A&D Weighing

12 Tips You Can Use to Perform Stable Measurements With a Microbalance

Table of Contents

Common challenges in precision weighing and with microbalances

- "The display value keeps changing and never seems to settle"
- "I get an inconsistent result every time"
- "There just seems to be something wrong with my microbalance"
- "I'm not even sure that I installed the microbalance correctly"

The microbalance is an extremely sensitive device. Its scale interval of 1 μg (microgram) 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, as with the BM-20 microbalance. When making comparisons to length, this 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 set-up environment or the way the user interacts with the microbalance can significantly affect measurement stability. The trouble is, however, that most users may not realize what is actually making measurements *appear* unstable.

The purpose of this Product Note is to shed light on typical instability factors, in relation to both installation and operation, and then help you solve most problems by yourself.

In case you still have difficulty in achieving stable measurements after reading this, or simply want expert advice or assessment at your location of use, please contact your local A&D representative.

Terms used and their concepts

Zero point and span value

The zero point is the output of a balance before the weighing sample is placed on its pan, and is used as the base point of measurement. The span value on the other hand is the amount of change in the output as a result of the sample being placed on the pan, indicating the net weight of the sample.

To obtain a span value, you need to subtract the display value at the zero point from the display value when the sample is loaded. 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.

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

Repeatability

Repeatability is the variation in the measured values when the same mass is loaded repeatedly under the exact same conditions (based on the premise that the 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 weighings will fall within ± 0.004 mg of their mean value with a probability of 68% (see Figure 1).

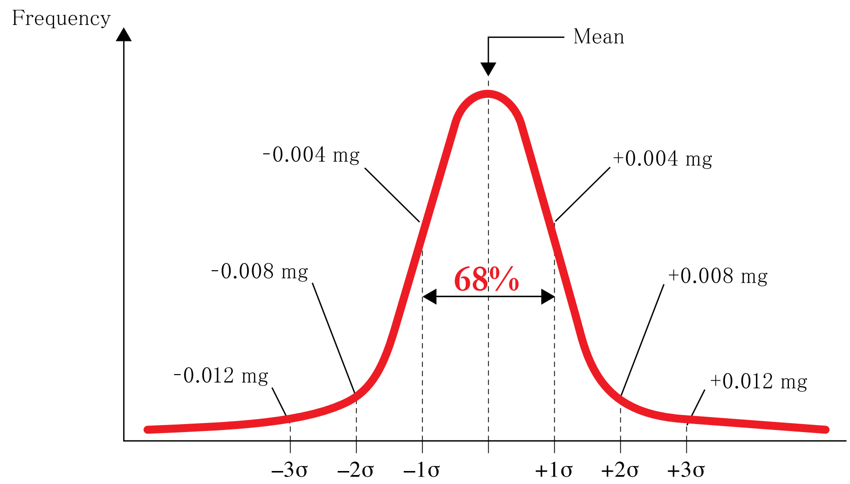


Figure 1. Assumed distribution when the standard deviation is 0.004 mg

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 is also known to adversely affect the repeatability performance. For these reasons, whether you can achieve stability in microgram measurements will depend greatly on how much you can suppress the movement of the zero point.

