Omar Beihat

Method of Basic Testing of Electrical Appliances and Comparison to Full Testing from Viewpoint of Safety

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Abstract

Author:	Omar Beihat
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The goal of this thesis is to provide a detailed understanding of the basic testing process of electrical appliances at SGS Fimko, in accordance with the IEC 60335 standard. In addition, the thesis aims to analyze the differences between conducting basic testing and a previous full testing of an appliance to determine if there are significant differences in the results.

The project was conducted by gaining extensive knowledge of the IEC 60335 standard's tests and doing basic testing in the laboratory to observe different appliances safety performance. The most important tests and methods were listed to this thesis according to past observations, on which of the tests matter to the safety of the appliance.

After comparing chargers which had a full testing conducted, a conclusion was reached. If an appliance which had full testing done, would had only basic testing done, the result would not have changed. The primary reason for the lack of significant difference between the full testing and basic testing of the appliance is likely due to the nature of the testing that the appliance was subjected to. Appliances that undergo full testing are often those that are being certified, and manufacturers have a strong incentive to build these appliances in compliance with safety standards to obtain the certification mark. However, for appliances that are subject to basic testing by a safety authority, manufacturers may not have built them according to European safety standards as they may sell the appliance globally and are not aimed specifically at the internal market of the European Union.

Keywords: safety testing, IEC 60335, electrical appliance, standard

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Tämän opinnäytetyön tavoitteena on tarjota yksityiskohtainen ymmärrys SGS Fimkon suorittamasta sähkölaitteiden perustestauksesta IEC 60335 -standardin mukaisesti. Lisäksi tavoitteena on analysoida perustestauksen ja aikaisemman täyden testauksen eroja laitteiden testaamisessa ja selvittää, ovatko tulokset merkittävästi erilaisia.

Projekti toteutettiin hankkimalla laaja ymmärrys IEC 60335 -standardin testeistä ja tekemällä perustestaus laboratoriossa erilaisten sähkölaitteiden turvallisuuden tarkkailemiseksi. Tärkeimmät testit ja menetelmät listattiin tähän opinnäytetyöhön aiempien havaintojen perusteella, jotta saatiin selville, mitkä testit ovat tärkeitä laitteen turvallisuuden kannalta.

Verrattaessa latureita, jolle oli suoritettu täysi testaus, tehtiin johtopäätös, että jos laitteelle olisi tehty vain perustestaus, tulokset eivät olisi olleet erilaisia. Tämän merkittävän eron puuttuminen perustestauksen ja täyden testauksen välillä johtuu todennäköisesti siitä, millaisesta syystä testaus on laitteelle tehty. Laitteet, jotka käyvät läpi täyden testauksen, ovat usein niitä, joita sertifioidaan, ja valmistajilla on vahva kannustin rakentaa nämä laitteet turvallisuusstandardien mukaisesti saadakseen sertifikaattimerkin. Kuitenkaan laitteita, joita turvallisuusviranomainen testauttaa, eivät niiden valmistajat välttämättä ole rakentaneet eurooppalaisten turvallisuusstandardien mukaisesti. Niitä laitteita myydään maailmanlaajuisesti, eikä niitä ole suunnattu nimenomaan Euroopan unionin sisämarkkinoille.

Avainsanat: turvallisuustestaus, IEC 60335, sähkölaite, standardi

Contents

List of Terms and Abbreviations

Accessible part:	Part of a surface that can be touched by means of test probe B of IEC 61032, and if the part or surface is metal, any conductive part connected to it.
Basic insulation:	Insulation applied to live parts to provide basic protection against electric shock.
Class I appliance:	Appliance in which protection against electric shock does not rely on basic insulation only but which includes an additional safety precaution, in that conductive accessible parts are connected to the protective earthing conductor in the fixed wiring of the installation in such a way that conductive accessible parts cannot become live in the event of a failure of the basic insulation.
Class II appliance:	Appliance in which protection against electric shock does not rely on basic insulation only but in which additional safety precautions are provided, such as double insulation or reinforced insulation, there being no provision for protective earthing or reliance upon installation conditions.
Combined appliance:	An appliance incorporating heating elements and motors.

Double insulation:	Insulation system compromising both basic insulation and supplementary insulation.
Functional insulation:	Insulation between conductive parts of different potential which is necessary only for the proper functioning of the appliance.
IP rating:	An Ingress Protection rating.
Live part:	Conductor or conductive part intended to be energized in normal use, including a neutral conductor but, by convention, not a PEN Conductor.
Peak value:	The highest value found within one period of AC voltage.
PEN Conductor:	Protective Earthed Neutral conductor combining the functions of both a protective conductor and neutral conductor.
Rated current:	Current assigned to the appliance by the manufacturer.
Rated power input:	Power input assigned to the appliance by the manufacturer.
Rated voltage:	Voltage assigned to the appliance by the manufacturer.
Rated voltage range:	Voltage range assigned to the appliance by the manufacturer, expressed by its lower and upper limits.

Reinforced insulation:	Single insulation applied to live parts, that provides a degree of protection against electric shock equivalent to double insulation.
RMS value:	Root mean square value. An AC voltage’s peak value divided by square root of two.
Safety extra-low voltage:	Voltage not exceeding 42 V between conductors and between conductors and earth, the no-load voltage not exceeding 50 V.
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.
Type X attachment:	Method of attachment of the supply cord such that it can be easily replaced.
Type Y attachment:	Method of attachment of the supply cord such that any replacement is intended to be made by the manufacturer, its service agent or similar qualified person.
Type Z attachment:	Method of attachment of the supply cord such that it cannot be replaced without breaking or destroying the appliance.
T-marking:	A thermal value denoted in degrees Celsius, which a cable is rated to withstand.

1 Introduction

In order to ensure that electrical appliances are safe for consumers to use, they undergo a series of tests that evaluate various aspects of their design, construction, and performance. These tests are typically conducted according to industry standards, such as the IEC 60335 standard, which provides a framework for evaluating the safety of household and similar electrical appliances.

The full testing of a device according to the IEC 60335 standard is expensive and time consuming to conduct, so another custom for ensuring devices' safety has been developed: basic testing of an appliance. It involves selecting a subset of tests from the standard that are relevant to the specific appliance being tested.

The tests chosen are different for each type of appliance. Different tests may be required for a hot plate than for a hair dryer, depending on their respective electrical characteristics and intended uses. These tests are designed to assess critical safety factors such as electrical insulation, resistance to fire, and protection against electric shock.

The purpose of this thesis is to provide a comprehensive understanding of the basic testing conducted on electrical appliances according to the IEC 60335 standard at SGS Fimko. Additionally, this thesis will analyse the differences of conducting only the basic testing compared to a previous full testing of an appliance, and whether the results would differ significantly.

The findings from this analysis can provide valuable insights into the effectiveness of basic testing in ensuring product safety. It can also help to improve the safety of electrical appliances and increase consumer confidence in the products they use.

2 Organizations and Concepts

2.1 What Is IEC?

IEC stands for the International Electrotechnical Commission. It is an international organization that develops and publishes standards for electrical, electronic, and related technologies. The IEC was established in 1906 and is currently headquartered in Geneva, Switzerland.

The IEC's mission is to promote international cooperation on all questions of standardization and related matters in the fields of electrical and electronic technologies. It is a non-profit organization that brings together experts from industry, government, academia, and other organizations to develop consensus-based standards and specifications that are widely used and recognized around the world.

IEC standards cover a wide range of topics, including safety, electromagnetic compatibility, energy efficiency, and environmental impact. Manufacturers, regulators, and other stakeholders use them to ensure that electrical and electronic products and systems are safe, reliable, and interoperable.

IEC standards are recognized by most countries around the world and are often adopted as national or regional standards. Compliance with IEC standards can help manufacturers access global markets and improve the safety and performance of their products. [1.]

2.2 What is a Standard?

A standard is a set of guidelines or criteria established by a recognized authority or organization to ensure consistency, safety, and quality in a particular area. These guidelines can cover technical, safety, environmental, or other aspects of products, processes, or services. Standards can be developed by industry associations, regulatory agencies, or professional societies using a consensus-based process that involves input from experts and stakeholders. Standards are important because they help to ensure consistency, interoperability, and safety across different products, processes, and services, and facilitate trade by establishing a common set of requirements and guidelines that are recognized by different countries and regions. [2.]

2.3 IEC Standards

IEC publishes around 10 000 IEC international standards which touch on most of the appliances found on the market. The focus of this thesis is IEC 60335, which deals with the safety of electrical appliances for household and similar purposes. This standard covers appliances with their voltage not more than 250 V for single-phase appliances and 480 V for other appliances including direct current supplied appliances and battery-operated appliances. [3;4.]

