

COMMENTARY

An Electronic Analytical Balance: A Key Instrument in the Laboratory

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Abstract: Digital analytical balances are crucial in laboratory settings for accurately determining an object's mass. The precision of these balances highlights their importance in scientific endeavours. This study explores the significance of achieving equilibrium and other relevant concepts in analytics to advance the field. It examines a range of factors, with the balance as a focal point: identifying analytical challenges, where the balance plays a critical role in pinpointing potential areas of error or inconsistency; aligning well-established constitutive and operational concepts with these challenges; evaluating new theories; and developing clinical and laboratory tests based on current knowledge. This overview is a condensed compilation of data-sourced from pharmacopoeias and gathered via search engines such as Google Scholar, PubMed, and Scopus. The concept of balance is introduced not only as a physical principle but also as a pervasive notion that extends across various aspects of our work. The diverse array of motor skills is explored, accompanied by an essential scale for assessing them, shedding light on the depth and intricacy of the topic.

Keywords: analytical balance, electronic balance, Indian pharmacopoeia, sensitivity

1 Introduction

Weighing is a crucial step in analytical procedures, and it is made possible by using balance, an essential tool in our work. It isn't easy to imagine modern analytical procedures without electronic balances widely utilised in various fields. The balance is a device that plays a crucial role in determining the mass of an object. Although the SI unit of mass is the kilogram, we often work with smaller units such as μg , mg, or g. While most weighing instruments rely on different physical principles to determine the mass, they are generally based on weight, the gravitational force (FG) exerted by the Earth on the object being weighed. Understanding the principles of electronic balances is not just a theoretical exercise but a practical necessity in our work, as it allows us to accurately measure and analyses substances, thereby enhancing the precision and reliability of our results. The expression defines weight,

$$FG = m \cdot g \quad (1)$$

Where m is the mass of the object in kilograms and g is the local acceleration due to gravity in meters per square second (which is 9.81 m.s^{-2} at sea level). It is important to understand the two most common gravitational force weighing principles: force compensation and mass comparison with a known mass. This understanding determines whether the mass is directly measured (*e.g.*, using a beam balance) or calculated from the weight using the equation $FG = m \cdot g$ (*e.g.*, using a balance with electromagnetic force compensation). Having a clear grasp of this distinction and understanding its impact on the measuring principles of the balance is essential for proficiently operating electronic balances.

1.1 Types of balances

1.1.1 Electronic Balances

The electronic balance function is based on the fundamental force compensation principle to measure weight. When an object is placed on the balance, it exerts a gravitational force that is counteracted by either elastic deformation or an electromagnetic force. Elastic deformation

occurs when the object presses down on a spring element, causing it to react with a compensation force (F_c). This force, measured in Newtons, is calculated using the equation,

$$F_c = C_s \times \Delta s \quad (2)$$

C_s represents the spring constant in Newtons per meter, and Δs is the length change due to elastic deformation in meters.

Strain gauges measure strain or elongation and convert it into electrical resistance. High-resolution balances also use an electromagnetic force, known as the Lorentz force, to stabilize the load cell. This force is created by a current inside a coil surrounding a permanent magnet. Understanding the function of force compensation is essential for effectively operating electronic balances.

1.1.2 Mechanical Balances

The equal-arm beam balance is a widely used mechanical weighing instrument. It uses a two-arm lever and two weighing pans to measure an object's weight. The object is compared against counterweights positioned on the opposite end of the lever. Carefully selected counterweights maintain the balance beam in equilibrium.

1.2 Equipment

Balances can be classified based on their scale interval or readability, which refers to the smallest mass increment the balance can measure. Nowadays, most electronic balances display the weighing value on a digital screen rather than using traditional mechanical methods such as beam balances. Additionally, modern balances are equipped with features that indicate when the reading has stabilized and can be recorded or printed. They can also be integrated with other equipment like printers or electronic systems like laboratory information management systems. Analytical equipment used for tests like a loss on drying, thermogravimetry, and dynamic vapour sorption often includes built-in balances to measure changes in a sample's mass under specific conditions.