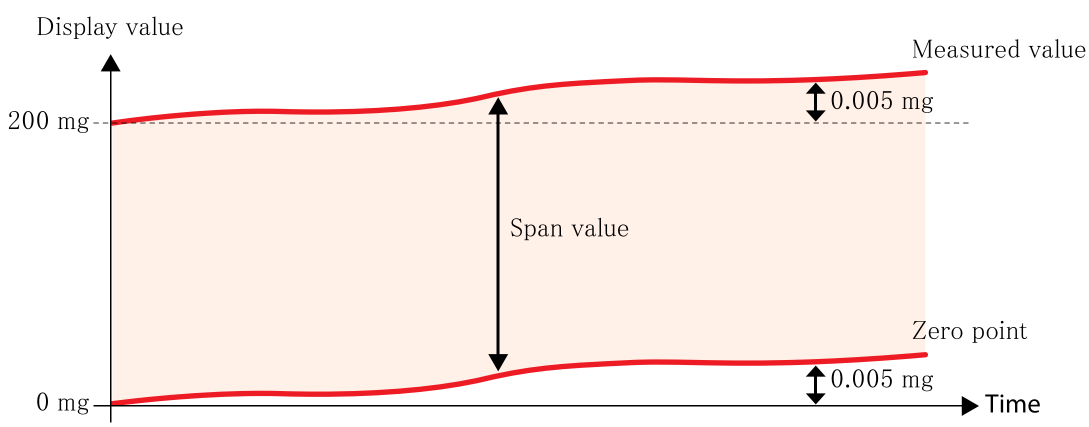


Figure 2. The span value remains fairly constant while the zero point may drift.

Tips in relation to “installation”

Tip: 1

Avoid or isolate all possible sources of vibrations even when you cannot actually feel them

Why?

Microbalances 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 microbalance unstable.

Solution

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

① Install the microbalance 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 people’s passage 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 microbalance on a heavy, rigid workbench, where no activity other than weighing is to 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 being transmitted.

④ Use a passive anti-vibration table recommended by the balance manufacturer, such as the AD-1671 from A&D.

AD-1671 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 microbalances.

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 microbalance to achieve stability again.

⑥ Lower the weighing speed of the microbalance.

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

Finally, it is desirable that the place is ⑦ far away from routes with high traffic or heavy objects moving, and ⑧ 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 not just the measurement accuracy but also the stability of the zero point (refer to “Zero point and span value” as well as “Zero point drift” on pp.4-5).

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 easily affect results by seriously worsening the repeatability of a microbalance.

Solution

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

① Maintain the room temperature within a certain range. Use an air conditioner as necessary.

Daily temperature fluctuations of 4°C or less (within 10 to 30°C) and short term fluctuations of 0.2°C/30 minutes or less are recommended.

② At the same time, keep the microbalance away from the air conditioner vent, and cover it with an external breeze break (draft shield), such as the A&D AD-1672.

AD-1672 Tabletop Breeze Break

While air conditioning can keep the temperature in the room at a steady level, it also generates airflows.

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 “Prevent airflows and air pressure changes” on p.11).

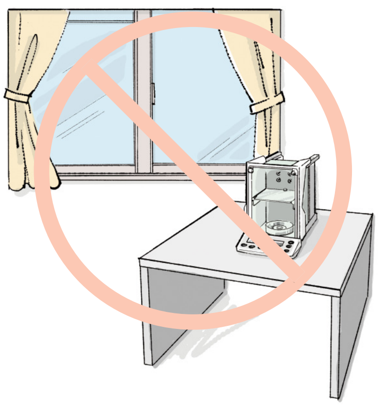
As a countermeasure, the microbalance should be arranged so that it is not directly hit by airflows. In addition to keeping a distance from the air conditioner, use of a large, external breeze break that covers the entire microbalance unit has proven to be highly effective and is therefore strongly recommended. It is also a good idea to have a partition between the air conditioner and the set-up area.

③ Keep any heat generating devices (e.g. furnace, lamp, etc.) far away from the microbalance, or if possible, out of the room.

If you cannot move those devices, do not perform measurement while they are in operation (see Case Study on p.10).

④ Avoid installing the microbalance in areas close to external air (near windows, doors, etc.) or subject to direct sunlight.

Also, walls that have outside air on the other side often go below or above room temperature. For this reason, it is best to install the microbalance near a wall that has another room on its opposite side.



⑤ Set up the microbalance 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 being transmitted, not to mention vibrations.

⑥ 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 due to a shift in humidity.

Solution

Control changes in humidity, using an air conditioner as necessary.

Daily humidity fluctuations of 10% or less is recommended.

