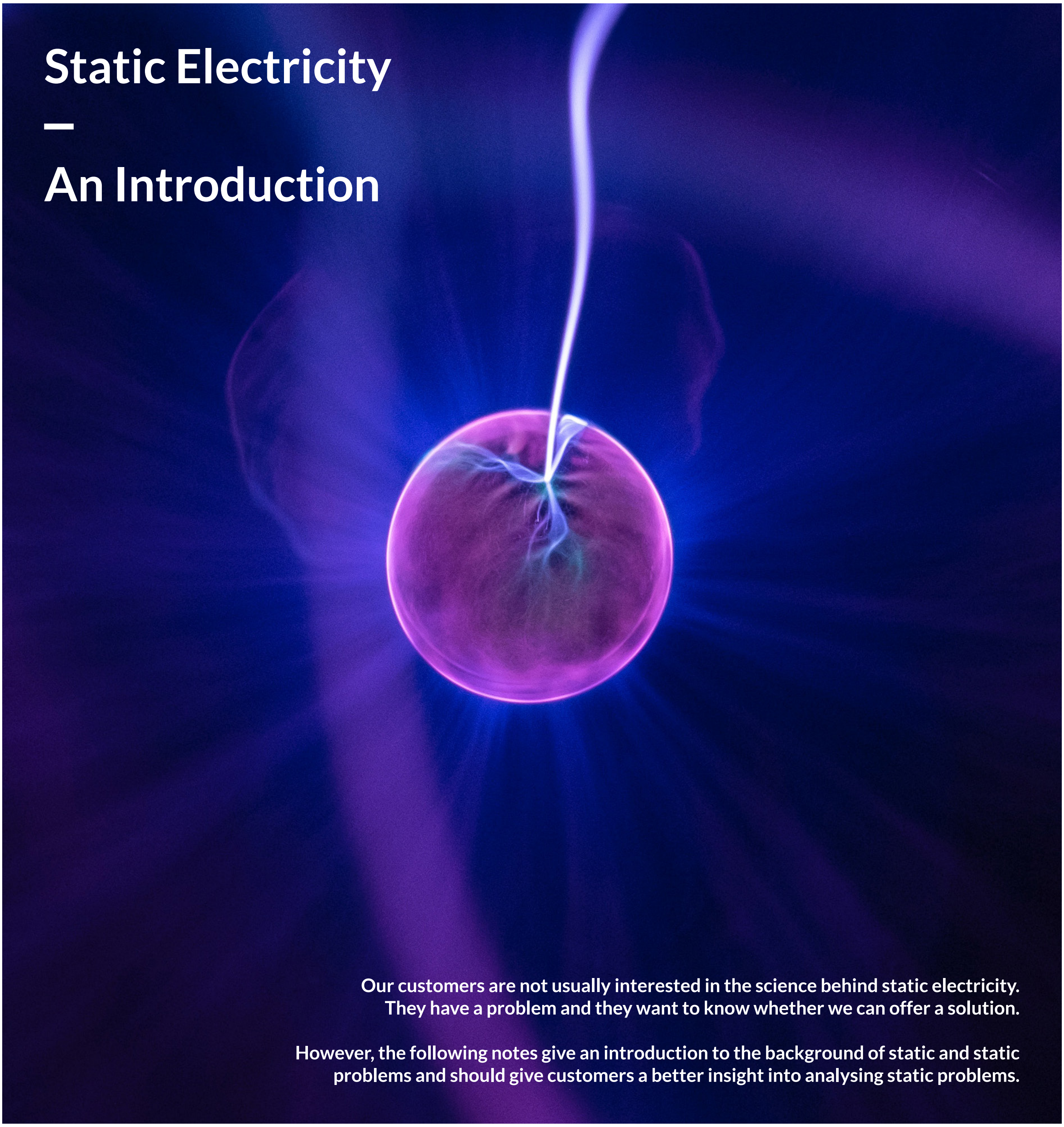
Static Electricity – An Introduction



Our customers are not usually interested in the science behind static electricity. They have a problem and they want to know whether we can offer a solution.

