

# HANDBOOK

## Guide for Electrical Equipment Testing



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**Electrical equipment  
testing handbook**

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# Electrical equipment testing handbook

## 1. Introduction

Electrical safety is divided in two large fields:

- Safety of electrical installations
- Safety of electrical equipment

This handbook is dealing with the safety of electrical equipment. There are many steps that must be taken to assure an appropriate safety of equipment. Safety management of electrical equipment, standards, test methods and documentation are explained in this book.

The authors hope that this handbook will help the reader to better understand the background of electrical equipment testing and to be able to perform safety tests in a fast and professional manner. Any feedbacks are highly appreciated.

### 1.1 Why testing safety of electrical equipment?

Primary goal is to use all electrical equipment without danger. Common accidents caused by electrical equipment are:

- Injuries through electric shock caused by malfunctioned equipment
- Injuries through overheated equipment
- Fire and explosions

Most people are not aware that every (even the smallest) piece of electrical equipment can cause fatal accident.

Many studies proved that the cost and consequences of accidents caused by electrical impaired equipment exceeds the investments in testing by far.

Of course accidents cannot be excluded completely by regular testing of safety. However they can be limited to an acceptable level.

The field of safety of electrical equipment is well covered by a series of published standards that are dealing with electrical equipment design, testing instruments and procedures. Standards are important to have a unique and traceable testing system worldwide.

Testing of electrical equipment is not regulated in the same way in all countries. For instance in Germany, UK, Australia a lot of efforts were put in last years to increase the overall electrical safety. In these countries thorough and well documented testing of all electrical equipment during its complete lifetime is regulated by law.

Through their positive experience it can be assumed that other countries will follow in the future.

Testing safety of electrical equipment can be divided by type of electrical equipment and type of testing.

According to the standards electrical equipment is divided in:

- Electrical appliances,
- Electrical equipment in medical use,
- Electrical machines,
- Electrical switchgears.

Types of safety tests of electrical equipment are:

- Type testing.
- End of line testing,
- Maintenance testing,
- Testing after modification and repair,
- Periodic testing

## 1.2 Types of electrical equipment safety tests

### **Type testing**

Type testing is a conformity to regulations test made on one or more representative of the production.

Type tests are carried out by test houses or manufacturers and standards are applied as technical base to regulations requirements. These tests are very strict and include safety, EMC, functional, climatic tests etc.

### **End of line testing (routine manufacturing testing, production testing)**

These tests are carried out by manufacturers to ensure that produced equipment works properly and is safe. Each piece of electrical equipment must be subjected to this test.

### **Maintenance testing**

If electrical equipment requires maintenance operations or the maintenance is required for a system with the electrical equipment built in, then the electrical safety shall be verified for the equipment or system after finished maintenance.

### **Testing after modification or repair**

After modification or repair of an appliance or other electrical equipment, it is required to make verification of safety operation of the equipment in addition to regular operation test. Safety test is based on routine test for the equipment that can be supplemented with others, based on modifications made,

### **Maintenance (before putting into service, after modifications and after repair) testing**

Test carried out on an item to verify that its performance remains within specified limits, after having made certain adjustments or after repair.

The extent of these tests depends on the nature of the adjustment/repair. Retest period must be considered.

### **Periodic (recurrent) testing**

Test carried out periodically to determine whether the equipment is in satisfactory condition. It is not as strict as other tests. Testers must be aware of its limitations. The

test usually consists of visual inspection and electric tests. Retest period must be considered.

## 1.3 Compliance marks

Compliance marks are telling us a lot about the safety of a product.

### CE mark

In the European Union all electrical equipment product must conform to specified safety and electromagnetic compatibility standards. The conformity is declared with the CE mark. The mark is given by the producer or importer who must also prepare and sign conformity declaration to state that their product conforms to related regulations.



*Fig. 1.1. CE mark*

### Independent certification marks

It is (unfortunately) known from the practice that many self-certified products usually do not meet the specified safety standard.

Some producers are testing their products at specialized testing laboratories. If the safety inspection passed the product gets a certification mark from an independent laboratory. Of course the level of confidence in electrical safety of a certified product can be higher than in a non-certified one.



*Fig. 1.2. Examples of independent certification marks*

As most of equipment on the market is self-certified this is an additional argument that all electrical equipment should be subjected to thorough and regular safety checks. This is recommended regardless of the local regulations.

## 1.4 Standardization

Standards are important to have an unique system worldwide. Standards are covering design and testing of all kind of electrical equipment.

Important standards relevant to testing safety of electrical equipment are listed in this chapter.

### 1.4.1 International / European standards

#### Standards for safety of electrical equipment

Only fiducially marks of international standards are listed for particular product groups whereas particular parts cover certain areas or characteristic in the product group.

General appliance testing

EN 60950 Safety of information technology equipment

EN 60335 Safety of household and similar electrical appliances

EN 61010 Safety requirements for electrical equipment for measurement, control, and laboratory use

EN 60598 Safety of luminaries

Appliances for medical use

EN 60601 Medical electrical equipment -Basic safety and essential performance

EN 62353 Medical electrical equipment - Recurrent test and test after repair of medical electrical equipment

Electrical machines

EN 60204 Safety of machinery - Electrical equipment of machines

Switchgears

EN 60439 Low-voltage switchgear and control gear assemblies

**Test equipment feature standards**

EN 61557 Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c.- Equipment for testing, measuring or monitoring of protective measures

VDE 404 Measuring equipment for testing electrical safety of electrical appliances

**National standards**

Some countries have published their own standards. For instance in the German VDE 0701-0702 or VDE 0751 series were launched for periodic equipment testing. In these standards there are many novelties that cannot be found in international standards yet.

## 1.4.2 National legislation

Not the standards but legislation in individual countries is normative for obligatory activities regarding safety testing. In the legislation there is often further instruction for performing these activities (e.g. retest periods are defined) and which relevant standards should be considered.

**Examples:**

Germany

Energiewirtschaftsgesetz EnWG

Gesetz für technische Arbeitsmittel (GSG)

Medizinproduktgesetz (MPG)

Unfallverhütungsvorschrift der Berufsgenossenschaften BGV A3 (VBG 4)

Gemeindeunfallversicherung GUV-V A2

United Kingdom:

Code of practice

## 1.5 Safety management

The term safety management summarizes all necessary steps that must be taken to assure the safety of electrical equipment through its complete lifetime.

These steps are:

- Quality type testing performed by the producer
- Obtaining an independent certification mark for the product (recommended)
- A strict quality end control at producer
- Quality maintenance of the product
- Correct handling with the product according to product manuals and working instructions
- Often visual checks by the user
- Regular safety check performed by a skilled person (visual check, testing of safety, “Logbook” of appliance, documentation of tests, etc.)
- Adequate corrective measures in case of a noticed safety problem. The figure below shows how individual factors can improve / worsen the safety level of electrical equipment

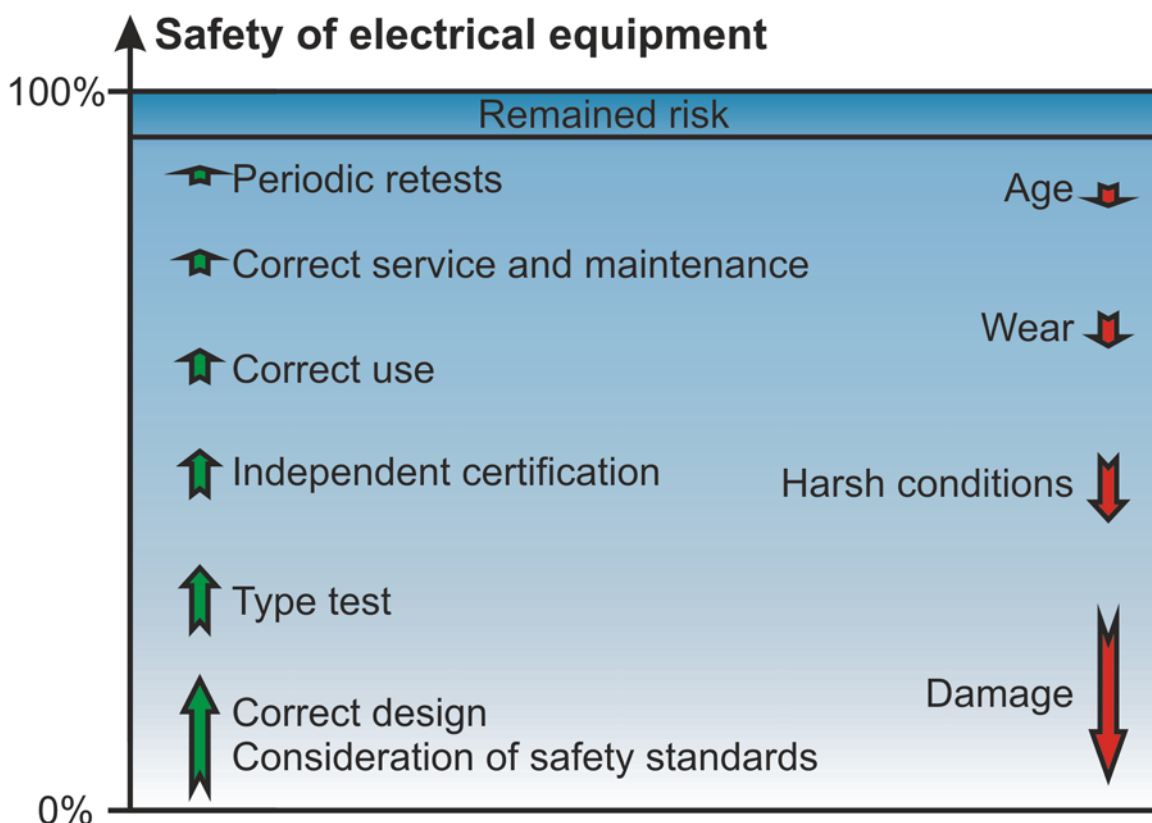


Fig 1.3. Safety management

## 1.6 Selection of METREL test equipment related to standard

Requirements for safety operation of electrical equipment are defined in so called equipment's product standards, in addition special standards exist covering maintenance and testing of electrical equipment during their usage, In the table below relevant standards and best-suited METREL measuring instruments according to type of equipment and type of testing are listed.

Type of testing  Type of instrument	Type testing End of line testing (routine manufacturing testing)	Maintenance and after repair testing	Periodic testing
<b>Portable electrical appliances</b>	IEC/EN 60335 IEC/EN 60950 IEC/EN 61010  CE Multitester	VDE 701  AlphaPAT BetaPAT OmegaPAT AlphaGT	VDE 702  AlphaPAT BetaPAT OmegaPAT AutoPAT AlphaGT
<b>Electrical appliances in medical use</b>	VDE 750 IEC/EN 60601	VDE 751 EN 62353	VDE 751 EN 62353
<b>Electrical machines</b>	  CE Multitester	EN60204  CE Multiservicer CE Multitester	EN60204  CE Multiservicer CE Multitester
<b>Electrical switchgears</b>	EN60439  CE Multiservicer CE Multitester	EN60439  CE Multiservicer CE Multitester	EN60439  CE Multiservicer CE Multitester

## 2. Appliance testing – general

### 2.1 Classification of appliances (by field of use)



Typical appliances are:

- Laboratory equipment
- Measuring and regulating equipment
- Power supplies
- Heating appliances
- Handheld tools
- Luminaries
- Consumer electronic
- Information and communication technology (computers, fax machines, scanners etc.)
- Prolongation cords, IEC supply cords
- Appliances for medical use

Before testing the user must know the appliance construction e.g. protection class.

