



A BRIEF GUIDE TO

**STATIC
SOLUTIONS**

Ian Pavey

Chilworth
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Chilworth

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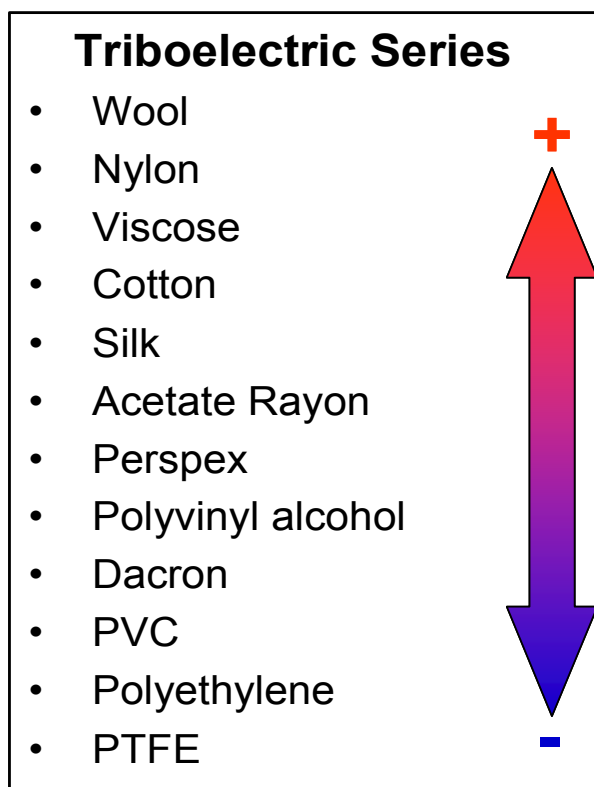
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FUNDAMENTALS OF STATIC ELECTRICITY

Charge and Charge Generation

The atoms and molecules of all materials include both positive protons and negative electrons. Usually these are present in equal numbers, thereby balancing each other, in which case the material is said to be electrically neutral, or “uncharged”. If for whatever reason there are fewer electrons than protons, the material is said to be positively charged, and if there are more electrons than protons, negatively charged.

Whenever two different materials contact one another, invariably energy considerations mean that electrons have a preference to be on one side of the interface than the other. At points of contact electrons will therefore move across the interface, leaving one material with an electron deficit,



while the other acquires a surplus. That is, each is said to have acquired opposite charge. If the materials are rubbed together the number of points of contact is increased when compared with simple contact, which therefore increases the charge acquired. Moreover, the harder and more vigorous the rubbing, the greater the amount of charge transferred.

Experimenters have produced lists of materials ordered so that electrons always have a tendency to move from any material in the

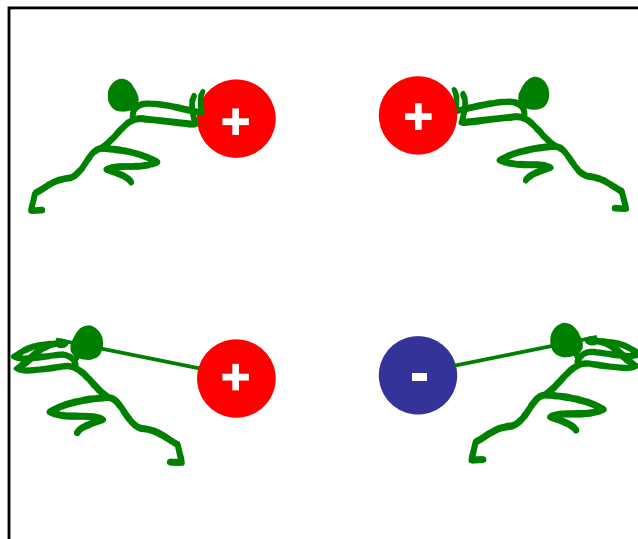
list to all other materials below them. Hence, materials will be seen to acquire positive charge when contacting or rubbing materials below them in

the list. Such lists are known as triboelectric series.

Since each material in the list acquires negative charge compared with the one above it, it follows that the further apart materials are in the list the greater will be the charge acquired. Hence, triboelectric series can be used to predict both the polarity and magnitude (at least qualitatively) of charge acquired in a particular situation. Having said that, the precise order of materials in triboelectric series can depend on seemingly trivial differences in nominally the same materials (e.g. low levels of impurity), so that the lists produced by different workers are sometimes slightly different. Charge is measured in Coulombs, which is commonly abbreviated to “C”. The Coulomb has a direct physical meaning in that it is equivalent to about 6.2×10^{18} electrons.

Voltage

There is always an attractive force between opposite charges (positive and negative), and a force of repulsion between like charges (two positive charges or two negative charges). Hence, in order to push like charges together, or pull opposite charges apart, work must be done to overcome the forces.



This is reversible in that, if released, the charges will return to their original location, and in so doing, work can be done by them. In other words, the original movement of charges could be seen as increasing potential energy. If the potential energy of charges is increased by 1 Joule/Coulomb (that is, work equivalent to 1 J is required to move 1 C of charge to its new location), the electrical potential of that charge is said to have increased by

1 Volt (commonly abbreviated to “1 V”). Hence, voltage is not synonymous with charge (as is sometimes mistakenly thought) but truly is a measure of the potential energy of an amount of charge.

A re-statement of the above in mathematical form clearly presents the relationship between electrical potential (often referred to as voltage) and mechanical or heat energy:

$$1 \text{ V} \equiv 1 \text{ J.C}^{-1}$$

Resistance, Resistivity and Current

When we are concerned with static electricity we are usually concerned with the forces between charges (see the above section on voltage), which are present even when the charges are stationary: hence *static* electricity. It is true that when we are talking about electrical discharges (spark-type events) the instantaneous movement of charge is high, although the phenomenon itself comes about because of the forces between charges, whether they are stationary or moving. Nevertheless, even though we are concerned with the effects that are characteristic of static electricity, charge can and does move through solid objects, just as it does in other branches of electrical technology.

The rate at which charge travels is referred to as electric current, and is measured in Ampères (commonly referred to as “Amps” and abbreviated to “A”). One Amp is equivalent to charge being moved at the rate of 1 C.s^{-1} . Charge only moves in response to a potential (or voltage) difference between one part of an object and another, and the magnitude of the current is dependent on the magnitude of the potential difference. It is also dependent on a property of the object, referred to as its resistance.

