METHODS FOR THE CALIBRATION OF ELECTROSTATIC MEASURING INSTRUMENTS

Contents

January 2014

Foreword

It is necessary that electrostatic measuring instruments shall be formally calibrated to give confidence in the results of measurements, to satisfy ISO 9000 and to support any contractual or legal requirements. Suitable methods are described in the present Standard for formal calibration of the main instruments used for electrostatic measurements. These methods are based on measurements whose accuracy can be traceable to National Standards.

Correct understanding of practical electrostatic conditions and assessment of the characteristics of materials requires both the use of calibrated instruments and the use of appropriate methods of measurement. While it is often not necessary for electrostatic measurements to be made to high accuracy there is need for confidence in the values obtained and that they are within known levels of accuracy.

1. Scope

Methods are described for formal calibration of the main instruments used for electrostatic measurements. These methods enable the accuracy of measurements with these instruments to be related to National Standards of electrical parameters.

- electrostatic fieldmeters for measurement of electric field
- proximity voltmeters for measurement of surface voltage
- electrostatic voltmeters for zero current drain voltage measurements
- electrostatic fieldmeters for measuring space potential
- Faraday Pails for measurement of charge
- charge decay test units for assessment of the suitability of materials
- air ionization test units
- charge measurement units

The methods described are based on the methods in British Standard BS 7506: Part 2: 1996 [1] updated in the light of experience. No comparable alternative methods are available in standards literature. Methods for the calibration of voltage, current, resistance, capacitance and separation distance measurements are not included as these are available in the Standards literature.

2 References

2.1 Normative reference: *"Methods for measurements in Electrostatics"* British Standard BS7506: Part 2: 1996

2.2 Informative references

A number of published papers relevant to the present Standard are listed in Annex B.

3 Definitions

For the purpose of this standard, the definitions in Annex A will apply.

4 Common features for calibration

4.1 Introduction

All instruments used in calibration work shall be calibrated with reference to National or International Standards according to the procedures and requirements of BS EN 30012-1. The following sections describe a number of common requirements for calibration of electrostatic measuring instruments.

4.2 *Voltage source*

Voltages are typically required of both polarities from $\pm$10V up to $\pm$30kV. The source needs to be stable and with low ripple to better than 1% and preferably to 0.2% of the voltage level applied. More than one power supply unit may be needed to cover the required range with adequate stability and ease of adjustment.

Voltage levels for calibration should be used from less than 25% of the most sensitive full scale range to at least 25% of the least sensitive range. They should cover 100% of all ranges except the least sensitive.

4.3 *Voltage measurement system*

The voltage measuring system should cover the full range of measurement needed for both polarities. Voltage measurements should be made with direct independent connection to the calibrator plates. Connection should preferably be separate from the voltage source so that it may be calibrated and used independently. The accuracy of measurement should be better than 0.2% for high accuracy and better than 1% for medium accuracy instruments.

Voltages up to 1000V may be measured using a digital multimeter. For higher voltages a high voltage resistive divider should be used to present a known fraction of the voltage to a precision digital voltmeter.

For voltages and voltage dividers working at over 1000V precautions should be taken to avoid corona as corona discharge currents could affect accuracy. To avoid the input impedance of the measuring voltmeter influencing accuracy, the high voltage divider should be calibrated in conjunction with its measurement voltmeter. Resistor values of 1000M and 1M are convenient for the high and low voltage arms of a divider.

The voltage values at which the voltage measuring instruments are calibrated should be those at which calibration measurements are to be made to avoid any linearity errors at interpolation between calibration values.

4.4 Resistors and capacitors

High voltage capacitors and resistors, as used for the calibration of charge decay instruments and charge plate monitors, should be calibrated in situ in the unit or set-up used for calibration. Calibration of the values of capacitance and resistance should be made to better than 1\%.

4.5 Distance measurements

Distance measurements should be made using slip gauges. Calibration should be checked every two years.

4.6 Temperature and Humidity

Sensors used to provide supporting temperature and humidity information should be formally calibrated or, if incorporated into instrumentation, should at least be precalibrated.

4.7 Standard instrument calibration certificate information

The calibration certificate needs to include the following information:

a) the name of the organization issuing the certificate
b) certificate number
c) customer identity
d) instrument type number
e) instrument serial number
f) date of calibration
g) name of person who carried out the calibration and name and signature of authorized signatory
h) identification of method of calibration used (e.g. reference number of Standard)
i) overall assessed accuracy of each aspect of calibration
j) physical measurement information relevant to the calibration set-up
k) reference information on the date and place of calibration of measuring instruments used and the accuracy of these calibrations
l) list of applied parameters with derived values and the actual instrument readings observed with values for upper and lower ranges where sensitivity ranges overlap

The calibration certificate of an instrument dispatched to a customer direct from manufacture should record the 'as dispatched' values. The calibration certificate of an instrument returned from a customer should record the ‘as dispatched’ calibration as well as, where practical, the values 'as received'. If no adjustments are needed the calibration values presented on the calibration certificate are designated 'as received and dispatched'. If it has been necessary to change components or make adjustments then the instrument is recalibrated in the sealed condition ready for dispatch and both the 'as received' and 'as dispatched' values are presented on the calibration certificate.

