Electrostatic Charges and Their Effects on Weighing

METTLER-TOLEDO

How to deal with static samples to achieve fast and accurate results

Electrostatically charged samples or containers can be difficult to weigh. Problems with balance stability or measurement drift can often be caused by static charges. This application note explains measures that can be taken to prevent electrostatic charges building up, but more importantly what can be done to dissipate these charges once they have been generated. Understanding electrostatic charges and the effects they can have on samples and containers are critical to avoid disruption to weighing processes.

What is Static

Static is the accumulation of electrical charges on the surface of a non-conductive material. The phenomenon of static electricity requires the separation of positive and negative charges. When two different materials are in contact with one another, electrons can move from one material to the other, which leaves a positive charge on one material, and an equal negative charge on the other.

What Causes Electrostatic Charges

Friction is the most common way for electrostatic charges to be generated on an object. Everyone remembers the experiment in physics class, where a glass rod is rubbed with a cloth and will then attract small pieces of paper or lift the hair away from your head. Typical laboratory examples include:

Drying a glass beaker with a cloth

- Handling a volumetric flask with disposable gloves
- Unpacking a laboratory vessel from a plastic bag
- Filling a vessel with loose materials (bulk)

Charge separations are caused by rubbing, for example, when tare containers are grasped or lifted. This is fostered by materials that have a strong electrical insulation effect, such as PTFE or plastic materials (like polypropylene, polycarbonate or polystyrene), but also glass. In addition, unfavourable external conditions, such as a dry atmosphere, poorly grounded floors, or the use of plastic gloves, can contribute to the formation of charge separation and, thus, to electrostatic charging.

However, charges can also arise without the involvement of friction. Merely separating two different materials, such as lifting a glass flask off of a plastic surface is sufficient to generate a strong static charge.

The Effects on Weighing and Weighing Accuracy

Electrostatic charges can cause sample handling difficulties, errors in weighing results, and longer weighing times. The effect on the accuracy and reproducibility of the measured value can be very significant.

The presence of static is often recognisable by:

- Drifting measurement readings
- Non-repeatability of measurement results
- Balance instability (or stabilisation time longer than usual)

Drift and non-repeatability of results, and balance instability is usually due to the dissipation of electrostatic charges. These observations are due to the vertical component of the Coulomb force continually changing, which makes it difficult to obtain a precise measurement difficult.

Electrostatic charges also disrupt the weighing process if the sample or opening of the tare container is charged.

When this happens, powder can 'jump' from the spatula onto the tare container, causing precision working to become an ordeal *(as illustrated in Figure 1)*. Dry powders are very susceptible to static influences and can be troublesome to weigh. Weighing a small quantity into a large glass or polymer vessel represents the classic use case where an electrostatic charge could significantly increase the error of the weighing result.

Figure 1. 'Jumping' powder during the weighing-in step caused by electrostatic charges.

The cause of these issues is a net charging of the weighing sample that, without additional measures, is not reduced or is reduced only slowly. If weighing vessels are charged, polar opposite charges on the metal surfaces of the weighing chamber are attracted to them *(see Figure 2)*. This attraction between the charged vessel to the weighing pan and the charges on the weighing chamber produce an additional force that the balance measures as supposed extra weight. Typically, under such influences, balances take a long time to stabilise, and the measurement is inaccurate due to the additional disruptive force.

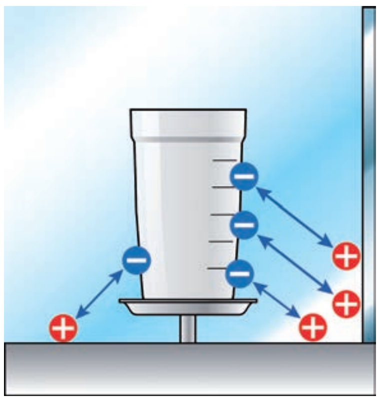

Figure 2. A negative charge on the measuring flask and a positive charge on the balance housing cause a force to be exerted between the balance and the vessel. The vertical component of this force adds to the weight of the flask and influences the weighing result.

The effects on the weighing accuracy could be:

- The reported value could be more or less than the real weight
- Errors in the range of 1–100 mg have been observed

Because the charges generated can be negative or positive, and either attract or repel each other, the real weight may be more or less than the reported value. Errors of a few milligrams to 100 mg have been observed, which is highly significant in terms of percentage error when weighing small samples.

Yet there are cases where the problem is difficult or indeed impossible to notice. For example, it is possible to achieve a stable weight with a net electrostatic force present, without any of the typical indicators that static is affecting the weighing result.

How Quickly do Charges Dissipate?

Electrostatic charges dissipate over time:

- Depending on the conditions, charge dissipation can take a few seconds or minutes, or several hours in a controlled dry atmosphere (relative humidity ≤ 20%).
- Good insulators (e.g. borosilicate glass or laboratory grade plastics) can make charge dissipation slower.

Charges dissipate fast from poorly insulating materials (good electrical conductors), but this can be very slow with items made from a good insulator (poor electrical conductor).

Most laboratory vessels are made of borosilicate glass, which is an excellent electrical insulator. The same is true for almost all laboratory-grade plastics used in the manufacture of laboratory items. Even common window glass (sodium silicate glass) makes a good insulator under dry conditions. These good insulating materials can slow down charge dissipation. Clean glassware taken straight from the laboratory dishwasher carries and holds a large amount of charge.

The time constant of charge dissipation is influenced by the surface conductivity. The higher the surface conductivity of the charged body, the faster the electrostatic charges can drain away. Next to the material's intrinsic properties, the surface conductivity also depends to a great extent on the relative air humidity and the degree of surface contamination.

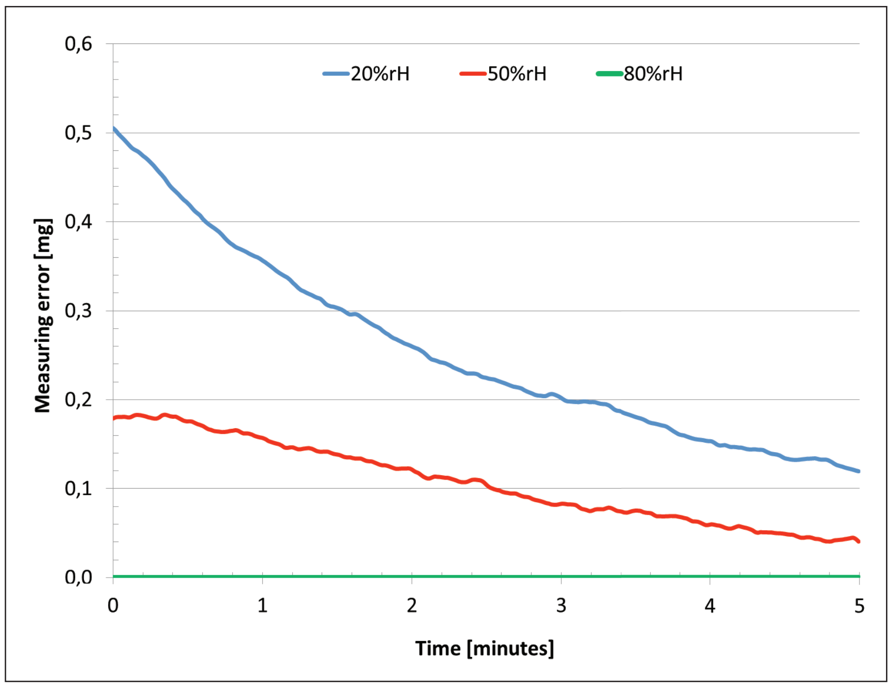

Figure 3. Glass Vessel - Electrostatic charge dissipation over time in varying humidity conditions.

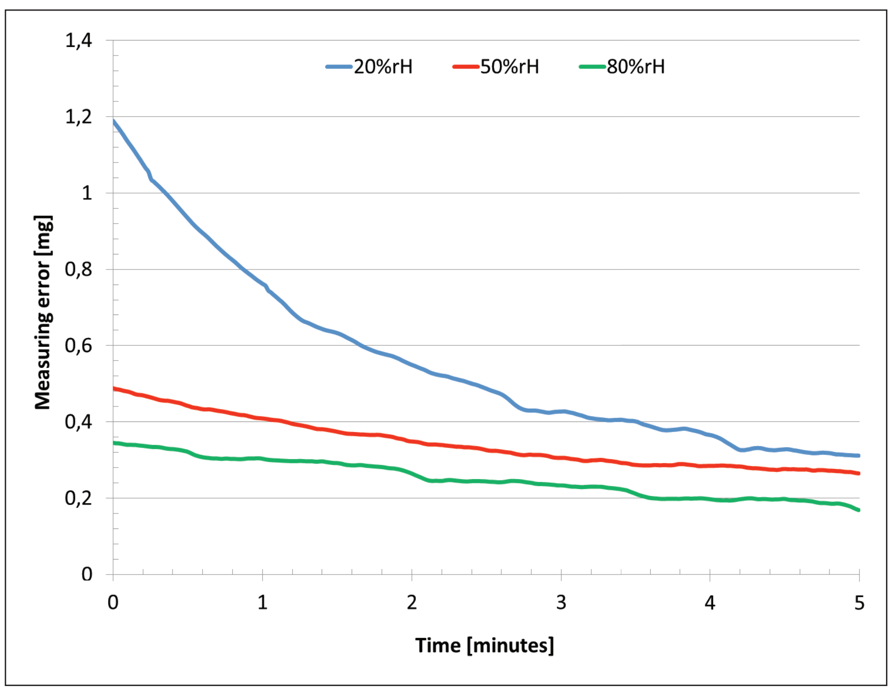

Figure 4. PTFE Vessel - Electrostatic charge dissipation over time in varying humidity conditions.

