G.7.3 Cord anchorages and strain relief for non-detachable power supply cords

G.7.3.1 General

Safeguards against strain being transmitted to the equipment terminations of the conductors of cords or interconnecting cables connected to ES2 circuits, ES3 circuits or PS3 circuits are specified below.

G.7.3.2 Cord strain relief

G.7.3.2.1 Requirements

A knot shall not be used as a strain relief mechanism.

A screw that bears directly on the cord or cable shall not be used as a strain relief mechanism unless the cord anchorage, including the screw, is made of insulating material and the screw is of comparable size to the diameter of the cord being clamped.

When a linear force and a torque are applied to a **non-detachable power supply cord** or cable, a **basic safeguard** shall minimize strain from being transmitted to the cord or cable terminations.

The linear force applied to the cord or cable is specified in Table G.6. The force is applied in the most unfavourable direction for 1 s and repeated 25 times.

Table G.6– Strain relief test force

Mass of the equipment kg	**Force** N
Up to and including 1	30
Over 1 up to and including 4	60
Over 4	100

A torque of 0,25 Nm is applied for 1 min to the cord or cable immediately after the linear force application. The torque is applied as close as practicable to the strain relief mechanism and is repeated in the opposite direction.

Compliance is determined by applying the specified force and torque, by measurement, and visual inspection. There shall be no damage to the cord or conductors and the displacement of the conductors shall not exceed 2 mm. Stretching of the cord outer jacket without displacement of the conductors is not considered displacement.

G.7.3.2.2 Strain relief mechanism failure

If the **basic safeguard** (strain relief mechanism) should fail and strain is transmitted to the **non-detachable power supply cord** or cable terminations, a **supplementary safeguard** shall ensure that the earth termination is the last to take the strain.

*Compliance is determined by inspection and, if necessary, by defeating the **basic safeguard** and inspecting the conductor slack while applying the force in Table G.6.*

G.7.3.2.3 Cord sheath or jacket position

The cord or cable sheath or jacket shall extend from the **basic safeguard** (strain relief mechanism) into the equipment at least one-half the diameter of the cord or cable.

Compliance is checked by inspection.

G.7.3.2.4 Strain relief and cord anchorage material

The cord anchorage shall either be made of insulating material or have a lining of insulating material complying with the requirements for **basic insulation**. Where the cord anchorage is a bushing that includes the electrical connection to the screen of a screened power cord, this requirement shall not apply.

If the **basic safeguard** (strain relief mechanism) is made of polymeric material, the **basic safeguard** shall retain its structural properties following the mould stress relief according to Clause T.8.

*Compliance is determined by inspection and by applying the force and torque tests of G.7.3.2.1 after the **basic safeguard** has come to room temperature.*

G.7.4 Cord entry

Safeguards against electric shock and electrically-caused fire from cords or cables connected to ES2 circuits, ES3 circuits or PS3 circuits are specified below.

The entry of a cord or cable into the equipment shall be provided with **safeguards** against electric shock as specified in Clause 5. If the cord jacket passes the electric strength test of 5.4.9.1 for **supplementary insulation**, the cord jacket may be considered a **supplementary safeguard**.

The cord or cable entry shall be provided with a **supplementary safeguard** to:

– prevent abrasion of the cord or cable outer surface; and

– prevent the cord or cable from being pushed into the equipment to such an extent that the cord or its conductors, or both, could be damaged or internal parts of the equipment could be displaced.

*Compliance is determined by an electric strength test between the cord or cable conductors and **accessible** conductive parts following the tests of G.7.3.2.1. The test voltage shall be for **reinforced insulation** in accordance with 5.4.9.1.*

G.7.5 Non-detachable cord bend protection

G.7.5.1 Requirements

The **non-detachable power supply cord** of **hand-held equipment** or equipment intended to be moved while in operation shall be provided with a **safeguard** against jacket, insulation, or conductor damage due to bending at the equipment entrance.

Alternatively, the inlet or bushing shall be provided with a smoothly rounded bell-mouthed opening having a radius of curvature equal to at least 1,5 times the overall diameter of the cord with the largest cross-sectional area to be connected.