5. Calibration procedures

5.1 Electrostatic Fieldmeters

5.1.1 Apparatus

The philosophy for calibration of electrostatic fieldmeters is to use a pair of plane parallel conducting surfaces to define the electric field E in the central region between them as E = V / d – where V is the applied voltage and d the separation distance. The sensing aperture of the fieldmeter is mounted flush with the surface of one of the plates. The plates must be large enough compared to their spacing to ensure that fringing fields from the periphery of the plates and the influence of any external charges in the vicinity do not influence the electric field at the centre of the above plates. Furthermore the spacing between the plates must be sufficient that the perturbation of the electric field by the internal structure of the sensing region of the fieldmeter does not penetrate across the gap between the plates.

The electric field for calibrating electrostatic fieldmeters is set up by application of a stable continuous voltage between a pair of plane and parallel metal plates [1,2]. The fieldmeter instrument is mounted with its sensing aperture flush with the inner surface in the middle of one of the plates (see Figure 5.1.1 and 5.1.2).

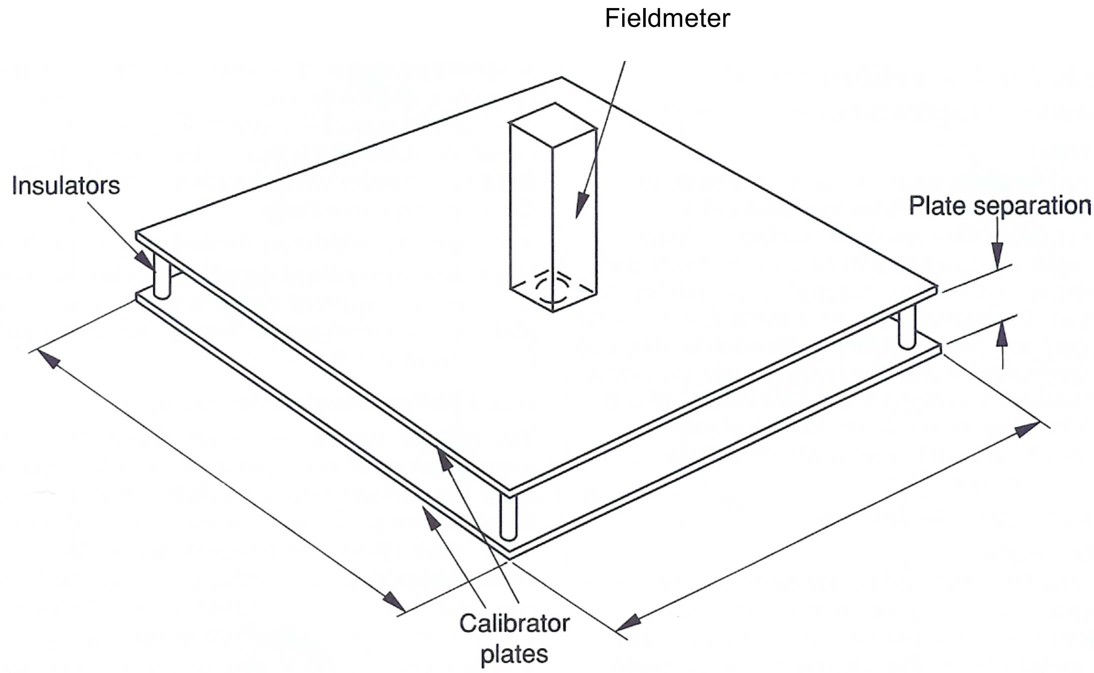

Figure 5.1.1: General arrangement for calibration of electrostatic fieldmeters

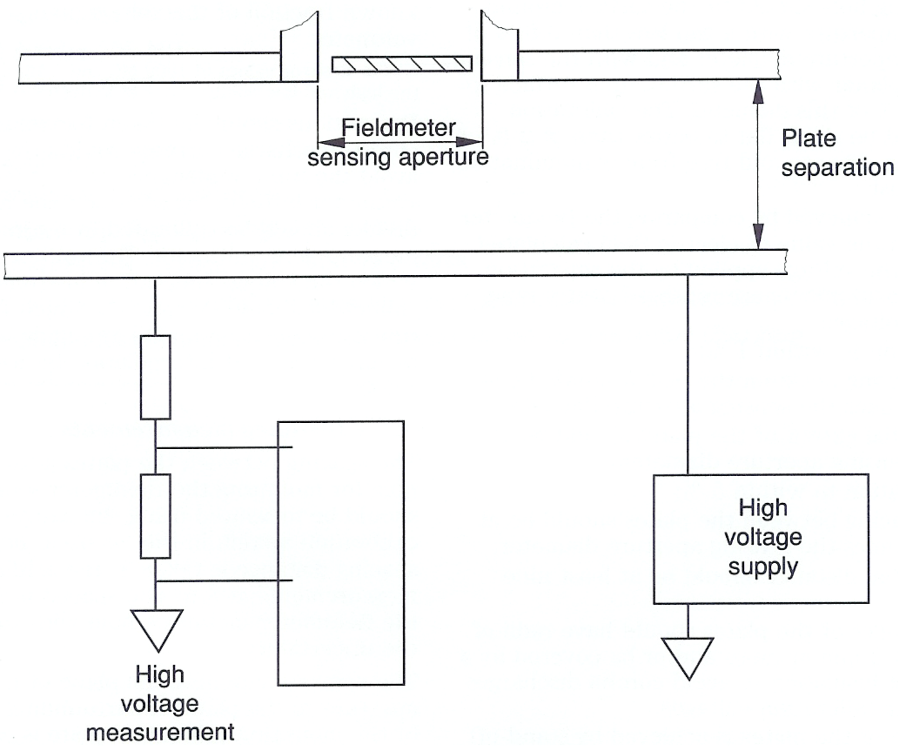

Figure 5.1.2: Mounting of fieldmeter sensing aperture flush to calibration plate

<u>For calibration to within 1%:</u>

- the spacing between the plates should be at least 1.5 times the sensing aperture diameter;
- the radial extent of the plates should be at least 15 sensing aperture diameters.