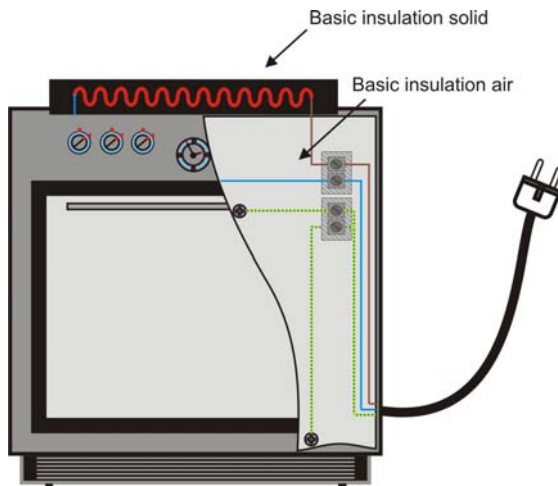
### 2.2 Classification of appliances (by protection classes)

According to the design electrical equipment can be divided in three classes. In the table below the differences between classes are described.

Class	I	II	III
<b>Marking</b>	no		
<b>Connection to protection (PE) conductor of the installation.</b>	yes all accessible conductive parts (case etc.) are connected to the PE connection.	no	no connection to mains
<b>Basic insulation</b>	performed	performed	performed / looser limits
<b>Supplementary or reinforced insulation</b>	not needed in general, needed if there are accessible unearthed conductive parts <sup>1)</sup>	performed	not needed
<b>Supply cord</b>	three pole (L,N, PE)	can be two pole	two pole
<b>Notes</b>	installation must have adequate earth resistance		must be supplied from a SELV (safety low voltage) source, typically 12 V or 24 V

<sup>1)</sup> Class I equipment can be combined with class II safety measures!

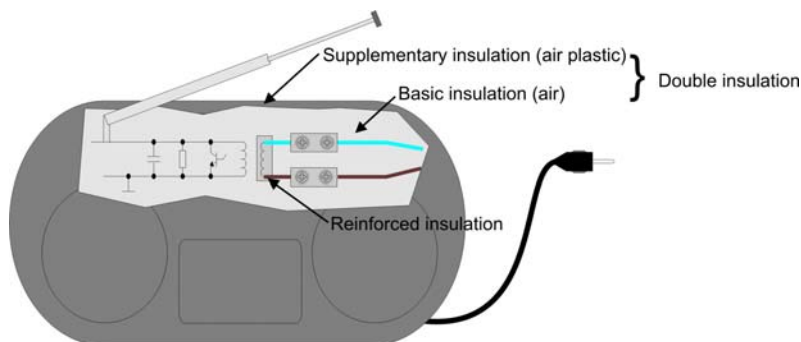
Explanation of terms:



**Fig.2.1. Class I device**

Typical Class I device with :

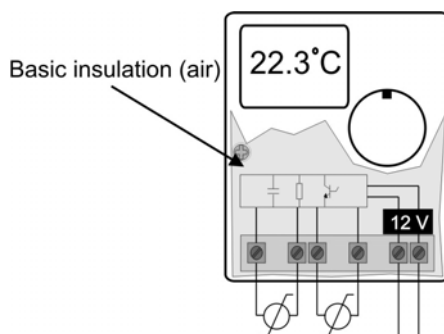
- accessible conductive parts are connected to PE connection
- basic insulation (air or solid) as protection between live conductors and conductive parts (enclosure)



**Fig.2.2. Class II device**

Typical Class II device with:

- basic and supplementary insulation as general protection
- reinforced insulation serves as protection between live conductors and accessible conductive part



**Fig.2.3. Class III device**

Class III device have looser limits for basic insulation.

## 3. Portable electrical appliances - measurements

In this chapter portable appliance tests are described. For each test:

- There is a short explanation which safety measure is checked.
- Some typical faults are described.
- The measuring connection is shown.
- Typical safety limits are given.
- Important notes and hints are summarized.

### 3.1 Visual check

Maybe it sounds strange but visual check is the most important and effective part of an appliance test. The visual inspection discloses most of faults!

Electrical testing often does not disclose failures that become apparent on visual inspection.

A thorough visual check must be carried out before each electrical safety test.

#### Scope of test:

Items that should be checked:

- Inspection of appliance for sign of damage.
- Inspection of flexible supply cable for damage.
- Any signs of pollution, moisture, dirt that can jeopardize safety. Especially openings, air filters, protection covers and barriers must be checked!
- Are there signs of corrosion?
- Are there signs of overheating?
- Inscriptions and marking related to safety must be clearly readable.
- Installation of the appliance must be performed according to the user manuals.
- During visual inspection the measuring points for the electrical testing have to be determined too.

#### Note:

For Class II and Class III devices visual inspection is often the only applicable safety test!

### 3.2 Protective circuit continuity test (Earth bond)

#### Scope of test:

With the protective circuit continuity test (earth bond) test, the following is determined:

- That the contacts between accessible conductive parts and PE conductor are firm.
- That PE wire in the appliance supply cord is undamaged.

- That there are no signs of poor contacts, corrosion etc.

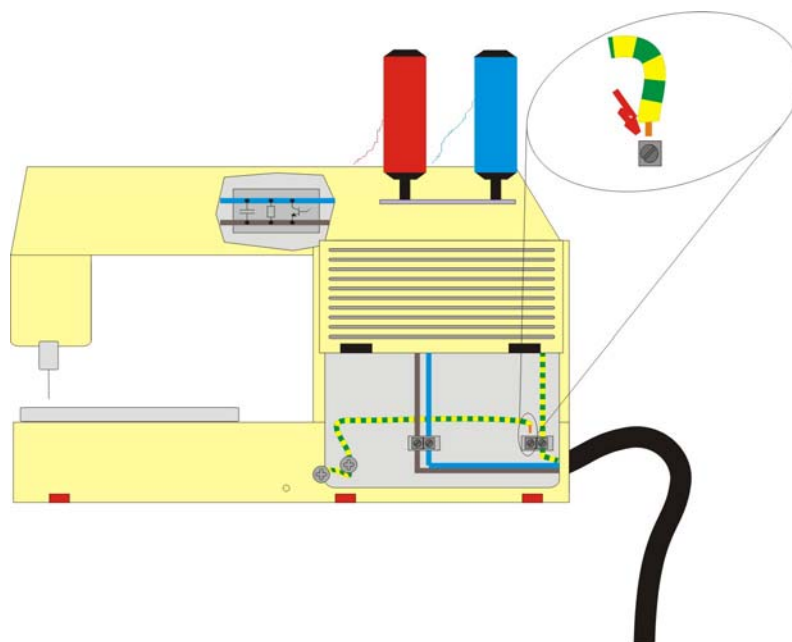
### Examples of faults, possible consequences

**Fault :** Accessible conductive part was not connected to PE conductor after repair.

**Result:** Dangerous contact voltage occurred on unconnected accessible conductive part. There is a possibility of electrical shock if this part would be touched. In this case the leakage would flow through the body instead through PE conductor to earth.

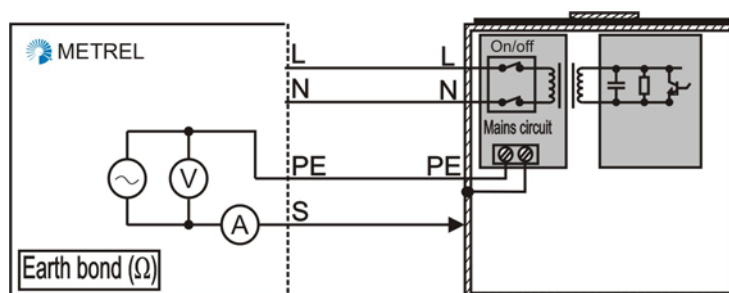
**Fault:** PE wire is broken in supply cord.

**Result:** There is no path to the earth for fault currents. Again the leakage would flow through the body instead through PE conductor to earth if enclosure would be touched. This is extremely dangerous in case of a live to earth (e.g. insulation) fault in the appliance since live voltage can occur on the enclosure.



**Fig. 3.1.** Examples of faults of PE connections

### Measuring principle / limits



**Fig. 3.2.** Earth bond test

Test signal is applied between PE pin of supply cord and accessible conductive parts

connected to the PE

**Typical limits:**

VDE 0701-0702:	< 0,3 $\Omega$ up to 5 m cord length + 0,1 $\Omega$ per 7,5 m cord length max. 1 $\Omega$
UK regulations:	0.1 $\Omega$ up to 0.5 $\Omega$ , depends on fuse size and supply cord length

**Parameters:**

Test current	VDE 0701-0702	200mA, as per IEC/EN 61557-4
	UK regulations	depends on appliance type and selected standard (100 mA, 200 mA, 4 A, 10 A, 25 A)

Measuring equipment designed according to VDE 0404 must have the AC output isolated. For UK regulations galvanic separation is preferred.

For more limits and parameters refer to METREL User Manuals and Appendixes.

**Notes:**

- Flexible supply cords must be folded during test! If the result is changing during the measurement this means that the test failed.
- Care should be taken to assure a good contact between probe and conductive parts of tested appliance. Especially at expected results below 0.3  $\Omega$  the result could be affected by contact resistance.
- Some (IT) equipment may have accessible conductive parts that are earthed only for screening purposes. These non-safety parts are not subjected to the earth bond test. Such connections may be checked with low currents (100 mA, 200 mA).
- Galvanic separation of measuring circuit is preferred (obligatory for VDE tests). Otherwise additional current paths via ground can occur (through uninsulated floor, other connections with earth like EMC shields etc.). That can result in too low readings.

### 3.3 Insulation

**Scope of test**

Insulation resistance between live conductors and all accessible conductive parts (earthed and isolated) is checked. This test discloses faults caused by pollution, moisture, deterioration of insulation material etc. The capacitive part of leakage currents is not measured because of the DC test voltage.

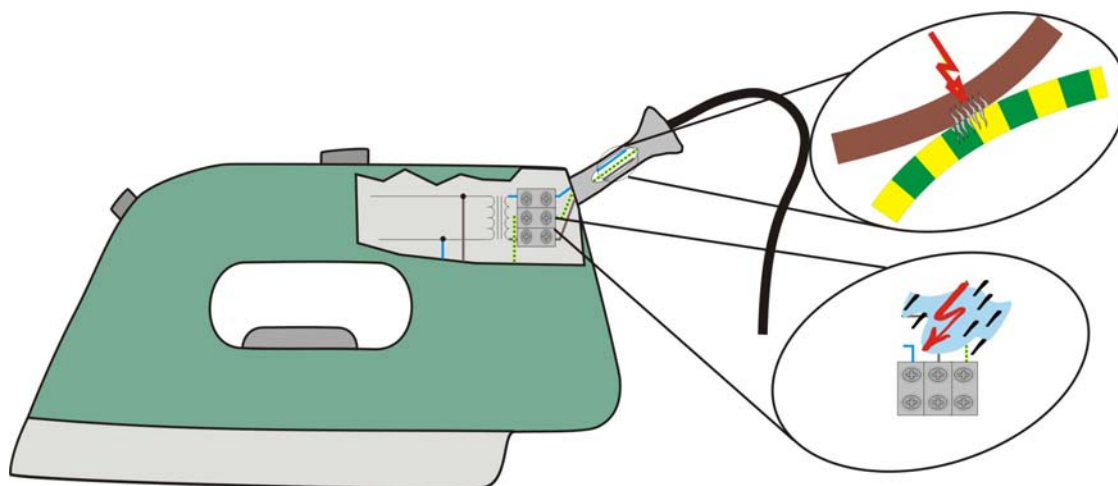
**Examples of faults**

**Fault:** Decreased insulation resistance between live parts and isolated accessible conductive part. Typical reasons are dirt, dust, moisture. Slots and openings in the enclosure are especially critical.

