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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 laboratories;
- 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.

2. Introduction

In most laboratories the balance is a critical item of equipment. Incorrect functioning of the item will have an effect on test results. For a variety of reasons balances can either malfunction or their outputs drift.

The purpose of this technical note is to give guidance to balance users to determine when action is required to ensure that a balance remains fit for use.

The need to determine fitness for use of a particular balance is determined by the user checks described in Section 7.

These checks establish if any change in performance relative to the last full calibration of the balance has occurred and if this change is significant. Significant changes would warrant further investigation and possibly adjustment and re-calibration of the balance. In these cases, it will also be necessary to determine the possible effect on results which have been obtained using the balance in the period prior to this check and subsequent to the last satisfactory check.

However, **not all changes to a balance's performance give cause for concern.**

The **Limit of Performance** is a calculation of the balance's capability using the results of the repeatability readings together with the maximum scale error. It is provided on a calibration report and can be calculated approximately from the user checks.

The fitness for use of a balance can be determined by recalculating its **Limit of Performance** to determine if it remains suitable for user needs. The end user needs to determine what capability is required and then compare this with a balance's limit of performance. For example, if a measurement to 1 mg is required, will the balance at hand give meaningful measurements at this level ? ie. is the limit of performance equal to or less than 1 mg ?

In some cases the **Limit of Performance** may be higher than the original capability of the balance. For instance a laboratory may use a balance with a resolution of 0.0001 g consistently for a task or specification that requires a **Limit of Performance** with a resolution of 0.001 g. In such a case, the last decimal point is redundant (and should not be considered) and hence, a balance with a higher **Limit of Performance** may be quite fit for use although it exceeds the value shown on a calibration certificate.

3. Features of electronic balances

Single-range

Single range force compensation balances are readable to the same accuracy over the operating range (capacity) of the balance.

Dual-range

Dual-range balances operate over two ranges, the discrimination of the reading decreasing for the higher capacity range. These balances may have a switch which allows the user to alternate between the two ranges. Repeatability and scale value checks need to be performed in both ranges if they are used.

Poly-range

The displayed range automatically changes, by dropping off a decimal point or rounding to the smallest displayed increment, as the mass increases. 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.

Balances with internal calibration function

Laboratories with balances that have an internal calibration function must be able to demonstrate that traceability to the original calibration is maintained (which may necessitate switching off this function).

4. Balance location – environmental factors

Service check-ups

A balance located in a harsh environment may require maintenance. There are a number of organisations able to perform yearly service checks, to 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. A fine haired artist's brush can be used for parts of the balance which are hard to reach. Refer to Note 1.

Temperature

Modern balances generally perform well over a wide range of temperatures. Temperature changes or temperature differentials can, however, affect balance operation. Therefore, it is recommended that balances be kept away from windows where there is excessive heating from the sun.

Wind

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. This is often brought about when a heavy article is placed on the bench or removed between weighing operations. Sometimes it can be as little as someone leaning against the bench or walking around if the floor is of poor construction.

The best practice is to isolate the balance, if at all possible, on its own support. A solid structure under the balance can be effective and can be made to fit a variety of situations. It should dampen the effects of vibration and bench movement.

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. The most frequently observed problem relates to the magnetic field associated with the use of cast iron masses. Refer to Note 3.

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 scale value or repeatability user checks.

Many balances now come with zero tracking facilities. When a mass is removed, the balance will automatically re-zero itself. When removing samples, care must be taken to ensure the pan is kept clean of spilt material. Material left on the pan will be tared out which will lead to errors if it is removed during subsequent weighings.

User checks

Scale value and repeatability checks may be performed at any time. The minimum frequency required by NATA is every month for the scale value (single point) check and every six months for the repeatability check. Refer to Section 7 for guidance on user checks.

6. Full calibration

This shall be undertaken at least every three years in accordance with the NATA Accreditation Requirements and shall be performed at the laboratory where the balance is to be used.

A **NATA, or equivalent, endorsed report** is required covering the calibration except where the laboratory is approved to perform in-house balance calibrations. (See NATA Technical Note 28). The calibration authority must use reference standards that are **appropriate and traceable** to a national standard for mass. Refer to Notes 4 and 5.

The **Limit of Performance** of the balance obtained from the calibration certificate for each range needs to be checked to ensure it is fit for use prior to putting the balance into operation after each calibration.

In order to assess the user checks described below, the following information needs to be obtained from the calibration certificate:

- The limit of performance for each range calibrated (F);
- The maximum standard deviation of the repeatability readings (s_r(max));
- The maximum scale reading correction (C_{max});
- The expanded uncertainty associated with the maximum correction. U(C_{max}).

