A&D Weighing

12 RECOMMENDATIONS

to Perform Stable Measurements with a Lab Balance

Common Challenges in Precision Weighing and With lab balances

- The display value keeps changing and never seems to settle
- Non-repeatable weighing results
- Values vary throughout the day
- Improper Installation

Lab balances are extremely sensitive devices. Balance divisions can be as small as 1 µg (microgram), which is equivalent to 1/1,000,000 of the weight of a paper clip (about 1 g). Its resolution can reach as high as 1/22,000,000, which is like having the ability to measure the distance between London and Paris (approx. 340 km) in increments of only 1.5 cm!

With such high sensitivity, it should be no surprise that even the slightest disturbances caused by the environment or the way the user interacts with the balance can significantly affect the measurements. The trouble is, however, that it can be difficult to identify and troubleshoot factors influencing the results.

The purpose of this white paper is to shed light on typical instability factors, in relation to both installation and operation, allowing users to diagnose and correct any issues with the balance.

Terms Used and Their Concepts

Zero Point and Span Value

The zero point is used as the base point of measurement. The span value on the other hand is the difference between the zero point and the displayed weight.

In normal use, you should set the display value to zero before each measurement with either a re-zero/tare key or zero tracking function*, so that the measurement display value will be equal to the span value.

Repeatability

Repeatability is the variation in the measured values when the same weight is loaded repeatedly under the exact same conditions (consistency of results is influenced by the person, sample, measurement procedure and environment as well as the balance itself).

Repeatability is typically expressed using the standard deviation (σ) calculated from a series of span values. For example, a standard deviation of 0.004 mg indicates that the results (span values) of a number of repeated weighments will fall within ± 0.004 mg of their mean value with a probability of 68% (see Figure 1).

**Note: With a zero tracking function the balance automatically tracks its zero point and prevents the display value drifting away from zero.*

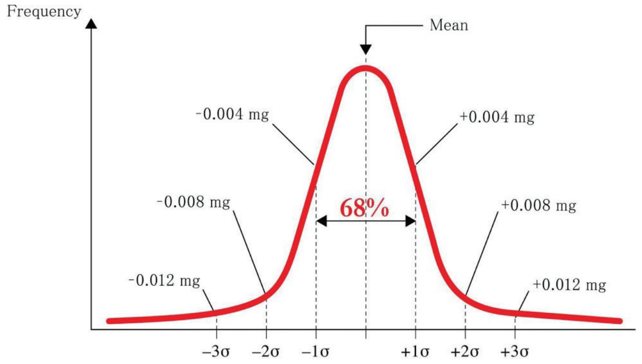


Figure 1. Assumed distribution when the standard deviation is 0.004 mg

Zero-point Drift

Both the zero point and span value will vary, or “drift”, with ambient temperature or due to other factors. The purpose of weighing is to determine a span value. Hence, balance manufacturers generally specify the possible rate of such drift for the span value (i.e. sensitivity drift). However, virtually no manufacturers provide any specification for the drift of the zero point, which is much more susceptible to environmental changes than the span value.

A display value that drifts and never settles upon placing the sample is often a reflection of the zero-point drifting while the span value remains fairly constant (see Figure 2). The zero-tracking function can only keep the display value at zero at the start of each measurement.

A rapid drift or fluctuation of the zero point will also adversely affect the repeatability performance. For these reasons, whether you can achieve stability in high precision weighing will depend greatly on how much you can suppress the movement of the zero point.

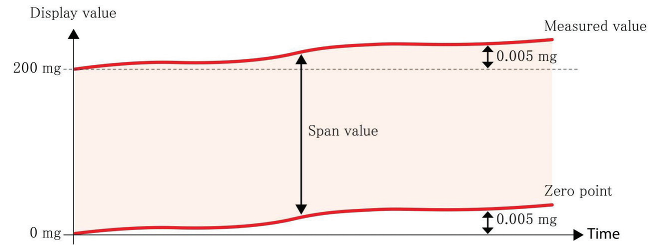


Figure 2. The span value remains fairly constant while the zero point may drift.

