General Accreditation Guidance

User checks and maintenance of laboratory balances

January 2018

User checks and maintenance of laboratory balances

1. Summary

This document provides guidance information on:

- the specific features of various types of balances used in facilities;
- factors which may affect proper performance of balances;
- balance calibration issues; and
- user checks, together with the evaluation of these checks, to determine ongoing satisfactory performance of balances.

The methods in this document (user checks) are loosely based on those found in *Monograph 4, The Calibration of Weights and Balances,* E Morris and K Fen, Australian Government National Measurement Institute.

2. Introduction

In most facilities, the balance is a critical item of equipment which must operate correctly and have suitable traceability in order to ensure the quality of test results. However, for a variety of reasons balances can either malfunction or their outputs drift over time.

The purpose of this technical note is to give guidance to balance users on how to monitor any drift or change in measurement over time and to ensure that a balance remains fit for use. This is achieved through periodic single point checks and through repeatability checks (refer to Section 7).

A measure of a balance's capability, the **Limit of Performance** is calculated using the results of the repeatability readings together with the maximum scale error. The limit of performance is the upper limit of measurement error that may be expected when no corrections are made and only one reading is taken. A balance user can request for the limit of performance to be reported on a calibration report and this number can be approximately recalculated at any one time using the results from the user checks (refer to Section 7).

An end user may use the limit of performance to determine if the balance meets their needs based on the users' required error allowance for the measurements they undertake.

A balance user can also determine the minimum mass for which a weighing device will provide meaningful measurements (refer to Section 7).

3. Features of electronic balances

Single-range

Single range balances have the same resolution i.e. number of decimal places over the whole operating range.

Dual-range

Dual-range balances operate over two ranges, the resolution of the reading decreasing for the higher capacity range, for example 0.001 mg up to 20 g and then 0.01 mg from 20 g to 200 g. Repeatability and scale value checks need to be performed in both ranges if they are used.

Poly-range

Poly range balances have more than two ranges and resolutions. Repeatability and scale value checks need to be performed at the top of each range. This may require several checks depending on the number of ranges used.

Balance adjustment

Modern balances can be compensated for their drift due to changes in temperature, ageing of electronics and other influence factors. This is a very useful feature and helps the balance maintain its accuracy over time. It is achieved by loading either an external mass, as per the procedure in the user manual, or by activating the loading of an internal mass located inside the balance. This adjustment is usually at only one point in its range and is not an actual calibration even though it is often referred to as such by some of the manufacturers.

When using an external mass to perform a balance adjustment, it must be noted that even calibrated masses are not exactly equal to their nominal value and there are different classes of masses with different maximum errors. Consequently, if the calibration service provider uses their masses to adjust the balance and then the end user adjusts the balance by using a different mass (by either using a different external mass or by activating the internal mass) then there will be a shift in the balance by the amount that the two masses differ. This can be a significant difference for high resolution balances. It is, therefore, important that the balance calibrator and the end user both use the same adjustment mass (preferably the internal calibration mass when available) so that the corrections and the limit of performance on the calibration report are valid.

4. Balance location – environmental factors

Service check-ups

A balance located in a harsh environment may require maintenance. Yearly service checks can help ensure that the balance is performing correctly. If any adjustments are required at this time, then a full calibration may be necessary and a new endorsed report obtained.

Dust

Balances should be maintained as dust free as possible. Any cleaning should be performed without moving the balance (refer to Note 1).

Temperature

Temperature changes or temperature differentials can affect balance operation. Therefore, it is recommended that balances be kept away from windows where there is excessive heating from the sun. Refer to manufacturer's specification for the expected drift due to changes in temperature.

Air draughts

Draughts can cause readings to fluctuate beyond acceptable limits. Sometimes the accommodation prevents the proper placement of the balance in a draught free area. If this is the case, the balance must be shielded from draughts using partitions or balance shields (refer to Note 2).

Vibration

A balance needs to be located on a bench that is stable (ie. not able to move or flex). Many benches, including steel benches, can bend or move sufficiently to affect the readings of a balance, e.g. by placing a heavy article on the bench.

The best practice is to isolate the balance, if at all possible, on its own support.