**Result:** Dangerous contact voltage on accessible conductive parts not connected to protective circuit. There is a risk of electrical shock if this part would be touched.

**Fault:** Deteriorated insulation between live parts and earthed conductive parts in the appliance.

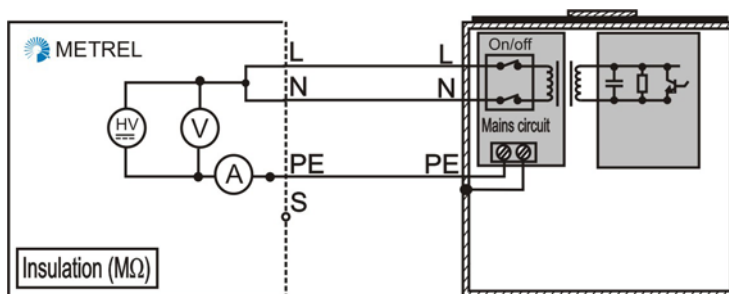
**Result:** Too high leakage current, tripping of RCDs, sparking, overheating of appliance.



**Fig. 3.3.** Examples of insulation faults

**Measuring principle / limits:**

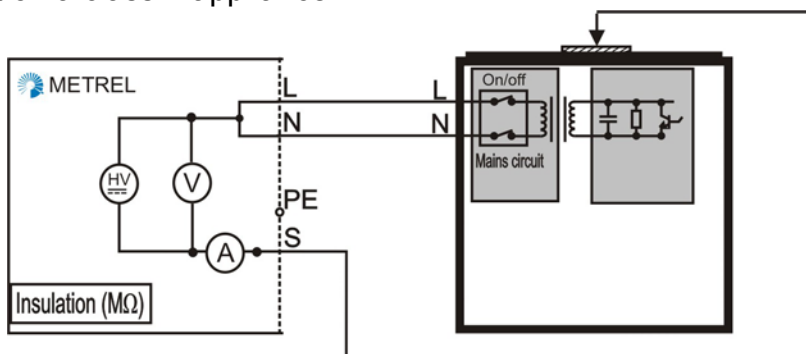
Measurement on a class I appliance:



**Fig. 3.4.** Example of the insulation test on a Class I appliance

High DC voltage test signal is applied between connected live pins and PE contact of supply cord. Unearthed accessible conductive parts are NOT included in this test and are measured as Class II items.

Measurement on a class II appliance:



**Fig. 3.5.** Example of the insulation test on a Class II appliance

High DC voltage test signal is applied between connected live pins and accessible conductive parts separated from protective circuit. Each accessible conductive part

shall be tested separately.

**Typical limits:**

VDE, UK regulations	Class I	1 MΩ
	Class II	2 MΩ
	Class III	250 kΩ

Limits for appliances with heating elements or mineral insulations are lower.

**Parameters:**

Test voltage:	typically 500 V, 250 V for not EN 60950 compliant IT equipment
---------------	--

Measuring equipment designed according to VDE 0404 must have the HV output isolated.

For more limits and parameters refer to METREL instruments User Manuals and Appendixes.

**Notes:**

- On/Off switches must be closed. If after the switches were closed all safety relevant parts are not included the results will be impaired. This is often the case in electronic or relay driven On/Off circuits. In this case leakage current tests can be performed as an alternative.
- This test cannot be applied on Class II appliances without accessible conductive parts.
- The subleakage test is recommended to be performed after the insulation test too.
- Test voltage level is usually selected in the same level as maximum possible supply voltage.
- IT equipment not designed according to EN 60950 can be damaged by the 500 V test voltage.

### 3.4 Subleakage test

**Scope of test**

Overall impedance between live conductors and all accessible conductive parts (earthed and isolated) is checked with this test. Capacitive leakage paths (input filter capacitors, transformers, cables...) are included in the result, too.

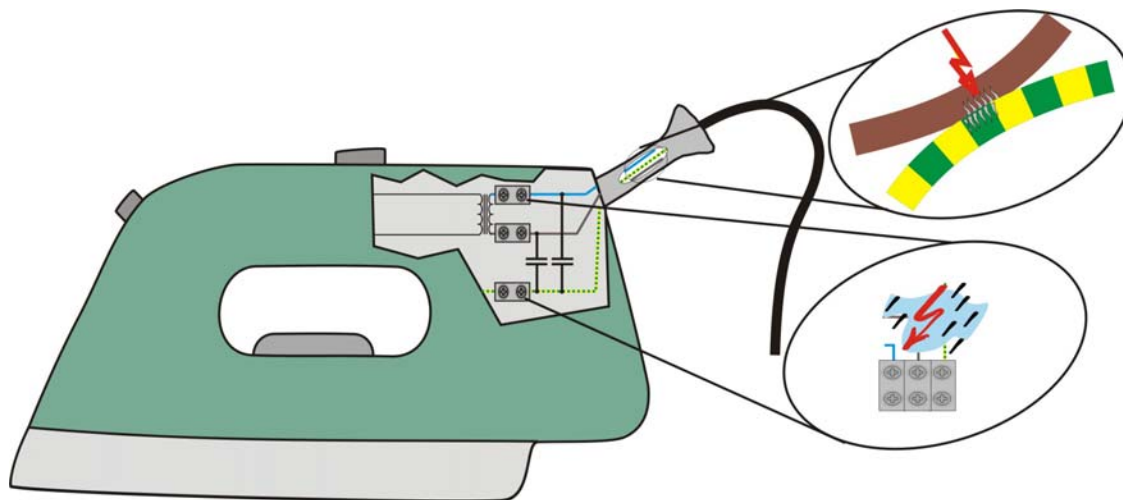
**Examples of faults**

**Fault:** Decreased insulation between live parts and isolated accessible conductive part caused by dirt, dust, moisture etc.

**Result:** Dangerous contact voltage on accessible conductive part. There is a risk of electrical shock if this part would be touched.

**Fault:** As the insulation in appliance between live and earthed parts deteriorates the overall leakage current can increase over the safety leakage limit level.

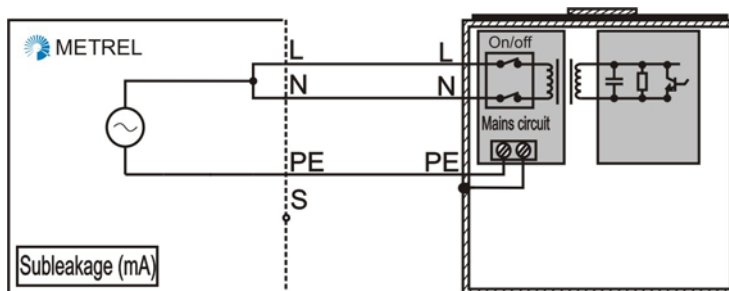
**Result:** Too high leakage currents result in tripping of RCDs. Bad insulation can result in sparking and local overheating of appliance. This is especially dangerous in case of bad earthing of the installation.



**Fig. 3.6.** Examples of excessive leakage currents

**Measuring principle / limits**

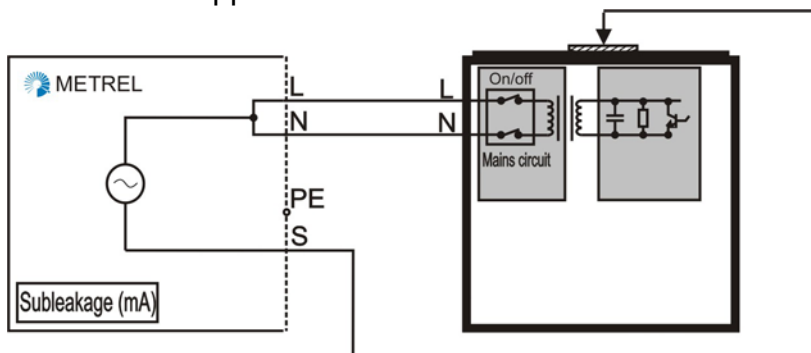
Measurement on a class I appliance.



**Fig. 3.7.** Example of subleakage test on a Class I appliance

AC test signal is applied between connected live pins and PE contact of supply cord. Accessible conductive parts not connected to protective circuit are NOT included in this test and are measured as Class II items.

Measurement on a class II appliance.



**Fig. 3.8.** Example of subleakage test on a Class II appliance

AC test signal is applied between connected live pins and accessible conductive parts not connected to protective circuit. Each accessible part shall be tested alone.

**Typical limits:**

VDE 0701-0702	Class I	1 mA/kW or 3.5 mA whichever is greater
	Class II	0.5 mA

UK regulations	Class I portable, handheld	0.75 mA
	Class I heating appliance	0.75 mA or 0.75 mA/kW whichever is greater, with 5 mA max.
	Class I other	3.5 mA
	Class II	0.25 mA
	Class III	0.5 mA

**Parameters:**

Test voltage:	typically 40 V to 50 V, results are scaled to maximal nominal supply voltage
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Measuring equipment designed according to VDE404 must have the AC output isolated. For more limits and parameters refer to METREL instruments User Manuals and Appendixes.

**Notes:**

- On/Off switches must be closed. If after switches were closed all safety relevant parts are not included the results will be impaired. This is often the case in electronic or relay driven On/Off circuits. In this case or if in doubt leakage current tests can be performed as an alternative.
- This test cannot be applied on Class II appliances without accessible conductive parts.
- Appliances with leakage currents >3.5mA should be marked.
- This measurement returns similar results as leakage tests on powered appliances. The subleakage result is usually higher (up to 2 times) because of connected L and N conductors.
- The subleakage test is suitable for IT appliances (at connected mains voltage the test must last longer to allow booting up the equipment).

### 3.5 Leakage current tests - general

**Scope of test**

In this test the sum of leakage currents caused by appliance insulation resistances (resistive currents through the insulation material, fault currents through decreased insulation) and capacitances (capacitive leakage current) is checked. Even leakage currents in range of mA are dangerous. The danger increases if the installation is not properly earthed.

Excessive leakage currents are most often caused by deterioration of the appliance insulation (pollution, ageing, moisture) or faults in mains circuits of appliances.

In general three leakage currents are measured: the differential leakage current, the PE conductor (direct) leakage current and the touch leakage current.

### 3.6 PE conductor leakage current test

This test is sometimes called direct leakage test too.

#### Scope of test

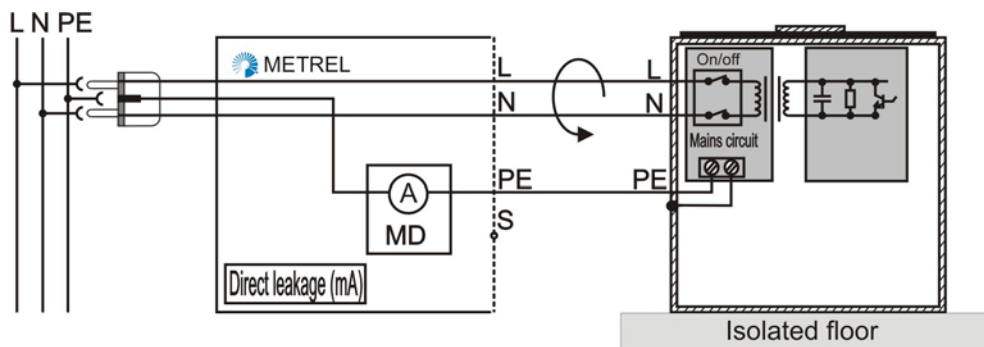
See chapter 3.5 *Leakage current tests*.

#### Examples of faults

See chapter 3.4 *Subleakage current tests*.

#### Measuring principle / limits

Measurement on Class I appliance:



**Fig. 3.9.** Example of the PE conductor current test

Appliance is powered on. The current flowing through appliance PE conductor is measured.