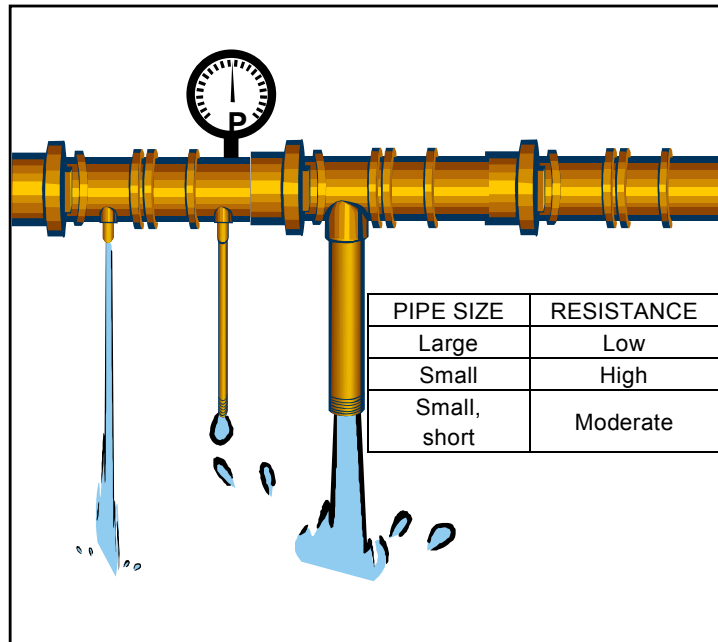
This can be expressed as Ohm’s Law:

$$I = \frac{\Delta V}{R}$$

where ΔV is the potential difference (in Volts) across resistance, R (in Ohms), and I is the resulting current in Amps.

Resistance is dependent on both the geometry of the object and a property of the material from which it is made, known as resistivity.

Consider an object of simple geometry, such as a cylinder. Intuitively, one might imagine (correctly) that the longer the cylinder the greater the resistance, and the larger the diameter the smaller the resistance. (Sometimes it is easier to consider the



analogous situation of a liquid flowing through a pipe as result of a pressure difference from one end to the other.)

Hence, the relationship between resistance and geometry can be expressed as:

$$R = \rho_v \frac{L}{A}$$

where R is the resistance from one end of the object to the other (Ohms), L is the length of the object (m), and A is the cross sectional area (m^2). ρ_v is the volume resistivity of the material from which the object is made, and a quick look at the units of the other variables will confirm that the units of volume resistivity must be Ohm-metres (Ohm.m or $\Omega.m$).

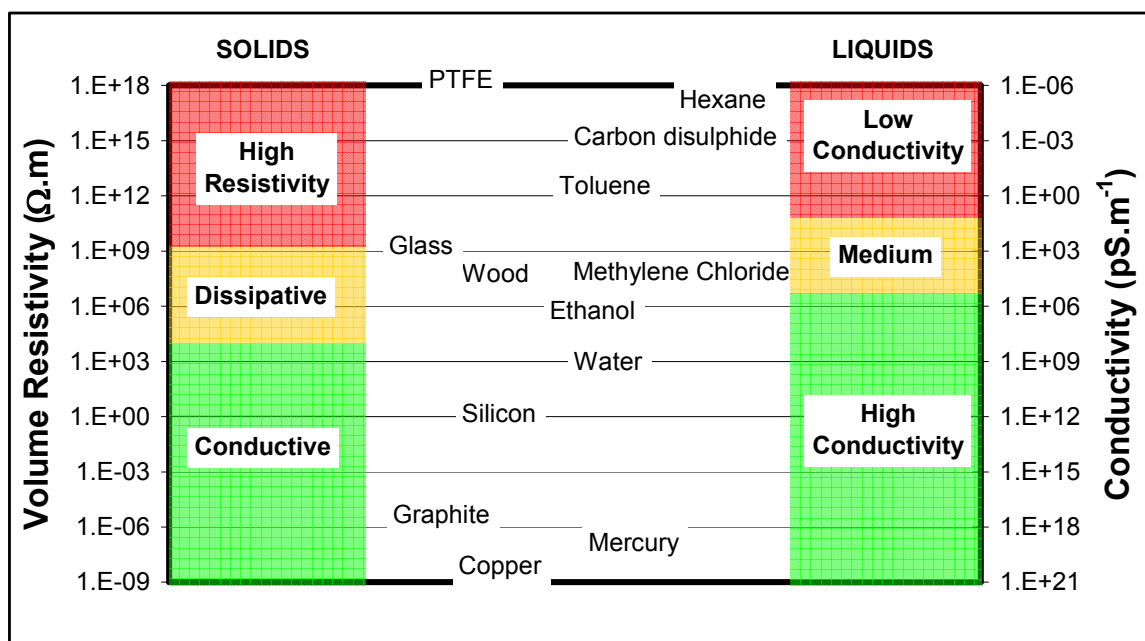
Traditionally, reference is made to conductivity for liquids, and resistivity for other materials, though there is no fundamental reason why this should be so. Conductance and conductivity are the reciprocals of resistance and

resistivity, respectively, so it can easily be seen that the following relationships also apply:

$$I = \Delta V.G \quad \text{and} \quad G = \gamma \frac{A}{L}$$

where G is conductance in Siemens (S) and γ is conductivity in Siemens per metre ($S.m^{-1}$), though the conductivity of liquids is often given in picoSiemens per metre ($pS.m^{-1}$).

Typical resistivity and conductivity values of a number of materials are indicated below.



Where solids are of high resistivity, it is sometimes the case that surface contamination, including water adsorbed from atmospheric humidity, results in charge being much more readily transferred across the surface than through the bulk. In that case a surface resistivity is defined as the resistance between parallel linear electrodes the same distance apart as they are wide. An equation equivalent to the one previously given relating resistance to geometry can then be given for surface measurements:

$$R = \rho_s \frac{L}{W}$$

where ρ_s is the surface resistivity, L the length of surface between electrodes (m), and W the width of the electrodes (m). Clearly the units of surface resistivity are simply the Ohm, though to differentiate between this specific property of a material and resistance, the units of surface resistivity are often given as “Ohms per square”, which can be abbreviated to Ohms/□ or Ω/\square .

To add to the possible confusion, reference is sometimes made to “surface resistance” as an alternative specific property to surface resistivity. Surface resistance is measured using parallel linear electrodes whose width is ten times greater than the distance between the electrodes. Hence, surface resistance is numerically ten times smaller than surface resistivity.