Tip: 4

Wait until the microbalance is sufficiently warmed up and acclimatized to the room temperature and humidity

Why?

It usually takes from 8 to 12 hours for a microbalance to adjust to the room environment after being plugged in. During this period the zero point drift becomes particularly large, worsening repeatability (see Case Study on p.10).

Solution

Install and plug in the microbalance 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 and the thermal distribution within the microbalance more even the longer the microbalance is hooked up to a power source. It is therefore advisable that the microbalance is constantly connected to a power source where possible.

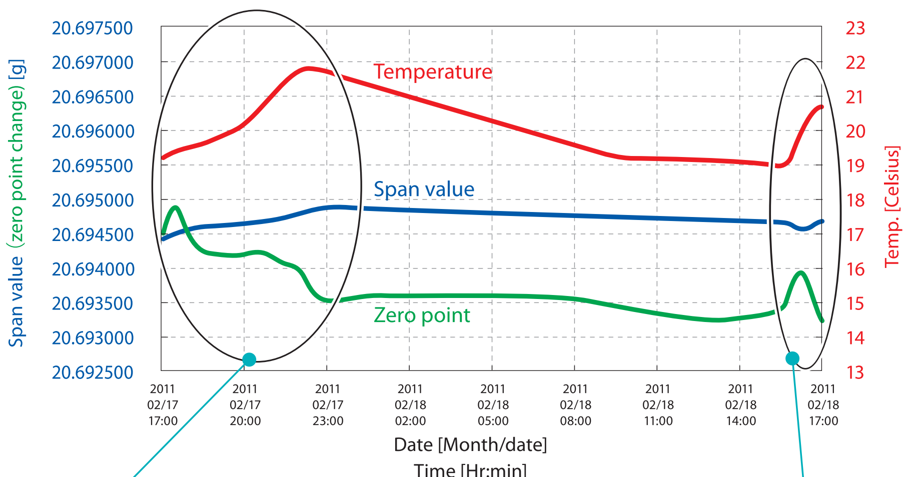
Case Study

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

*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).

Further, repeatability (standard deviation) was calculated for every 10 consecutive span values (Graph 2).

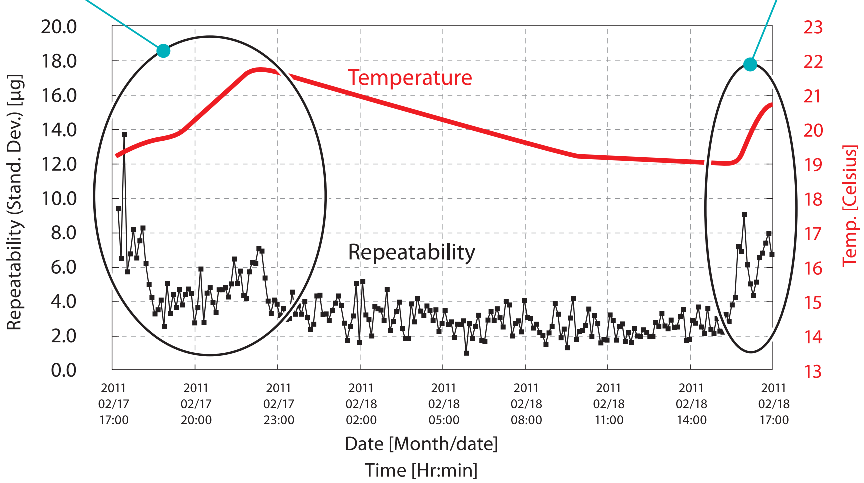
As you can see, both the zero point and repeatability were clearly influenced by temperature changes.



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

Effect of the BM-22 being warmed up.

Sudden rise in temperature due to a nearby furnace



Graph 2. Temperature and repeatability changes over 24 hours

Tip: 5

Prevent airflows and air pressure changes

Why?

Breezes or air circulation hitting the microbalance destabilizes measurements. Flows from an air conditioner can not only sway the balance unit but cause temperature fluctuation, to which microgram measurements are especially susceptible (see also Tip: 2 “Ensure that the ambient temperature is stable” on p.7).

