

# Product Qualification and Compliance Verification of ESD protective items

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## International Standard Requirements

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According to IEC 61340-5-1: 2007 [1] and ANSI/ESD S20.20: 2007 [2] a compliance verification plan has to be established to ensure organization's fulfillment of the requirements of ESD control program plan. Measurements can be categorized in two groups: compliance verification and product qualification. Product qualification is performed during the initial selection of ESD protective items. Process control and periodic checks in ambient conditions are included in compliance verification. The following technical requirements are presented in IEC 61340-5-1: 2007 [1] and ANSI/ESD S20.20: 2007 [2]:

Grounding	ESD protected areas
Equipotential bonding systems	Packaging materials
Personnel grounding	Marking

## Measurements in Practice

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Qualifications of ESD protective items are challenging to realize in practice. Most of the control measurements are related to the evaluation of possible electrostatic source circuits although ESD is an RF phenomenon which has a frequency dependency. Therefore DC measurements may result erroneous conclusions.

Primarily a standard test method shall be used in qualification and compliance verification. A non standard test method is chosen when the standard test method is inadequate because of the specific reason. A modern ESD control program is focused on products and a process. Process monitoring is typically based on measurements of electrostatic field, potential, mobile and immobile charges and charge transfer. Standard test methods do not necessarily cover the case specific needs of qualification or compliance verification because of the product and process related details, which cannot be generalized.

Measurement techniques of electrostatics and ESD measurements vary. Sometimes the slow response of the very low current is measured in a function of time. Oppositely there are often needs to measure extremely fast phenomenon and high currents.

Measurements are not always complicated technically, but an adequate analysis of the results may be challenging to perform. Random errors can be estimated statistically, but an analysis of systematic errors and avoidance of gross errors require a theoretical background and experience in measurements.

In practice measurements are categorized as follows:

Material analysis  
ESD protective items  
EPA measurements

Process evaluation  
ESD withstand tests  
Risk assessment

## Measurement Conditions

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Environmental conditions for product qualification should be 12 % RH and 23 °C [1]. Test conditions are described in more details in measurement standards, for example: "The atmosphere for conditioning and testing shall be 23 °C ± 2 °C and 12 % ± 3 % relative humidity. The conditioning time prior to testing shall be at least 48 h, or as otherwise agreed." [3].

A preconditioning of the samples affects the results. It is essential that there are no abrupt changes in conditions just before qualification. Compliance verification is typically carried out in ambient conditions. "For measurements in practical situations the ambient temperature and relative humidity shall be recorded." [4]

There are several reasons why qualification has to be carried out in low humidity conditions. 12 % RH is a kind of compromise which is not the worst case condition as sometimes explained. In continental climate relative humidity drops down below 10 % in large buildings during long lasting cold periods.

Charge dissipation is slower and charge accumulation is more efficient at low humidity. Therefore electrostatic phenomena can be reproduced more accurately in low moisture. The reliability and repeatability of measurements are also dependent on test conditions. Leakage current in test setup may be difficult to control in moist conditions.

## Resistance and Resistivity

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Resistivity and resistance are common measurements in protection against ESD, because it is often suspected that the measured resistance can be used for determining a time constant of an electrostatic source circuit. This assumption may also cause fundamental errors due to several uncertainty factors related to measurement.

Typically resistance and resistivity have a significant voltage dependency. Measurements are made with the relatively low open circuit test voltages ( $U \leq 100$  V). The breakdown voltage of a test circuit may only be slightly higher than open circuit test voltage.

Resistance is also highly dependent on frequency. ESD is a wide band phenomenon where imaginary components cannot be ignored. Therefore resistance does not necessarily correlate with the real ESD.

In practice a connection resistance of the real ESD circuit differs a lot from the resistance measured with the standard electrodes due to different contact areas, materials, pressing forces, etc. In addition there are other several uncertainty factors related to the low current measurement techniques such as capacitive loading, orientation, electrification and leakage.

Resistance measurements nullify possible electrostatic source circuits. Therefore resistances shall always be measured after electrostatic analysis, not before.

Computational errors may result while the resistance of the measurement circuit is converted to the resistivity of the sample and vice versa. Resistance of the measurement circuit is related to the certain test arrangement. According to IEC 61340-5-1: 2007 [1] surface resistance is measured with a concentric ring electrode IEC 61340-2-3 [4].