Capacitance

As air is forced into a bottle the pressure in the bottle will rise. If the same amount of air is forced into a bottle of smaller capacity, the pressure will rise more quickly and end up at a higher value.

Similarly, if charge is added to a conductor, forcing the like charges together causes the potential on the conductor to rise (see also the section on voltage). How quickly the potential rises depends on a property of the conductor that is referred to as capacitance. A simple equation shows this mathematically:

$$V = \frac{Q}{C}$$

where V is the potential in Volts (V), Q is the charge in Coulombs (C) and C is the capacitance in Farads (F). It should be noted that 1 F is a very large capacitance such that in practical situations sub-multiples such as picoFarads (1 pF = 10^{-12} F), nanoFarads (1 nF = 10^{-9} F) and microfarads (1 μ F = 10^{-6} F) are commonly used.

The capacitance of a conducting object depends on a number of factors. It increases with the size of the object and as the object gets closer to a

nearby earthed object. It also depends on the nature of the material in the gap between it and the nearest other objects. Nevertheless, some typical capacitance values of common objects are given below.

Object	Capacitance (pF)
Small metal items (e.g. scoop)	10 – 20
Small containers (e.g. bucket)	10 - 100
Medium containers (e.g. 200 litre drum)	50 – 300
Person	100 - 300
Car	500
Major plant items (e.g. reaction vessel)	100 – 1000
Road tanker	1000

Capacitance Loading and Charge Decay Time

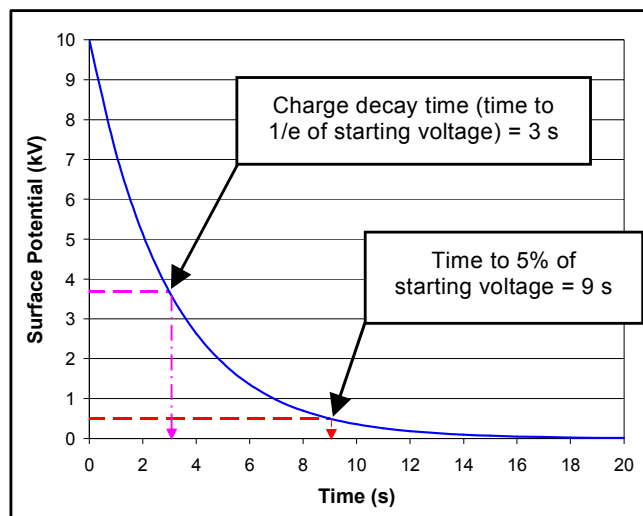
Static problems and hazards do not usually arise because of charge per se, but because of the potential at which those charges are present. Hence, one indicator of the likelihood of a problem arising from a material becoming charged is the relationship between charge on the object and its voltage, which is close to the definition of capacitance. Where materials may not be good conductors this is conveniently expressed as capacitance loading.

The capacitance loading of a material is the effective capacitance for charges residing on the surface when compared with a standardised arrangement. Capacitance loading is therefore a dimensionless number, and the greater its value the less problematic will be any charge acquired.

If something acquires charge that could cause a problem or hazard, intuitively one might also be interested in how quickly that charge will be lost once charging ceases and the item comes into contact with a good earth. It turns out that this depends on both the resistivity of the material and the same factors that affect capacitance loading. Resistivity can of course be used as an indicator for how readily charge will be lost, but charge decay time is a true and direct measurement of exactly that, and is therefore often more revealing.

Typically charge is lost in a broadly exponential way, although substantial deviations from a true exponential are very common, including decays that never reach zero. Hence, charge decay time is not the time required to lose all charge, but a characteristic time for a measured decay curve.

For a simple exponential decay such as the one shown (but rarely encountered in practice), the characteristic time used would commonly be the “time constant” - the time after which the charge has dropped to $1/e$ of its initial value. For those rare situations where a true exponential decay applies, it can be shown that 95% of the charge would be lost after 3 charge decay times have elapsed, and 99% of the charge after 5 charge decay times.



In practice, when something is acquiring charge, the net charge will be a consequence of both the rate of charge acquisition and the rate of charge loss. Hence, charge decay time (and resistivity) are not only indicators of how quickly charge will be lost, but often how much charge will be encountered in practical situations.

Electrostatic Discharges

Electrostatic discharges is the generic name for what are commonly thought of as sparks, or spark-like events. All electrostatic discharges in air occur because the potential gradient above or across a charged surface is sufficiently high to ionise the air in the vicinity. This leads to a conducting path through the air across which the charge causing the high potential gradient can transfer. Where charge is limited, this will only be a very short- duration phenomenon before the charge is all transferred, the potential gradient drops and the air returns to normal. However, the energy dissipated as the charge transfers leads to a transient temperature and pressure excursion, the latter being detected by observers as an audible crack. Simultaneously the recombination of electrons and ions leads to visible light being emitted.

Although the basic phenomenon is always the same, the progress of the discharge depends on the nature of the materials between which the charge transfers. Simplistically this has led to different types of discharge being identified each with their own characteristic dissipated energies.

i) Spark Discharges

Spark discharges occur between two conductive objects. Once the discharge is initiated, provided charge is not being replenished, all charge will be conducted across the source object to the point of initiation and will be involved in the discharge. If the receiving conductor is earthed, all the received charge will be conducted away without raising the surface potential at the discharge, and hence allowing all the charge to be transferred. It therefore follows from the earlier discussions (though the full explanation need not be given here) that an ideal approximation for the energy dissipated in such a discharge can be given as:

$$W = \frac{1}{2} CV^2$$

where W is the energy dissipated (Joules), C is the capacitance of the charged object (Farads), and V the potential of the charged object immediately prior to the discharge (Volts).

Spark discharges are probably the discharges we are most familiar with, as this is the type which occurs between people (the human body is a good conductor) and metal items such as cars, door handles, supermarket trolleys, etc, etc.

In principle spark discharges can be of any energy provided the capacitance and voltage are sufficiently high. However, very large, high-capacitance objects are likely to be earthed, even if unintentionally, so in practice inadvertent spark discharges are unlikely to exceed a few hundred millijoules. Nevertheless, they are capable of igniting a wide range of flammable gases, vapours and powders, as well as providing annoying, if harmless, shocks to personnel.

ii) Brush Discharges

Brush discharges might be between an insulating material and a conductor or between two insulating materials. In this case, after initiation of the discharge, charge cannot transfer to (or from) the point of discharge by conduction because of the insulating nature of the material. Hence, the potential gradient at the point of discharge quickly drops, quenching the discharge. However, multiple small discharges will almost simultaneously occur between the initial discharge channel and nearby parts of the insulator. The net result is a number of very small discharge channels joining into one a short distance above the insulator. With a little imagination, the appearance is that of a brush or broom – hence “brush discharge”.