Magnetism

Force compensation balances are susceptible to magnetism. Changes in readings, or reading offset, can occur if the magnetic field surrounding the balance is changed, for example, with cast iron masses (refer to Note 3). Similarly balances should not be placed on a metal surface which may induce a magnetic susceptibility.

5. Correct use of balances

Tare function/zero check

This operation must be performed prior to each weighing to ensure the balance is at zero and has not drifted since the last reading. It must be remembered, however, that taring should only be carried out initially when performing either the single point check or repeatability user checks.

Many balances now come with zero tracking facilities. When a mass is removed, the balance will automatically re-zero itself. Care must, therefore, be taken when removing samples.

User checks

Single point and repeatability checks may be performed at any time. Guidance is provided in the *General Equipment Table* published by NATA for checking frequencies.

6. Full calibration

A full calibration should be performed in-situ, see note 5 below.

A **NATA, or equivalent, endorsed report** is required covering the calibration except where the facility is approved to perform in-house balance calibrations (refer to NATA's *Equipment assurance, in-house calibration and equipment verification*). The calibration service provider must use reference standards that are **appropriate and traceable** to a national standard for mass.

As part of the full calibration service, the Limit of Performance of the balance will be calculated for each measurement range. The end user can then use the reported limit of performance to determine if the balance still meets their measurement requirements.

In order to assess the user checks described below, the user of the balance must ensure the following information is reported on each calibration certificate:

- The limit of performance for each range calibrated;
- The standard deviation of the repeatability readings, sometimes just called the repeatability or repeatability of the measurement in a calibration report S_r;
- The largest reported scale reading correction across the measurement range(C_{Cal});
- The expanded uncertainty associated with the above largest correction. $U(C_{Cal})$.

Trade measurement, Verifying Authorities

NATA accepts calibrations for masses carried out by Verifying Authorities provided that they are reported on a Regulation 13 certificate.

Further information and a listing of Verifying Authorities is available on the National Measurement Institute (NMI) website at www.measurement.gov.au.

7. User checks

Single point check

This is a check that the balance's sensitivity has not changed significantly since it had its last full calibration, for example, that the scale value corrections and limit of performance on the calibration report are still valid.

The mass used must be stable, close to full capacity (typically not less than 80% where practical) of the required balance range being checked and be of symmetrical shape (usually cylindrical) so that the mass can be centred and evenly distributed on the balance. For poly range balances, each range must be checked. The mass must be carefully handled and stored so that its mass value does not change due to scratches, dust, contamination, etc. Ideally, a single mass is to be used, however this may not be practical for larger scale devices.

The user check mass must be calibrated, be of a suitable material and ideally have an uncertainty which is less than 2.26 S_r of the balance for which it is being used, or is comparable to the resolution of the balance.

It is highly recommended the end user performs a user check soon after a full calibration in order to ensure the process is working correctly.

<u>Single point check procedure Method 1</u>

Where the weighing machine is electronic and has a so-called 'calibration' facility that allows the output of the machine to be adjusted between zero and an internally or externally applied weight, it is advisable for this facility to be operated prior to the daily check, and also for it to be operated regularly before the weighing machine is used, to permit compensation for changing environmental factors such as temperature and air density.

a) Tare the balance and record the zero reading (z_1);
b) Place the calibrated mass(es) (M) on the balance and record the indicated mass (m_1);
c) Remove the mass(es) from the balance. Do not tare the balance;
d) Place the calibrated mass(es) on the balance and record the indicated mass (m_2);
e) Remove the mass(es) from the balance and record the balance reading (z_2).

Calculate the correction for each separate weighing:

$C_1 = M - (m_1 - z_1)$
$C_2 = M - (m_2 - z_2)$
$C_{User\text{-}Check\ Correction} = (C_1 + C_2)/2$
$\Delta C = C_{User\text{-}Check\ Correction} - C_{Calibration\ report\ correction}$

Where $C_{Calibration\ report\ correction}$ is the correction at load M as found on the last calibration report.

If

$$|\Delta C| \leq \sqrt{\{U^2 + (1.6s_r)^2 + U_M^2\}}$$

where U is the uncertainty of the correction at load M as found on the last calibration report and U_M is the uncertainty of the user check calibrated mass

it is unlikely the balance's characteristics have changed significantly since it had its last full calibration. These checks may typically be repeated monthly and by following this method the recalibration interval may be extended depending on the user's requirements.