1.3 Installation

Analysts should review the manufacturer's information before installing a balance. The conditions of the facility where the balance is installed affect its performance.

1.4 Location

To ensure accurate measurements, it is imperative to place the balance in an optimal environment with regulated temperature and humidity and a consistent and clean electrical power supply. The location should be free of drafts and positioned away from potential sources of interference, such as ovens, furnaces, air conditioner ducts, cooling fans, electromagnetic radiation, direct sunlight, and magnetic fields. However, in some instances, it may be impractical to position the balance in an ideal environment due to potential facility issues such as air currents, extreme temperatures, humidity, nearby vibrations, and the use of corrosive materials. Under such circumstances, when the balance is situated near equipment or systems that produce vibration, drafts, electromagnetic radiation, magnetic fields, or fluctuations in temperature or humidity, it is essential to assess by replicating the worst-case scenario. Additionally, the balance may need to be placed within a fume hood in cases involving hazardous materials.

1.5 Precautions

To maintain the accuracy of a balance, it is crucial to consider the installation conditions and location. Factors such as temperature, humidity, barometric pressure, air currents, dust, electrostatic and magnetic forces, and vibrations in the environment can affect the performance of balances. It's essential to take precautions to minimize these effects. It's important to avoid exposing the balance to direct sunlight, as it can affect its temperature. The ideal relative humidity for weighing should be between 40% and 60%. Properly grounding the balances is essential to avoid electrostatic charging. Additionally, metal weighing vessels or antistatic devices can help further reduce electrostatic charging. Balances should be placed on stable, non-magnetic, and vibration-proof surfaces.

Precision balances are engineered to measure small masses accurately for analytical purposes. The weighing pan is typically enclosed to minimize the impact of dust collection and air currents. It's essential to ensure that balances are precisely levelled using a bubble or electronic level.

After levelling, the balances should be calibrated using built-in weights (if available) or external calibrated weights. After connecting to the power supply, balances should be allowed to warm up before use.

1.6 Weighing Vessels

A weighing vessel and closure made of inert materials compatible with the measurement process is crucial when weighing substances. The size of the weighing boat should not compromise the accuracy of the measurement. Generally, smaller weighing vessels provide more precise results than larger ones. However, there are instances where larger weighing ships may be more practical, such as when the sample needs to be diluted after weighing to prevent potential transfer errors. To ensure precise measurements, it's essential to assess the impact of the weighing vessel on the accuracy of the measurements by including it as a tare in the corresponding equipment performance checks [1–3].

2 Weighing Procedure

2.1 Operation of Analytical Balance

They choose the correct balance that aligns with quantity and performance requirements for accurately weighing materials. The guidelines outlined in the Indian Pharmacopoeia general chapter are designed to ensure the precise utilization of the balances. Before using the balance, the user must assess the environment for any potential vibration, presence of air currents, cleanliness, and calibration status. Analysts must carefully select the appropriate receiver for the material to guarantee the accurate measurement of the specimen's weight. The receiver should be clean, dry, and inert, and its combined weight, along with the specimen, should not exceed the maximum capacity of the balance. When utilizing a properly maintained and calibrated analytical balance for small samples, the weighing uncertainty is predominantly influenced by repeatability, which the size and surface area of the weighted object can impact.

It is essential to utilize tiny, low-mass receivers to mitigate these effects, particularly when measuring low-weight specimens. In certain situations, larger weighing vessels may be more practical, especially when the sample requires dilution after weighing to prevent potential transfer errors. The repeatability test should be conducted with the receiver positioned on the weighing pan as a preload. Receivers made from nonmagnetic materials should be used to avert magnetic interference with electronic balance components, and they should be operated at ambient temperature to prevent the formation of air currents within the weighing chamber.