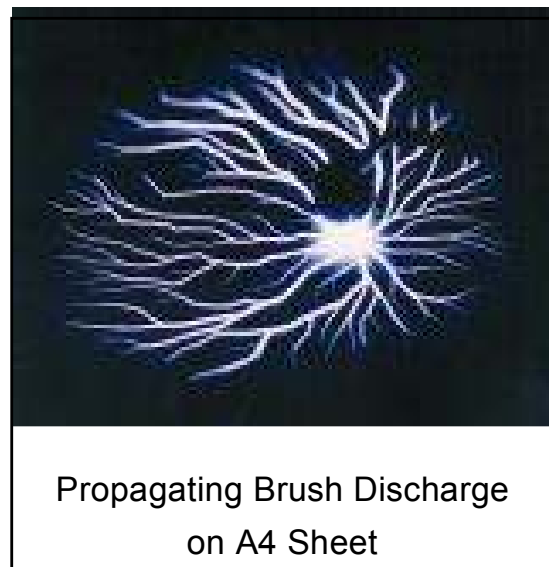
From experiments it is known that brush discharges can ignite gas mixtures with ignition energies up to about 3 mJ – 4 mJ (determined using spark discharges of known energy).

iii) Propagating Brush Discharges

Despite the name, the only similarity between brush discharges and propagating brush discharges is that both occur from insulators.

If the insulator is in the form of a thin sheet in close contact with an earthed conductor, the high capacitance of the free insulating surface means a very high charge density can be acquired. When a discharge is initiated further discharges also propagate from some way away across the surface to join the main discharge channel.

Because the original charge density was so high, a lot of charge can be transferred in this way, which means the energy dissipated can be very high – in excess of 1000 mJ in some cases. With such a high energy, not only can many types of flammable atmosphere be ignited from this type of discharge (gases, vapours, and powders) but it is the one electrostatic discharge that can cause direct injury to personnel.



When charged insulating powder particles fall on to an existing heap of charged powder, gravity forces them together against the repulsive force of the like charges. As discussed earlier, this leads to an increase in surface potential, and an increase in potential gradient across the developing heap. Eventually the potential gradient is high enough to initiate a discharge across a local area of the surface (near the outer extremity of the heap), which then propagates radially across much of the surface towards the centre. As the heap will generally be conical (for a central point of powder addition) these discharges are commonly known as “cone discharges”, and sometimes as “bulking brush discharges”.

Experience suggests that the energy dissipated from cone discharges across fine powders is unlikely to exceed 10 mJ. However, it is also known

that the energy of cone discharges increases with both the particle size of the powder and the diameter of the heap or container. Experiments and subsequent analysis suggests that the maximum energy dissipated from such discharges can be given by:

$$W = 5.22D^{3.36}d^{1.46}$$

where W is the maximum discharge energy in milliJoules, D is the diameter of the earthed conductive container holding the powder in metres, and d the particle diameter in millimetres.

Cone discharges can certainly ignite many flammable gases and vapours, and almost certainly some relatively sensitive powders.

v) Lightning

Lightning occurs as a result of charged water droplets in large storm clouds, so sometimes it has been speculated that clouds of charged mists or powders in industrial situations might produce similar effects.



Of course, no industrial installation approaches the size of large storm clouds, which supports the conclusion by observation that this type of discharge will not occur in normal sized plant.

vi) Corona

Corona occurs as a result of the high local electric field around a sharp point which is either itself charged to a high potential or is in the vicinity of something else charged to a high potential.

The high field means that ionisation occurs in the region of the point, though because the potential gradient rapidly drops off with distance from the point, it does not provide a complete conductive path from the point to the nearby object. Hence, no spark or brush discharge can occur. Instead, positive and negative ions are the result, which either drift towards

or away from the sharp point depending on the polarity. Hence, corona permits charge transfer from one place to another, but by drift of ions rather than rapid conduction within an ionising region.

Corona is therefore considered to be a low energy and benign type of discharge, incapable of igniting most flammable atmospheres. The only possible exception would be exceptionally sensitive gases (such as hydrogen), or gases dispersed in an oxygen rich atmosphere.

ELECTROSTATIC PROBLEMS

Typical Problems

There are so many problems arising from unwanted static electricity that it would be quite impossible to list them all. However, certain types of problem arise repeatedly in many different guises.

i) Electrostatic Discharge

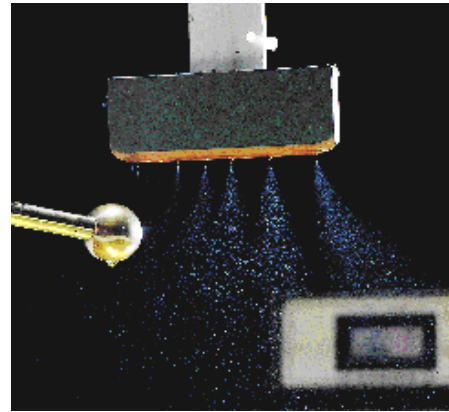
Electrostatic discharges can result in annoying shocks to personnel, damage to sensitive electronic components, and spurious alarms, to name but a few. (Ignitions leading to fire and explosion hazards will be dealt with separately).

ii) Sticking

Many materials stick where they are not wanted as a result of static electricity. Powders stick in areas where seals are to be made, preventing effective sealing. Dust sticks to intermediate and finished products affecting quality and appearance. Small items, such as tablets and capsules, sometimes lift from conveyors and/or stick to machinery, disrupting production. Powders can stick inside containers making them difficult to get out. Textiles can also stick to machinery, and clothing clinging to the wearer is a common problem.

iii) Unwanted Trajectory

Materials in flight are sometimes attracted towards a surface such that they do not go where they should. Liquid and powder streams may not cleanly enter bottles and other containers, hitting the neck and running down the outside instead. In printing and coating inks can sometimes be drawn to areas other than those intended, leading to a reduction in print and coating quality. Plastic sheets that should stack simply slide off one another.



Investigation

If static charge is known or suspected to be the problem, the first thing to do is to obtain or measure the electrostatic properties of all the materials involved. In particular resistivity (conductivity, for liquids) and/or charge decay time will be of interest, preferably at more than one humidity.