However, the following notes give an introduction to the background of static and static problems and should give customers a better insight into analysing static problems.

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BACKGROUND

Static electricity is an undeveloped science because, historically, it was not seen as useful - this contrasts with current electricity, which had many uses in providing energy and power.

Since the 1940s the greater use of plastics and new technologies have made electrostatics a more researched area, but the general level of knowledge about static electricity is still quite low.

In industrial applications, it is often still a matter of judgement, not science. There are too many physics and chemistry complexities involved to allow a perfect analysis. There are also problems with measurement.

WHAT IS STATIC?

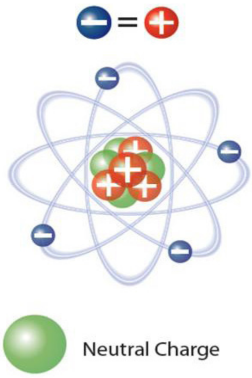
Static is an electrical imbalance on the surface of a material which can interact with surrounding materials.

This imbalance occurs when an atom (or molecule) gains or loses an electron. Normally the atom is in equilibrium with the same number of positive protons in the middle of the atom and electrons.

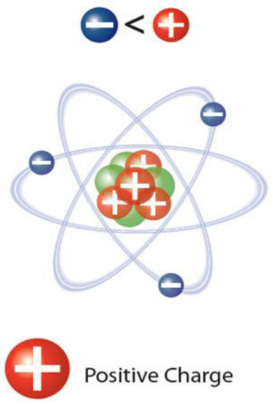
Electrons move easily from one atom to another. They form positive ions (where an electron is missing) or negative ions (a single electron, or an atom with an extra electron). When this imbalance occurs it is called static electricity.

An electron has an electric charge of (-) 1.6 x 10-19 Coulombs. A proton has the same charge with a positive polarity. The static charge in Coulombs is directly proportional to the surplus or deficit of electrons i.e. the number of imbalanced ions.

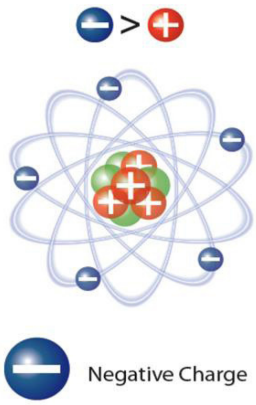
The Coulomb is the basic unit of electrical charge which represents the surplus or deficit of electrons. (An ampere of current is the movement of 1 Coulomb of charge per second).



A positive ion has a missing electron. So it can easily accept an electron from a negative static charge:



A negative ion can be a single electron or an atom/molecule with too many electrons:



In both cases there is an electron available to neutralise a positive charge.

Notes:

HOW IS STATIC GENERATED?

The main causes of static electricity are:

1. **Contact and Separation between two materials (including friction, travelling over rollers etc)**
2. **Rapid heat change (e.g. material going through an oven)**
3. **High energy radiation, UV, x-ray, intense electric fields (not very common in industry)**
4. **Cutting action (e.g. a slitter or sheet cutter)**
5. **Induction (standing in the electric field generated by a static charge)**