<u>For calibration to within 5%:</u>

- the spacing between the plates should be at least 1.5 times the sensing aperture diameter;
- the radial distance should be at least nine diameters.

Adequacy in the radial size of the calibration plates may be tested by shorting the plates together and observing any signal change on the most sensitive range when a piece of charged plastic is brought near the outside of the plate gap.

The mounting hole should be a close fit for the spigot around the sensing aperture. The fit should be better than 0.5% of the sensing aperture diameter and with the sensing aperture coplanar with the surrounding surface to within $\pm$0.1% of this diameter. The error in matching the plane of the sensing aperture to the plane of surrounding inner surface of the mounting calibration plate is established using slip gauges to measure the thickness of the mounting plate at four equispaced points around the mounting hole and measuring the height of the spigot of each fieldmeter calibrated.

The calibration plates should be rigid, flat to better than 2 % of plate spacing, smooth and free from contamination and loose dust. The rigidity should be adequate to avoid any change in plate separation by the loading of the heaviest fieldmeter instruments to be calibrated.

The outer edges of the plates should have radii of curvature of 2 mm or more and/or be covered by a local layer of insulation to avoid corona discharges at the higher calibration voltages (for example over 5kV).

If separation of the plates is achieved by stand-off insulators between the plates these should be mounted at the outer periphery of the plates so that any charge trapped on the insulators during high voltage operation has no influence of the electric field in the central region. This is particularly important when the plates are shorted together to check the zero setting of the fieldmeter.

With the calibration system in the 'as used' condition the spacing distance between the plates is measured using slip gauges. Measurements of separation distance are taken at four equispaced positions around the fieldmeter mounting hole. The separation spacing is taken as the arithmetic mean of measurements with calculation of the uncertainty.

5.1.2 Procedure

Calibration is achieved by comparing the fieldmeter reading with the value of electric field provided by dividing the voltage applied by the separation gap. The measurements are repeated over a range of applied voltages.

Mount the fieldmeter on the calibration unit with its sensing aperture flush with the inner surface it its mounting plate. Switch on the high voltage supply and allow it to stabilize.

With the calibrator plates shorted together take the initial (zero) reading of the fieldmeter display and/or output signal.

Apply voltages between the calibrator plates to give readings from around 25% of the most sensitive range up to at least 25% of the least sensitive range of the fieldmeter. For autoranging instruments use voltages which give readings less than 25% and more than 90% of each range so there is some overlap between ranges. Use the voltage values for calibration at which the voltage measuring system has been calibrated.

Repeat the calibration measurements for both polarities.

Note 1. Calibration to 90% of full scale may not be feasible where the least sensitive range is over 500 kV m^{-1}. After increasing the calibration voltage to maximum, check the readings as the voltage is decreased with a specific check on the zero reading.

Note 2. Differences between increasing and decreasing values of voltage or changes in zero reading may be due to charging of any insulation in the sensing region of the fieldmeter or to dust between the calibration plates. If the plates may have dust on their surfaces it is necessary to clean both the upper and lower calibrator plates.

5.1.3 Results

The results of calibration are a Table of instrument readings with corresponding the values of voltages applied and calculated values of the field. Measurements shall be made for both polarities.

5.1.4 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 4.7.

5.1.5 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in Section 4.7 a Table listing values of applied voltages, the corresponding values of electric field and the actual instrument readings observed for both polarities (with values of upper and lower ranges where sensitivity ranges overlap).

5.2 Proximity Voltmeters

5.2.1 Apparatus

Proximity electrostatic voltmeters come in two basic forms:

- The electric field observed at the sensing aperture of an earthed electrostatic fieldmeter at a defined separation distance from the surface to be measured relates directly to the voltage on the surface. Readings are not linearly dependent on gap and can be influenced by any electrostatic charges in the vicinity.
- Voltage follower probes are a fieldmeter mounted close to the test surface so that their electric field readings are determined only by the nearby surface and there is no influence from any electrostatic charges in the vicinity. The voltage applied to give zero electric field, usually via a servo control loop, is then the surface voltage

5.2.2 Arrangements for calibration

5.2.2.1 Electrostatic fieldmeter:

Fieldmeter proximity voltmeters are calibrated by mounting the instrument with its sensing aperture at the specified 'normal' operating distance perpendicular to the middle of a large plane metal surface and recording the reading of the instrument as a function of voltage applied to the metal plate. The calibration arrangement is shown in Figure 4.2.1. For calibration to $\pm$1 % accuracy, the radial extent of the calibrator plate should be at least five times the separation distance between the sensing aperture and the plate. There should be no surfaces nearer than 1 m which can retain static charge and no earthed surfaces nearer than 0.5 m. Insulators used to mount or support the calibration plate should be on the opposite side to the voltmeter.

> Note: Many proximity voltmeters are set for an operating distance of 100 mm so a radial extent of five times the separation distance requires a calibration plate of at least 1 m square.

