Weighing the Right Way

GWP®
Good Weighing Practice
by METTLER TOLEDO

- Experience
- Improved weighing
- Flawless operation
- Precise results

Proper Weighing
with Laboratory Balances

METTLER TOLEDO

Proper Weighing with Laboratory Balances

Introduction

Weighing is one of the most common tasks in the laboratory. Advanced micro, semi-micro, analytical and precision balances have now been perfected to such a degree that, in general, no special weighing rooms are needed.

Technological advances in electronics have considerably simplified the operation of balances, drastically cut weighing times, and made the balances so adaptable that they can now be integrated directly into a production process.

The risk inherent in this progress, however, is that not enough care will be taken to prevent disturbing influences from the surrounding area. These usually involve physical effects which are measurable for micro, semi-micro and analytical balances, and which analytical balances cannot suppress because they result in measurable weight changes (e.g. through slow evaporation, moisture uptake), or forces which act on the weighing pan and weighing sample (e.g. magnetism, electrostatics) and which are interpreted by the balance as weight changes.

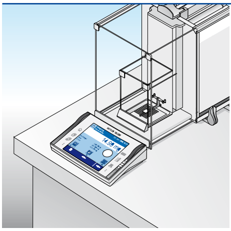
The purpose of these instructions is to explain the most important points to be noted when working with micro, semi-micro and analytical balances if high-quality results are required.

After some brief pointers concerning the location and proper operation of the balances, the disturbing influences on weighing will be discussed in detail. Most of these influences are recognizable by a slow change in the weight display (drift).

Since correct interpretation of the technical data is also of immense importance in the assessment of a weighing result, the most common technical terms are explained at the end.

Location of the Balance

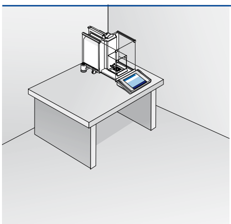
The precision and reproducibility of weighing results is closely associated with the location of the balance. To ensure that your balance can work under the best conditions, please observe the following guidelines:



Weighing bench

- Stable (lab bench, lab table, stone bench).
  Your weighing bench should not sag when work is carried out on it and should transfer as few vibrations as possible.
- Antimagnetic (no steel plate).
- Protected against electrostatic charges
  (no plastic or glass).
- Wall or floor installation
  The weighing bench should be fixed either to the floor or on the wall. Mounting the bench on both places at once transfers vibrations from wall and floor.
- Reserved for the balance.

The place of installation and the weighing bench must be stable enough that the balance display does not change when someone leans on the table or steps up to the weighing station. Do not use soft pads underneath, such as writing mats.
It is better to position the balance directly over the legs of the bench, since the area is subject to the fewest vibrations.

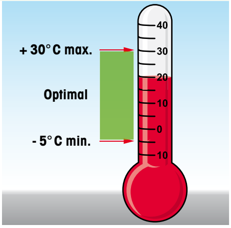


Work room

- Vibration-free
- Free from drafts

Place the weighing bench in a corner of a room. These are the most vibration-free areas of a building. Ideally, the room should be accessed through a sliding door to reduce the influence of door movements.

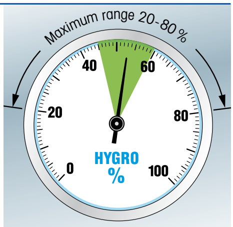
Temperature



- Keep the temperature of the room as constant as possible. Weighing results are influenced by temperature! (Typical drift: 1-2 ppm/°C).
- Do not weigh near radiators or windows.

METTLER TOLEDO balances with "FACT" (fully automatic motorized self-calibration) can compensate virtually all the remaining temperature drift. For this reason, "FACT" should always be switched on.

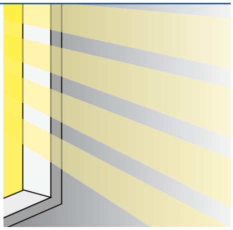
Atmospheric humidity



- Ideally, the relative humidity (% RH) should be between 45 and 60 %. Balances should never be operated above or below the measuring range of 20 to 80 % RH.

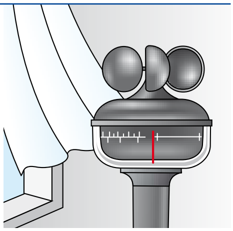
Constant monitoring is advisable with micro balances. Changes should be corrected whenever possible.

Light



- If possible, place the balance on a window-free wall. Direct sunlight (heat) will influence the weighing result.
- Place the balance a significant distance from lighting fixtures to avoid heat radiation. This especially applies to light bulbs. Use fluorescent tubes.

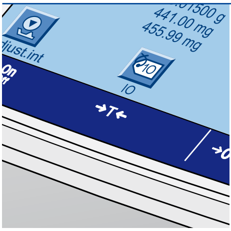
Air



- Do not place the balance in the air flow of air conditioners or devices with ventilators, such as computers or large laboratory devices.
- Place the balance a sufficient distance from radiators. In addition to the potential temperature drift, strong currents of air could interfere with operation of the balance.
- Do not place the balance next to a door.
- Avoid places with high traffic.
  Passersby will usually create a draft at the weighing location.

Operation of the Balance

Micro, semi-micro, analytical and precision balances are measuring instruments of the highest precision. The following points will help you obtain reliable weighing results.



Switching on

- Do not disconnect the balance from the power supply and always leave it switched on. This allows the balance to reach thermal equilibrium.
- When you switch the balance off, use the display key (on older models the tare key). The balance is now in standby mode. The electronics are still energized and no warm-up period is necessary.

TIP: We recommend a different warm-up time for each balance when it is first connect to the power supply. These are:

- Up to 12 hours for micro balances
- Approximately 6 hours for semi-micro and analytical balances
- Approximately 3 hours for precision balances

Apart from these guidelines, always observe the minimum times specified in the operating instructions.