The cord bending **safeguard** shall:

– be so designed as to protect the cord against excessive bending where it enters the equipment; and

– be of insulating material; and

– be fixed in a reliable manner; and

– project outside the equipment beyond the inlet opening for a distance of at least five times the overall diameter or, for flat cords, at least five times the major overall cross-sectional dimension of the cord.

G.7.5.2 Test method and compliance criteria

*The equipment is so placed that the axis of the cord bending **safeguard**, where the cord emerges, projects at an angle of 45° when the cord is free from stress. A mass equal to $10 \times D^2$ g is then attached to the free end of the cord, where D is the overall diameter or, for flat cords, the minor overall dimension of the cord, in millimetres.*

If the cord guard is of temperature-sensitive material, the test is made at 23 °C ± 2 °C.

Flat cords are bent in the plane of least resistance.

Immediately after the mass has been attached, the radius of curvature of the cord shall nowhere be less than 1,5 D.

Compliance is checked by inspection, by measurement and, where necessary, by test with the cord as delivered with the equipment.

G.7.6 Supply wiring space

G.7.6.1 General requirements

The supply wiring space provided inside, or as part of, the equipment for permanent connection or for connection of an ordinary **non-detachable power supply cord** shall be designed:

– to allow the conductors to be introduced and connected easily; and

– so that the uninsulated end of a conductor is unlikely to become free from its terminal, or, should it do so, cannot come into contact with:

  - an **accessible** conductive part that is not connected to a **protective conductor**' or
  - an **accessible** conductive part of **hand-held equipment**; and

– to permit checking before fitting the cover, if any, that the conductors are correctly connected and positioned; and

– so that covers, if any, can be fitted without risk of damage to the supply conductors or their insulation; and

– so that covers, if any, giving access to the terminals can be removed with a **tool**.

Compliance is checked by inspection and by an installation test with cords of the largest cross-sectional area of the appropriate range specified in Table G.4.

G.7.6.2 Stranded wire

G.7.6.2.1 Requirements

The end of a stranded conductor shall not be consolidated by soft soldering at places where the conductor is subject to contact pressure unless the method of clamping is designed so as to reduce the likelihood of a bad contact due to cold flow of the solder.

Spring terminals that compensate for the cold flow are considered to satisfy this requirement.

Preventing the clamping screws from rotating is not considered to be adequate.

Terminals shall be located, guarded or insulated so that, should a strand of a flexible conductor escape when the conductor is fitted, there is no likelihood of accidental contact between such a strand and:

– **accessible** conductive parts; or

– unearthed conductive parts separated from **accessible** conductive parts by **supplementary insulation** only.

G.7.6.2.2 Test method and compliance criteria

Compliance is checked by inspection and, unless a special cord is prepared in such a way as to prevent the escape of strands, by the following test.

A piece of insulation approximately 8 mm long is removed from the end of a flexible conductor having the appropriate nominal cross-sectional area. One wire of the stranded conductor is left free and the other wires are fully inserted into, and clamped in the terminal. Without tearing the insulation back, the free wire is bent in every possible direction, but without making sharp bends around the guard.

If the conductor is an ES3 source, the free wire shall not touch any conductive part which is ***accessible*** *or is connected to an* ***accessible*** *conductive part or, in the case of double insulated equipment, any conductive part which is separated from* ***accessible*** *conductive parts by* ***supplementary insulation*** *only.*

If the conductor is connected to an earthing terminal, the free wire shall not touch any ES3 source.

G.8 Varistors

G.8.1 General

A varistor shall comply with:

– the **safeguards** against electric shock of G.8.2; and

– the **safeguards** against fire of G.8.3 if the method “reduce the likelihood of ignition” of 6.4.1 is chosen.

The **safeguards** against fire of G.8.3 are not applicable to a varistor used in a suppression circuit whose clamping voltage (see IEC 61051-1) is above a.c. **mains transient voltage**.

NOTE 1 A varistor is sometimes referred to as an MOV or a VDR.

NOTE 2 Such connections described above make the varistor a **PIS**.