The calibration plate should be smooth, free from contamination and loose dust and flat to better than + 2 % of the voltmeter separation distance. Plate edges should have a radius of curvature of 2 mm or more and/or be covered by a local layer of insulation to avoid corona discharges at the higher calibration voltages.

The spacing between the fieldmeter sensing aperture and the plate for earthed fieldmeter instruments should be measured using slip gauges. The distance shall be measured with an accuracy better than 0.5 % for high accuracy instrument and 2 % for medium accuracy. For voltage null instruments the separation distance is not measured so long as it is less than 10 % of the minimum radius radial distance of the surface surrounding the sensing aperture.

5.2.2.2 Voltage follower probe:

The probe head unit should be mounted by an insulating support with the sensing aperture separated from the clean flat calibration plate a distance similar to the sensing aperture. The mounting insulation must be suitable to withstand the highest calibration voltage to be used. It must also be well shielded from the sensing aperture to avoid any possibility that residual charge can influence observations.

All surfaces that could become charged and influence readings need to be kept well away from the sensing unit – at least 0.1m.

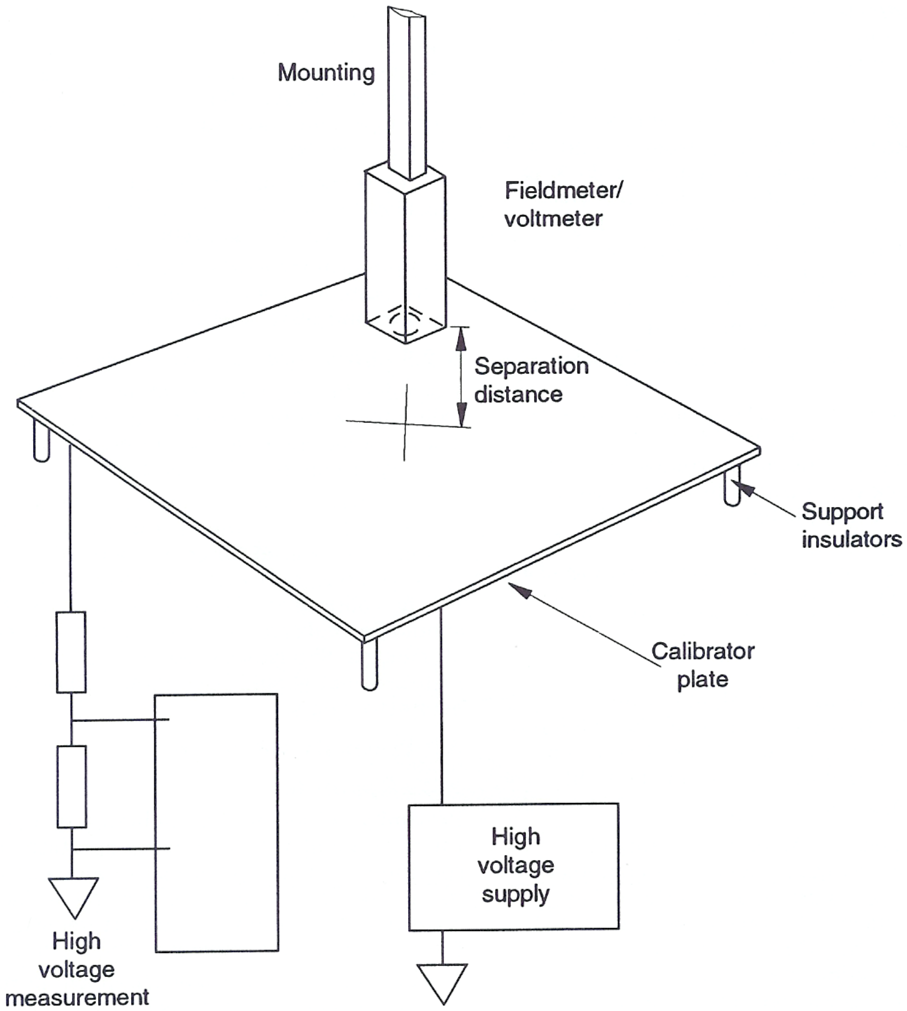

Figure 5.2.1: general arrangement for calibration of a fieldmeter proximity voltmeter

5.2.3 Voltage source and measuring system

The voltage source and voltage measurement system should fulfill the requirements described in Sections 4.2 and 4.3.

5.2.4 Procedure

Mount the voltmeter at the specified separation distance, connect it to earth, switch on and allow to stabilize. Read the initial (zero) value with the calibration plate shorted to earth.

Apply voltages to the plate to give readings from around 25 % of the most sensitive range up to at least 25 % of the least sensitive range. For multirange instruments use voltages which give readings from less than 25 % to more than 90 % of each range. Readings should be made on both ranges where there is overlap between ranges.

Measure the output for both increasing and decreasing voltages including zero for both polarities.

Note 1. Differences in readings between increasing and decreasing calibration voltage may be due to charging of insulation in the sensing region of the voltmeter, dust on the calibration plate or charge on nearby surfaces.

Note 2. The influence of any initial charge on nearby surfaces may be tested by checking the zero readings of the voltmeter when mounted to a clean metal 'zero check chamber' and then as mounted into the calibration position with the calibration plate connected to earth.

5.2.5 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 4.

5.2.6 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in 4.7. a Table listing values of applied voltages, the corresponding values of electric field and the actual instrument readings observed for both polarities (with values of upper and lower ranges where sensitivity ranges overlap).