Recommendations in Relation to Installation

#1: Avoid or Isolate All Possible Sources of Vibrations Even When You Cannot Actually Feel Them

Why?
Lab balances are highly susceptible to minute vibrations, which can be caused by:

- Strong winds that sway the building (or adjacent buildings)
- High tides or waves near a seashore
- Movement of people, handcarts or forklifts, etc.
- Trains or automobiles running close by
- Distant earthquakes, etc.

Vibrations such as those above are often indiscernible to humans but strong enough to make a lab balance unstable.

Solution
Here is a list of what you can do to minimize the effects of vibrations:

1. Install the balance in a corner of the room next to a wall, but not touching it.

   The center of a room has weaker construction, and the floor tends to shake more easily. On the other hand, there are usually structural supports in the corners of a room which make them less likely to shake.

2. Find an area where traffic can be kept to a minimum.

   If possible, a dead-end area with low foot traffic should be selected. Also, avoid an area near a door, whose opening and closing can cause disturbances such as vibrations and air movements.

3. Set-up the balance on a heavy, rigid workbench, where no activity other than weighing will be conducted. A dedicated weighing table is best.

   The bench should be separated by a few centimeters from the wall and other workbenches/ tables in order to prevent vibrations from being transmitted.

4. Use a passive anti-vibration table recommended by the balance manufacturer.

Anti-vibration Table

   Note that active anti-vibration tables employing costly air suspension actually become a source of vibration themselves and are not suitable for use with lab balances.

5. Do not perform measurements after (not to mention during) earthquakes or while a low pressure system such as a thunderstorm is passing.

   There is presently no established method of stabilizing low frequency vibrations caused by these phenomena. Further, if the building is constructed as a quake-absorbing structure, once an earthquake occurs it may take several days for the lab balance to achieve stability again.

6. Lower the weighing speed of the balance.

   Most balances today enable you to adjust the response characteristics whereby you can trade- off speed against stability.

7. Keep the balance away from routes with heavy moving objects.

8. Install the balance on as low a floor as possible of a rigid building built on a solid foundation, preferably the ground floor.

TIP #2: Ensure That The Ambient Temperature is Stable

Why?
Changes in ambient temperature affect the measurement accuracy and the stability of the zero point (refer to “Zero point and span value” as well as “Zero-point drift”).

The movement of the zero point is not normally apparent on the display while the balance’s zero tracking is activated. However, a zero point that is drifting or fluctuating rapidly will affect results by seriously worsening the repeatability of a the balance.

Solution
Here is a list of what you can do to minimize the effects of temperature variation:

- Maintain the room temperature within a certain range, typically between +5°C to +40°C.

  Daily temperature fluctuations of 4°C or less (within 5 to 30°C) and short term fluctuations of 0.2°C/30 minutes or less are recommended.

- Keep the balance away from any room ventilation sources, and cover it with an external breeze break (draft shield).

Tabletop Breeze Break

Further, the on/off control of the air conditioner around the set temperature can cause repeated temperature changes of about 0.5°C. Such airflows combined with minute temperature fluctuation will have a particularly destabilizing effect on a microbalance (see also Tip: 5).

- Keep any heat generating devices (e.g. furnace, lamp, etc.) far away from the balance, or if possible, out of the room.

  If you cannot move those devices, do not perform measurement while they are in operation.

- Avoid installing the balance in areas close to external air (near windows, doors, etc.) or subject to direct sunlight.

  Also, any external walls are more likely to fluctuate in temperature. For this reason, it is best to install the balance on an internal wall.

- Set up the balance on a non-metal workbench of low thermal conductivity.

  The workbench should be separated by a few centimeters from the wall in order to prevent heat transmission or vibrations.

- Find a large room for installation and limit the number of people entering at the time of measurement.

  Human body heat can easily increase the temperature of a small room.

TIP #3: Ensure That The Ambient Humidity is Stable

Why?
Zero-point drift is also caused by moisture slowly being accumulated on or released from the weight sensor.

Solution
Control changes in humidity. Daily humidity fluctuations of 10% or less is recommended.

TIP #4: Wait Until the balance is Sufficiently Warmed Up and Acclimatized to the Room Temperature and Humidity.

Why?
It can take up to 24 hours for the most precise lab balances to adjust to the room environment. Lower precision balances will take less time depending on their readability, to adjust to the room environment after being plugged in. During the warm-up period, the zero point drift is increased.