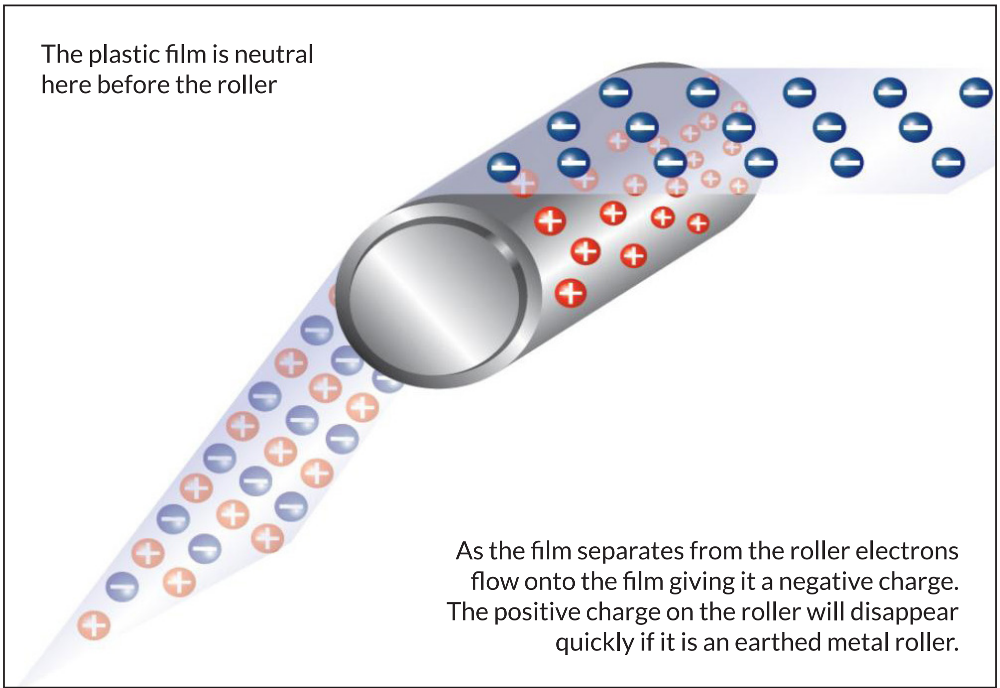
Contact and separation is probably the most common cause of static in industry where film and sheet are being processed. It happens when material unwinds or passes over a roller. This process is not fully understood, but the clearest explanation of how the static is generated here is an analogy with a plate capacitor where mechanical energy to separate the plates of a capacitor is converted into electrical energy:

$$\text{Resultant Voltage} = \frac{\text{Starting Voltage} \times \text{Resultant distance between plates}}{\text{Starting distance between plates}}$$

When the material touches the roller a small charge flows from the material to the roller causing an imbalance. As the material leaves the roller the voltage is magnified like the separating plates of a capacitor.

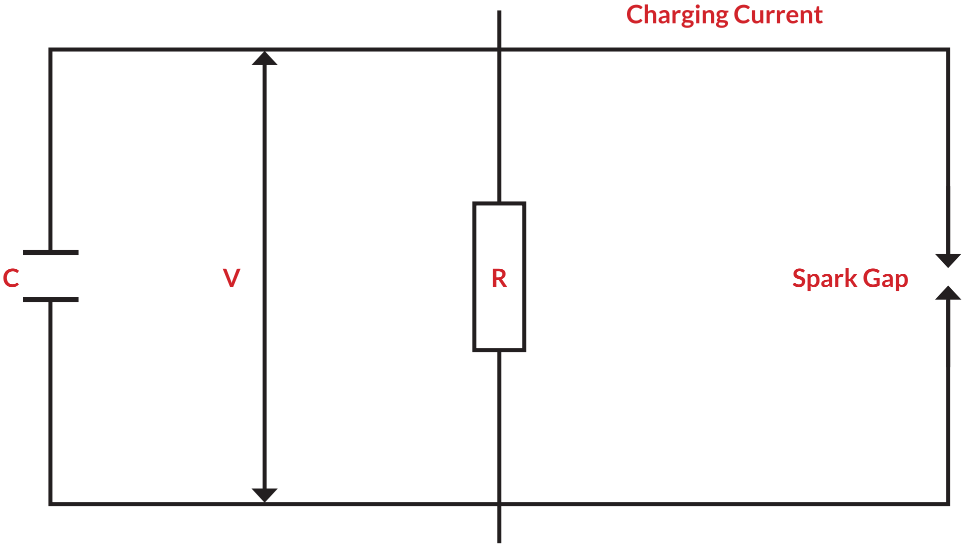
The size of the resultant voltage is limited in practice by the breakdown strength of the surrounding materials, surface conduction etc. You often hear small cracks, or static discharges, as the material leaves the roller.

This is where the static has reached the breakdown strength of the surrounding air.



Notes:

In theoretical terms, a static charge can be represented by a simple electrical circuit:



C is the capacitor function which stores the charge, like a battery. It is usually the surface of the material / product.

R is the charge relaxation ability of the material / system - usually a small current flow. If the material is conductive the charge will escape to earth and so will not become a problem. If the material is non-conductive, the charge cannot escape and so can become a problem.