Appliance must be placed isolated against ground to prevent that a part of the leakage current would flow directly to ground instead through the PE conductor and ground.

Unearthed accessible conductive parts are not included in this test. They are considered as class II parts and are checked in the Touch Leakage test.

#### Typical limits:

VDE 0701- 0702	Class I	1 mA/kW or 3.5 mA whichever is greater
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UK regulations	Class I portable, handheld	0.75 mA
	Class I heating appliance	0.75 mA or 0.75 mA/kW whichever is greater, with 5 mA max.
	Class I other	3.5 mA

For more limits and parameters refer to METREL instruments User Manuals and Appendixes.

Measuring equipment designed according to VDE404 must have specified frequency response from DC to 1 MHz (MD characteristic).

#### Notes:

- If leakage currents differ for different appliance operating modes all modes must be checked. The highest result (it is the worst) must be considered!
- If the position of line and neutral conductor in the installation or appliance plug is not predefined, the test must be performed in both directions with higher result considered.
- Appliance must be placed isolated against ground to prevent that a part of the leakage current would flow directly to ground instead through the PE conductor and ground. This is the main defectiveness compared to the differential leakage test.

### 3.7 Differential leakage current test

#### Scope of test

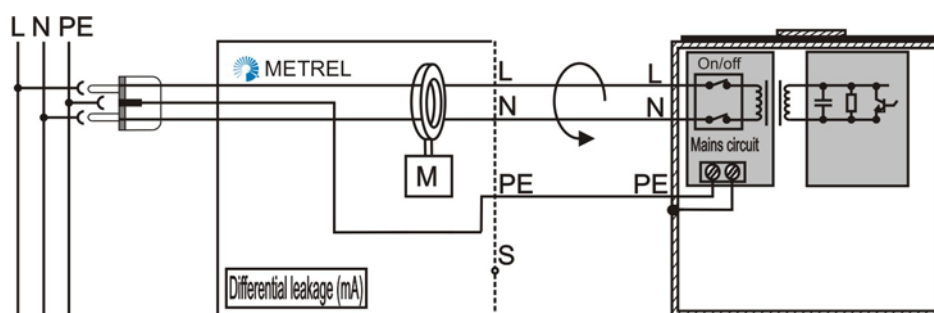
See chapter 3.5 *Leakage current tests*.

#### Examples of faults

See chapter 3.4 *Subleakage current test*.

#### Measuring principle / limits

Measurement on Class I appliance:



**Fig. 3.10.** Example of differential leakage current test

Appliance must be powered on. The leakage current is measured as the difference of currents through L and N supply conductors. The result does not depend on what floor the appliance is placed.

Unearthed accessible conductive parts are NOT included in this test. They are considered as class II parts and are checked in the Touch Leakage test.

#### Typical limits:

For limits and parameters see chapter 3.6 *PE conductor leakage current test*.

Measuring equipment designed according to VDE404 must have specified frequency response from 40 Hz to 1 MHz (M characteristic).

**Notes:**

- If leakage currents differ for different appliance operating modes all modes must be checked. The highest result must be considered!
- If the position of line and neutral conductor in the installation or appliance plug is not predefined, the test must be performed in both directions with higher result considered.
- The differential leakage current test is preferred compared to the PE conductor test since placing the appliance on conductive floor does not disturb the measurement result.

### 3.8 Touch leakage test

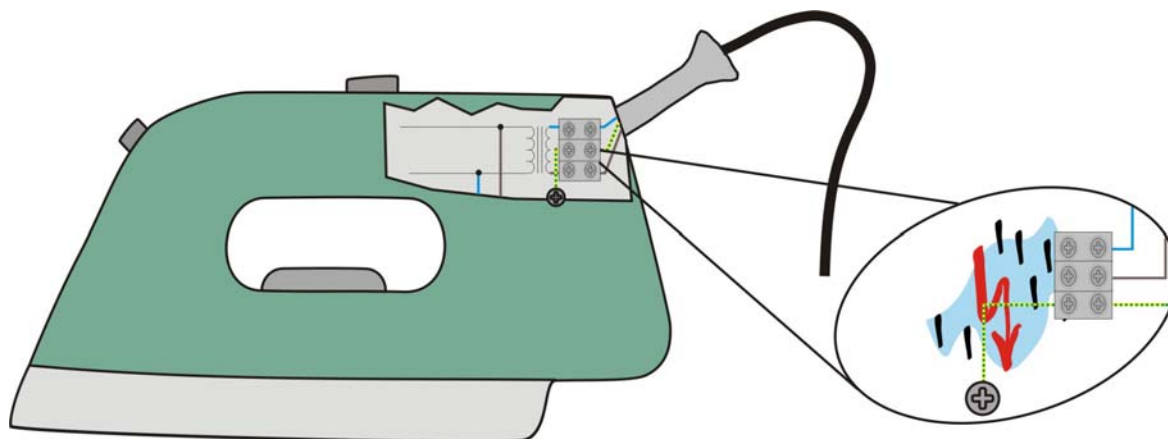
**Scope of test**

Leakage (capacitive, resistive, fault) currents that would flow via the unearthed accessible conductive part (if touched) through body to ground are measured in this test.

**Examples of faults**

**Fault:** Decreased insulation between live parts and isolated accessible conductive part because of dirt, dust and moisture.

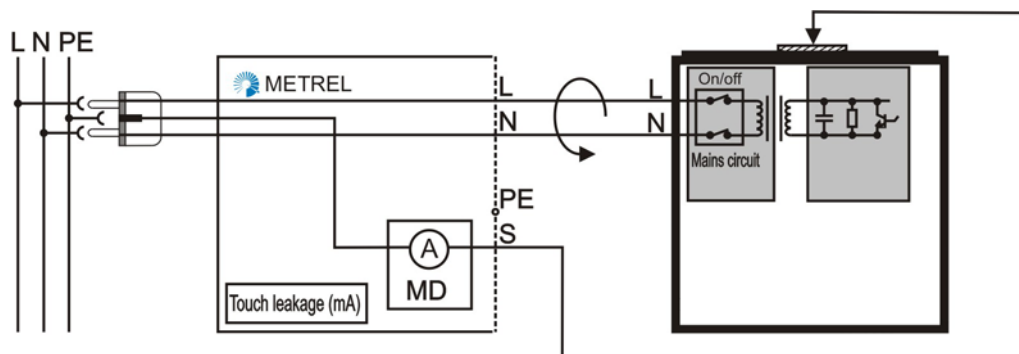
**Result:** Dangerous contact voltage on accessible conductive part. There is a risk of electrical shock if this part would be touched.



**Fig. 3.11.** Example of excessive touch leakage

**Measuring principle / limits:**

Measurement on a class II appliance (same procedure is used for isolated accessible conductive parts on class I appliances).



**Fig. 3.12.** Example of the touch leakage current test

Appliance is powered on. The current through the isolated accessible conductive parts is measured (each part separately). The measuring probe simulates the human body and is grounded inside the measuring instrument.

**Typical limits:**

VDE 701/702	Class II	0.5 mA
UK regulations	Class II	0.25 mA
	Class III	0.5 mA

For more limits and parameters refer to METREL instruments User Manuals and Appendixes.

Measuring equipment designed according to VDE0404 must have specified frequency response from DC to 1 MHz (MD characteristic).

**Notes:**

- Each isolated accessible conductive part must be checked separately. The highest results must be considered.
- This is an alternative measurement if insulation and subleakage tests are questionable.
- This is often the only applicable leakage measurement if supply is not allowed to be interrupted.
- If touch leakage currents differ for different appliance operating modes all modes must be checked. The highest result must be considered!
- If the position of line and neutral conductor in the installation or appliance plug is not predefined, the test must be performed in both directions with higher result considered.
- The measuring instrument must be well grounded during the test.

### 3.9 Polarity test

#### Scope of test

With this correct polarity of IEC leads, prolongation cords etc is checked. This test is obligatory in countries (e.g. UK, Australia) where the position of line and neutral conductors is predefined. With the polarity test shorts, crossed and opened wires in cords can be found.

#### Examples of faults

**Fault:** L and N wires are crossed in the prolongation cord.

**Result:** the protection circuit installed in the L input of the appliance will not be functional.

**Fault:** L and N wires are crossed in the supply lead.

**Result:** the fuse installed in the appliance's L wire will blow only in a case of a short between L and N but not in a L to PE short.

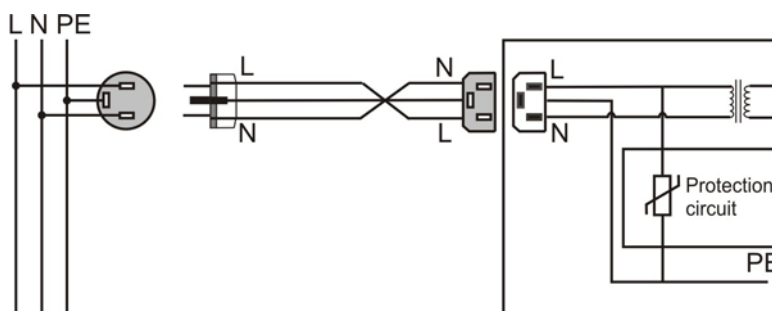


Fig. 3.13. Failure of wires polarity

#### Measuring principle / limits

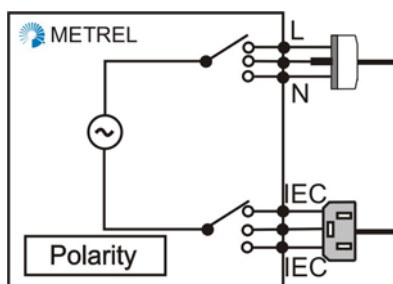


Fig. 3.14. Example of the polarity test

#### Limits:

Typical reported results:	PASS, L open, N open, PE open, L-N crossed, L-PE crossed, N-PE crossed, L-N shorted, L-PE shorted, N-PE shorted, multiple faults.
---------------------------	---

### 3.10 Load and leakage currents (measurement with current clamps)

#### Advantages of clamp measurements are:

- Measured electrical equipment does not need to be disconnected from the mains.
- Selective current tests can be performed by embracing individual conductors.
- Individual currents can be measured without disconnections.

#### Scope of test – load currents

Current clamp is a standard measuring transducer for power and load measurements. For AC currents from 100mA up to several 1000AAC measuring with current clamps is simple and quite accurate. Current clamps are best suited:

- For functional testing of fixed installed appliances.
- For functional testing of appliances with nominal currents >16A.
- For troubleshooting of current paths in appliances.

#### Scope of test – leakage currents

With current clamps leakage currents can be measured too. However this measurement has many serious drawbacks:

- Results are not accurate. They are strongly influenced by external magnetic and electric fields (caused by load currents, big conductive surfaces close to voltage sources etc). At currents below 10mA the influences can likely make the results unusable.
- Embracing all live and neutral conductors in a single and three phase system would theoretically return the leakage current. This principle often does not work well in practice.

Therefore measuring of leakage currents range of several mA can not be treated as accurate. A lot of presumptions and experience of the user are needed to obtain relevant results.

Local regulations must be checked whether the current clamp leakage test results can be considered as relevant.

#### Examples of faults for which troubleshooting with current clamp is recommended

**Fault:** A propeller of pump is stuck in the fixed installed appliance. High supply currents are flowing while the pump is supposed to work.

**Result:** High fault currents can result in dangerous overheating in the appliance. This can cause fire!

**Fault:** A powerful heater with high nominal leakage was fixed installed.

**Result:** Occasional tripping of the RCD. Dangerous contact voltages can occur on accessible conductive parts if the electrical installation is not designed properly.