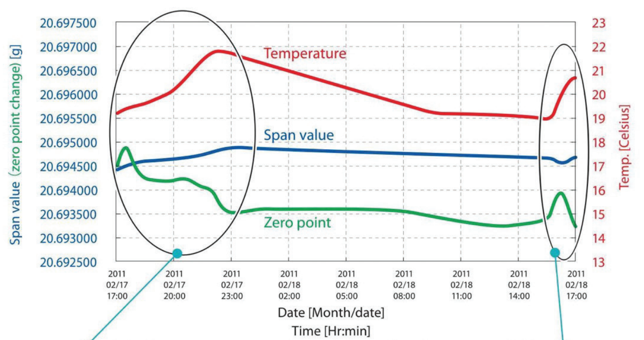
Solution
Install and plug in the balance at least a day before starting measurements while the environmental conditions of the room are kept constant.

The characteristics of the electronic components become more stable as the balance achieves thermal equilibrium. It is therefore advisable that the balance is continuously connected to power.

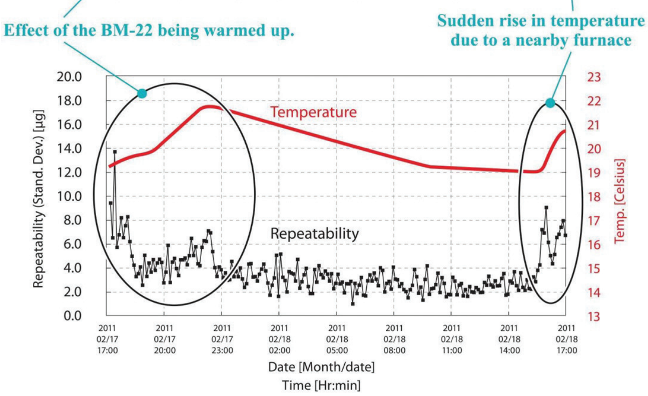
Case Study
The two graphs below show data taken at a university research laboratory over a 24 hour period using BM-22 microbalance*. Its internal calibration weight (approx. 20 g) was automatically applied and removed in 40-second cycles, simultaneously logging the balance temperature, zero point and span value (Graph 1).

Repeatability (standard deviation) was calculated for every 10 consecutive span values (Graph 2).

Both the zero point and repeatability were clearly influenced by temperature changes.



Graph 1. Temperature, zero point and span value changes over 24 hours



Graph 2. Temperature and repeatability changes over 24 hours

**Note: The BM-22 is a smart-range model with 5.1 g / 22 g capacity and 0.001 mg (1 µg)/0.01 mg readability. Its repeatability specification for a 1 g weight is 0.004 mg (4 µg).*

TIP #5: Prevent Airflows and Air Pressure Changes

Why?
Breezes or air circulation surrounding the balance can destabilize measurements. Breeze from air conditioners can impact balance stability and the cold air could introduce temperature fluctuations, to which microgram measurements are especially susceptible (see also Tip: 2 “Ensure that the ambient temperature is stable”).

Other potential sources of air and pressure changes could be people passing by or even opening and closing of doors.

Solution
Here is a list of what you can do to minimize the effects of airflows and air pressure changes:

1. Keep the balance away from the source of any breezes, such as ventilators or air conditioners.

   If that is difficult, use partitions to cut off direct breezes.
2. Put an external breeze break (draft shield) over the balance.

   In addition to protecting the balance from air movement, this can also mitigate the effect of temperature changes.
3. If possible, replace swinging doors with sliding doors as the former causes larger pressure changes. Also, avoid making the room airtight. Secure a vent to let air in and out if necessary.
4. Do not perform measurements when a rapid fluctuation in atmospheric pressure is observed.

   Measurements are easily disturbed by rapid atmospheric pressure changes as well as swaying of the building due to strong winds caused by the passing of a low-pressure system. (see also Tip: 1)

   For stable weighing, it is desirable that daily fluctuation of atmospheric pressure be 10 hPa or less.