2.4 EN Standards

EN standards are modifications to IEC standards made by CENELEC. The organization can also approve IEC standards without modification, meaning that any appliances made after the publishing of an EN standard, the appliances must conform to the regulations to be sold on the European Union markets. EN standards always override all IEC standards. Also, if an EN standard of an IEC standard has not been published, the IEC standard cannot be taken into consideration during testing.

2.5 Certification

Certification is a process by which a third-party organization evaluates and confirms that a product, service, or system meets certain requirements or standards. This evaluation can involve testing, inspection, and audit procedures to ensure that the product, service, or system meets the established criteria.

Certification can be voluntary or mandatory and is often used to provide assurance to customers, regulators, or other stakeholders that the product, service, or system is of a certain quality or standard. Certification can also be used to facilitate trade by providing a common set of requirements and guidelines that are recognized by different countries and regions. [5.]

3 Technical Concepts Related to Testing

3.1 Measurement Uncertainty

Measurement uncertainty means that a given measurement is accurate to a certain point. Every given measurement device has its own measurement uncertainty depending on many factors, such as the quality of the measurement device, errors in the measurement procedure, environmental conditions and measurement calibration intervals of the measurement device.

It represents the range of values within which the true value of the quantity being measured is expected to lie with a certain level of confidence. It is usually expressed as a range of values in percentage or the measurement device’s own units. For example: ±2 % or ±2 °C.

A low measurement uncertainty indicates a high level of confidence in the measurement result, while a high measurement uncertainty indicates a lower level of confidence in the result.

That means, that if a device that measures temperature measures a value of 21.5 °C with a measurement uncertainty of ±2 °C, it means that at that given moment, the temperature can be anywhere from 19.5 °C to 23.5 °C.

The reason this is important, is because when measuring for example voltage or temperature, the standards have given a maximum value for a permissible result. When a measured value falls within the uncertainty of the limit, a decisive result cannot be given. This means that the verdict given can be pass/fail with condition, depending on the probability of distribution.

As illustrated in Figure 1, when the limit value is given, and there are four measurements (Illustrated with black circles) with the given uncertainty (Illustrated with red lines), it is possible to be certain that measurements 1. and 4. are either pass or fail. For measurements 2. and 3. it is no longer possible to say with certainty, that is the measured value over or under the limit value. For these measurements a verdict of pass/fail with condition is given.

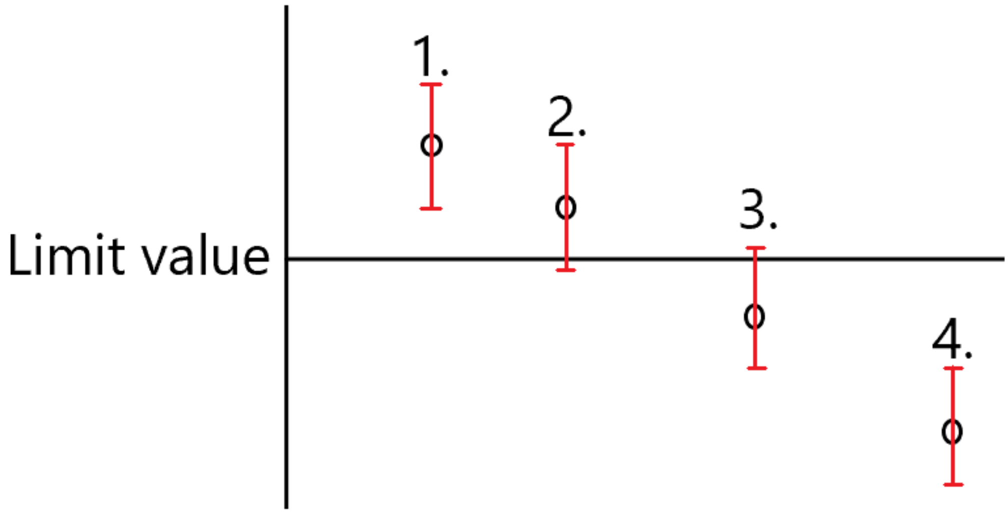


Figure 1 Illustration of measurement points with measurement uncertainty.

3.2 Clearance and Creepage

Clearance and creepage are both measurements of distance between two points. As figure 2 illustrates, clearance travels the shortest path in the air, going around all obstacles. Creepage on the other hand travels on a surface, going around all obstacles and jumping gaps that are less than 1 mm.

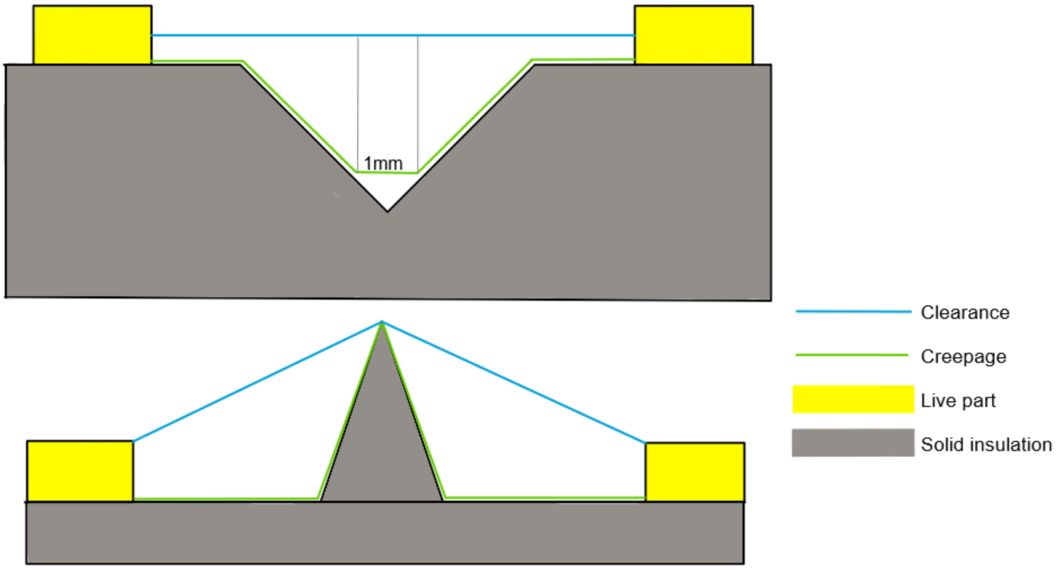


Figure 2 An illustration of the difference in clearance and creepage.

3.3 Overvoltage Categories

“Overvoltage category is a numeral defining a transient overvoltage condition“ [6, 131].

- Equipment in overvoltage category IV is for use at the origin of the installation, such as electricity meters.
- Equipment in overvoltage category III is equipment in fixed installations, such as switches.
- Equipment in overvoltage category II is equipment that consumes energy that are supplied from a fixed installation, such as home appliances.
- Equipment in overvoltage category I is equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level.

[6, 131.]

4 Tools Used in Testing

4.1 Thermocouple

The most used method for measuring temperature is by thermocouples.
A thermocouple is a sensor that consists of two different types of metal, which are welded together at one end. Due to Seebeck effect, when the connection's temperature heats up or cools down, the other ends of the thermocouple which are not connected produces a voltage difference. This voltage can be read as a measurement of temperature. The voltage graphs change depending on which type of thermocouple is used. The different types are for example: E, J, K, M, N and T. [7.]

All the mentioned types are Nickel-alloy thermocouples:

- Type E is chromel-constantan
- Type J is iron-constantan
- Type K is chromel-alumel
- Type M is 82%Ni/18%Mo-99.2%Ni/0.8%Co
- Type N is Nicrosil-Nisil
- Type T is copper constantan

[7.]

The most used one is the K type, due to its general performance and low cost. It is the default type of thermocouple used if properties from other types are not required. [8.]

Another type that is commonly used for applications, where strong magnetic fields are present is the T type. Both copper and constantan are non-magnetic metals, which means that magnetic fields do not abruptly change the characteristics of the thermocouple. [8.]

The tip of the thermocouple is glued onto the surface to measure its temperature. It is important that too much glue is not used, because it can affect the thermal reading of the thermocouple. A small blob, so that the thermocouple tip stays in place is enough.

Tape may be used for strain relief on the wire, but never on top of the welding point.

4.2 Digital Multimeter

A digital multimeter is a measurement device, which can be used to measure many different things. For example: Voltage, current, temperature, resistance and continuity. It is the best tool for measuring voltage in frequencies below 100kHz. It is accurate within +-2% for voltage and current. This makes it the most versatile tool for a testing engineer.