Single point check procedure Method 2

Alternatively user checks may be carried out between full calibrations on a daily or before use basis. Where the weighing machine is electronic and has a so-called 'calibration' facility that allows the output of the machine to be adjusted between zero and an internally or externally applied weight, it is advisable for this facility to be operated prior to the daily check, and also for it to be operated regularly before the weighing machine is used, to permit compensation for changing environmental factors such as temperature and air density.

The checks should include checking or adjusting the zero of the weighing machine, followed by the placement of a single weight (usually of a size appropriate to the normal range or load of use for the weighing machine) on the load receptor. The balance's indication should be recorded.

The laboratory's procedure for the daily, or before-use, check should define an action limit or error allowance that is appropriate for the use of the machine.

Following this method, the calibration interval for the balance should be reduced to every 12 months.

Repeatability check

The 6 monthly repeatability check seeks to determine if the balance output changes with repeated measurements by performing 10 measurements of the same mass. It is the change in the magnitude of the spread of responses (largest standard deviation) that is important, and this is compared with the standard deviation obtained at the last full calibration and reported on the calibration report. One set of repeatability checks should be performed in each measurement range of the balance.

The value of the mass should be close to the maximum measurement range for which the instrument is used (or one for each scale range for a dual scale or poly-range balance) and like the mass used for the single point check must be symmetrical in shape and stable.

Repeatability check procedure

a) Tare the balance and record the zero reading (z_1);
b) Place the selected mass(es) which is close to the maximum capacity of the range being checked on the balance and record the indicated reading (m_1);
c) Remove the mass(es) from the balance and record the balance reading (z_2);
d) Without taring the balance, place the same selected mass(es) on the balance and record the indicated reading (m_2);
e) Remove the mass(es) from the balance and record the balance reading (z_3);
f) Repeat (d) and (e) so that 10 complete set of readings are obtained.

Calculate the difference (r_i) between each reading and its corresponding zero reading:

$r_i = m_i - z_i$

Calculate the standard deviation (s) of the difference $r_1, r_2, \ldots r_n$ from the formula

$s_{user\ check} = \sqrt{[\Sigma (r_i - R)^2 / (n - 1)]}$

Where i = 1 to n, and R = mean of the values of r_i

If the standard deviation ($s_{user\ check}$) is less than twice that from the last calibration report (s_r), it is unlikely the balance's characteristics have changed significantly since it had its last full calibration.

Assessment of user checks

If there are significant changes, as measured by the user checks (both single point and repeatability checks), the following should be undertaken:

1. Check and rectify any environmental problems, e.g. draughts, temperature fluctuations, etc. (refer to Section 4)
2. Repeat the check.
3. If the balance still falls outside of this guideline, it should be determined what effect this change in performance has had on previous test results obtained using this balance.

Recalculate the Limit of Performance (as noted below) and then decide if the instrument is still fit for use based on the Limit of Performance as required by the test methods for which the balance is used, or, the magnitude of the change in the Limit of Performance since the last calibration. This will influence the decision as to whether or not the balance requires servicing and recalibration.

Limit of performance

To assist with the above decisions, it may be helpful to make a rough estimation of the current limit of performance of the balance using the following formula:

$$\text{User defined limit of performance} = 2.26\ s_w + |Corr_w| + U(C_{Cal})$$

Where:

s_w is the larger standard deviation of the repeatability standard of either:

a) that reported on the last full calibration report S_r; or

b) that determined by the user repeatability check $S_{user\ check}$.

$|Corr_w|$ is the **absolute** value of $|C_{Cal}| + \Delta|C_{user\ check}|$

$|C_{Cal}|$ is the largest correction reported on the last full calibration report.

$\Delta|C_{user\ check}|$ is the change in user check correction from that measured at the time of the last full calibration, to that measured now.

$U(C_{Cal})$ is the expanded uncertainty associated with $|C_{Cal}|$ as shown on the calibration report.

If there is any doubt whether or not the balance requires recalibration, the calibration service provider who last calibrated the balance should be consulted. These experts are usually conversant with the particular limits on capabilities and specifications of the various models of balances. If there has been a significant change, it will also be necessary to determine the possible effect on test results which have been obtained using the balance in the period prior to this check and subsequent to the last satisfactory check.