2.1.1 Solid Samples

Various receptacles can be utilized when determining solid materials' weight, including paper, dishes, funnels, and sealed vessels such as bottles, vials, or flasks. It is not recommended to use hygroscopic papers for weighing, as they can impact the accuracy of the results. Weighing dishes are typically constructed from aluminium or polymer, and antistatic weighing dishes are available for materials that retain static electricity. Weighing funnels are usually made of glass or polymer and possess the characteristics of a weighing dish and a transfer funnel. This simplifies the weight powder transfer to a narrow-necked vessel, such as a volumetric flask. For solid samples that are volatile or deliquescent, it is essential to weigh the material into a sealed vessel. Analysts should opt for a sealed vessel with a small opening, where feasible, to minimize sample weight loss from volatilization or weight gain from the adsorption and absorption of atmospheric water.

2.1.2 Liquid Samples

Employing inert, enclosed vessels as receivers is imperative when obtaining liquid samples. Analysts should opt for an enclosed vessel with a small opening and expeditiously replace the enclosure after material transfer for volatile or deliquescent liquids. Selecting receiver and enclosure materials compatible with the liquid sample is crucial. This ensures a proper seal to avert leaks, particularly for liquids with low viscosity, surface tension, or boiling point.

2.2 Weighing for Quantitative Analysis

When conducting quantitative analyses, measuring a specific sample quantity accurately is essential. Any errors made while weighing the sample can result in inaccurate analytical measurements in the future.

2.2.1 Addition Weighing

One common technique for handling non-volatile solid or liquid samples is addition weighing. First, place the receiving vessel on the balance to perform this method and wait for the display to stabilize. Then, zero the balance, add the required quantity of material to the vessel and wait for the display to stabilize again. Record the weight and then transfer the material to an appropriate container. If there is uncertainty about the complete transfer, re-weigh the receiving vessel and record the weight difference. To reduce transfer errors, it is recommended to use a larger tare vessel during the dilution step.

2.2.2 Dispense Weighing

Standard containers are impractical when working with emulsions or thick liquids, such as ointments. To handle this, zero out the balance and place the sample in a clean and suitable container, such as a bottle, tube, transfer pipet, or syringe. Once the balance display becomes stable, take note of the weight and transfer the desired amount of the sample to a receiving container, like a volumetric flask. Lastly, return the pipet or syringe to the balance. The difference between the two weighing values will give you the weight of the transferred sample.

2.2.3 Gravimetric Dosing

During the sample standard preparation and capsule filling processes, it is standard practice to position the volumetric flask, vial, or capsule shell on balance and wait for the reading to stabilize. The balance is then zeroed, and precise amounts of the solid or liquid components are added to the receiving vessel using dosing units. The weights are then recorded. This automated dosing process reduces the influence of human and environmental variables, ensuring a more precise weighing procedure.

2.3 Safety Considerations When Weighing

In the process of weighing substances, ensuring safety is of utmost importance. Analysts must thoroughly review the Material Safety Data Sheet to understand the required precautions before handling any substance. Hazardous materials should be handled in a controlled environment with proper air filtration. Some substances may be toxic or allergenic, existing in liquid or finely divided particle form. Analysts must wear masks and gloves to protect themselves from inhalation and skin contact when working with such substances, which is essential when dealing with any chemical. If the container needs to be manipulated during weighing, gloves should be worn to prevent the transfer of moisture and oils.

The balance and weighing vessel must be appropriate for the quantity and performance requirements and clean and dry. The combined weight of the weighing boat and material should not exceed the maximum capacity of the balance. When using a weighing vessel on balance, it's essential to center it on the weighing pan and avoid direct contact with bare hands using tweezers. Once the balance display stabilizes, tare the balance and carefully add the desired material to the weighing vessel to prevent spillage. Record the weighing value once the balance display stabilizes again. To ensure precision in material transfer, it's crucial to be accurate. If there is any uncertainty about the transferred amount, re-weigh the weighing vessel to determine the variance [2].

2.4 Critical Samples

2.4.1 Electrically Charged Samples and Receivers

When handling finely divided dry powders, it is essential to consider the potential for static electricity. This can lead to inaccuracies in weight measurements and specimen loss during transfer. If a balance displays inconsistent readings, it could indicate the presence of a static charge. Specialized balances equipped with antistatic devices can effectively tackle this issue. These devices utilize piezoelectric components to generate ions that neutralize the static charge when touching the powder being weighed. Additionally, commercially available antistatic weighing boats, guns, and screens can help reduce static charge.

Controlling the laboratory's relative humidity is crucial as it impacts the accumulation of static charge, which, in turn, can affect weighing precision. Static charge may result from operator attire and can particularly affect borosilicate glassware and plastic receivers in low relative humidity environments. Moreover, static charge can also be influenced by the gloves worn by the operator. Addressing these concerns involves placing the container in a metal holder to mitigate static charge and employing antistatic gloves to alleviate the problem. When

weighing a low-boiling point liquid, using a container with a narrow, gas-tight enclosure is essential. First, the analyst should zero the container and the enclosure, add the required sample amount and seal the enclosure. Once the balance display has stabilized, the analyst can record the sample's weight.

2.4.2 Warm and Cool Samples

Before conducting any measurements, it is essential to allow samples at temperatures different from those in the surrounding environment to acclimate to the lab conditions. Failing to do so can lead to inaccurate readings. For example, when dealing with warm samples, the perceived weight may be lower than the actual weight due to heat convection. If a flask is warmer than the surrounding air, it can cause the air to rise along the sides of the flask, decreasing the perceived weight of the contents due to viscous friction.

2.4.3 Hygroscopic Samples

Hygroscopic materials are substances that quickly take in moisture from the surrounding air, causing them to become heavier gradually. To prevent moisture absorption, it is essential to promptly weigh hygroscopic samples or store them in an entirely free container. Analysts should use a moisture-free container and lid, add the required sample quantity, and seal the container. Once the balance display has stabilized, the analyst can record the specimen's weight.

2.4.4 Aseptic or Bio-hazardous Samples

Precise measurement of sterile or biohazardous samples necessitates conducting the procedure within a clean bench, biosafety cabinet, isolator, or a comparable containment apparatus. The airflow inside the containment device may influence the accuracy of measurements, underscoring the importance of analysts conducting a comprehensive qualification study using appropriate weight artefacts to determine the suitability of the balance for operation in such an environment.

2.4.5 Weighing Corrosive Materials

When using a balance, it is essential to exercise caution, especially when dealing with corrosive chemicals such as salts. Even a small spill of these substances on the balance pan or inside the balance housing can lead to substantial damage. To prevent this, analysts should weigh such materials in sealed containers like bottles or syringes. If a spill does happen, depending on the severity of the spill, the balance may need to be reevaluated or requalified [2, 3].

3 Qualification

When devising qualification plans, users should consult standard operating procedures and recommendations from manufacturers.

3.1 Operational Qualification

Following the installation of the equipment, either the user or a qualified third-party vendor should perform an operational qualification. Initially, the equipment must be activated, and the balance should be allowed time to stabilize by the manufacturer's guidelines, which may range from 1 to 24 hours, depending on the specific type of balance being utilized. Subsequently, analysts must conduct the requisite operational qualification procedures tailored to the kind of balance in use. These procedures ensure the mechanical mobility of all movable parts and verify indication stability:

- (1) Manually triggered or automatic adjustment through built-in weights;
- (2) Operation of ancillary equipment;
- (3) Tare function;
- (4) Initial calibration.

Various electronic analytical balances come with manual or automatic adjustment weights built in to reduce balance drift over time and compensate for fluctuations in ambient temperature. Calibration is typically carried out during operational qualification and should be performed regularly afterwards. It is crucial to conduct calibration where the balance is regularly used for operations.

3.2 Performance Qualification

Weighing instruments must undergo regular calibration and checks to meet specific requirements. In addition to calibrations, performance checks must be conducted. The minimum standards for performance checks are provided below. Each user's quality management system

determines the frequency of qualification and performance checks.

4 Calibration

It's crucial to conduct calibration when the balance is first used as part of the operational qualification and then periodically as part of the performance qualification. Calibration is an essential aspect of balance qualification and can be performed by the user or a qualified entity. The main goal is to ensure that the measurement results are traceable to SI units, also known as metrological traceability.

The calibration process involves identifying and recording the measurement uncertainty in a calibration certificate. To uphold traceability, it is advisable to calibrate the balance before any maintenance activity that could noticeably impact its measuring performance. Primary operations such as repairs, relocation of the balance, or mechanical adjustment of weighing parameters necessitate recalibration. However, recalibration is unnecessary for minor operations such as levelling the balance or adjusting using built-in weights.

5 Performance checks

During the assessment of balance performance, the examination focuses on the comprehensive evaluation of random and systematic errors. The results obtained are then compared against predetermined criteria to ascertain the suitability of the balances. Suitability requires that errors do not exceed 0.10%. Significant weighing parameters such as repeatability and sensitivity are evaluated during performance checks. Repeatability appraises the balance's random error, while sensitivity assesses the principal component of the balance's systematic error. Additional parameters, including eccentricity and their impact on the systematic error of balances, are also thoroughly assessed when calibrating. Since these parameters contribute less to systematic error, investigating only sensitivity during a performance check is often satisfactory. In such cases, the acceptance criterion is set at half the overall permitted systematic error of 0.10%, equating to 0.05%.

5.1 Repeatability

Random error is a significant factor in measurement uncertainty when weighing small quantities. This can be determined by calculating the standard deviation of the readings obtained using the following process:

Select a single weight denomination that exceeds 5 per cent of the balance's maximum capacity. If this results in a test load below 100 mg, then 100 mg should be used, as handling smaller weights can be challenging. Zero the instrument, place the chosen test load on the weighing pan and record the reading. Repeat the entire process, including zeroing, at least ten times. Satisfactory repeatability is achieved if:

$$2 \times \frac{s}{m_{snw}} \leq 0.10 \quad (3)$$

Note: if $s < 0.41 \times d$, where d is the readability (scale interval) of the balance, replace s with $0.41 \times d$; s = standard deviation of the weighing values (*e.g.* in grams); m_{snw} = most negligible net weight (*e.g.* in grams).

The minimum weight of a balance is the smallest amount of substance that can be accurately weighed while still meeting the requirements of the repeatability test. This value is determined based on the repeatability test results and is crucial for accurate measurements.

$$m_{min} = 2000 \times s \quad (4)$$

Note: if $s < 0.41 \times d$, replace s by $0.41 \times d$; The minimum weight is determined based on the balance's performance during the repeatability measurement and may vary over time. On the other hand, the minimum net weight is a requirement set by the user, which typically remains constant and should not be less than the minimum weight.

5.2 Sensitivity

When conducting a sensitivity test, we evaluate the primary component of the systematic error of the balance. It is a common practice to carry out this test under typical usage conditions, meaning that a test load reflecting a typical application is used. However, suppose the test load falls at the lower end of the measuring range (below 5% of the balance capacity). In that

case, this practice becomes insignificant due to the predominant influence of random error. The deviation in sensitivity increases nearly linearly with the load, making it more significant in the upper part of the weighing range. A specific procedure is followed to assess sensitivity using a test load with a mass ranging from 5% to 100% of the balance's capacity. The steps include zeroing the instrument, placing the chosen test load on the weighing pan, and recording the indication. The sensitivity is satisfactory if:

$$(I - m)/m \times 100 \leq 0.05 \quad (5)$$

m = nominal weight of the test load or its conventional mass (see conditions below), *e.g.* in grams; I = indication (weighing value), *e.g.* in grams.

When performing an evaluation, it is generally considered acceptable to utilize the nominal weight as the test load value, provided that the relative maximum permissible error of the test load (*i.e.*, the maximum permissible error of the test load divided by the nominal weight) does not exceed one-third of the sensitivity test specification, which is 0.05%. If this criterion cannot be satisfied, it becomes necessary to utilize the conventional mass value of the test load indicated on the weight calibration certificate for the evaluation. In such instances, the user must ensure that the weight uncertainty divided by the nominal weight is one-third of 0.05% [3,4].

6 Balance Applications

Analytical balances are explicitly designed to measure minimal differences in mass, offering highly accurate measurements. They are enclosed in a transparent box with doors to shield the balance from external factors affecting their precision. Due to the need for extreme accuracy, analytical balances are used in controlled environments to ensure precise measurements [5]. These balances can determine the mass of an object with a high degree of precision, typically up to 0.001 grams. To function correctly, they require specific environmental conditions to prevent any alteration in the weighing process [6].

Analytical balances are utilized in various scientific and laboratory applications, such as creating precise standards for experiments, developing formulations with accurate measurements, determining the density of substances, conducting interval weighing for specific time points, performing routine testing of micropipettes for consistency, and preparing samples for analysis. Laboratory laboratories frequently use analytical balances to weigh ingredients in producing solutions, compounds, and medications. Regular calibration is advised, especially when the balance is first being used, after it has been relocated, following any adjustments to its level, and after significant temperature or atmospheric pressure changes. Modern analytical balances can automatically perform this calibration when they detect environmental changes [7].

Analogue analytical balances rely on mechanical measurement principles for their accuracy. On the other hand, digital analytical balances utilize electronic methods to measure and transmit weight-related data. These balances function through an electromagnetic system, which includes a photocell that identifies the plate's position and an electromagnet that adjusts to counteract the force generated by the load on the plate. Since digital analytical balances measure forces, they need to be calibrated to account for the gravitational intensity at the location where the weighing takes place [8].

The pharmaceutical industry is now incorporating metrology-based concepts to manage the life cycle of weighing instruments. While the traditional practice of conducting a daily balance check is still widely ingrained in the minds of many users, the industry is increasingly adopting state-of-the-art methods for testing and calibrating balances and scales based on risk management principles [9].

The interpretation of calibration within the Ph. Eur. (European Pharmacopoeia), which aligns with the definition in the International Vocabulary of Metrology (VIM), signifies a significant shift towards a more scientific understanding of metrology in the pharmaceutical industry. With the introduction of the General Chapter on Balances for Analytical Purposes in Pharmacopoeias, measurement uncertainty is gaining importance in the quality management of weighing instruments in the pharmaceutical sector.

Furthermore, the significance of "as found" and "as left" calibration, as stated in the Ph. Eur., has been incorporated into pharmaceutical quality management systems to ensure traceability of measurement results obtained during routine instrument use. This trend aims to achieve a globally harmonized approach to metrology for balances within the pharmaceutical industry [4, 10].

7 Regulatory implications for standardization

According to ISO 9000, quality control ensures that laboratory analysis results are consistent, accurate, and within specified limits of precision. It involves precise sample description, quantitative analysis, and daily performance evaluation to ensure the continual production of valid data. AQC is achieved through laboratory control of analytical performance, initial calibration, and systematic daily checks [11].

The concept of calibration and verification is essential in maintaining the accuracy of measuring instruments. Calibration involves comparing the instrument to a standard and adjusting it if necessary, while verification confirms that it meets specified requirements. Calibration is essential for detecting and rectifying errors, while verification ensures the measurement error is within an acceptable limit. Both processes are crucial for ensuring the reliability of analytical testing in a Pharmaceutical Quality Control laboratory. These two concepts are included in a unique concept called Metrological confirmation, which comprises a set of operations required to ensure that measuring equipment conforms to the requirements for its intended use. Metrological confirmation typically involves calibration, verification, necessary adjustments or repairs, subsequent recalibration, comparison with the metrological requirements for the equipment's intended use, and any required sealing and labelling. Establishing the acceptance limits or requirements throughout these processes is crucial.

Pharmaceutical industries are bound by Good Manufacturing Practices (GMPs), requiring instrumentation to remain validated. The site calibration program plays a critical role in meeting these standards. In Europe, GMPs, and in the United States, current GMPs (cGMPs) are mandatory practices that adhere to guidelines recommended by regulatory agencies overseeing authorisation and licensing for manufacturing and selling food, drug products, and active pharmaceutical products. These guidelines outline the minimum requirements that pharmaceutical or food product manufacturers must meet to ensure the highest quality of products and minimise risks to consumers and the public [13]. The U.S. FDA enforces 13 cGMPs in a Code of Federal Regulations, Parts 210 and 211. Specifically, 21 CFR 211 states that equipment manufacturing drugs should be routinely calibrated, inspected, or checked. Section 211.160 of Subpart I emphasises laboratory controls and requires calibration of all instruments at suitable intervals by an established written program [14]. In the global pharmaceutical industry, the International Council of Harmonization (ICH) and the European Commission have guidelines stating that critical equipment for ensuring the quality of pharmaceutical ingredients should be calibrated according to written procedures and an established schedule. However, specific procedures, verification methods, and acceptance criteria are not defined [15].

The European Directorate for the Quality of Medicines and Healthcare (EDQM) oversees the European Pharmacopoeia Commission and develops its General Chapters and Monographs with expert groups. The Official Medicines Control Laboratories (OMCL) is a network of laboratories under the Council of Europe that provides guidelines for calibration and qualification of laboratory instruments, which are not mandatory but can be used for establishing calibration methods and frequencies. In the United States, the American Society for Testing Materials (ASTM) has also developed similar calibration guidelines for instruments and reference materials [11, 16]. The calibration parameters guidelines of different global regulations for an Analytical Balance mentioned in Table 1.

Table 1 Calibration Regulations and Guidelines for an Analytical Balance

Test	USP	FEU	ISO	OMCL
Calibration Frequency	ND	ND	ND	ND
Linearity	Yes	No	Yes	Yes
Sensitivity	Yes	No	Yes	No
Accuracy*	Yes	No	Yes	Yes
Precision	Yes	No	Yes	Yes
Eccentricity	Yes	No	Yes	Yes
Drift	No	No	No	Yes
Minimum weight	Yes	No	No	Yes
Measurement uncertainty	No	No	Yes	Yes

Note: "Accuracy" is referred to as trueness in the International Vocabulary for Metrology and documents of the ISO.

8 Conclusions

The Systems and Controls section in electrical and computer engineering offers a comprehensive framework for designing controllers across various application domains related to analytical

balance. Initially developed within electrical engineering, this dynamic field has become a crucial enabling and supporting technology for various analytical sectors, including energy, transport, manufacturing, biology, defence, and robotics. Systems science and control engineering constitute a modern engineering discipline and applied mathematics field encompassing systems' design, measurement, analysis, and control. Control engineering, or control system engineering, is a subset of systems science and control engineering that focuses on designing, optimizing, and evaluating control systems. The current theories on equilibrium are discussed, emphasizing the importance of promptly disseminating newly acquired knowledge to analytical teams. This enhances the collective understanding of analytical procedures related to balance and fosters a culture of continuous learning and improvement within our profession.

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Transparency Statement

The lead author, Dr. Ritu Tiwari, affirms that this manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that any discrepancies from the study as planned (and if relevant, registered) have been explained.

Conflict of Interest

All authors declare that they have no conflicts of interest.

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