It is possible to see voltage’s RMS value or peak value. If the voltage is DC, peak value equals RMS value. However, if the voltage is AC, getting the RMS value might not be as simple as just dividing by square root of two. This works if the waveform is sinusoidal. However, if the voltage is not sinusoidal, the RMS value may be incorrectly displayed on the digital multimeter. These kinds of non-sinusoidal voltages may appear for example with switch mode power supplies, or in devices which have positive or negative reactance. That is why to get a true reading of the voltage, an oscilloscope or a true RMS multimeter is used.

4.3 Oscilloscope

An oscilloscope is not a versatile tool, but it does one thing extremely well, which is measuring voltage at higher frequencies. Most oscilloscopes can measure voltage up to 5MHz. This covers most of the common appliances that can be found for consumers. Instead of only getting a reading, it is also possible to see what the waveform looks like.

4.4 Spring Hammer

A spring hammer as illustrated in figure 3, is used to deliver a blow to a specific place at a specific force. Normally 0.5 J to 2 J spring hammers are used for testing purposes. It works such, that there is a plastic ball that is drawn back, tensioning a spring, and being locked in a place. When the ball is released by pressing the spring hammer onto a surface, it delivers the exact amount of force to the end of the tip when the spring hammer is placed horizontally.

It is extremely important that when delivering the blow, the spring hammer should not be placed vertically delivering a blow from above or below the device under test. This can greatly affect the precision of the blow delivered on the surface due to gravity. Blows delivered from above the device can have a greater impact on the device under test than intended. Blows delivered from below the device can have a reduced impact on the device under test than intended.

Figure 3 A spring hammer. [9]

4.5 Digital Force Gauge

A digital force gauge as illustrated in figure 4 is used to measure pushing or pulling force. In testing, it is used to determine a force used in testing access to live parts and to make sure the strain relief in appliances is adequate.

Figure 4 Digital force Gauge. [10]

4.6 Torque Meter

A torque meter as illustrated in figure 5, is used to measure rotation force. It is used in testing to check if screws and strain reliefs can withstand the rotation force specified in the standard IEC 60335 [6, 79].

Figure 5 Torque meter. [11]

4.7 Datalogger

As the name implies, datalogger is used to log data. It typically includes sensors or inputs to measure various things such as temperature, pressure, humidity or voltage. Dataloggers can also include memory to store the collected data, but often they are connected to a computer or a network for real-time monitoring or data transmission.

Dataloggers are widely used for testing purpose. Mainly to log temperatures with thermocouples and voltage at set intervals for devices under testing, but also for logging data to monitor the testing environment to be certain that environmental conditions have not affected test results.

The interval used for heating tests is 10 seconds, due to the length of the tests, and to preserve the measurement device of undue stress. Sometimes dataloggers are kept on for hours, if not days or weeks for some tests.

4.8 Calliper

A calliper as illustrated in figure 6, is the most common device used for measuring distance between two points. However, it is not the most accurate way to conduct a measurement. Often, if the same person were to conduct a measurement of two points at different times, the result may vary. This tool is used for a rough estimate to give an indication if a distance between two points is closer to pass or fail. If the result is close to the limit value, another method like a microscope may be used.
A calliper is used most of the time simply because it is the fastest.

Figure 6 Calliper. [12]

5 Testing the Appliance

Testing an appliance is a complicated process. It requires evaluation on case-by-case basis. Determining the tests done for each electrical appliance requires a thorough understanding of the IEC 60335 standard. The tests done shall be the most relevant in terms of safety to each type of appliance.

5.1 Prechecks and Preparation

When a sample is brought in, it is first evaluated of obvious defects such as accessible live parts or other dangerous defects in the appliance. After initial checks, pictures are taken of the package and the device in good lighting. Then the testing plan is made. Depending on the device, some tests are made, while some are not.

The standards used in basic testing of electrical household appliances is IEC/EN 60335-1 and all their amendments in conjunction with the most appropriate 60335-2 part and all its amendments. There are many part 2 standards, but only one is chosen for a particular test. For example, 60335-2-29 is chosen for a battery charger, while 60335-2-9 is chosen for grills, toasters, and similar portable cooking appliances.

To make sure that all the correct part 2 standards are chosen, CENELEC site is checked for the most up-to-date published EN standards. Sometimes they may be withdrawn. Any withdrawn standards are not considered when testing appliances.

5.2 Choosing the Tests

The standard IEC 60335 has many tests intended for full testing of a device [6, 2]. They are the following:

“6. Classification
7. Marking and instructions
8. Protection against access to live parts
9. Starting of motor-operated appliances
10. Power input and current
11. Heating
12. Void
13. Leakage current and electric strength at operating temperature
14. Transient overvoltages
15. Moisture resistance
16. Leakage current and electric strength
17. Overload protection of transformers and associated circuits.
18. Endurance
19. Abnormal operation
20. Stability and mechanical hazards
21. Mechanical strength
22. Construction
23. Internal wiring
24. Components
25. Supply connection and external flexible cords
26. Terminals for external conductors
27. Provision for earthing
28. Screws and connections
29. Clearances, creepage distances and solid insulation
30. Resistance to heat and fire.
31. Resistance to rusting
32. Radiation, toxicity, and similar hazards.”
[6, 2.]

These are the chapters which include the tests in the standard. Each chapter include many tests, and rarely all the tests are applicable to one appliance because the part 1 is created for many appliances and is extremely broad.

However, in basic testing, only the more relevant tests are chosen that can be done within a limited time, for instance in 6-8 hours. They must be chosen logically. This knowledge comes with experience, but also with common sense. For example, heating tests are quite common to be chosen for a device. But if the device's normal operation does not produce much heat, and there are no heating resistors found in the initial inspection, this common test may be skipped for time savings.

Most common tests that are chosen for the devices in basic testing are included the following Clauses:

"6. Classification
7. Marking and instructions
8. Protection against access to live parts
10. Power input and current.
11. Heating
13. Leakage current and electric strength at operating temperature
19. Abnormal operation
20. Stability and mechanical hazards
21. Mechanical strength
25. Supply connection and external flexible cords
27. Provisions for earthing
29. Clearances, creepage distances and solid insulation."
[6, 2.]

5.3 Basic Testing

Each of the Clauses include many tests within, but only the ones which are the most relevant for safety or quick are chosen for basic testing.
The methods, in which the tests are conducted are explained below in the following subchapters.

5.3.1 Classification

Electrical appliances are classified based on their electrical characteristics, such as voltage, frequency, and power consumption. This classification helps ensure that the appliance is used safely and correctly in different environments and with different power sources.

“Appliances shall be one of the following classes with respect to protection against electric shock:

Class 0, Class 0I, Class I, Class II, Class III.

Compliance is checked by inspection and by the relevant tests.” [6, 24.]

In European standard EN 60335-1{2012} class 0 and class 0I is removed. This means that in European markets appliance classes 0 and 0I are not allowed. [13, 7.]

“Appliances shall have the appropriate degree of protection against harmful ingress of water.

Compliance is checked by inspection and by the relevant tests.” [6, 24.]

Often the IP rating is not checked by tests, but only by visual inspection. The part 2 of IEC 60335 standard defines the required IP rating for an appliance if such requirement exists.

5.3.2 Marking and Instructions

Proper markings are checked that are required.

“Appliances shall be marked with the

- rated voltage or rated voltage range in volts;
- symbol for nature of supply, unless the rated frequency is marked;

- rated power input in watts or rated current in amperes;
- name, trade mark or identification mark of the manufacturer or responsible vendor;
- model or type reference;
- symbol IEC 60417-5172 (2003-02) for class II appliances only."

[6, 24.]
Symbol IEC 60417-5172 (2003-02) for class II appliances is illustrated in figure 7.

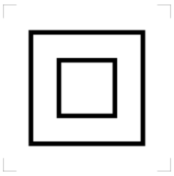


Figure 7 Symbol IEC 60417-5172 (2003-02). [14]

5.3.3 Protection Against Access to Live Parts

A visual test is done to the appliance to find possible openings in the casing where a test probe could fit inside and make contact with a live part. The appliance is used in all positions when it is operated in as in normal use with removal of any detachable parts that can be opened without using a tool [6, 31]. The probes used for this type of testing are called "test probe B" and "test probe 13" [6, 31].

Test probe B, which is illustrated in figure 8 is also called a jointed test finger. It has exact measurements specified in standard IEC 61032 [15].

