*A current derived from a source having a no-load voltage not exceeding 12 V (AC or DC) and equal to 1,5 times **rated current** of the appliance or 25 A, whichever is higher, is passed between the earthing terminal or earthing contact and each of the **accessible metal parts** in turn. The test is carried out until steady conditions have been established.*

*The voltage drop between the earthing terminal of the appliance or the earthing contact of the appliance inlet and the **accessible metal part** is measured. The resistance calculated from the current and this voltage drop shall not exceed 0,1 Ω. The resistance of the **supply cord** is not included in the resistance calculation.*

27.6 The printed conductors of printed circuit boards shall not be used to provide earthing continuity in **hand-held appliances**. They may be used to provide earthing continuity in other appliances if at least two tracks are used with independent soldering points and the appliance complies with 27.5 for each circuit.

Compliance is checked by inspection and by the relevant tests.

28 Screws and connections

28.1 Fixings, the failure of which may impair compliance with this standard, electrical connections and connections providing earthing continuity shall withstand the mechanical stresses occurring in normal use.

Screws used for these purposes shall not be of metal that is soft or liable to creep, such as zinc or aluminium. If they are of insulating material, they shall have a nominal diameter of at least 3 mm and they shall not be used for any electrical connections or connections providing earthing continuity.

Screws used for electrical connections or for connections providing earthing continuity shall screw into metal.

Screws shall not be of insulating material if their replacement by a metal screw could impair **supplementary insulation** or **reinforced insulation**. Screws that may be removed when replacing a **supply cord** having a **type X attachment** or when undertaking **user maintenance** shall not be of insulating material if their replacement by a metal screw could impair **basic insulation**.

Compliance is checked by inspection and by the following test.

Screws and nuts are tested if they are:

– *used for electrical connections;*
– *used for connections providing earthing continuity, unless at least two screws or nuts are used;*
– *likely to be tightened:*
  - *during **user maintenance**;*
  - *when replacing a **supply cord** having a **type X attachment**;*
  - *during installation.*

The screws or nuts are tightened and loosened without jerking:

– *10 times for screws in engagement with a thread of insulating material;*
– *5 times for nuts and other screws.*

Screws in engagement with a thread of insulating material are completely removed and reinserted each time.

When testing terminal screws and nuts, a cable or flexible cord of the largest cross-sectional area specified in Table 13 is placed in the terminal. It is repositioned before each tightening.

The test is carried out by means of a suitable screwdriver, spanner or key and by applying a torque as shown in Table 14.

Column I is applicable for metal screws without heads if the screw does not protrude from the hole when tightened.

Column II is applicable for:

– *other metal screws and for nuts;*
– *screws of insulating material:*
  - *having a hexagonal head with the dimension across flats exceeding the overall thread diameter;*
  - *with a cylindrical head and a socket for a key, the socket having a cross-corner dimension exceeding the overall thread diameter;*
  - *with a head having a slot or cross-slots, the length of which exceeds 1,5 times the overall thread diameter.*

Column III is applicable for other screws of insulating material.

Table 14 – Torque for testing screws and nuts

Nominal diameter of screw (outer thread diameter) *mm*	***Torque*** *Nm*		
	I	***II***	***III***
≤ 2,8	*0,2*	*0,4*	*0,4*
> 2,8 and ≤ 3,0	*0,25*	*0,5*	*0,5*
> 3,0 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*	*2,0*	*1,0*
> 5,3	*–*	*2,5*	*1,25*

No damage impairing the further use of the fixings or connections shall occur.

28.2 Electrical connections and connections providing earthing continuity shall be constructed so that contact pressure is not transmitted through non-ceramic insulating material that is liable to shrink or to distort unless there is sufficient resiliency in the metallic parts to compensate for any possible shrinkage or distortion of the insulating material.

This requirement does not apply to electrical connections in circuits of appliances for which:

– 30.2.2 is applicable and that carry a current not exceeding 0,5 A;
– 30.2.3 is applicable and that carry a current not exceeding 0,2 A.

Compliance is checked by inspection.

