Training Material for Balances (1)

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Marketing Department
A&D Company, Limited

Contents

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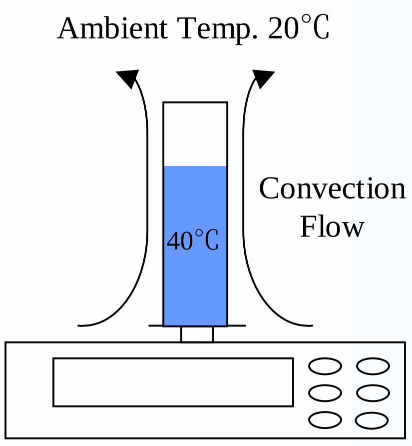
Things you should know before using a balance

1. Convection Flow

A) Effects of Convection Flows



If the surface of the sample (object to be measured) is hotter than the ambient temperature, an ascending air current will be generated near the sample.

Since this air current will lift up the sample, the balance will display a weight that is lighter than the actual sample.

As the sample cools down and the convection flow becomes weaker, the displayed weight will gradually increase, making the balance appear unstable.

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1. Convection Flow

B) Preventing Convection Flows

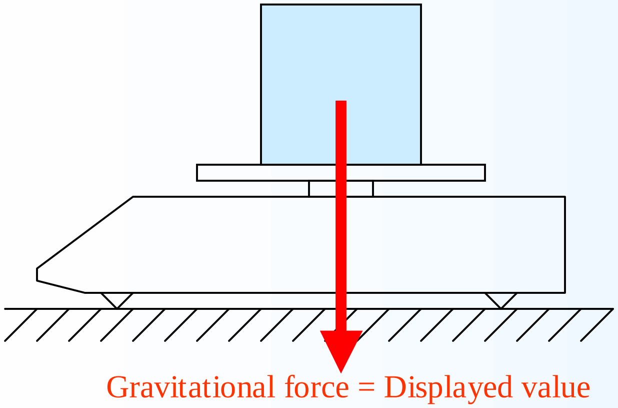
- Wait until the sample and the tare are balanced with the ambient temperature.
- Refrain from directly touching the sample or the tare. Use tweezers instead.
- Do not place the balance where there could be a rapid temperature change (e.g. near a window, under direct sunlight, etc.)
- If a temperature change is inevitable, take countermeasures such as shielding the balance from the surrounding heat, etc.

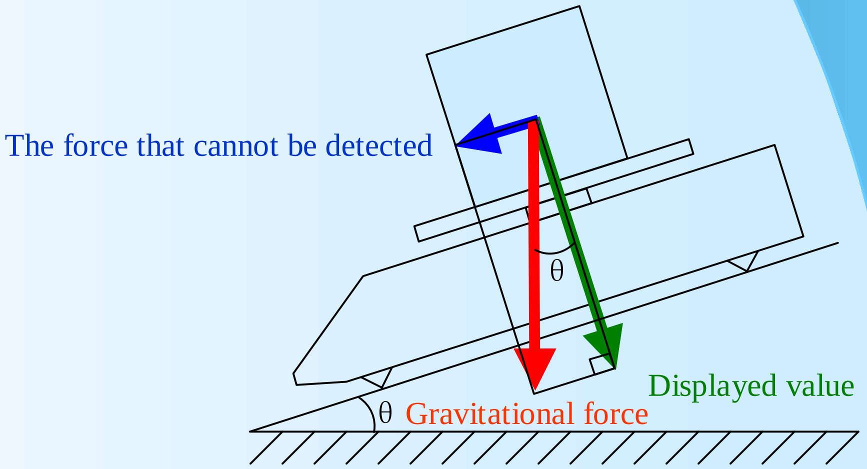
2. Tilting

A) Effects of Tilting

When a balance is placed horizontally, it detects the gravitational force that is applied to the sample vertically.

However, if the balance is placed on a slope, the gravitational force applied to the sample will be broken down to the longitudinal and lateral directions of the balance. As the balance detects only the longitudinal force, it will display a smaller value than the actual weight of the sample.