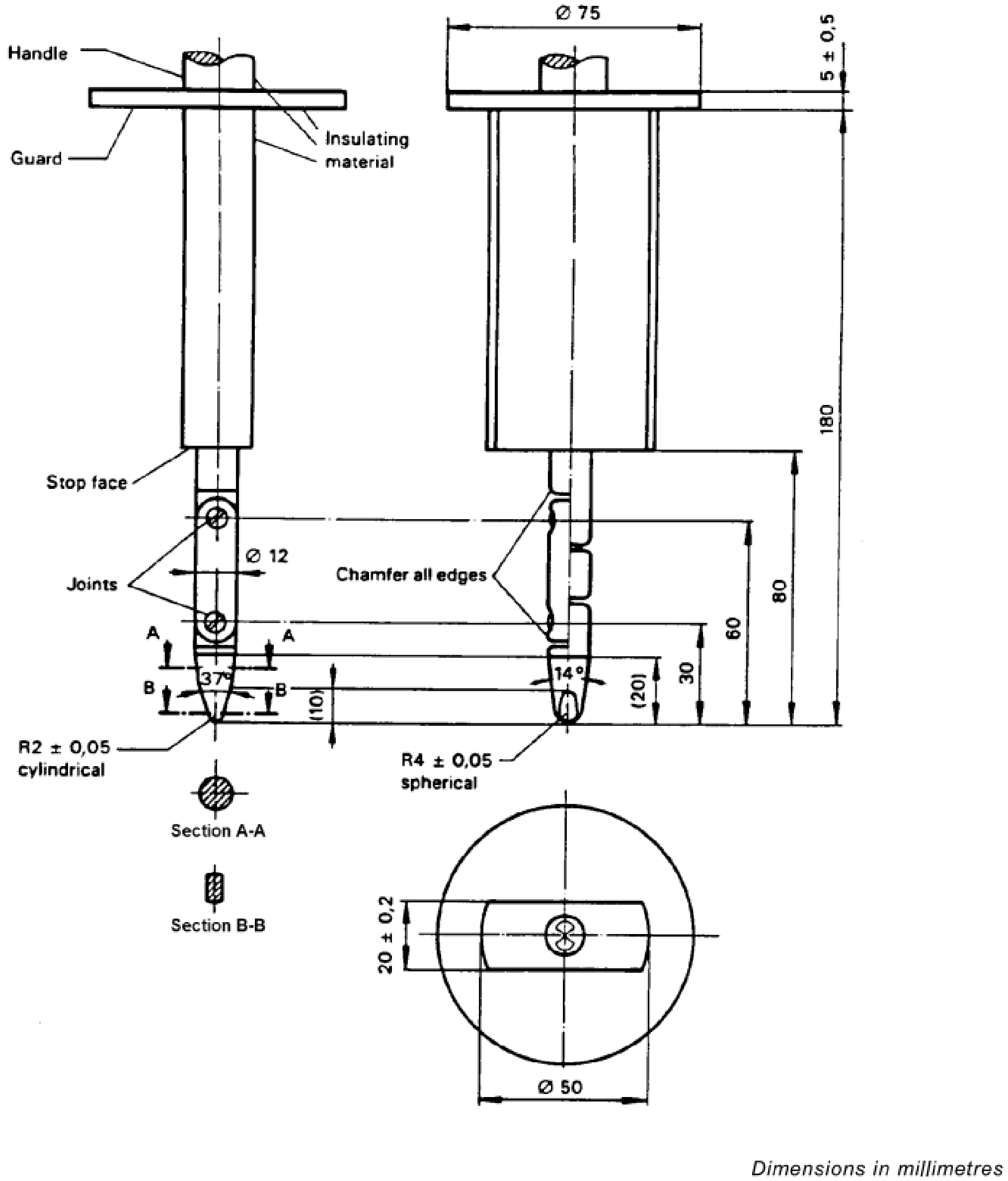


Figure 8 Measurements of test probe B. [15, 17]

Test probe B is inserted into any opening in the appliance with a force not exceeding 1 N. The appliance may be in any possible position, with the exception for appliances normally used on the floor with a mass exceeding 40 kg are not tilted. Test probe B may be rotated and angled before, during and after insertion into any position. 20 N of force may be used if the test probe B is in a straight position. [6, 31.]

Test probe 13, as illustrated in figure 9 is used for class II appliances only. It can be applied to any openings with a force not exceeding 1 N. [6, 31.]

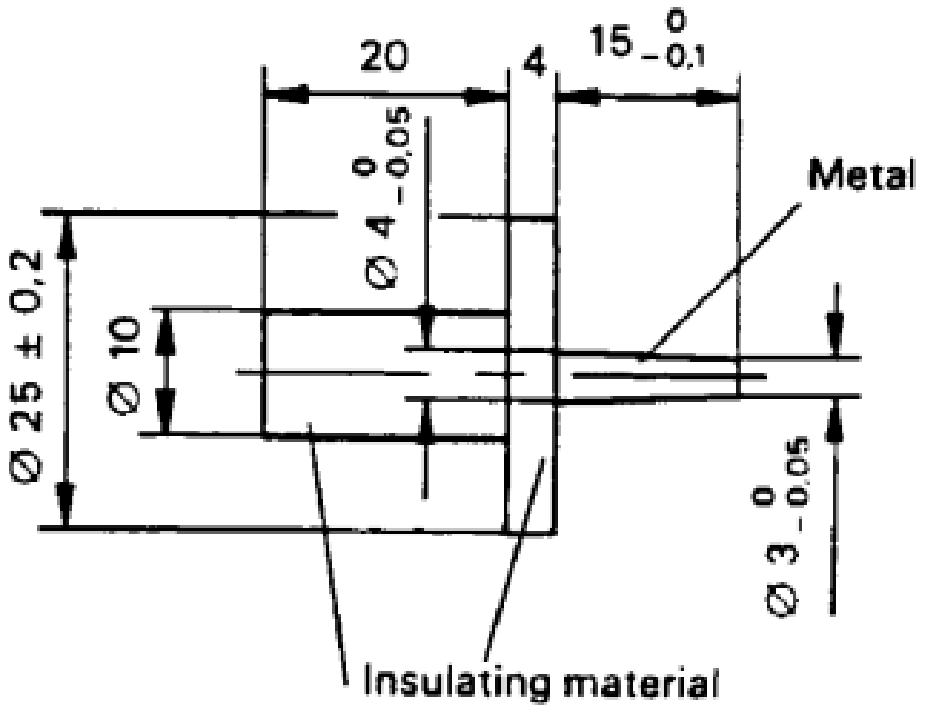


Figure 9 Measurements of test probe 13. [15, 25]

An accessible part is not considered to be live if the part is supplied at safety extra-low voltage, provided that for alternating current the peak value of the voltage does not exceed 42.4 V and for direct current the voltage does not exceed 42.4 V. [6, 32.]

5.3.4 Power Input and Current

When an appliance is marked with a rated power input, the power input in normal conditions shall not deviate more than the deviation shown in Table 1 [6, 33].

Table 1 Power input deviation. Copied from [6, 33].

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

The permissible deviation depends on the type of appliance and the rated power input. Often, the appliances do not have a lower limit, but only an upper limit for deviation.

Having a power intake lower than stated is generally not dangerous, but it may result in reduced performance or functionality of an electrical appliance. However, having a power intake higher than stated can be dangerous, as it can cause the appliance to overheat and potentially start a fire. It is important to ensure that electrical appliances are operated within their rated power intake range to ensure safe and reliable operation.

Part 2 of the IEC 60335 standard defines in which group each kind of appliance belongs to. For example, battery chargers are tested as motor-operated appliances.

When conducting the test for power input, the specific instructions for the operation of the appliance are as follows:

- “All circuits which can operate simultaneously are actuated.
- The appliance is supplied rated voltage.
- The appliance is operated under normal operation.”

[6, 33.]

Clause 10 also includes tests for the current deviation measurements, but it is not chosen for basic testing because the power deviation test matters more and gives a good indication on whether the appliance is dangerous or not in terms of current intake.

5.3.5 Heating

The heating tests are designed to ensure that household and similar electrical appliances operate safely and do not pose a risk of fire or other hazards due to excessive heat generation. There are specific guidelines on how an appliance is to be constructed, so that no excessive heating is generated.

All appliances are operated under normal operation for the duration of the heating tests. The type of appliance defines the power or voltage input.

Heating appliances are operated at 1.15 times rated power input, while motor-operated appliances and Combined appliances are supplied with the most unfavourable voltage between 0.94 times and 1.06 times the rated voltage [6, 34-36].