## Triboelectrification

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When two pieces of neutralized electrically floating objects are approaching and touching each other, objects become charged. Speed of removal, capacitive coupling, back flow current, leakage, electrochemical effects, contamination and moisture all affect chargeability.

Despite the modern test methods it is still quite challenging to characterize triboelectrification due to low repeatability and reproducibility. If the same test sequence in the same test setup is repeated several times, amount of charge and polarity may change.

## Electrostatic Field and Potential

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A simple user interface encourages people to make measurements with electrostatic field meters. However, it is essential to understand a theory of electrostatics before making measurements. An electric field at a certain point is equal to the electric force per unit charge. Therefore the SI unit of electric field magnitude is Newton per Coulomb [N/C]. Electric field depends on charge, permittivity and distance. On the other hand, an electrostatic field is a negative gradient of potential and it is often represented as [V/m]. Potential  $V$  is potential energy per unit charge [ $V=Nm/C=U/C$ ].

Magnitude of electrostatic field depends on surface charge density: 
$$E = \frac{\sigma}{\epsilon_0} \quad (1)$$

Uniformly charged insulating sheet has half of the electrostatic field compared to the same charge density of conductive material:

$$E = \frac{\sigma}{2 \epsilon_0} \quad (2)$$

In practice an electrostatic field to be measured is always disturbed by the meter. Therefore it is important to clarify a positioning of the meter into test setup. Meters are typically sensitive to calibration distance. Guard planes are needed for establishing a homogenous electrostatic field required for the measurement.

It is important to choose the correct instrument for qualification and compliance verification. AC- type of non contact voltmeters for example shall be chosen for the analysis of large conductive objects when measurement distance cannot be set accurately. Contacting voltmeters with the low input impedance and low capacitance can be chosen for small conductive objects. Non contacting DC – feedback sensors are adequate while a sensor can be placed close to the conductive or dissipative surface. Electrostatic field meters shall be chosen for the analysis of insulators. Electric field or potential measurement shall never be used for an acceptance test as alone. However, rejection can be based on objective and rational analyses of the measurements.

## Electrostatic Charge

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Mobile charge can be easily measured with a nanocoulomb meter, but results are often affected by unknown electromotive forces, thermoelectricity and leakage currents. Scrolling reading indicates errors in measurement. Charges can be categorized into a mobile and immobile charge. The speed of charge transfer is an important test parameter. It is essential to understand a frequency dependency while source parameters are used for ESD risk analyses. If a mobile charge is expected to transfer in nanoseconds during ESD, Charge accumulation should not be measured in seconds. That is the reason why mobile charges are typically integrated from ESD curves measured with a current shunt or transformer and an oscilloscope.

## Charge Decay

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Currently there are not too many reliable methods available for charge decay measurements. Mr. John Chubb wrote an interesting article about existing test methods in 2002: “There are several methods for measurement of ‘charge decay’ described in ‘standard’ documentation and in published literature. The methods of measurement are very different and many of the methods do not provide the information likely to be expected by uninitiated/unskilled users and are susceptible to the construction of the materials tested.” [5]

Two different test methods are presented in IEC 61340-2-1: “The first method determines the dissipation of charge deposited on the surface of the material by a corona discharge. The resulting decrease in surface potential is observed using a field meter or equivalent equipment.” [3] The first corona method is useful in many cases, but initial delay between corona charging and measurement may cause faulty conclusions. On the other hand such an efficient ionization may not be expected to see in nature. Corona ionization may also cause physical changes on the surface to be ionized.

“The second method determines the dissipation of charge from a charged plate through an object under test by applying a potential to the metallic plate, disconnecting the voltage source and observing the decrease in potential of the plate by means of a field meter or other equivalent equipment. This method is applicable to measurement of charge dissipation via products such as finger cots, gloves and hand tools.” [3]

A Charge plate monitor (CPM), can be used for the analysis of conductive objects, but there are several reasons why CPM should not be used for material analyses. Capacitance between the sample and metal plate is typically much higher than the capacitance of charged plate. This may cause results which are not related to the electrostatic behavior of the sample. The physics of the junction between the sample and metal plate is complicated: A voltage and current dependency, breakdown field strength, avalanche and polarization all of them affect charge decay properties. In addition, isolating materials cannot be charged up by a direct high voltage connection and a charging period has to be longer than the discharge period. “This approach may be useful for assessing how quickly charge may be removed from a conducting item in contact with a material - such as a person standing on flooring. It does NOT, however, measure the ability of a material to dissipate charge on its own surface.” [5]

The shape and size of object may also prevent the usage of standard test setup. FTMS 101 method 4046 can be used for example only if the sample is planar, homogeneous, and electrically dissipative [6].