Weights and measures reports

State weights and measures authorities are normally Verifying Authorities which provide legal traceability for masses and volumetric measures. NATA accepts calibrations for masses carried out by Verifying Authorities (even those which are not accredited) provided that they are reported on a Regulation 13 (previously a Regulation 80) certificate. However, some of these bodies perform other calibrations (eg. balances) which are outside the scope of their Verifying Authority appointment. **NATA does not accept these calibration certificates.**

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

Scale value check and masses

Scale value checks are performed to ensure that the balance output continues to give the same value for the same known mass. In this way, the scale value check compares the current performance of the balance against its performance at the time of the previous full calibration of the balance. As this is only a user check and not a calibration, the masses do not have the same rigorous traceability requirements as do masses used for the calibration procedure.

The important aspects are that the value of the mass be:

- known;
- stable (ie. does not vary from one check to the next); and
- close to the full capacity (ie. not less than 80%) of the balance range being checked.

Masses should be of symmetrical shape (usually cylindrical) so that the mass can be centred and evenly distributed on the balance. In order to identify changes in instrument performance, it is essential that the same mass/masses be used each time, unless a certified mass is used.

A **user assigned mass** can be used. These non calibrated masses must be placed on **each balance** at the time a full calibration of the balance is performed and the displayed value is assigned to it. Refer to Note 6.

It should be noted that such a mass is not calibrated but has had a value assigned to it **relative to that balance**. The assigned value must be determined for **each** balance, or balance range, on which the mass is to be used. Refer to Note 7.

Alternatively, a **certified mass** may be used provided the value of the mass has been determined by a NATA accredited laboratory that has provided an endorsed report detailing the calibrated value of the mass and the uncertainty of that measurement.

Which option to choose ?

User assigned masses are an economical option. **Certified masses** are generally only used at a central laboratory as they are not usually available for monthly use at laboratories remote from a central laboratory.

Laboratories are encouraged to have user assigned masses readily available as they can be used as a means of checking the performance of a balance at any time. For example, if test results appear doubtful or results have been challenged.

<u>Scale value check procedure</u>
(Reference: *The Calibration of Weights and Balances,* E Morris and K Fen, Australian Government National Measurement Institute).

a) Tare the balance and record the zero reading (z_1);
b) Place the calibrated or assigned value mass(es) (mass 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 or assigned value 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:

$$C_1 = M - (m_1 - z_1)$$

$$C_2 = M - (m_2 - z_2)$$

$$\text{Correction} = 0.5(C_1 + C_2)$$

If the change in correction is less than 3 times s_r(max) the balance is fit for continued use. Otherwise the balance may need repair or adjustment (see also under assessment of user checks where the limit of performance can be used to determine if the balance is still fit for purpose).

Repeatability check

The repeatability check seeks to determine if the balance output changes with repeated measurements (ie. 10) of the same mass. It is the change in the magnitude of the spread of responses (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.

For a repeatability check it is important that the weight of the mass used remains constant throughout the period between checks. **It does not need to be a certified mass or have an assigned value.** The weight of the mass should be close to the maximum weighing capability of the balance (or of each scale range for a dual scale or poly-range balance). However, for convenience, the certified or user-assigned mass used for the scale value check is usually used for the repeatability rather than using two different masses (or sets of masses).

Repeatability check procedure
(Reference: *The Calibration of Weights and Balances,* E Morris and K Fen, Australian Government National Measurement Institute).

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

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

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

If the standard deviation (s) is less than twice s_r(max) the balance is fit for continued use (see also under Assessment of user checks).

Assessment of user checks

If there are significant changes, as measured by the user checks, then recalibration may be warranted. However, before recalibration is considered, the following should be undertaken:

1. Check and rectify any environmental problems:

    - are there draughts or vibrations?
    - is the balance level?
    - are there any interferences with the pan ie. dirt or cover contacting the pan?
    - with more precise balances, check draught covers for static electricity (if static electricity is a problem the draught shield needs to be treated with an anti-static spray).
    - is there any magnetic interference?
    - is the balance affected by temperature changes?

2. Repeat the check.

3. If the balance still fails the check, then it is useful to determine what effect this change in performance has had on previous test results obtained using this balance. This should influence the decision as to whether or not the balance requires servicing and recalibration. This will depend upon:

    - the limit of performance required by the test methods for which the balance is used.
    - the limit of performance of the balance as established at the last full calibration.
    - the magnitude of the change in the limit of performance of the balance.

Limit of performance

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

$$F = 2.26\ s_w + |Corr_w| + U$$

Where:

s_w is the larger repeatability standard deviation of:

a) that reported on the last full calibration report; and
b) that determined by the user repeatability check.

$|Corr_w|$ is the **absolute** value of the larger scale correction of:

a) the largest value of the correction reported on the last full calibration report; and
b) that determined by the user scale value check.

U is the expanded uncertainty associated with $|Corr_w|$ as shown on the calibration report.

If there is any doubt whether or not the balance requires recalibration, the calibration authority who last calibrated the balance should be consulted. These authorities 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 documented.

8. Specimen worksheets

Two worksheets have been provided at the end of this document as suggested formats for recording data of balance user checks.

9. 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. Quarries and construction sites in particular can pose dust problems.