The Spark Gap is the limit to the voltage build-up.

The charging current is the charge generated by the action of the product over a roller etc.

The Charging Current charges up the capacitor (i.e. the product), increasing its voltage **V**. As the voltage increases, current flows through the resistor **R**. An equilibrium will be reached where the charging current is equal to the current flowing through the resistor. (Ohms Law applies here: voltage = current x resistance)

A static problem arises where the product has the ability to store a sizeable charge and a high voltage is present.

The static problem will show itself in the form of a spark, electrostatic repulsion/attraction or shocks to operators.

Polarity of the Charge

The static charge may be positive or negative. For AC static eliminators and passive dischargers (brushes) the polarity of the charge is not usually important.

Notes:

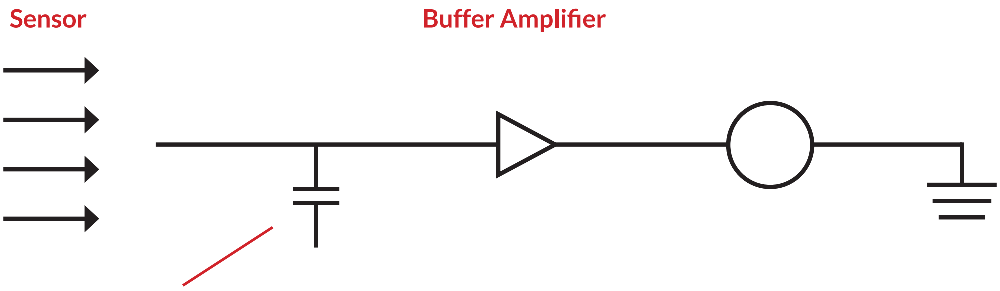
MEASUREMENT OF STATIC ELECTRICITY

Measuring the static electricity is important. It allows you to see if there is static present, its size and where it is being generated.

It was seen earlier that static electricity is actually a surplus or deficit of electrons which is measured in Coulombs. As it is not possible to measure the charge in a material in Coulombs, the electric field strength or surface voltage related to the static charge is measured. This is the accepted method of measuring static in industry.

The relationship between the field strength and voltage is that the former is the voltage gradient at any point.

Fraser 715 Meters measure surface voltage. They use circuitry:



The voltage across this capacitor varies directly with the charge.

Using Q (charge) = C m (capacitance) x V (voltage), the capacitance is set at the measuring distance of 100mm. This means that the charge Q varies directly with the voltage V.

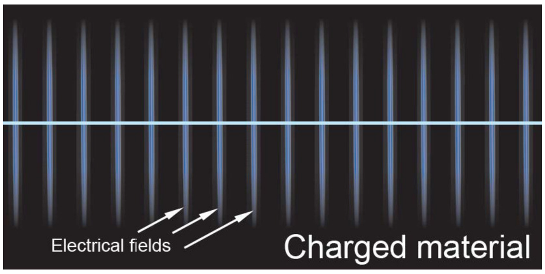
Fraser meters are simple to use and very useful in analysing problems.

Notes:

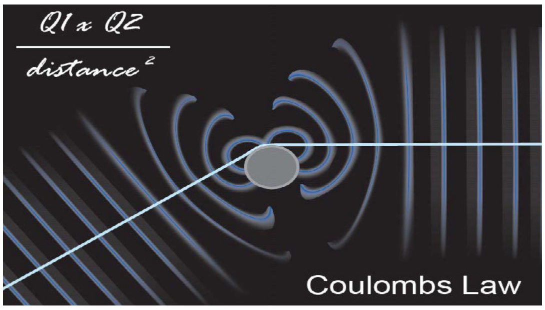
It is important to follow operating instructions when measuring static. The electric field behaves in unique ways and must be understood. One of the most interesting characteristics of the electric field, which is very important when trying to measure the charge is shown below.