JCI 155v5 Charge Decay Unit

If solids or powders have volume resistivities of more than about 10^9 Ohm.m, and/or charge decay times of more than a few seconds, some electrostatic problems might be expected, especially where process speeds suggest high levels of charging might be possible. Similarly, if liquids have conductivities of less than about 100 pS.m^{-1} (1000 pS.m^{-1} if there is a second phase dispersed in the liquid) electrostatic problems might be expected.

For solids where static problems may be suspected, especially for relatively thin materials such as sheets and films, capacitance loading will

also be important, since this will indicate just how big a problem might be expected for a given charge. Values of 1 – 2 will indicate even modest charge levels could be a problem, while as the capacitance loading increases through 5 to 10 or more, problems arising from any charge acquired will be increasingly less likely to manifest themselves.

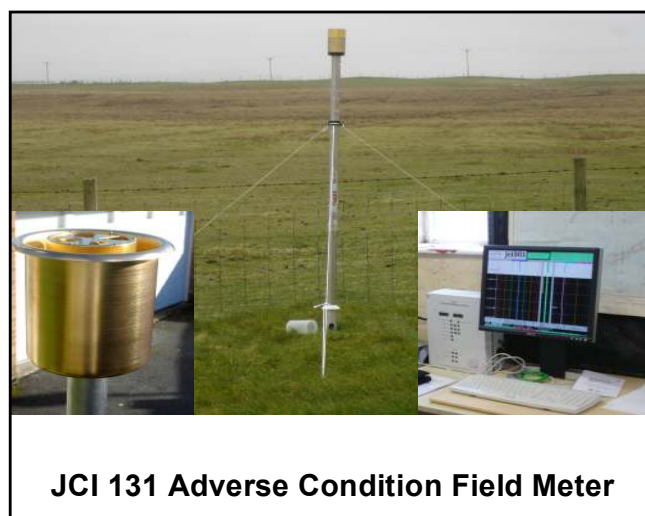
For some materials, especially powders with borderline resistivities, a measure of chargeability might also be useful. A high chargeability would indicate a likelihood of problems even for modest resistivities.

If possible, the use of a field meter or static monitor might help to identify exactly where a problem is arising. The readings do have to be used with care though, as nearby walls, plant items, or any good earth, will tend to mask the reading that might otherwise have been obtained. Hence, a high reading can be taken as indicative of a charge being present, supporting the proposal that a



JCI 140 Hand Held Static Monitor

problem might be due to static, while a low or zero reading can only be taken as indicating static is not the problem, if support can be obtained from the other measurements recommended above.



JCI 131 Adverse Condition Field Meter

Solutions

If the investigation has shown that the cause of the problem could be static electricity, or indeed if it is obviously so, there are a number of approaches that might be taken to address the problem.

i) Earthing

All conductive or static dissipative items that might become charged and cause a problem should be properly earthed. This includes plant items and equipment, personnel, packaging and even process materials. Ensuring conductive and dissipative items are, and remain, properly and reliably earthed, is a guaranteed way of avoiding their retaining static charge.

In this context, earthing conductors with a resistance of less than 10^6 Ohms will ensure they are suitably earthed whatever the circumstances. Similarly, earthing static dissipative items with a resistance of not more than 10^8 Ohms will be adequate. For the avoidance of nuisance shocks it is recommended that personnel should wear static dissipative footwear (sometimes referred to as “antistatic”). To avoid any confusion with possible hazards (see next section), it is recommended that dissipative footwear should have a maximum resistance of 10^8 Ohms, though if there is definitely no ignition hazard on site, a more relaxed 10^9 Ohms would be good enough to avoid shocks.

For process materials, such as powders, it may not always be convenient to formally earth them. However, placing them in an earthed conductive container would be sufficient, provided they remain there long enough to lose most of any charge acquired. This time can be determined from the measured charge decay time, though for materials defined as conductive or dissipative, this should be very quick.

Whatever earthing path is chosen it is important that it is robust. Hence, earthing cables, including flying earth leads where used, should be substantial and well made to avoid breaking and inadvertently losing the earth connection.

ii) Resistivity Modifiers

For insulating materials, earthing is not possible and attempts to do so are pointless. For some materials, increasing the humidity, the use of additives, or a topical treatment can all be used to render an otherwise insulating material static dissipative. Exactly what condition or treatment is required in order to be able render a material or item static dissipative will be very much a matter for testing, and with a little forethought, such tests should be included in those undertaken for the initial assessment.

Once it has been demonstrated what conditions are required to render the material static dissipative, it will be sufficient to ensure those conditions are maintained and then apply the principals of earthing described above.

iii) Minimise Charge Generation

In principal it might be possible to reduce charge generation to a level whereby it is no longer a problem. Having said that, this approach can be fraught with difficulty so that, apart from control of charge on liquids, it is rarely the solution of choice.

One approach is to reduce the speed of processes. This can be effective for pumping and processing of liquids, including two-phase systems, though for other process materials it is often not possible.

Another approach that has occasionally been used is to identify a material that is close to the problem material in the triboelectric series (see the first section: Charge and Charge Generation). If process equipment can be constructed from, or lined with, the identified material, charge generation should be minimised. Clearly this approach would address the problem at source, though identifying the best paired material may require quite an extensive series of trials.

iv) Charge Neutralisation

The final approach is to accept that insulating materials will become charged, and then neutralise that charge before it becomes a problem. This can be done using static eliminators. These fire a stream of oppositely charged ions at the charged surface such the charge is exactly neutralised.

A wide range of such static eliminators is available to suit many practical situations, though to get the best, or indeed any, result, they must be mounted in the correct location. Also, it must be realised that as soon as the static eliminator has been passed, charge may be generated again. Hence, a static eliminator may be required immediately prior to each problem location.



This approach is commonly used for a wide range of situations from the protection of electronic components, to preventing flash and dust from adhering to plastic mouldings and packaging, to aiding powder flow from hoppers.



ELECTROSTATIC HAZARDS

The most common and important hazard due to unwanted static electricity in industrial situations, is that arising from the possible ignition of flammable materials by electrostatic discharges. Under European and national legislation, such hazards *must* be addressed at the design stage (alongside other possible ignition sources). The effectiveness of any preventative, and/or protective measures, must be verified at the time of commissioning and then periodically reviewed throughout the life of the process and/or plant.

Typical Hazards

In the present context, all electrostatic hazards arise from different types of electrostatic discharge, and in most cases it is the risk of ignition that is of concern. To give an idea of the types of situations where electrostatic hazards can arise, a few examples are given below though clearly, of necessity, this can only touch the surface.

An operator was manually adding water to toluene already in a vessel, using a hose through an open manway. The exceptionally high charge generated by stirring a dispersion of water in toluene resulted in a discharge across the liquid surface, and ignition of the toluene vapour in the head space.

Addition of powder from a plastic sack through the manway in vessels containing flammable solvents, has been the source of many ignition incidents and continues to be a common hazard. Pouring the powder from the sack leads to charging of the plastic, resulting in a brush discharge to the vessel – just where flammable solvent vapour is emerging from the open manway.

Without formal checks, sections of metal pipework can be isolated by the insertion of flexible hose sections or some types of section-to-section

seals. This is a common hazard that also applies to metal nozzles and lances on the end of flexible hoses. The isolated conducting pipe can become charged, leading to a spark discharge to an adjacent section or to other items of plant. Such discharges could well be incendive to any flammable atmosphere that might be present.

An operator put his hand into a lined container collecting tablets from a tablet compressor. He received such a powerful shock that he was unable to use his arm for much of the rest of the day. The tablets were charged, and collecting them in the container meant charge transferred to the inside of what turned out to be an insulating liner. With the earthed conducting container, this was exactly the configuration for a propagating brush discharge - the most powerful type of electrostatic discharge commonly encountered - and known to be capable of direct injury to personnel.

Hazard Assessment



When assessing electrostatic hazards, the first thing to determine is whether flammable atmospheres *could* be present, and if so just how sensitive they are to ignition. This is given by the Minimum Ignition Energy (MIE). For most common gases and vapours it will generally be sufficient to obtain literature values of MIE. However, if the flammable atmosphere that might be present is a mist or a powder, the complexity of the combustion process means that the MIE must be determined from a sample of the actual material being handled. In some cases this can be obtained from the supplier, but often a measurement will have to be specially commissioned.

The next part of the assessment is to consider each type of electrostatic discharge whose characteristic energy (see the Fundamentals section) could ignite the flammable atmospheres that is or might be present. For

each potentially hazardous discharge, a careful review of the plant and process must be undertaken to see if and where such discharges could arise. As propagating brush discharges are a direct hazard to personnel, the plant should be reviewed for situations likely to lead to this type of discharge whether or not a flammable atmosphere could be present.

Finally, although not a direct hazard, the involuntary reaction of personnel to even quite small shocks can lead to a secondary hazard, especially where fast moving machinery might be present or falls are a possibility. Hence, in all but the most benign of environments it would always be preferable to prevent spark discharges occurring if at all possible.

Control of Electrostatic Hazards

i) Preventing Discharges

Spark discharges can ignite a wide range of flammables gases, vapours mists and powders. However, they can be completely avoided by ensuring all conductive and static dissipative items are properly earthed. For fixed plant, that means a resistance of less than 10^6 Ohms to earth. For static dissipative items, that means a resistance of not more than 10^8 Ohms to earth, a value that would be acceptable for portable metal items not actively involved in a process (e.g. in storage, or simply being moved through an area). For personnel, a resistance of not more than 10^8 Ohms to earth is also required.

Fixed plant items and components can either be earthed by the physical connection to other parts of the plant, or by a direct cable connection. Portable items will often require a flying-earth-lead to be connected before they are used in a process, though earthing via static dissipative wheels or Skids, and a static dissipative floor, may be good enough during storage or passing through an area.

Wherever fixed cables or flying-earth-leads are used, they must be robust and their initial and continuing effectiveness confirmed. It is recommended that the resistance to earth of fixed items and components should be checked after initial installation, after re-assembly following maintenance, and at least annually as part of a programme of planned preventative maintenance. For flying-earth-leads, it is recommended that formal regular checks should be quarterly, though operators should visually check them every time they are used. Footwear should be checked regularly too – preferably daily.

Brush discharges only arise from insulating materials and the ignition-hazard they pose can therefore be avoided by ensuring no insulating materials ever come into contact with a flammable atmosphere. In reality this is often not practical, so an alternative approach is to limit the size of items made from insulating materials. The following table gives maximum surface areas of insulating materials that are permissible in places where flammable gas or vapour atmospheres are or could be present.

Zone ⁺	Maximum Area (cm ²)		
	Group IIA ⁺	Group IIB ⁺	Group IIC ⁺
0	50	25	4
1	100	100	20
2	No Limit*	No Limit*	No Limit*

⁺ Details of Zone designations and gas groups can be found in IEC 60079 and other publications.

* Provided charging mechanisms capable of generating hazardous potentials are unlikely in normal operation

In the event that it is not possible to keep below the sizes in the table, special testing and/or special precautions may be required, in which case expert advice must be sought.

Although brush discharges are known to be capable of igniting gases and vapours with Minimum Ignition Energies (MIEs) of less than about 3 mJ – 4 mJ, they have never been known to ignite powders in air, even when the most sensitive powders have been tested under controlled laboratory conditions. Nevertheless, it would be prudent to avoid brush discharges in

the presence of the most sensitive of powders – say those with MIEs less than 1 mJ, or where there is an oxygen-rich environment.

Propagating brush discharges can be avoided by ensuring the necessary structures of a thin insulator that might become charged on both sides, or a thin insulator on an earthed conducting backing, are not present. In this context, “thin” means less than about 8 mm – any thicker and the only concern is the possibility of brush discharges. Even where the necessary structure is present, propagating brush discharges will not occur if a sufficiently high charge cannot be acquired by the insulating film. This would be the case if the breakdown strength of the film is less than 4 kV or if there is no process capable of generating the high charge, though expert help will probably be required to confirm one or both of these.

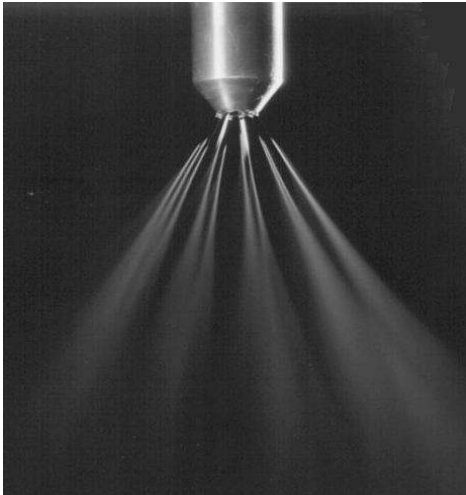
Cone discharge hazards can only be reduced or avoided by changing the powder or the vessel. If neither can be changed, and cone discharges have been shown to be a potential problem, the only option is to avoid the flammable atmosphere that may be above the powder, perhaps by inerting.

Lightning type discharges will not occur inside normal sized plant, and lightning from storms is outside the scope of this document. Hence, this will not be discussed here.

Corona will generally be avoided by complying with the recommendations already given for other types of discharge. The only exception is where corona is utilised as a means of passive or active static elimination. Corona is only truly of concern for very sensitive gases, like hydrogen, and such devices should therefore not be used where Group IIC gases could be present. However, for all other types of flammable atmosphere, provided the static eliminator is designated by the manufacturer as appropriate for the area, and it is being used according to the guidance from the manufacturer or an expert in electrostatics, the hazard should be minimal.

ELECTROSTATIC APPLICATIONS

Typical Applications



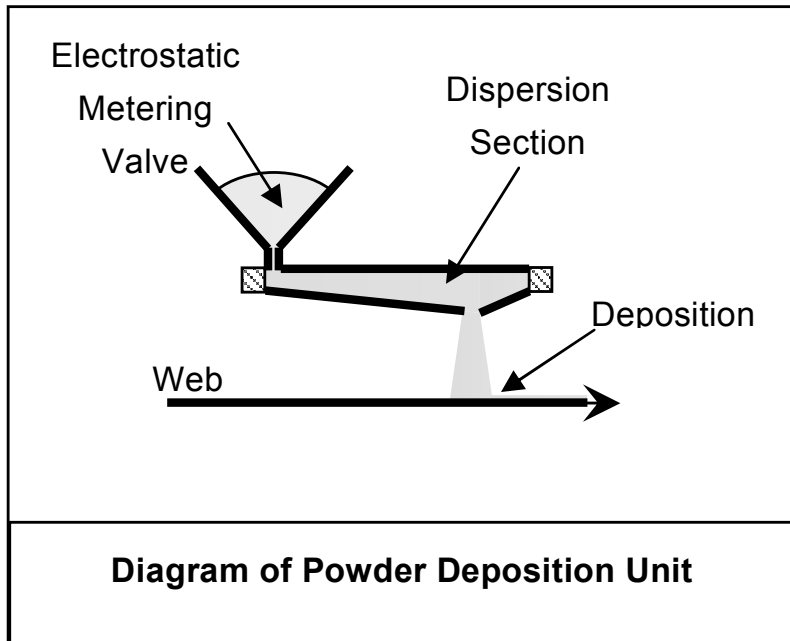
Static electricity is used in an ever widening range of applications. This started nearly 100 years ago with the development of electrostatic precipitators, now widely used to control particulates in flue gas from industrial furnaces and boilers. And many will be unaware that the basic concepts of the ubiquitous photocopier and ink jet printer are entirely reliant on harnessing electrostatic effects.

There are many other applications of static electricity, whether fully developed or still in research and development. Static electricity can be used to temporarily hold items together (known as “pinning”), separate different materials from one another, or even separate coarse particles from fine particles of the same material.

Electrostatic forces on liquids can be harnessed to produce sprays of exceptionally narrow and controllable drop size spectrum, which have been used for high quality thin coatings, spray drying of fine powders (powder sprayed direct from solution can have particles sizes down to single microns or smaller), and even micro-encapsulation. Rotating electric fields can be used to selectively rotate some types of particle suspended in liquids (such as single cell organisms), opening the way to discrimination not obtainable in other ways. Static electricity can be used to apply surface finishes, such as liquid paints and dry powders (powder coating).

Chilworth Global’s consultants have actively worked in all of the areas referred to above, but two applications are picked out to give a little more detail, opposite.

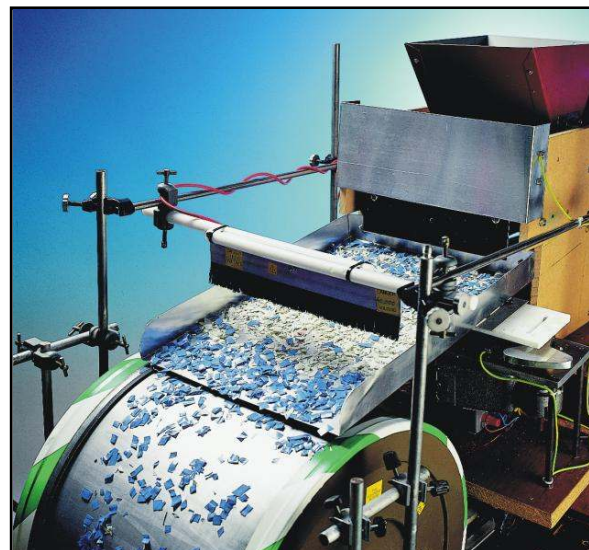
A client needed to produce a very diffuse but very uniform powder deposition under full electronic control.



A development programme, run entirely at Chilworth Global, proved the concept first at bench scale and then pilot scale. A full scale prototype unit for installation on the client's production line has now been designed, built and installed for trials

purposes.

Another client needed to demonstrate that a packaging material he wanted to use could be successfully separated from waste for recycling. Conventional separation techniques had failed to achieve the desired separation and electrostatics seemed a promising approach. Initial feasibility trials confirmed this, leading to a full development project at Chilworth Technology.



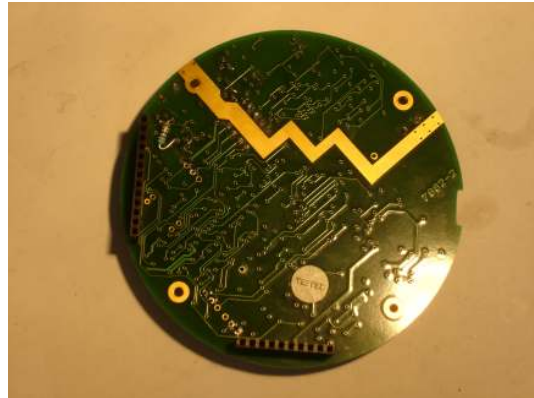
Prototype Automatic Electrostatic Plastic Separator

The project reached a successful conclusion when a pilot scale unit was successfully designed and demonstrated. Using two electrostatic separation methods in series, this was able to automatically extract the

client's material from real mixed plastic waste (from a recycling centre) to a purity of better than 99%.