5.3 Electrostatic Voltmeter

5.3.l Calibration method

Calibration is achieved by applying calibrated voltages to the input terminal of the electrostatic voltmeter and recording the readings against the applied voltages.

Where the voltage measurement is made using an electrostatic fieldmeter in a defined and stable mechanical arrangement and where the fieldmeter is separable from the Electrostatic voltmeter system then this unit should be pre-calibrated in its own right.

5.3.2 Voltage source and measuring system

The voltage source and voltage measurement system should fulfill the requirements described in Sections 2.2 and 2.3.

5.3.3 Arrangements for calibration

If the measuring region of the voltmeter is earth shielded from the surrounding environment there is no need to control charges on nearby surfaces. If the voltmeter assembly is open then readings will be susceptible to charges nearby. In this case care must be taken to earth shield the surroundings and also the operator.

5.3.4 Procedure

Switch on the voltmeter and allow to stabilize. Earth the input connection and record the zero reading. Apply voltages to give readings from around 25 % of the most sensitive range up to at least 25 % of the least sensitive range. For multi-range instruments use voltages which give readings less than 25 % and more than 90 % of each range so there is some overlap. Repeat the measurements for both polarities.

5.3.5 Results

List the values of applied calibration voltages and the corresponding readings for both polarities.

5.3.6 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 4.7.

5.3.7 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in 4.7 a Table listing the readings observed for each value of applied calibration voltagefor both polarities (with values for upper and lower ranges where sensitivity ranges overlap).

5.4 Space potential measurement

5.4.1 Calibration method

The local potential in a large volume may be measured using an electrostatic fieldmeter. The electric field measured by the fieldmeter relates to the local space potential approximately as:

$$E = f\,V / d \qquad (1)$$

- where E is the electric field created at the fieldmeter sensing aperture ($V\,m^{-1}$), V the local voltage (volts) and d is the effective diameter of the fieldmeter (meters).

The response of a particular fieldmeter to the local space potential in a particular mounting support arrangement is established by electrically isolating it, and any associated external power supply and data display equipment, from ground and applying to it a measured voltage. The electric field observed by the fieldmeter, with linear response to values of electric field at its sensing aperture, varies linearly with applied voltage until the voltage of the fieldmeter equals that of the local space potential - when the electric field becomes zero. Measurement of the variation of response with applied voltage thus enables the response of the fieldmeter, when connected to earth, to be formally related to the local space potential in the vicinity of the fieldmeter. The variation of response with potential of the fieldmeter is most easily established when the ambient space potential is zero.

5.4.2 Voltage source and measuring system

The voltage source and voltage measurement system should fulfill the requirements described in Sections 2.2 and 2.3.

5.4.3 Arrangements for calibration

Measurements are preferably made under conditions where the space potential around the fieldmeter is zero or is stable. If conditions are varying slowly then calibration may be achieved from readings with at least 2 well spaced apart voltage levels in a timescale short compared to the rate of variation of ambient conditions.

Isolate the fieldmeter and any associated signal processing and display circuits from earth. Connect the voltage source and voltage measurement instrument to the fieldmeter earth bonding connection.

Note: It is not necessary for the fieldmeter to be pre-calibrated as full calibration I established by the procedure specified.

5.4.4 Procedure

Switch on the fieldmeter and allow it to stabilize. Record the fieldmeter response when it is at earth potential and with at least 2 applied voltages. Repeat the measurements for both polarities. The applied voltages must cover a range sufficiently widely spaced that the variation of response to applied voltage can be shown to be linear and its value calculated with an error less than 2% for high precision measurements or 5% for low precision measurements.

Where several ranges of fieldmeter sensitivity may be involved the above measurements need to be repeated for each range with at least 25% overlap in applied voltages.

5.4.5 Results

List the values of applied calibration voltages and the corresponding readings for both polarities.

5.4.6 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 4.7.

5.4.7 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in 4.7 a Table listing the readings observed for each value of applied calibration voltage for both polarities (with values for upper and lower ranges where more than one range of sensitivity of the fieldmeter is involved).

5.5 Faraday Pail

5.5.1 Calibration method

The charge sensitivity of a Faraday Pail system is best measured directly using a virtual earth charge measuring amplifier because the pail remains at earth potential so all the measurement charge is transferred to the measurement circuit. Alternatively, the charge introduced into a Faraday Pail system may be measured from the increase in the voltage in relation to the capacitance of the pail system. For such measurements account needs to be taken of the charge sharing that occurs between the charge source and the pail capacitance.

The design of a Faraday Pail system needs to conform to the requirements [1] that:
a) the charge on all material introduced into the pail in practical use shall couple only to the pail with negligible coupling to surrounding surfaces
b) that the pail is well shielded against any electric fields that may arise from the system surroundings.

5.5.2 Calibration methods

For systems based on the use of virual earth charge measurement circuits calibration of charge sensitivity may be made by:
a) discharge of a calibrated capacitor charged to a calibrated voltage to the pail
b) flow of a defined current to the pail for a defined period of time

For systems based on measurement of the voltage increase of the pail capacitance calibration of charge sensitivity may be made by:
c) discharge of a calibrated capacitor charged to a calibrated voltage to the pail
d) measurement of the capacitance of the pail system and the sensitivity of its voltage measurement arrangement

5.5.3 Discharge of charged capacitor

The principle is to charge a calibrated capacitor to a calibrated voltage and discharge this into the input of the charge measurement circuit. The virtual earth measurement circuit ensures the input connection remains at earth potential and all the charge ($Q = CV$) is transferred from the charged capacitor to the feedback capacitor with the voltage appearing as the output voltage.

