A matter of balance: calibration and use of weighing instruments

In the modern laboratory, where commercially prepared consumables now predominate, it is important to remember the importance of the measurement of weight. Here, Peter Riddle concludes his back-to-basics series with a look at laboratory balances.

Most, if not all, laboratories will have access to balances, whether this is to weigh kilogram or milligram quantities. Weighing raw materials to prepare reagents in clinical laboratories has now been replaced largely by the purchase of ready-made reagents, stains and culture media, but there remain instances where the ability to weigh with accuracy and precision is required in analytical procedures.

The term 'balance' is derived from the original beam balances. These worked by comparing the unknown weight of a substance with weights of known mass using pans suspended from a beam, the pivot point of which lay an equal distance from each pan. The mass of the unknown was determined when the beam was in balance. Beam balances were either the two-pan variety in which weights were added by hand, or the single-pan form in which a system of weights was added by a selection mechanism. Most laboratories now use direct-reading electronic balances where the weight is determined via a pressure transducer located under the single pan.

Laboratory staff should be aware that the weighing operation may be a source of error in the analytical process and that it may be difficult to detect. The precision may be excellent but the accuracy may be poor because of a failure to detect an error due to improper balance calibration or drift. Balances are classified into several categories.

Top-loaders are balances with 0.001 g or 1 mg readability and above, where readability is the lowest possible digit seen on the display. Analytical balances use enclosed weigh pans and come in two basic varieties: micro balances, accurate to 1 µg, and semi-micro balances (10 µg).

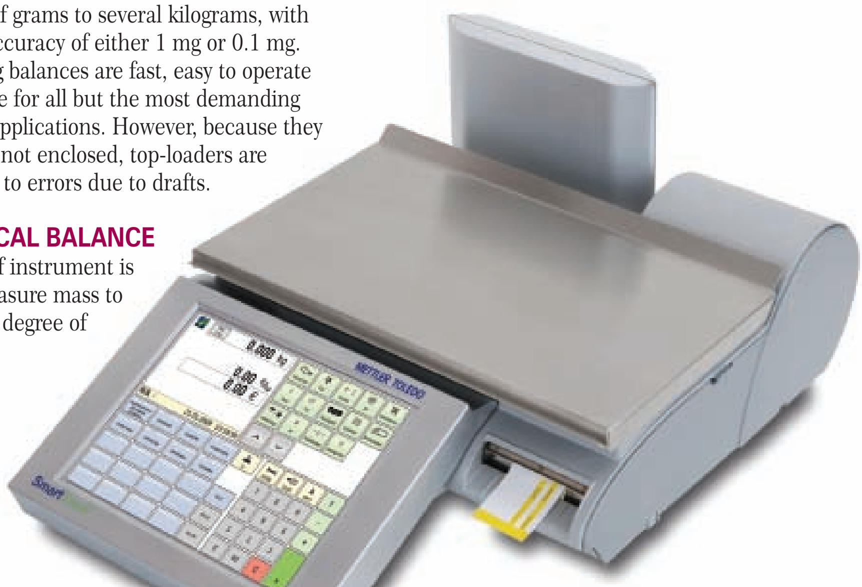
As the name implies, top-loading balances accept samples on a pan that sits on top of the instrument, directly above the weigh cell. Top-loader capacities range from the low hundreds of grams to several kilograms, with specified accuracy of either 1 mg or 0.1 mg. Top-loading balances are fast, easy to operate and suitable for all but the most demanding analytical applications. However, because they are usually not enclosed, top-loaders are susceptible to errors due to drafts.

ANALYTICAL BALANCE

This type of instrument is used to measure mass to a very high degree of precision. The weighing pan(s) of a high-accuracy analytical balance may be found inside a see-through enclosure with doors so that dust does not collect and any air currents in the room do not affect the delicate balance.

Two-pan analytical balance
These balances consist of a symmetrical beam and three knife-edges. The two terminal knives support the pans and a central knife-edge acts as a pivot about which the beam swings.

Single-pan mechanical balance
Single-pan instruments generally comprise a beam with two knife-edges, one to support the weighing pan and the other acting as a pivot. A fixed counterweight balances the load on the pan. The displays on these balances tend to be of the optical variety and the user can usually adjust the sensitivity of the balance.



Modern weighing instruments have come a long way from their balance-beam origins.

Use and maintenance

Single-pan electronic balances are easy to use. Individual requirements will dictate the degree of accuracy required but a few general rules should be followed, particularly when weighing small quantities.