28.3 Space-threaded (sheet metal) screws shall only be used for electrical connections if they clamp the parts together.

Thread-cutting (self-tapping) screws and thread rolling screws shall only be used for electrical connections if they generate a full form standard machine screw thread. However, thread-cutting (self-tapping) screws shall not be used if they are likely to be operated by the user or installer.

Thread-cutting, thread rolling and space-threaded screws may be used in connections providing earthing continuity provided it is not necessary to disturb the connection:

– in normal use;
– during **user maintenance**;
– when replacing a **supply cord** having a **type X attachment**; or
– during installation.

At least two screws shall be used for each connection providing earthing continuity, unless the screw forms a thread having a length of at least half the diameter of the screw.

Compliance is checked by inspection.

28.4 Screws and nuts that make a mechanical connection between different parts of the appliance shall be secured against loosening by means such as spring washers, lock washers and crown type locks as part of the screw head, if they also make electrical connections or connections providing earthing continuity. Sealing compound that softens on heating may also be used to provide security against loosening but only for screw connections not subject to torsion in normal use.

This requirement does not apply to screws in the earthing circuit if at least two screws are used for the connection or if an alternative earthing circuit is provided.

Rivets used for electrical connections or for connections providing earthing continuity shall be secured against loosening if these connections are subject to torsion in normal use. A rivet having a non-circular shank or an appropriate notch may be used to secure against loosening if these connections are subject to torsion in normal use.

NOTE This requirement does not imply that more than one rivet is necessary for providing earthing continuity.

Compliance is checked by inspection and by manual test.

29 Clearances, creepage distances and solid insulation

Appliances shall be constructed so that the **clearances**, **creepage distances** and solid insulation are adequate to withstand the electrical stresses to which the appliance is liable to be subjected.

Compliance is checked by the requirements and tests of 29.1 to 29.3 that are carried out separately.

*If coatings are used on printed circuit boards to protect the microenvironment (type 1 protection) or to provide **basic insulation** (type 2 protection), normative Annex J applies. The microenvironment is pollution degree 1 under type 1 protection. For type 2 protection, the spacing between the conductors before the protection is applied shall not be less than the values as specified in Table 1 of IEC 60664-3:2016. These values apply to **functional insulation**, **basic insulation**, **supplementary insulation** as well as **reinforced insulation**.*

NOTE The requirements and tests are based on IEC 60664-1:2007 from which further information can be obtained.

29.1 **Clearances** shall not be less than the values specified in Table 16, taking into account the **rated impulse voltage** for the overvoltage categories of Table 15, unless, for **basic insulation** and **functional insulation**, they comply with the impulse voltage test of Clause 14.

For appliances intended for use at altitudes exceeding 2 000 m, the **clearances** in Table 16 shall be increased according to the altitude correction factor in Table A.2 of IEC 60664-1:2007.

If the construction is such that the distances could be affected by any of the following:

– distortion;
– movement of parts;
– assembly of parts;
– wear of **basic insulation**;
– wear of **functional insulation**,

the impulse voltage test is not applicable and the **clearances** for **rated impulse voltages** of 1 500 V and above specified in Table 16 are increased by 0,5 mm.

The impulse voltage test is not applicable:

– when the microenvironment is pollution degree 3; or
– for **basic insulation** of **class 0 appliances** and **class 0I appliances**; or
– to appliances intended for use at altitudes exceeding 2 000 m.

Appliances are in overvoltage category II.

NOTE 1 Informative Annex K gives information regarding overvoltage categories.

Table 15 – Rated impulse voltage

Rated voltage[a] V	**Rated impulse voltage** V **Overvoltage category**		
	I	**II**	**III**
≤ 50	330	500	800
> 50 and ≤ 150	800	1 500	2 500
> 150 and ≤ 300	1 500	2 500	4 000
NOTE 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.			
[a] For multi-phase appliances, the line to neutral or line to earth voltage is used for **rated voltage**.			

Table 16 – 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]
1 500	0,5 [c]
2 500	1,5
4 000	3,0
6 000	5,5
8 000	8,0
10 000	11,0
NOTE If the **rated impulse voltage** is not specified in the table, **clearances** for intermediate values of Table 16 can be determined by interpolation.	
[a] The distances specified apply only to **clearances** in air. [b] The smaller **clearances** specified in IEC 60664-1:2007 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.	

Compliance is checked by inspection and by measurement.

Parts, such as hexagonal nuts that can be tightened to different positions during assembly, and movable parts are placed in the most unfavourable position.

*A force is applied to bare conductors, other than those of heating elements, and **accessible surfaces** to try to reduce **clearances** when making the measurement. The force is:*

– *2 N, for bare conductors;*
– *30 N, for **accessible surfaces**.*

The force is applied by means of test probe B of IEC 61032. Apertures are assumed to be covered by a piece of flat metal.

NOTE 2 The way in which **clearances** are measured is specified in IEC 60664-1:2007.

NOTE 3 The procedure for assessing **clearances** is given in informative Annex L.

29.1.1 The **clearances** of **basic insulation** shall be sufficient to withstand the overvoltages likely to occur during use, taking into account the **rated impulse voltage**. The values of Table 16, or the impulse voltage test of Clause 14, are applicable.

The **clearance** at the terminals of tubular sheathed heating elements may be reduced to 1,0 mm if the microenvironment is pollution degree 1.

Lacquered conductors of windings are considered to be bare conductors.

Compliance is checked by measurement.

29.1.2 **Clearances** of **supplementary insulation** shall be not less than those specified in Table 16.

Compliance is checked by measurement.

29.1.3 **Clearances** of **reinforced insulation** shall be not less than those specified in Table 16, using the next higher step for **rated impulse voltage** as a reference.

*Compliance is checked by measurement. For **double insulation**, when there is no intermediate conductive part between the **basic insulation** and **supplementary insulation**, **clearances** are measured between **live parts** and the **accessible surface**, and the insulation system is treated as **reinforced insulation** as shown in Figure 11.*

29.1.4 The **clearances** for **functional insulation** are the largest values determined from:

– Table 16 based on the **rated impulse voltage**;
– Table F.7a in IEC 60664-1:2007 based on 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 does not exceed 30 kHz;
– Clause 4 of IEC 60664-4:2005 based on 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 of Table 16 are largest, the impulse voltage test of Clause 14 may be applied instead unless the microenvironment is pollution degree 3 or the construction is such that the distances could be affected by wear, by distortion, by movement of the parts or during assembly.

However, **clearances** are not specified if the appliance complies with Clause 19 with the **functional insulation** short-circuited.

Lacquered conductors of windings are considered to be bare conductors. However, **clearances** at crossover points are not measured.

The **clearance** between surfaces of **PTC heating elements** may be reduced to 1 mm.

Compliance is checked by measurement and by a test if necessary.

29.1.5 For appliances having higher **working voltages** than **rated voltage**, for example on the secondary side of a step-up transformer, or if there is a resonant voltage, the **clearances** for **basic insulation** are the largest values determined from:

– Table 16 based on the **rated impulse voltage**;
– Table F.7a in IEC 60664-1:2007 based on 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 does not exceed 30 kHz;
– Clause 4 of IEC 60664-4:2005 based on 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** applied for **basic insulation** are selected from Table F.7a of IEC 60664-1:2007 or Clause 4 of IEC 60664-4:2005, then the **clearances** of **supplementary insulation** shall be not less than those specified for **basic insulation**.

If the **clearances** applied for **basic insulation** are selected from Table F.7a of IEC 60664-1:2007, then the **clearances** of **reinforced insulation** shall be dimensioned as specified in Table F.7a to withstand 160 % of the withstand voltage required for **basic insulation**.

If the **clearances** applied for **basic insulation** are selected from Clause 4 of IEC 60664-4:2005, then the **clearances** of **reinforced insulation** shall be twice the value required for **basic insulation**.

If the secondary winding of a step-down transformer is earthed, or if there is an earthed screen between the primary and secondary windings, **clearances** of **basic insulation** on the secondary side shall be not less than those specified in Table 16, using the next lower step for **rated impulse voltage** as a reference.

For circuits supplied with a voltage lower than **rated voltage**, for example on the secondary side of a transformer, **clearances** of **functional insulation** are based on the **working voltage**, which is used as the **rated voltage** in Table 15.

Compliance is checked by measurement.

29.2 Appliances shall be constructed so that **creepage distances** are not less than those appropriate for the **working voltage**, taking into account the material group and the pollution degree.

NOTE 1 The **working voltage** for parts connected to the neutral is the same as for parts connected to the line and this is the **working voltage** for **basic insulation**.

Pollution degree 2 applies unless:

– precautions have been taken to protect the insulation, in which case pollution degree 1 applies;
– the insulation is subjected to conductive pollution, in which case pollution degree 3 applies.

NOTE 2 An explanation of pollution degree is given in informative Annex M.

Compliance is checked by measurement.

NOTE 3 The way in which **creepage distances** are measured is specified in IEC 60664-1:2007.

Parts such as hexagonal nuts that can be tightened to different positions during assembly, and movable parts are placed in the most unfavourable position.

*A force is applied to bare conductors, other than those of heating elements, and **accessible surfaces** to try to reduce **creepage distances** when making the measurement. The force is:*

– *2 N, for bare conductors;*
– *30 N, for **accessible surfaces**.*

The force is applied by means of test probe B of IEC 61032.

The relationship between the material group and the comparative tracking index (CTI) values, as given in Subclause 4.8.1.3 of IEC 60664-1:2007, is as follows:

– *material group I:* $600 \leq CTI$;
– *material group II:* $400 \leq CTI < 600$;
– *material group IIIa:* $175 \leq CTI < 400$;
– *material group IIIb:* $100 \leq CTI < 175$.

These CTI values are obtained in accordance with IEC 60112:2003 including IEC 60112:2003/AMD1:2009 using solution A. If the CTI value of the material is unknown, a proof tracking index (PTI) test in accordance with normative Annex N is carried out at the CTI values specified, in order to establish the material group.

NOTE 4 The procedure for assessing **creepage distances** is given in informative Annex L.

*In a **double insulation** system, the **working voltage** for both the **basic insulation** and **supplementary insulation** is taken as the **working voltage** across the complete **double insulation** system. It is not divided according to thickness and dielectric constants of the **basic insulation** and **supplementary insulation**.*

29.2.1 Creepage distances of **basic insulation** shall not be less than those specified in Table 17. However, if the **working voltage** is periodic and has a frequency that exceeds 30 kHz, the **creepage distances** shall also be determined from Table 2 of IEC 60664-4:2005. These values shall be used instead if they exceed the values in Table 17.

Except for pollution degree 1, if the test of Clause 14 has been used to check a particular **clearance**, the corresponding **creepage distance** shall not be less than the minimum dimension specified for the **clearance** of Table 16.

Table 17 – 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	4,0
400			1,0	2,0	2,8	4,0	5,0	5,6	6,3
500			1,3	2,5	3,6	5,0	6,3	7,1	8,0
> 630	and	≤ 800	1,8	3,2	4,5	6,3	8,0	9,0	10,0
> 800	and	≤ 1 000	2,4	4,0	5,6	8,0	10,0	11,0	12,5
> 1 000	and	≤ 1 250	3,2	5,0	7,1	10,0	12,5	14,0	16,0
> 1 250	and	≤ 1 600	4,2	6,3	9,0	12,5	16,0	18,0	20,0
> 1 600	and	≤ 2 000	5,6	8,0	11,0	16,0	20,0	22,0	25,0
> 2 000	and	≤ 2 500	7,5	10,0	14,0	20,0	25,0	28,0	32,0
> 2 500	and	≤ 3 200	10,0	12,5	18,0	25,0	32,0	36,0	40,0
> 3 200	and	≤ 4 000	12,5	16,0	22,0	32,0	40,0	45,0	50,0
> 4 000	and	≤ 5 000	16,0	20,0	28,0	40,0	50,0	56,0	63,0
> 5 000	and	≤ 6 300	20,0	25,0	36,0	50,0	63,0	71,0	80,0
> 6 300	and	≤ 8 000	25,0	32,0	45,0	63,0	80,0	90,0	100,0
> 8 000	and	≤ 10 000	32,0	40,0	56,0	80,0	100,0	110,0	125,0
> 10 000	and	≤ 12 500	40,0	50,0	71,0	100,0	125,0	140,0	160,0

NOTE 1 Lacquered conductors of windings are considered to be bare conductors, but **creepage distances** for **basic insulation** in other than a **double insulation** construction need not be greater than the associated **clearance** specified in Table 16 taking into account 29.1.1.

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 Except for circuits on the secondary side of an isolating transformer, the **working voltage** is considered to be not less than the **rated voltage** of the appliance.

NOTE 4 For **working voltages** > 50 V and ≤ 630 V, if the voltage is not specified in the table, the values of **creepage distances** can be found by interpolation.

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

Compliance is checked by measurement.

29.2.2 Creepage distances of **supplementary insulation** shall be at least those specified for **basic insulation** in Table 17, excluding its NOTE 1 and NOTE 2, or Table 2 of IEC 60664-4:2005, as applicable.

Compliance is checked by measurement.

29.2.3 Creepage distances of **reinforced insulation** shall be at least double those specified for **basic insulation** in Table 17, excluding its NOTE 1 and NOTE 2, or Table 2 of IEC 60664-4:2005, as applicable.

Compliance is checked by measurement.

29.2.4 **Creepage distances** of **functional insulation** shall be not less than those specified in Table 18. However, if the **working voltage** is periodic and has a frequency that exceeds 30 kHz, the **creepage distances** shall also be determined from Table 2 of IEC 60664-4:2005. These values shall be used instead if they exceed the values in Table 18.

The **creepage distances** may be reduced if the appliance complies with Clause 19 with the **functional insulation** short-circuited.

Table 18 – Minimum creepage distances for functional insulation

Working voltage V			**Creepage distance** mm **Pollution degree**[a]						
			1	**2**			**3**		
				Material group			**Material group**		
				I	**II**	**IIIa/IIIb**	**I**	**II**	**IIIa/IIIb** [b]
		≤ 10	0,08	0,4	0,4	0,4	1,0	1,0	1,0
50			0,16	0,56	0,8	1,1	1,4	1,6	1,8
125			0,25	0,71	1,0	1,4	1,8	2,0	2,2
250			0,42	1,0	1,4	2,0	2,5	2,8	3,2
400 [c]			0,75	1,6	2,2	3,2	4,0	4,5	5,0
500			1,0	2,0	2,8	4,0	5,0	5,6	6,3
> 630	and	≤ 800	1,8	3,2	4,5	6,3	8,0	9,0	10,0
> 800	and	≤ 1 000	2,4	4,0	5,6	8,0	10,0	11,0	12,5
> 1 000	and	≤ 1 250	3,2	5,0	7,1	10,0	12,5	14,0	16,0
> 1 250	and	≤ 1 600	4,2	6,3	9,0	12,5	16,0	18,0	20,0
> 1 600	and	≤ 2 000	5,6	8,0	11,0	16,0	20,0	22,0	25,0
> 2 000	and	≤ 2 500	7,5	10,0	14,0	20,0	25,0	28,0	32,0
> 2 500	and	≤ 3 200	10,0	12,5	18,0	25,0	32,0	36,0	40,0
> 3 200	and	≤ 4 000	12,5	16,0	22,0	32,0	40,0	45,0	50,0
> 4 000	and	≤ 5 000	16,0	20,0	28,0	40,0	50,0	56,0	63,0
> 5 000	and	≤ 6 300	20,0	25,0	36,0	50,0	63,0	71,0	80,0
> 6 300	and	≤ 8 000	25,0	32,0	45,0	63,0	80,0	90,0	100,0
> 8 000	and	≤ 10 000	32,0	40,0	56,0	80,0	100,0	110,0	125,0
> 10 000	and	≤ 12 500	40,0	50,0	71,0	100,0	125,0	140,0	160,0

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