Most of the times for motor-operated appliances and combined appliances, using 0.96 times the rated voltage will not result in a higher heating output, so for basic testing only 1.06 times rated voltage is used for conducting the heating tests.

The appliance is placed in a position stated in the clause 11.2 as follows:

“Hand-held appliances are held in their normal position of use” [6, 34]. Normal position is defined by the instructions of the appliance.
“Built-in appliances are installed in accordance with the instructions” [6, 34].

“Other heating appliances and other combined appliances are placed in a test corner as follows:

- Appliances normally placed on a floor or table in use, are placed on the floor as near to the walls as possible.
- Appliances normally fixed to a wall are fixed to one of the walls, as near to the other wall and floor or ceiling as is likely to occur, taking account the instructions.
- Appliances normally fixed to a ceiling are fixed to the ceiling as near to the walls as is likely to occur, taking into account in the instructions.

Dull, black-painted plywood approximately 20 mm thick is used for the test corner, the supports and for the installation of built-in appliances.” [6, 34-35.]

Even if the appliance being tested does not strictly fall under one of the categories of hand-held appliances, built-in appliances, heating appliances or motor-operated appliances, its category is defined in the appropriate part 2 of the standard.

Temperature rises are measured by fine-wire thermocouples. They are attached to the appliance so that they have minimal effect on the temperature of the appliance.

“The appliance is operated for a duration corresponding to the most unfavourable conditions of normal use” [6, 36].

The duration is defined in the part 2 of the standard and is usually until stable conditions are reached or for 60 minutes. However, for appliances like toasters that are not powered on continuously for longer periods of time, the duration is defined a lot more precisely. In the case of toasters, it is operated for 15 minutes. If the toaster is constructed to toast more than a single slice of bread at one time, the appliance is operated for a further 5 minutes with only one slice of bread inserted in the toaster in the most unfavourable position [16, 18].

Temperature limits for heating tests are found in tables 2 and 3 for each part of the appliance. This table also defines where temperatures shall be measured from.

Table 2 Maximum normal temperature rises. Copied from [6, 37].

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*
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*

Table 3 Maximum normal temperature rises continued. Copied from [6, 38].

Part	Temperature rise K	
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:*		
– *of bare metal*	*50*	
– *of coated metal*	*60*	
– *of glass and ceramic*	*65*	
– *of plastic having a thickness exceeding 0,3 mm*	*75*	
Surfaces of handles, knobs, grips and similar parts which are continuously held in normal use (e.g. soldering irons):		
– *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*	

Rarely all of the measuring points in table 3 are used for a single appliance. Some appliances might not even have all the components that are listed in the table. Only the measuring points which apply are measured.

5.3.6 Leakage Current and Electric Strength at Operating Temperature

"At operating temperature, the leakage current of the appliance shall not be excessive and its electric strength shall be adequate" [6, 39].

Leakage current is what its name implies, current that leaks from an appliance. Devices can leak current through insulation and other means. Low leakage current is not dangerous and is allowed in the appliances. There are limits set for the requirements the appliances need to meet to be deemed safe.

Electric strength is determined by how much voltage an appliance can withstand between the functional parts and touchable parts of the appliance. In case over voltage protection outside of the appliance fail and the functional parts gain an increased voltage, the electric strength of the appliance must be adequate to protect the user.

"The appliance is operated under normal operation for the duration specified in 11.7" [6, 39].

This applies only for the measurement of leakage current. Clause 11 is the heating tests, so this test can sometimes be conducted at the same time as the heating tests for time savings, because the test conditions are most of the time the same.

The test conditions for testing leakage current are determined as follows:

Heating appliances are operated at 1.15 times the rated power input, while motor-operated appliances and combined appliances are supplied at 1.06 times rated voltage [6, 39-40].

For class I, class II and class III appliances, the leakage current is measured by means of the circuit is illustrated in figure 10. For class I appliances, a low impedance ammeter capable of measuring the true r.m.s. value of the leakage current may also be used instead of the circuit illustrated in figure 10. [6, 40.]

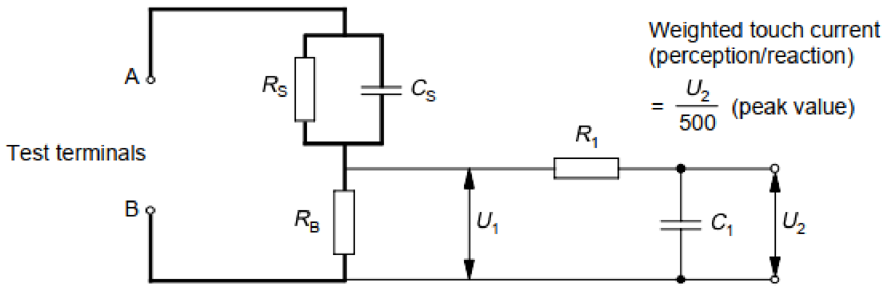


Figure 10 Measuring network for touch current. Copied from [17, 27].

The leakage current is measured between any pole of the supply and accessible metal parts connected to metal foil having an area not exceeding 20 cm × 10 cm which is in contact with accessible surfaces of insulating materials. [6, 40.]

The metal foil having an area not exceeding 20 cm × 10 cm is supposed to simulate a human palm touching the appliance at a specific point and measuring the current that leaks from that specific area.

The measured leakage current shall not exceed the following values:

- “Class II appliances: 0.35 mA peak.
- Class III appliances: 0.7 mA peak.
- Portable class I appliances: 0.75 mA.

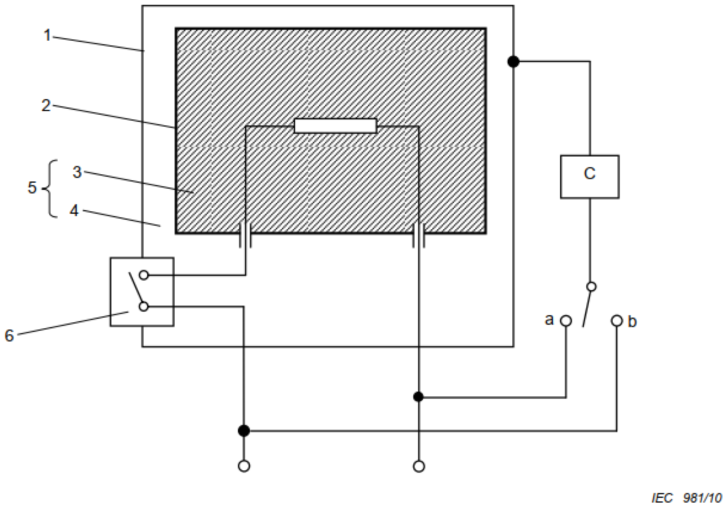
Stationary class I heating appliances: 0.75 mA or 0.75 mA per kW rated power input of the appliance with a maximum of 5 mA, whichever is higher.” [6, 40.]

For class II and class III appliances the peak value is measured, while for class I appliances r.m.s. value is measured.

The connections for single phase class II appliances’ leakage current measurements are defined by figure 11. For other than class II appliances but single phase, connections are defined by figure 12.

For class I appliances, when measuring the leakage current between N and PE the incoming PE wire must be disconnected while conducting the measurement.

The measurement must be contained within the appliance. What is happening outside of the appliance shall not interfere with the measurement result.



Key

C circuit of Figure 4 of IEC 60990

1 **accessible part**

2 inaccessible metal part

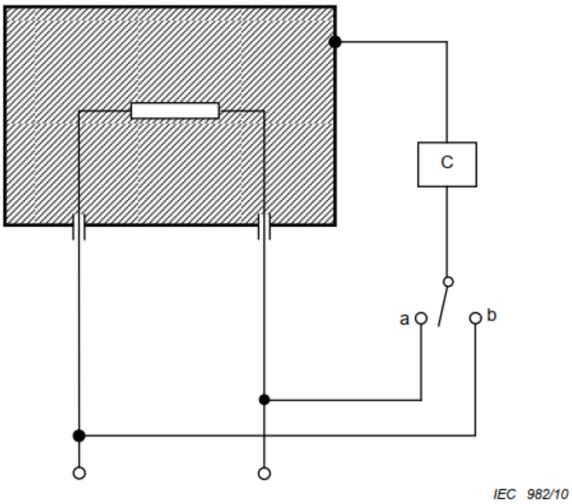
3 **basic insulation**

4 **supplementary insulation**

5 **double insulation**

6 **reinforced insulation**

Figure 11 Circuit diagram for leakage current measurement of class II appliances. Copied from [6, 103].



Key

C circuit of Figure 4 of IEC 60990

NOTE For **class 0I appliances** and **class I appliances**, C may be replaced by a low impedance ammeter.