Monitoring the Environment

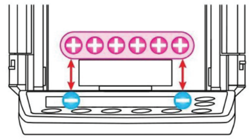
Controlling the environmental conditions is a prerequisite for stable measurement with a lab balance.There are devices that allow you to monitor and record, with date and time, changes in temperature, humidity, atmospheric pressure and even vibration. Additionally, most environmental loggers, when connected to a balance, can save mass values sent from the balance together with the environmental data.

Weighing Environment Logger

Operational Tips

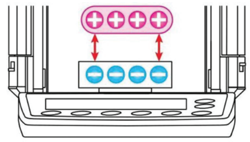
TIP #6: Prevent or Eliminate Static Electricity

Why?
Static, while often overlooked, can seriously impact precision weighing. An electrostatically charged object induces the opposite charge in nearby objects. The resulting attraction will make stable measurement extremely difficult.



Error when weighing a charged object.

Initially, the static will cause the object to appear heavier. The value then changes as static is dissipated into the air or via the weighing pan.



Error when a charged object approaches.

Static attraction can pull the weighing pan in the opposite direction and cause values to drift.

Filter papers, disposable weigh boats and plastic centrifuge containers can all become charged just from normal handling. Charged powders can be displaced, causing cross-contamination.

Solution
Here is a list of what you can do to minimize the effects of static electricity:

1. Keep the room humidity higher than 40% RH - between 45% and 65% is ideal.

   Static will easily occur when humidity drops below 40% RH. This is especially common in dry winters, during which people and their clothing can also quickly become charged.Select a balance with a weighing chamber whose glass panes are treated with conductive material. This will prevent the electrical lines of force from entering the weighing chambers.
2. Avoid using plastic or glass containers under low humidity conditions. Use metal containers instead.

   Non-conductive materials such as plastic or glass are highly susceptible to static electricity.

Microbalance with built-in ionizer (static eliminator)

External Ionizer (static eliminator)

3. The most effective method of eliminating static is by using an ionizer. Ionizers are either built into the balance or can be used externally, depending on the model. The simple process only requires the user to hold the sample in front of the ionizer for 2 seconds before starting the measurement.

   Higher quality models will use a fan-less ionizer which doesn't create a breeze that can blow away samples or impact the measurement.

   See the video on the BM Series page at **www.andweighing.com.**

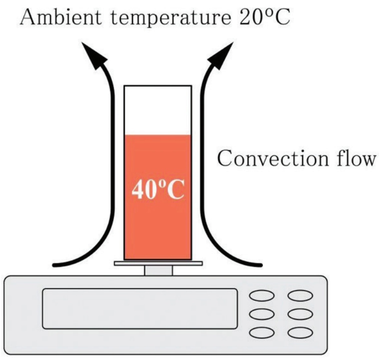


Figure 3: Convection Flow

TIP #7: Minimize Convection Flows Inside the Weighing Chamber

Why?
Samples that have a different temperature than the surrounding environment can create convection flows which will create air currents and effect the balance performance.

When the temperature of the sample is higher, a layer of ascending warm air will be generated around it, which will then push the sample upward and make the value appear lighter, as shown by Figure 3. (Conversely, when it is lower, the value will appear heavier.)

As the sample cools down and the convection flow becomes weaker, the display value will gradually increase, making the measurement unstable.

In addition, a convection flow can occur when you open the door to the weighing chamber and replace the air inside. This will bring changes in temperature to the chamber and become another factor for drift and poor repeatability.

Body heat from your hand can also disturb the temperature in the chamber.

Solution
Leave the weighing sample and container near the balance, or inside the balance, for a sufficiently long time for acclimatization to occur before starting measurements.

When placing the weighing sample on the pan, open the door only to a minimal degree, and close it gently but swiftly.

Never transfer the sample or container with your hand. Instead, use tweezers that are long enough to reach the pan area without having to put your hand in.

TIP #8: Avoid transferring body heat to the balance

Why?
Body heat and breathing can affect the weighing sensor and cause values to drift.

Solution
Maintain adequate distance from the balance. Ensure that your body heat is not elevated while performing measurements. The best measure is to put an external breeze break (draft shield) over the balance to protect against any external heat influence.

TIP #9: Minimize shock and vibrations

Why?
Shocks to the load cell result in variations in the zero point and reduced repeatability.

Solution
Gently open and close the chamber doors and place samples on the pan with care to avoid shock or vibration.

