13.2 *The leakage current is measured by means of the circuit of Figure 10 between any pole of the supply and accessible metal parts and metal foil with an area not exceeding 20 cm × 10 cm in contact with accessible surfaces of insulating material, connected together.*

The metal foil has the largest area possible on the surface under test, without exceeding the dimensions specified. If its area is smaller than the surface under test, it is moved so as to test all parts of the surface. The heat dissipation of the tool shall, however, not be affected by the metal foil.

Three-phase tools, which are suitable for single-phase supply, are tested as single-phase tools with the three sections connected in parallel. For single-phase tools and three-phase tools to be tested as single-phase tools, the leakage current is measured with the selector switch shown in Figure 3, in each of the positions 1 and 2, and the switch S1 in "on" position.

For three-phase tools not suitable for single-phase supply, the leakage current is measured according to Figure 4, with the switches a, b and c in the "on" position. For tools intended to be connected in star connection only, the neutral is not connected.

The leakage current is measured within 5 s after the application of the test voltage and shall not exceed the following values:

– *to accessible metal parts and metal foil:*
  - *for class I tools 0,75 mA;*
  - *for class II tools 0,25 mA;*
  - *for class III tools 0,5 mA.*

If the tool incorporates one or more capacitors, and is provided with a single-pole switch, the measurements are repeated with the switch in the "off" position.

14 Moisture resistance

14.1 The enclosure of the tool shall provide the degree of protection against moisture in accordance with the classification of the tool.

Compliance is checked by the appropriate treatment specified in 14.1.2, with the tool conditions as in 14.1.1.

14.1.1 *The tool is not connected to the supply.*

Tools are turned continuously through the most unfavourable positions during the test.

Tools with type X attachment are fitted with the lightest permissible type of flexible cord of the smallest cross-sectional area specified in 25.2; other tools are tested as delivered.

Electrical components, covers and other parts which can be removed without the aid of a tool are removed and subjected, if necessary, to the relevant treatment with the main part.

14.1.2 *Tools other than IPX0 are subjected to tests of IEC 60529 as follows:*

– *IPX1 tools are subjected to the test described in 14.2.1;*
– *IPX2 tools are subjected to the test described in 14.2.2;*
– *IPX3 tools are subjected to the test described in 14.2.3;*
– *IPX4 tools are subjected to the test described in 14.2.4;*
– *IPX5 tools are subjected to the test described in 14.2.5;*
– *IPX6 tools are subjected to the test described in 14.2.6;*
– *IPX7 tools are subjected to the test described in 14.2.7.*

For this last test, the tool is immersed in water containing approximately 1,0 % NaCl.

Immediately after the appropriate treatment, the tool shall withstand the electric strength test of Clause 15, and inspection shall show that there is no trace of water on insulation which could result in a reduction of creepage distances and clearances below the values specified in 28.1.

Tools which are not subject to spillage of liquid in normal use are allowed to stand in normal test-room atmosphere for 24 h before being subjected to the test of 14.3.

14.2 Tools subject to spillage of liquid in normal use shall be so constructed that such spillage does not affect their electrical insulation.

Compliance is checked by the following test:

Tools incorporating an appliance inlet are fitted with an appropriate connector and flexible cord; tools with type X attachment are fitted with the lightest permissible type of flexible cord of the smallest cross-sectional area specified in 25.2; other tools are tested as delivered.

Electrical components, covers and other parts which can be removed without the aid of a tool are removed, except those fulfilling the test of 21.22.

The liquid container of the tool is completely filled with water containing approximately 1,0 % NaCl, and a further quantity, equal to 15 % of the capacity of the container, or 0,25 l, whichever is the greater, is poured in steadily over a period of 1 min.

Immediately after this treatment, the tool shall withstand an electric strength test as specified in Clause 15, and inspection shall show that there is no trace of water on insulation which could result in a reduction of creepage distances and clearances below the values specified in 28.1.

The tool is allowed to stand in normal test-room atmosphere for 24 h before being subjected to the test of 14.3.

14.3 Tools shall be proof against humid conditions which may occur in normal use.

Compliance is checked by the following humidity test.

Cable entries, if any, are left open; if knock-outs are provided, one of them is opened.

Electrical components, covers, and other parts which can be removed without the aid of a tool are removed and subjected, if necessary, to the humidity test with the main part.

The humidity treatment is carried out in a humidity cabinet containing air with a relative humidity of (93 ± 2) %, obtained e.g. by placing in the humidity cabinet a saturated solution of Na_2SO_4 or KNO_3 in water, having a sufficiently large contact surface with the air. The temperature of the air, at all places where samples can be located, is maintained within 1 K of any convenient value t between 20 °C and 30 °C. In order to achieve the specified conditions within the cabinet, it is necessary to ensure constant circulation of the air within and, in general, to use a cabinet which is thermally insulated.