It is necessary to use a good quality capacitor to avoid any influence of charge leakage from the time of charging to the time of connection to the charge measurement circuit. The test voltage should not be less than 10V to minimise the risk of influence from contact potentials. It is wise to discharge the capacitor via a resistor to limit the maximum inrush current to within the current drive capability of the virtual earth input amplifier stage. A resistor of 10,000 ohms is likely to be suitable. It is difficult to define small values of capacitance (less than 100pF), because of the uncertain influence of lead capacitance, this approach to calibration is not suitable for quantities of charge less than around 1nC.

The capacitance of the capacitor and of the Faraday Pail need to be measured using a formally calibrated capacitance meter. The values of these two capacitances need to be known so that the increase in voltage of the pail can be related to the charge sharing between the two capacitors.

Calibration must take place with the earthed shield around the pail in place. Absence of influence from charge on nearby surfaces should be checked and precautions taken to avoid influence by choice of operator clothing and shielding surfaces nearby.

Where low voltages are used for calibration a check needs to be made for the possible influence electrochemical potential differences between materials. A simple check is to observe readings with zero voltage applied to the contact and use this as an offset for subsequent readings. For high sensitivity measurements it may be necessary to gold plated contacting surfaces to avoid electrochemical voltage effects.

5.5.4 Flow of defined current

A current into a virtual earth charge measuring amplifier can be defined with a calibrated voltage source and a calibrated resistor. A defined quantity of charge can be achieved by switching this current flow to the pail and its charge measurement circuit for a defined period of time. This method of calibration is described in Section 5.9.

5.5.5 Calibration by measurement of capacitance and voltage sensitivity

The capacitance is measured using a calibrated capacitance meter. The earthed protective shield of the Faraday pail system needs to be in place in case this adds capacitance. Where pail capacitance values are low, say below 100pF, care needs to be taken to minimize the influence of capacitance coupling to the operator hand. The simplest approach is to have the measuring contact supported on a rod of good insulation so the lead connecting to the capacitance meter is not close to the hand. The pail capacitance can be measured as the change in capacitance value as the measuring connection is moved from just a short distance away from contact and to touch contact with the pail.

The voltage sensitivity is measured by noting the charge in reading of the voltage measurement system when a defined voltage is applied to the pail.

The charge sensitivity is obtained as:

$$S = \text{Pail capacitance (F)} * \text{(reading per V)} \qquad \text{C/(unit of reading)}$$

5.5.6 Procedure

Switch on the Faraday Pail charge measurement circuit and allow to stabilize after zeroing. Zero the display of output signal reading, release and then monitor readings for zero drift over a time comparable to normal measurement time.

<u>For charged capacitor calibration:</u>

Connect one pole of the calibration capacitor to the earth connection of the Faraday Pail system. The other pole of the capacitor is then connected first to the calibration voltage source and then moved to contact the pail. Apply quantities of charge to the pail to give readings from around 10 % of the most sensitive range up to at least 25 % and preferably up to 95% of the least sensitive range. It is desirable there is some overlap across multiple ranges. Repeat the measurements for both polarities. To avoid test voltages less than 10V with multi-range instruments it may be necessary to use a number of values of capacitor. The quantity of charge transferred by a capacitor C (Farads) at a voltage V (volts) is $Q = CV$ coulombs.

<u>For timed current calibration:</u>

Connect the calibrator to the input of the charge measurement circuit or to the Faraday Pail and allow time for any residual charge on cable connections to dissipate – checked by observing stability of zero reading. Apply quantities of charge to the pail to give readings from around 10 % of the most sensitive range up to at least 25 % and preferably up to 95% of the least sensitive range. It is desirable there is some overlap across multiple ranges. Repeat the measurements for both polarities.

<u>For capacitance and voltage sensitivity calibration:</u>

Measure the capacitance of the pail in its normal use position and with the earthed shield in place.

Switch on the Faraday Pail voltage sensor system and allow to stabilize. Earth and then isolate the Faraday pail from earth and take readings over a time comparable to normal measurement to check for zero reading drift. Apply voltages to the pail to give readings from around 10 % of the most sensitive range up to at least 25 % and preferably up to 95% of the least sensitive range. It is desirable there is some overlap across multiple ranges. Repeat the measurements for both polarities.

The charge sensitivity is calculated from the capacitance of the pail C (Farads) and the voltage sensitivity V (volts) as $Q = CV$ coulombs.

5.5.7 Voltage source and measuring system

The voltage source and voltage measurement system should fulfil the requirements described in Sections 2.2 and 2.3.

5.5.8 Results

The average value and the standard deviation should be calculated for each set of calibration measurements.

5.5.9 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 2.7.

5.5.10 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in 2.7:

A Table listing the averaged readings observed for each set of values of voltages and capacitances used for both polarities (with values for upper and lower ranges where sensitivity ranges overlap).

5.6 Charge Decay Time Measuring Apparatus

5.6.1 Voltage sensitivity calibration

The voltage sensitivity calibration is made in terms of a uniform potential on a conducting test plate surface covering the whole test aperture area and close to the test aperture edge. The conducting surface should have a small separation below the edge of the test aperture (for example 0.5 mm) so that calibration voltages up to at least 1000V can be applied.