Cascade Metrology has introduced the new approach to material analyses in 32<sup>nd</sup> annual EOS/ESD Symposium 2010. In this study electrostatic properties of items under test are characterized in a changing electrostatic field [7].

## ESD Measurements

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ESD tests are mainly related to the sensitivity classification of components or final products. There are several standardized test models for ESD testing: Human Body Model (HBM), Human Metal Model (HMM), Charged Device Model (CDM), and Machine Model (MM).

Additionally there are also non standard ESD withstand test methods for example cable discharge, transmission line pulse, charged board event etc. Withstand tests are typically made in independent or internal test laboratories.

Electrostatic discharges may also be captured from the real sources for the risk analysis [8]. For example objects to be touched with CDM sensitive parts can be characterized by electrostatic discharge attenuation test [9].

According to IEC 61340-5-1 static discharge shielding is recommended for the protective packaging to be used outside EPA. ESD shielding limits the current and attenuates the maximum energy from 1 000 V human body model discharge to less than or equal to 50 nJ integrated over 500  $\Omega$  resistor. A test method for evaluating shielding bags is presented in ANSI/ESD STM11.31 [10].

## Measurement Services

Product qualification is primarily a reliability issue but it also has impact on expenditures. Characteristics which do not exist should not be paid for. On the other hand it is necessary to follow standard requirements to ensure customer satisfaction and continuous business.

Measurement activities require relatively high initial costs which can be avoided by using external services. Qualification and compliance verification may be compared with the similar services such as calibration and maintenance. The work has to be done, but it should not be directed to unskilled people. Professional skills achieved by continuous learning increase costs.

Organization's internal measurements become profitable when the service provider's costs are expected to reach the organization's own costs. This is a rationale and objective character for planning measurement routines. Depending on a calculation method, the critical point for establishing profitable service is approximately 60 % work load per assignment (Figure 1). In a case of lower work load it will be more economical to outsource the service.

From the business point of view an internal measurement service increases client's fixed costs and reduces a profit margin of the core business. Independent laboratory service reduces a margin of sales [11]. Client's internal resources can be released to the core business.

Third party assessments are essential for finding new objective improvements. In practice optimal and cost effective qualification is difficult to achieve without impartial third party service.

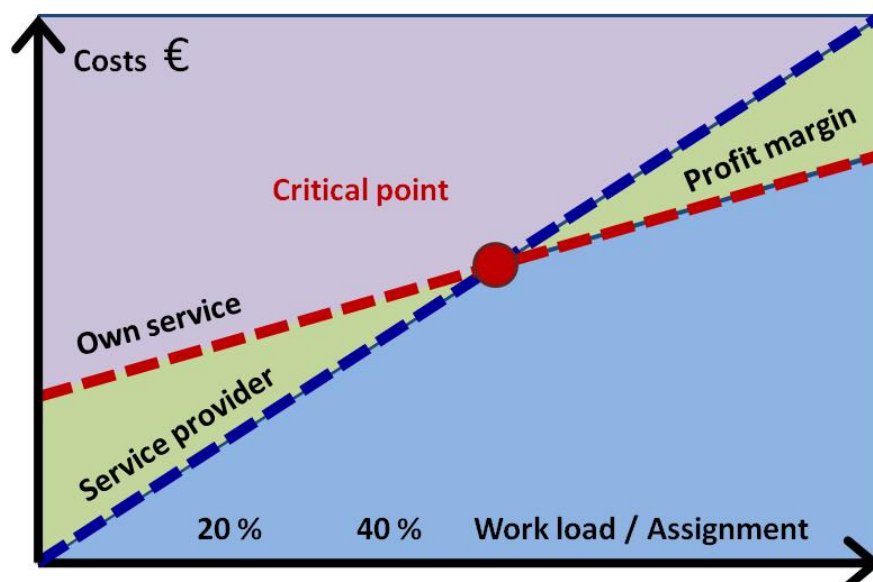


Figure 1 Cost structure of the measurement service

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