Typical Development Approach

The range of possibilities for electrostatic applications is very wide, with new ones coming to the fore all of the time. For example, the very high electrostatic forces at short range may make them eminently suitable for use in “lab on a chip” applications. Variable focal length liquid lenses have also been proposed and tested, electrostatically produced fibres may have medical applications and have already been used in liquid crystal displays. However, whatever new concept is proposed the recommended approach is always very similar.



After initial consideration of an outline proposal, a more considered technical concept will be proposed, which can then be tested as a benchtop feasibility study.

In general the initial concept will need tweaking, but if all goes well, a benchtop demonstrator of the principles will be successfully completed permitting the design of a small-scale laboratory prototype. More lessons will be learnt at the laboratory prototype stage, but a successful outcome will lead to a proposal for a pilot scale unit which would be expected to be a small version of the final production unit. Finally, the prototype production unit will be designed, constructed and commissioned for full scale proving trials.

By operating in this way, there is the flexibility to change direction in response to unforeseen problems, such that the production prototype may be completely different from the concept that was originally tested on the bench. Furthermore, the financial commitment for the client for whom the

development is being carried out, is always in proportion to the level of confidence in a successful outcome. For example, at the concept stage, the only commitment is for a short benchtop feasibility trial, while by the time approval is given to design and fabricate the production prototype, success at the pilot stage means that there is little doubt that the prototype will be successful.

In all cases, all that is needed is the spark of an idea ignited by the background information, from somebody with a need, from concepts and real stories presented in documents such as this. Taking the idea to a company such as Chilworth Global, with the necessary vision and expertise, is then a major step to converting that idea into reality.

STANDARDS AND GUIDELINES

This document is of necessity a brief overview of issues, including how to assess and address relatively straightforward hazards issues. Especially in the case of hazards, a number of published standards and documents provide much more detailed information on relevant legislation, assessment and control of flammable atmospheres (which should usually be the first priority), and control of a full range of possible ignition sources, of which static electricity is just one. If there is any doubt, it is strongly recommended that original standards and guidelines are consulted and/or expert help sought.

Some of the more useful standards are listed below.

1. Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (commonly referred to as ATEX 137).
2. Dangerous Substances and Explosive Atmospheres Regulations 2002. Statutory Instrument 2002 no. 2776 (this is the UK implementation of ATEX 137, commonly known as DSEAR).

3. IEC 60079: “Explosive Atmospheres”. There are many parts to this standard, including Parts 10-1 and 10-2 dealing with hazardous area classification (for flammable atmospheres.) Many parts have been adopted by CEN and BSI, in which case instead of “IEC” the alternative prefixes “EN” and “BS EN” may also be used.
4. BS EN 1127-1:2007: “Explosive atmospheres. Explosion prevention and protection. Part 1. Basic concepts and methodology.” This standard provides information about a full range of possible ignition sources which must be addressed, including static electricity. Basic control methods are given.
5. CLC/TR 50404:2003: “Electrostatics – Code of practice for the avoidance of hazards due to static electricity”. This guidance document provides a good deal of background information on electrostatic hazards for a wide range of industrial process operations, and how to deal with them. Originally published by CENELEC, the British Standard version has a “PD” prefix to the given document number.
6. IEC 61340: “Electrostatics”. There are many parts to this standard, dealing with a range of electrostatic tests and measurements, including for specific types of equipment and installations. Many parts have been adopted by CENELEC and BSI, in which case instead of “IEC” the alternative prefixes “EN” and “BS EN” may also be used.
7. BS 7506-1:1995: “Methods for measurement in electrostatics. Guide to basic electrostatics”. This standard describes the principles for a number of types of electrostatic measurements.
8. BS 7506-2:1996: “Methods for measurement in electrostatics. Test methods”. This standard gives specific test methods based on the principles given in Part 1.

Ian Pavey graduated from Bath University with a BSc (Hons) in Chemical Engineering, and after acquiring some practical experience of electrostatic hazards while working as a process development engineer, joined the University of Southampton's Electrostatics Group. There he gained a M.Phil. in applied electrostatics and thereafter specialised in electrostatic applications, problems and hazards. After leaving Southampton Ian worked for ICI for 11 years on a wide range of projects developing new applications of static electricity for many of the company's divisions. He has been at Chilworth Global since 1991.

Whilst at Chilworth, Ian's responsibilities have included undertaking a variety of problem-solving and research projects where electrostatics is involved. This has included leading multi-national research projects under EC Framework programmes, such as investigating powder handling and processing problems caused by static electricity in industrial processes, and developing new tests for anti-static footwear. Ian is a member of the Static Electrification Group of the Institute of Physics, and a past member of the group's committee. He is also a current member of BSI's GEL/101 committee dealing with electrostatic standards.

During 30 years working in the field of electrostatics, Ian has published numerous articles covering subjects from new electrostatic applications, to powder handling problems, to fundamental research leading to new understanding of hazardous situations. In addition, he is a named inventor on a number of patents in areas from electrostatic sprays for agricultural purposes to electrostatic fibre production for liquid crystal displays.



Chilworth Global brings together leading expert consultants in the field of process safety with GLP compliant laboratories to provide a single point of contact for process safety needs. Chilworth's laboratories determine electrostatic and flammability data for materials and undertake chemical reaction hazard and regulatory testing. Chilworth's consultant engineers provide expertise in all aspects of electrostatics (applications, problems and hazards), fire and explosion safety, and chemical reaction hazards. For further information on all Chilworth products and services, see www.chilworth.co.uk

JCI is Chilworth's brand name for their well-established range of electrostatic instruments, of which just three are mentioned below. The JCI 140 static monitor is a handheld detection and measurement instrument used widely in many industries and by electrostatic professionals. The JCI 155 Charge Decay Unit assesses the electrostatic properties of materials for safety and QA purposes. The JCI 131 is an electric field meter suitable for use in adverse conditions, including long term monitoring outdoors. All have a range of optional accessories enhancing and extending functionality, making for the most comprehensive range of exceptional quality instruments of their type available. For further information on the full range of JCI electrostatic measurement instrumentation, see www.jci.co.uk

Chilworth Technology Limited
Beta House Southampton Science Park
Southampton SO16 7NS
United Kingdom

+44 (0)23 8076 0722 T
+44 (0)23 8076 7866 F
info@chilworth.co.uk E
www.chilworth.co.uk W

GLP & ISO/IEC 17025
LABORATORIES

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