5.6.2 Decay time calibration

Calibrated decay times are provided using calibrated resistors and capacitors in parallel to earth from the test plate across the test aperture. The resistors and capacitors must be of good quality, with a linear voltage characteristic and be able of withstanding voltages up to at least 1 kV.

Decay time constant values from the values of calibrated resistors and capacitors should be provided for each decade of time over the main operating range of the instrument. To cover the range of interest of materials used for static control decay time constant values should be provided from 100 ms to 100 s – for example 0.10, 1, 10 and 100s.

Calibration of the resistors and capacitors should be carried out in situ in the test set-up.

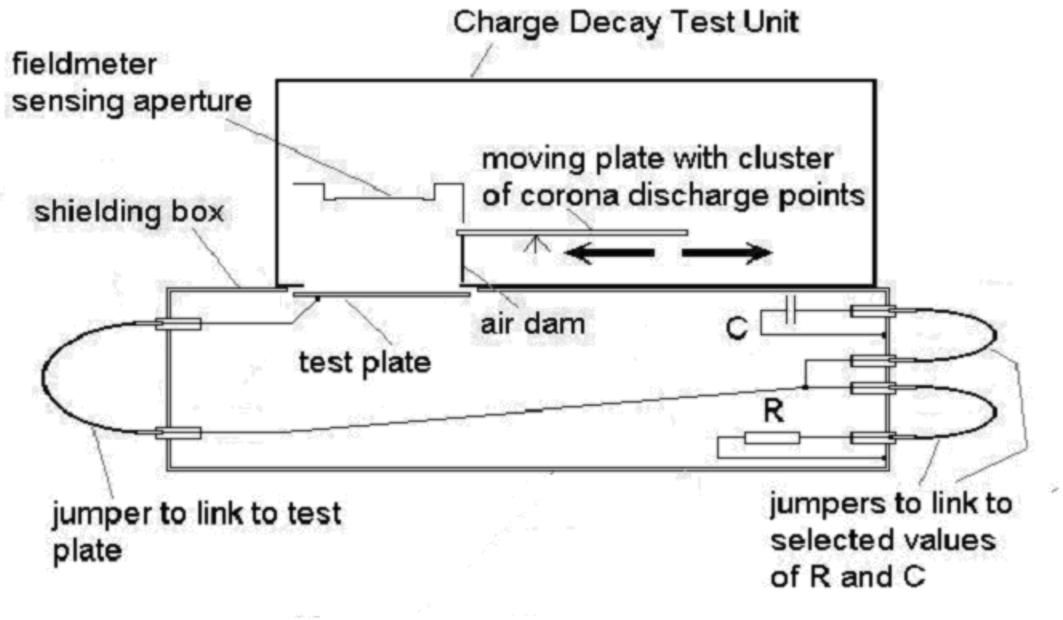

Figure 5.6.1: General arrangement for calibration of charge decay test instruments

5.6.3 Voltage source and measuring system

The voltage source and voltage measurement system should fulfill the requirements described in Sections 4.2 and 4.3.

5.6.4 Voltage calibration procedure

Mount the charge decay unit on the calibrator unit with the test aperture over the test plate. Disconnect resistors and capacitors from the test plate to earth. Switch on the charge decay instrument and allow to stabilize. Connect the test plate to earth and measure the initial (zero) reading. Apply calibrated voltages to the plate to give readings from around 5 % of the most sensitive range up to at least 25% of the least sensitive range of the surface voltage measurement and record the measured values. For multi-range instruments use voltages which give readings less than 25% and more than 90% of each range so there is some overlap. Repeat the measurements for increasing and decreasing voltage including zero and for both polarities. Record all individual measurements.

5.6.5 Decay time calibration procedure

Connect an initial combination of resistor and capacitor from the test plate to earth. Use the charge decay test unit to charge the test surface to a voltage between 100V and 1000V. Measure the time for the voltage developed on the test plate to fall from the voltage at which timing starts to 1/e of this voltage. This is the ‘time constant’ for this combination of R and C. Measure at least 3 decay time constant values for each polarity and for each combinations of resistors and capacitors providing a suitable range of decay time constant values. The decay time values observed are to be compared to decay time values calculated from $\tau = RC$ – where R is resistance in ohms, C is in Farads and τ is in seconds.

Where operation of the charge decay test unit can be linked to a computer for analysis of observations, either on-line or off-line, then the values of decay time constants obtained by this method should be measured and recorded.

At least 3 time constant measurements must be made for each polarity at each combination of resistor and capacitor.

5.6.6 Results

The average decay time for each combination of resistor and capacitor values and the standard deviation should be calculated with positive and negative values used together.

5.6.7 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 2.7.

5.6.8 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in 4.7.

1) A Table listing values of applied voltages and the actual instrument readings observed for both polarities (with values of upper and lower ranges where sensitivity ranges overlap).

2) A Table listing the averaged values of measured charge decay time constants for each combination of resistor and capacitor value and the associated standard deviation. Each entry should be accompanied by the value of the theoretical $\tau = RC$ time constant calculated for the particular combination of resistance and capacitance values.

5.7 AIR IONISATION TEST UNITS

5.7.1 Calibration method

Air ionization test units are calibrated by a) applying defined voltages of both polarities to the test plate, measuring the voltage sensitivity, and then b) measuring the time for the plate voltage to decay from a set initial voltage to a set end point percentage of the initial voltage. For air ionization units the initial voltage is chosen as ±1000V and the end point voltage as 10% of this – 100V.