Electric Field:

- is a region of space in which electrical (Coulomb) forces act
- every charged object is surrounded by an electric field
- the field lines run perpendicular to the material and shows the direction in which the force acts
- it can be coupled with other bodies with important consequences for measuring and neutralising the charge



The electric field lines run perpendicular to the charged material when it is in open air. When the electric field is like this it is easy to make accurate and intelligent measurements.



When the charged material passes over a roller, the electric charge couples with the roller and seems to disappear. It is impossible to make an accurate measurement near the roller. The electric field "returns" when the material leaves the roller and so can be measured again.

Notes:

Problems Caused By Static Electricity

There are 4 main areas:

1. Electro-Static Attraction or Repulsion
2. Fire Risk - EX Areas
3. Shocks to Operators
4. Electro-Static Discharge in Electronics

1. ELECTRO-STATIC ATTRACTION OR REPULSION

This is probably the most widespread problem in the plastics, packaging, paper, textile and similar industries i.e. the main markets for Fraser products.

It shows itself as product misbehaviour, sticking together, repelling each other, sticking to machinery, dust attraction on mouldings, bad winding and many other symptoms.

Coulomb's law governs attraction and repulsion. Basically it is an inverse square law.

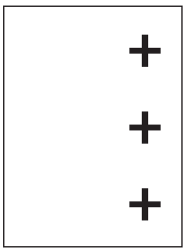
In simplified form:

$$\text{Force of attraction or repulsion (in Newtons)} = \frac{\text{Charge (A) x Charge (B) in Coulombs}}{(\text{Distance between objects in m})^{2}}$$

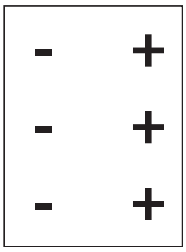
Thus the severity of the problem is directly related to the size of the static charge and the distance between the objects being attracted or repelled.

Attraction or repulsion follows the field lines of the electric field. (Often called flux lines when they represent force or displacement). If the two charges are of the same polarity they will repel each other.

If they are of different polarities they will attract each other. If only one of the products is charged it will cause attraction by creating a mirror-image charge in the non-charged products:



Charged Object



Mirror image charge is created on one side of the uncharged object, although it is still electrically balanced as a whole.

Notes:

2. FIRE RISK - EX AREAS

The risk of fire is very important in the coating, gravure printing and other industries where combustible solvents are used. The static charge on the film causes a spark discharge which ignites the solvent and creates a fire.

The following is a brief theoretical introduction into the ability of a static discharge to cause ignition in combustible environments.

The ability of a discharge to cause ignition depends on many variables:

- **Type of Discharge**
- **Rate of Discharge**
- **Source of Discharge**
- **Energy of Discharge**
- **Presence of combustible environment - often a solvent gas, but can be dust or liquid**
- **MIE Minimum ignition energy of the combustible environment**

Types of Discharge:

Three relevant types: Spark, Brush Discharge and Propagating Brush Discharge.

Spark:

Usually comes from a reasonably conductive body which is isolated electrically. This could be a human body, machine part Mor tool. It is assumed that the entire energy is dissipated in a Mspark. If the energy is more than the MIE of the solvent vapour then an ignition could occur. The energy in a spark is calculated: Energy in Joules = 1/2 C V2

Brush:

Usually happens when a corner of a machine part concentrates the charge in a larger sheet or web of non-conductive material. Generally lower in energy than a spark and so less incendive.

Propagating Brush Discharge:

Occurs on highly resistive plastic sheets and webs where there is a high charge density of the opposite polarity on each side of the material. This may be caused by rubbing or powder coating bombardment.

The effect is like discharging a plate capacitor and can be more incendive than a spark.

Source and Energy of Discharge:

Size and geometry are important factors. The larger the body, the more energy it can contain. Sharp points increase field strength and encourage discharge.

Rate of Discharge:

If the body holding the energy is not very conductive, e.g. a human body, the resistance will slow the discharge and reduce its danger. For the human body the rule of thumb is that it should be regarded as capable of igniting all solvents with an MIE of less than 100mJ, even though 2 or 3 times this energy is stored in the body energy.

A corona discharge has not been considered here. It is a slower, low energy discharge from a point. It is only regarded as problematic in the most sensitive areas.

Notes:

2. FIRE RISK - EX AREAS *(continued)*

MIE (Minimum Ignition Energy):

The Minimum Ignition Energy of the solvent and its concentration in the hazardous area are important. If the MIE is less than the discharge energy a fire could result.

Other sources of ignition in hazardous areas are ungrounded operators and floating conductors. An operator walking through a hazardous area in trainers or similar non-conductive footwear risks a discharge from his body which can cause ignition to sensitive solvents. An unearthed and conductive piece of machinery is similarly dangerous. Good earthing is essential for everything in a hazardous area.

It is important that inexperienced salespeople obtain advice before specifying equipment in these areas. We are under a duty to make sure that the equipment we offer is suitable for the customer's application - at the very least this means that the customer confirms that the certification of our products is suitable for their application.

We have 3 products which have been ATEX certified for use in hazardous areas. These are:

EX 715 Static Meter

This is the only ATEX certified static meter available.

EX-HPSD

Passive static dischargers widely used in gravure printing and coating.

EX-1250

Electrical static eliminator bar with a wide range of applications.

Notes:

3. SHOCKS TO OPERATORS

Shocks to operators are becoming more important as health and safety issues increase in importance and scope.

Static shocks are unpleasant, but not usually dangerous, unless they cause a recoil reaction. There are 2 common causes:

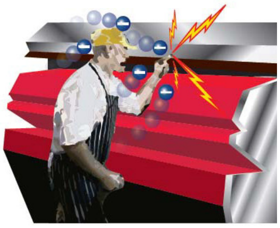
1. Induction Charging
2. Shocks from the Product

Induction Charging:

If a person is standing in the electric field of a charged object, such as a winding reel of film, their body may get charged by induction.

The operator becomes charged, this charge stays in the operators body if they are wearing insulative shoes until he/she touches an earthed part of the machinery. Then the charge will zap to earth giving the operator a shock.

This happens also when the operator is handling charged objects and materials - the charge builds up in the body because of insulative shoes.



When the operator touches a metal part of the machine the charge can escape and cause a shock.

The shocks that result from people walking over nylon carpets are due to the static generated between the carpet and the shoes. The shocks which car drivers receive when they get out of a car is due to the charge generated between the seat and the driver's clothes as they are separated. The solution to the latter is to touch a metal part of the car, such as the door frame, as the driver leaves the seat.

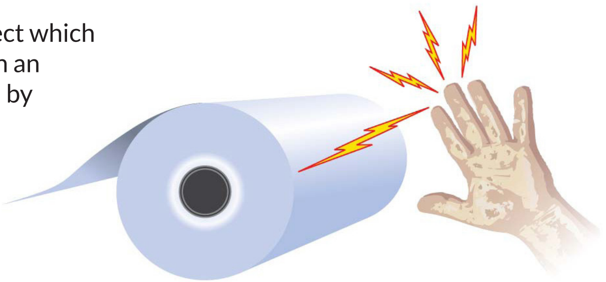
This allows the charge to go to earth through the car and its tyres without giving a shock.

Shocks from the Product:

It is possible, but less common, for an operator to receive a shock from the material.

If there was a very big charge in the winding reel, the operator's fingers could concentrate the charge until it reaches its breakdown point and forms a discharge.

Alternatively, if there is a metal object which is not connected to earth standing in an electric field, it can become charged by induction. Because the metal object is conductive the charge is mobile and will discharge to a person who touches it.



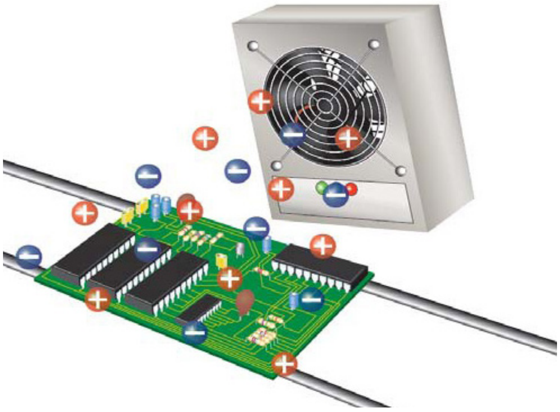
Notes:

4. ELECTRO-STATIC DISCHARGE IN ELECTRONICS

This is a market requiring specialist knowledge - please be sure to ask the factory for advice before making proposals to the customer.

Controlling static electricity is important when handling electronic assemblies and components on modern control systems, including RFID tags and labels. In electronics the problematic levels of static electricity can be very small - just a few volts, compared to the thousands of volts which are typical in other industrial applications. This requirement for balanced ionisation makes many normal AC static eliminators unsuitable.

We supply Ionstorm, 2020 Blowers and specially balanced AC Bars (1250-50) to this market.



Often the danger is from the static charge in the human body - which can be considerable. This is why people in electronics assembly wear wrist straps - the wrist straps drain the static charge in the body. Ionisation equipment is used to neutralise the charge in other products and materials where earthing is not applicable- including non-conductive materials.

The current in the discharge from the human body or other object generates heat which evaporates junctions, interconnects and the gap between tracks in the electronic components. The high voltage also breaks down the thin oxide coatings on MOS and other coated devices.

This causes failure of the product. Sometimes the component is not completely destroyed which can be even more problematic as the failure will occur later when the product is being used.

General rule: make sure that the body or other products do not contain a static charge when handling or being close to sensitive components.

This requires a combination of earthing and ionisation. There is a European and International standard covering the handling of sensitive electronic components:

EN / IEC 61340-5-1:2001

Important: this is a market for specialist knowledge and we will not be concentrating on it during this training session.

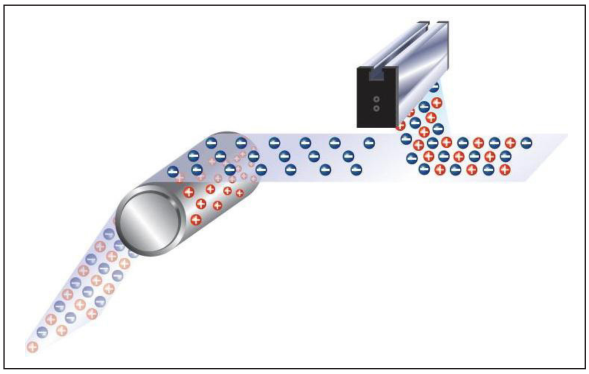
Notes:

METHODS OF NEUTRALISING STATIC ELECTRICITY

Neutralising static electricity on a conductive material is simple: allow it to flow to earth in the form of current. On non-conductive materials this will not happen because the charge will not flow - hence the name 'static'.

In industrial situations the best way of neutralising non-conductive materials is to provide electrical particles of the opposite polarity to the static charge. The best way of supplying these oppositely charged particles is with ionised air. Ionised air consists of free moving positive and/or negative ions which readily combine with the electrical imbalance min the material to neutralise it.

The ionised air provides ions of the opposite polarity to the charge. In this case because the static charge is negative, the positive ions in the ionised air combine with the negative static charge and so neutralise it. The unused ions go to earth or combine with other ions and water molecules.



Fraser manufactures two types of equipment which generate ionised air:

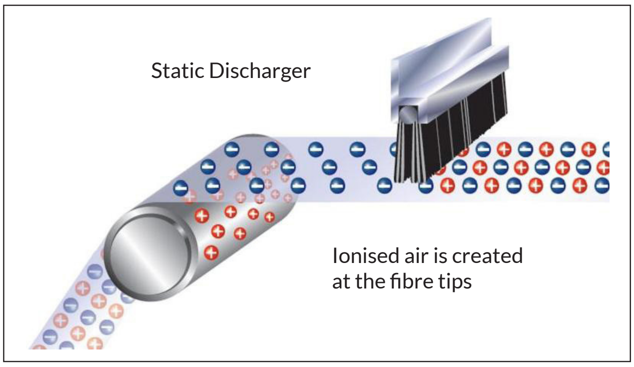
- Electrical static eliminators
- Passive static dischargers (anti-static brushes)

Notes:

PASSIVE STATIC DISCHARGERS OR ANTI-STATIC BRUSHES

'Passive' should not be interpreted as 'weak'. This is not the case. In fact passive static dischargers have an unrivalled ability to neutralise high charges.

