability of the test results. The discharge return cable of the generator must be maintained at a distance of at least $0,2$ m from the EUT while the discharge is being applied and should not be held by the operator. For contact discharges, the tip of the discharge electrode must touch the EUT before the discharge switch is operated. For painted surfaces covering a conducting substrate, the procedure is as follows: If the coating is not declared to be an insulating coating by the equipment manufacturer, the pointed tip of the generator should penetrate the coating to make contact with the conducting substrate. Coatings declared as insulating by the manufacturer should only be subjected to air discharge. The contact discharge test should not be applied to such surfaces. For air discharges, the ESD generator should approach the EUT as quickly as possible until contact between the electrode and the EUT is established (without causing mechanical damage). After each discharge, the ESD generator (discharge electrode) should be removed from the EUT. The generator is then retriggered for a new single discharge. This procedure should be repeated until the discharges are completed. In the case of an air discharge test, the discharge switch used for contact discharge should



NOTE The pin is in the plane ABCD which is perpendicular to the specimen under test.

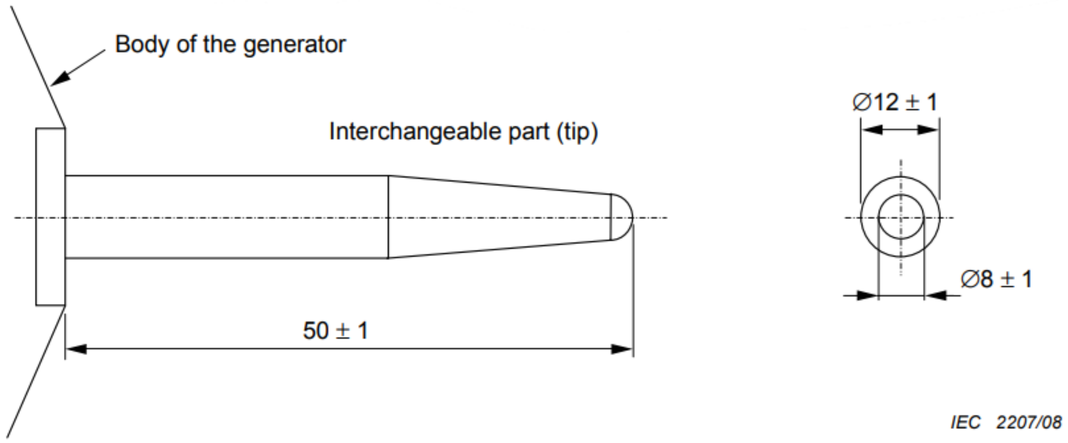
Figure (32) Scratch-resistance test for protecting layers

be closed. Simulating discharges to objects placed or installed near the EUT shall be done by applying the discharges of the ESD generator to a coupling plane in the contact discharge mode.

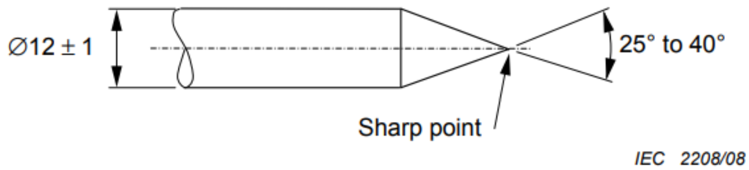
- Discharge to the HCP shall be performed horizontally to the edge of the HCP. At least 10 single discharges (in the most sensitive polarity) shall be applied at the front edge of each HCP opposite the center point of each unit (if applicable) of the EUT and 0.1 m from the front of the EUT. The long axis of the discharge electrode shall be in the plane of the HCP and perpendicular to its front edge during the discharge. The discharge electrode shall be in contact with the edge of the HCP before the discharge switch is operated.
- A minimum of 10 single discharges (in the most sensitive polarity) shall be directed towards the center of one vertical edge of the coupling plane (refer to Figures 4 and 5). The coupling plane, measuring $0,5\text{ m}\cdot 0,5\text{ m}$, is aligned parallel to and positioned $0,1$ m away from the EUT. Discharges should be administered to the coupling plane, varying positions adequately to ensure complete illumination of all four faces of the EUT. Each Vertical Coupling Plane (VCP) position is considered to illuminate a $0,5\text{ m}\cdot 0,5\text{ m}$ area of the EUT surface.

General information on test setup:

- ground reference plane (GPR): it must be provided on the floor of the laboratory. It must be a metallic sheet, either copper or aluminum, with a minimum thickness of 0.25 mm. Other metallic materials are acceptable as long as they have a minimum thickness of 0.65 mm. It should extend at least 0.5 m beyond the Equipment Under Test (EUT) or the horizontal coupling plane (when applicable) on all sides and must be linked to the protective grounding system.
- A minimum distance of 0.8 m must be maintained between the Equipment Under Test (EUT) and the laboratory walls or any other metallic structure.
- The ESD generator's discharge return cable must be linked to the ground reference plane. However, the discharge return cable should be kept at a minimum distance of 0.2 m from other conductive components in the test setup, excluding the ground reference plane.The bonding and grounding connections to the ground reference plane should be low-impedance, achieved, for instance, through the utilization of mechanical clamping devices, especially in high-frequency applications.
- If coupling planes are specified, such as for the indirect application of the discharge, they must be constructed from a metallic sheet (preferably copper or aluminum) with a minimum thickness of 0.25 mm (other metallic materials may be used, but they should have a minimum thickness of at least 0.65 mm). These coupling planes should be connected to the Ground Reference Plane (GRP) through a cable equipped with a 470 kΩ resistor at each end. The resistors must be capable of



Discharge electrode for air discharges



Discharge electrode for contact discharges

Figure (33) Discharge electrodes of the ESD generator

withstanding the discharge voltage. Both the resistors and cables should be insulated to prevent short circuits to the GRP when the cable rests on it.

Table-top equipment:

- non-conductive table, (0.8 ± 0.08) m high, standing on the ground reference plane;
- A horizontal coupling plane (HCP) measuring (1.6 ± 0.02) m $\cdot$ (0.8 ± 0.02) m should be positioned on the table. The Equipment Under Test (EUT) and its cables must be separated from the coupling plane by an insulating support with a thickness of (0.5 ± 0.05) mm.

see figure 34.

Regarding floor-standing equipment the EUT should be separated from the ground reference plane by an insulating support with a thickness ranging from 0.05 m to 0.15 m. Additionally, the cables of the EUT must be isolated from the ground reference plane using an insulating support with a thickness of (0.5 ± 0.05) mm, and this cable isolation should extend beyond the edge of the EUT isolation. See figure 35.

The ungrounded equipment are equipment or part(s) of equipment whose installation specifications or design precludes connection to any grounding system, i.e. battery-operated equipment. For those kind of devices the test set up is similar to the one previously seen apart from those differences:

- Table-top equipment: If the EUT has a metallic accessible part intended to receive the ESD pulse, this part must be linked to the Horizontal Coupling Plane (HCP) through a cable equipped with bleeder resistors.
- Floor-standing equipment: A cable containing bleeder resistors should be employed to connect the metallic accessible part, designated to receive the ESD pulse, with the Ground Reference Plane (GRP).

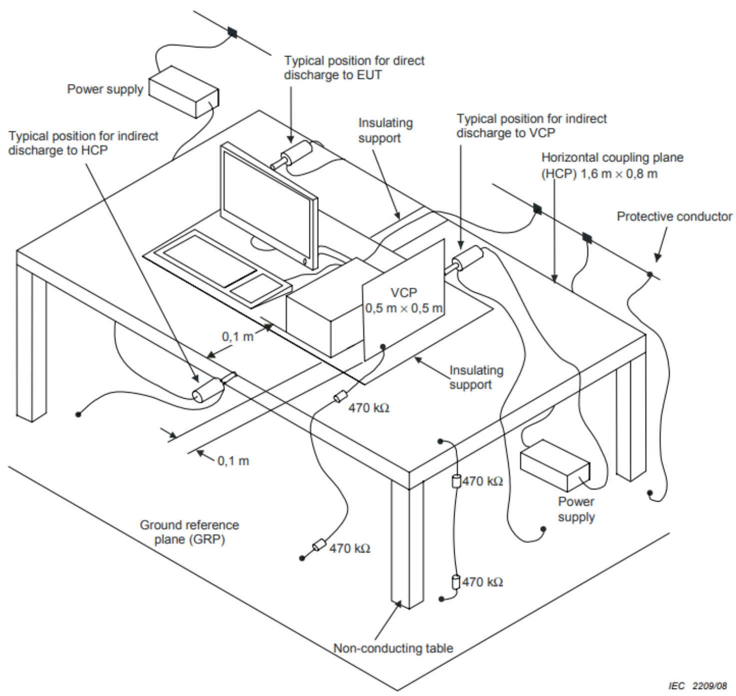


Figure (34) EMC test: example of test set-up for table-top equipment, laboratory tests

The climatic conditions are the following:

- ambient temperature: 15° C to 35° C;
- relative humidity: 30% to 60%;
- atmospheric pressure: 86 kPa to 106 kPa;

The test results should be categorized based on the impact on function or performance degradation of the equipment under test. This classification is relative to a performance level set by the manufacturer, the entity requesting the test, or as mutually agreed upon by the manufacturer and the product purchaser. The suggested classification is outlined as follows:

- Normal performance is maintained within the limits specified by the manufacturer, requestor, or purchaser;
- There is a temporary loss of function or degradation of performance that ceases after the disturbance ends, and the equipment under test recovers its normal performance without operator intervention;
- there is a temporary loss of function or degradation of performance, and correction requires operator intervention;
- there is a loss of function or degradation of performance that is not recoverable, owing to damage to hardware or software, or loss of data.

3.20.2 Electrical fast transient/burst immunity test

Fast transient tests are performed for 2 minutes for each polarity, those are the specifications:

- 0.5 kV peak at 5 kHz repetition frequency for signal ports, control ports and wired network ports;
- 0.5 kV peak at 5 kHz repetition frequency for input and output DC power ports;
- 1 kV peak at 5 kHz repetition frequency for input and output AC power ports;

Regarding the test set up here are the devices needed:

- ground reference plane;
- coupling device (network or clamp);
- decoupling network;

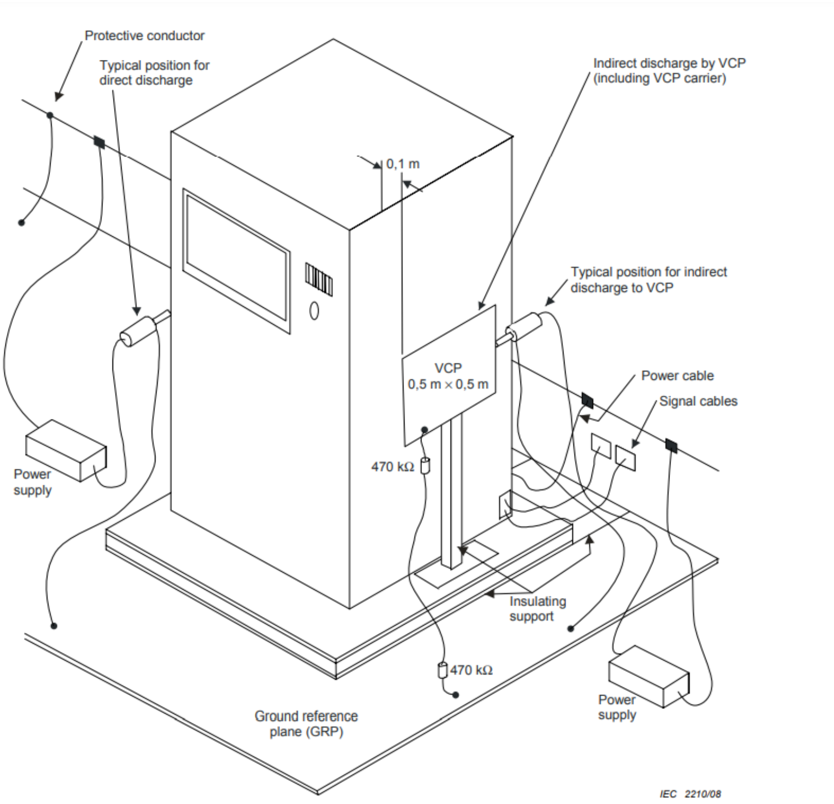


Figure (35) EMC test: example of test setup for floor-standing equipment, laboratory tests

- test generator, including the calibration or measurement means.

The equipment under test (EUT) should be positioned on a ground reference plane, separated by an insulating support approximately 0.1 m thick. For tabletop equipment, the EUT's location should be 0.8 m ± 0.08 m above the ground plane (refer to figure 36). The reference ground plane, preferably made of copper or aluminum with a minimum thickness of 0.25 m, should extend beyond the EUT by a minimum of 0.1 m on all sides. The actual dimensions of the ground plane depend on the size of the EUT, with a minimum size of 1 m · 1 m. The reference ground plane must be linked to the protective earth. There should be a minimum separation of over 0.5 m between the EUT and all other conductive structures (e.g., shielded room walls), excluding the ground plane beneath the EUT. The EUT should be grounded according to the manufacturer's installation specifications, and no additional grounding connections are permitted.

The grounding cables from the test equipment to the ground reference plane and all bondings should minimize inductance. Coupling devices, connected to the lines between the EUT and the decoupling network or between two equipment units undergoing testing, must be employed for applying test voltages.

With the coupling clamp, ensure a minimum distance of 0.5 m between the coupling plates and all other conductive structures, except for the ground plane beneath the coupling clamp and EUT. The length of signal and power lines between the coupling device and the EUT should not exceed 1 m.

If the equipment comes with a non-detachable supply cable longer than 1 m, gather the excess length into a flat coil with a diameter of 0.4 m, positioned 0.1 m above the ground reference plane. Maintain a distance of 1 m or less between the EUT and the coupling device.

The following methods explain how to couple the test voltage to the EUT:

- Power supply ports:
  - from figure 54 an example of test set-up for direct coupling of the EFT/B disturbance voltage via a coupling/decoupling network is shown.

  - If the line current exceeds the specified current capability of the coupling/decoupling network, specifically exceeding 100 A, the test voltage must be delivered to the EUT through a 33 nF coupling capacitor, see figure 53.
- I/O and communication ports: those illustrations 34 and 55 demonstrate the proper utilization of the capacitive coupling clamp for applying the disturbance test voltage to I/O and communication ports.
- Earth connections of the cabinets: The test location on the cabinet should be the terminal designated for the protective earth conductor. The test voltage is then administered to the protective earth (PE) connection through the coupling/decoupling network, as depicted in figure 54.

The climatic conditions are the following:

- ambient temperature: 15° C to 35° C;
- relative humidity: 30% to 60%;
- atmospheric pressure: 86 kPa to 106 kPa;

The classification of test results shall be based on the operating conditions and functional specifications of the equipment under test. The following criteria will be used for classification, unless alternative specifications are provided by product committees or in product specifications:

- The expected outcome is the equipment displaying normal performance within the specified limits;
- Temporary degradation or loss of function or performance that self-recovers;
- Temporary degradation or loss of function or performance requiring operator intervention or system reset.
- Degradation or loss of function that is not recoverable due to damage to equipment (components) or software, or loss of data.

Equipment must not pose any danger or become unsafe due to the applied tests. Generally, a positive test result indicates that the equipment demonstrates immunity throughout the test duration and, at the test's conclusion, meets the functional requirements outlined in the technical specifications. The technical specifications may outline effects on the equipment deemed insignificant and acceptable. In such cases, it should be confirmed that the equipment autonomously regains its operational capabilities at the conclusion of the test, and the duration of any loss of functionality should be documented.

3.20.3 Injected currents

The source of disturbance addressed in this section primarily involves an electromagnetic field originating from intentional RF transmitters, which can influence the entire length of cables connected to installed equipment. The dimensions of the affected equipment, typically a subset of a larger system, are considered to be small in comparison to the wavelengths of the interfering signals. The leads entering and exiting the EUT (e.g., power lines, communication lines, interface cables) function as passive receiving antenna networks and signal conduction paths for both intentional and unintentional signals. Tests are necessary to evaluate induced disturbances resulting from electromagnetic fields generated by intentional RF transmitters within the frequency range of 150 kHz to 80 MHz. In certain scenarios, for compact equipment (where dimensions are less than a quarter-wavelength, i.e., /4), specific product standards may specify extending the stop frequency up to a maximum of 230 MHz. In such cases, the coupling and decoupling devices must meet the common-mode impedance parameter observed at the (EUT) port, see table 24. The test levels, established at the (EUT) port of the coupling devices, for both frquency intervals (150 kHz to 80 MHz and 0.15 MHz to 230 MHz) are the following:

- Signal ports, control ports and wired network ports: 1 V (RMS, unmodulated);
- Input and output DC power ports: 1 V (RMS, unmodulated);
- Input and output AC power ports: 3 V (RMS, unmodulated);

During equipment testing, this signal is 80% amplitude modulated with a 1 kHz sine wave to simulate real-world threats.

Those are the main items of the test set up:

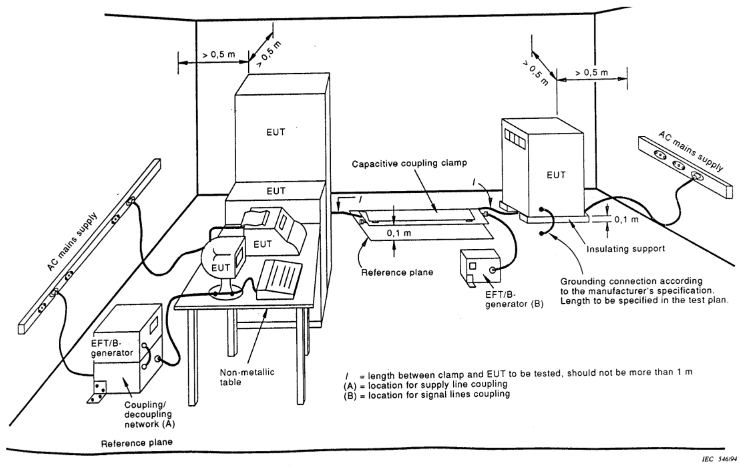


Figure (36) General test set-up for fast transient/burst immunity test

- The test generator encompasses all equipment and components necessary for delivering the disturbing signal to the input port of each coupling device at the specified signal level and injection point. A typical setup includes various items that may be separate or integrated into one or more test instruments (Figure 56):
  - RF generator(s), G1, covering the relevant frequency band and capable of being amplitude modulated by a 1 kHz sine wave with an 80% modulation depth. They should offer manual control (e.g., frequency, amplitude, modulation index) or, in the case of RF synthesizers, be programmable with frequency-dependent step sizes and dwell times.
  - Attenuator T1 (typically 0 dB to 40 dB), with a sufficient frequency rating to regulate the disturbing test source output level. T1 may be included in the RF generator and is optional.
  - RF switch S1, enabling the disturbance test signal to be switched on and off during EUT immunity measurements. S1 may be included in the RF generator and is optional.
  - Broadband power amplifier(s) PA, which may be necessary to amplify the signal if the RF generator's output power is insufficient.
  - Low-pass filters (LPF) and/or high-pass filters (HPF), which may be required to prevent interference from (higher order or sub-) harmonics with certain EUT types, such as RF receivers. When necessary, they should be inserted between the broadband power amplifier, PA, and attenuator T2.
  - Attenuator T2 (fixed, $\geq$ 6 dB), with adequate power ratings. T2 is provided to reduce VSWR (Voltage Standing Wave Ratio) caused by the mismatch of the coupling device to the power amplifier.
- Coupling and decoupling devices must be employed to effectively couple the disturbing signal (across the complete frequency range, maintaining a specified common mode impedance at the EUT port) to the diverse cables linked to the EUT. Simultaneously, these devices should prevent test signals from impacting other devices, equipment, and systems that are not undergoing testing. The preferred coupling and decoupling devices are CDNs due to their benefits in test reproducibility and AE protection. The primary parameter for these devices is the common mode impedance observed at the EUT port, see table 24. The CDN's performance should not be unreasonably compromised by magnetic material saturation caused by the EUT's current draw. Ideally, the network construction should counterbalance the magnetizing impact of the forward current with that of the return current. If the EUT features functional earth terminals (e.g., for RF purposes or high leakage currents), they must be linked to the reference ground plane:
  - Through the CDN-M1, if the EUT's characteristics or specifications allow. In such cases, the (power) supply should be delivered via an appropriate CDN-Mx-type network.
  - When the characteristics or specifications of the EUT don't permit the presence of a CDN-M1 network in series with the earth terminal for RF or other reasons, the earth terminal should directly connect to the reference ground plane.

  See figure 57 for the schematic setup of CDN .

The equipment under test (EUT) is positioned on an insulating support with a height of 0.1 m $\pm$ 0.05 m above a reference ground plane. Alternatively, a non-conductive roller or caster within the range of 0.1 m $\pm$ 0.05 m above the reference ground plane can be utilized instead of the insulating support. All cables exiting the EUT must be elevated at a minimum height of 30 mm above the reference ground plane.

If the equipment is designed for mounting in a panel, rack, or cabinet, it should be tested in this configuration. The support for the test sample, when required, should be constructed of a non-metallic, non-conductive material. Equipment grounding should align with the manufacturers installation instructions.

When coupling and/or decoupling devices are necessary, they should be positioned between 0.1 m and 0.3 m from the EUT (denoted as distance L in this standard). This distance is measured horizontally from the projection of the EUT onto the reference ground plane to the coupling and/or decoupling device (refer to Figure 10). It's important to note that the distance L is not mandated to be the same on all sides of the EUT but should fall within the range of 0.1 m to 0.3 m.

For a single-unit EUT, it should be placed on an insulating support 0.1 m above the reference ground plane. In the case of table-top equipment, the reference ground plane may be situated on a table (refer to Figure 58). All cables designated for testing must have coupling and decoupling devices inserted. These devices should be positioned on the reference ground plane, making direct contact at a distance of 0.1 m to 0.3 m. from the EUT. The cables connecting the coupling and decoupling devices to the EUT should be as short as possible, not bundled or wrapped, and should be elevated at least 30 mm above the reference ground plane. The interface cable linking the Equipment Under Test (EUT) and the Auxiliary Equipment (AE) should be kept as short as possible. If the EUT has additional earth terminals, where permissible, these should be connected to the reference ground plane through CDN-M1 (i.e., the AE port of CDN-M1 is then linked to the reference ground plane).

In cases where the EUT is equipped with a keyboard or a hand-held accessory, the artificial hand should be positioned on the keyboard or wrapped around the accessory and connected to the reference ground plane.

Auxiliary Equipment (AE) necessary for the proper operation of the EUT, as defined by the specifications of the product committee (e.g., communication equipment, modem, printer, sensor, etc.), along with AE essential for ensuring data transfer and function assessment, must be connected to the EUT through coupling and/or decoupling devices.

Efforts should be made to limit the number of cables to be tested where possible. However, all types of physical ports should undergo the injection process. The test evaluation follows the same criteria as in Radiated, radio-frequency, electromagnetic field immunity test.

3.20.4 Radiated, radio-frequency, electromagnetic field immunity test (80 MHz to 6 GHz

Electronic equipment is often influenced by electromagnetic radiation, commonly emitted by sources like handheld radio transceivers, fixed-station radio and TV transmitters, vehicle radio transmitters, and various industrial electromagnetic devices. The prevalence of radio telephones and other RF-emitting devices operating in the 80 MHz to 6 GHz frequency range has notably risen in recent years. Many of these services utilize modulation techniques with a non-constant envelope. The electromagnetic environment is defined by the intensity of the electromagnetic field, for this test there is a 3 V/m field strength. The recommended types of test equipment include:

- Anechoic Chamber:
  - Adequate size to maintain a uniform electromagnetic field with respect to the Equipment Under Test (EUT).
  - Additional absorbers may be used to reduce reflections in partially lined chambers.
- EMI Filters: Ensure that filters introduce no additional resonance effects on connected lines.
- RF Signal Generator(s):

  - Capable of covering the frequency band of interest.
  - Capable of amplitude modulation by a 1 kHz sine wave with an 80% modulation depth.
  - Manual control or programmable RF synthesizers with frequency-dependent step sizes and dwell times.
  - Use of low-pass or band-pass filters may be necessary to avoid harmonic-related issues.
- Power Amplifiers:
  - Amplify both unmodulated and modulated signals.
  - Provide antenna drive to achieve the required field level.
  - Harmonics generated by the power amplifier should meet specified criteria.
- Field Generating Antennas:
  - Biconical, log periodic, horn, or any linearly polarized antenna system.
  - Should satisfy frequency requirements.
- Isotropic Field Sensor:
  - Should have adequate immunity to the measured field strength.
  - Fiber optic link or adequately filtered signal link to an external indicator.
- Associated Equipment:
  - Record power levels for the required field strength.
  - Control the generation of the specified field strength during testing.

See figure 40. In case of a table-top equipment the EUT is placed on a non-conductive table 0.8 m high. Floor-standing equipment should be elevated on a non-conductive support ranging from 0.05 m to 0.15 m above the supporting plane. The utilization of non-conductive supports serves to prevent inadvertent grounding of the Equipment Under Test (EUT) and avoids distortion of the electromagnetic field. To ensure the latter, the support structure should be inherently non-conductive, rather than relying on an insulating coating applied to a metallic structure. If floor-standing equipment can be safely placed on a non-conductive platform measuring 0.8 m in heightapplicable to equipment that is not excessively large or heavy, or where elevation poses no safety riskit may be arranged accordingly. Any departure from the standard testing method, as described, should be explicitly documented in the test report. Once the calibration has been confirmed, the generation of the test field can commence. Initially, the Equipment Under Test (EUT) is positioned with one face aligned with the calibration plane. The illuminated face of the EUT should be within the Uniform Field Area (UFA), unless deliberate partial illumination is being applied. The frequency ranges are systematically swept while the signal is modulated. Pauses are allowed for adjustments to the RF signal level or for switching oscillators and antennas as needed.

In cases where the frequency range is swept incrementally, the step size should not exceed 1% of the preceding frequency value. The dwell time of the amplitude-modulated carrier at each frequency must be sufficient for the EUT to be exercised and respond, with a minimum duration of 0.5 seconds.

Typically, the test is conducted with the generating antenna facing each side of the EUT. If the equipment is designed for multiple orientations (e.g., vertical or horizontal), all sides should be exposed to the field during the test. The test results should be categorized based on the impact on the equipment under test (EUT), considering the loss of function or degradation of performance concerning a predefined performance level set by the manufacturer, test requester, or mutually agreed upon by the manufacturer and purchaser. The suggested classification is outlined as follows:

- Normal Performance:The EUT operates within the specified limits defined by the manufacturer, requestor, or purchaser.
- Temporary Loss or Degradation: The EUT experiences a temporary loss of function or performance degradation during the disturbance, which automatically ceases after the disturbance ends. The equipment recovers its normal performance without requiring operator intervention.
- Temporary Loss or Degradation with Operator Intervention: The EUT encounters a temporary loss of function or performance degradation that necessitates operator intervention for correction.
- Irrecoverable Loss or Degradation: The EUT suffers a loss of function or degradation of performance that is not recoverable, typically due to hardware or software damage, or loss of data.

Table (24) Main parameter of the combination of the coupling and decoupling device

	Frequency band		
Parameter	0.15 MHz to 24 MHz	24 MHz to 80 MHz	80 MHz to 230 MHz
$\lvert Z_{ce} \rvert$	150 Ω ± 20 Ω	$150\ \Omega^{+60\ \Omega}_{-45\ \Omega}$	150 Ω ± 60 Ω

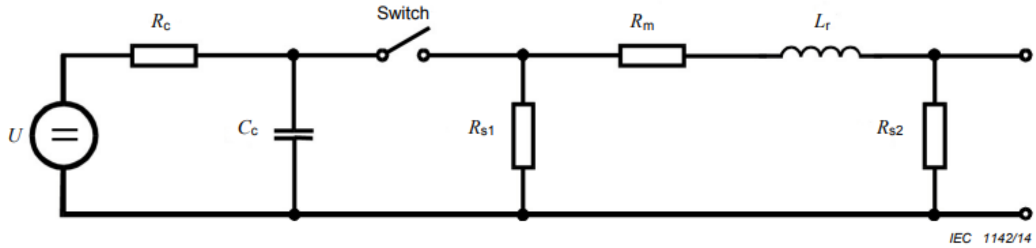


Figure (37) Surge immunity test, simplified circuit diagram of the combination wave generator;
1. U : High voltage source
2. R_c : Charging resistor
3. C_c : energy storage capacitor
4. R_s : impulse duration shaping resistor
5. R_m : impedance matching resistor
6. L_r : rise time shaping inductor

3.20.5 Surge immunity test

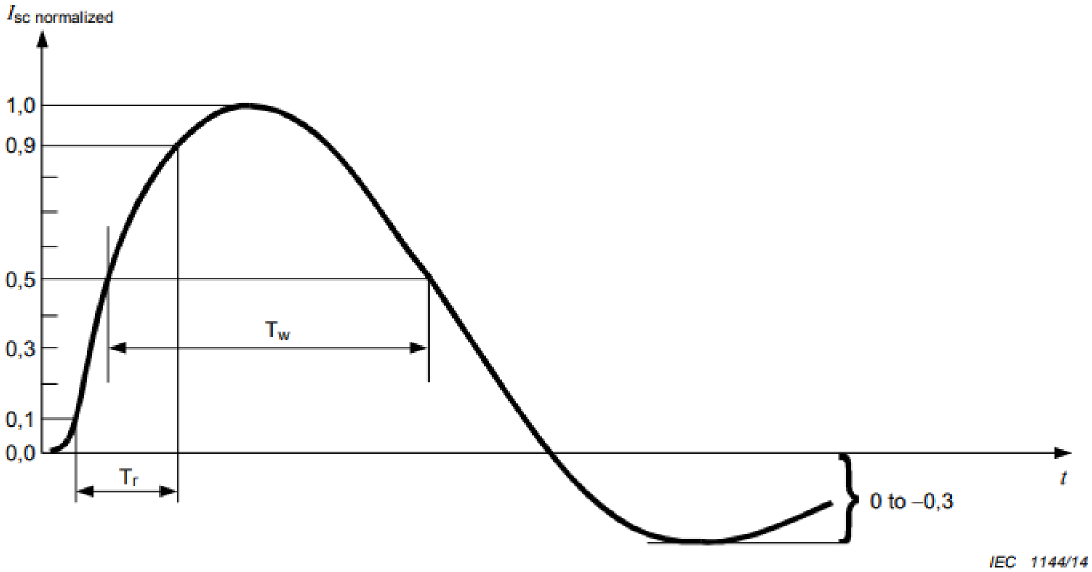
As regard household appliances the test consists of applying 5 pulses for each polarity successively between:

- phase and phase: 1 kV;
- phase and neutral: 1 kV;
- phase and earth: 2 kV;
- neutral and earth: 2 kV;

There is a 90° delay between the positive pulse and the phase of the angle of the AC line voltage. while for the negative pulse and the phase of the angle of the AC line voltage the delay is 270°. In this case a 1.2/50 μs (front time/ duration time) combination wave generator is applied to the EUT, ruthless speaking it means that according to the circuit shown in figure 37, the values of R_{S1}, R_{S2}, R_m, L_r and C_c are selected in order to deliver a 1.2/50 μs voltage surge at open-circuit conditions, regarding the current a waveform of short-circuit current 80/20 μs is delivered at the output. See figures for the current and voltage waveform.

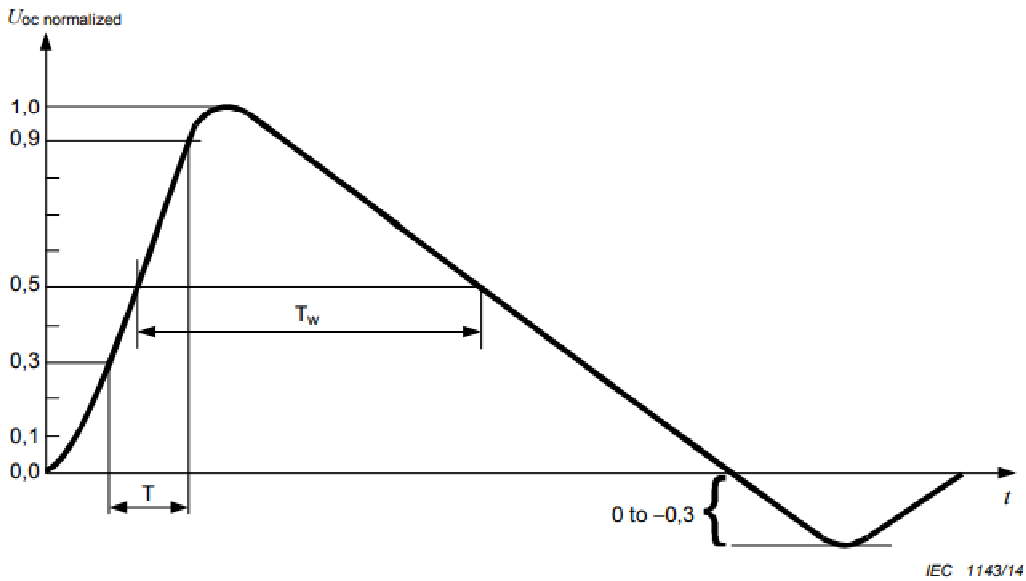
The effective output impedance of a combination wave generator is determined by the ratio of the peak open-circuit output voltage to the peak short-circuit current at the same output port. In the case of this generator, the specified ratio establishes an effective output impedance of 2 Ω. The following devices are part of the set up:

- equipment under test (EUT);
- auxiliary equipment (AE) when required;
- cables (of specified type and length);
- coupling/decoupling networks (CDNs):
  - The decoupling network, when applied to the a.c. or d.c. power lines, offers a relatively high impedance to the surge waveform while permitting current to reach the Equipment Under Test (EUT). This impedance facilitates the development of the voltage waveform at the output of the coupling/decoupling network and prevents the surge current from returning to the a.c. or d.c. power supply. High-voltage capacitors serve as the coupling element, sized to enable the complete durations of the waveform to be effectively coupled to the EUT.



Front time: $T_f = 1,25 \times T_r = 8\ \mu s \pm 20\ \%$
Duration: $T_d = 1,18 \times T_w = 20\ \mu s \pm 20\ \%$

Figure (38) Waveform of short-circuit current 80/20 μs at the output



Front time: $T_f = 1,67 \times T = 1,2\ \mu s \pm 30\ \%$
Duration: $T_d = T_w = 50\ \mu s \pm 20\ \%$

Figure (39) Waveform of open-circuit voltage 1.2/50 μs at the output

– For input/output (I/O) and communication lines, the decoupling network's series impedance restricts the available bandwidth for data transmission. The coupling elements may include capacitors, provided that the line can tolerate the capacitive loading effects, as well as clamping devices or arrestors.

- combination wave generator (CWG);

The 1.2/50 μs surge is to be administered to the equipment under test (EUT) power supply terminals through the capacitive coupling network, as illustrated in Figures 5, 6, 7, and 8. The incorporation of decoupling networks is essential to prevent potential negative impacts on equipment not undergoing testing but powered by the same lines. Additionally, these networks ensure an adequate decoupling impedance for the surge waveform, enabling the application of the specified wave to the lines being tested. The CDN specification chosen from Table 4 should align with the current rating of the equipment under test (EUT). For instance, an EUT with a 5 A rating should undergo testing using a CDN that adheres to the specifications of a 16 A rated CDN. If a higher current-rated CDN is selected, it must meet the specification requirements outlined in Table 4 for the corresponding lower current rating of the EUT. As an example, a CDN rated at 64 A can be employed for testing an EUT rated at 5 A if it satisfies the specification requirements for a 16 A rated CDN. Unless otherwise specified, the power cord connecting the Equipment Under Test (EUT) to the coupling network should not exceed a length of 2 meters. Finnaly, the evalutation of the test is the same as the one applied in the Radiated, radio-frequency, electromagnetic field immunity test.

3.20.6 Voltage dips immunity test

Electrical and electronic equipment may experience disruptions in power supply such as voltage dips, short interruptions, or variations. Voltage dips and short interruptions result from faults in both public and non-public power networks or installations, often caused by abrupt changes in significant loads. In some instances, there may be consecutive occurrences of dips or interruptions. Voltage variations are induced by continuously fluctuating loads connected to the power network. These occurrences are inherently stochastic and can be loosely defined for laboratory emulation by quantifying the deviation from the rated voltage and the duration. The voltage levels specified in this document are based on the equipment's rated voltage (U_T) for the purpose of voltage testing, see table 25 for voltage levels. CHIEDERE AL PROF SE SERVE LA TABELLA DELLA SPECIFICHE DEL TEST GENERATOR. The transition between U_T and the altered voltage is sudden. The step can commence and conclude at any phase angle on the mains voltage. Several devices could be used to perform the test but the most suitable one in terms on space and cost is a tapped transformer, see figure 41.

To replicate interruptions and voltage variations, two transformers with adjustable output voltages are employed. Voltage drops, increases, and interruptions are emulated by cyclically closing either switch 1 or switch 2. Importantly, these two switches are never simultaneously closed, and an interval of up to 100s with both switches open is considered acceptable. The switches must be operable independently of the phase angle, and this requirement can be met by employing semiconductor switches constructed with power MOSFETs and IGBTs. The test should be conducted with the Equipment Under Test (EUT) connected to the test generator using the shortest power supply cable specified by the EUT manufacturer. In cases where no cable length is specified, the cable length used should be the shortest one suitable for the application of the EUT. The Equipment Under Test (EUT) should undergo testing for every chosen combination of test level and duration, involving a sequence of three dips or interruptions with a minimum interval of 10 seconds between each test event. In the case of voltage dips, alterations in the supply voltage must occur at zero crossings, and at additional angles deemed critical by product committees or specified in individual product specifications. These angles are preferably selected from 45°, 90°, 135°, 180°, 225°, 270°, and 315° on each phase.

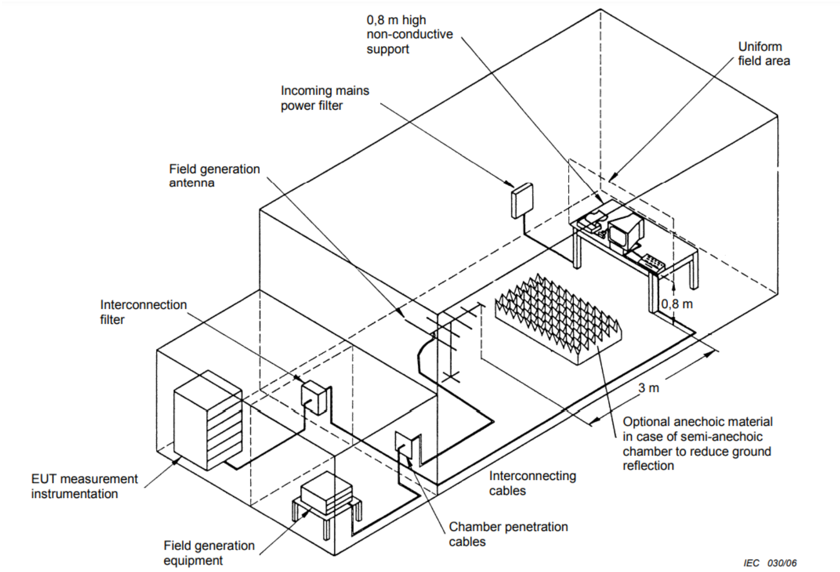


Figure (40) Example of RF test facility

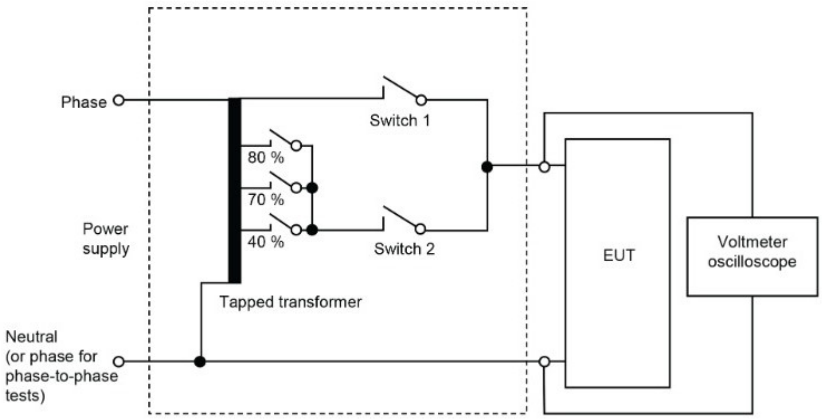


Figure (41) Schematic of test instrumentation for voltage dips using a tapped transformer and switches

Table (25) Input AC power ports

Environmental phenomena		Test level in % U_T	Duration for voltage dips	
			50 Hz	60 Hz
Voltage dips in % U_T	100	0	0,5 cycles	0,5 cycles
	60	40	10 cycles	12 cycles
	30	70	25 cycles	30 cycles

4 Test methods for winding wires

4.1 Electrical resistance

Electrical resistance refers to the d.c.resistance of a 1-meter wire at $20°C$. The chosen method must ensure a precision of 0.5%. In the case of bunched wires, a length of up to 10 meters should be utilized, and the ends must be soldered before conducting the measurement. When assessing resistance to identify an excessive number of broken wires, a 10-meter length of bunched wire is recommended. If the resistance (Rt) is measured at a temperature (t) other than 20° C, the resistance at 20° C (R_{20}) should be calculated using the following formula:

$$R_{20} = \frac{R_t}{1 + \alpha \cdot (t - 20)} \tag{29}$$

In the temperature range between 15°C and 35°C, the specified temperature coefficients are as follows:

- For copper: $\alpha_{20} = 3.96 \cdot 10^{-3}$ K^1
- For aluminium: $\alpha_{20} = 4.07 \cdot 10^3$ K^{-1}

4.2 Breakdown voltage

The testing voltage should be an alternating current (a.c.) voltage with a nominal frequency of 50 Hz or 60 Hz Hz. The application of the test voltage should commence at zero and then be incrementally increased at a consistent rate in accordance with table 26.

The following equipment is required for the testing procedure:

- A test transformer with a minimum rated power of 500 VA, capable of providing an alternating current (a.c.) voltage with an undistorted sine waveform under test conditions. The transformer should have a peak factor within the range of 25% and the ability to supply a current of 5 mA with a maximum voltage drop of 2%.
- A fault detection circuit that operates at a current of 5 mA or higher.
- An arrangement designed to ensure a uniform rise of the test voltage at the specified rate.
- An oven with forced air circulation.
- A polished metal cylinder, 25 mm ± 1 mm in diameter, mounted horizontally (refer to figure 42), and electrically connected to one terminal of the test voltage supply.
- A twisting device, as illustrated in figure 43, capable of twisting two pieces of wire for a length of 125 mm.
- Strips of metal foil, each 6 mm in width, and pressure-sensitive tape, 12 mm in width.
- A container containing metal shot made of stainless steel or nickel-plated iron. The diameter of the shot should not exceed 2 mm, and periodic cleaning by suitable means is necessary.
- A metal mandrel,50 mm ± 2 mm in diameter.
- Another metal mandrel, 25 mm ± 1 mm in diameter.

4.2.1 Enamelled round wire

- For enamelled round wire with a nominal conductor diameter up to and including 0.100 mm, a straight length of wire with insulation removed at one end should be connected to the upper

Table (26) Rates of test voltage increase

Breakdown voltage V		**Rates of increase** V/s
Over	**Up to and including**	
-	500	20
500	2500	100
2500	-	500

Table (27) Loads applied to the wire

Nominal conductor diameter mm		**Load** N
Over	**Up to and including**	
-	0.018	0.013
0.018	0.02	0.015
0.02	0.022	0.02
0.022	0.025	0.025
0.025	0.028	0.03
0.028	0.032	0.04
0.032	0.036	0.05
0.036	0.04	0.06
0.04	0.045	0.08
0.045	0.05	0.1
0.05	0.056	0.120
0.056	0.063	0.15
0.063	0.071	0.2
0.071	0.08	0.25
0.08	0.09	0.3
0.09	0.1	0.4

terminal, following the configuration shown in figure 42. The wire is wound once around the cylinder, and a load specified in table 27 is applied to the lower end to maintain close contact with the cylinder. The test voltage, as per specified in the beginning, is then applied between the conductor of the wire and the cylinder. The testing is conducted at room temperature, and a total of five specimens are subjected to this procedure. The individual results from the five tests should be documented and reported.

- Enamelled round wire with a nominal conductor diameter exceeding 0.1 mm up to and including 2.500 mm. For this test, a straight length of wire approximately 400 mm long, with insulation removed at both ends, shall be twisted back on itself for a distance of (125 ± 5) mm using the twisting device illustrated in figure 43 . The wire ends are then joined, and a load is applied with the number of twists specified in table 28. The loop at the end of the twisted section shall be cut at two places to create maximum spacing between the cut ends. Any bending necessary to achieve adequate separation between the two wire ends should avoid sharp bends or damage to the coating. The test voltage, as specified in the beginning, is applied between the conductors of the wires. This testing procedure is conducted on five specimens, and the individual results from the five tests are to be documented and reported. Test at elevated temperature.
  - A DUT prepared according to the previous test is put in the oven at 3° C. The application of the test voltage, as outlined in the beginning, should occur between the conductors of the wires not less than 15 minutes after placing the specimen in the oven. The entire test procedure must be concluded within 30 minutes. A total of five specimens are subjected to testing, and the individual results from these five tests should be documented and reported.
- Round wire with a nominal conductor diameter over 2.500 mm. Test at Room Temperature:
  A straight length of wire, with sufficient length and insulation removed at one end, shall be bent around a mandrel as depicted in figure 44. The mandrel's diameter should measure 50 mm ± 2 mm. Placing the specimen in the container is followed by surrounding it with shot, ensuring at least a 5 mm gap between the specimen and the inner container walls. The specimen's ends should be

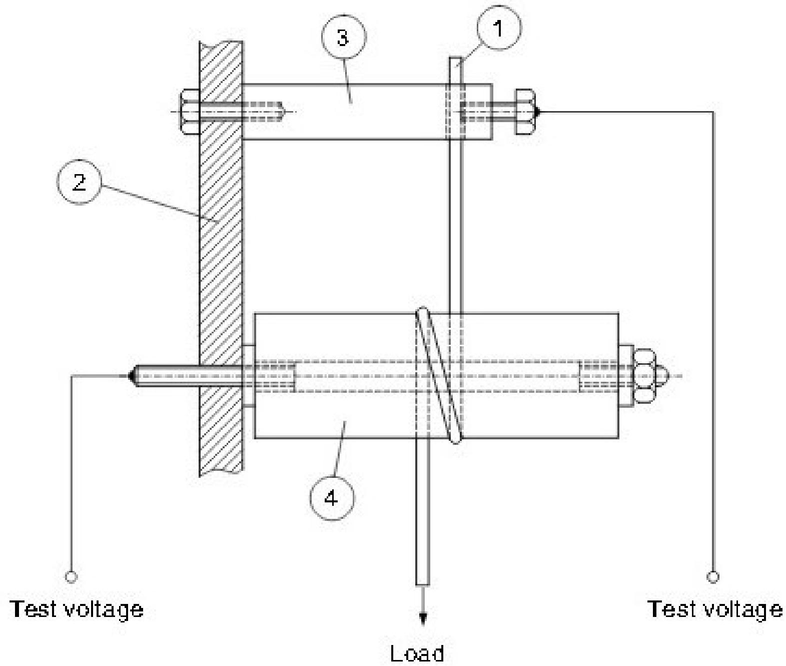


Figure (42) Arrangement of cylinder and DUT for breakdown voltage test (winding wires)
1 DUT
2 insulating
3 upper terminal
4 cylinder

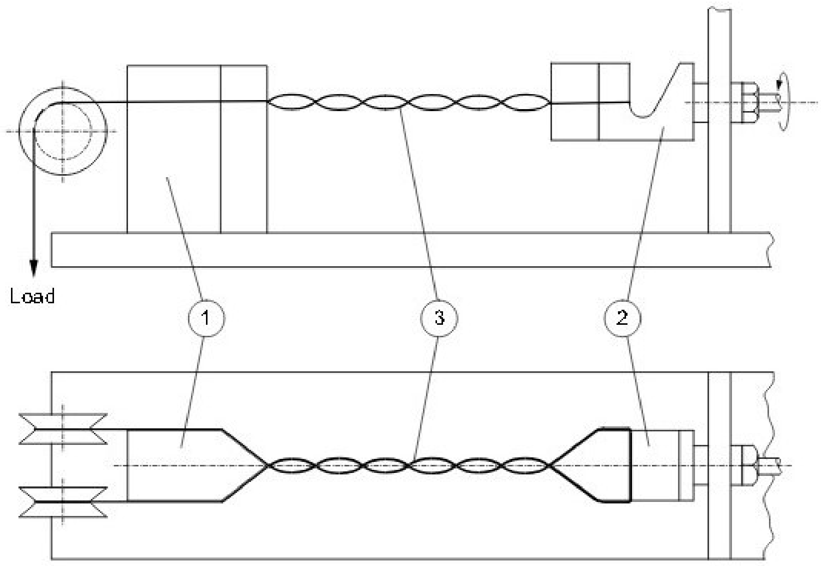


Figure (43) Device for twisting DUT for breakdown voltage (winding wires)
1 spacer
2 rotary box
3 DUT

Table (28) Loads applied to the wire and number of twists

Nominal conductor diameter mm		**Load** N	**Number of twists**
Over	**Up to and including**		
0.1	0.25	0.85	33
0.25	0.355	1.7	23
0.355	0.5	3.4	16
0.6	0.71	7	12
0.71	1.06	13.5	8
1.06	1.4	27	6
1.4	2	54	4
2	2.5	108	3

of adequate length to prevent flashover. Gently pouring metal shot into the container covers the specimen at a depth of 90 mm. The shot, not exceeding 2 mm in diameter, is typically made of stainless steel, nickel, or nickel-plated iron. Periodic cleaning of the shot with a suitable solvent, such as 1,1,1-trichloroethane, is required.
The test voltage, as specified in the beginning, is then applied between the conductor and the shot. Note: Upon mutual agreement between the purchaser and supplier, the test may be conducted with the specimen submerged in oil. The choice of oil should align with either IEC 60296 standards or as specified in the agreement between the customer and supplier. A total of five specimens undergo testing, and individual results from these five tests should be documented and reported.

- A DUT prepared according to the previous test is put in the hoven at 3° C. The shot and container must undergo preheating within the oven at the test temperature and remain there during the loading of the test specimen. The loading process of the test specimen should be conducted with great care to prevent any damage. Application of the test voltage, as specified in the beginning, should take place not less than 15 minutes after placing the specimen in the oven. The entire test procedure must be completed within 30 minutes, and the temperature must be maintained within ±3° C. A total of five specimens undergo testing, and the individual results from these five tests should be documented and reported.

4.2.2 Fibre wound round wire

Test at room Temperature:

A straight length of wire, with sufficient length and insulation removed at one end, is to be bent 10 turns around a mandrel as illustrated in figure 45. The mandrel's diameter should be:

- 25 mm ± 1 mm for a nominal diameter up to and including 2.500 mm.
- 50 mm ± 2 mm for a nominal diameter over 2.500 mm.

The specimen is then placed in the container, following the configuration shown in figure 45, and is surrounded by shot with at least a 5 mm gap between the specimen and the inner container walls. A minimum distance of 2.5 mm should be maintained between adjacent turns. The ends of the specimen should be of sufficient length to prevent flashover. Gently pouring metal shot into the container covers the specimen at a depth of 90 mm. The shot, not exceeding 2 mm in diameter, is typically made of stainless steel, nickel, or nickel-plated iron. The shot should be cleaned annually.

The test voltage, as specified in the beginning, is then applied between the conductor of the wire and the shot. Note: Upon mutual agreement between the purchaser and supplier, the test may be conducted with the specimen submerged in oil. The choice of oil should align with either IEC 60296 standards or as specified in the agreement between the customer and supplier. A total of five specimens undergo testing, and the individual results from these five tests should be documented and reported. A DUT prepared according to the previous test is put in the oven at 3° C. The shot and container must be preheated in the oven to the test temperature and remain there during the loading of the test specimen. The

Dimensions in millimetres

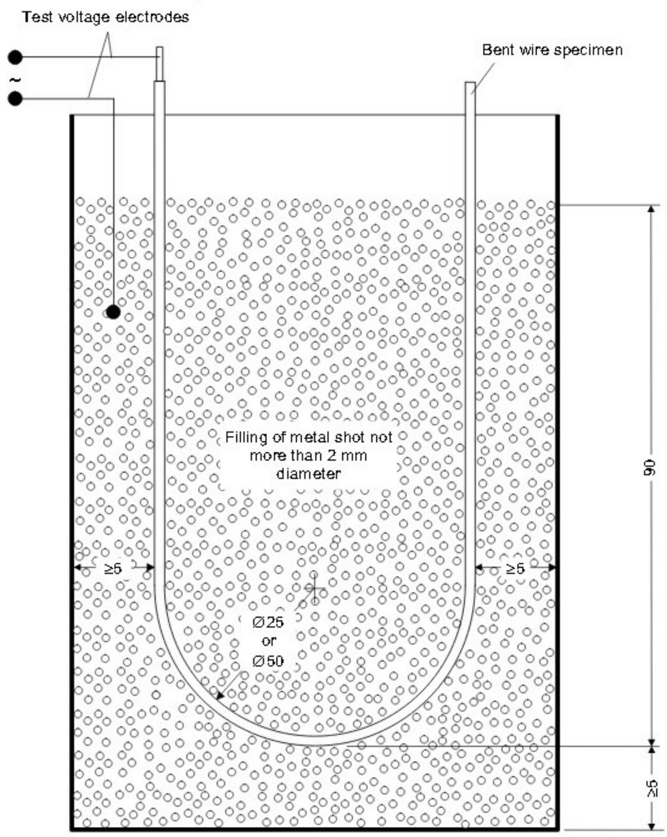


Figure (44) U-bend DUT for breakdown voltage test (winding wires) loading operation for the test specimen should be carried out very gently to prevent any damage. The application of the test voltage, as outlined in the beginning, should take place not less than 15 minutes after placing the specimen in the oven. The entire test procedure must be completed within 30 minutes, and the temperature must be maintained within at ±3° C. A total of five specimens undergo testing, and the individual results from these five tests should be documented and reported.

4.2.3 Rectangular wire

Test at Room Temperature:

A straight wire, approximately 350 mm in length with insulation removed at one end, is to be bent flat around a mandrel following the configuration shown in figure 44. The diameter of the mandrel should be:

- 25 mm ± 1 mm for nominal thicknesses up to and including 2.500 mm.
- 50 mm ± 2 mm for nominal thicknesses over 2.500 mm.

The specimen is then placed in the container, and a gap of at least 5 mm is maintained between the specimen and the inner walls of the container. The ends of the specimen should be long enough to prevent flashover. Gently pouring metal shot into the container covers the specimen at a depth of 90 mm. The shot, not exceeding 2 mm in diameter, typically consists of balls made of stainless steel, nickel, or nickel-plated iron. The shot should be cleaned periodically.

The application of the test voltage, as outlined in the beginning of this chapter, should take place between the conductor of the wire and the shot. Upon mutual agreement between the purchaser and supplier, the test may be conducted with the specimen submerged in oil. The choice of oil should align with either IEC 60296 standards or as specified in the agreement between the customer and supplier. A total of five specimens undergo testing, and the individual results from these five tests should be documented and reported. A DUT prepared according to the previous test is put in the hoven at 3° C. The shot and the container must undergo preheating within the oven at the test temperature and remain there during the loading of the test specimen. The loading operation for the test specimen should be carried out very gently to prevent any damage. The application of the test voltage, as described in the beginning of this chapter, should occur no less than 15 minutes after placing the specimen in the oven. The entire testing procedure must be concluded within 30 minutes, and the temperature must be maintained within ±3° C. A total of five specimens will undergo testing, and the individual results from these five tests should be documented and reported.

4.3 Continuity of insulation (applicable to enamelled round and tape wrapped round wire)

The continuity of insulation is quantified by the number of faults per unit length of wire, identified through an electrical testing circuit.

4.3.1 Low-voltage continuity (nominal conductor diameter up to and including 0.050 mm)

A wire specimen, measuring (30 ± 1) m, is to be pulled at a speed of (275 ± 25) mm/s between two felt pads immersed in an electrolytic solution of sodium sulfate in water (30 g/l). The wire's conductor and the solution are connected to an electrical circuit with an open-circuit direct current test voltage of (50 ± 3) V (refer to figure 46). The applied force on the wire should not exceed 0.03 N. Faults are to be identified using an appropriate relay and counter system. The counter activates when the wire coating has a resistance below 10 kΩ for a duration of at least 0.04 s, and it does not activate when the resistance is 15 kΩ or more.

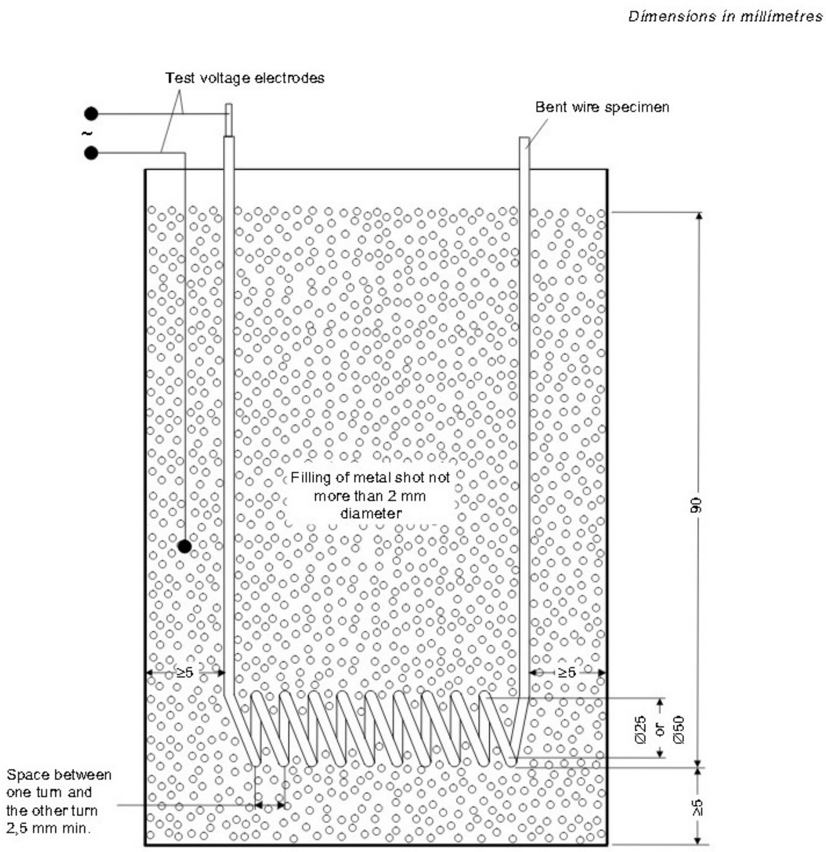


Figure (45) Coil wound DUT for breakdown voltage (winding wires)

The fault detection circuit is expected to operate with a speed response of (5 ± 1) m/s, and the fault counter should repeat at a rate of (500 ± 25) counts per minute during testing with a bare wire. A single test is to be conducted, and the number of faults per 30 m of wire length should be reported.

4.4 High-voltage continuity (nominal conductor diameter over 0.050 mm up to and including 1.600 mm)

A wire specimen, with the conductor grounded, is drawn over a "V"-grooved electrode (pulley) or through a graphite brush electrode at a consistent speed. A direct current test voltage is applied between the electrode and ground. Any insulation faults in the wire are identified and recorded using a counter. The outcome is expressed in faults per 30 m.

The specified equipment includes:

- A high-voltage power supply capable of delivering a filtered direct current voltage with a ripple content below 5%. The open-circuit test voltage is adjustable within the range of 350 V to 2.000 V. The short-circuit current is limited by internal series resistance to (25 ± 5) A at any test voltage, with not more than a 75% drop in voltage in the presence of a 50 MΩ fault resistance.
- A fault detection circuit designed to operate at a fault current specified in table 29. It exhibits a response speed of (5 ± 1) ms, and the fault counter repeats at a rate of (500 ± 25) counts per minute during testing of a bare wire.
- Dual high-voltage electrode pulleys, as depicted in figure 47, made of stainless steel, offering a wire contact length of approximately 25 mm on each pulley.
- A high-voltage electrode pulley in accordance with figure 48, constructed from stainless steel, providing a wire contact length of 25 mm to 30 mm.
- A graphite fiber brush electrode assembly following the configuration in figure 49. This assembly is designed to ensure that conductive brushes completely surround and contact the wire surface for a

Dimensions in millimetres

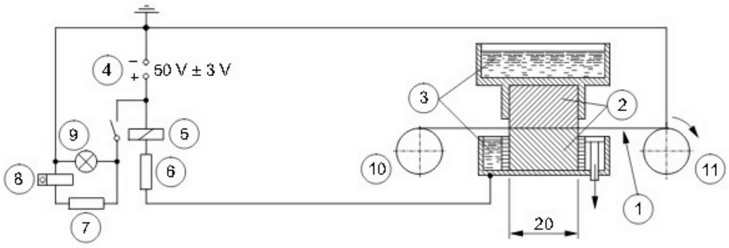


Figure (46) Apparatus for testing the low voltage continuity of covering (winding wires).

1 wire
2 felt pads
3 electrolytic solution bath (30 g)
4 d.c. supply
5 relay
6 resistor 50 kΩ
7 resistor 50 kΩ
8 counter
9 pilot lamp
10 delivery spool with winding wire
11 take-up spool

Table (29) Fault currents

Test voltage (d.c.) V	**Fault current** μA
2000	12
1500	10
1000	8
750	7
500	6
350	5

length of (25 ± 2.5) mm (refer to figure 47). The graphite fiber brush electrode should be inspected, cleaned, or replaced in the presence of excessive wear or accumulation of foreign material. The assembly must remain electrically isolated throughout the test duration to prevent false readings at the specified voltages.

- Earthed guide pulleys with an outside diameter of (50 ± 2.5) mm and a root diameter of (40 ± 2.5) mm, spaced (140 ± 2) mm apart.
- A surge damping resistor of 4.7 MΩ with a tolerance of 10%, installed in the high-voltage line.

The earth insulation for the high-voltage electrode must consist of a high-resistivity material that is non-hygroscopic, non-tracking, and easily cleanable. It should provide sufficient clearance to withstand a continuous voltage of 3.000 V. No shielding should be employed on the high-voltage lead to ensure a minimum capacitance to ground during switching and counting events. The drive motor should be of the brushless type and possess adequate power to sustain the necessary speed for pulling a 1.600 mm wire.

A wire specimen, measuring 30 m $\pm$ 1 m, is to be drawn at a speed of (275 ± 25) mm/s over the high-voltage electrode pulley or through the graphite brush electrode positioned between the earthed guide pulleys. The wire's conductor and the electrode should be connected to the electrical circuit, and the open-circuit direct current test voltage should be adjusted as per table 30 with a tolerance of $\pm 5\%$. The polarity of the test voltage should be positive with respect to the earthed conductor of the wire. The number of faults per 30 m of wire length must be reported.

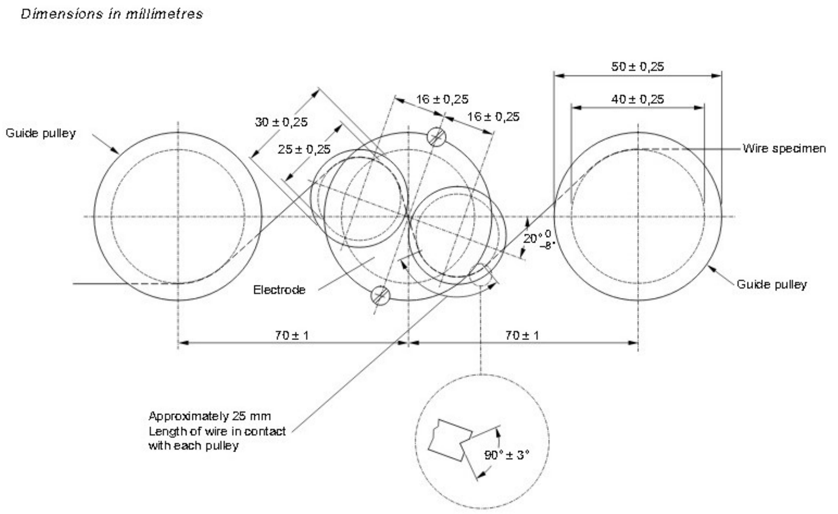


Figure (47) high voltage d.c. continuity-pulleys for wire size 0.005 mm to 0.25 mm (winding wires)

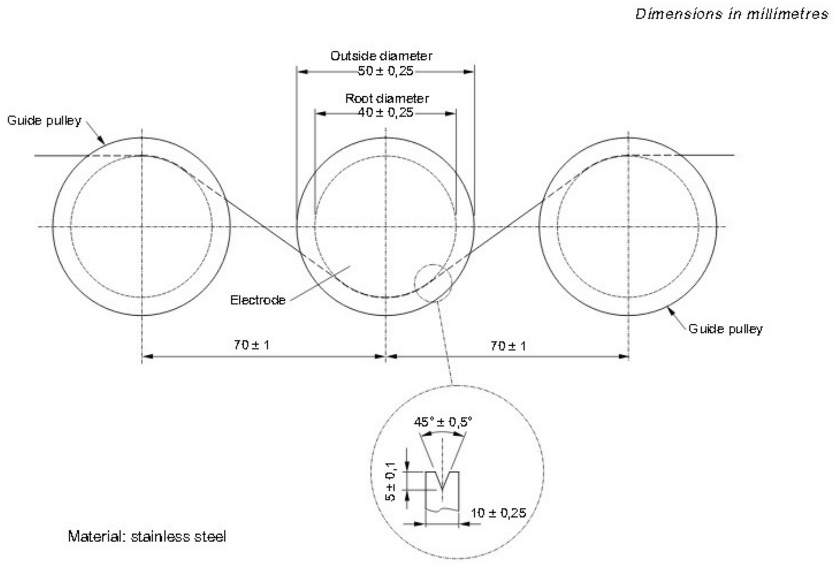


Figure (48) Pulleys dimensions and spacing for wire size 0.25 mm to 1.6 mm (winding wires)

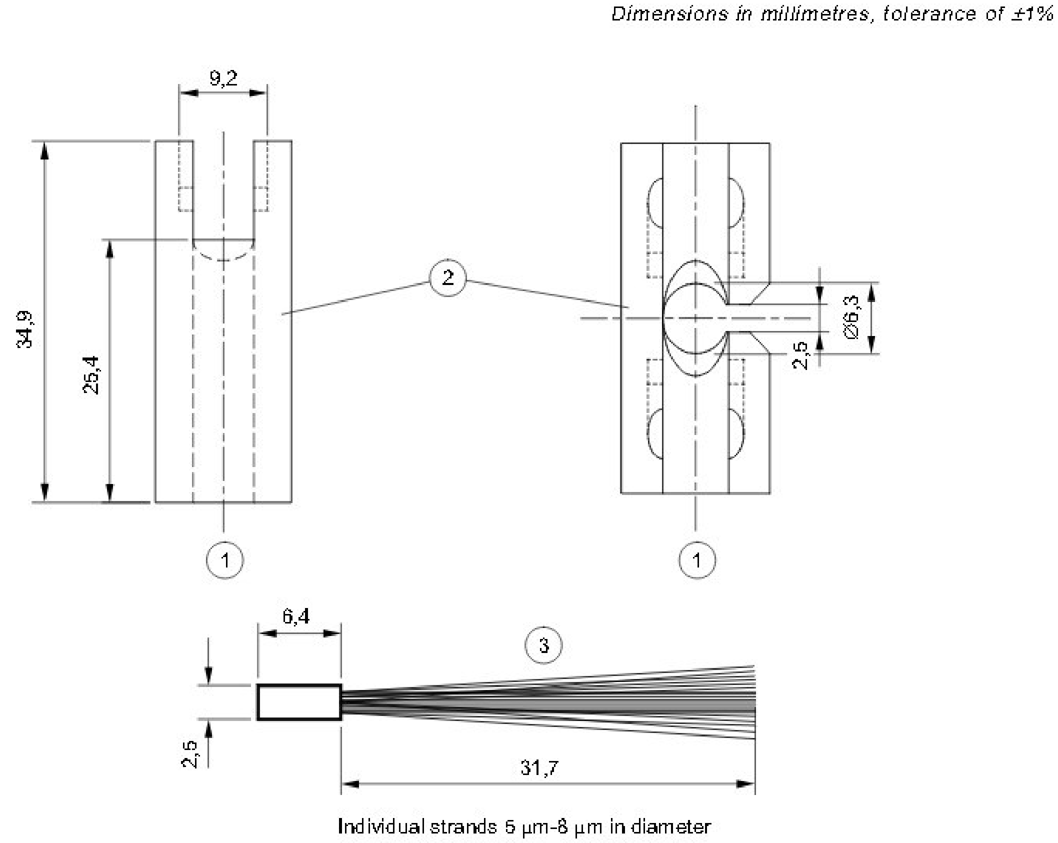


Figure (49) Graphite fibre single brush electrode assembly (winding wires).
1 wire path
2 brush mounting block
3 single graphite brush

Table (30) Test voltages

Type of conductor	Nominal conductor diameter mm		Voltage (d.d.) V		
	Over	Up to and including	Grade 1	Grade 2	Grade 3
Copper	0.05	0.125	350	500	750
	0.125	0.25	500	750	1000
	0.25	0.5	750	1000	1500
	0.5	1.6	1000	1500	2000
Aluminium	0.4	1.6	500	1500	-

4.4.1 Dielectric dissipation factor (applicable to enamelled wire and bunched wire)

A wire segment is considered analogous to a capacitor, where the insulation serves as the dielectric, the conductor functions as one electrode, and the surrounding medium acts as the second electrode. This capacitor configuration is integrated into a circuit designed to operate at the specified frequency. The circuit is suitable for measuring both the capacitive and resistive components, enabling the determination of the dielectric dissipation factor. The designated equipment comprises:

- An impedance meter, operating at the frequency stipulated in the applicable standard. It should ensure a precision of ±1% based on capacitance, covering the capacitance range required by the specimen at this frequency.
- A frequency generator, equipped with a sinusoidal voltage output possessing a frequency specified in the relevant standard.
- For Test Method A: A metal bath, conforming to the configuration in figure 50, filled with any suitable liquid metal (alloy). It must include a heating system that maintains temperature control within ±1° C.
- For Test Method B: Two metal blocks featuring a heating system that effectively controls the temperature to within ±1° C.
- A conducting suspension.

Those are the following specimens:

- Specimen for a metal bath electrode: A straight piece of wire shall be bent into a U-shape to be lowered into the metal bath according to figure 50. As shown in figure 50 the DUT must be dive in the metal bath (test method A).
- Specimen for a conductive suspension electrode:
  - For enamelled round wire with a nominal conductor diameter up to and including 0.100 mm, a straight wire segment of (100 ± 5) mmin length should be wound around a straight piece of bare copper wire with a diameter ranging from 1 mm to 2 mm. Subsequently, this wound assembly is to be coated with a conductive suspension. This can be achieved, for instance, by applying a layer of an aqueous graphite dispersion onto the specimen, followed by drying, such as for 30 minutes at 100° C in an oven with forced air circulation.
  - For enamelled round wire with a nominal conductor diameter over 0.100 mm and enamelled rectangular wire, a straight wire segment approximately 150 mm in length is to be coated with a conductive suspension. This coating can be applied, for instance, by brushing a layer of an aqueous graphite dispersion onto the wire. The length of this applied layer should be (100 ± 5) mm. Subsequently, the specimen is to be dried, for example, for 30 minutes at 100° C in an oven with forced air circulation.

  Such DUT is to be positioned between the two metal blocks. It should then be connected to the impedance meter and left to attain the specified test temperature. Subsequently, the dielectric dissipation factor is to be directly read from the impedance meter.

Only one DUT must be tested and those are the features to be reported : the dielectric dissipation factor, the test frequency and the test temperature.

Table (31) Nominal cross-sectional area of conductors

Rated current of appliance A	**Nominal cross-sectional area** mm^2	
	Flexible cords	**Cable for fixed wiring**
≤ 3	0,5 and 0,75	1 to 2,5
> 3 and ≤ 6	0,75 and 1	1 to 2,5
> 6 and ≤ 10	1 and 1,5	1 to 2,5
> 10 and ≤ 16	1,5 and 2,5	1,5 to 4
> 16 and ≤ 25	2,5 and 4	2,5 to 6
> 25 and ≤ 32	4 and 6	4 to 10
> 32 and ≤ 50	6 and 10	6 to 16
> 50 and ≤ 63	10 and 16	10 to 25

Table (32) Torque for testing screws and nuts

Nominal diameter of screw (outer thread diameter) mm	**Torque** Nm		
	I	**I**	**II**
≤ 2.8	0,2	0,4	0,4
> 2.8 and ≤ 3	0,25	0,5	0,5
> 3 and ≤ 3.2	0,3	0,6	0,5
> 3.2 and ≤ 3.6	0,4	0,8	0,6
> 3.6 and ≤ 4.1	0,7	1.2	0,6
> 4.1 and ≤ 4.7	0,8	1.8	0,9
> 4.7 and ≤ 5.3	0,8	2	1
> 5.3	-	2,5	1,25

4.5 Pin hole test

The purpose of this test is to detect insulation defects post-treatment with a saltwater solution, aligning with the objective of the high-voltage continuity test in section High voltage continuity test. For conductors with a nominal diameter less than 0.07 mm, a wire specimen of approximately 1.5 m in length is used, while for conductors with a nominal diameter equal to or exceeding 0.07 mm, a specimen of approximately 6 m in length is employed.

For a nominal diameter less than 0.07 mm, 1 m $\pm$ 0.05 m of wire is wound into a round shape with a diameter of 100 mm $\pm$ 50 mm. For a nominal diameter of 0.07 mm or more, 5 m $\pm$ 0.2 m of wire is wound into a round shape with a diameter of 300 mm $\pm$ 100 mm. The specimen is then placed in an air circulation oven at 125° C $\pm$ 3° C for 10 minutes (refer to note 1 below) unless otherwise specified in the relevant specification. Following this heat treatment, without any bending or stretching (see note 2 below), the specimen, upon cooling to room temperature, is immersed in an electrolytic solution of sodium chloride (2 g/l) with the addition of a proper quantity of phenolphthalein alcohol solution (30 g/l) for easy identification of any pinholes (typically manifested as pink streams in the solution). The conductor of the wire and the solution are connected to an electrical circuit with an open-circuit direct current test voltage of (12 ± 2) V. The voltage is applied for 1 minute, with the specimen serving as the negative electrode relative to the solution, and to prevent excessive heating, the short-circuit current is limited to 500 mA. The observed number of pinholes, without magnification (normal vision), should be documented. Notes:

1. The results may lack significance without undergoing the specified heat treatment.
2. The stretching of the wire may result in the formation of pinholes in the electrolytic solution.
3. Due to the aqueous nature of this test, certain enamel types that exhibit crazing behavior in water may yield misleading results.

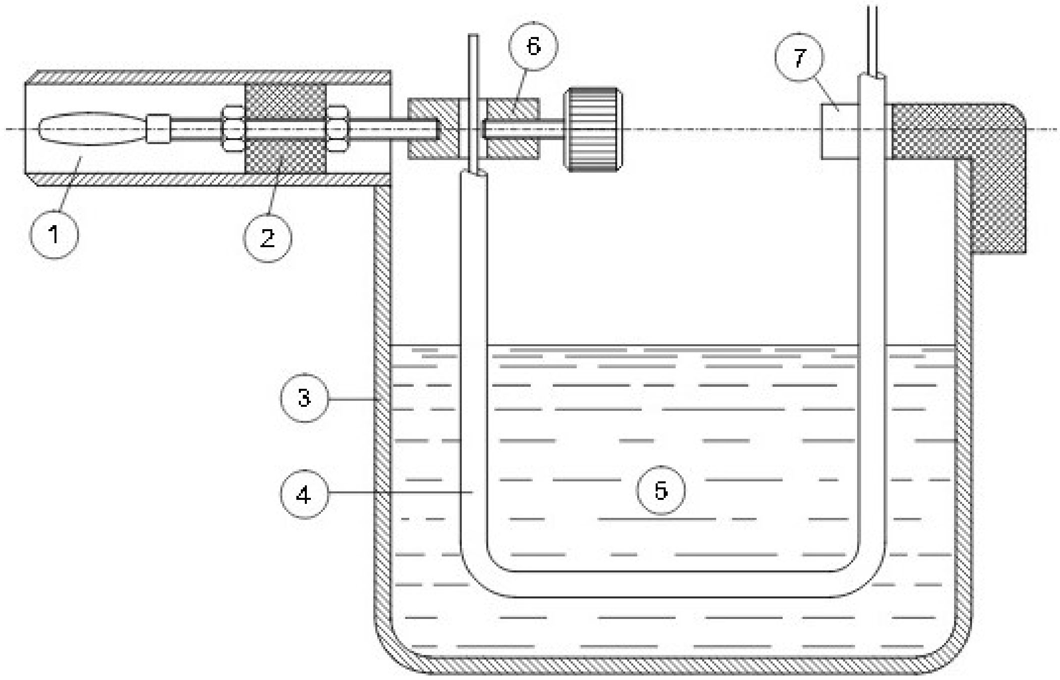


Figure (50) Suitable electrode arrangement for testing the dielectric dissipation factor (winding wires).
1 plug
2 insulating material
3 metallic container
4 DUT
5 electrode
6 terminal
7 insulated clamp

Table (33) Minimum creepage distances for basic insulation

Working voltage V	**Creepage distance** mm **Pollution degree**						
	1	**2**			**3**		
		Material group			**Material group**		
		I	**II**	**IIIa/IIIb**	**I**	**II**	**IIIa/IIIb**[a]
≤ 50	0,18	0,6	0,85	1,2	1,5	1,7	1,9
125	0,28	0,75	1,05	1,5	1,9	2,1	2,4
250	0,56	1,25	1,8	2,5	3,2	3,6	4
400	1	2	2,8	4	5	5,6	6,3
500	1,3	2,5	3,6	5	6,3	7,1	8
> 630 and ≤ 800	1,8	3,2	4,5	6,3	8	9	10
> 800 and ≤ 1000	2,4	4	5,6	8	10	11	12,5
> 1000 and ≤ 1250	3,2	5	7,1	10	12,5	14	16
> 1250 and ≤ 1600	4,2	6,3	9	12,5	16	18	20
> 1600 and ≤ 2000	5,6	8	11	16	20	22	25
> 2000 and ≤ 2500	7,5	10	14	20	25	28	32
> 2500 and ≤ 3200	10	12,5	18	25	32	36	40
> 3200 and ≤ 4000	12,5	16	22	32	40	45	50
> 4000 and ≤ 5000	16	20	28	40	50	56	63
> 5000 and ≤ 6300	20	25	36	50	63	71	80
> 6300 and ≤ 8000	25	32	45	63	80	90	100
> 8000 and ≤ 10000	32	40	56	80	100	110	125
> 10000 and ≤ 12000	40	50	71	100	125	140	160

[a] Material group IIIb is allowed if the working voltage does not exceed 50 V.

Table (34) Minimum creepage distances for functional insulation

Working voltage V	**Creepage distance** mm **Pollution degree**						
	1	**2**			**3**		
		Material group			**Material group**		
		I	**II**	**IIIa/IIIb**	**I**	**II**	**IIIa/IIIb**[a]
≤ 10	0,08	0,4	0,4	0,4	1	1	1
50	0,16	0,56	0,8	1,1	1,4	1,6	1,8
125	0,25	0,71	1	1,4	1,8	2	2,2
250	0,42	1	1,4	2	2,5	2,8	3,2
400[b]	0,75	1,6	2,2	3,2	4	4,5	5
> 630 and ≤ 800	1,8	3,2	4,5	6,3	8	9	10
> 800 and ≤ 1000	2,4	4	5,6	8	10	11	12,5
> 1000 and ≤ 1250	3,2	5	7,1	10	12,5	14	16
> 1250 and ≤ 1600	4,2	6,3	9	12,5	16	18	20
> 1600 and ≤ 2000	5,6	8	11	16	20	22	25
> 2000 and ≤ 2500	7,5	10	14	20	25	28	32
> 2500 and ≤ 3200	10	12,5	18	25	32	36	40
> 3200 and ≤ 4000	12,5	16	22	32	40	45	50
> 4000 and ≤ 5000	16	20	28	40	50	56	63
> 5000 and ≤ 6300	20	25	36	50	63	71	80
> 6300 and ≤ 8000	25	32	45	63	80	90	100
> 8000 and ≤ 10000	32	40	56	80	100	110	125
> 10000 and ≤ 12000	40	50	71	100	125	140	160

NOTE 1 For PTC heating elements, the creepage distances over the surface of the PTC material need not be greater than the associated clearance for working voltages less than 250 V and for pollution degrees 1 and 2. However, the creepage distances between terminations are those specified in the table.

NOTE 2 For glass, ceramics and other inorganic insulating materials that do not track, creepage distances need not be greater than the associated clearance.

NOTE 3 For tracks on printed wiring boards under pollution degree 1 and pollution degree 2 conditions, the values specified in Table F.4 of IEC 60664-1 apply. For voltages less than 100 V , the values must not be less than those specified for 100 V .

NOTE 4 For working voltages > 10 V and ≤ 630 V, if the voltage is not specified in the table, the values of creepage distances may be found by interpolation.

[a] Material group IIIb is allowed if the working voltage does not exceed 50 V.

[b] The working voltage between phases for appliances having a rated voltage in the range of 380 V to 415 V is considered to be 400 V.

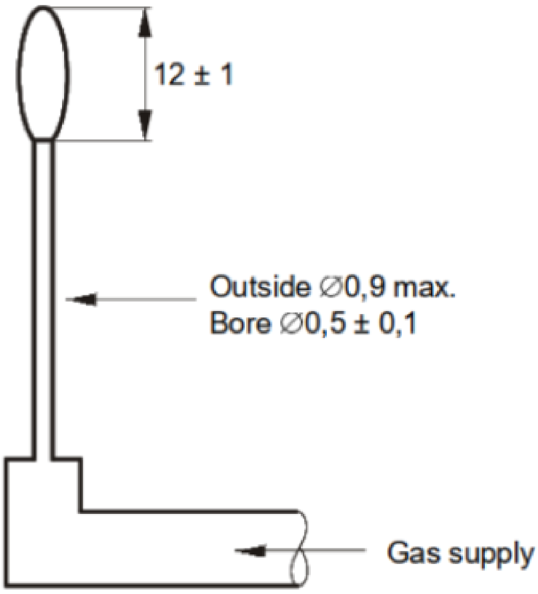


Figure (51) needle-flame test burner adjustment

Table (35) Voltage waveform specification at the EUT port of the CDN

Surge voltage parameters under open-circuit conditions	Coupling impedance	
	18 μF (line-to-line)	9 $\mu F \pm 10\ \Omega$ (line-to-ground)
Peak voltage		
Current rating $\leq$ 16 A	Set voltage +10%/-10%	Set voltage +10%/-10%
16 A < current rating $\leq$ 32 A	Set voltage +10%/-10%	Set voltage +10%/-10%
32 A <current rating $\leq$ 63 A	Set voltage +10%/-10%	Set voltage +10%/-15%
63 A <current rating $\leq$ 125 A	Set voltage +10%/-10%	Set voltage +10%/-20%
125 A <current rating $\leq$ 200 A	Set voltage +10%/-10%	Set voltage +10%/-25%
Front time	1.2 $\mu s \pm 30\%$	1.2 $\mu s \pm 30\%$
Duration		
Current rating $\leq$ 16 A	50 $\mu s \pm 10\ \mu s / -10\ \mu s$	50 $\mu s \pm 10\ \mu s / -25\ \mu s$
16 A < current rating $\leq$ 32 A	50 $\mu s \pm 10\ \mu s / -15\ \mu s$	50 $\mu s \pm 10\ \mu s / -30\ \mu s$
32 A <current rating $\leq$ 63 A	50 $\mu s \pm 10\ \mu s / -20\ \mu s$	50 $\mu s \pm 10\ \mu s / -35\ \mu s$
63 A <current rating $\leq$ 125 A	50 $\mu s \pm 10\ \mu s / -25\ \mu s$	50 $\mu s \pm 10\ \mu s / -40\ \mu s$
125 A <current rating $\leq$ 200 A	50 $\mu s \pm 10\ \mu s / -30\ \mu s$	50 $\mu s \pm 10\ \mu s / -45\ \mu s$

NOTE The current rating is the CDN rating

[a] The measurement of the surge voltage parameters shall be performed with the a.c./d.c. power port of the CDN open-circuit.

[b] The values shown in this table are for a CWG with ideal values. In case the CWG generates parameter values close to the tolerances, the additional tolerances of the CDN may generate values out of tolerances for the CWG-CDN combination.

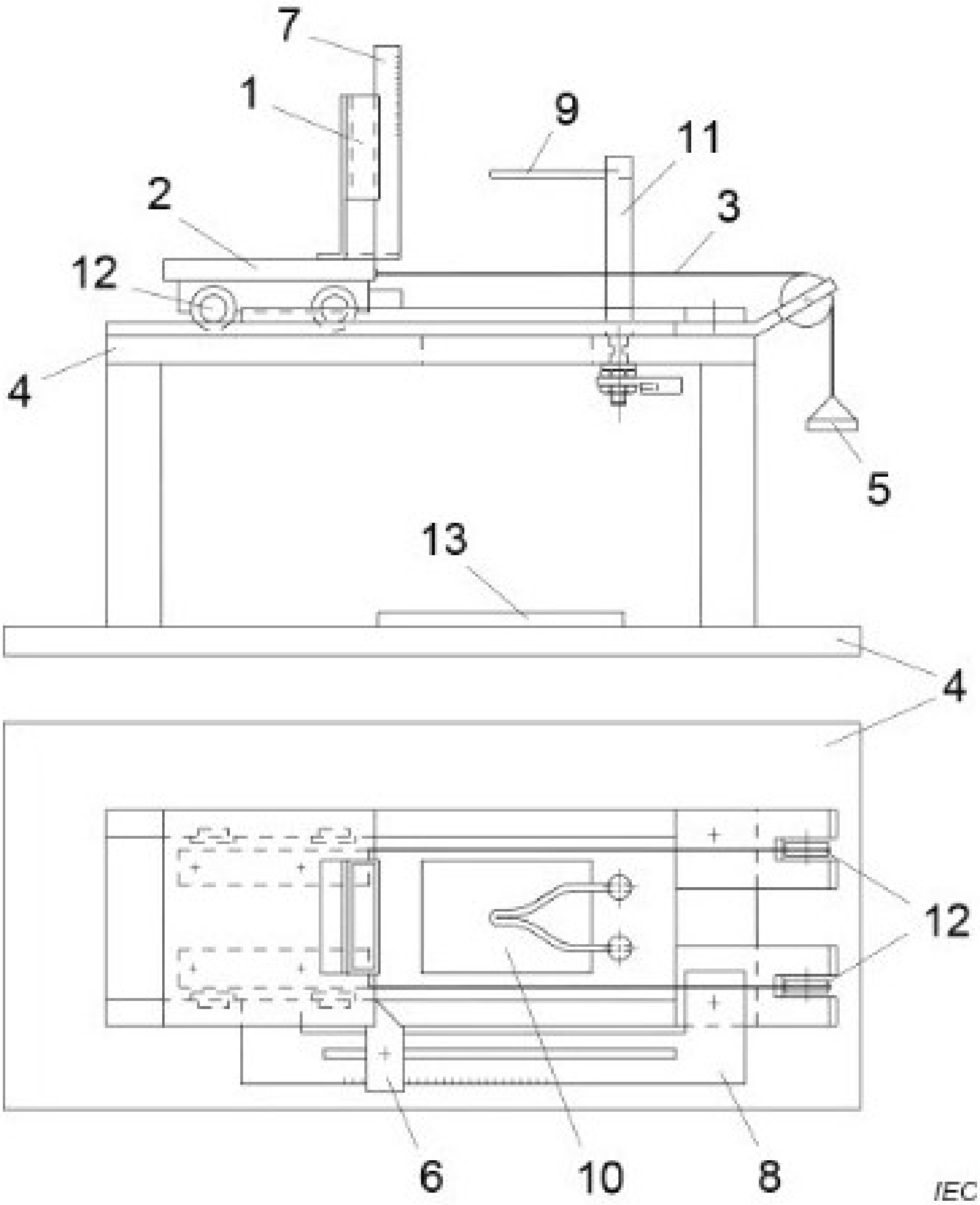


Figure (52) Glow wire test apparatus example

1 Test specimen support
2 Carriage
3 Tensioning cord
4 Base plate
5 Weight
6 Adjustable stop
7 Scale to measure height of flame
8 Penetration adjustment
9 Glow-wire
10 Cut-out in base plate for falling particles
11 Glow-wire mounting stud
12 Low-friction rollers
13 Specified layer

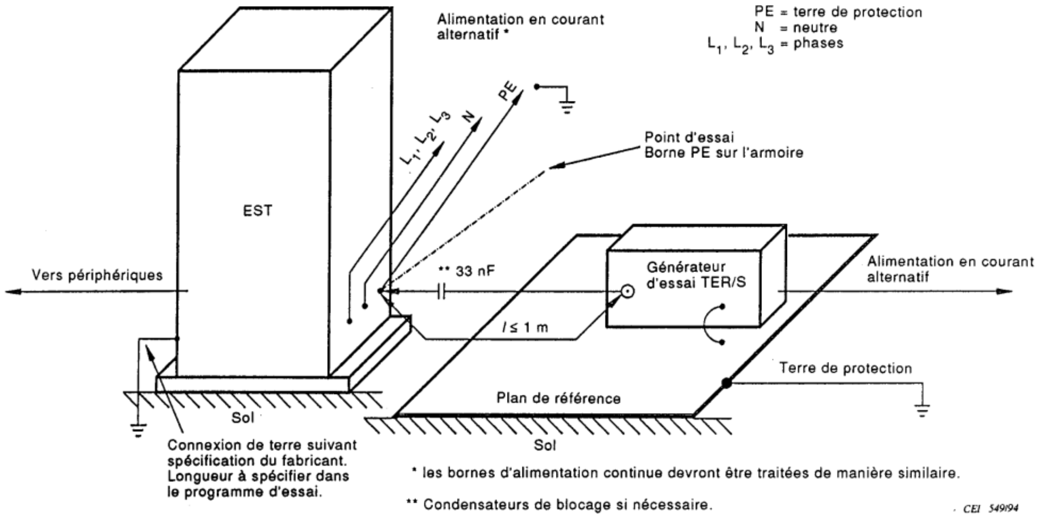


Figure (53) Electrical fast transient/burst immunity test

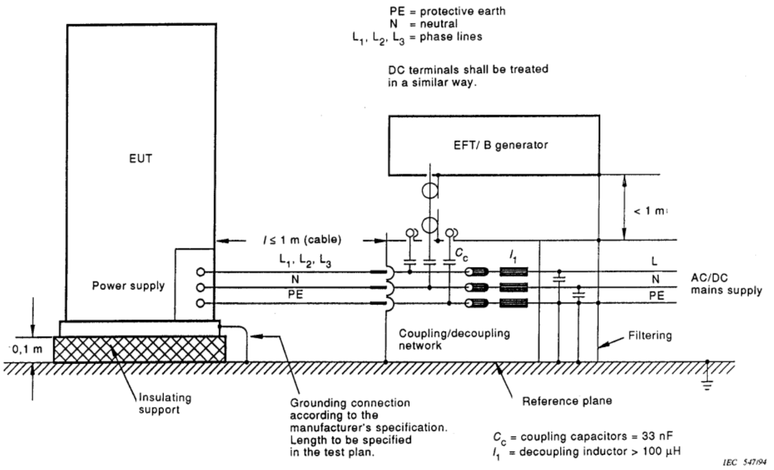


Figure (54) Electrical fast transient/burst immunity test, direct coupling of the test voltage to a.c. d.c. power supply

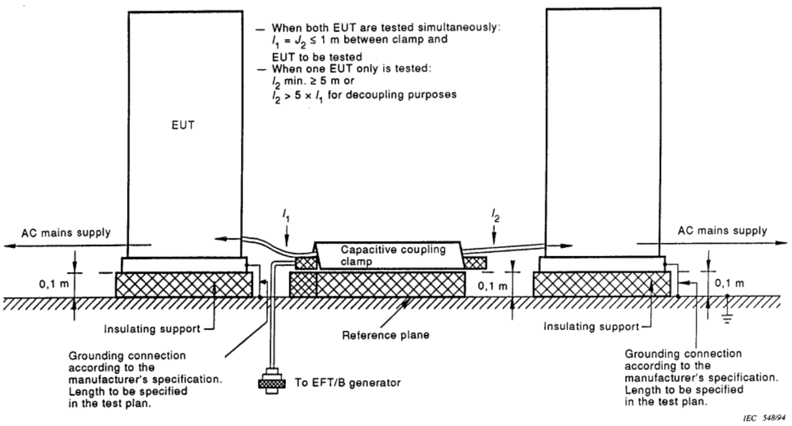
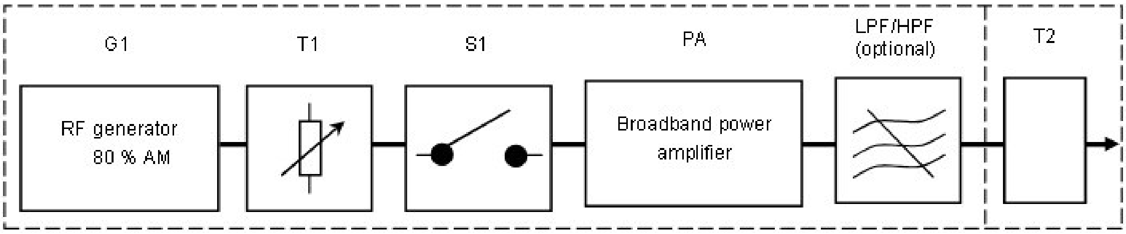
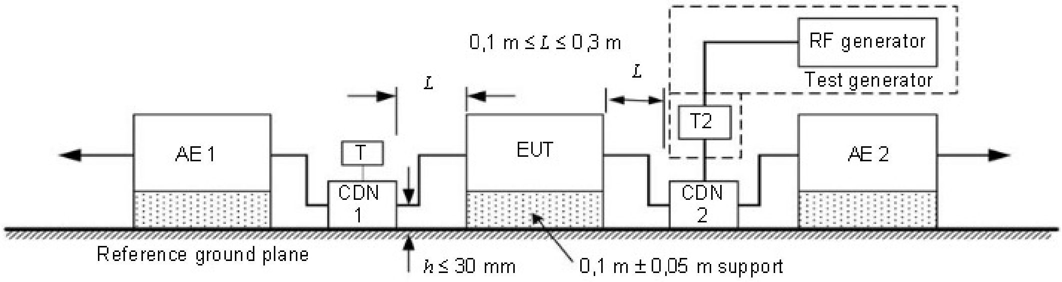


Figure (55) Electrical fast transient/burst immunity test voltage by the capacitive coupling clamp



G1	RF generator	T1	Variable attenuator
PA	Broadband power amplifier	T2	Fixed attenuator (6 dB)
LPF/HPF	Low pass filter and/or high pass filter (optional)	S1	RF switch

Figure (56) Injected current test generator setup



Schematic setup for immunity test used for CDN

Figure (57) Injected current schematic setup for immunity test used for CDN

Table (36) Maximum normal temperature rises

Part	**Temperature rise** K
Windings[a], if the winding insulation according to IEC 60085 is:	
- class 105 (A)	75 (65)
- class 120 (E)	90 (80)
- class 130 (B)	95 (85)
- class 155 (F)	115
- class 180 (H)	140
- class 200 (N)	160
- class 220 (R)	180
- class 250	210
Pins of appliance inlets:	
for very hot conditions	130
for hot conditions	95
for cold conditions	45
Terminals, including earthing terminals, for external conductors of stationary appliances, unless they are provided with a supply cord	60
Ambient of switches, thermostats and temperature limiters[b]:	
without T-marking	30
with T-marking	T-25
Rubber, polychloroprene or polyvinyl chloride insulation of internal and external wiring, including supply cords:	
without temperature rating or with a temperature rating not exceeding 75°*C*	50
with temperature rating (T)[j] where T exceeds 75°*C*	T-25

Continued on next page

Table 36 – continued from previous page

Part	Temperature rise K
Cord sheaths used as supplementary insulation	35
Sliding contacts of cord reels	65
Points where the insulation of wires can come into contact with parts of a terminal block or compartment for fixed wiring, for a stationary appliance not provided with a supply cord.	50[c]
Rubber, other than synthetic, used for gaskets or other parts, the deterioration of which could affect safety:	
when used as supplementary insulation or as reinforced insulation	40
in other cases	50
Lampholders with T-marking[d]	
B15 and B22 marked T1	140
B15 and B22 marked T2	185
other lampholders	T-25
Lampholders without T-marking [d]	
E14 and B15	110
B22, E26 and E27	140
other lampholders and starter holders for fluorescent lamps	55
Material used as insulation, other than that specified for wires and windings[e]:	
impregnated or varnished textile, paper or press-board	70
laminates bonded with:	
melamine-formaldehyde, phenol-formaldehyde or phenol-furfural resins	85 (175)
urea-formaldehyde resin	65 (150)
printed circuit boards bonded with epoxy resin	120
moulding of:	
phenol-formaldehyde with cellulose fillers	85 (175)
phenol-formaldehyde with mineral fillers	100 (200)
melamine-formaldehyde	75 (150)
urea-formaldehyde	65 (150)
polyester with glass reinforcement	110
silicone rubber	145
polytetrafluoroethylene	265
pure mica and tightly sintered ceramic material when such materials are used as supplementary insulation or reinforced insulation	400
thermoplastic material[f]	-
Wood, in general[g]	65
Wooden supports, walls, ceiling and floor of the test corner and wooden cabinet:	
stationary appliances liable to be operated continuously for long periods	60
other appliances	65
Outer surface of capacitors[h]:	
with marking of maximum operating temperature (T)[i]:	T-25
without marking of maximum operating temperature:	
small ceramic capacitors for radio and television interference suppression	50
capacitors complying with IEC 60384-14	50
other capacitors	20
External enclosure of motor-operated appliances except handles held in normal use [za, zb]:	
of bare metal	50
of coated metal[zc]	60
of glass and ceramic	65
of plastic having a thickness exceeding $0,3$ mm[zd]	75
Surfaces of handles, knobs, grips and similar parts which are continuously held in normal use (e.g. soldering irons):	
Continued on next page	

Table 36 – continued from previous page

Part	Temperature rise K
of metal	30
of porcelain or vitreous material	40
of moulded material, rubber or wood	50
Surfaces of handles, knobs, grips and similar parts which are held for short periods only in normal use (e.g. switches):	
of metal	35
of porcelain or vitreous material	45
of moulded material, rubber or wood	60
Parts in contact with oil having a flash-point of t °C	t-50

NOTE 1 If other materials than those mentioned in the table are used, they are not to be subjected to temperatures in excess of their thermal capabilities as determined by ageing tests.

NOTE 2 The values in the table are based on an ambient temperature not normally exceeding 25°C but occasionally reaching 35°C. However, the temperature rise values specified are based on 25°C.

NOTE 3 The temperature of the terminals of switches is measured if the switch is tested in accordance with Annex H.

[a] To allow for the fact that the average temperature of windings of universal motors, relays, solenoids and similar components is usually above the temperature at the points on the windings where thermocouples are placed, the figures without parentheses apply when the resistance method is used and those within parentheses apply when thermocouples are used. For windings of vibrator coils and a.c. motors, the figures without parentheses apply in both cases. The temperature rise limit of windings in transformers and inductors mounted on printed circuit boards is equal to the thermal class of the winding insulation reduced by 25 K provided the largest dimension of the winding does not exceed 5 mm in cross section or length. For motors constructed so that the circulation of air between the inside and the outside of the case is prevented but which are not necessarily sufficiently enclosed to be considered airtight, the temperature rise limits may be increased by 5 K.

[b] T means the maximum ambient temperature in which the component or its switch head can operate. The ambient is the temperature of the air at the hottest point at a distance of 5 mm from the surface of the component concerned. However, if a thermostat or a temperature limiter is mounted on a heat-conducting part, the declared temperature limit of the mounting surface (Ts) is also applicable. Therefore, the temperature rise of the mounting surface has to be measured. The temperature rise limit does not apply to switches or controls tested in accordance with the conditions occurring in the appliance.

[c] This limit may be exceeded if the instruction specified in 7.12.3 is supplied.

[d] Locations for measuring the temperature rises are specified in Table 12.1 of IEC 60598-1.

[e] The values in parentheses apply to locations where the part is fixed to a hot surface.

[f] There is no specific limit for thermoplastic material. However, the temperature rise has to be determined in order that the tests of 30.1 can be carried out.

[g] The limit specified concerns the deterioration of wood and it does not take into account deterioration of surface finishes.

[h] There is no limit for the temperature rise of capacitors that are short-circuited in 19.11.

[i] Temperature marking for capacitors mounted on printed circuit boards may be given in the technical sheet.

[j] IEC 60245 Types 53 and 57 supply cords have a T rating of 60°C;
IEC 60245 Type 88 supply cords have a T rating of 70°C;
IEC 60227 Types 52 and 53 supply cords have a T rating of 70°C;
IEC 60227 Types 56 and 57 supply cords have a T rating of 90°C.

[za] Values for temperature rises of accessible parts in case of appliances that may be used by vulnerable people are given in relevant Parts 2.

[zb] When the thickness of plastic coating does not exceed $0,3$ mm, the temperature rise limits of coated metal or glass and ceramic apply.

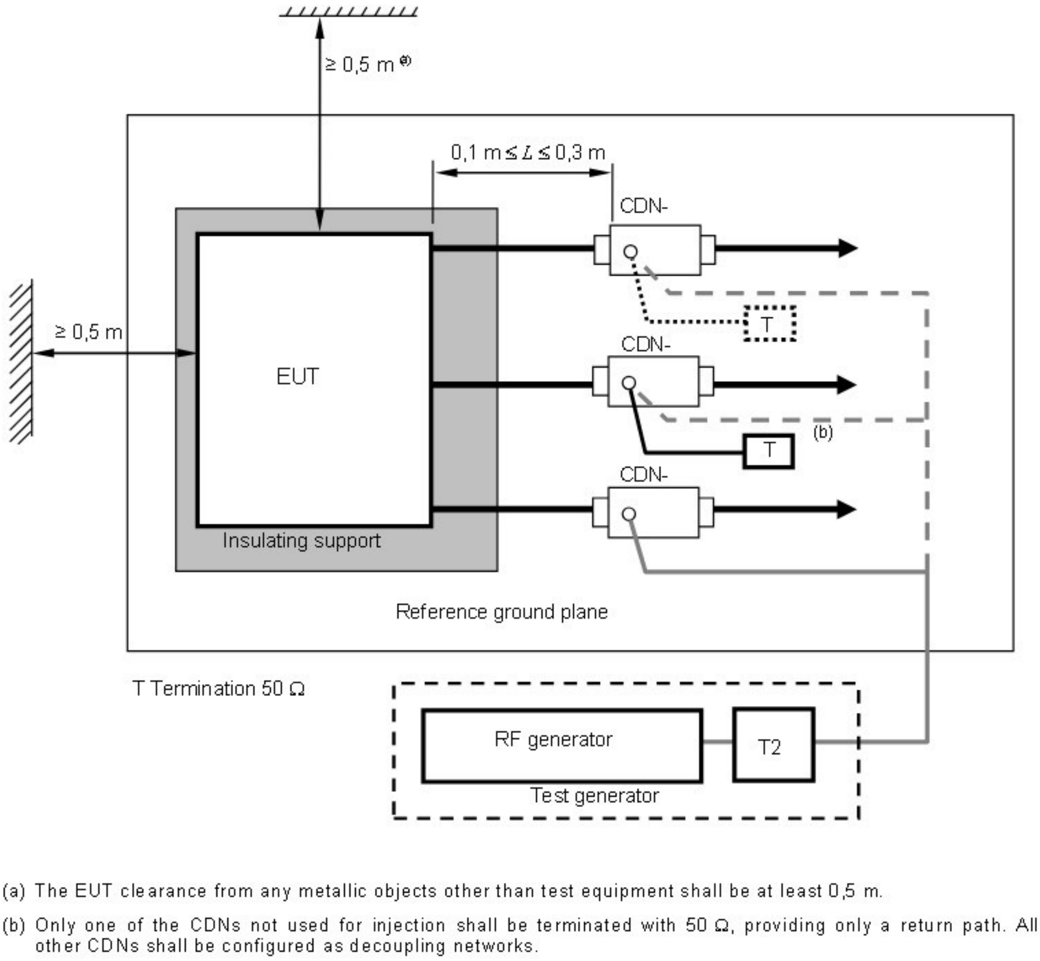


Figure (58) Injected current test setup with single unit EUT (top view)

[zc] Metal is considered coated when a coating having a minimum thickness of 80 μm made by enamel or non substantially plastic coating is used.
[zd] The temperature rise limit applies also for plastic material having a metal finish of thickness less than $0,1$ mm.

5 Overall facility budget

In conclusion, after deeply studying the selected International Standards, the equipment of the laboratory facility had been chosen. As regards the required budget, an average price of commercial instruments is shown in the tables 37, 38 and 39, which refer to the three investigated standards. The table 40 shows the overall budget for the calibration laboratory.

Table (37) Instrumentation test for winding wires (CEI 55014-1,2) - Overall equipment budget

Description	**Price (€)**
Pinhole tester	1500
Breakdown Voltage Test Apparatus With 3 Boost Speed	4000
Bare Wire Mandrel Winding and Torsion Tester	5500
Heated Circulating Baths with MX Temperature Controllers	3000
Total price	14000

Table (38) Instrumentation test for household appliances (CEI EN 60335-1) - Overall equipment budget

Description	**Price (€)**
Test fingers	1000
Leakage tester (Associated Research model 620L	10000
Wattmeter	12000
Temperature probes	200
Impulse generator	6000
Waterproof rain test chamber for IXP1-7 degrees of protection	4500
Thermal cycle test chamber	8500
Associated Research Hypot 3805	2000
Spring hammer	500
Torque meter	1000
Torque screwdriver	50
Earth Bond Resistance Tester	1500
Glow wire test full equipment	200
Oxygen Bomb Ageing Tester	12000
Test Equipment For Automatic Cord Reels Endurance	6000
High voltage generator	4000
Digital Storage Oscilloscope	5000
voltage generator	1000
Total price	74000

Table (39) Instrumentation test for household appliances (CEI EN 60335-2) - Overall equipment budget

Description	**Price (€)**
EFT/Electrical Fast Transient Burst Generators & Simulators	2950
CDN-M3-16A Coupling & Decoupling Network	1600
EFT-CAL-KIT Burst Generator Calibration Kit	3000
ESD Guns IF Insulating Foil for ESD Compliance Testing	200
ESD Test Table/Bench with Coupling Planes and Grounding Cables:	5000
GRC Series Ground Cable w/ 470k Ohm Resistors for ESD Voltage Bleeding	200
Anechoic chamber	550000
Amplifier Research 1 GHz Radiated Immunity Test System:	20000
Schwarzbeck STLP 9129 Stacked Logarithmic Periodic Antenna	6000
Rent Rohde & Schwarz FSV7 Signal and Spectrum Analyzer	25000
30 MHz - RF Current Monitor Probes	1000
RF cables	200
All Wood Non-Conducting EMC Test Table	2000
Coupling/decoupling network	1500
Surge Generator	7500
Total price	626150

Table (40) Calibration laboratory budget

Description	**Total price (€)**
Fluke 8588A 240-3-14 Reference Multimeter 8 12 Digit 3 ppm Includes ISO17025 Accredited Calibration Certificate Delivery 32 weeks	23000
Fluke 5550A 240-3-14 Multiproduct Calibrator 11 ppm Includes ISO17025 Accredited Calibration Certificate, hard box and set general pure cables Delivery 12-15 weeks	70000
5XSC600 Oscilloscope calibration option up to 600 MHz for Fluke 5550A (price valid for simultaneous purchase of the basic unit) Delivery starting from October 2023	32000
5XSC1100 Oscilloscope calibration option up to 1100 MHz for Fluke 5550A (price valid for simultaneous purchase of the basic unit) Delivery starting from October 2023	39000
Fluke 1621-S-256 Thermohygrometer. Includes 2 Standard Accuracy sensors, wall mounting kit, 7 m cable for sensor, RS232 cable, 9936 management software Delivery 20 weeks	3500
8588A-Lead Comprehensive Measurement Lead Kit for 8558A/8588A Delivery 6-8 weeks	1400
5440-7002 Test Lead Set, Banana, Low Thermal delivery time 6-8 weeks	2400
Total price	171300

References

[1] CEI EN. Household and similar electrical appliances - Safety Part 1: General requirements . Standard, Comitato elettrico italiano, May 2013.

[2] CEI EN IEC. Amendment 2 - Winding wires - Test methods - Part 5: Electrical properties. Standard, Comitato elettrico italiano, 2019.

[3] CEI EN IEC. Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 1 : Emission . Standard, Comitato elettrico italiano, 2021.

[4] CEI EN IEC. Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 2 : Immunity - Product family standard. Standard, Comitato elettrico italiano, 2021.