Figures 3 and 4 show the electrostatic charge dissipation over a period of five minutes for a glass vessel compared to a PTFE vessel. Both graphs show larger measurement errors in lower relative air humidity environments (blue lines = 20% RH). In every case, the weighing errors reduce over time, as the charge dissipates. Figure 3 shows that a glass flask is unable to become charged at 80% relative air humidity (green line). However, for PTFE containers, even when the air humidity is high, significant weighing errors are observed over several minutes *(see Figure 4)*.

Preventing and Eliminating Static Charges

Tips to avoid generating electrostatic charges whilst weighing in the laboratory:

- Use electrically conductive or anti-static treated materials whenever possible:

- Plastic and glass vessels can quickly become charged and are therefore non-ideal materials.

- SmartPrep weighing funnels from METTLER TOLEDO are specifically designed for this purpose.

- Avoid contact between dissimilar materials when handling
- Avoid unnecessary rubbing of the vessel (especially touching it whilst wearing protective gloves).

- If possible use weighing tweezers for handling containers.

- Increase air humidity in air-conditioned rooms:

- Electrostatic charges frequently occur during the winter season in heated (dry) rooms.

- The optimum relative humidity is 45 - 60%.

- Make sure that the balance and the weighing pan are always electrically grounded.

- All METTLER TOLEDO balances fitted with three-pin plugs are automatically grounded

- Avoid wearing electrically insulated footwear. Use grounded shoes and grounding straps instead.

The simplest way to avoid static charges is to use conductive materials, such as those already offered in many plastic laboratory vessels. With these vessels, the disruptive charges drain away via the weighing pan that is grounded, and the charge is eliminated. Unfortunately, it is often not possible for the user to freely select the material of the tare container for many applications.

It also helps to make sure that the user does not substantially contribute to the buildup of electrical charges by wearing insulated footwear or unnecessarily rubbing or holding the vessel with protective gloves. A very dry atmosphere also fosters the charging of weighing samples, especially in winter. A relative humidity of 45 - 60% can reduce the problem, although this alone often does not resolve the problem altogether.

Reducing the Forces Produced by Static Charges

Tips to avoid generating electrostatic charges whilst weighing in the laboratory:

- Electrically shield the tare container and sample in a metal basket (which acts as a Faraday cage)
- Use a smaller tare vessel, to reduce surface area and weight, which has a direct relation to the forces generated.
- Ensure that the sample is placed centrally on the weighing pan, and ensure minimum possible protrusion beyond the rim.
- Use a light electrically conductive underlay to increase the distance between the tare vessel and the surface of the weighing area.
- Use a Faraday Cage

A Faraday cage is an enclosure made of a mesh of conductive material, which is used to block electrostatic and electromagnetic fields. The ErgoClip from METTLER TOLEDO *(Figure 5)* is a small metal basket that acts as a Faraday cage, and is optimally designed for shielding electrostatic charges. It eliminates the disruptive influence of having a differently charged tare container and balance interior, and has the added advantage that it holds the tare vessel securely in a defined position.

Figure 5. Weighing with an ErgoClip, a small metal basket, which acts as a tare vessel holder and shields the vessel from electrostatic charges.

Elimination of Charge in Difficult Cases

Using PTFE vessels (or other strong electrical insulators)

When using materials with a very strong electrical insulation effect, additional measures may be required. A grounding strap between the spatula and grounded surface may be helpful. Sometimes even simply wrapping the container with uncoated aluminium foil can help to eliminate the disruptive static effects. If this doesn't work, a multi-electrode high-voltage ioniser, should be used. Keeping the sample within the electrode area for longer may also help to ensure discharge (i.e. up to 20 seconds).

Working with dry powders

Problems similar to those with tare containers also occur with test substances. Powdery substances that have just been dried in plastic containers can easily be charged, and exhibit the typical jumping from spatula onto other surfaces phenomenon. In this situation, passing the spatula loaded with sample in front of a high-voltage ioniser has proved to be effective. Powdered samples on the insides of bottlenecks or vessel openings can be prevented from jumping by increasing the time the vessel spends in the vicinity of the ioniser electrode.

Summary

Balance users need to aware of the causes and effects of electrostatic charges in relation to weighing. Wherever possible, preventative action should be taken to reduce or eliminate the build-up of static charges, in order to avoid any errors or delays in the weighing results. Various tips and recommendations are provided on how to reduce the effects of static in a weighing environment. In addition, established solutions for deionisation of the weighing vessel or sample are described and compared. The ability to automatically detect and eliminate the presence of electrostatic charges during a weighing process.

Further Reading

Weighing the Right Way Guide, Proper Weighing with Laboratory Balances, METTLER TOLEDO, Doc. No. 720906, January 2015, www.mt.com/weighing-guide

Reichmuth A et al.; The Uncertainty of Weighing Data Obtained with Electronic Analytical Balances.

Microchimica Acta 148, 133–141 (2004) DOI 10.1007/s00604-004-0278-3

Reichmuth A (2001); Weighing accuracy with laboratory balances. Proc 4th Biennial Conf. Metrol. Soc. Australia, Broadbeach (QLD, AU), p 38

Reichmuth A, Mettler Toledo; Einflüsse und deren Vermeidung beim Wägen

Reichmuth A, Mettler Toledo; Weighing small samples on laboratory balances