2. Tilting

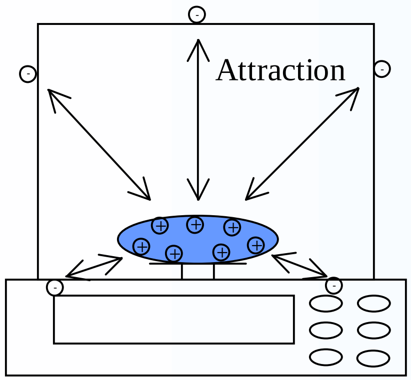
B) To Avoid Tilting

- Level the balance using its leveling feet.
- If leveling is difficult, calibrate the balance in the current position.

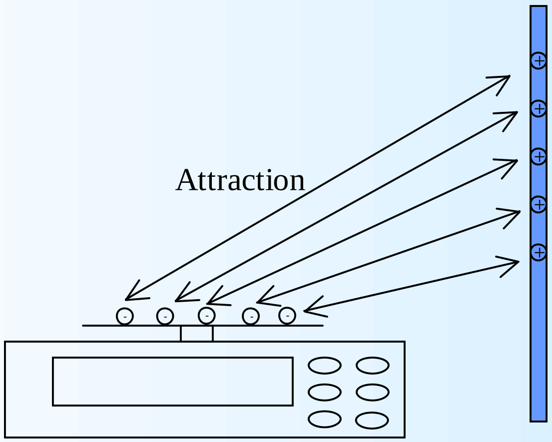
3. Static Electricity

A) Problems due to Static Electricity

When the sample is electrostatically charged, the sample and the objects surrounding the sample will attract each other. This makes an accurate measurement difficult. Moreover, the static electricity moving into the air or the weighing pan over time will cause a gradual change in the displayed value.



Measuring a charged object



There is a charged object nearby

When a charged object comes closer, the opposite electricity will be generated in the surrounding objects. Consequently, the charged object and the surrounding objects will attract each other. (Dielectric Polarization)

3. Static Electricity

In winter, for example, operators wearing sweaters can be electrostatically charged. When electrostatically charged operators use an electronic balance, the displayed value may well become unstable.

A&D’s analytical balances are equipped with a breeze break whose surface has an evaporated thin metal layer to shield the chamber from outside static electricity. Our resin breeze breaks are also coated with antistat.

3. Static Electricity

B) Causes of Static Electricity

- Contact electrification occurs when two objects make contact with each other.
- Frictional electrification occurs when objects are rubbed together.
- Peel electrification occurs when peeling something off from an object.
- Impact electrification occurs when objects collide with each other.

Materials susceptible to static electricity

- resin, glass, powder, insulators such as film and paper

Places where static electricity is easily generated

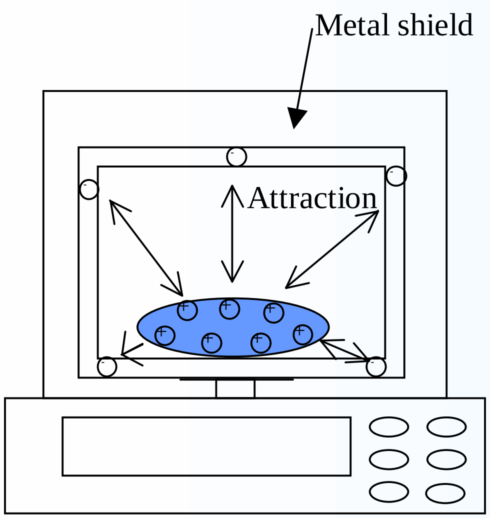
- production lines or belt conveyers, dried places, etc.

It is widely believed that little static electricity occurs where the humidity is kept higher than 45%RH. In actuality, static electricity often exists where there is constant friction, such as on production lines and belt conveyers.

3. Static Electricity

C) Preventing Static Electricity

Two principal measures to prevent static electricity are removal and shielding.



- Eliminate the static electricity using AD-1683
- Enclose the charged object with a metal tare to block the electricity
- Apply an antistatic agent
- Raise the humidity (not lower than 45%RH)

3. Static Electricity

D) Troubles caused by Static Electricity

(Case 1)
In a production line of secondary batteries, frictional electrification took place between the stainless secondary batteries and resin jigs, causing a zero drift on AD-4212A-200. Simply placing AD-1683 near the weighing sensor solved the problem.

(Case 2)
In an application process of cream solder where the discharge rate was periodically checked with AD-4212A-100, there was a resin breeze break near the weighing sensor. This breeze break was electrostatically charged and was making the weighing value unstable. Again, AD-1683 solved the problem.

(Case 3)
We received a complaint from a GP-12K user saying that the counting mode was not stable enough, and that even A&D's repair service did not fix the problem. It was later found that they were counting resin components placed in a resin bowl, near the entrance of a building. In addition to avoiding the wind from the entrance, we recommended using AD-1683, wrapping the bowl with an aluminum foil, or applying antistat.

4. Magnetic Material

A) Influence of Magnetic Materials

When measuring a magnetic material or a magnetized sample, it may attract and be attracted to the surrounding components of the balance, or be influenced by the magnetic force of the sensor coil. This will lead to inaccurate weighing results.

B) Measures to counter Magnetic Materials

Keep a distance between the sample and the balance.

- Use the underhook and increase the distance between the sample and the balance.
- Cover the sample with highly permeable, soft magnetic material, such as permalloy (magnetic shielding).

5. Air Current (Wind)

A) Influence of Air Currents

Weighing becomes unstable when the weighing pan or the sample are subject to wind. Even an air current that is too weak for a human to sense can easily make the measurement unsteady.

Places where Air Currents often occur

Near an air conditioner, near a doorway, near a passageway, wherever there is a temperature change

B) Measures to counter Air Currents

- Change the location and install the balance where the influence of the air current is insignificant.
- Attach a breeze break and prevent the direct contact of the wind.
(Caution: There is a possibility of static electricity depending on the material the breeze break is made from.)

6. Vibration

A) Influence of Vibrations

Weighing becomes unstable when the balance is subject to vibrations. Low-frequency vibrations are especially troublesome.

Situations in which Vibrations often occur

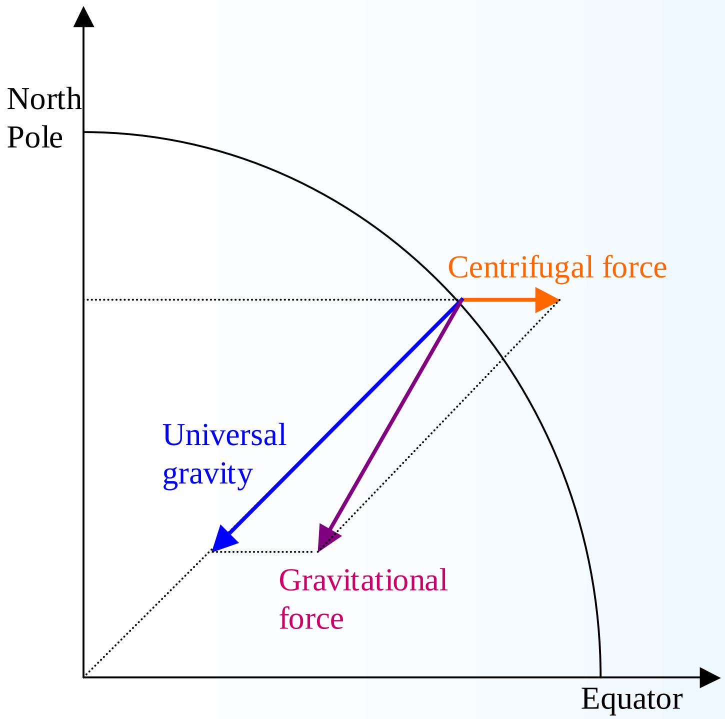
- On the 2nd floor or higher of a building
- Windy days
- In an earthquake-proof building after there is an earthquake
- Unstable ground (reclaimed land, riverside, seaside, etc.), especially on a windy day
- Seaside, on a day of high waves

B) Measures to counter Vibrations

- Set the response speed at “SLOW”
- Install the balance on an anti-vibration table, such as AD-1685

7. Acceleration of Gravity

A) What is Gravity?



Objects on the earth are constantly subject to the “universal gravity,” which attracts them toward the center of the earth, as well as the “centrifugal force” caused by the rotation of the earth.

The gravitational force is the resultant of the universal gravity and the centrifugal force.

7. Acceleration of Gravity

The “magnitude of the gravitational force” (F) is the product of the “acceleration of gravity” (g) and the “mass of the object” (m).

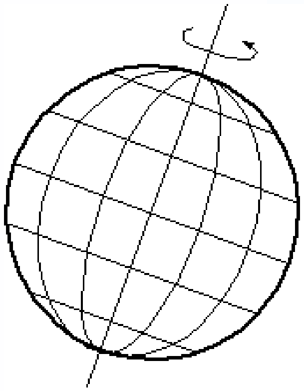
$$F=mg$$

In fact, what electronic balances measure is the gravitational force on the sample. Therefore, if the acceleration of gravity varies, the displayed value will also vary.

The acceleration of gravity varies with latitude and altitude.

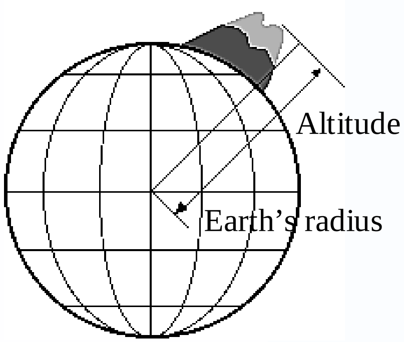
7. Acceleration of Gravity

B) Changes in the Acceleration of Gravity



Changes by latitude

Earth’s rotation generates the centrifugal force, which counteracts the universal gravity. The centrifugal force becomes larger closer to the equator. In contrast, the acceleration of gravity becomes smaller closer to the equator.



Changes by altitude

If the latitude is the same, the higher the altitude, the longer the distance from the center of the earth. Hence, the acceleration of gravity is also smaller. For instance, if a weight measured on the ground is 500g, is then measured at an altitude of 100m,

$$500.000g \times \frac{(\text{Earth's radius})^2}{(\text{Earth's radius} + 100m)^2} = 499.9843g$$

* On the premise that the earth’s radius is 6,371,000m

7. Acceleration of Gravity

C) Influence of the Acceleration of Gravity

What happens when a balance calibrated with a 100.0000g weight at our Kensei factory is brought to a different location?

Location	Acceleration of Gravity (m/sec^2)	Displayed Value (g)	Difference from Kensei Factory (g)
Helsinki	9.819	100.1939	0.1939
Paris	9.809	100.0918	0.0918
Kensei Factory	9.800	100.0000	0.0000
Tokyo	9.798	99.9796	-0.0204
Singapore	9.781	99.8061	-0.1939

To avoid these variances, a balance with a high resolution needs calibration at the point of use. In case of a scale with a lower resolution, select a preset acceleration of gravity according to the area of use.

8. Buoyancy

Air has a density of approximately 1.2kg/m^3 and therefore analytical balances are affected by buoyancy.

Ex) Measuring a 200g stainless steel weight (density 8g/cm^3) when barometric pressure is 1000hPa and air density is 0.0012g/cm^3

$$\begin{aligned}\text{Effect of Buoyancy} &= \text{Air Density} \times \text{Volume of the Weight}\\ &= 0.0012\text{g/cm}^3 \times 200\text{g} \div 8\text{g/cm}^3\\ &= 0.03\text{g}\end{aligned}$$

If barometric pressure changes to 980hPa, the error due to buoyancy is:

$$\begin{aligned}\text{Error due to Buoyancy} &= 0.03\text{g} - 0.03\text{g} \times \frac{980\text{hPa}}{1000\text{hPa}}\\ &= 0.6\text{mg}\end{aligned}$$

For example, suppose we calibrate a balance using a 200g weight when the barometric pressure is 1000hPa. If the next day the barometric pressure is 980hPa, the balance will display 200.0006g for the same 200g weight.

Maximum Permissible Errors On Initial Verification & In Service

Example of GP-30K*

Accuracy Class of GP-30K

- Maximum Capacity:	Max. = 30kg
- Verification Scale Interval:	e = 1g
- Actual Scale Interval:	d = 0.1g
- Number of Verification Scale Intervals:	n = 30,000g/1g = 30,000

(n = maximum capacity/verification scale interval)

According to the principles of classification prescribed by the OIML, if the

Verification scale interval is:	$0.1g \leq e$
Number of verification scale intervals is:	$5,000 \leq n \leq 100,000$

then the accuracy class should be Class II.

* Verification model

Maximum Permissible Errors

For Class II

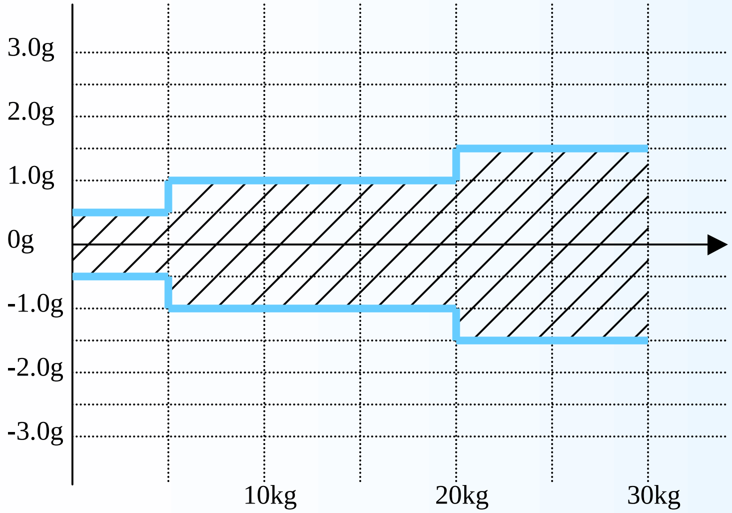
(GP-30K: Max. = 30kg, e = 1g, d = 0.1g)

Number of Verification Scale Intervals		Maximum Permissible Errors		
		On Initial Verification		In Service
$0 \leq n \leq 5{,}000$	0kg ~ 5kg	0.5e	0.5g	1.0g
$5{,}000 < n \leq 20{,}000$	5kg ~ 20kg	1.0e	1.0g	2.0g
$20{,}000 < n \leq 100{,}000$	20kg ~ (31kg)	1.5e	1.5g	3.0g

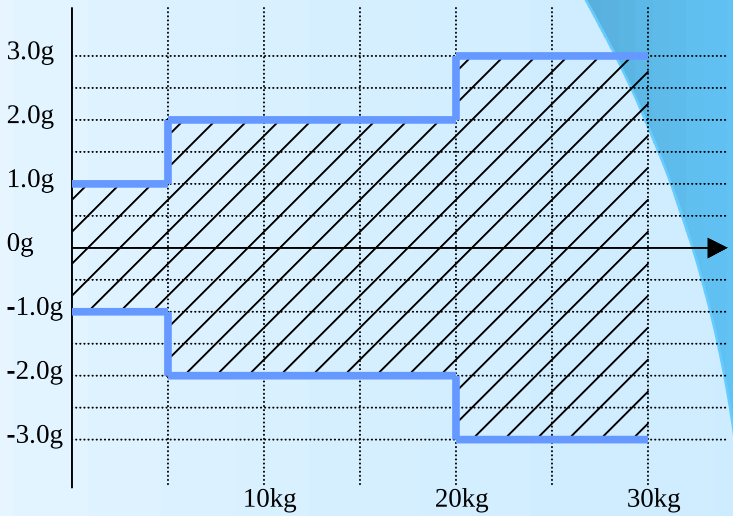
Maximum Permissible Errors

For corner (eccentric) loading, the indications must meet the maximum permissible errors on initial verification when a load corresponding to 1/3 of the maximum capacity is applied at four positions, half the distance from the center (e.g. 10kg for GP-30K).

The maximum permissible errors in service shall be twice the maximum permissible errors on initial verification.



On initial verification



In service

Validations

What Is Validation?

<u>Requirements come from Pharmaceutical Industries</u>

All drugs sold in the U.S. must be certified by the FDA (U.S. Food and Drug Administration) and be manufactured in compliance with GMP. Hence, GMP has become the national standard for all pharmaceutical companies.

- GLP
  - Good Laboratory Practice
  - Regulation related to the safety inspection of medicine
  - GLP assures quality and reliability of inspection data.
- GMP
  - Good Manufacturing Practice
  - Standard related to the production of medicine and quality control
  - GMP assures that products have a certain level of quality.

Items To Be Recorded

- Why, how and by whom the work was done
- Who was in control
- What equipment was used
- What results were obtained
- What problems were encountered
- How those problems were overcome

IQ	=	Installation Qualification
OQ	=	Operational Qualification
PQ	=	Performance Qualification

IQ, OQ, PQ

Installation Qualification

- Check if…
  - The delivered equipment is in accordance with the requested design and specifications.
  - The equipment has been installed under proper conditions.
  - The environment is adequate for the equipment.

