Static Electricity
Causes and Cures

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Static Electricity - Causes and Cures

About Meech:

Static electricity causes productivity, quality and safety problems throughout industry. In the form of electrostatic attraction or repulsion it generates dust contamination and product misbehaviour. As an electrostatic discharge it gives shocks to operators, starts fires and destroys electronic components by the million.

Meech has specialised in industrial electrostatics for over 40 years. This experience enables us to develop products which match the changing needs of our customers. The Meech range encompasses four technologies and includes over 40 products.

Our mission is to develop effective and durable products that are relevant to our customers' needs; to maintain the highest levels of response and service and to develop the best possible support system for our clients in our field of electrostatics.

As the first specialist manufacturer of static elimination equipment worldwide to be approved as an ISO 9002 registered company, we take our commitment to quality seriously.

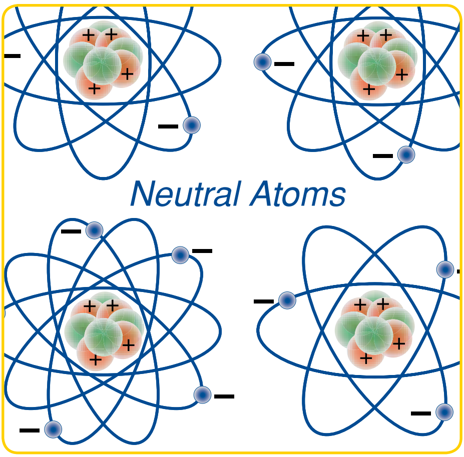
The international quality approvals covering some, or all of our products include:

Introduction

Quality products must be supported by good service. Meech Distributors throughout the world share our commitment to quality and participate in our continuous training programme. This keeps them informed about developments in applications and technology so they can offer the highest level of customer service and support.

The purpose of this booklet is to look at what static is, how it occurs, the methods available to counteract it and how Meech uses these methods in a variety of industrial applications. It is not intended to be an exacting, scientific reference manual; instead its aim is to answer the most commonly asked questions about static electricity posed by Distributors and Customers alike.

To understand this booklet it is helpful to familiarise yourself with the various terms which can be found in the glossary at the end of this booklet.



Static Electricity - Causes and Cures

What Is Static Electricity ?

When a material or object holds a net electrical charge, either positive or negative, it is said to have a static charge. The term static is a relative one as in many cases static charges will slowly decrease over a period of time. The length of time that this takes is dependent on the resistance of the material. For practical purposes the two extremes can be taken as plastics and metal. Plastics generally have very high resistivities. This allows them to maintain static charges for long periods of time; on the other hand metals have very low resistances and an earthed metal object will hold its charge for an imperceptibly small period of time.

Static electricity is usually measured in volts. Whilst mains voltages of 220 volts AC are considered dangerous, levels of static electricity of 100 kV are common.

The voltage present on a material is dependent on two factors; the amount of charge on the material and the capacitance of the material. The simple relationship is Q=CV where Q is the charge, V the voltage and C the capacitance of the material. It can be seen that for a given charge on a material, the lower the capacitance the higher the voltage and vice versa. Plastics generally have very low capacitive values and hence a small charge can produce very high voltages. Conversely metals tend to have high capacitive values and therefore a relatively high charge will produce low voltages. This is why, in practice, problems with static electricity are most noticeable when working with plastic, as it is the voltage level which causes the attraction of dust, operator shock and misbehaviour of materials.

There are two main types of static electricity, volumetric and surface. Volumetric static charges are charge imbalances within the body of a material whereas surface static electricity is only present on the very outer surface of a material.

In practice nearly all the static electricity problems found in industry relate to surface charges. Whilst there is no way of neutralising volumetric static charges they rarely cause a problem and their effects are normally minimal when compared to surface static charges.

How Is Static Created ?

There are three main causes of static electricity; friction, separation and induction.

Friction

As two materials are rubbed together the electrons associated with the surface atoms on each material come into very close proximity with each other. These surface electrons can be moved from one material to another. The direction in which the electrons travel either from Material A to Material B or vice versa depends on the Triboelectric Series (See page 18). Materials on the positive side of the Triboelectric Series will tend to give up their surface electrons and become positively charged whilst conversely materials on the negative side of the series tend to gain electrons and hence a negative charge. The harder the two materials are pressed together the greater the exchange of electrons and hence a higher charge is generated.