Air turbulence or pressure change caused by people passing by, the opening and closing of doors and so forth, also lowers the stability of microbalances.

Solution

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

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

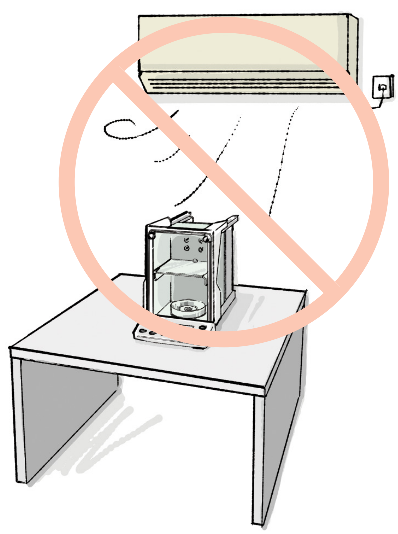
If that is difficult, use partitions to cut off direct breezes.

② Put an external breeze break (draft shield) over the microbalance, such as A&D’s AD-1672.

In addition to protecting the microbalance from air movement, this can also mitigate the effect of temperature changes.

③ If possible, replace swinging doors with sliding doors as the former cause larger pressure changes. Also, avoid making the room airtight. Secure a vent to let air in and out if necessary.

Of course, avoid setting up the microbalance near a door, from which people and external air can enter and disturb the measurement.



④ Do not perform measurements when a rapid fluctuation in atmospheric pressure is observed.

Measurement is 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 “Avoid or isolate all possible sources of vibrations even when you cannot actually feel them” on pp.5-6).

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

Monitoring the environment

As has become clear by now, controlling the environmental conditions is a prerequisite for stable measurement with a microbalance. For this purpose, it will be very convenient if you have a device that can simultaneously measure multiple key environmental parameters, such as A&D’s AD-1687.

The AD-1687 allows you to monitor and record with date-and-time changes in temperature, humidity, atmospheric pressure, and even vibration. Moreover, when connected to an A&D balance, it saves mass values sent from the balance together with these environmental data.

AD-1687 Weighing Environment Logger

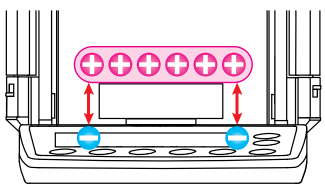
Tips in relation to operation

Tip: 6

Prevent or eliminate static electricity

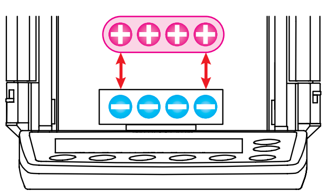
Why?

Static, while often overlooked, can seriously degrade 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

The object will 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 handle the effects of static electricity:

① Keep the room humidity higher than 40% RH.

Static will easily occur when humidity drops below that level. This is especially common in dry winters, during which people and their clothing can also quickly become charged.

② Select a microbalance with a weighing chamber whose glass panes are treated with conductive material, such as BM-20 or BM-22.

This will prevent the electrical lines of force entering the weighing chamber in case the operator's clothing is charged, such as polyester lab coats.

③ 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.

④ Use an ionizer (static eliminator). Better yet, use a microbalance with a built-in ionizer, as the BM-20, pictured at right.

This is the quickest, easiest and surest way to completely remove static charge from weighing samples and containers. All you need to do is hold them in front of the ionizer for a second or two before starting the measurement. The ionizers supplied by A&D are fanless, direct current (DC) type, which create no breeze that could blow away fine powder samples.

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

BM-20 Microbalance

AD-1683 Static Eliminator

Tip: 7

Minimize convection flows inside the weighing chamber

Why?

If, for example, you bring in a weighing sample from another location and measure it right away, there may be a difference in temperature between the sample and its surroundings.