Press keys gently, or ideally, use a remote input device, such as an external indicator, to avoid pressing the keys altogether.

It is also advised to perform “pre-loading” – placing a weight on the pan once or twice before starting actual measurements – to allow the weight sensor a break in and warm up period.

Microbalance with remote display

TIP #10: Use the Internal Calibration prior to each session.

Performing an internal calibration will automatically adjust the balance to current environmental conditions which may have varied since previous measurements.

Some balances also allow for an automatic internal repeatability test to determine current standard deviation and identify potential performance issues.

TIP #11: Always wait for the stability indicator to appear before recording the weight.

Balances can exhibit slightly different behavior depending on the measurement conditions, including the operator at the time. Try to be as consistent as possible with each weighment- duplicating as close as possible the location on the pan, the opening of the door, sample time on the pan, etc.

Measured this way, balances will provide more repeatable, reliable results.

When the sample is powder, adding it to a weigh boat should be done outside the balance in order to maintain the same interval as well as to prevent cross contamination inside the weighing chamber.

TIP #12: Disable the Zero-tracking Function When the Amount to be Weighed is 100 µg or Below

When the sample placed is lighter than 100 µg, the measured value increases so slowly that if the zero tracking is active the balance may judge it to be a drifting of the zero point. As a result, the display value will remain zero.

Please note that without zero tracking the zero-point drift is visible on the display. It is therefore recommended to re-zero the balance immediately before each measurement.

Appendix A: Case Study: Measuring a 20-µg Polystyrene Sphere

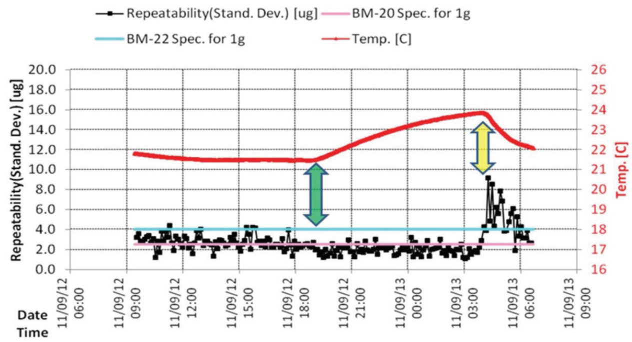
Static was removed from a single sub-mm polystyrene sphere using the built-in ionizer of the BM-20. Note that the door is open a minimal distance, in this case 3 cm, and that the user's hand never enters the chamber.

Here we see the final value of 20 µg as indicated by the stable icon. See the video on the BM Series page at www.andweighing.com.

Appendix B: AND-MEET Measurement Environment Evaluation Tool

A&D has developed a way to measure and quantify the actual environment where a balance operates. Called AND-MEET, this tool uses a Data Logger (below). Using the repeatability test function, the balance records the weighing data, zero point and span, together with environmental readings: T, RH and atmospheric pressure, saving data over a 24-hour period in a .CSV file (below). AND-MEET graphically displays the weighing environment making it easier to identify issues (below, bottom)

BM-20	SN	T1000414	VR	1.31			
#	Date	Time	Stable	Reading	T	RH	Pressure
1	2/10/2012	15:49:32	ST	+00.000019 g	+20.45C	49%	1017hPa
2	2/10/2012	15:49:52	ST	+20.574303 g	+20.45C	49%	1017hPa
3	2/10/2012	15:50:12	ST	+00.000038 g	+20.46C	49%	1017hPa
4	2/10/2012	15:50:32	ST	+20.574310 g	+20.46C	49%	1017hPa



**Data captured with AND-MEET. Note that measurement stability improves after 1900h, when fewer people are in the building (green arrow). At 0400h air conditioning turns on, which blows air and causes the spike in repeatability (yellow arrow).*

Appendix C: Tweezers for Use with a balance

The two tweezers supplied with BM Series balances are above the ruler in the photo. Below the ruler is a special version of the *AD-1689 tweezers* modified: 1) to be easier to squeeze shut, so that users can hold them closer to the far end, keeping their hand further outside of the chamber; 2) a finer and extended tip, increasing the overall reach of the tweezers. Contact A&D for more details.

A&D Weighing

andweighing.com