Leveling

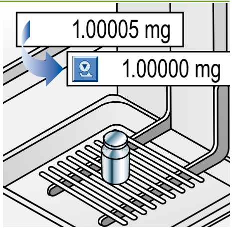
- Align the balance.
  To do this, check that the air bubble is in the center of the level indicator. Use the leveling feet to make adjustments. You must then adjust the sensitivity of the balance. The exact procedure is described in the operating instructions for the balance.

TIP: To ensure and document that the balance is correctly leveled every time for example, to comply with GxP1) we recommend the Excellence Plus family of balances with the built-in automatic warning function "LevelControl".

[1] GxP Good Laboratory Practice (GLP) or Good Manufacturing Practice (GMP)

Adjustment

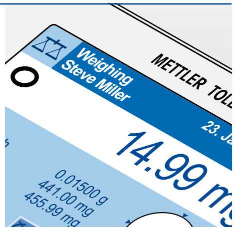
- Adjust the sensitivity of the balance regularly, especially
  - when you operate the balance for the first time
  - when you change the location of the balance
  - after leveling the balance
  - after major changes in temperature, humidity or air pressure.



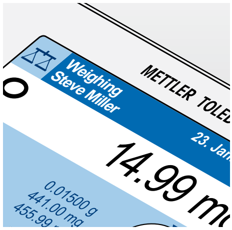
TIP: If a fully automatic calibration following, for example, a temperature change is important to you, it would be worthwhile to acquire balances with "FACT," which calibrate automatically. These models also allow you to extend the time interval for routine checks.

Reading

- Check that the balance displays exactly zero at the start of each weighing. Tare, if needed, to avoid zero errors.
- Read off the result only after the small round circle in the upper left of the balance display has faded. The weighing result is released through this stability detector.

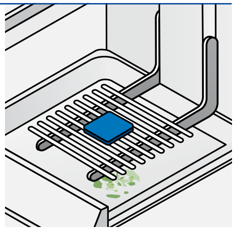


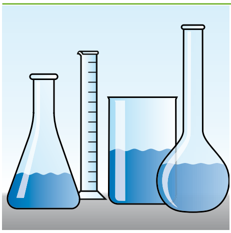
TIP: The Excellence Plus line offers an advanced stability detector. These balances display unstable measurement values in **blue**. Once stability is regained, the display immediately changes to **black** and the circle in the upper left disappears. This allows you to identify a stable weighing result faster, safer and more reliably.



Weighing pan

- Always place the weighing sample in the middle of the weighing pan. This will prevent corner load errors.
- With micro and semi-micro balances, the weighing pan should first be loaded once briefly after a relatively long pause (>30 min) to deactivate the "initial weighing effect".





Weighing vessel

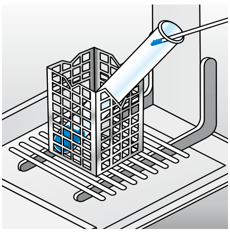
- Use the smallest possible weighing vessel.
- Avoid weighing vessels made of plastic when atmospheric humidity is below 30-40 %. These conditions increase the risk of electrostatic charge.

  Materials with a high degree of electrical insulation, such as glass and plastic, can become electrostatically charged. This can drastically distort the weighing result. For this reason, make sure you take the appropriate corrective measures (for more, see page 14: Electrostatics)

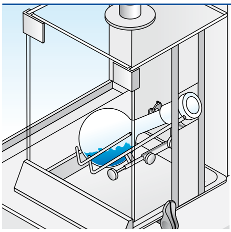
- The weighing vessel and the sample it contains should have the same temperature as the surroundings. Temperature differences can lead to air currents that distort the weighing result (see page 7: Temperature).
  After removing the weighing vessel from a drying oven or dishwasher, allow it time to cool before placing it on the balance.

- If possible, do not use your hands to place the weighing vessel in the weighing chamber. You could alter the temperature and atmospheric humidity of the weighing chamber and the weighing vessel, which would have an adverse effect on the measurement process.

The "ErgoClip Basket" taring container holder.



TIP: Different taring container holders offer optimal conditions for error-free and safe weighing (see illustrations).



Round bottomed flasks on special taring container holders "ErgoClip Flask" and "MinWeigh Door".

Draft shield

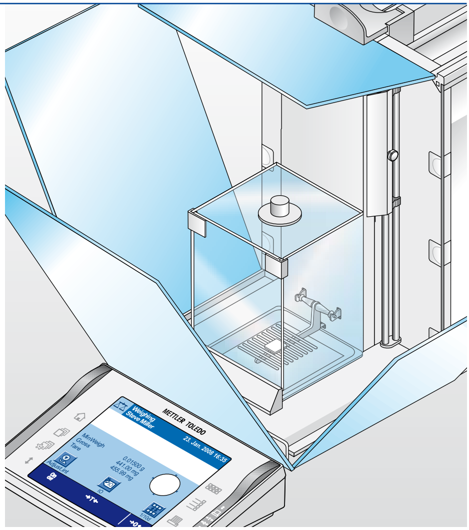
- Open the draft shield only as far as necessary. This will keep the climate in the weighing chamber constant, and the weighing result will not be influenced.
- Adjust balances that have an automatic and configurable draft shield, such as the instruments of the Excellence Plus family, so that the opening of the draft shield is minimal.

TIP: To make weighing simpler and more precise, even under the most challenging conditions, we recommend specific accessories for our Excellence and Excellence Plus families of balances. These balances will yield the best results, even when you are weighing extremely small samples with narrow tolerances under unfavorable ambient conditions. Our special draft shield "MinWeigh Door," for example, is designed to be perfect for use in weighing cabinets. But it also offers advantages for "normal" weighing conditions. It can improve the repeatability of the net reading by a factor of about two!

Using "SmartGrid," a weighing pan with a special grid structure, stabilizes weighing so well that the draft shield doors for 4-digit analytical balances can normally be left open during weighing.

Care of the balance

- Keep the weighing chamber and weighing pan clean.
- Use only clean vessels for weighing.
- The balance can be cleaned with conventional window-cleaning fluid.
- Do not use cloths that contain fusel oil.
- Do not brush contaminants into potential openings.
- Before cleaning, remove all removable parts, such as the weighing pan.



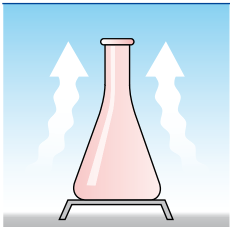
TIP: On Excellence and Excellence Plus analytical balances, each of the draft shield panes can be removed for cleaning in a dishwasher.

Physical Influences

If the weight display does not stabilize, the result slowly drifts in one direction, or quite simply if wrong values are displayed, this is often due to undesired physical influences. The most frequent causes are:

- Influences of the weighing sample
- Influences on the balance from the surrounding area
- Moisture gain or loss by the weighing sample
- Electrostatically charged weighing samples or vessels
- Magnetic weighing samples or vessels

In the next section we shall explain these influences and what causes them in more detail, and describe corrective measures.



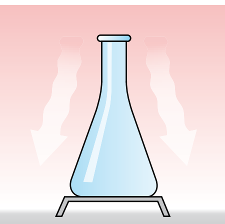
Temperature

Problem

The weight display of a weighing sample drifts in one direction.

Possible reasons

The balance has not been connected to the power supply long enough.



There is a temperature gradient between the weighing sample and the surroundings that leads to air currents along the weighing vessel. The air flowing along the side of the vessel generates a force in an upward or downward direction that falsifies the weighing result. This effect is called dynamic buoyancy. The effect does not die away until a temperature equilibrium is established. The following applies: A cold object appears heavier, a warm object lighter. This effect can lead to problems, especially in differential weighings with semi-micro, micro and ultra-micro balances.

Example

You can test the dynamic buoyancy with the following experiment: Weigh a conical or similar flask and record the weight. Hold the flask in your

hand for about one minute and repeat the weighing. Because of its higher temperature and the temperature gradient that developed, the flask appears lighter.
(The perspiration on your hand plays no role in this effect. Otherwise the sample would have become heavier).

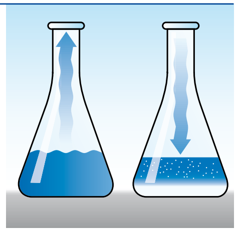
Corrective measures

- Never weigh samples taken directly from a dryer or refrigerator
- Acclimatize weighing sample to the temperature of the lab or weighing chamber
- Hold sample containers with tweezers
- Never put your hand in the weighing chamber
- Choose sample vessels with a small surface area

Moisture gain/evaporation

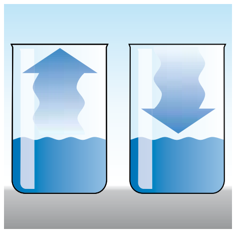
Problem

The weight display of a weighing sample permanently drifts in one direction.



Possible reasons

You are measuring the weight loss of volatile substances (e.g. the evaporation of water) or weight increase of hygroscopic weighing samples (atmospheric moisture gain).



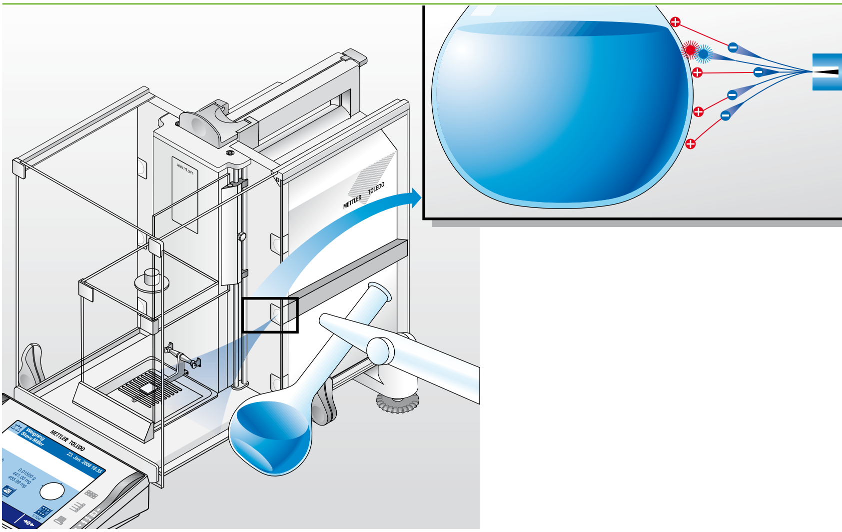
Using a weighing vessel with a larger opening increases the risk of measuring errors through evaporation or condensation.

Example

You can reproduce this effect with alcohol or silica gel.

Corrective measures

Use clean and dry weighing vessels and keep the weighing pan free from dirt and water drops. Use vessels with narrow necks and mount covers or stoppers. Do not use cork or cardboard supports for flasks with a circular base. Both can gain or lose a considerable amount of water. Metal triangular holders or the "ErgoClips" for the Excellence and Excellence Plus family of balances are neutral in this regard.



Electrostatics

Problem

Each weighing shows a different result. The weight display is unstable. The repeatability of the result is poor.

Possible reasons

Your weighing vessel or the sample has become electrostatically charged. Materials with low electrical conductivity such as glass, plastics, powder or granulates cannot or can only very slowly (over hours) drain away electrostatic charges. This charging occurs primarily through stirring or rubbing during the handling or transport of containers or materials. Dry air with less than 40 % relative humidity increases the risk of this effect.

The weighing errors arise through the electrostatic forces that act between the weighing sample and the surroundings. These electrostatic charges can be measured by micro, semi-micro and analytical balances and lead to the weighing errors described.

Example

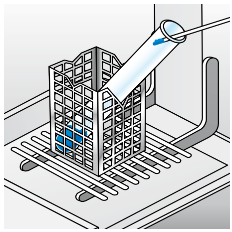
A clean glass or plastic vessel that has been gently rubbed with a woolen cloth shows this effect quite clearly.

Corrective measures

- Increase the atmospheric moisture
  Electrostatic charging is particularly a problem in winter in heated rooms. In air conditioned rooms, setting the air conditioning to increase the humidity (45-60 % relative humidity) can help.
- Screen electrostatic forces
  Place the weighing vessel in a metal container.
- Use other weighing vessels
  Plastic and glass charge quickly and are therefore unsuitable. Metal is a better material.
- Use antistatic guns.
  The commercially available products, however, are not effective in all situations.
- Use external or internal antistatic kits from METTLER TOLEDO.

Note: The balance, and hence the weighing pan, should always be grounded. All METTLER TOLEDO balances with three-pin power plugs are automatically grounded.

"ErgoClip Basket" taring container holder.

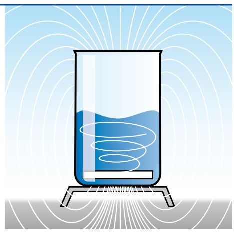


! TIP: The "ErgoClip Basket" taring container holder does an excellent job of eliminating electrostatics, thereby effectively preventing the described problems with tubes and test glasses.

Magnetism

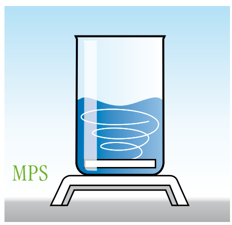
Problem

The weight of a weighing sample depends on its position on the weighing pan. The repeatability of the result is poor. But the display remains stable.



Possible reasons

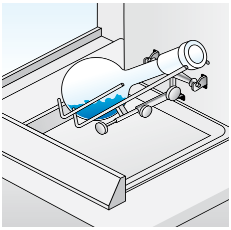
You are weighing a magnetic material. Magnetic and magnetically permeable objects exert a mutual attraction. The additional forces that arise are wrongly interpreted as a load.
Practically all objects made of iron (steel) are highly permeable to magnetic forces (ferromagnetic).



Corrective measures

If possible, demagnetize the magnetic forces by placing the weighing sample in a vessel made of Mu Metal film, for example. Since the magnetic force decreases with increasing distance, the sample can be distanced further from the weighing pan by using a non-magnetic support (e.g. beaker, aluminum stands). The same effect can be achieved by means of a hanger. This "below-the-balance" setup is built in as standard with most METTLER TOLEDO micro, semi-micro, analytical and precision balances. Wherever possible, METTLER TOLEDO uses non-magnetic materials to keep this effect to a minimum.

"ErgoClip Flask" taring container holder for balances in the Excellence and Excellence Plus lines.



TIP: To weigh average- and large-sized magnets with precision balances we recommend an "MPS Weighing Pan" (Magnetic Protection System). For analytical balances, we recommend using a triangular holder, which increases the distance between the magnets and the weighing pan. For balances in the Excellence and Excellence Plus lines, we offer special "ErgoClips" for this purpose.

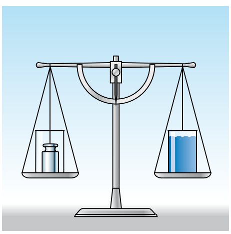
Static buoyancy

Effect

A weighing sample weighed in air and in a vacuum does not have the same weight.

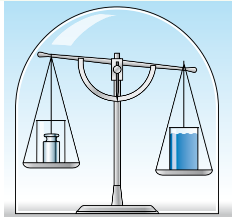
Reason: «A body experiences a loss in weight equal to the weight of the medium it displaces» (Archimedes' principle). This principle provides an explanation of why ships float, a balloon rises, or why the weight of a sample is affected by atmospheric pressure.

The medium that surrounds our weighing sample is air. The density of the air is approximately 1.2 kg/m³ (depending on the temperature and atmospheric pressure). The buoyancy of the weighing sample (body) is thus 1.2 kg per cubic meter of its volume.



Example

If we place a 100 g calibration weight in a beaker on a beam balance and then add water to an identical beaker on the other weighing pan until the



weighing beam is in equilibrium, the two weighing samples, weighed in air, have the same weight.
If we then enclose the beam balance with a bell jar and generate a vacuum in it, the weighing beam will tilt to the side with the water, since the water displaces more air owing to the larger volume, and has hence experienced a greater buoyancy. In vacuum there is no buoyancy. Therefore, in the vacuum, there is more than 100 g of water on the right side.

	Reference weight	Water
Weight in air	100 g	100 g
Density	8000 kg/m³	1000 kg/m³
Volume	12.5 cm³	100 cm³
Buoyancy	15 mg	120 mg
Weight in vacuum	100.015 g	100.120 g

Corrective measures

The sensitivity of the balance is adjusted with reference weights of density 8.0 g/cm³. In the weighing of samples of different density, an air buoyancy error arises. In weighings with high measurement accuracy, the displayed weight should be corrected accordingly.

In weighings on different days (differential weighings, comparative weighings), check atmospheric pressure, atmospheric humidity and temperature, and calculate the air buoyancy correction as follows:

Procedure to determine the mass of a weighing sample:

$$\rho_a = \frac{0.348444\ p - h(0.00252\ t - 0.020582)}{273.15 + t}$$

1. Calculate air density

ρ	air density in kg/m³
P	atmospheric pressure in hPa (= mbar) (use weighing station pressure)
h	relative atmospheric humidity in %
t	temperature in °C

2. Determine the mass of the weighing sample (correct air buoyancy)

$$m = \frac{1 - \frac{\rho_a}{\rho_c}}{1 - \frac{\rho_a}{\rho}} W$$

m	mass
a	air density in kg/m³
ρ	density of the weighing sample
c	conventional body density (8000 kg/m³)
W	weighing value (balance display)

Example

Balance display 200.000 g

Atmospheric pressure 1018 hPa

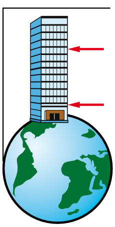
Relative atmospheric moisture 70 %

Temperature 20 °C

Density of weighing sample 2600 kg/m³

$$\rho_a = \frac{0.348444 \cdot 1018 - 70\,(0.00252 \cdot 20 - 0.020582)}{273.15 + 20} = 1.2029 \text{ kg/m}^3$$

$$m = \frac{1 - \frac{1.2029 \text{ kg/m}^3}{8000 \text{ kg/m}^3}}{1 - \frac{1.2029 \text{ kg/m}^3}{2600 \text{ kg/m}^3}} 200 \text{ g} = 200.0625 \text{ g}$$



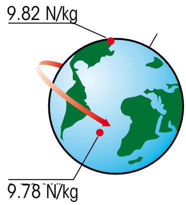
Gravitation

Effect

The weighing values are different when the weighing height changes. For example, the weight display changes when the weighing is performed 10 m higher (e.g. moving from the first floor to the fourth floor of a building).

Reason

To determine the weight of a body, the balance measures the weight force, i.e. the force of attraction (gravitational force), between the earth and the



weighing sample. This force depends essentially on the latitude of the location and its height above sea level (distance from the center of the earth).

The following holds:

1. The further a weight is from the center of the earth, the smaller the gravitational force acting on it. It decreases with the square of the distance.

$$F_G = G \frac{m_1 \cdot m_2}{d^2}$$

2. The nearer a location is to the equator, the greater the centrifugal acceleration due to the rotation of the earth. The centrifugal acceleration counteracts the force of attraction (gravitational force).
The poles are the greatest distance from the equator and closest to the earth's center. The force acting on a mass is therefore greatest at the poles.

Example

In the case of a 200 g weight that shows exactly 200.00000 g on the first floor, the following weight results on the fourth floor (10 m higher):

$$200\text{ g}\,\frac{r_{\text{Erde}}^2}{(r_{\text{Erde}}+\Delta)^2} = 200\text{ g}\,\frac{(6\,370\,000\text{ m})^2}{(6\,370\,010\text{ m})^2} = 199.99937\text{ g}$$

Corrective measures

Level and adjust the balance whenever it is moved or before using it for the first time.

! TIP: Balances with built-in "FACT" (fully automatic motorized self-calibration) perform this calibration automatically. METTLER TOLEDO balances of the Excellence and Excellence Plus line come standard with "FACT".

Technical Terms

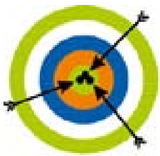
Readability

The readability of a balance is the smallest difference between two measured values that can be read on the display. With a digital display this is the smallest numerical increment, also called a scale interval.

Standard readabilities (or scale intervals) for various balance types				
Ultra-micro balances	1d[1] =	0.1 µg	= 0.0000001 g	7-digit
Micro balances	1d =	1 µg	= 0.000001 g	6-digit
Semi-micro balances	1d =	0.01 mg	= 0.00001 g	5-digit
Analytical balances	1d =	0.1 mg	= 0.0001 g	4-digit
Precision balances	1d	= 1 g to 1 mg	= 1 g to 0.001 g	0 to 3-digit

[1] 1d = 1 digit = one numerical increment

TIP: "DeltaRange" and "DualRange" balances feature two different types of readability, which makes them an attractive alternative in terms of price.



Accuracy

Qualitative name for the degree to which test results approximate the reference value, which can be the correct or expected value, depending on the definition or agreement [DIN1) 55350-13].

Or in short: How close the balance display comes to the actual weight of a weighing sample.

Accuracy classes of test weights

Summary of various weight pieces in the same accuracy classes.

The recommendation of the weight class according to OIML2) R111 ensures that the error limits with regard to the weight classification are observed

[1] DIN German Institute for Standardization

[2] OIML International Organization of Legal Metrology

and that the material and surface quality correspond to this international recommendation. **www.oiml.com**

As part of control of inspection, measuring and test equipment, quality management standards require that balances be calibrated or adjusted at particular intervals with traceable weights. Certified weights with a corresponding accuracy class must be used for this purpose.

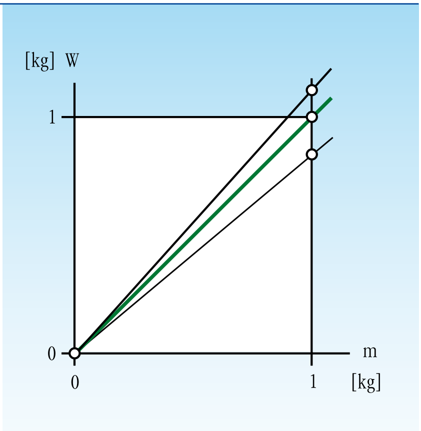
Sensitivity

Change in the output variable of a measuring instrument divided by the associated change in the input variable ([VIM] 5.10)[1)].

For a balance, the change in the weighing value ΔW divided by the load variation Δm

$$S = \frac{\Delta W}{\Delta m}$$

The sensitivity is one of the most important specifications of a balance. The specified sensitivity of a balance is generally understood to be global sensitivity (slope), measured over the nominal range.



Sensitivity between weighing value W and load m, on the example of a balance with a nominal range of 1 kg. The middle line shows the characteristic curve of a balance with correct sensitivity (slope). The upper characteristic curve is too steep (sensitivity too high, exaggerated for reasons of illustration), while the lower curve is not steep enough (too little sensitivity).

Temperature coefficient of the sensitivity

Sensitivity is temperature-dependent. The degree of dependence is determined via the reversible deviation of the measured value owing to the influence of a temperature change in the surroundings. It is given by the temperature coefficient of the sensitivity (TC) and corresponds to the percentage deviation of the weight display (or sample weight) per degree Celsius. With an XP balance, for example, the temperature coefficient of the sensitivity is 0.0001%/°C.

This means that for a temperature change of 1 degree Celsius, the sensitivity changes by 0.0001 % or one millionth.

[1)] VIM International Vocabulary of Basic and General Terms in Metrology

The temperature coefficient can be calculated as follows:

$$TC = \frac{\Delta S}{\Delta T} = \frac{\frac{\Delta R}{m}}{\Delta T} = \frac{\Delta R}{m\,\Delta T}$$

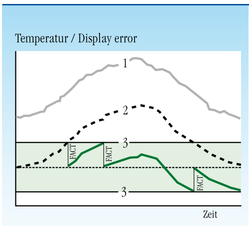
In this equation, ΔS is the change in sensitivity and ΔT the temperature change. The sensitivity change ΔS is equal to the result change ΔR divided by the weighing load m, or after taring by the sample weight. With this information the deviation of the measuring result at a specified temperature change can be calculated by rearranging the above equation.
For the display value we can then obtain:

$$\Delta R = (TC\,\Delta T)\,m$$

If you weigh a load (sample weight) of 100 g on the XP/XS analytical balance, and the ambient temperature in the laboratory has changed by 5 °C since the last calibration, this can lead to the following maximum result change ΔR (with the temperature coefficient of the XP of 0.0001 %/°C) in the worst case scenario:
If, on the other hand, the load were only 100 mg, that is 1000 times less,

$$\Delta R = (TC\,\Delta T)\,m = (0.0001\ \%/°C \cdot 5\ °C)\ 100\ g = 0.5\ mg$$

the maximum deviation would also be correspondingly less and amount solely to 0.5 µg.



FACT

Abbreviation for "Fully Automatic Calibration Technology" ("FACT"). Automatic calibration of the sensitivity, depending on the type and linearity of a balance. The calibration is triggered whenever a predetermined temperature change is exceeded.

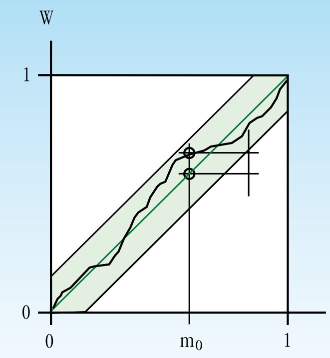
During production, internal weights are traceably connected to international measuring standards by means of "primary calibration". In this process, the mass of the internal weight is determined by placing a certified weight on the balance and storing the value in the balance.

proFACT

Abbreviation for "Professional Fully Automatic Calibration Technology" ("proFACT"). Professional automatic adjustment of sensitivity.

TIP: The Excellence and Excellence Plus family of semi-micro and analytical balances has two internal weights. This means that, during calibration, the balance tests not only the sensitivity but the non-linearity.

Linearity (Non-linearity)



The linearity expresses how well the balance is capable of following the linear relation between the load m and the displayed value W (sensitivity). Here, the characteristic weighing curve is imagined as a straight line between zero and maximum load (see: Sensitivity).

On the other hand, the non-linearity defines the width of the band within which a positive or negative deviation of the measured value from the ideal characteristic curve can occur.

For the METTLER TOLEDO Excellence Plus Analytical Balance XP205DR, for example, the deviation from the linear course of the characteristic curve is maximum ±0.15 mg over the entire weighing range of 200 g.

Repeatability

Repeatability is a measure of the ability of a balance to supply the same result in repetitive weighings with one and the same load under the same measurement conditions ([OIML[1)] R 76 1] T.4.3).

The series of measurements must be carried out by the same operator, by the same weighing method, in the same location on the same pan support, in the same installation location, under constant ambient conditions, and without interruption.

[1)] OIML International Organization of Legal Metrology

The standard deviation of the measurement series is a suitable measurement for expressing the value of the repeatability.

Particularly with high resolution balances, the magnitude of the repeatability is a property that depends not only on the balance. Repeatability is also affected by the ambient conditions (drafts, temperature fluctuations, vibrations), by the weighing sample, and in part by the skill of the person performing the weighing.

The following example shows a typical series of measurements, performed on a semi-micro balance with a readability of 0.01 mg.

x_1	=	27.51467 g	x_6	=	27.51467 g
x_2	=	27.51466 g	x_7	=	27.51467 g
x_3	=	27.51468 g	x_8	=	27.51466 g
x_4	=	27.51466 g	x_9	=	27.51468 g
x_5	=	27.51465 g	x_{10}	=	27.51467 g

Let us now determine the mean value and the repeatability of this series of measurements.

Mean value:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

x_i = i-th result of the series
N: Number of measurements (weighings), usually 10
The mean value is x = 27.514667 g.

$$s_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

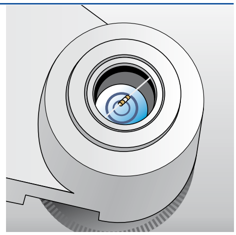
The standard deviation s is used as a measure of the repeatability t. Consequently, the repeatability of the measurement series is s = 0.0095 mg.
The uncertainty in the measurement result is around two to three times the repeatability u ≈ 2s... 3s i.e. the true result x lies within the interval x - u < x < x + u

In our series of measurements is u ≈ 2 s ≈ 2 x 0.01 mg = 0.02 mg, so that we can specify the weighing result by x ± u = 27.51467 g ± 0.02 mg
The very lowest measured value to be expected for this load with the balance used in the above series of measurements is thus 27.51465 g and the largest is 27.51469 g, which agrees well with the series of measurements.

Traceability

The property of a measurement result, via an unbroken chain of comparative measurements with stated measurement uncertainties, relative to suitable nationally or internationally applicable standards ([VIM][1] 6.10). The normal weight pieces used for mass measurements are traced to the superordinate standards.

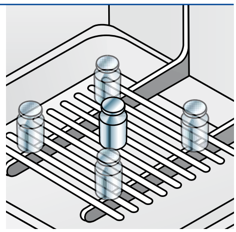
Leveling



Setup of a balance in its reference position (as a rule, horizontally), i.e. setting up its direction of action parallel to the perpendicular orientation of the balance. As a rule, this is the same as setting up the housing of the balance horizontally. The result is distorted by the cosine of the angle of inclination. Corrective measures: All balances offer the option of leveling by using adjustable feet.

TIP: The Excellence Plus balance has "LevelControl, a fully automatic level monitoring function. LevelControl automatically warns you and documents when the balance is not leveled, which increases measuring reliability and eliminates the risks inherent in visual control, such as when using a measuring cabinet.

Corner load



1. Deviation of the measurement value through off-center (eccentric) loading. The corner load increases with the weight of the load and its removal from the center of the pan support.

If the display remains consistent even when the same load is placed on different parts of the weighing pan, the balance does not have corner-load deviation. For this reason, with high-precision balances, it is important to make sure the weighing sample is always placed exactly in the middle.

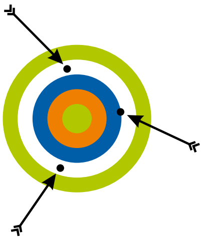
The official designation for corner load is: "off-center loading error".

[1] VIM International Vocabulary of Basic and General Terms in Metrology

Reproducibility

The degree of approximation between the measurement values of the same measured variable, even though the individual measurements are carried out under different conditions (which are specified) with regard to:

- the measuring process
- the observer
- the measuring device
- the measuring location
- the conditions of use
- the time



Accuracy

Qualitative term as a judgement regarding the systematic deviation of measurements. The closeness of agreement between the expected value (mean value) of a series of measuring values and the true value of the object being measured ([ISO[1)] 5725] 3.7).

Remarks

The accuracy can be evaluated only when there are several measurement values, as well as a recognized correct reference value.

Precision

Qualitative term as a judgement regarding the mean variation of measurements.

The closeness of agreement between independent measurement values obtained under stipulated conditions ([ISO[1)] 5725] 3.12).
Precision depends only on the distribution of random errors and does not relate to the true value of the measurement variable (accuracy).

Example

The ability of a measuring instrument to supply measurement values that seldom deviate.

[1)] ISO International Standards Organization

Remarks

Precision can be evaluated only when there are several measurement values.

Measurement uncertainty

A parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably attributed to the measurement variable ([VIM][1] 3.9).

This parameter, i.e. the measurement uncertainty, is generally expressed by the standard uncertainty u or the expanded measurement uncertainty U (confidence interval). GUM[2] contains instructions on determining measurement uncertainty. According to GUM, the measurement uncertainty is obtained by totaling the quadratic errors when these are not mutually influential.

Note

There are a variety of methods for calculating measurement uncertainty. In the pharmaceutical industry the reference content is often determined according to the U.S. Pharmacopeia. Otherwise, measurement uncertainty is often determined based on ISO[3] 17025. The latter corresponds to the GUM method.

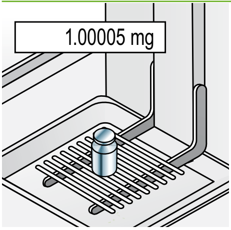
! TIP: In most countries, METTLER TOLEDO Service offers these measurement uncertainty calculations on-site, at the customer's request.

Minimum initial weight value

The value below which the relative deviation of a measuring result is too large.

! TIP: METTLER TOLEDO balances in the Excellence Plus line offer superior weighing technology for successfully weighing the very smallest of weighing samples.

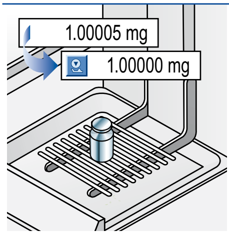
[1] VIM International Vocabulary of Basic and General Terms in Metrology
[2] GUM Guide of Uncertainty of Measurement [3] ISO International Standards Organization



Calibration

Determining the deviation between the measurement value and the true value of the measurement variable under specified measuring conditions.

TIP: METTLER TOLEDO Excellence and Excellence Plus balances document each error on the display or send it to an external software program or printer.



Adjustment

Determining the deviation between the measurement value and the true value of the measurement variable under specified measuring conditions. A correction should then be made.

TIP: METTLER TOLEDO Excellence and Excellence Plus balances document each error by showing it on the display or sending it to an external software program or printer. For software, we recommend using "LabX balance" with integrated inspection, measuring and test equipment in accordance with METTLER TOLEDO Good Weighing Practice™ (**www.mt.com/GWP**).

GWP® – Good Weighing Practice™

The GWP® planetary sytem

With Good Weighing Practice™ (GWP®), METTLER TOLEDO offers you the perfect solution. If you decide to opt for GWP®, you will have an expert team on hand at all important stages of the weighing process – for evaluation and selecting the most appropriate weighing solution, during commissioning, calibration, and even routine operation.

With GWP®, METTLER TOLEDO is offering the first globally valid guideline for weighing systems. This guideline is the starting point for a package of measures that is tailored to customer applications. And by tailored we mean: The most economical yet safest weighing solution. Detecting a deviation too late or not at all? This is probably something you want to avoid. Good Weighing Practice™ represents "risk-free weighing", as it guarantees the safety and quality of your products.

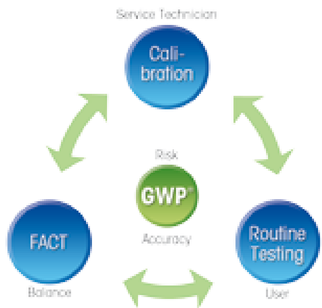
The GWP® triangle

- Routine operation
- How should my balance be tested?
- How often should tests be conducted?
- How can I minimize the required time and expense?

Regular maintenance of your laboratory balance by an authorized service technician is recommended to ensure that your weighing remains accurate for years to come. Regular maintenance will also extend the life of your balance.

Independent service technicians test and document the correct functioning of the balance using accredited calibration processes.

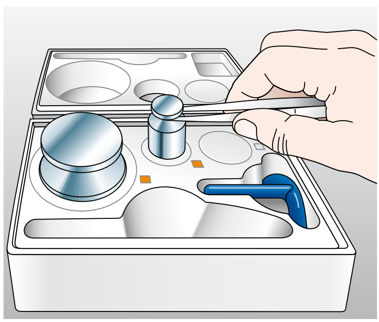
Balances with "FACT" require fewer routine tests. Intelligent balance functions reduce the time and expense of testing and offer additional quality assurance.



The user periodically performs short tests and immediately knows whether the balance is weighing within process tolerances.

Between maintenance intervals, it is a good idea to use certified external weights to check the balance yourself to identify any measurement errors immediately.

TIP: It is important to use suitable test weights for these routine tests. With the "CarePac" weight sets, METTLER TOLEDO offers the user worry-free testing. Tailored to the GWP® guideline, these weight sets contain the correct weights, testing tolerances, weighing tweezers, gloves and testing instructions.



With the "CarePac" weight sets, you are always on the safe side.

You can find more detailed information on Good Weighing Practice™ at **www.mt.com/GWP**.

Mettler-Toledo AG,
Laboratory & Weighing Technologies
CH-8606 Greifensee, Switzerland
Phone +41-44-944 22 11, Fax +41-44-944 30 60
Internet: http://www.mt.com

AT	**Mettler-Toledo GmbH.,** A-1230 Wien
AU	**Mettler-Toledo Ltd.,** Port Melbourne, Victoria 3207
BE	**N.V. Mettler-Toledo S.A.,** B-1932 Zaventem
BR	**Mettler-Toledo Ltda.,** 06455-000 Barueri/São Paulo
CA	**Mettler-Toledo Inc.,** Ontario, Canada
CH	**Mettler-Toledo (Schweiz) GmbH,** CH-8606 Greifensee
CN	**Mettler-Toledo (Shanghai) Co., Ltd.,** Shanghai 200233
CZ	**Mettler-Toledo, s.r.o.,** CZ-10000 Prague 10
DE	**Mettler-Toledo GmbH,** D-35396 Giessen
DK	**Mettler-Toledo A/S,** DK-2600 Glostrup
ES	**Mettler-Toledo S.A.E.,** E-08908 Barcelona
FR	**Mettler-Toledo S.A.,** F-78222 Viroflay
HK	**Mettler-Toledo (HK) Ltd.,** Kowloon
HR	**Mettler-Toledo, d.o.o.,** HR-10000 Zagreb
HU	**Mettler-Toledo, Kft,** H-1139 Budapest
IN	**Mettler-Toledo India Pvt Ltd,** Mumbai 400 072
IT	**Mettler-Toledo S.p.A.,** I-20026 Novate Milanese
JP	**Mettler-Toledo K.K.,** Tokyo 143
KR	**Mettler-Toledo (Korea) Ltd.,** Seoul 137-130
KZ	**Mettler-Toledo Central Asia,** 480009 Almaty
MX	**Mettler-Toledo S.A. de C.V.,** México C.P. 06430
MY	**Mettler-Toledo (M) Sdn. Bhd.,** 40150 Selangor
MY	**Mettler-Toledo (S.E.A.),** 40150 Selangor
NL	**Mettler-Toledo B.V.,** NL-4004 JK Tiel
NO	**Mettler-Toledo A/S,** N-1008 Oslo

PL **Mettler-Toledo, Sp. z o.o.,** PL-02-822 Warszawa

RU **Mettler-Toledo Vostok ZAO,** 101000 Moscow

SE **Mettler-Toledo AB,** S-12030 Stockholm

SG **Mettler-Toledo (S) Pte. Ltd.,** Singapore 139959

SI **Mettler-Toledo, d.o.o.,** SI-1236 Trzin

SK **Mettler-Toledo,** SK-83103 Bratislava

TH **Mettler-Toledo (Thailand) Ltd.,** Bangkok 10320

TW **Mettler-Toledo Pac Rim AG,** Taipei, 114

UK **Mettler-Toledo Ltd.,** Leicester, LE4 1AW

US **Mettler-Toledo, Inc.,** Columbus, OH 43240

For all other countries:

Mettler-Toledo AG
PO Box VI-400, CH-8606 Greifensee, Switzerland
Phone +41-44-944 22 11, Fax +41-44-944 31 70

www.mt.com

For more information

Mettler-Toledo AG
Laboratory & Weighing Technologies
CH-8606 Greifensee, Switzerland

Printed in Switzerland 720906