Operational Qualification

- Check if…
  - The equipment, installed under proper conditions, operates properly (not required to satisfy the manufacturer's specifications).

Performance Qualification

- Prove that the equipment consistently maintains a certain level of performance when it is used for inspecting actual samples
- Assure that the equipment consistently provides reliable and accurate measurements in daily analyses

Uncertainty

What Is Uncertainty?

- Inference of the reliability of a measured value, taking into account errors caused by the installation environment
- Each variation relating to the measurement that had a large effect on the measurement (uncertainty component) is expressed as a standard deviation. All of the standard deviations are combined and then expanded to have a level of confidence of approximately 95% (coverage factor $k = 2$)

Major uncertainty components that affect the calibration of a balance

- Uncertainty of the calibration weight
- Uncertainty of repeatability
- Uncertainty of rounding error (digital display)
- Uncertainty of eccentric loading error
- Uncertainty of temperature characteristics (sensitivity drift)

The square-root of the sum of squares of all the uncertainty components is called the "combined standard uncertainty." When the coverage factor k = 2, the combined standard uncertainty is multiplied by two, which is called the "expanded uncertainty."

Typical Question

Q) What is the uncertainty of this balance?

A) Uncertainty is a comprehensive, evaluated value of the performance of weighing, taking into consideration different environments. Therefore, uncertainty cannot be determined based solely on the performance of the balance.

Recently, there has been a tendency to specify uncertainty for weighing results in scientific and technical papers. As a result, it has become necessary to evaluate the balance to be used as one of the uncertainty components.

Examples (Rough Estimates)

Minimum Weighing Value	Model	Calibration Point (No Tare)	Expanded Uncertainty ($k = 2$)
0.01 mg	GH-202	50 g	0.17 mg
	GH-252	100 g	0.31 mg
0.1 mg	GR-120 / GH-120	100 g	0.4 mg
	GR-200 / GH-200	200 g	0.6 mg
0.001 g	GX-200 / GF-200	200 g	0.004 g
	GX-600 / GF-600	500 g	0.004 g
	GX-1000 / GF-1000	1 kg	0.005 g
0.01 g	GX-2000 / GF-2000	2 kg	0.04 g
	GX-6100 / GF-6100	5 kg	0.05 g

i. Electronic balances are presumed to operate correctly in favorable environments.

ii. Uncertainty components considered for calibration are: 1) calibration weight, 2) repeatability, 3) rounding error, 4) eccentric loading error, and 5) temperature characteristics.

iii. Uncertainty is influenced by the condition of the electronic balance and environment at the time of calibration. As such, for purposes of accuracy, it is necessary to estimate the uncertainty of the actual balance machine in the environment in which calibration will be performed. The above examples are only the estimates of the calibration uncertainty calculated using actual balances.

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Calculating Uncertainty of GH-252

1) Uncertainty based on calibration weight

The calibrated weights to be used will be calculated as having the expanded uncertainties indicated below (coverage factor *k* = 2). The 100g weight to be used for calibrating GH-252 has the expanded uncertainty of 0.15mg, and the variance of the uncertainty is 0.00563mg.

Nominal Value	Expanded Uncertainty (*k* = 2)
50g	0.101 mg
100g	0.15 mg
200g	0.25 mg
500g	1.0 mg
1kg	1.5 mg
2kg	3 mg
5kg	5 mg

The expanded uncertainties of the calibrated weights above demonstrated the capability to calibrate OIML Class E2 weights at A&D’s calibration room.

Calculating Uncertainty of GH-252

2) Uncertainty based on repeatability

Uncertainty variance is 0.0009mg when based on the specification (repeatability) of GH-252, .

3) Uncertainty based on rounding error

Uncertainty variance is 0.000017mg when based on the minimum display value of GH-252.

4) Uncertainty based on eccentric loading error

Uncertainty variance is 0.00333mg when based on the specification of GH-252 at the time of production.

5) Uncertainty based on temperature characteristics

Uncertainty variance is 0.01333mg when based on the specification (sensitivity drift) of GH-252, if the change in temperature at the time of calibration is within Δ2ºC.

The expanded uncertainty will be twice the square-root of the sum of these variances.

$$\text{Expanded Uncertainty} = 2 \times \sqrt{0.00563 + 0.0009 + 0.000017 + 0.00333 + 0.01333} = 0.31\text{mg}$$