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 faint changes in temperature to the chamber and become another factor for drift and poor repeatability.

Putting your hand into the weighing chamber will also disturb the temperature in the chamber.

Solution

Leave the weighing sample and container near the microbalance, or inside the balance on the shelf, 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 minimum degree, and close it gently but swiftly.

Never grab 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.

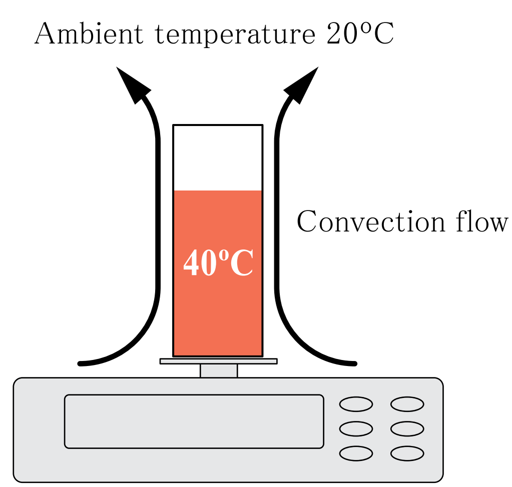


Figure 3. Convection flow

Tip: 8

Protect the microbalance from your body heat and breath

Why?

Heat emitted from your body or conveyed by your breath can affect the weighing sensor and cause values to drift. Your breath, if strong, can also create airflows and destabilize measurements.

Solution

Only draw as close to the microbalance as is necessary. Take measures to contain your body heat such as wearing a lab coat and mask. Avoid performing measurements immediately after meals, after which your body heat increases. The best measure is to put an external breeze break (draft shield) such as the AD-1672 over the microbalance.

Tip: 9

Avoid impacts or tremors to the sensor

Why?

Sensor shocks result in variations in the zero point and reduced repeatability.

Solution

Do not open or close the doors roughly causing an impact. Avoid poking the weighing pan with tweezers or dropping the sample on the pan.

Press keys gently, or ideally, use a remote controller. The AD-8922A is recommended when the microbalance is on an anti-vibration table, as any vertical force can tilt the balance leading to inaccuracies.)

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

AD-8922A Remote Controller shown on the right

Tip: 10

Use the internal calibration of the microbalance for a quick check of the environmental conditions at the time

Count the number of seconds required to complete the internal calibration. If it took longer than usual, it is a sign that there is something wrong with the measurement environment and it would be best to delay the measurement until a later time.

Alternatively, with A&D's BM-20/22 microbalances, it is possible to run an automatic repeatability test, which automatically measures the internal calibration weight (approx. 20 g) 10 times and calculates repeatability (standard deviation), to inspect the performance under the given environment.

Tip: 11

Set a consistent time interval for reading the display value

Microbalances can exhibit slightly different behavior depending on the measurement conditions, including the operator at the time. Using a stop-watch, decide how many seconds after placing the sample* you find it most comfortable to record the display value. If it was, say, 20 seconds, then always read the values after 20 seconds for all further measurements as well.

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

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

*Note: The weigh boat can be used as a test weight.

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 microbalance 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 minimum distance, in this case 3 cm, and that the user's hand never enters the chamber.