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, the best way to check if it is affecting the reading is as follows. Compare 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: In-house calibrations may only be conducted for the laboratory's own use either within the laboratory itself, or at a central calibration laboratory carrying out calibrations for other departments within their own company (see NATA Technical Note 28). In-house calibrations must be performed, at the laboratory where the balance is to be used.

Note 5: 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 authority 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 laboratory depending upon the balance capacities and limits of performance required by the test methods.*

Note 6: Calibrating authorities at the time of full calibration are usually prepared to weigh masses nominated by the user and will include the displayed values (ie. assigned mass readings) obtained in the balance calibration report. Alternatively, users can do this themselves provided it is performed on the same day that the balance is calibrated and they record the values obtained.

It is important that all the masses to be used are checked in the manner in which they are to be used and not just as single masses.

<u>Example:</u>
If the laboratory has three 2 kg masses which are to be used to check 3 balances – one of 2 kg capacity, one of 4 kg capacity and another of 6 kg capacity, then:

- all three masses need to be placed on the 6 kg balance and the total mass recorded.
- two 2 kg masses similarly placed on the 4 kg balance (the actual marking of the masses to be recorded) and the total mass recorded.
- if any one of the 2 kg masses is to be used for checking the 2 kg balance, then each must be placed separately on the balance and the mass and identification of the mass recorded. Alternatively if only one of the 2 kg mass is used then only its mass needs to be assigned and its identification recorded.

Note 7: The assigned value is purely for a particular balance/mass combination and will not have had any balance corrections applied to it. If, for example, a laboratory has three balances and the same mass is used for scale value checks on all three, it will be necessary to determine an assigned value appropriate for each of the balances at the time of each three-yearly balance calibration.

For example:

Balance	Assigned value for mass “A”
Balance 1	1000.7 g
Balance 2	1000.4 g
Balance 3	1000.9 g

The same mass was used but each balance gave a different value. The individual assigned value obtained for that balance must be used in the user checks performed for that balance eg. Balance 2 must use the assigned value 1000.4 g for mass “A”.

10. References

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

NATA Technical Note 28 – In-house calibrations and measurement uncertainty.

(Name of Laboratory or Section)

Record of monthly single point check

MAKE: MODEL: MAXIMUM LOAD:

TYPE: (Single pan / top loading / digital readout / “delta” range)

SERIAL NO: LOCATION:

SCALE RANGE: SCALE DIVISION: READABILITY:

DATE CHECKED:

Single point check

Reference: *The Calibration of Weights and Balances*, E Morris and K Fen Australian Government, National Measurement Institute

The departure of the scale from its nominal value is measured close to maximum capacity.

Certified calibrating mass (M) = ___________

Ist zero reading (z_1) = ___________

Ist reading of standard mass (m_1) = ___________

2nd reading of standard mass (m_2) = ___________

2nd zero reading (z_2) = ___________

$C_1 = M - (m_1 - z_1)$ = ___________

$C_2 = M - (m_2 - z_2)$ = ___________

$\text{Correction} = \frac{(C_1 + C_2)}{2}$ = ___________

Note: If the correction has **changed** by more than 3 times the standard deviation of the repeatability determined at the last 3-yearly calibration then the balance may require servicing, adjustment and calibration.

Testing officer: ______________________________

Checked by: ______________________________

Comments:

(Name of Laboratory or Section)

Record of six monthly repeatability check

MAKE: MODEL: MAXIMUM LOAD:

TYPE: (Single pan / top loading / digital readout / “delta” range)

SERIAL NO: LOCATION:

SCALE RANGE: SCALE DIVISION: READABILITY:

DATE CHECKED:

Repeatability of reading (Six-monthly check)

Reference: *The Calibration of Weights and Balances*, E Morris and K Fen Australian Government, National Measurement Institute

Calibrating Mass (M) = g

Number	Pan load	Scale reading (mg)	Difference (mg) $r = m - z$
1	0	z_1 =	r_1 =
	M	m_1 =	
2	0	z_2 =	r_2 =
	M	m_2 =	
3	0	z_3 =	r_3 =
	M	m_3 =	
4	0	z_4 =	r_4 =
	M	m_4 =	
5	0	z_5 =	r_5 =
	M	m_5 =	
6	0	z_6 =	r_6 =
	M	m_6 =	
7	0	z_7 =	r_7 =
	M	m_7 =	
8	0	z_8 =	r_8 =
	M	m_8 =	
9	0	z_9	r_9 =
	M	m_9 =	
10	0	z_{10} =	r_{10} =
	M	m_{10} =	

Standard Deviation $s = \sqrt{[\Sigma (r_i - R)^2 / (n - 1)]}$

where $i = 1$ to n, $r_i = m_i - z_i$, and R = mean of values of r

Note: If the new value of the standard deviation is greater than twice the value obtained when the balance was last calibrated (ie. 3-yearly calibration), then the balance may require calibration, and possibly servicing and adjustment. Alternatively the Limit of Performance may be recalculated to determine whether the balance is still suitable for the user's needs.

Checked by: