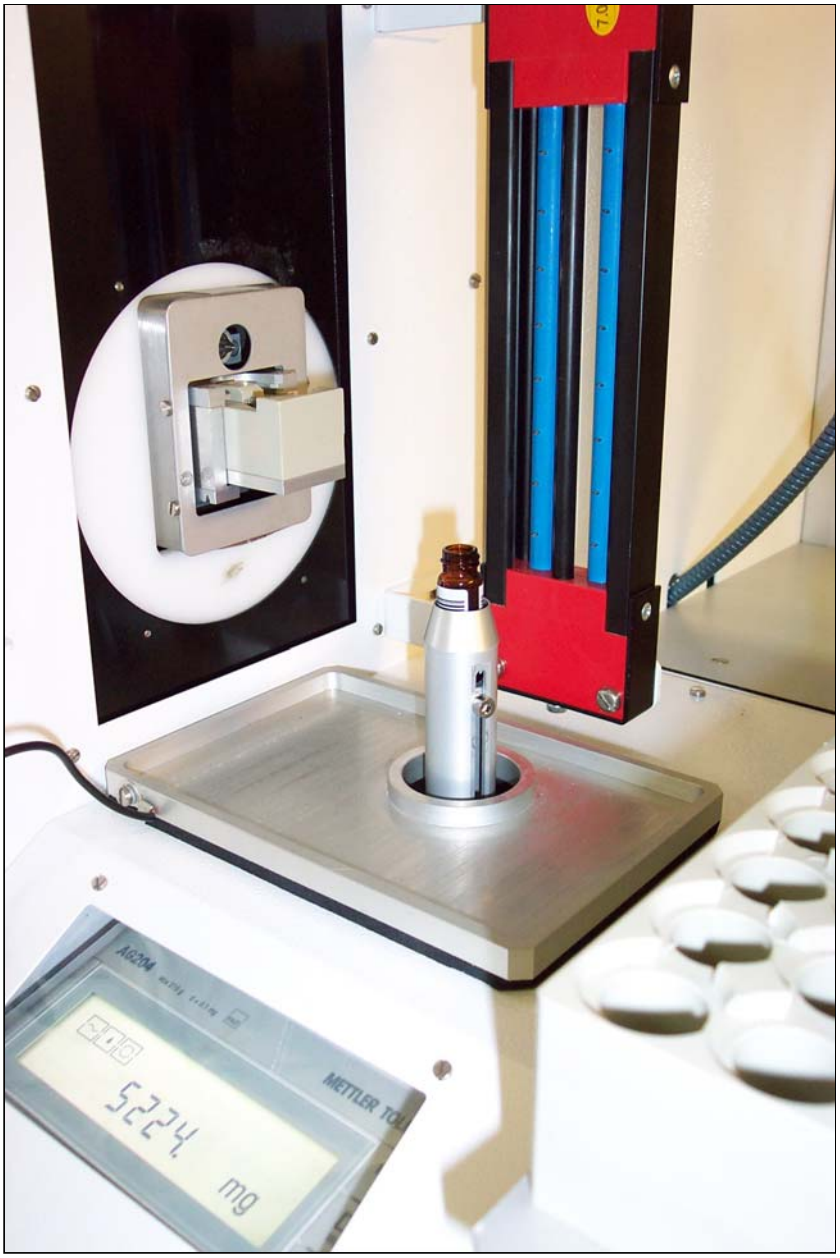
Balance Accuracy

FlexiWeigh



The balance is an integral part of the FlexiWeigh workstation. The role and limitations of the balance are important to understand in this environment.

This technical note describes the different types of balances that have been integrated into the FlexiWeigh workstations and offers details of their specifications.

Understanding the uncertainty of measurement associated with different types of weighing, both for static and dynamic systems, is important. The methods for calculating these factors are described in this Technical Note.

METTLER TOLEDO

Table 1: Definition of Terms

Readability:	The smallest difference between two measured values that can be read on the display.
Repeatability:	The ability of a balance to provide the same result for repeated weighing of the same load under the same measurement conditions.
Linearity:	The capability of the balance to follow the linear relation between the load and the displayed value.
Cornerload:	Inaccuracy of the balance factor for objects that are not placed centrally on the balance.
Accuracy:	Closeness of the agreement between the determined result and the true value.
Precision:	Extent of mutual agreement between of several measured values, independent of the true value.

Table 2: Comparison of Balance Specifications for Different Balance Types

BALANCE:	AG204	AG285 *	SAG204/01	SAG 285/01 *
Maximum Capacity	210 g	81 g	210 g	81 g
Taring Range	0 - 210 g	0 - 81 g	0 – 210 g	0 – 81 g
Readability	0.1 mg	0.01 mg	0.1 mg	0.01 mg
Repeatability	0.1 mg	0.05 mg	0.1 mg	0.02 mg
Linearity	± 0.2 mg	± 0.1 mg	± 0.2 mg	± 0.03 mg
Typical 3σ value **	± 0.25 mg	± 0.112 mg	± 0.25 mg	± 0.037 mg
Stabilization time ***	3 s	> 20 s	3 s	> 20 s
Sensitivity - temperature drift	± 1.5 ppm/°C		± 2 ppm/°C	
Sensitivity – long term stability	± 0.003 %		± 0.003 %	

* Balances have an additional set of parameters for 0 g – 210 g range, but these are not relevant for the FlexiWeigh application.

** 3σ value calculated using dynamic weighing method (see page 3).

*** Stabilization time refers to the time taken for the balance to stabilise in an automated system and does not necessarily correspond with METTLER TOLEDO figures quoted for stand alone balance modules of this type.

Static vs. Dynamic Weighing

Remembering that a balance reading is not exact but it is ± another value holds significance. The uncertainty of this value will depend on a number of factors, including whether the measurement is static or dynamic. An example of a static measurement is: weigh a tube on a balance, remove from the balance, add powder to the tube, re-weigh the tube to determine the weight of the tube + powder. This is less accurate than a dynamic measurement. An example of a dynamic measurement is: weigh a tube, add powder whilst the tube is still on the balance, read the weight before removing the tube from the balance.

Determination of the Uncertainty of Measurement

(a) For a Dynamic Weighing

The uncertainty value is known as 3σ (where σ is the statistical standard deviation, equal to the square root of the statistical variance: $v = \sigma^2$). The 3σ value is made up from four components, according to the following equation:

$$3\sigma = \sqrt{a^2 + b^2 + c^2 + d^2}$$

where:
a = readability
b = repeatability
c = linearity
d = cornerload

For robotics, it can be assumed that d = 0, because vials or tubes are centred on the balance when they are weighed.

In the case of dynamic weighing, i.e. when the balance is zeroed and the powder is added directly to a tube or vial on the balance, as is the case with FlexiWeigh, the calculation for the SAG204/01 balance, for example, is:

a = 0.1mg
b = 0.1 mg
c = 0.2 mg
d = 0.0 mg

which gives 3σ = 0.25 mg

Therefore, any value that is read on an SAG204/01 balance whose total weight is less than 81g is ± 0.25mg. This fact is not due to any robotics, but is general behaviour of all balances, which must be taken into account when a value is read on any balance.

(b) For a Static Weighing

The situation is different for a static weighing. In the case of static weighing, i.e. when a vessel is tared, taken off the balance, powder is added, then the vessel is re-weighed on the same balance in order to determine the amount of powder added, the standard deviation for a static weighing is calculated as follows:

From a statistical point of view, there are two totally mutually independent events E1 and E2.

E1: The first weighing (tare of the vessel) T with a variance of V
E2: The second weighing (gross weigh of the vessel), on the same balance, W with a variance of V
Where V= σ^2 calculated according to the previous section.

The purpose of this section is to calculate the variance V' and deduce the 3σ' associated with adding (or subtracting) several values relating to several mutually independent events.

In this case, the quantity (Q) of powder added between events E1 and E2 is defined as Q=W-T.
The error in the measurement of Q is:

(1) ln(Q)=ln(W-T)

(2) Derivation: $\frac{\partial Q}{Q}=\frac{\partial W}{W-T}-\frac{\partial T}{W-T}$

(3) To calculate the error, the equation (2) becomes: $\frac{\Delta Q}{Q}=\frac{\Delta W+\Delta T}{W-T}$

(4) Considering that Q=W-T, this is equivalent to: V'=V+V=2V

(5) Meanwhile V= σ^2 and V'= σ'^2

(6) Hence $\sigma'^2=2\,\sigma^2 \Rightarrow \sigma'=\sqrt{2} \times \sigma \Leftrightarrow 3\,\sigma'=\sqrt{2} \times 3\sigma$

For example, the previous calculation showed that using the SAG204/01 balance, the 3σ = 0.25 for each balance reading where the quantity is less than 81g.

In this example:

Event E1: the tare of the tube: T
Event E2: the weighing of the tube after adding powder: W

Consequently, the 3σ' for the quantity of powder added Q=W-T is: $3\sigma'=\sqrt{2} \times 3\sigma$

$$\Rightarrow 3\sigma'=\sqrt{2} \times 0.25 = 0.35$$

This means that each quantity of powder Q measured using the static weighing method on an SAG204/01 balance is ± 0.35mg.

Comparison of Dynamic vs Static

In this worked example, using an SAG204/01 balance, the dynamic weighing method used by FlexiWeigh has a 3σ of 0.25 mg and the static has a 3σ of 0.35 mg. The dynamic weighing method is clearly more accurate, and care should be taken about validating dynamic weights using a static weighing method. For hints on the best way to approach this, see page 5.

Validation of a Dynamic Weighing

Consequently, if it is necessary to double check the weight reported by the FlexiWeigh, the user must be extremely cautious about how this is carried out. The calculations shown in this document should be taken into account before any testing is undertaken to validate the FlexiWeigh weight recorded.

With an AG204, the dynamic weighing method used by FlexiWeigh has a 3σ of 0.25 mg and the static method to validate the weights measured by FlexiWeigh has a 3σ of 0.35 mg, as previously illustrated. This means that if the difference is less than 0.25 + 0.35 = 0.60mg, the result is validated. Examples of similar calculations with different METTLER TOLEDO balance types are shown in the table below. Note: All the balances presented here are used at their best performances in terms 3σ.

Table 3: Uncertainty Measurement (3σ) Calculations for Different Balance Types

	AG204 or SAG204/01	AG285	SAG285/01
Dynamic weighing method	± 0.25 mg	± 0.112 mg	± 0.037 mg
Static weighing method	± 0.35 mg	± 0.158 mg	± 0.052 mg
Maximum permitted difference between the same weight measured by two different methods	± 0.60 mg	± 0.270 mg	± 0.089 mg

Confirming a Weighing

When attempting to confirm a weighing on an external balance, the factors described above must be taken into consideration. Beware of comparing readings from the FlexiWeigh to another balance reading. Take into account the 3σ value of the other balance, as well as that from the FlexiWeigh.

In addition, the balance itself should be considered a factor, as this will be subject to drift over time. The powder could also be a cause for some variation, as it may have hygroscopic tendencies, which will serve to alter the weight of the same sample over a period of time.

Tips for attempting to confirm a FlexiWeigh powder dispensing measurement on another balance:

- Aim to use the same type of balance for both weight measurements
- Aim for the minimum delay between weight measurements to reduce potential error factors resulting from absorption, balance drift, temperature changes, etc.

Additional Factors Affecting Weighing

Other factors that should be taken into account with a balance reading are:

- Air flow
- Electrostaticity
- Humidity
- Temperature
- Pressure
- Bench stability

The FlexiWeigh workstation design eliminates some of the factors listed above. For example, the factors associated with air flow are eliminated by having the enclosure; the electrostaticity is minimized by use of the in-built ionization system, and the issue of bench stability is easily addressed at an early stage.

Effect of the Ionizer

The ionizer, which is important for good powder dispensing, can have an additive (or subtractive) effect on the values shown on the balance when it is ON. The FlexiWeigh is able to detect these fluctuations and the powder dispensing algorithm is able to filter most of this effect.
However, all the values recorded by FlexiWeigh are correct, as the initial weighing (Tare or Zero operation) and the final weighing are strictly measured under the same conditions. These conditions are:

- Ionizer OFF: no additive effect
- Nose Up
- Nose Out

For example, this is the reason that a user can request a minimum dispense target of 2.0 mg. However, because the FlexiWeigh powder algorithm measures an additive effect when the ionizer is set to ON of, for example -0.3mg, the FlexiWeigh powder algorithm will decide to set a new minimum target of 1.7 mg. When the algorithm finishes its dispensing, it will turn off the ionizer, and the value on the balance will increase by +0.3mg, and the FlexiWeigh will record the final weight made without the ionizer effect.

Calibration

The balance should be calibrated regularly (e.g. once a day for internal calibration). The balance is capable of detecting automatically that it needs an internal calibration. At this point the AutoCal symbol flashes on the balance screen. The FlexiWeigh software will allow the balance to perform the Autocalibration, only if a process is not running at that time. If a process is running, then the balance will autocalibrate once the process has finished.