Before being placed in the humidity cabinet, the sample is brought to a temperature between t and (t + 4) °C. The tool is considered to be brought to the specified temperature by keeping it at this temperature for at least 4 h before the humidity treatment.

The tool is kept in the cabinet for 48 h.

Immediately after this test, the tool shall withstand the tests of Clause 13 at rated voltage or the mean of the rated voltage range with the tool switch in the "on" position and under the following conditions.

For single-phase tools and for three-phase tools to be tested as single-phase tools: S1 of Figure 3 in the "off" position.

For three-phase tools not suitable for single-phase supply: a in Figure 4 in the "on" position, b and c in "off" position.

Then the tool shall withstand the test of Clause 15 in the humidity cabinet, or in the room in which the tool was brought to the prescribed temperature after reassembly of those parts which may have been removed.

14.4 Liquid systems shall not subject the user to an increased risk of electrical shock during foreseeable misuse.

Compliance is checked by the following test:

The residual current device, if any, shall be disabled during the test.

The tool is operated at rated voltage with approximately 1,0 % NaCl solution in the following modes if applicable:

- *after overfilling of the fluid reservoir by 15 % of the capacity of the container, or by 0,25 l, whichever is the greater;*
- *omission of a washer or other user removable part;*
- *mis-assembly of liquid system connections routinely made by the user.*

In each mode, the tool is operated for 1 min in all positions consistent with the relevant part 2 and the manufacturer's instructions while monitoring the leakage current as in Clause 13. During the test the leakage current shall not exceed:

- *2 mA for a class II tool;*
- *5 mA for a class I tool.*

Following this test, the tool shall meet the test of 13.1 after being allowed to dry for 24 h at ambient temperature.

14.5 Liquid systems shall be constructed of components capable of withstanding the pressure in normal use without leaking.

Compliance is checked by the following test:

The liquid system is closed and an approximately 1,0 % NaCl solution at a hydrostatic pressure equal to twice the pressure stated in 8.12.2 d) 1) is applied for 1 h. The leakage current of accessible parts is measured as described in Clause 13. During the test the leakage current shall not exceed:

- *2 mA for a class II tool;*
- *5 mA for a class I tool.*

Following this test, the tool shall meet the test of 13.1 after being allowed to dry for 24 h at ambient temperature.

The residual current device, if any, shall be disabled during the test.

14.6 Residual current devices used to provide protection from shock in the case of failure of the liquid system shall comply with IEC 61540 and shall meet the following requirements a) to c):

a) The RCD shall disconnect both mains conductors, but not the earth conductor if provided, when the leakage exceeds 10 mA and with a maximum response of 300 ms.

   Compliance is checked by inspection and the test of 9.9.2 of IEC 61540. In addition, during the test, the earthing conductor shall not become disconnected.

b) The RCD shall be reliable for its intended use.

   Compliance is checked at rated voltage by operating the residual current device under conditions of simulated leakage as in (a) above during conditions of locked rotor of the tool for 50 cycles. The residual current device shall operate correctly for all cycles.

c) The RCD shall be installed such that it is unlikely to be removed during use or routine normal maintenance.

   This requirement is considered fulfilled if the residual current device is fixed to the tool or the power supply cord connected to the tool.

   Where fitted in the supply cord, the residual current device shall be provided with Type Y attachment or Type Z attachment for connection with the supply cord and interconnecting cord.

   Compliance is checked by inspection.

15 Electric strength

15.1 The electric strength shall be adequate.

Compliance is checked by the tests of 15.2.

Protective impedance is disconnected from live parts before carrying out the tests.

The tests are made on the tools at room temperature and not connected to the supply.

15.2 *The insulation is subjected for 1 min to a voltage of substantially sinusoidal waveform, having a frequency of 50 Hz or 60 Hz. The value of the test voltage and the points of application are shown in Table 2, unless otherwise specified.*

Accessible parts of insulated material are covered with metal foil.

