# Introduction to Static Electricity

## 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.

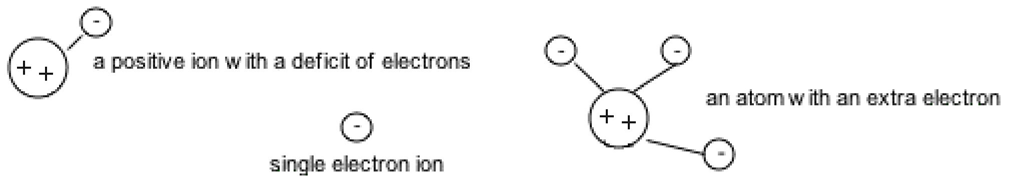
In industrial applications, it is often still a matter of judgement, not science. There are too many physics and chemistry complexities involved to allow a perfect analysis. There are also problems with measurement.

## What is Static Electricity?

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 as 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 (-) $1.6 \times 10^{-19}$ 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, whereas 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.



# How is Static Electricity Generated?

The main causes of static electricity are:

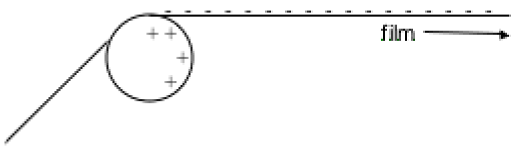
1. Contact and Separation between two materials (including friction, travelling over rollers etc)
2. Rapid heat change (e.g. material going through an oven)

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:

Resultant Voltage = Starting Voltage X (End distance between plates / Start distance between plates).

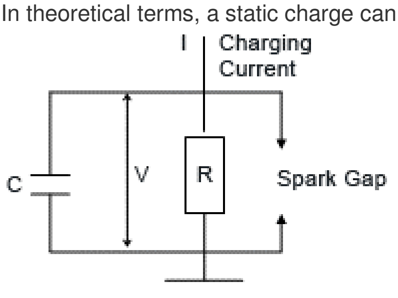
When the material touches the roller a small charge flows from the material to the roller causing an imbalance. As the material leaves the roller the voltage is magnified like the separating plates of a capacitor. The size of the resultant voltage is limited in practice by the breakdown strength of the 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.




The plastic film is neutral before the roller, but as the film separates from the roller electrons flow onto the film giving it a negative charge. The positive charge on the roller will disappear quickly if it is an earthed metal roller.

On most machines there will be many rollers and the level of charge and polarity of the charge may change often. The important place to investigate the static charge is immediately before the problem area. If the charge is neutralised too early it may regenerate before it reaches the problem area.

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.

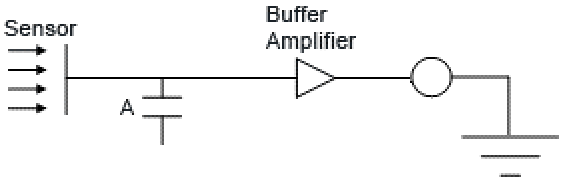
# Measurement of Static Electricity

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.

The Fraser 710 Meters measure surface voltage. They use circuitry:




**A**: The voltage across this capacitor varies directly with the charge.

Using Q (charge) = C (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.

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.

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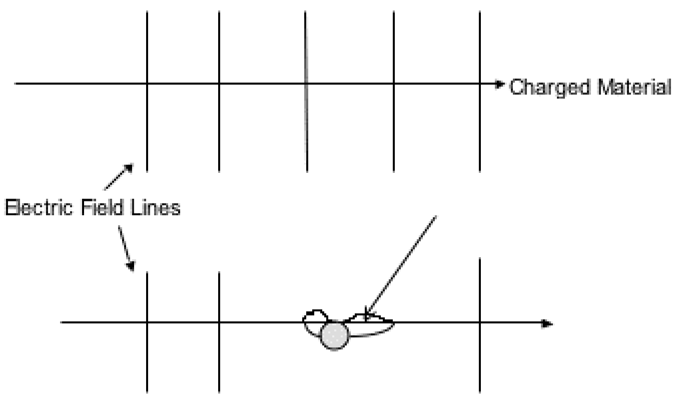
Electric field:

- is a region of space in which electrical (Coulomb) forces act.
- every charged object is surrounded by an electric field.
- the field line run perpendicular to the material and show 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.

# Problems caused by Static Electricity

There are 4 main areas:

**Electro-Static Discharge in Electronics**
This is considered here briefly because it is important when handling electronic assemblies and components on modern control systems.

The main danger is from the static charge in the human body - which can be considerable. The current in the discharge generates heat which evaporates junctions, interconnects and the gap between tracks. The high voltage also breaks down the thin oxide coatings on MOS and other coated devices.

Often 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 your body does not contain a static charge when handling sensitive components. See European Standard CECC 00015 for further details.

**Electro-Static Attraction or Repulsion**
This is probably the most widespread problem in the plastics, paper, textile and similar industries.

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 -

Force (in Newtons) = (Charge A x Charge B in Coulombs) / ((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.

**Fire Risk**
The risk of fire is not the most common static problem in industry. But it is very important in the coating, printing and other industries where combustible solvents are used.

The most common 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.

The following information gives a brief introduction into the ability of a static discharge to cause ignition in combustible environments. It is important that inexperienced salespeople obtain advice before specifying equipment in these areas.

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 and Propagating Brush Discharge:

**Spark**: usually comes from a reasonably conductive body which is isolated electrically. This could be a human body, machine part or tool. It is assumed that the entire energy is dissipated in a spark. 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 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.

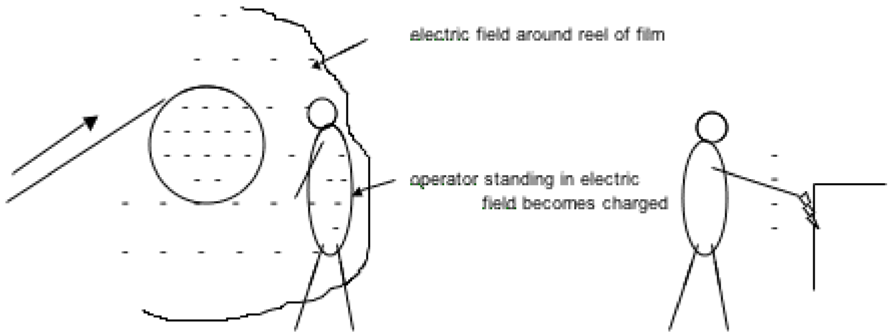
A corona discharge has not been considered here. It is a slower, low energy discharge from a point. It is only regarded as problematic in the most sensitive areas.

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.

**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:

Induction charging:
If a person is standing in the electric field of a charged object, such as a winding reel of film, his/her body may get charged by induction.




The charge stays in the operator`s body if he/she is 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 shown above, 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.