Figure 12 Circuit diagram for leakage current measurement of class I appliances. Copied from [6, 104].

Electric strength measurement

The appliance is disconnected from the supply and the insulation is subjected to a voltage having a frequency of 50 Hz or 60Hz for 1 minute [6, 41].

The voltage is applied between live, functional parts and the appliance’s accessible parts. When an appliance has a class II construction, metal foil is used to cover the appliance without the metal foil touching metallic parts. [6, 41.]

The appliance shall withstand a voltage specified in table 4 for each of the appliance’s type of insulation.

Table 4 Voltage for electric strength test. Copied from [6, 41].

Insulation	Test voltage V			
	Rated voltage [a]			Working voltage (U)
	SELV	≤150 V	>150 V and ≤250 V [b]	>250 V
Basic insulation	500	1 000	1 000	1,2 U + 700
Supplementary insulation		1 250	1 750	1,2 U + 1 450
Reinforced insulation		2 500	3 000	2,4 U + 2 400

[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 > 150 V and ≤ 250 V.

[b] For appliances having a **rated voltage** ≤ 150 V, these test voltages apply to parts having a **working voltage** > 150 V ≤ 250 V.

The appliances meant for use by households in Europe always cover a rated voltage of 220 V to 240 V, or 230V. So that is the rated voltage by the appliance that is considered when testing for electric strength.

For class I appliances, the appliance must meet the requirements of basic insulation. Meaning 1 000 V according to table 4 [6, 41].

For class II appliances, the appliance must meet the requirements of supplementary insulation or reinforced insulation. For an appliance to meet the requirements of supplementary insulation, the material thickness (if plastic) must be more than 1mm. For reinforced insulation, the thickness requirement is increased to 2mm. [6, 96.]

When testing class II appliances, it is always assumed first that the appliance complies with the reinforced insulation requirements. All class II appliances are tested with 3 000 V electric strength test first. If it fails, then a subsequent test with 1 750 V is conducted.

For failure to occur, the appliance must conduct over 100 mA of current within 60 seconds of reaching the target voltage for testing the electric strength test.

5.3.7 Abnormal Operation

The Clause of Abnormal operation covers fault tests for electric appliances. All appliances that come in for basic testing will be tested for abnormal operation. The appropriate part 2 of the standard has the most applicable tests for each appliance group and most often, one or two of them are chosen. For some appliances, a universal test in the part 1 of the standard may give the worst result in terms of safety.

"Appliances shall be constructed so that as a result of abnormal or careless operation, the risk of fire, mechanical damage impairing safety or protection against electric shock is obviated as far as is practicable.

Electronic circuits shall be designed and applied so that a fault condition will not render the appliance unsafe with regard to electric shock, fire hazard, mechanical hazard or dangerous malfunction." [6, 47.]

During the tests, only one abnormal condition may be simulated at any one time unless stated otherwise [6, 48].

The different types of appliances also have test conditions for the duration of the test. They may be the same conditions as in the heating tests, but most of the time they differ. More voltage or power is usually what changes in addition to position of the appliance. Some test may also have a single fault condition. It means that a single component of the appliance is presumed to be broken or at a faulty condition, and it cannot continue to carry out its functions.

The most common tests that are given by the part 1 of the standard are the following:

Appliances that have heating elements are tested under the same conditions as specified in the heating tests of Clause 11, but so that heat dissipation is restricted. Supply voltage is determined such, that it is 0.85 times the rated input power when device is operated normally, and the power input has stabilized. [6,48.]

Appliance is tested under the same conditions as specified in the heating tests of Clause 11. Any control that limits the temperature during the heating test is short-circuited. If the appliance has more than one control, only one control is short-circuited at any one time. [6,48.]

Appliance is operated normally, with a stalled condition. Any motor or moving part of the appliance is locked. If the appliance has more than one motor or moving part, they are locked separately. Appliances are supplied at their rated voltages for a period, that depends on the type of the appliance. [6,49.]

- 30 s for handheld appliances and appliances that have to be kept switched on by a hand or a foot.
- 5 min for other appliances that are operated while they are attended.
- Until steady conditions are reached for all other appliances.

[6,49.]

If the appliance incorporates printed circuit boards without certified components, an electronic single fault condition is simulated. Most often an electrolytic capacitor is short-circuited after a rectifying component.

This test has restrictions, like short circuits cannot be made between primary and secondary sides of a transformer, and certified components cannot be altered in any way.

“During the tests, the appliance shall not emit flames, molten metal, or poisonous or ignitable gas in hazardous amounts and temperature rises shall not exceed the values shown in table 5.

After the tests, and when the appliance has cooled to approximately room temperature, compliance with Clause 8 shall not be impaired and the appliance shall comply with Clause 20.2 if it can still be operated” [6, 54.]

Clause 20.2 is the tests for mechanical hazards in an appliance. Mainly for moving parts and spinning motors. [6, 56.] The tests are explained more thoroughly in the next chapter.

Table 5 Maximum abnormal temperature rise. Copied from [6, 54].

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] *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 30.1 can be carried out.*

The test corner or wooden supports intended to hold fixed appliances shall not have a temperature rise of over 150 K. The insulation of supply cord shall not have a temperature rise of 150 K or if it has a T marking above 75 °C, T+75 K. [6, 54.]

5.3.8 Stability and Mechanical Hazards

Clause 20 includes the tests for appliance’s stability and mechanical hazards [6, 55-56].

“Appliances, other than fixed appliances and hand-held appliances, intended to be used on a surface such as the floor or a table, shall have adequate stability.” [6, 55].

The appliance is not connected to a socket-outlet, and it is placed in any normal position of use on an incline, at an angle of 10°. The supply cord is placed in the most unfavourable position. [6, 56.]

Appliances intended to be filled with liquids by the user, are tested empty or filled with the most unfavourable amount of water up to the capacity stated in the instructions. [6, 56.]

“The appliance shall not overturn.” [6, 56].

This test is repeated for appliances incorporating heating elements on a plane of 15°. The appliance may overturn, but then the heating tests of Clause 11 are repeated, and the temperature rises of surfaces may not be exceeded. [6, 56.]

Mechanical hazards

Components of an appliance, that have the potential to cause harm during regular use should be enclosed or positioned in a way that offers appropriate protection against personal injury as far as is reasonable. This requirement, however, does not extend to parts of the appliance that must be exposed to allow it to perform its intended function. [6, 56.]

Mechanical hazards are most commonly found in appliances incorporating fans, and in sharp edges of appliances. Compliance is tested by visual inspection and using test probe B and test probe 13 as was done in Clause 8, protection against access to live parts. All detachable parts and parts intended to be serviced are removed before the testing. The test can also be conducted using the tester's own arms using extreme caution while having the appliance disconnected from all power sources and preventing accidental start-up of the appliance.

5.3.9 Mechanical Strength

"Appliances shall have adequate mechanical strength and be constructed to withstand such a rough handling that may be expected in normal use.

Compliance is checked by applying blows to the appliance in accordance with test Ehb of IEC 60068-2-75, the spring hammer test." [6, 56-57.]

The appliance is supported, so that it cannot move. An impact energy of 0.5 J or more if stated in part 2 of the standard is applied horizontally to any point of the enclosure that is likely to be weak. [6, 57.]

Weak points can be identified by feel and visual inspection. Sections of the enclosure that protect live parts and moving parts are tested thoroughly. Normally grilles that protect heating elements, clips and screws that keep two halves of the enclosure together and places where material is thin, are the most likely to fail and may cause the appliance to become dangerous by exposing live parts or reducing clearance and creepage distances, making the insulation of the appliance weaker.

"After the test, the appliance shall show no damage that could impair compliance with this standard and compliance with 8.1, 15.1 and Clause 29 shall not be impaired" [6, 57].

Test 8.1 is the protection against access to live parts, test 15.1 is moisture resistance and Clause 29 is clearances, creepage distances and solid insulation test. This means that after applying three blows to all points that are likely to be weak, all the above-mentioned tests will be re-evaluated by visual inspection or by conducting the test again.

The appliance shall not have any live parts accessible by test probes B and 13. If the appliance has a degree of protection against moisture, the protection shall not be impaired after the spring hammer test. And lastly, clearance and creepage distances shall not be lowered after the tests.

5.3.10 Supply Connection and External Flexible Cords

Clause 25 includes the tests for supply cables and other external flexible cords. They shall have adequate protection against external ingress, mechanical damage, and environmental conditions.