Table 2 – Test voltages

Points of application	Test voltage V		
	Class III tools and construction	**Class II tools and construction**	**Other tools**
1. Between live parts and accessible parts separated from live parts by			
– basic insulation only	500	–	1 250
– reinforced insulation	–	3 750	3 750
2. For parts with double insulation, between metal parts separated from live parts by basic insulation only, and			
– live parts	–	1 250	1 250
– accessible parts	–	2 500	2 500
3. Between metal enclosures or covers lined with insulating material and metal foil in contact with the inner surface of the lining, if the distance between live parts and these metal enclosures or covers, measured through the lining, is less than the appropriate clearance as specified in 28.1	–	2 500	1 250
4. Between metal foil in contact with handles, knobs, grips and the like and their shafts, if these shafts can become live in the event of an insulation fault	–	2 500	2 500
5. Between accessible parts and internal diameter of cord guard wrapped with metal foil	–	2 500	1 250
6. Between the point where a winding and a capacitor are connected together, if a resonance voltage *U* occurs between this point and any terminal for external conductors, and			
– accessible parts [a)]	–	–	2 *U* + 1 000
– metal parts separated from live parts by basic insulation only	–	2 *U* + 1 000	–

[a)] The test between the point where a winding and a capacitor are connected together, and accessible parts or metal parts, is only made where the insulation is subjected to the resonance voltage under normal running conditions. Other parts are disconnected, and the capacitor is short-circuited.

Initially, not more than half the prescribed voltage is applied, then it is raised rapidly to the full value.

No flashover or breakdown shall occur during the test.

The high-voltage transformer used for the test must be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current is at least 200 mA.

The overcurrent relay must not trip when the output current is less than 100 mA.

Care is taken that the r.m.s. value of the test voltage applied is measured within ±3 %.

Care is taken that the metal foil is so placed that no flashover occurs at its edges or the edges of the insulation.

For class II construction incorporating both reinforced insulation and double insulation, care is taken that the voltage applied to the reinforced insulation does not overstress the basic insulation, or the supplementary insulation.

In cases where basic insulation and supplementary insulation cannot be tested separately, the insulation provided is subjected to the test voltages specified for reinforced insulation.

When testing insulating coatings, the metal foil may be pressed against the insulation by means of a sandbag of such a size that the pressure is about 5 kPa (0,5 N/cm^2). The test may be limited to places where the insulation is likely to be weak, for example where there are sharp metal edges under the insulation.

If practicable, insulating linings are tested separately.

For tools with heating elements incorporated, the test voltages specified in IEC 60335-1 apply to the heating elements only and not to other parts of the tool.

16 Overload protection of transformers and associated circuits

Tools incorporating circuits supplied from a transformer shall be so constructed that, in the event of short circuits which are likely to occur in normal use, excessive temperatures do not occur in the transformer, or in the circuits associated to the transformer.

Examples of short-circuits which are likely to occur in normal use are the short-circuiting of bare or inadequately insulated conductors of safety extra-low voltage circuits which are accessible, and the internal short-circuiting of lamp filaments.

A failure of insulation complying with the requirements specified for basic insulation of class I or class II construction is not, for the purpose of this requirement, considered as likely to occur in normal use.

Compliance is checked by applying the most unfavourable short circuit or overload which is likely to occur in normal use, the tool being operated at a voltage equal to 1,06 times, or 0,94 times, rated voltage, whichever is the more unfavourable.

The temperature rise of the insulation of the conductors of safety extra-low voltage circuits is determined, and shall not exceed the relevant value specified in Table 1 by more than 15 K.

The winding temperature of transformers shall not exceed the value specified for windings in 18.9, except for transformers which comply with IEC 61558-1.

NOTE Protection of transformer windings may be, for example, obtained by the inherent impedance of the winding, or by means of fuses, automatic switches, thermal cut-outs or similar devices incorporated in the transformer, or similar devices located inside the tool only accessible with the aid of a tool.

17 Endurance

17.1 Tools shall be so constructed that, in extended normal use, there will be no electrical or mechanical failure that might impair compliance with this standard. The insulation shall not be damaged and contacts and connections shall not work loose as a result of heating, vibrations, etc.

Moreover, overload protection devices shall not operate under normal running conditions.

Compliance is checked by the test of 17.2 and, for tools provided with a centrifugal or other starting switch, also by the test of 17.3.

Immediately after these tests, the tool shall withstand an electric strength test as specified in Clause 15, the test voltages being, however, reduced to 75 % of the specified values. Connections shall not have worked loose, and there shall be no deterioration impairing safety in normal use.

17.2 *The tool is operated intermittently with no-load for 24 h of operation at a voltage equal to 1,1 times rated voltage, and then for 24 h at a supply voltage equal to 0,9 times rated voltage.*

The tool may be switched on and off by means of a switch other than that incorporated in the tool.

Each cycle of operation comprises an "on" period of 100 s and an "off" period of 20 s, the "off" periods being included in the specified operating time.

The operating period for tools for short-time or intermittent operation is equal to the operating time, if this is limited by the construction of the tool; otherwise, it is in accordance with the prescriptions given in part 2, or with the marking, whichever is the more unfavourable.

During the test, the tool is placed in three different positions, the operating time, at each test voltage, being approximately 8 h for each position.

During this test, replacement of the carbon brushes is allowed, and the tool is oiled and greased as in normal use.

If the temperature rise of any part of the tool exceeds the temperature rise determined during the test of 12.1, forced cooling or rest periods are applied, the rest periods being excluded from the specified operating time.

During these tests, overload protection devices shall not operate.

NOTE The change of position is made to prevent abnormal accumulation of carbon dust in any particular place. Examples of the three positions are horizontal, vertically up and vertically down.

17.3 *Tools provided with a centrifugal or other automatic starting switch are started 10 000 times under normal load, and at a voltage equal to 0,9 times rated voltage, the operating cycle being that specified in 17.2.*

18 Abnormal operation

18.1 Tools shall be so designed that the risk of fire and mechanical damage impairing safety or the protection against electric shock as a result of abnormal operation is obviated as far as is practicable.

Fuses, thermal cut-outs, overcurrent protection devices or the like, incorporated into the tool, may be used to provide the necessary protection.

Compliance is checked by the tests of 18.2 to 18.9.

18.2 *Tools incorporating heating elements are subjected to the tests of 18.3 and 18.4. Moreover, tools provided with a control limiting the temperature during Clause 12 tests unless specifically excluded by part 2, are subjected to the tests of 18.5, and where applicable, to the test of 18.6.*

Only one abnormal condition is simulated each time. If more than one of the tests are applicable to the same tool, these tests are made consecutively.

Unless otherwise specified, the tests are continued until a non-self-resetting thermal cut-out operates, or until steady conditions are established. If, during the test, a heating element or an intentionally weak part is permanently open-circuited, the relevant test is repeated on a second sample. This second test shall be terminated in the same way, unless the test is otherwise satisfactorily completed.

An intentionally weak part is a part intended to fail under conditions of abnormal operation so as to prevent the occurrence of a condition which could impair compliance with this standard. Such a part may be a replaceable component, such as a resistor, a capacitor, or a thermal link, or a part of a component to be replaced, such as an inaccessible and non-resettable thermal cut-out incorporated in a motor.

18.3 *Tools with heating elements are tested under the conditions specified in Clause 12, but with restricted heat dissipation. The supply voltage, determined prior to the test, is that required to provide a power input of 0,85 times the rated power input under normal operation, when steady conditions have been established. This voltage is maintained throughout the test.*

The tool is allowed to cool down to approximately room temperature before being subjected to the test of 18.4.

18.4 *The test of 18.3 is repeated, but with a supply voltage, determined prior to the test, equal to that required to provide a power input of 1,24 times rated power input under normal operation, when steady conditions have been established. This voltage is maintained throughout the test.*

18.5 *The tool is tested under the conditions specified in Clause 12, under normal operation, the supply voltage being such that the power input is 1,15 times rated power input, but with any control which limits the temperature during the test of Clause 12 short-circuited.*

If the tool is provided with more than one control, these are short-circuited in turn.

18.6 *Unless an all-pole disconnection occurs during the test of 18.5 for class I tools with tubular sheathed and embedded heating elements, but which are not intended to be permanently connected to fixed wiring, the test of 18.5 is repeated, with the controls which limit the temperature during the test of Clause 12 not short-circuited, and one end of the element connected to earth. This test is repeated with the polarity of the supply to the tool reversed and with the other end of the element connected to earth.*

18.7 *The following test is performed with cutting tools, such as sawblades, grinding wheels, etc., removed.*

– *Tools incorporating a commutator motor are operated at a voltage equal to 1,3 times rated voltage, or the upper limit of the voltage range, for 1 min at no-load.*

After the tests of 18.2 to 18.7, the safety of the tool shall not have been impaired, in particular windings and connections shall not have worked loose. After these tests, the tool need not be capable of further use.

18.8 *The following categories of tools incorporating induction motors and:*

a) with a starting torque less than the full-load torque; or

b) started by hand; or

c) provided with moving parts which are liable to be jammed, or where the moving parts can be stopped by hand, the motor remaining switched on during this operation;

are connected, starting from cold, to their rated voltage or the upper limit of their rated voltage range with the moving parts locked

- *for 30 s for tools that are operated by hand during use;*
- *for 5 min for tools that are attended during use.*

At the end of the test period specified, or at the instant of operation of fuses, thermal cut-outs, motor protection devices, and the like, the temperature of the windings shall not exceed the values shown in Table 3.

18.9 *Tools incorporating three-phase motors are operated, starting from cold,*

- *for 30 s, if they are kept switched on by hand or continuously loaded by hand;*
- *or otherwise, for 5 min,*

with one phase disconnected, and under the torque producing normal load.

At the end of the test period specified, or at the instant of operation of fuses, thermal cut-outs, motor protection devices, and the like, the temperature of the windings shall not exceed the values shown in Table 3.

Table 3 – Maximum winding temperature

Protection of windings	Limiting temperature °C							
	Class							
	105	120	130	155	180	200	220	250
Protection by inherent impedance	150	165	175	190	210	230	250	280
Protection by protective devices which operate during the test	200	215	225	240	260	280	300	330

18.10 Electronic circuits shall be so designed and applied so that a fault condition will not render the tool unsafe with regard to electric shock, fire hazard, mechanical hazard or dangerous malfunction.

Compliance is checked by evaluation of the fault conditions specified in 18.10.2 for all circuits or parts of circuits, unless they comply with the conditions specified in 18.10.1.

If the safety of the tool under any of the fault conditions depends on the operation of a miniature fuse-link complying with IEC 60127-3, the test of 18.10.3 is made.

If a conductor of a printed circuit board becomes open-circuited, the tool is considered to have withstood the particular test, provided all three of the following conditions are met:

– *the base material of the printed circuit board withstands the test of Annex F;*
– *any loosened conductor does not reduce the creepage distances or clearances between live parts and accessible metal parts below the values specified in Clause 28;*
– *the tool withstands the tests of 18.10.2 with the open-circuited conductor bridged.*

NOTE Examination of the tool and its circuit diagram will reveal the fault conditions which have to be simulated, so that testing can be limited to those cases which may be expected to give the most unfavourable result.

18.10.1 *Fault conditions a) to f) specified in 18.10.2 are not applied to circuits or parts of circuits when both of the following conditions are met:*

– *the electronic circuit is a low-power circuit as described below;*
– *the protection against electric shock, fire hazard, mechanical hazard or dangerous malfunction of other parts of the tool does not rely on the correct functioning of the electronic circuit.*

An example of a low-power circuit is shown in Figure 11 and is determined as follows.

The tool is operated at rated voltage or at the upper limit of the rated voltage range and a variable resistor, adjusted to its maximum resistance, is connected between the point to be investigated and the opposite pole of the supply source. The resistance is then decreased until the power consumed by the resistor reaches a maximum. Any point closest to the supply at which the maximum power delivered to this resistor does not exceed 15 W at the end of 5 s is called a low power point. The part of the circuit farther from the supply source than a low power point is considered to be a low-power circuit.

The measurements are made from only one pole of the supply source, preferably the one that gives the fewest low power points.

NOTE When determining the low power points, it is recommended to start with the points close to the supply source.

18.10.2 *The following fault conditions are considered and, if necessary, applied one at a time, consequential faults being taken into consideration:*

a) short-circuit of creepage distances and clearances between conductive parts of different polarity, if these distances are less than the values specified in Clause 28, unless the relevant part is adequately encapsulated;

b) open-circuit at the terminal of any electronic component;

c) short-circuit of capacitors, unless they comply with IEC 60384-14;

d) short-circuit of any two terminals of an electronic component, other than an integrated circuit. This fault is not applied between the two circuits of an optocoupler;

e) failure of triacs in the diode mode;

f) failure of an integrated circuit. In this case the possible hazardous situations of the tool are assessed to ensure that safety does not rely on the correct functioning of such a component. All possible output signals are considered under fault conditions within the integrated circuit. If it can be shown that a particular output signal is unlikely to occur, then the relevant fault is not considered.

Components such as thyristors and triacs are not subjected to fault condition f).

Fault condition f) is applied to encapsulated and similar components if the circuit cannot be assessed by other methods.

NOTE Microprocessors are examples of integrated circuits.

Positive temperature coefficient resistors (PTC's) are not short-circuited if they are used within their manufacturer's declared specification.

In addition, each low-power circuit is short-circuited by connecting the low power point to the pole of the supply from which the measurements were made.

For simulation of the conditions, the tool is operated under the conditions specified in Clause 12, but at rated voltage or at the most unfavourable voltage within the rated voltage range.

When any of the fault conditions are simulated, the duration of the test is:

– *as specified in 12.4, but only if the fault cannot be recognized by the user, for example, change in temperature;*

– *as specified in 18.8, if the fault can be recognized by the user, for example, when the motor stops;*

– *until steady conditions are established, for circuits continuously connected to the supply mains, for example, stand-by circuits.*

In each case, the test is ended if interruption of the supply occurs within the tool.