G.8.2 Safeguards against electric shock

A varistor shall comply with IEC 61051-2, whether a **fire enclosure** is provided or not, taking into account all of the following:

– Preferred climatic categories (see 2.1.1 of IEC 61051-2:1991):
  - lower category temperature: – 10 °C
  - upper category temperature: + 85 °C
  - duration of damp heat, steady state test: 21 days.

– Maximum continuous voltage:
  - at least 1,25 times the **rated voltage** of the equipment or
  - at least 1,25 times the upper voltage of the **rated voltage range**.

  NOTE The maximum continuous voltages are not limited to values specified in 2.1.2 of IEC 61051-2:1991, other voltages can be used.

– Combination pulse (Table I group 1 of IEC 61051-2:1991, Amendment 1:2009).

For the test, a combination pulse is selected from subclause 2.3.6 in IEC 61051-2:1991, Amendment 1:2009. The test consists of 10 positive pulses or 10 negative pulses, each having a shape of 1,2/50 μs for voltage and 8/20 μs for current.

For the selection, a.c. **mains** voltage and overvoltage category, see Table 13.

Mains under 300 V is considered to be 300 V.

For overvoltage category IV of Table 13, a combination pulse 6kV/3kA is used except for 600 V, for which a combination pulse of 8 kV/4 kA is used. As an alternative, the combination pulse test of IEC 61051-2:1991, Amendment 1:2009 (2.3.6, Table I group 1 and Annex A), including consideration of the nominal **mains** voltage and overvoltage category, is acceptable.

In addition to the performance requirements of Table I group 1 of IEC 61051-2:1991 and Amendment 1:2009, the varistor voltage at the manufacturer's specified current after the test shall not have changed by more than 10 % when compared to the value before the test.

The body of surge suppression varistor shall comply with the needle flame according to IEC 60695-11-5, with the following test severities:

– Duration of application of the test flame: 10 s
– After flame time: 5 s

If the body of surge suppression varistor complies with **V-1 class material**, the needle flame test does not need to be performed.

G.8.3 Safeguards against fire

G.8.3.1 General

Supplementary safeguards to be provided against fire resulting from the failure of the varistor if the method “reduce the likelihood of ignition” of 6.4.1 is chosen are specified below.

A varistor shall be regarded as a **PIS**. In case the method “reduce the likelihood of ignition” is chosen, the varistor overload test of G.8.3.2; and **temporary overvoltage** test of G.8.3.3 shall be performed depending on the maximum continuous a.c. voltage of the varistor according to Table G.7.

Table G.7 – Varistor overload and temporary overvoltage test

Maximum continuous a.c. voltage of a varistor	Connection Between		
	L to N or L to L	L to PE	N to PE
1,25 × V_r to 2 × V_r	G.8.3.2	G.8.3.2 and G.8.3.3	G.8.3.2 and G.8.3.3
Over 2 × V_r to 1 200 + 1,1 × V_r	No test	G.8.3.3	G.8.3.3
Over 1 200 + 1,1 × V_r	No test	No test	No test
V_r is the **rated voltage** or the upper voltage of the **rated voltage range** of the equipment.			

G.8.3.2 Varistor overload test

*The following test is simulated as required by Table G.7 to either a varistor or a surge suppression circuit containing varistors connected across the **mains** (L to L or L to N), line to protective earth (L to PE), or neutral to protective earth (N to PE).*

The following test simulation circuit shall be used:

- *Voltage is the a.c source of 2 × V_r.*
- *Current is the current resulted from a test resistor R_x connected in series with the a.c source.*
- *V_r is the **rated voltage** or the upper voltage of the **rated voltage range** of the equipment.*

For line to neutral, if a fuse not exceeding 10 A is located in the equipment before and in series with the varistor, either an initial test resistor (R_1) may be used resulting in the same current as the fuse, or a short-circuit may be applied. If no fuse is connected in series, the test shall be performed with an initial test resistor R_1 = 16 × V_r.

For line to protective earth and neutral to protective earth, the test shall be performed with an initial test resistor R_1= 16 × V_r.

If the circuit does not open immediately during the initial application of test current, the test shall be continued until temperature stability (see B.1.6).

Subsequently, the test shall be repeated with new values of R_x (R_2, R_3, R_4, etc.) until the circuit opens.