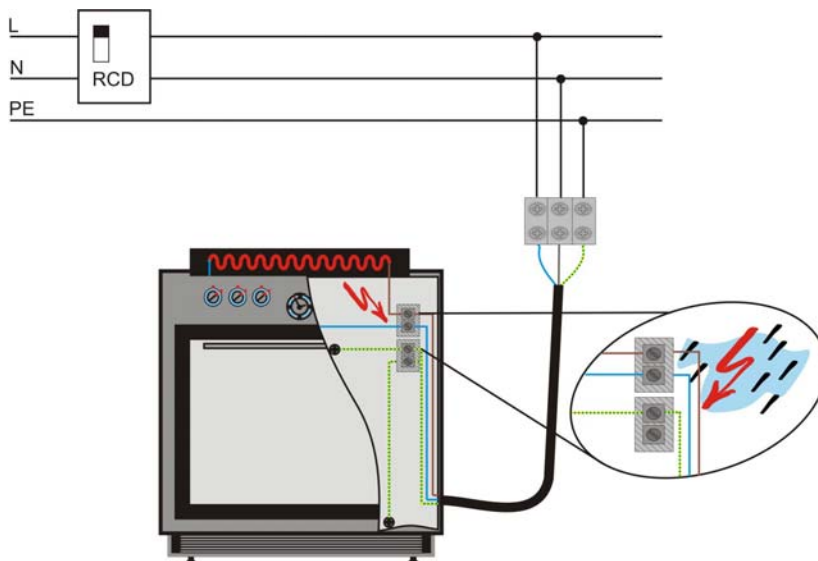


Fig. 3.15. Functional and leakage problems

**Measuring principle /limits**

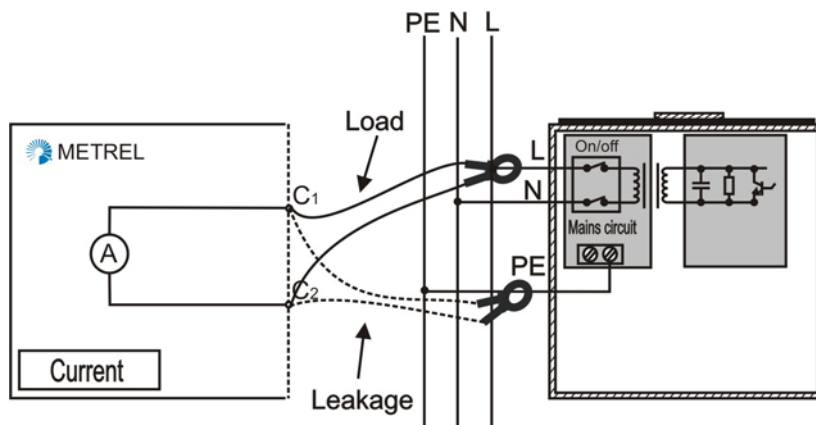


Fig. 3.16. Examples of clamp current tests

Appliance is powered on. By embracing separate conductors load or leakage currents can be measured.

**Typical limits – functional test**

up to several kVA	consider declared maximal power consumption of appliance (data on appliance label)
-------------------	--

Typical limits – leakage current test

See chapters 3.5 PE conductor leakage current test and 3.7 Touch leakage test.

**Notes:**

- For leakage current measurements special current clamps must be used (eg METREL A1019)
- If large load currents (>1A) are present in the nearness they would almost certainly disturb the leakage current results (too high readings).
- It is advisable that the user learns to become familiar with the influence of external fields. If the source of disturbance is known the influence can be minimized by using different techniques (changing the position of the clamp, placing the clamp close to earth potential, searching for the minimal reading etc).
- If in doubt it is recommended to use other leakage measuring methods.
- If leakage currents differ for different appliance operating modes all modes must be checked. The highest result must be considered!
- If the position of line and neutral conductor in the installation or appliance plug is not predefined, the test must be performed in both directions with higher result considered.
- The current clamp measurement is well suited for fixed installed equipment.

### 3.11 Functional test

**Scope of test**

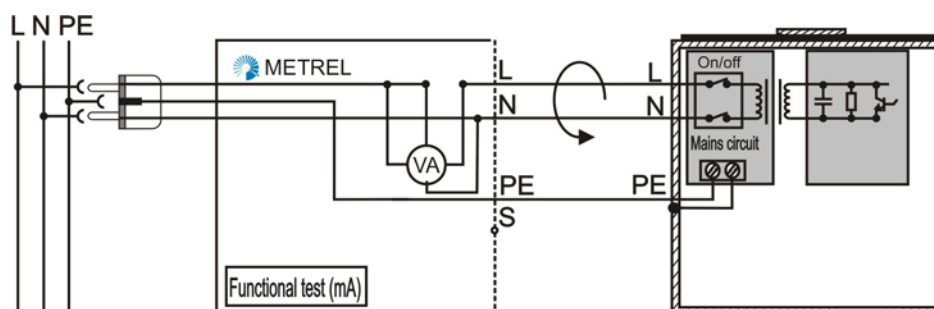
In its simplest form a functional check is simply a check to ensure that the appliance is working properly. The use of more sophisticated measuring instruments permits load testing, which is an effective way of determination if there are faults in the appliance.

**Examples of faults**

**Fault:** Improper assembling of appliances after repair is one of the common reasons for functional faults.

**Fault:** The possibility for failures is higher if appliances are working in dusty and moisturized environment, or if they used only occasionally.

**Result:** Improper operation of appliance, tripping of overcurrent disconnection devices.

**Measuring principle / limits**

**Fig. 3.17.** Example of functional tests

Appliance is powered on. The load current and supply voltage are measured in the measuring instrument. Load power or/and current are displayed on the measuring instrument.

**Typical limits for load currents**

up to several kVA	Depends on declared power consumption of appliance (data on appliance label)
-------------------	--

**Notes:**

- All appliance operating modes should be considered.
- The functional test is performed as the last step of a safety test sequence. It should be run only if all previous safety tests passed successfully! The functional test would rarely disclose a safety problem!
- This test is recommended after maintenance or repairing works. On appliances that are used in harsh environment (dust, moisture, heat) it is wise to include the functional test as a part of a periodic test too.

## 4. Optimal testing

For optimal maintenance and safety of electrical equipment following is important:

- Operators of test equipment must be skilled and competent to execute the tests correctly.
- Owners and users of appliances must be aware of the importance of electrical safety.
- Person or company that performs the tests should advise owners of electrical equipment: about the importance of regular tests and about possible dangers caused by faulty equipment and for that reason the equipment shall be regularly visual checked and properly maintained.
- Communication between users and testing personal is important!
- Appropriate test sequences should be selected.
- Modern measuring instruments should be used. Automatized test sequences, modern data documentation systems, labelling and other features assure simpler, faster and more reliable testing than with conventional appliance testers.
- Results and optional comments should be well documented. Especially disclosed safety problems must be very well described – especially important for medical equipment.
- Test results and data should be stored in a clear and consistent way. This will simplify and speed up future tests on same appliances.
- Problematic appliances must be immediately brought out of service and clearly marked. Marking (labelling etc.) off all tested appliances is recommended (status, test and retest, test sequence date etc.).
- Appropriate extent and retest periods should be defined.

### 4.1 Advising owners and users of appliances

As explained in chapters 3.1 and 5.1 regular visual checks are very important. A combination of visual and electrical testing will return the best result. It is recommended to advice the owners/user of equipment about following:

#### **General information:**

- Most often accidents happen because of electric shock and fire through overheating.
- Independent safety approvals are more valuable. CE mark is not an independent safety approval.
- Not only electrical equipment, electrical installation must be well maintained too.

#### **It is useful that basic visual checks are performed by the owner/user itself.**

- Serious safety faults can be found with visual checks.
- Any signs of damage, wearing, ageing, corrosion, moisture, overheating are dangerous.
- Equipment should be kept away from flammable items (curtains, paper etc.).
- Always use prolongation cables / splitters with PE conductor and appropriate

current capability.

### **Maintenance**

- The supply cable is one of the most exposed appliance part. It must be free and undamaged.
- Wet, hot and dusty environment are especially critical.
- Openings, slots, air gaps etc must be kept clean. Airflow must be assured.
- Appliances should be cleaned in off state and completely dried out before in use again.

## **4.2 Test sequences**

### **4.2.1 Selection of correct test sequence**

Test sequences are specified sets of measurements, limits and test parameters. Test sequences are specified in product standards, test standards and national regulative. They differ on base of selected test standard, type of testing, type of appliance, appliance protection class etc.

In this chapter proposed test sequences according to British Code of Practice, VDE 0701-0702 and IEC/EN 62353 are shown. Testing procedures for almost any piece of electrical appliance can be specified from these flowcharts. The procedures are optimized for use with METREL testing equipment and completely correspond with the standards.

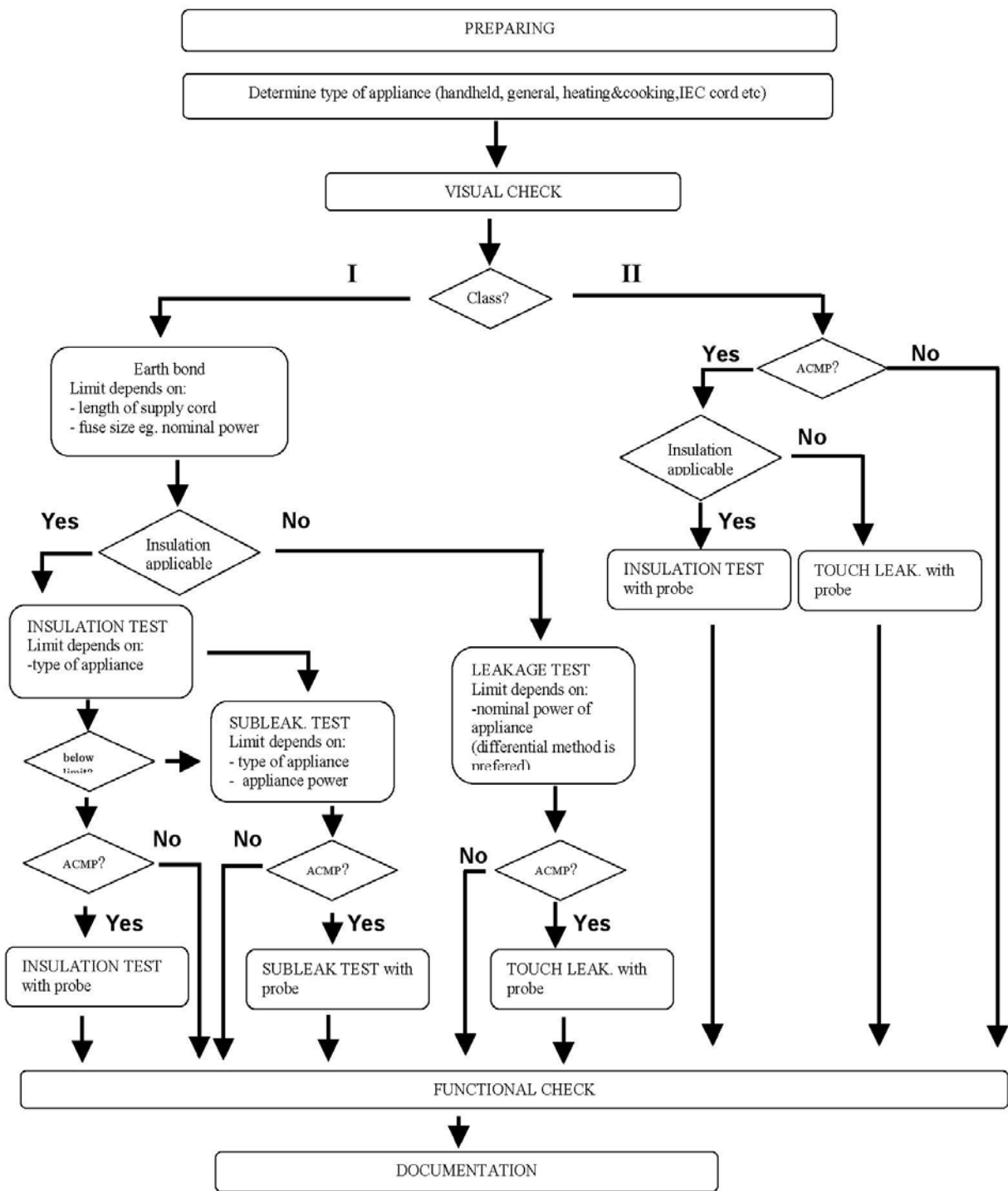
It is very important to select the correct test sequence. First the type and class of appliance must be determined. After that all safety relevant accessible conductive parts must be found. After that the test sequence, test limits and parameters must be selected.

It is of a great advantage if this can be made automatically by the measuring instrument – safety tester.

- Main advantages compared to standard test equipment are:
- Shorter time of measurement.
- No need for setting function, test parameters and limits for each measurement.
- Higher confidence in test results, smaller possibility to make mistakes.
- No wrong setups, no forgotten activities etc.

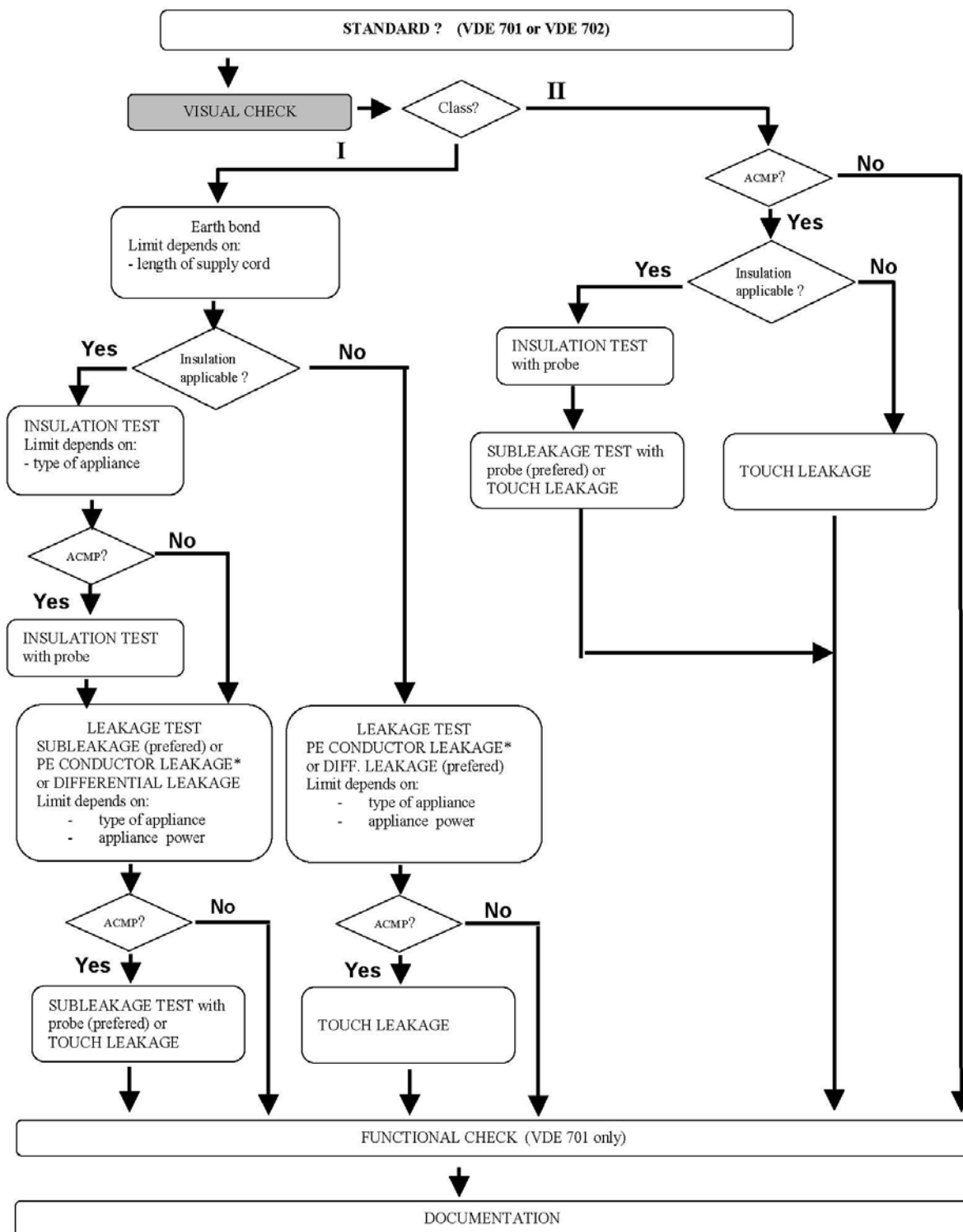
Further advantages of modern appliance tester will be described in chapter 7.

### 4.2.2 Flowchart of test sequences for testing of appliances according to British standards

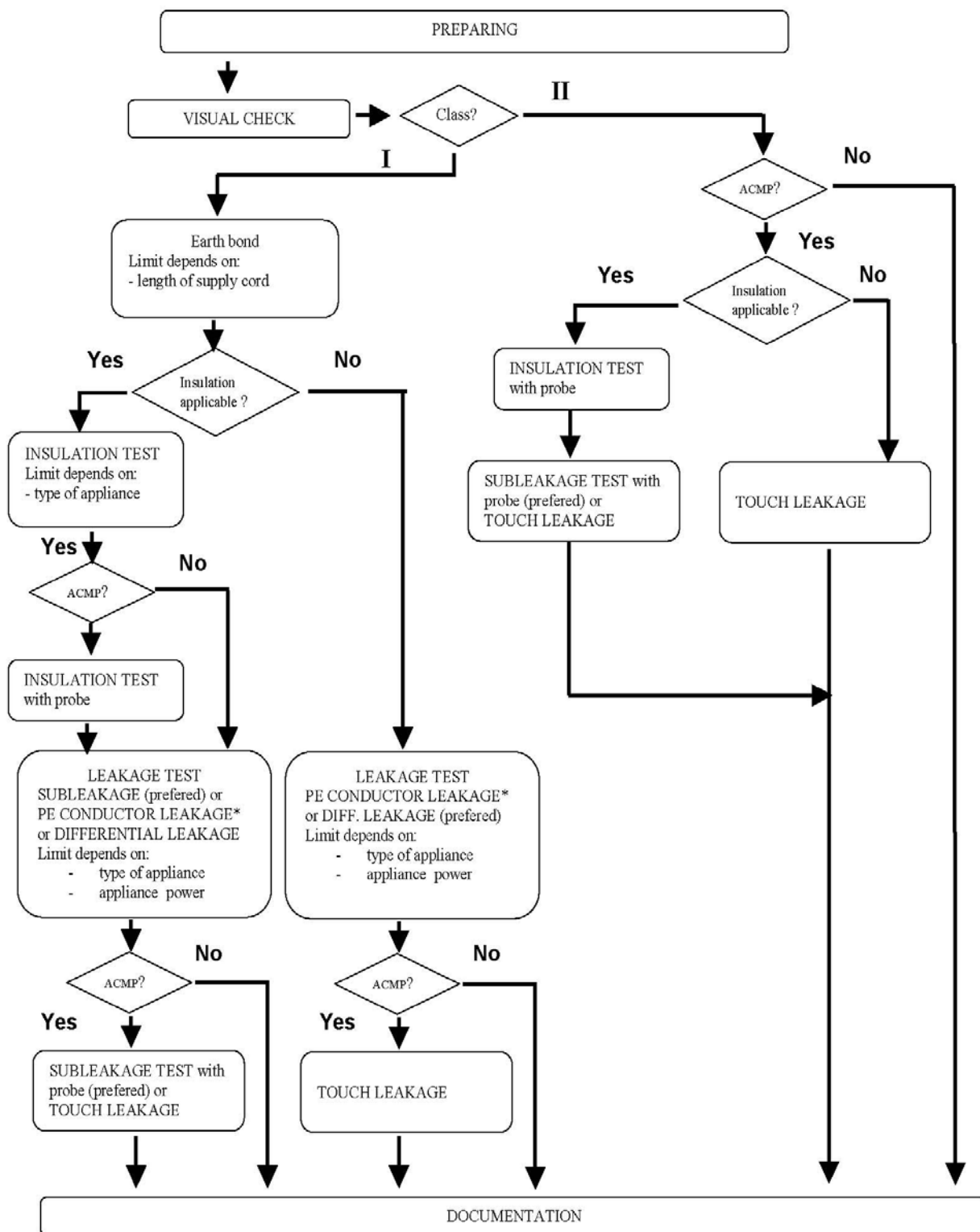


### 4.2.3 Flowchart of test sequences for testing of appliances according to VDE 0701-0702 standards

#### VDE 0701 procedure



VDE 0702 procedure



#### 4.2.4 Retest period

The interval between checks depends on field of use. Of course the retest interval must be shorter for use in schools or construction site than for normal domestic use.

Close attention must be paid to initial checks. After the first inspection(s) /tests it can be decided to change the retest period.

#### Some suggested initial frequency for inspection and testing of equipment

##### British code of practice

<i>Type of premises</i>	<i>Type of equipment</i>	<i>Protection class</i>	<i>Formal visual inspection (months)</i>	<i>Formal inspection and testing (months)</i>
Schools	Stationary IT Movable Portable Handheld	I	-	12
			-	12
			4	12
			4	12
			4	12
	Stationary IT Movable Portable Handheld	II	12	48
			12	48
			4	48
			4	48
			4	48
Hotels, Offices, Shops	Stationary IT Movable Portable Handheld	I	24	48
			24	48
			12	24
			12	24
			6	12
	Stationary IT Movable Portable Handheld	II	24	-
			24	-
			24	-
			24	-
			6	-
Public	Stationary IT Movable Portable Handheld	I	1	12
			1	12
			weekly	6
			weekly	6
			weekly	6
	Stationary IT Movable Portable Handheld	II	3	12
			3	12
			1	12
			1	12
			1	12
Construction sites 110V	Stationary IT Movable Portable Handheld	I	1	3
			1	3
			1	3
			1	3
			1	3

	Stationary	II	1	3
	IT		1	3
	Movable		1	3
	Portable		1	3
	Handheld		1	3

#### German legislation (GUV V A2)

<i>Type of premises</i>	<i>Formal inspection and testing (months)</i>	<i>Typical Equipment - examples</i>
Baths	6	water pumps prolongation cords centrifuges
Slaughterhouses	6	electrical tools
Public kitchens	6	coffee machines saws ovens
Fire fighting	12	lights pumps
Cleaning services	12	Vacuum cleaners
Laboratories	12	lights measuring instruments heaters
Schoolrooms	12	Projectors computers
Washhouses	12	washing machines
Construction sites Workshops	12	boring machines soldering apparatus climates
Offices	24	IT equipment
Old people homes	24	ovens lights

#### 4.2.5 Test sequences and limits preprogramed in METREL

In METRELs measuring instruments many hundred pre-programmed testing sequences with test limits and parameters are offered (contact METREL or local distributor for further information). Pre-programmed sequences cover in-service, maintenance and retest measurements, regardless of appliance type, safety class, supply cord length, nominal power, etc.