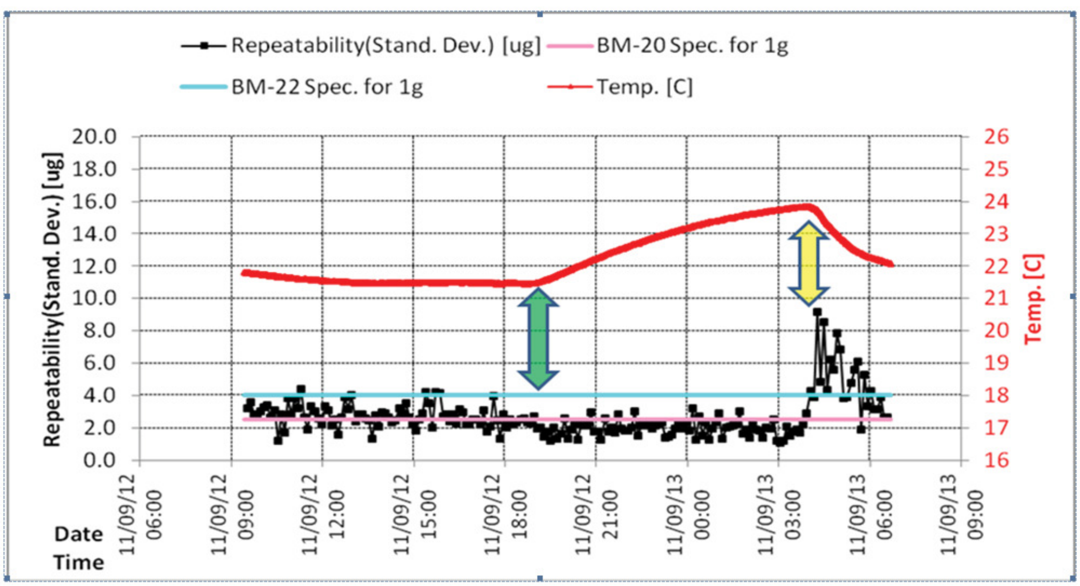
Here we see the final value of 20 µg as indicated by ○ (the stable icon). See this video on the BM Series page on our website.

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 the AD-1688 Data Logger (right), included with every BM Series balance. 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 (lower figure.)

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

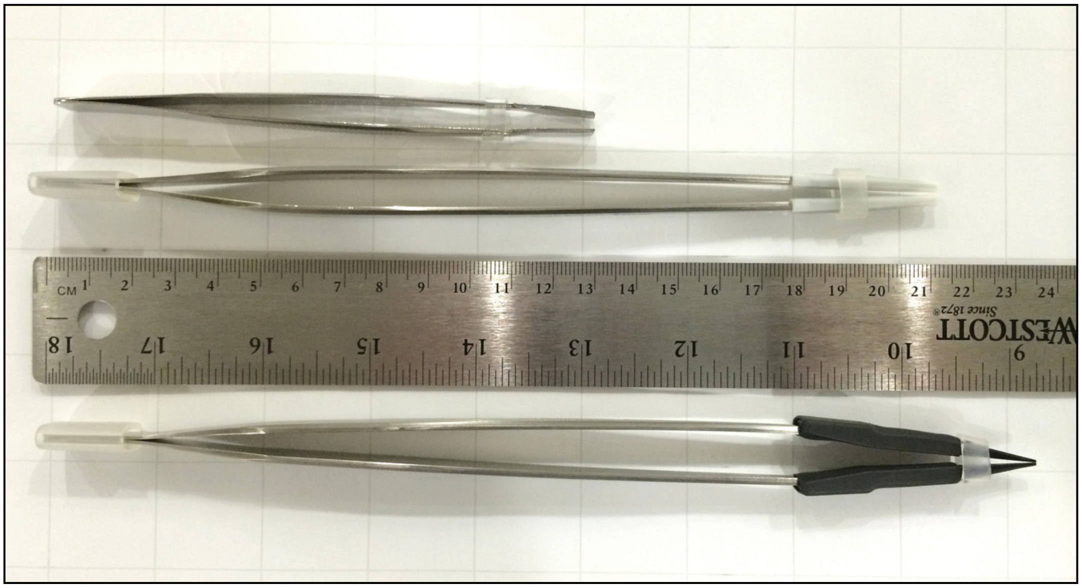


Data capture with AND-MEET. Note that measurement stability improves after 1900h, when fewer people are in the building (green arrow). At 0400h air conditioning turns on, which blows air and causes the spike in repeatability (yellow arrow).

Appendix C

Tweezers for use with a microbalance

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.



Not shown actual size. See ruler for scale.

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