A practical example is if a piece of polythene is rubbed on a nylon carpet with gentle force a moderate negative charge will be generated on the polythene, whereas if the force is increased a larger negative charge will be achieved. The speed of the rubbing action also has that effect on the level of charge, the faster the rubbing the higher the level of charge. This is due to the surface electrons gaining heat energy generated by the friction. This extra energy allows them to break their atomic bonds and transfer to other atoms.

Contact + Friction + Separation

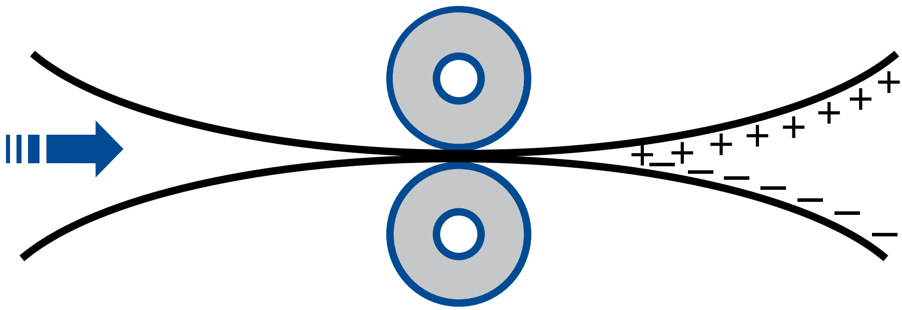
Separation

The method of charging by separation is similar to that of friction. When two materials are in contact the surface electrons are in close proximity to each other and upon separation have a tendency to adhere to one material or the other dependent upon their relative positions on the Triboelectric Series.

The faster the separation of the materials, the higher charge generated and conversely, the slower the separation the lower the charge. A common example is of a PVC web moving over a Teflon coated roller, as the materials separate the electrons will tend to adhere to the Teflon, generating a net negative charge on the Teflon and a net positive charge on the PVC.

Induction

Whilst of interest technically, induction does not play a significant role in our field. Static charges can be generated when materials are in the presence of a strong electric field. The surface of a material in close proximity to a high positive voltage will tend to become positively charged. The method of charging is caused by ionisation of the air between the surface of the material and the voltage source which carries surface electrons away from the material to the source, (ionisation is explained in methods of elimination). An example of induction is operators working near charged materials. The operator will himself become charged and on touching an earthed object will discharge to it, giving the operator an electric shock - often mistaken for a shock from the mains supply.



Contact + Pressure + Separation

What Factors Affect Static Electricity

Among the many factors that affect the generation and maintenance of a static charge are humidity, the type of material, repetition and change in temperature.

Type Of Material

Some materials are more readily charged than others. For example materials such as acetate will gain a charge very readily whilst glass will gain a charge less readily. Also the relative position of materials on the Triboelectric Series will determine whether a material charges positively or negatively dependent on the other material with which it has come into contact. For example hard rubber, when rubbed against nylon, will become negatively charged whilst when it is rubbed against polythene will become positively charged.

Humidity

Generally speaking the dryer the environment, the higher the level of static charge and conversely the higher the humidity, the lower the static charge. In relative terms water is a significantly better conductor of electricity than most plastics. Atmospheric humidity deposits small quantities of water on all surfaces in their environment and hence surface static charges on materials have a tendency to dissipate to earth by current flow through the surface moisture.

Repetition

Repeated actions such as friction or separation will increase the level of charge found on a material. For example a plastic web moving over a series of Teflon rollers will increase its surface charge after every roller.

Battery Effect

The combination of many charged items can lead to extremely high charges. For instance individual sheets of plastic with relatively low surface charges when stacked together can generate extremely high voltages.

Change In Temperature

As a material cools down it has a tendency to generate charge. The action of the cooling is to leave a net charge on the material throughout its entire volume. If the material is a very good insulator the internal (volumetric) static charge can be maintained for extremely long periods of time. However over time this charge normally migrates to the surface at which point it becomes a surface static charge. An example of this is an injection moulding which is seemingly neutral when hot but can subsequently be found to have a large surface charge once cool.

Methods of Elimination

The fundamental principle for neutralisation of static charges is the same whatever the technique used. Where a material has a positive surface charge electrons must be delivered to the surface to bring the charge back into balance. Where the surface charge is negative the excess electrons must be removed from the surface to neutralise the charge. The delivery or removal of electrons can be done by one of the three following methods, either

1. Movement of electrons through the material itself.

2. Movement of electrons through another material in contact with the surface.

3. Movement of electrons through ionisation of the surrounding air.

There is in actual fact a fourth method, sparking, which occurs when the surface voltage is sufficiently high to cause the air to become conductive. However the occurrence of sparking is normally due to the lack of application of other methods!

Humidity

As previously noted moisture on (or within) a material will tend to leach away static charges down to earth. For example paper generally has a relatively high moisture content and does not maintain particularly high levels of static. However if the paper is particularly dry static can become a severe problem.

Static Electricity - Causes and Cures

Passive Ionisation

The close proximity of a conductor to a charged object will tend to discharge it. For example Meech Model 974 Carbon Fibre Brushes will reduce static charges in materials passed in close proximity to the brush.

Radioactive Ionisation

Radioactive sources such as polonium cause ionisation of the surrounding air which will neutralise surface static charges. Meech do not supply Radioactive Eliminators.

A drawback of radioactive eliminators is the fact that they are only available on annual leases. The radioactive source loses its effectiveness over time and requires replacement on an annual basis.

Active Electrical Ionisation

By using high voltage AC or DC, ionised air can be produced which can then be used to neutralise surface charges. The use of AC or DC systems is application dependent. Further information on this is available in the applications section later in the booklet, from the Meech Manual or from our technical sales staff.

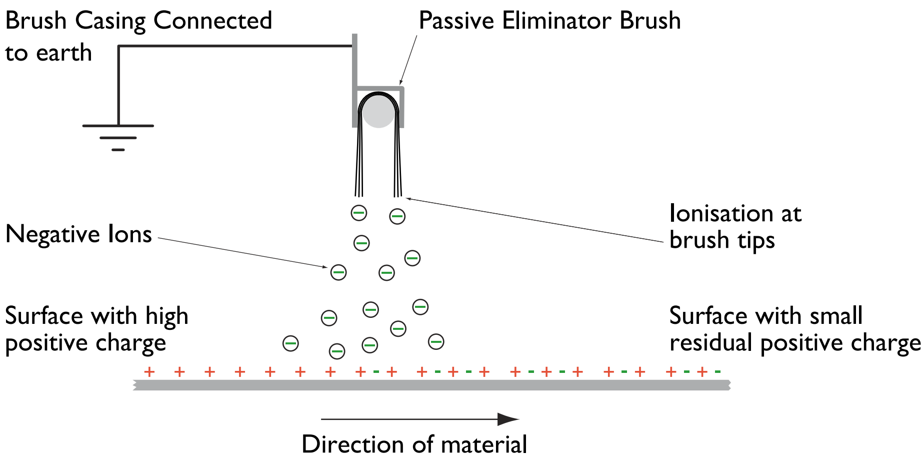


Diagram 1

Modes Of Operation Of Static Eliminators

Passive Eliminators

A charged object will generate an electric field between itself and any surrounding earthed object (or indeed any object of differing voltage). In the case of the Meech 974 passive eliminator the field is between the surface and the tips of the Carbon Fibre or Stainless Steel earthed brush. See Diagram 1.The fine point at the end of the individual bristles causes the electric field to be highly concentrated at this point. When the strength of this electric field reaches a sufficient value, ionisation of the air molecules surrounding the tip occurs.

In the example in Diagram 1 the positive charge on the surface of the material will cause electrons from the tip of the brush to jump to surrounding air molecules which will then have a net negative charge and are thus negative ions.

From the simple rule that opposite charges attract, the negative ion will be drawn to the positively charged Surface of the material. When the ion reaches the surface the extra electron the molecule is carrying is drawn from the molecule and delivered to the surface of the material. When this process has occurred in sufficient quantity the positive charge on the surface will be reduced. In this process there will come a time when the electric field generated between the surface and the tip of the brush is no longer sufficient to cause ionisation of the air and no further neutralisation takes place. In the instance of a negatively charged surface the opposite procedure takes place.

Passive eliminators are thus useful for reducing high levels of static charge, tens of kV's down to levels of a few kV's. However by their very nature they are not able to completely neutralise the surface charge.

Radioactive Eliminators

Radioactive eliminators employ polonium 210 or other low level radioactive source. In the process of radioactive decay alpha particles are emitted to the surrounding atmosphere. These high speed particles collide with the air molecules and in doing so cause the air to become ionised. This ionised air then neutralises nearby surfaces in similar fashion to the passive eliminators.

AC Eliminators

AC Eliminators operate at supply frequency. The mains voltage, 110 or 240 etc. is greatly increased using a ferro-resonating transformer, Meech Model 904, to generate voltages of between 4.5 and 7 kV. This high voltage is fed to the ionising pins, whilst the casing of the bar is connected to earth. See Diagram 2.

If we look at the positive cycle of the input waveform we will see that the electrode pin will be at a positive voltage compared to the casing. This generates a strong electric field between the two which is highly concentrated at the sharp point of the electrode pin. This in similar fashion to the passive bar generates positive ions at the pin point. These molecules are then repelled from the pin due to their like charge.

On the negative half of the cycle the opposite occurs and negative ions are created at the pin point. These again are repelled from the electrode pin due to their like voltage.

Thus around the ionising pin a cloud of positive and negative ions is produced. In the absence of outside influences the positive and negative ions are attracted to each other or to a nearby earth, such as the casing of the bar or nozzle, and would either neutralise each other or be dissipated to earth. However with the presence of a nearby static charge an ion will be attracted to on opposite charge on the surface of the material. At the surface

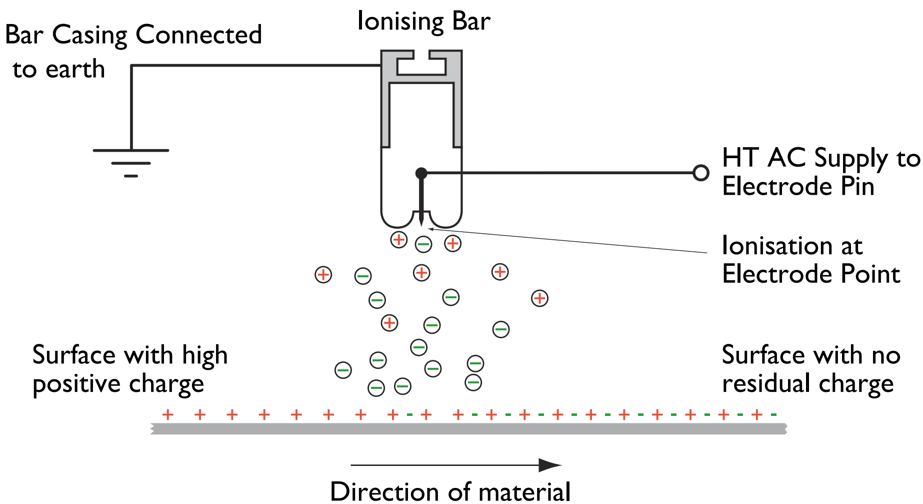


Diagram 2

of the material the electrons will be exchanged and the surface will be neutralised.

As the ionisation at the bar is not dependent upon the surface charge and ions are produced regardless of the proximity of a surface charge, complete neutralisation of a surface can be achieved. This is a significant advantage over the passive eliminators. The speed at which charges can be neutralised is dependent upon the rate of ion production and speed of repulsion of the ions from the emitter pins, which in turn is dependent on the voltage at the pin. The Model 915 Bar running at 7.0kV gives greater performance than when running at 5kV.

Pulsed DC Eliminators

Pulsed DC Eliminators like their AC counterparts produce ionised air by using high voltage. Whereas the AC units operate at supply frequency the Pulsed DC units operate at lower frequencies, in the case of the Meech Model 977v3 between 0.5-20 Hz. The 977v3 also features a variable output voltage from 6 - 14 kV peak to peak. The ionising bar consists of a series of emitters connected alternately to the negative and positive outputs of the 977v3. See diagram 3. The casing of the bar is made of plastic and hence there is no proximity earth. The output from the power supply is effectively a square wave switching from negative to positive at the chosen frequency. Looking at the positive half of the wave form the controller switches on the high output voltage connected to the positive emitters. This then sets up an electric field between the emitter and the surrounding earthed objects. At the sharp point of the emitter this field is extremely strong, and in similar fashion to the AC eliminators, positive ions are produced. The similar charge of the ion and the emitter drives the ions away from the bar.

On the negative half of the cycle the power supply delivers a high negative voltage to the alternate set of emitters. Again in similar fashion to the AC eliminators negative ions are produced at the emitter point.
A statically charged object in the vicinity of the ionising bar will attract or repel the ions, dependent upon their relative polarities. When the ions reach the statically charged surface, neutralisation takes place in a similar manner as described in the AC Eliminators section.
The low frequency of operation lends Pulsed DC equipment to long range neutralisation. The relatively long

duration of each half of the cycle cause large “clouds” of ions of alternating polarity to be emitted from the bar. This distance between the positive and negative ions close to the bar greatly reduces the rate of re-combination, (positive and negative ions coming together and cancelling each other out).

At long distances from the bar, less ions are deliverable to a statically charged surface and hence the speed of neutralisation is reduced. Hence when utilising Pulsed DC equipment on dynamic applications, such as moving webs, thought must be given to distance at which the bar will be mounted from the target surface.

An additional feature of the Pulsed DC system is that the output wave form can be altered and the duration of the negative and positive section of the wave form can be increased or decreased. For instance if the charge to be neutralised is known to be positive the duration of the negative part of the output can be increased and conversely the positive part of the wave form reduced.

This will increase the production of negative ions and decrease the production of positive ions, making the system more efficient at neutralising the positive charge. In similar fashion for a known negative charge the output can be biased towards positive ion production.

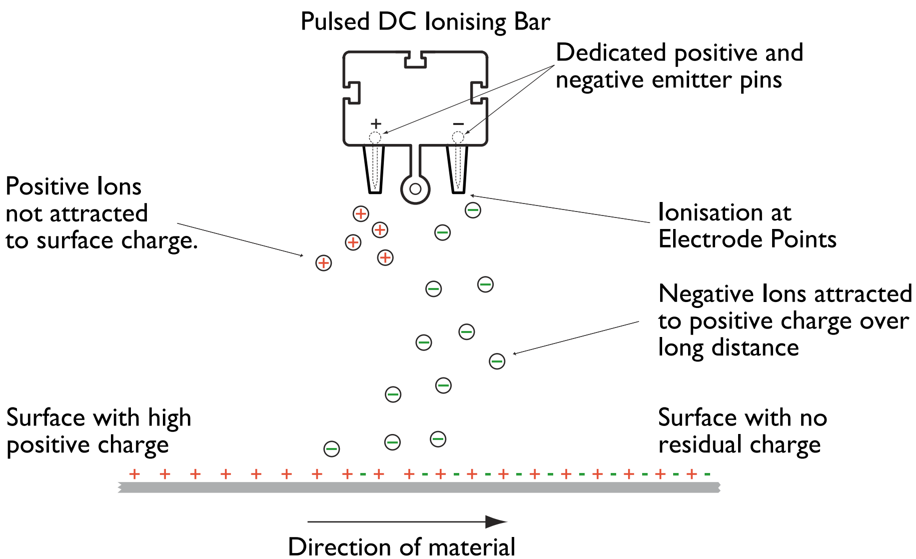


Diagram 3:

Other Aspects

Measurement

In order to select the correct equipment for a given application it is important to know the magnitude, and in some instances, the polarity of the charge to be neutralised. In cases where AC eliminators are to be used it is important to know the magnitude of the static charge so that the correct eliminator bar can be selected. In cases where Pulsed DC equipment is to be used, both the magnitude and the polarity of the static charge are important to allow the power and bias of the output to be set correctly. Whilst it is quite difficult to measure the actual amount of surface charge the surface voltage can be measured by looking at the electric field it generates.

The Meech Model 983v2 measures the electric field generated by a statically charged object, the unit of which is volts per metre. By measuring the field at a known distance the surface voltage can then be deduced. In the case of the Meech Model 983v2, the unit is calibrated for a distance of 150 mm from the surface of the charged object. The surface voltage and its polarity is then displayed on the screen.

High Accuracy Balanced Neutralisation

In the majority of applications the reduction of a static charge to a few hundred volts is normally sufficient to eliminate dust attraction and misbehaviour of the product. However in the electronics industry static charges of a few hundred volts can have disastrous consequences with modern micro-processor chips. In these instances it is important to ensure that the ionisation delivered by the neutralisation system is balanced. In such cases the Meech Series 200 range of products is recommended. This has been specifically developed for use in the electronics industry. For example, the Models 221 and 225 Ionised air blowers constantly monitor the ion ouput to ensure very exact neutralisation. Products can be neutralised to within a few volts of earth potential. This greatly reduces the risk of damage to components by, in terms of static charges, relatively low voltages.

Static Generation

As well as neutralising static it is also possible to generate static charges in materials by the use of high voltages. By passing materials through intense electric fields it is possible to charge materials either positively or negatively. This charge can be of assistance in a manufacturing process. A common usage of static generation is in high frequency welding applications where induced static charges are used to temporarily bond one item to another to hold them in place during the welding process. For further information on static generation applications please consult either the Meech Manual or Meech Static Eliminators Head Office.

Addressing Common Electrostatic Problems

Identification of the problem
There are four main troublesome difficulties arising in industry, deriving from electrostatic charges, with a fifth affecting only the electronics industry but with very serious and costly consequences.

Electrostatic attraction (ESA)
Airborne particles are attracted to charged surfaces or indeed charged airborne particles are attracted to a surface which could be totally free of any charge. This problem effects most plastic based industries in one form or another, spoiling finishes of painted products and causing rejects in quality in the food, pharmaceutical and medical industries.

In the printing industry dust attraction damages print finishes or indeed printing plates. The film industry also suffers with low quality prints and poor resolution projections in the cinemas.

The microscopic nature of semiconductor manufacture can be affected by this problem.

Material Misbehaviour
This is another form of ESA. However, instead of the contamination of products, the problem manifests itself in the form of the product itself, usually webs, fibres or sheets, sticking to themselves or equipment, misrouting or repelling. Automated processes are particularly prone to this problem.

Operator/Personnel Shocks
This is becoming increasingly significant as companies look to improved safety standards. Whilst shocks can be painful the effects are usually quite safe and short lived. However, in extreme cases, the debilitating effects can cause personnel collision or entrapment with associated machinery or can even initiate a fire or an explosion in hazardous areas.

Electrostatic Discharge (ESD)
This problem is associated to electronics assembly, installation and field service and also electronic component manufacture.

Voltages as low as 5 volts which have no real meaning in other industries, can cause catastrophic failure of electronic components or much worse, latent damage which results in field failure, by far the most costly in terms of repair and manufacturers' reputation.

Overview Of Solutions

Electrostatic attraction (ESA)

A variety of equipment is available to resolve this problem in many different ways. Some examples follow :

A. Injection Moulding - Neutralisation
Bathe components in ionised air. Often using AC Ionised air blowers or Pulsed DC bars.

This method will not remove attracted particles but will help prevent charging and thus prevent attraction of dust.

B. Injection Moulding - Particle Removal Where particles have already been attracted they can be removed effectively by the use of high velocity ionised air. This can be achieved for small components with Meech nozzles or guns, larger components by the use of 957 air curtains and with extremely large components the Meech JetStream system. Note: The use of ordinary compressed air will often fail to remove dust. It can also worsen the problem by generating further static charges on the material.

C. Webs
Single or doubled sided web cleaners could be deployed in this situation or high velocity blow off systems, air curtains etc.,

D. Silk Screen Printing - Long Range
Long range Pulsed DC Bars can be used to eliminate charged screens without causing drying. Ionising guns or air curtains can remove attracted particles from substrates pre printing.

E. Semi Conductors - Long Range
Pulsed DC can be used for this situation - stand alone or using air assist from HEPA filters.

Material Misbehaviour

A. Webs
Most commonly solved using AC ionising bars. The Model 915 bar offers the power to cope with fast, highly-charged webs.

Bars can be positioned either side of a web to achieve the best results, usually at the point where the problem occurs, or just prior to this position. An example would be where a web exits a roller or at the exit rollers of a flat bag making machine.

B. Sheets
Two major problems exist with sheets - they can repel or stick together when collating. Ionising bars or a 935 blower can be placed above the process to eliminate the static charges on the sheets and allow the process to continue.

On sheet feeders, static attraction causes multiple sheet pick-up rather than the single sheets required. Meech 957 air curtains can be used in this situation to create a blade of ionised air which penetrates the top layers of sheets allowing free separation.

C. Component Sticking And Repelling

On conveyors or bowl feeders, small plastic components can stick to the belt or inside the track of the bowl feeder: this leads to down time and ineffective production flow. Where components repel each other they can jump off or out of the delivery system.

Deploying ionising bars , long range preferably (AC bars with air assist or Pulsed DC) can resolve this problem. Meech 935 blowers may also be used in this situation.

Where larger components are concerned, repelling can cause components to fall over whilst in process transport e.g. blow moulded bottles on conveyors. The parrisons on blow moulding machines also can repel each other causing quality problems.

935 ionising blowers are generally used on transport systems. Long range Pulsed DC equipment is exceptionally useful for controllinhg the charges on parisons.

Operator/Personnel Shocks

This problem can occur in two ways and can be resolved in two ways.

1. Personnel can receive shocks from extremely highly charged material as it discharges through them to earth.
2. Operators can themselves become charged by handling or being in close proximity to highly charged material. When the operator is presented with a path to earth , usually metal objects or a machine, they discharge violently often believing they have had a mains shock.

The problem can be addressed by either neutralising the material with bars or blowers or by continuously neutralising the operator with long range Pulsed DC bars. In extreme cases both methods can be combined.

Static Electricity - Causes and Cures

Electrostatic Discharge (ESD)

The electronics industry predominantly addresses this problem by the use of conductive or static dissipative materials in the work place and in packaging.

All of these materials are earth bonded to the same electrical potential thus eliminating the possibility of potential differences and subsequent discharges.

However there are many areas in electronics where such materials cannot be used practically .

Clean Rooms The materials can cause contamination.Also the laminar air flows can generate static.

Powering-Up Testing PCB's and components may short out and present an electric shock hazard.

Auto Assembly The movement and separation within the equipment generates its own static charges.

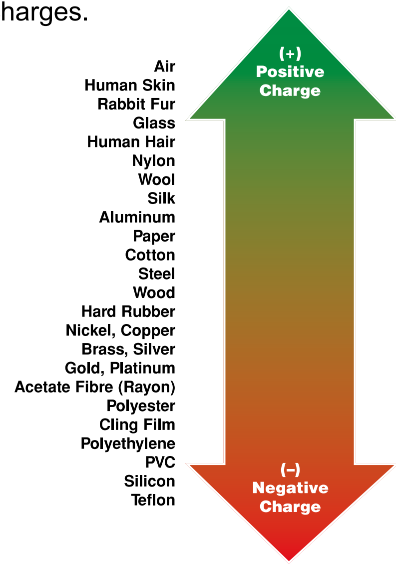
Product Assembly Where PCB's are assembled into equipment made from ordinary static generative materials

In all of these situations ionisation is recognised as a solution and sometimes as a supplement to traditional methods.

This is a very specialised area for 200 range of equipment. Series 200 which Meech has developed the series products are cleanroom friendly and give highly accurate, fast neutralisation.

Triboelectric Series

The position in the series indicates the relative polarity that is likely to occur when two of the materials are rubbed together but does not necessarily dictate the likely magnitude of the charges.



Glossary

Capacitance: A measure of the ability of a substance to hold charge.

Coulomb: The unit of measure of electrical charge.

Conductance: The higher the conductance of a material the easier charge will flow through it. Metals are very conductive.

Electron: A small atomic particle with a negative charge (1.6 x 10^{19} coulombs).

Ion: A molecule or atom with an electrical imbalance (a negative ion has an excess of electrons, a positive ion has a deficit of electrons).

Resistance: The higher the resistance of a material the harder it is for charge to flow through it. Insulators such as plastics are very resistive.

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