Note: All of the above steps and checks constitute the corrective actions for that balance and must be recorded.

Minimum Mass

In some industries, such as the pharmaceutical industry, users sometimes need to achieve a certain relative uncertainty such as ±0.1%. When the quantities become smaller and smaller, a point will be reached below which the required relative uncertainty can no longer be achieved. This point is the minimum mass.

The minimum mass M_{min} can be calculated from the equation

$$M_{min} = 2 \times S_r / U(rel)$$

Where S_r is the standard deviation of the repeatability reported at the last full calibration (as listed above) and U(*rel*) is the required relative expanded uncertainty.

8. Notes

Note 1: Dust is a problem if it gets into the balance mechanism. There is usually very little clearance between the pan spindle and wall of the force compensation cell.

Note 2: Opening of doors, windows and operation of fans and air conditioners can affect balance operation. It has even been found that an air conditioner output bouncing off the adjacent wall is sufficient to affect the stability of some balances.

Note 3: If there is a possibility that a mass is magnetic and affecting the reading it can be checked by. comparing the indicated value of the mass when placed directly on the pan against the indicated value when the mass is raised 10-15 cm above the pan on a tared, non-magnetic spacer. The magnitude of the effect could be up to 1 g in 1000 g. Larger, less predictable, changes can be caused by moving a large mass of magnetic material from under, or alongside, a balance.

Electronic balances should not be located near equipment/machinery with a strong electric field, eg. electric grinders, due to the possible ingress of magnetic material into the weighing cell. This can cause disproportionate errors due to the effect of the lever ratio in the mechanism.

Note 4: If the full range of a balance is not required, then it is only necessary to calibrate and check that portion of the range* of the balance actually used. If this is the case, the calibration is performed as if this reduced range is the full range of the balance and all calibration readings must be taken in this nominated, reduced range. However adequate warning, by way of a sign above or on the balance, must be given to prevent users inadvertently using the uncalibrated portion of the range of the balance.

Alternatively, it may be appropriate in some cases to request that the calibration service provider calculate the **Limit of Performance** for the balance over different working ranges* for which the balance is to be used. For example, a 30 kg balance may have a limit of performance of ± 0.4 g up to 10 kg but a limit of performance of ± 2.5 g up to 30 kg. If the limit of performance of the balance is just reported as "± 2.5 g", this balance would be deemed unsuitable for application requiring a limit of performance of ± 0.5 g or better. If, however, both limit of performances were reported with their ranges then the balance would meet the requirements of ± 0.5 g up to 10 kg and would also meet the requirements of ± 5 g up to 30 kg.

If this option is chosen, the balance must be clearly identified with these limitations and the **user checks** must be performed in all of these **ranges** to ensure that the balance continues to meet the different requirements of each range.

* *These ranges may be defined by the facility depending upon the balance capacities and limits of performance required by the test methods.*

Note: 5: **Moving a balance.** Weighing devices are to be recalibrated or have their calibration and performance verified if moved. This is particularly important for high resolution weighing machines.

Performance verification is to ensure the device is still fit for purpose by testing calibration and repeatability. Alternatively when moving a balance the user is to ensure the performance of the device has not been altered and is still fit for purpose by taking into account;

- weighing device design and intended use
- manufacture's manufacturer's instructions
- results of verification checks of calibration and repeatability show the device is fit for purpose at the new location
- linearity checking
- Environmental changes at the new location may differ to the original location and affect balance performance. Consider:
  - local gravity changes compared to the location at calibration
  - air movements (drafts)
  - temperature, both air and radiated (sunlight)
  - vibration and stability of weighing surface
  - sources of magnetic field interference (speakers, mobile phones and other equipment)

9. References

NMI Monograph 4, *The Calibration of Weights and Balances,* E Morris and K Fen, Australian Government National Measurement Institute.

NATA Publications

General Accreditation Criteria *Equipment assurance, in-house calibration and equipment verification*

General Accreditation Guidance *General Equipment Table*

AMENDMENT TABLE

The table below provides a summary of changes made to the document with this issue.

Section	**Amendment**
Entire document	This document replaces the former Technical Note 13. The document has been reviewed and updated to reflect the new accreditation criteria documentation structure.
Entire document	Added Security Classification Label