Measuring instrument requirements and calibration procedures follow those for charge decay test units – Section 5.5. Due allowance must be made for the capacitance of the test plate assembly to the values of formally calibrated capacitors used in conjunction with calibrated resistors to create defined decay time events.

5.7.2 Results

The average decay time for each combination of resistor and capacitor values and the standard deviation should be calculated with positive and negative values used together.

5.7.3 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 2.7.

5.7.4 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in 2.7.

1) A Table listing values of applied voltages and the actual instrument readings observed for both polarities (with values of upper and lower ranges where sensitivity ranges overlap).

2) A Table listing the averaged values of measured charge decay times from 1000V to 100V for each combination of resistor and capacitor value and the associated standard deviation. Each entry should be accompanied by the value of the theoretical decay time $t = 2.303 * \tau$ – with τ derived from the $\tau = RC$ time constant calculated for the particular combination of resistance and capacitance values.

5.8 CHARGE MEASUREMENT

5.8.1 Calibration method

A defined quantity of charge for calibration of charge measuring instruments can be provided by a defined current flow for a defined period of time.

A defined and stable flow of current can be achieved from a referenced voltage source and a defined precision resistor to earth. The flow of this current at the earth connection point may be electronically switched to flow into the input of the virtual earth measurement circuit for a defined period of time. If the current flow is continuous there is no influence from any distributed capacitance in the precision resistor or its connections. The electronic switch and the layout of the circuit need to be chosen that gives negligible charge injection at operation. The period for current flow can be derived with high accuracy and stability by scaling down from a quartz crystal oscillator. Each of the 3 factors determining the quantity of charge output (voltage, resistance and time) can be formally calibrated with reference to National Standards.

5.8.2 Results

The average decay time for each combination of resistor and capacitor values and the standard deviation should be calculated with positive and negative values used together.

5.8.3 Common aspects of calibration

Details of calibration measurements and associated information should be recorded as given in Section 4.7.

5.8.4 Calibration certificate information

The calibration certificate needs to include the following in addition to the standard information listed in 4.7.

A Table listing the values of nominal and actual injected charge together with instrument readings observed for both polarities with values of upper and lower ranges where sensitivity ranges overlap.

Annex A: (Normative)

DEFINITIONS

A1 capacitance loading

the surface potential achieved per unit quantity of charge for a thin film of a good dielectric divided by the surface potential achieved per unit of charge with a similar surface charge distribution on the test material

A2 charge decay

the migration of charge across or through a material leading to a reduction of surface potential at the area where the charge was deposited

A3 charge decay time

The time from the initial surface voltage level created by the charge put on to the surface (100%) to a selected, and a stated, end point fraction of this. The initial voltage value to be used is that 0.1s after the end of a short period charging action.

> ***NOTE***: *Convenient decay times for comparison between materials are the time from the initial surface voltage to 1/e of this (e is the base of the natural logarithm 2,7183) and to 10% of this.*

> ***NOTE***: *As the rate of charge decay may vary greatly during the progress of decay it is very useful to record the form of the variation of surface voltage with time.*

A4 conductive material

a material with a high mobility of charge so that the potential on the surface is retained for only a very short time

> ***NOTE***: *The charge decay time of conductive materials is generally less than 0.05 s.*

A5 corona

the generation of ions of either polarity by a high localised electric field

A6 dissipative material

a material which allows charge to migrate over its surface and/or through its volume in a time that is short compared to the time scale of the actions creating the charge or the time within which this charge will be effective or will cause an electrostatic problem.

> ***NOTE***: *For general avoidance of risks and problems in operations involving manual activities the decay time from the initial surface voltage at 0.1s to 10% of this needs to be less than 1.0 s. To avoid the risk of incendiary sparks the decay time needs to be longer than 0.01s.*

> ***NOTE***: *The dissipative capability of a material does not relate to its ability to remove charge from a conducting item in contact. This ability is determined by resistivity type measurements.*

A7 Fieldmeter

An instrument for measuring electric fields. The electric field measured is that at a defined sensing aperture

A8 insulative material

a material with very low mobility of charge so that charge on the surface is retained there for a long time

> ***NOTE:*** *The charge decay time of insulative materials is generally greater than 10 s.*

A9 Proximity voltmeter

A fieldmeter set up so that its reading relates directly to the potential on a large plane conducting surface a defined distance away or whose voltage is adjusted to null the observed electric field to measure the local voltage at the fieldmeter position.

A10 relative capacitance

(see capacitance loading)

A11 surface potential

the reading from a non-contacting electrostatic voltmeter or fieldmeter in the test equipment calibrated in terms of the potential on a plane conducting surface covering the equipment test aperture

Annex B: Bibliography

[1] *“Methods for measurements in Electrostatics”* British Standard BS7506: Part 2: 1996

[2] J N Chubb *“The calibration of electrostatic fieldmeters and the interpretation of their observations”* Inst Phys Conference ‘Electrostatics 1987’ Inst Phys Confr Series 85 p261

[3] J N Chubb *"A Standard proposed for assessing the electrostatic suitability of materials"* J. Electrostatics 2007

[4] J N Chubb *"An introduction to electrostatic measurements"* Nova Publishers 2010 (ISBN: 978-1-61668-251-4)

[5] J N Chubb, I Pavey *"The measurement of atmospheric electric fields using pole mounted electrostatic fieldmeters"* Paper submitted to J Electrostatics 2014 (http://www.infostatic.co.uk/List.html)