- Do not disconnect the balance from the power supply, and always leave it switched on. This allows the balance to reach thermal equilibrium. To 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 energised and no warm-up period is necessary.
- Always check that the balance is correctly levelled by checking the level indicator.
- Never weigh directly on the pan surface but use an appropriate container or weighing boat. Always place the weighing sample in the middle of the weighing pan, as 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'.
- Always allow the substance to be weighed to come to room temperature before weighing.
- If the instrument has a protective shield, always take the final reading with the doors closed to avoid draughts.
- The balance should be checked for drift each day using an external weight, and a record should be kept in a logbook to record the performance of the balance over time (usually 100 g for a balance with a readability to four decimal places, and a 10 mg or 100 mg weight for a micro balance).
- When handling calibration weights, always use forceps to avoid contamination from oils and salts from the hands.

BALANCE LOCATION

Balances must be sited on a firm, horizontal surface. Many balances, especially those measuring subgram quantities, will be fitted with a type of spirit level and adjustable feet to ensure a true level can be obtained. A vibration-free balance stand not in contact with both floor and wall may be required when weighing extremely small quantities.

The environment must be free of draughts and this is usually achieved by using an instrument with a glass draught shield. This is particularly important for balances with 1 mg or 10 mg readability. Do not place the balance next to a door, and avoid places with high traffic. The effect of draught is secondary for balances with readabilities of ±0.1 g.

Temperature fluctuations will also have a detrimental effect on the weighing process and most electronic balances now have some form of automatic temperature compensation.

Balances should also be protected against magnetism and static electricity, both of which have an adverse effect on the accuracy of the balance. Most manufacturers offer balances with 'antistatic' weighing pans and with draft shields coated with a substance that conducts electricity.

Balance levelling and adjustment must be performed to increase the sensitivity, accuracy and efficiency of the device.

INSTRUMENT CALIBRATION

The standard for laboratory accreditation is ISO 15189:2012, which specifies requirements for quality and competence in medical laboratories. At its most basic level, calibration involves comparing a mass reading against a standard weight. In the case of a laboratory balance, standard weights are graded according to class. There are four ASTM weight classes (1–4), with Class 1 being the most accurate, and Class 4 being the least accurate. The class of weight to be used corresponds to the accuracy of the balance. For laboratory balances, Classes 1 and 2 weights are most commonly used.

As analytical balances are used infrequently, it is likely that calibration is not carried out as often as ideally necessary. Also, how many laboratories confirm the calibration of a new balance? To calibrate, you simply need to place a calibration weight on the pan and record the result. If it is within predetermined limits then no further action is required. If the result is not within limits then the balance should be adjusted to the value of the calibration weight.

Balances need only be adjusted at a single point close to the maximum capacity of the instrument because modern instruments have a very stable linearity characteristic. Full calibration will require the balance to be checked throughout its working range using certified, traceable weights, although scheduled checking at low, mid and high levels should suffice to indicate any significant drift from true values. These procedures are usually carried out at service visits. Analytical balances can be calibrated externally or internally, as well as manually or automatically, depending on the model.

Modern balances have internal weights that can be used to make adjustments, but the internal weight must be checked against traceable weights when the instrument is serviced.

The International Organisation of Legal Metrology defines the maximal permissible errors for calibration weights and National Accreditation of Measurement and Sampling (NAMAS) requires that weights used for calibration should be traceable to UK national standards. However, for the purposes of good laboratory practice (GLP), standard certification under BS EN ISO 9000–9002 will suffice. External weights should be checked every four years.

Gravitational effects, due to altitude, mean that precision balances must be calibrated and adjusted at the place of use.

Calibration is also affected by changes in ambient temperature and thus balances should remain switched on to ensure temperature equilibrium. If the instrument has been switched off, or in the event of a power failure for an extended period of time, the balance should be switched on for a minimum of one hour before a weighing is made. Precision, micro and semi-micro balances need an adequate time to warm up. Precision balances need around three hours, while semi-micro and micro balances need six and 12 hours, respectively.

REPRODUCIBILITY

Reproducibility refers to the instrument's ability to deliver the same weight reading repeatedly for a given object, and to return to a zero reading after each weighing cycle. This is usually stated as the standard deviation that is determined from six to 10 measured values of a calibration weight.

LINEARITY

This test measures the ability of an instrument to provide consistent sensitivity throughout the weighing range. The test requires several nominally equal weights, each a fraction of the weighing capacity. The group together should approximate the weighing range of the instrument. For example, a 160 g capacity analytical balance might be tested with three 50 g weights.

Other articles in this 'Back to Basics' series by Peter Riddle (prriddle@hotmail.co.uk) are on centrifugation (February, page 76), liquid-handling devices (March, page 138) and pH meters and hydrogen ion concentration (April, page 202).