- R_2 = 8 × V_r Ω
- R_3 = 4 × V_r Ω
- R_4 = 2 × V_r Ω
- R_x = 0,5 × (R_{x-1}) Ω

During the test, the circuit may open due to the operation of a protective device such as a fuse, a thermal fuse or a GDT.

Components in parallel with the varistor that may be affected by this test shall be disconnected.

*During and following the test, there shall be no risk of fire and **equipment safeguards**, other than the varistor under test, shall remain effective.*

G.8.3.3 Temporary overvoltage test

*The **temporary overvoltage** test is simulated by the following test methods where applicable:*

*A varistor or a surge suppression circuit containing varistors connected between the **mains** conductors and the earth, "Line to Protective Earth" and "Neutral to Protective Earth", the **temporary overvoltage** described below is applied. The test method and compliance criteria are described in 8.3.8.1 and 8.3.8.2 of IEC 61643-11.*

- *Line to Protective Earth:*
  - *withstand 1,71 × U_0 for 5 s.*
  - *withstand 1 200 + 1,1 × U_0 V ac for 5 s or fail safely.*
- *Neutral to Protective Earth:*

- *withstand 1 200 V a.c. for 200 ms.*

NOTE 1 U_0 is the nominal a.c. voltage of the system as defined in IEC 61643-11, which is the nominal line to neutral voltage (r.m.s. value of the a.c. voltage) of the system to which the EUT is intended to be connected.

If a surge suppression circuit is used, the combination pulse specified in G.8.2 is applied before this test.

During the test, the circuit may open due to the operation of a protective device such as a thermal fuse or a GDT.

NOTE 2 For different power distribution systems, the **temporary overvoltages** are defined in Annex B of IEC 61643-1.

Components in parallel with the varistor that may be affected by this test shall be disconnected.

G.9 Integrated circuit (IC) current limiters

G.9.1 Requirements

IC current limiters used for current limiting in power sources to become PS1 or PS2 are not shorted from input to output if all of the following conditions are met:

– the IC current limiters limit the current to manufacturer's defined value (not to be more than 5 A) under **normal operating conditions** with any specified drift taken into account;

– the IC current limiters are entirely electronic and have no means of manual operation or reset;

– the IC current limiters are supplied by a source whose output does not exceed 250 VA;

– the IC current limiters output current is limited to 5 A or less;

– the IC current limiters limit the current or voltage to the required value with the manufacturer's defined drift, as applicable, taken into account after each of the conditioning tests.

At the choice of the manufacturer, the conditioning tests shall be conducted in accordance with G.9.2, G.9.3 or G.9.4. IC current limiters that meet the test program of either G.9.2, G.9.3 or G.9.4 are considered to comply with the above requirements.

A different sample may be used for each test.

The power source for the tests should be capable of delivering 250 VA minimum unless the IC current limiter is tested in the end product.

G.9.2 Test program 1

Test program 1 consists of the following:

– *10 000 cycles of turning enable on and off with a 100 Ω ± 5 Ω resistor and a 425 μF ± 10 μF capacitor in parallel with the output;*

– *10 000 cycles of turning enable on and off with a ferrite-core inductor having 0,35 mH ± 0,1 mH inductance at 1 kHz and a d.c. resistance not exceeding 1 Ω;*

– *10 000 cycles of turning enable on and off with the input connected to a capacitor rated 425 μF ± 1 μF and shorting the output;*

– *10 000 cycles of turning the input pin on and off with a capacitor rated 425 μF ± 1 μF connected to the input supply while keeping enable active and shorting the output;*

– *10 000 cycles of turning the input pin on and off with a ferrite-core inductor having 0,35 mH ± 0,1 mH inductance at 1 kHz and a d.c. resistance not exceeding 1 Ω connected to the input supply and return while keeping enable active and shorting the output;*

– *50 cycles with the enable pin held active with the output open-circuited, each cycle consisting of shorting the output and then opening the output;*

– *50 cycles with the enable pin held active while applying a short to the output, each cycle consisting of turning the power on and off;*

– *50 cycles with the enable pin held active while power is applied, each cycle consisting of shorting the output, removing power, reapplying power, removing the short, followed by removal of power.*

G.9.3 Test program 2

Test program 2 consists of the following:

– *50 cycles with the enable pin held active with the output open-circuited; each cycle consisting of shorting the output and then opening the output;*

– *50 cycles with the enable pin held active while applying a short to the output; each cycle consisting of turning the power on and off;*

– *50 cycles with the enable pin held active with the output loaded to maximum power, each cycle consisting of turning the power on and off;*

– *50 cycles with the enable pin held active while power is applied, each cycle consisting of shorting the output, removing power, reapplying power, removing the short, followed by removal of power;*

– *3 cycles of exposing the device (not energized) to 70 °C ± 2 °C for 24 h; followed by at least 1 h at room ambient; followed by at least 3 h at – 30 °C ± 2 °C; followed by 3 h at room ambient;*

– *10 cycles of exposing the device (while energized) to 50 °C ± 2 °C for 10 min; followed by 10 min at 0 °C ± 2 °C with a 5 min period of transition from one state to the other;*

– *7 days with the output short-circuited and the device wrapped in a double layer of* ***cheesecloth****. A quick acting 5 A fuse kept in series with the output shall not open and a current meter shall not show a current of more than 5 A.*

G.9.4 Test program 3

Test program 3 consists of the following:

– *Subclause H.17.1.4.2 of IEC 60730-1:2010;*

– *10 000 cycles of turning enable on and off with a 100 Ω resistor and 425 μF capacitor in parallel with the output;*

– *10 000 cycles of turning enable on and off with a ferrite-core inductor having 0,35 mH ± 0,1 mH inductance at 1 kHz and a d.c. resistance not exceeding 1 Ω connected in the output circuit;*

– *10 000 cycles of turning enable on and off while input connected to a capacitor rated 425 μF and shorting the output;*

– *10 000 cycles of turning input pin on and off while a capacitor rated 425 μF to the input supply keeping enable active and shorting the output;*

– *10 000 cycles of turning input pin on and off with a ferrite-core inductor having 0,35 mH ± 0,1 mH inductance at 1 kHz and a d.c. resistance not exceeding 1 Ω connected to the input supply keeping enable active and shorting the output;*

– *50 cycles with enable pin held active and applying short to output with power on and off;*

– *50 cycles with enable pin held active and output loaded to maximum power with power on and off;*

– *50 cycles with enable pin held active and applying power, apply short to output; remove power, apply power, remove short, remove power;*

– *3 cycles of exposing the device (not energized) to 70 °C for 24 h; followed by at least 1 h at room ambient; followed by at least 3 h at –30 °C; followed by 3 h at room ambient;*

– *10 cycles of exposing the device (while energized) to 49 °C for 10 min; followed by 10 min at 0 °C with a 5 min period of transition from one state to the other.*

G.9.5 Compliance criteria

After each of the tests above, the device shall limit the current in accordance with its specification as applicable or the device shall become open circuit. The open circuited device is replaced with a new sample and tests continued as applicable.

G.10 Resistors

G.10.1 General

When required by 5.5.6, ten samples are tested for the resistor test of G.10.2. A sample is a single resistor if used alone, or a group of resistors in series.

G.10.2 Resistor test

Before the test, the resistance of ten samples is measured.

The samples shall be subjected to the damp heat test according to IEC 60068-2-78, with the following details:

– temperature: (40 ± 2) °C;

– humidity: (93 ± 3) % relative humidity;

– test duration: 21 days.

Each sample is then subjected to 10 impulses of alternating polarity, using the impulse test generator circuit 2 of Table D.1. The interval between successive impulses is 60 s, and U_C *is equal to the applicable* ***required withstand voltage****.*

After the test, the resistance of each sample shall not have changed by more than 10 %. No failure is allowed.

The lowest resistance value of the ten samples tested is used to measure the current when determining compliance with Table 4.

NOTE If a resistor or a group of resistors is connected between a circuit supplied by the **mains** and coaxial cable, G.10.3 applies.

G.10.3 Resistors serving as safeguards between the mains and an external circuit consisting of a coaxial cable

G.10.3.1 General

Test requirements for resistors bridging insulation between the **mains** and an **external circuit** consisting of a coaxial cable and that ensure that they do not significantly change in value over a long period of time are given below.