"Appliances, other than those intended to be permanently connected to fixed wiring, shall be provided with one of the following means for connection to the supply mains:

- supply cord fitted with a plug;
- an appliance inlet having at least the same degree of protection against moisture as required for the appliance;
- pins for insertion into socket-outlets."

[6, 74.]

Supply cord is fixed to the appliance and must have a plug constructed to one end that is meant to connect to the socket-outlet. This type of construction is also known as type Y attachment. They are commonly found in household appliances, such as toasters, coffeemakers, and heaters. One such example can be found in an extension cord, as illustrated in figure 13.

This kind of supply connection shall not be replaced by an unqualified person. Only qualified technicians can replace a type Y attachment. [6, 29.]

Figure 13 Example of a supply cord fitted with a plug. [18]

An appliance inlet is a supply connection without a fixed supply cord. The cord can be removed and replaced easily by the user if the type of cable taken into consideration, so that the same wire gauge is replaced as was in the original cable. This type of construction is also known as type X attachment. They can be found for example in computer power supplies and some laptop chargers. Figure 14 illustrates this well.

Figure 14 Example of an appliance inlet and its supply cord. [19;20]

Pins for insertion is mainly for smaller appliances, where the whole appliance excluding the cord of the output is attached to the pins of the supply. This kind of appliance stays attached to the socket-outlet. This type of construction is also known as type Z attachment. They can be found for example in power supplies for phone chargers or for decoration lights. Pins for insertion is illustrated in figure 15.

Figure 15 Example of pins for insertion. [21]

Appliances, other than stationary appliances for multiple supply, shall not be provided with more than one means for connection to the supply mains [6, 74].

It is not allowed to have more than one connection to any kind of power supply for portable appliances. Some manufacturers might want to add a second supply cord to split the required load between two fuse groups for tools that draw higher current than the fuses for sockets are intended, but such practice is strictly prohibited [6, 74].

The nominal cross-sectional area of conductors in supply cords shall not be less than the value specified in Table 6 [6, 76].

Table 6 Minimum cross-sectional area of conductors. Copied from [6, 77].

Rated current of appliance A			Nominal cross-sectional area mm2
		≤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.

The rated current may not be marked on the appliance, but if the markings are in order, the rated power and voltage are marked on the appliance. The rated current can be calculated using this equation for power:

$$Rated\ Current = \frac{Rated\ Power}{Rated\ Voltage} \qquad (1)$$

The rated current must not exceed the corresponding nominal cross-sectional area of the supply cord's conductors found in table 6.

“Supply cords shall not be in contact with sharp points or edges of the appliance” [6, 77].

Sharp edges can easily damage the insulation of the supply cord, and possibly expose the copper conductors inside the cable. Sharp edges may be allowed in some circumstances, like if it is made of a soft material, like plastic. A softer material may not cause damage to the supply cord. This is reviewed on a case-by-case basis and even some sharp edges made of plastic may not pass this test.

“Appliances provided with a supply cord, and appliances intended to be permanently connected to fixed wiring by a flexible cord, shall have a cord anchorage. The cord anchorage shall relieve conductors from strain, including twisting, at the terminals and protect the insulation of the conductors from abrasion.” [6, 78.]

In this test the cord anchorage is tested. It is done by pulling and rotating the supply cord. Depending on the mass of the appliance, pull force ranges from 30 N to 100 N and rotation force (Torque) ranges from 0.1 Nm to 0.35 Nm. The forces applied are specified in Table 7 for each appliance weight class. [6, 79.]

Table 7 Pull force and torque applied to appliances. Copied from [6, 79].

Mass of appliance *kg*	***Pull force*** *N*	***Torque*** *Nm*
≤1	*30*	*0,1*
>1 and ≤4	*60*	*0,25*
>4	*100*	*0,35*

The testing begins by marking the supply cord’s starting position with a marker. The supply cord is then tied to a loop with a cable tie for the digital force gauge to hook onto, as close as possible to the appliance.

“The cord is then pulled, without jerking, for 1 s in the most unfavourable direction with the force specified. The test is carried out 25 times.” [6, 79.]

After the test, the cord shall not extrude more than 2 mm from the appliance. [6, 79.]

Then for the rotation test, the torque meter is attached to the supply cord by first cutting the cord about 30mm away from the appliance, or as close to the appliance as the torque meter allows [6, 79]. The torque meter is then tightened around the cord by the clamping mechanism in the torque meter.

The specified torque in Table 7 is applied for 1 minute. The cord shall not be damaged, shall show no strain at the terminals and no wires may come loose. [6, 79.]

5.3.11 Provisions for Earthing

“Accessible metal parts of class I appliances that may become live in the event of an insulation fault, shall be permanently and reliably connected to an earthing terminal within the appliance or to the earthing contact of the appliance inlet.

Class II appliances and class III appliances shall have no provision for earthing.” [6, 84].

The provision for earthing is tested by supplying 12 Volts of AC or DC, and a current equal to 1.5 times rated current of the appliance or 25 A, whichever is higher, between an appliance’s earthing terminal and each accessible metal part that may become live in event of insulation fault for 60 seconds. The resistance calculated from the current and voltage drop shall not exceed 0.1 Ω. [6, 86.]

5.3.12 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.

Clearances shall not be less than the values specified in Table 9, taking into account the rated impulse voltage for the overvoltage categories of Table 8.

Appliances are in overvoltage category II.” [6, 88-89.]

Table 8 Rated impulse voltage. Copied from [6, 89].

Rated voltage 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 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 9 Minimum clearances. Copied from [6, 90].

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

[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.

Appliances meant to be used in Europe, rated impulse voltage of 2 500 V applies. This means, that the minimum clearance for basic insulation, supplementary insulation and functional insulation is 1.5mm.

For reinforced insulation, instead of using the rated impulse voltage of 2 500 V, the next higher step is used as reference. According to Table 8, the next higher step from 2 500 V is 4 000 V. Minimum clearance for a rated impulse voltage of 4 000 V is 3.0mm. [6, 89-91.]

“Creepage distances of basic insulation shall not be less than those specified in Table 10” [6, 94].

Table 10 Minimum creepage distances for basic insulation. Copied from [6, 94].

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** 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** may be found by interpolation.

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

For all home appliances, Material group IIIa/IIIb is used. The pollution degree is either 2 or 3, depending on where the appliance is to be used according to instructions. If it is inside a home with no excessive amounts of moisture or particles such as dust, pollution degree 2 applies. If the appliance may be subjected to excessive amounts of moisture, water or particles, or the appliance is meant to be used outside, pollution degree 3 applies.

"Creepage distances for supplementary insulation shall be at least those specified for basic insulation in Table 10, while for reinforced insulation it shall be at least double those specified for basic insulation in Table 10." [6, 94.]

For minimum creepage distances of functional insulation, Table 11 applies.

Table 11 Minimum creepage distances for functional insulation. Copied from [6, 95].

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	1,0	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 [b]	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 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.

Compliance is checked by measurement. The most common tool used for measuring clearances and creepages is a calliper or a microscope.

“Supplementary insulation and reinforced insulation shall have adequate thickness, or have a sufficient number of layers, to withstand the electrical stresses that can be expected during the use of the appliance.

The thickness should be at least:

- 1 mm for supplementary insulation
- 2 mm for reinforced insulation

Each layer of material shall withstand the electric strength test of 16.3 for supplementary insulation. Supplementary insulation shall consist of at least 2 layers of material and reinforced insulation of at least 3 layers.” [6, 96.]

The electric strength test of Clause 16.3 for supplementary insulation is 1 750 V for appliances with rated voltage between 150 V and 250 V [6, 46]. However, this test is done when there is doubt about the quality of the material, or when there are less than 3 layers found.

To measure the thickness of insulation material, a calliper is used. When the distance is less than 2 mm, an air gap must be found between the insulating material and a live part for the appliance to fulfil the requirements of double insulation.

6 Comparing Basic Testing to Full Testing

Basic testing provides valuable insight about an electrical appliance’s safety. However, because it does not cover the whole IEC 60335-1 standard, basic testing cannot prove that the appliance under test complies fully with the IEC 60335-1 standard.

The results of three chargers full testing were analysed, and only the tests that would be conducted in basic testing were taken into account for the charger’s safety evaluation. These test results can be found in Table 12, Table 13 and Table 14 for chargers A, B and C respectively.

By comparing the results of the two testing methods, this chapter aims to provide insights into the effectiveness of basic testing and the value of conducting full testing for appliances that do not seek certification.