In the table below there are links to pre-programmed test sequences:

<b>Test sequences proposed by:</b>	<b>Included in instruments</b>	<b>Links</b>
AUSTRALIAN / NEW ZEALAND Code of practice	AlphaPAT BetaPAT OmegaPAT	<a href="http://www.metrel.si">www.metrel.si</a>
British Code of Practice	AlphaPAT BetaPAT OmegaPAT	<a href="http://www.metrel.si">www.metrel.si</a>
VDE, ÖVDE regulations (Germany, Austria)	AlphaGT701/702	<a href="http://www.metrel.si">www.metrel.si</a>

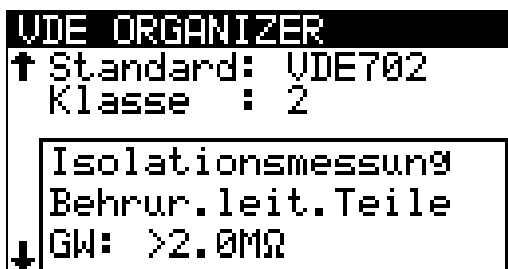
Examples of preprogramed test sequences in METREL measuring instruments:



**Fig. 4.1** Example for Autotest of appliance according to British standard instrument OmegaPAT



**Fig. 4.2** Example for Autotest of extension lead according to British standard instrument OmegaPAT



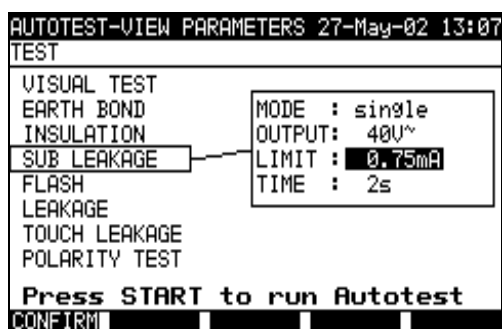
**Fig. 4.3** Example for Autotest of a class II appliance lead according to VDE 701 standard instrument AlphaGT

## 4.2.6 Customized test sequences in portable appliance testers

Sometimes the test sequence cannot be chosen from pre-programmed ones. Some typical examples when customized sequences are to be used are:

- Special tests procedures defined by the equipment manufacturer.
- Functional and leakage tests must last longer (e.g. for functional test to check all operation modes, IT equipment to boot up completely)
- Stricter test procedures are defined for checking appliances after repair (e.g. higher earth bond currents, insulation test).
- Stricter test procedure is defined because of appliance age or work in aggravating conditions.
- Fixed connected appliances that cannot be disconnected (only clamp current test is applicable).

An unlimited number of customized test sequences can be defined and stored in METREL instruments. In the figures below there is an example of customized test sequences in METREL measuring instruments:



**Fig. 4.4** Example of set up of parameters for a customized test sequence – instrument OmegaPAT

## 5. Test data management

### 5.1 Documentation of test data

Following data are to be stored with each test:

- Operator data
- Appliance data
- Test results with date and time of measurement
- Test reports are to be made on request
- Retest period of appliance
- Modern PAT testers enable comments to be added

In some (visible) places condition of equipment should be clearly labelled.

For medical equipment test data (results, date, notes) must be entered in equipment's logbook.



*Fig. 7.1. Examples of test data screens*

#### Operator (user) data

Information about operator (user) data is important for traceability and confidence in results.

#### Test results are:

- Test results (e.g. 0.45 Ω, 17.7 MΩ).
- Test limits (0.5 mA, 500 kΩ) to compare results to safety limits defined in standards.
- Evaluation of result (e.g. PASS, conditional PASS) e.g. comparison against safety limits.
- Test parameters (EarthBond 200 mA, Insulation Resistance 500 V) to assure that correct measurement setup was used.
- Test date to define when next retest has to be performed. Suitable also for sorting results, for view history of results etc.
- Appliance data:

**Appliance ID (Appliance No.)**

In some countries it is obligatory to mark each appliance with an unique identification number (ID).

Advantages of using unique IDs for each appliance are:

- Easier browsing through appliances in database.
- Necessary if all data are stored in one data base
- If code of test sequence is applied to the ID the appropriate test sequence can be read directly from the ID code. Some METREL PAT testers support this option.

ID numbers are often printed as barcode labels and are stucked on the measured appliance. A newer technology is to read/write the ID number via RFID tags.

**Appliance Name**

Short description of appliance should be entered in these lines. That is suitable also for later sorting of results, retesting etc.

**Site, Building**

Short description or address of test site can be entered in these lines. That is suitable also for later sorting of results, retesting etc.

**Retest period**

The retest period defines when next testing of appliances has to be performed.

**Repair code, Notes, Comments**

It is a good practice to add short comments to the test. That helps to better classify and evaluate the work later. It is recommended to enter short comments:

- To notice noted deviations or special activities (e.g. change of fuse, fixing of a supply plug).
- To note activity (first inspection, routine check, service).
- Any deviations from normal (long duration of test, etc.).

**5.2 Labelling of appliances**

Information that are usually labelled on the appliance:

- Appliance ID number (as bar code).
- Appropriate test code for appliance (as bar code).
- Retest date.
- Current functional status of appliance (PASS, FAILED, OUT OF SERVICE, etc).





Fig. 7.2. Example of info labels about actual status of appliance

### 5.2.1 Bar Code technology

Bar code technology is the today most common technology for labelling of appliances. Bar code labels can be printed:

- With help of special PCSWs for generating bar code labels
- With test instruments and compatible printers (some METREL instruments support this option)

METRELS PAT testers support following functionalities with bar code labels:

- Reading appliance ID.
- Reading autotest (shortcut) sequences.
- AlphaPAT enables printing of labels with external printer.

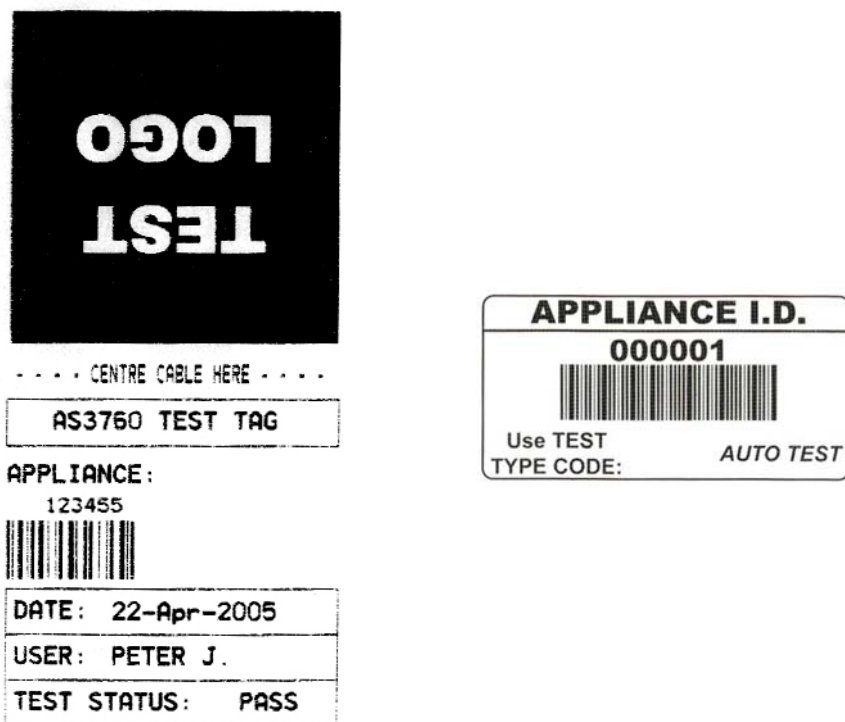


Fig. 7.3. Examples of bar code labels with test code and appliance ID



**Fig. 7.4.** Example of a complete system for printing appliance labels (AlphaPAT + Intermec C4 printer)

### 5.2.2 RFID technology

RFID is a newer technology that enables contact less reading from and writing data to RFID tags. There are following advantages compared to standard labels:

- Tags are less sensitive to moisture, light, scratches, ageing etc.
- Data can be written into tags, including test results.
- Comparison of data on the field (previous vs. Actual, observing of trends).
- Test data can be password protected.

Unfortunately RFID technology is still expensive compared to the bar code technology.

Some METRELS testers supports the RFID technology.

Following functionalities are supported with METRELS technology:

- Viewing autotest results,
- Viewing autotest sequence,
- Saving autotest sequence and results to instrument memory,
- Storing autotest sequence and/or results to the RFID tag.



Fig. 7.5. Example of a complete system for printing appliance labels

## 6. PAT PC software packages

PAT PC SW packages enable users to manage the measurement results and belonging data. Basic functionalities that a PAT PC Software package should have are:

- Transferring measurement results and parameters from PAT to a PC.
- Documentation of test results and data.
- Addition of report header data.

Modern PC SW packages like METREL's NewPATlink offer further functionalities:

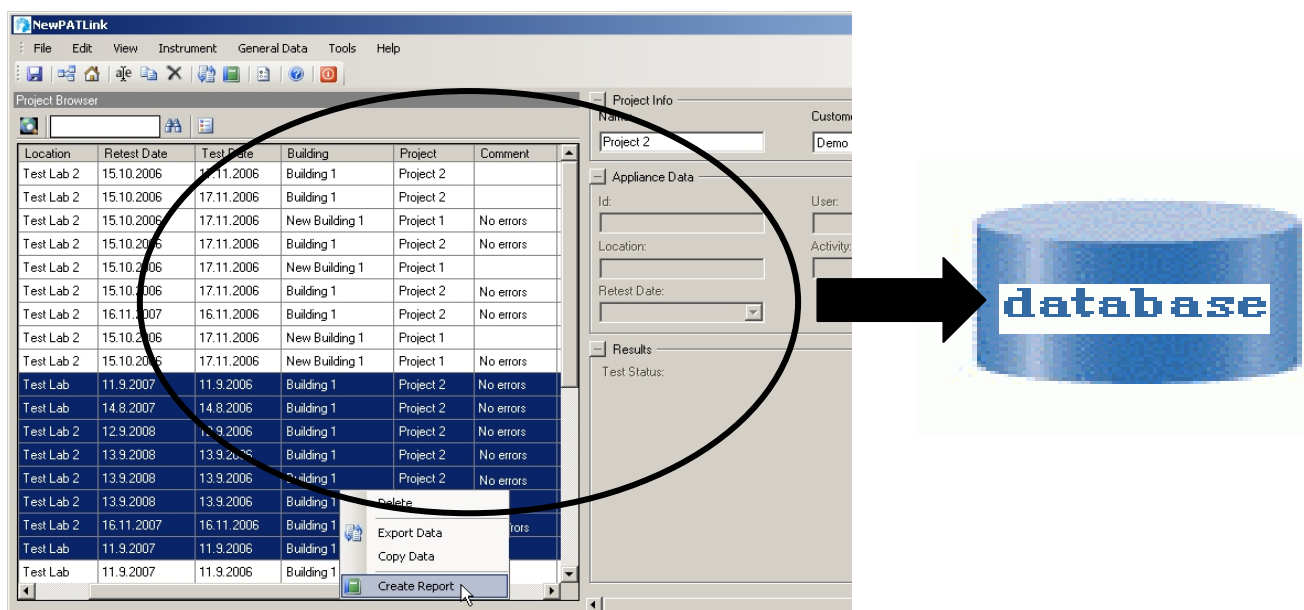
- Generation of standardized test reports (country dependant).
- Transferring measurement plans with optional past results from PC to PAT (two-way communication)
- Easy browsing through current and past projects with help of editors.
- Easy comparison with past results, viewing trends.
- Generation of invoices.
- The most important functionalities will be explained on base of METREL PAT PC Software packages PATlink ver.4.0 and NewPATlink.

### 6.1 Documentation of test results and data

The PCSW package must allow to store test results and data to a database or file.

Database supported PCSW packages have the advantage that the complete base of test results and data is available at once.

File system based packages have data stored in different files and all data is not accessible at once.



**Fig. 8.1.** Example of data to be stored in database (New PATlink)

## 6.2 Addition of header data

In header data additional important data are entered like customer data, performer and operator data, addresses etc.



Fig. 8.2. Header in PC SW New PATlink

## 6.3 Generation of standardized test reports

Test reports are usually handover to the customers. Beyond test results and parameters a test report usually includes data about location, operator, customer, comments, description of performed activities etc. Reports can be stored to file (archive), printed out or sent by email from within the application (depending on user's desktop environment).

In some countries the content of test report is predefined.

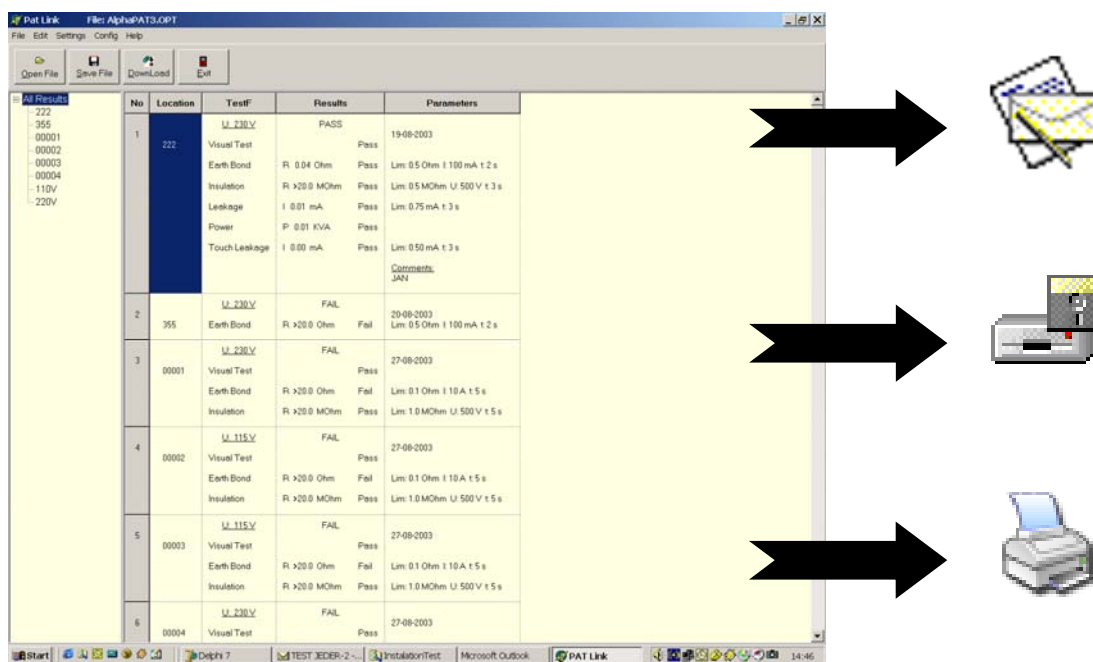



Fig. 8.3. Example of a test report - PATlink



The screenshot shows a window titled "Report Creator" with a "TEST PROTOCOL" form. The form includes fields for Customer, Validator, Operator, and Instrument Data. The Instrument Data section contains a table with the following information:

Type:	Serial Number:	Last Calibration:
MI 3301	00000005	1.1.0001 0:00:00

Below the table are two large text areas labeled "Content of Report (Operator Comments)" and "Test Report Results / Conclusion". At the bottom of the window are buttons for "Print", "< Previous", "Next >", and "Cancel".

*Fig. 8.4. Example of a part of a test protocol - NewPATlink*

## 6.4 Browsing through current and past projects with help of editors

A project is a pre-prepared hierarchical structure of appliances to be tested. A browser displays a hierarchical list of projects, several levels of buildings and appliances and is customizable. Users can use advanced filters to present the data in the browser according to their needs. Customization includes filtering and sorting of browser's data. Some examples are shown on picture below.

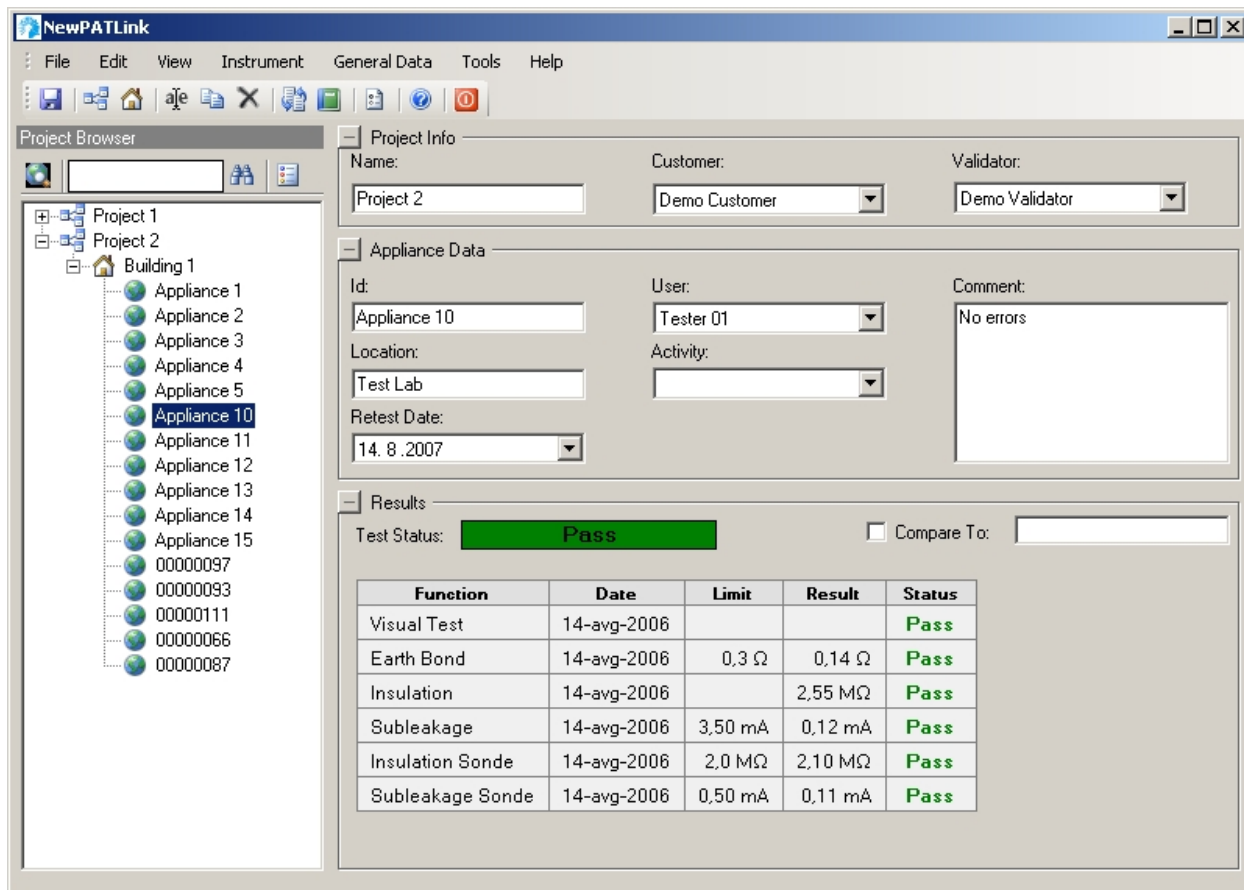


Fig. 8.4. Examples of project editor (New PATlink)

### 6.5 Easy comparison with past results – observing trends

This functionality allows to compare current results with past results. Together with each past result a visual mark is displayed indicating a comparison result. This allows the user to follow the trends of test results. For medical testing comparison with past results must be performed if the results are approaching close to the safety limit.

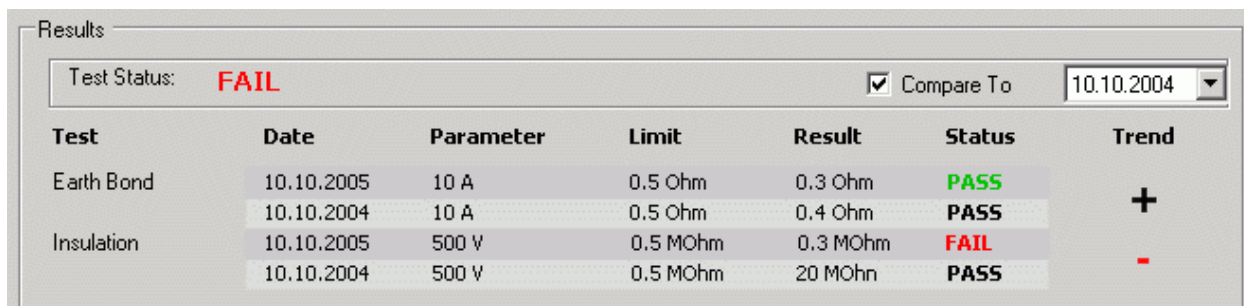


Fig. 8.5. Example of data comparison (New PATlink)

### 6.6 Export to spreadsheet programs

Some customers or performer want the reports and invoices in a customized form. Data can be exported to Excel where they can be further customized with standard PC tools.

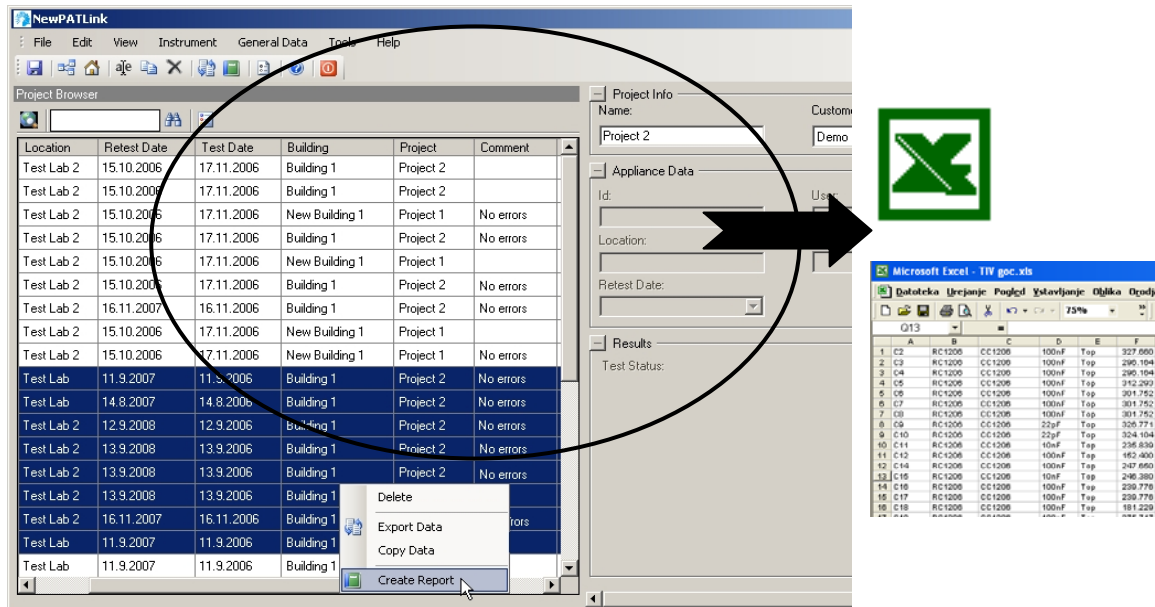


Fig. 8.6 Example of data exported to Microsoft Excel.

## 7. METREL instruments



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