Ten samples of resistors (a sample is a single resistor if used alone or a group of resistors in series) are subjected to the conditioning of G.10.2 and followed by the test of G.10.3.2 or G.10.3.3 as applicable.

G.10.3.2 Voltage surge test

Each sample is subjected to 50 discharges from the impulse test generator circuit 3 of Table D.1, at not more than 12 discharges per minute, with U_c equal to 10 kV if the sample resistor is connected to coaxial cable connected to antenna (see Table 14).

G.10.3.3 Impulse test

Each sample is subjected to 10 pulses from the impulse test generator circuit 1 of Table D.1, with U_c equal to 4 kV or 5 kV of alternating polarity with a minimum of 60 s interval between pulses as applicable (see Table 14).

G.10.3.4 Compliance criteria

After the tests of G.10.3.2 or G.10.3.3, the resistance of each sample shall not have changed by more than 20 %. No failure is allowed.

G.11 Capacitors and RC units

G.11.1 General

The requirements below specify conditioning criteria when testing capacitors and RC units or discrete components forming an RC unit and serving as **safeguards** and provides selection criteria for capacitors and RC units that comply with IEC 60384-14.

G.11.2 Conditioning of capacitors and RC units

When required by 5.5.2.1, the following conditioning is applied when evaluating a capacitor or an RC unit to the requirements of IEC 60384-14.

The duration of the damp heat, steady-state test as specified in 4.12 of IEC 60384-14:2005, shall be 21 days at a temperature of (40 ± 2) °C and a relative humidity of (93 ± 3) %.

Capacitors subjected to a duration that is longer than 21 days during the above test are considered acceptable.

G.11.3 Rules for selecting capacitors

The appropriate capacitor subclass shall be selected from those listed in Table G.8, according to the rules of application in the table.

Table G.8 – Capacitor ratings according to IEC 60384-14

Capacitor subclass according to IEC 60384-14	Rated voltage of the capacitor V r.m.s.	Type test impulse test voltage of the capacitor kV peak	Type test r.m.s. test voltage of the capacitor kV r.m.s.
Y1	Up to and including 500	8	4
Y2	Over 150 up to and including 300	5	1,5
Y4	Up to and including 150	2,5	0,9
X1	Up to and including 760	4 [a]	-
X2	Up to and including 760	2,5 [a]	-

Rules for the application of this table.

1 The voltage rating of the capacitor shall be at least equal to the **r.m.s. working voltage** across the insulation being bridged, determined according to 5.4.1.8.2.

2 For a single capacitor (X type) serving as **functional insulation**, failure of the capacitor shall not result in the failure of a **safeguard** and the **type test** impulse test voltage shall be at least equal to the **required withstand voltage**.

3 A higher grade capacitor than the one specified may be used, as follows:

- subclass Y1 if subclass Y2 is specified;
- subclass Y1 or Y2 if subclass Y4 is specified;
- subclass Y1 or Y2 if subclass X1 is specified;
- subclass X1, Y1 or Y2 if subclass X2 is specified.

4 Two or more capacitors may be used in series in place of the single capacitor specified, as follows:

- subclass Y1 or Y2 if subclass Y1 is specified;
- subclass Y2 or Y4 if subclass Y2 is specified;
- subclass X1 or X2 if subclass X1 is specified.

5 If two or more capacitors are used in series they shall comply with 5.5.2.1 as applicable and comply with the other rules above.

[a] For capacitance values of more than 1 μF, this test voltage is reduced by a factor equal to $\sqrt{C}$, where C is the capacitance value in μF.

G.11.4 Examples of the application of capacitors

Table G.9 gives examples for the number of Y capacitors required bridging **basic insulation**, **supplementary insulation** or **reinforced insulation** based on the **required withstand voltage**. Table G.10 gives the maximum voltage that can appear across a Y capacitor based on the **peak working voltage**.

Table G.11 gives examples for the number of Y capacitors required bridging **basic insulation** and **reinforced insulation** based on the **temporary overvoltages**. Table G.12 gives examples of the application of X capacitors selected in accordance with Table G.8.