Passive dischargers consist of a large number of very fine conductive points. The fine points concentrate the electric charge in the material until the electric field strength of the air reaches 3MV/m. At this point the dielectric of the air breaks down and ionised air is created.



The ionised air allows the exchange of ions needed to neutralise the charge. The static discharger must be earthed to allow the this exchange charges to go to earth.

Passive dischargers do not need to touch the material. On materials with a low / medium static charge level the tips of the fibre should be about 5mm from the material. Where the static charge is higher, a well designed passive discharger may be positioned at a greater distance from the material. Use a static meter to see best position.

Fraser Static Dischargers use three materials to provide the sharp points: carbon fibre (6-7m in diameter), soft stainless steel yarn (11-12m) and conductive acrylic (15m). The characteristics and uses of each material are explained in the sales brochure for static dischargers.

Notes:

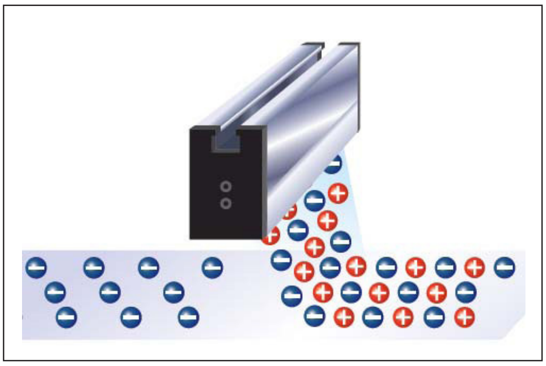
ELECTRICAL STATIC ELIMINATORS

Electrical static eliminators generate ionised air by applying a high voltage to an emitter pin. This produces a cloud, or corona, of ionised air.

The corona is typically about 150-200mm around the emitter pins.

The ionised air is produced by applying a high voltage to a sharp point. So its performance is not dependent on the presence of a static field.

Electrical static eliminators can use AC high voltage or DC high voltage to produce ionisation. AC high voltage produces both positive and negative ions from the same emitter pins. DC high voltage produces either positive or negative from the emitter pins.



Fraser makes electrical static eliminators in the form of bars, blowers, guns, nozzles and air knives using this principle. Air can be used to transport the ions from the electrical static eliminator to where they are needed.

Notes:

ADVANTAGES AND DISADVANTAGES OF EACH TYPE OF EQUIPMENT.

The ionised air is produced by applying a high voltage to a sharp point. So its performance is not dependent on the presence of a static field.

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Passive:

- low cost, cheap to replace in dirty areas such as coating
- simple to install - just needs an earth connection
- good for high charges and high speeds
- some models ATEX certified - see certification

But

- cannot reduce a charge to zero - usually a small residual charge
- not suitable for 3-dimensional products, such as mouldings
- fibres must be kept clean
- must be positioned close to the material

Electrical:

- longer range
- can reduce charge to zero
- produces ions which can be transported by air
- higher credibility - customers often do not think that something so simple as anti-static brushes can be effective
- wide range of products, including dust removal
- long life
- EX1250 suitable for many EX applications - see certification

But

- much more expensive than passive

Notes:

HUMIDITY

The generation of static electricity is influenced by the humidity in the factory or general weather conditions. On a damp day less static will be generated than on a very dry day.

Some people believe that damp air becomes conductive and the static charge leaks away through it. This is wrong. The conductivity of dry air and damp air is nearly the same.

However damp air can deposit a microscopic layer of water onto the product which increases the surface conductivity and so allows some charge to travel to earth. This applies to a degree to most materials - even hydrophobic materials which cannot absorb water.

Hydroscopic materials, like uncoated paper, can also absorb water which increases its volume conductivity as well as its surface conductivity.

In some factories, for example in the printing and textile industry, it is practical to increase the general humidity level. But this is not usual.

Most factories do not have the possibility to control the environment and in many cases this is not desirable because it would affect the production processes or products adversely.

Notes: