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Electrostatics

When handling flammable liquids: Risks of electrostatic ignition in the laboratory?

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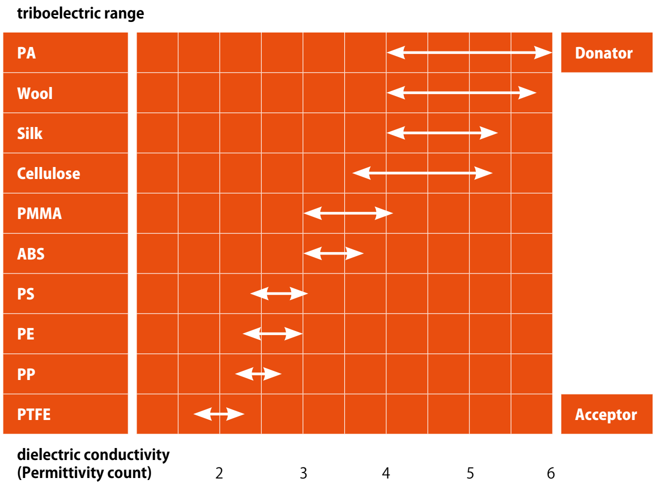
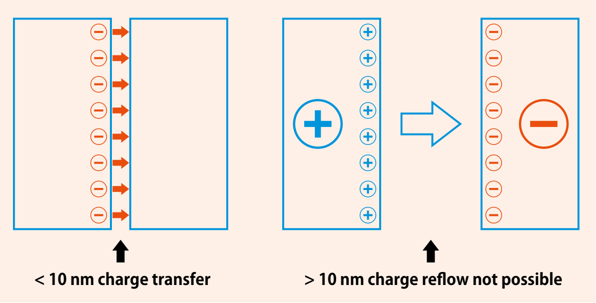
Electrostatics, commonly known as static electricity, is not produced through friction of two surfaces as per popular belief. It is generated by separating surfaces which have previously been in intensive contact. In this context, intensive contact refers to a surface having a dwell time, even if short, and a maximum distance of 10 mm to the other contact surface.

Depending on the conductivity and position in the triboelectric series, materials tend to pick up charged particles on their surfaces or transmit charged particles to the adjacent surface. In this case, conductive materials serve as electron suppliers (donator), while insulating materials absorb charged particles (acceptor).



Materials with higher permittivity serve as electron suppliers (donors). Those with lower permittivity tend to accept charged particles (acceptors).

If the surfaces are separated quickly after such a charge transfer, and if at least one of these materials is a poor conductor of electricity, the electrical charge can no longer be transferred back to its origin. Consequently, this inability for charged particles to be transferred back results in an excess charge on one surface, while a charge deficiency is created on the other surface. During separation a voltage is generated, reaching up to the magnitude of kV.



Charge transfer upon contact, charge separation by surface separation.

Therefore, electrostatics is always a surface effect and occurs on the surface on a molecular or atomic level.

When working with solids, it is easy to recognize separation processes that may lead to chargers, as these are generally visible movements.
In general, visible movements are always present. Removing film layers, decanting material from a container or removing a synthetic piece of clothing from the body (fleece, polyester) are all examples that can lead to noticeable and sometimes visible static charge transfers.

As previously explained, for charge separation to occur at least one of the materials involved requires to be a poor conductor.

Poor conductors (or „insulators") include most plastics like PE, PVC, PVDF, PTFE, etc. However, solids are not measured in units of conductivity (unit: S/m) but in terms of their resistance (unit: Ωm). Siemens/ meter being the reciprocal of ohmmeter, the values are directly comparable, i.e. low conductivity corresponds to high resistance.

Liquids are also to be distinguished from an electrostatic point of view. Some substances also demonstrate a high resistance, meaning a poor ability to conduct electric charge.

These include, for example, aliphatic/aromatic hydrocarbons, such as ethers, as well as widely used solvents such as toluene, n-heptane, n-hexane, xylenes, etc.

Some nitriles (such as acetonitrile) and some esters are special in that they lead to unexpectedly high supercharges despite having relatively good conductivity - so far an unknown and hardly investigated effect. This means that electrostatic protection is especially important for such substances.

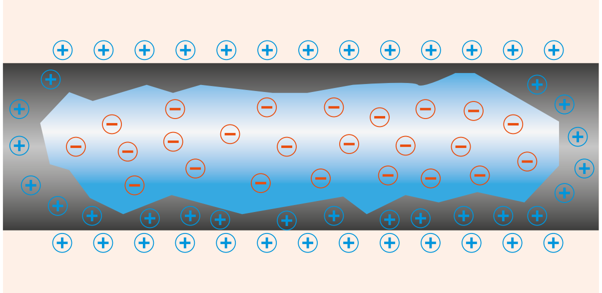
However, unlike to solids, the process of surface separation of liquids is not always recognizable as such.

It is difficult to visually distinguish between flowing and stagnant conditions of a liquid-filled glass pipe or semi-transparent HPLC tube.

Even if so: the liquid always remains in contact with the inside surface of the tube/pipe. **However, no surfaces are separated in this process, are they?**

This is common misconception. Unlike solids, a so-called electrochemical double layer (also called a Helmholz double layer) at the container or pipe wall with different electrically charged layers. While the liquid flows along the pipe, the charge layer primarily located in the liquid is carried along.

Surface roughness, flow-inhibiting installations and cross-sectional changes favour these effects, increasing the charge of the system.



Charge separation on a molecular basis during transfer.

Of course, a certain volume of liquid as well as flow velocities are required in order to generate a charge.

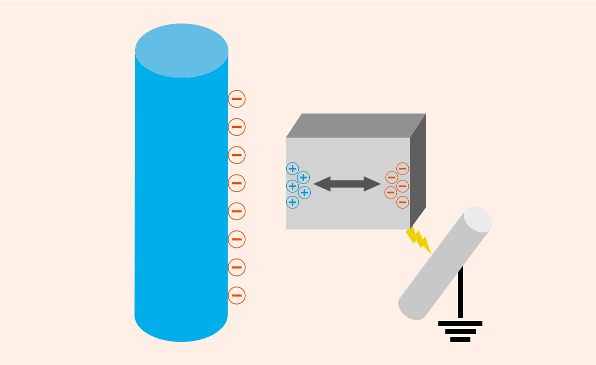
In a closed system a flow velocity of typically <1 m/s is regarded as uncritical, as up to this point an equilibrium of charge transfer and charge reflow exists. However, this limit does not apply to pipe-exit conditions or decanting, since here different volume/surface ratios are given. Furthermore, stopping the liquid flow will not allow for a charge reflow.

For the given reasons, filling a test tube from a laboratory wash bottle does not meet the criteria that lead to critical electrostatic charges, even though the wash bottle is also made of insulating material (generally LDPE or HDPE).

However, charges quantity is transferred at increasing velocities. **This situation may occur in capillaries and tubes of HPLC systems,** particularly when multiple tubes are combined, thus increasing the flow of waste solvents through a single tube. The associated separation or charging processes can be sufficiently strong to result in an electrostatic field being formed around the transfer tubes. If there are components inside the affected charge area which are conductive (such as metal parts) as well as non-grounded, they will become subject to a charge polarisation. This means that the opposing polarity increases towards the field; the same polarity is repelled. This polarisation effect of charged particles in non-grounded, conductive components can be so strong that a discharge of the excess charge or - depending on polarity - an equalisation of the charge deficit to the next grounded point takes place. Both generally manifest themselves in form of sparks.

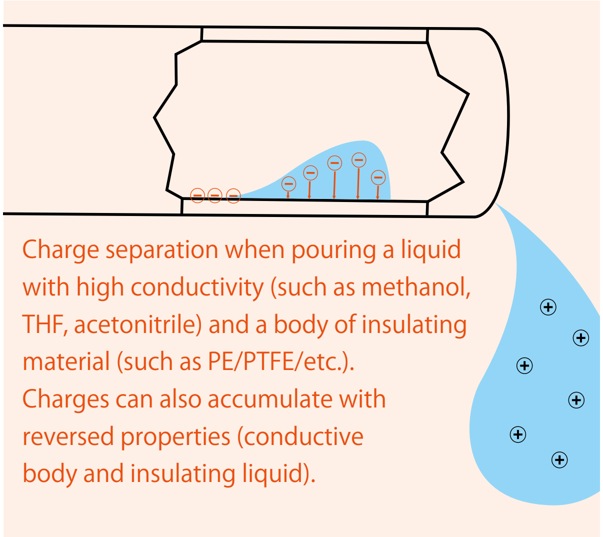
Risks of electrostatic ignition in the laboratory?

A typical example of building up a charge through induction are metallic components such as couplings or brackets connected to a transfer tube made from insulating material.



Polarisation of conductive, non-grounded parts through „induction". This may lead to a charge equalisation in form of a spark.

Even when pouring liquids flowing over surfaces and are, subsequently, collected in containers (e.g. waste solvents that are poured through a funnel into a collection container), charges may accumulate. Initially, the funnel may take on one polarity due to the separation process between liquid and funnel.



Charge separation when pouring a liquid with high conductivity (such as methanol, THF, acetonitrile) and a body of insulating material (such as PE/PTFE/etc.). Charges can also accumulate with reversed properties (conductive body and insulating liquid).

The oppositely charged liquid collects in the container and transmits its charge to the container. If the funnel and container are not electrically/electrostatically connected to each other, a different electric potential forms on both components, i.e. a charge that can be discharged in the form of sparks. This creates an ignition risk.

Incidents with damaging effects due to electrostatic charges and discharges when transferring liquids and waste solvents are well-known and documented.

How do you avoid electrostatic ignition risks when handling solvents in laboratories?

There are three different types of electrostatic discharge that apply to laboratory conditions.
A risk assessment taking into account the three types is used to evaluate the risk as well as to specify safeguards, and by this mitigates electrostatic hazards.

The most common type is the discharge by spark which always occurs when conductive materials are charged by separating their surfaces from insulating materials or by „induction".

These charged, conductive objects may include

- **packaging materials such as canisters, alloy bottles, metal containers**
- **persons**
- **tools such as funnels, pipe components, sieves and filters**
- **as well as flammable solvents with high conductivity (alcohols, ketones)**

if their charges cannot be discharged.

The charge accumulates in the same way as in a capacitor. If the potential is high enough, the charge is equalized with another conductive object to another potential (generally to the grounded point).

The use of conductive or dissipative earthing materials prevents spark discharges.

The charge is equalised via the ground connection and a possible charge is harmlessly discharged. At the same time, conductive, grounded containers are capable of grounding the conductive liquids they hold.

The safe grounding of conductive components prevents spark discharges. Dissipative materials must also be grounded.

The second relevant type of discharge is the brush discharge.

This occurs on surfaces made of insulating material which have been charged by separating operations such as rubbing, wiping, the removal of protective films, etc., or by spraying.

Insulating solid surfaces can only be charged by such surface processes. Charging via induction does not occur in insulating materials, as the poor conductivity does not allow the charged particles in the material to be moved/polarised.

If a charged insulating surface is given a grounded conductor, such as by the approach of a metal object or a person, the electrostatic field concentrates towards this grounding point and develops into a spark manifesting on the surface - the brush discharge.

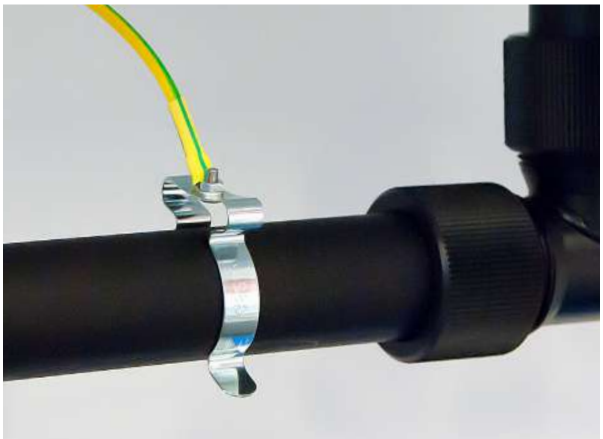
Brush discharges are lower in energy than spark discharges and cannot ignite flammable dust-air mixtures with a minimum ignition energy of > 1 mJ. However, the energy of the brush discharge is sufficient to ignite flammable solvent vapours or combustible gases.

Depending on the combustible material (e.g. belonging to the explosion group IIC) and how likely ignitable solvent vapour-air mixtures are (e.g. "occasional" (zone 1), an insulating material surfaces > 20 cm^2 made of insulating material may be evaluated as critical.

In certain conditions, containers such as canisters, bottles etc or tools made of insulating material are supplied with a manufacturer release for use with flammable solvents. However, the operator must observe the manufacturer specifications and conditions of use (such as „Dry wiping prohibited", „...only for designated use", etc.).

To protect against brush discharges, surfaces made of insulating material must not be charged by rubbing, wiping, or similar operations in the simultaneous presence of flammable vapours.

Alternatively, the use of conductive or dissipative materials is recommended, as they discharge safely when grounded. In this way the prerequisite for brush discharge, namely charged insulation surfaces, is not given.



Using conductive or dissipative grounding materials avoids insulation surfaces being present. This means that the prerequisite for brush discharges is no longer given.

The third type of discharge observed in laboratories is the propagating bush discharge.

This mainly occurs inside plants and on surfaces made of insulating material if so-called „strong charge-generating processes" take place simultaneously.
For example, these conditions are present in insulating tubes through which aerosols or solid particles are transferred at high velocities.

A tube exposed to the conditions of propagating brush discharge is generally recongisable by a dark mark, with a length of several centimetres. At the centre of the mark preforation of the wall due the discharge can be seen.

A propagating brush discharge contains enough energy to ignite fuel-air mixtures of any kind. However, as several conditions are required for the generation of this type of discharge, the probability of occurrence is relatively low. If in doubt, seek an expert opinion.

Since propagating brush discharges only occur on surfaces made of insulating material, the use of conductive or dissipative transport or conveyor systems is also an adequate safeguard in this situation.

Electrostatics and its ignition risks is a very complex issue. The requirements for components and parts used in so-called hazardous areas, i.e. zones in which flammable atmospheres occur frequently and to a great extent, are effectively regulated.

But even in areas with high air exchange and lower solvent volumes which are not defined as hazardous zones, care must be taken to avoid creating electrostatic ignition sources near emission points or in areas of handling solvents. An electrostatic discharge occurring in this area would inevitably cause the mixture to ignite and, in a worst-case scenario, would cause the container to explode.

Instead, this emission should initially be avoided by using suitable filtration systems. If this is not possible, care must be taken to ensure that no electrostatic hazards can be created near solvent emission points or in areas where these substances are handled (i.e. waste solvent collection points).

In order to do so, it must be ensured that not only the previously specified safeguards for solvent systems are applied, but also additional mitigations such as grounding of operators through dissipating floor mats and appropriate footwear are considered. Electrostatic requirements for the hazardous areas listed above are regulated differently depending on national regulations.

In Germany, the "Technische Regel für Gefahrstoffe" („Technical Regulations for Hazardous Substances"), or TRGS 727 (formerly TRBS 2153), stipulates electrostatic requirements in hazardous areas under the title „Prevention of ignition hazards due to electrostatic charge".

At European level, CENELEC (EUROPEAN COMMITTEE FOR ELECTROTECHNICAL STANDARDIZATION) CLC/TR 50404:2003 superseded by CLC/TR 60079-32-1:2015 Electrostatics - Code of practice for the avoidance of hazards due to static electricity, is applied.

These regulations describe hazards and specify safety measures. Therefore, this source can also be used as reference or for specific questions.

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