Table 12 Test results of charger A

Test	Result	Verdict
Classification	Correct classification	Pass
Marking and instructions	Correct markings and instructions found	Pass
Protection against access to live parts	No live parts accessible	Pass
Leakage current	0.003 mA [0.35 mA limit]	Pass
Electric strength	3000 V between pins of appliance and casing: <100 mA	Pass
Electronic fault	No fire, molten metal or gasses detected	Pass
Mechanical strength	No visible damage	Pass
Residual voltage	16 V after 1 second of disconnection	Pass
Internal wiring	No sharp edges next to wireways	Pass
Cable type and cross-sectional area of conductors	H03VVH2-F [2X0.75mm^2]	Pass
Cord anchorage and torque	Cord did not extrude more than 2mm, no strain in wires	Pass
Clearance and creepage	F = 7.14mm, R = 6.34mm F = 7.14mm, R = 8mm	Pass
Transformer construction	Sufficient insulation found	Pass

Table 13 Test results of charger B

Test	Result	Verdict
Classification	Correct classification	Pass
Marking and instructions	Correct markings and instructions found	Pass
Protection against access to live parts	No live parts accessible	Pass
Leakage current	<0.01 mA [0.35 mA limit]	Pass
Electric strength	3000 V between pins of appliance and casing: <100 mA	Pass
Electronic fault	No fire, molten metal or gasses detected	Pass
Mechanical strength	No visible damage	Pass
Residual voltage	0 V after 1 second of disconnection	Pass
Internal wiring	No sharp edges next to wireways	Pass
Cable type and cross-sectional area of conductors	H03VVH2-F [2X0.75mm^2]	Pass
Cord anchorage and torque	Cord did not extrude more than 2 mm, no strain in wires	Pass
Clearance and creepage	F = 3.8 mm, R = 11.6 mm F = 3.8 mm, R = 11.6 mm	Pass
Transformer construction	Sufficient insulation found	Pass

Table 14 Test results of charger C

Test	Result	Verdict
Classification	Correct classification	Pass
Marking and instructions	Correct markings and instructions found	Pass
Protection against access to live parts	No live parts accessible	Pass
Leakage current	0.007 mA [0.35 mA limit]	Pass
Electric strength	3000 V between pins of appliance and casing: <100 mA	Pass
Electronic fault	No fire, molten metal or gasses detected	Pass
Mechanical strength	No visible damage	Pass
Residual voltage	20 V after 1 second of disconnection	Pass
Internal wiring	No sharp edges next to wireways	Pass
Cable type and cross-sectional area of conductors	H03VVH2-F [2X0.75mm²]	Pass
Cord anchorage and torque	Cord did not extrude more than 2 mm, no strain in wires	Pass
Clearance and creepage	F = 18 mm, R = 8.2 mm F = 18 mm, R = 8.2 mm	Pass
Transformer construction	Sufficient insulation found	Pass

In all three sample cases, the result with basic testing would seem to show that the appliance would give the same perception of safety as full testing. The appliance passed all of the tests chosen for basic testing.

7 Conclusions

The analysis conducted with this small sample size indicated that basic testing provides a similar perception of device’s safety as full testing. Indeed, the small sample size has a significant impact on the final result. It does not provide a true overall perception of the safety of all devices that would undergo basic testing.

The analysis was performed specifically on fully tested chargers seeking for the certification mark. Manufacturers have a strong incentive to build these appliances in compliance with safety standards to obtain the certification mark to make the certification process quick and cost-effective. On the other hand, for devices that are not intended for certification, the standard may not even be considered. In Finland, devices are required to comply with CENELEC standards, which are based on IEC standards. It is possible that in other parts of the world, such requirements do not exist, and the manufacturer has produced their product for that kind of market. Then a Finnish importer discovers the product and decides to bring it to Finland for sale. Of course, the seller wants to sell their device, so they just put the importer's label on it, slightly modify the appearance of the device, and place it on the shelves for sale in Finland. Devices sold in Europe must have the CE marking, which means that the device complies with EU directives, but the manufacturer itself assigns the marking. It does not actually mean anything because, in Finland, only the importer is reliable for ensuring that the manufacturer has conformed to the regulations of the EU directives for the electrical appliance [22, 8].

To obtain a more reliable result regarding the difference between basic testing and full testing, more analysis and tests would need to be conducted.

References

1 International Electrotechnical Commission. Who we are [Internet]. IEC website; [cited 2023 Mar 15] Available from: https://www.iec.ch/who-we-are

2 International Organization for Standardization. Standards in our world. [Internet] ISO website; [cited 2023 Mar 15] Available from: https://www.iso.org/sites/ConsumersStandards/1_standards.html

3 International Electrotechnical Commission. What we do [Internet]. IEC website; [cited 2023 Mar 15] Available from: https://www.iec.ch/what-we-do

4 International Electrotechnical Commission. IEC 60335-1:2020 [Internet]. IEC webstore; 2020 Sept [cited 2023 Mar 23] Available from: https://webstore.iec.ch/publication/61880

5 Integrated Assessment Service. ISO Frequently Asked Question [Internet]. IAS Website; [cited 2023 Apr 7] Available from: https://ias-certification.com/frequently-asked-question-in-usa/#toggle-id-1

6 International Electrotechnical Commission. 2020. IEC 60335-1:2020 Household and similar electrical appliances - Safety - Part 1: General requirements

7 Omega. Thermocouple probes [Internet] Omega website; [cited 2023 Apr 13] Available from: https://www.omega.com/en-us/resources/thermocouple-hub

8 Thermocouple [Internet]. Wikipedia; 2023 May 3 [cited 2023 Apr 13]. Available from: https://en.wikipedia.org/wiki/Thermocouple

9 Lansbury International. Impact Test Requirements and Product Safety Standards [Internet]. Lansbury International website; [cited 2023 Apr 16]. Available from: https://www.springhammer.co.uk/

10 Kern & Sohn. Digital force gauge FK [Internet]. Kern & Sohn website shop; [cited 2023 Apr 17] Available from: https://www.kern-sohn.com/shop/en/measuring-instruments/force-gauges/FK/

11 Sper Scientific Direct. Portable handheld Torque Meter [Internet]. Sper Scientific Direct website shop; [cited 2023 Apr 17] Available from: https://sperdirect.com/products/torque-meter

12 RS Components. Mitutoyo 150mm Digital Caliper 0.01 mm Resolution, Metric & Imperial with UKAS Calibration [Internet]. RS Components webstore; [cited 2023 Apr 18]. Available from:

https://fi.rsdelivers.com/product/mitutoyo/50019630/mitutoyo-150mm-digital-caliper-001-mm-resolution/3074571

13 Cenelec. 2012. EN 60335-1:2012 Household and similar electrical appliances - Safety - Part 1: General requirements

14 International Organization for Standardization. Class II equipment [Internet]. ISO Webstore; [cited 2023 Apr 21]. Available from: https://www.iso.org/obp/ui#iec:grs:60417:5172

15 International Electrotechnical Commission. 1997. IEC 61032:1997 Protection of persons and equipment by enclosures - Probes for verification

16 International Electrotechnical Commission. 2019. IEC 60335-2-9:2019 Household and similar electrical appliances - Safety - Part 2-9: Particular requirements for grills, toasters and similar portable cooking appliances

17 International Electrotechnical Commission. 2016. IEC 60990:2016 Methods of measurement of touch current and protective conductor current

18 Helsingin Puutarhatarvike. Jatkojohto 4-osainen + valokytkin maadoitettu 1,5m [Internet]. Helsingin Puutarhatarvike webstore; [cited 2023 Apr 23] Available from: https://www.helsinginpuutarhatarvike.fi/product/4423/jatkojohto-4-osainen--valokytkin-maadoitettu-15m

19 RS Components. RS Pro 500W PC Power Supply [Internet]. RS Components webstore; [cited 2023 Apr 23]. Available from: https://fi.rsdelivers.com/product/rs-pro/rs-pro-500w-pc-power-supply-200-240v-ac-input-33v/2011836

20 IndustrialField. EU European Power Cable [Internet]. Amazon webstore; [cited 2023 Apr 23]. Available from: https://www.amazon.com/European-Desktop-Computer-Monitor-Adapters/dp/B07XZKFRB7

21 Retro Game Supply. Power supply for NEC PC Engine, CoreGrafX 1 & 2 [Internet]. Retro Game Supply webstore; [cited 2023 Apr 23]. Available from: https://en.retrogamesupply.com/collections/frtvaexecption/products/power-supply-for-nec-pc-engine-coregrafx-1-2

22 Tukes. Sähkölaitteiden valmistus, maahantuonti ja myynti [Internet]. Tukes website: Tukes; 2017 [cited 2023 May 27]. Available from: https://tukes.fi/tuotteet-ja-palvelut/sahkolaitteet