Weights, Balances & Uncertainty

The factors that can influence which balance is appropriate for your application are:

1. Capability – the need for multiple balances
2. Readability
3. Capacity
4. “Accuracy” vs. “readability”
5. Repeatability and linearity
6. Units of measure
7. Platform dimensions
8. Environmental consideration
9. Communications interface
10. 21 CFR Part 11 compliance
11. Data reporting
12. Legal-for-trade requirements

As with any other testing device or sensor in the laboratory, a complete understanding of the factors that can influence proper weighing/test results is very important.

For proper installation and maintenance of a balance, it is important to limit uncertainty. Uncertainty can be defined as a statistical estimated amount or percentage by which an observed or calculated value may differ from the true value.

Determining Uncertainty

For this exercise, presume that the balance indication, the sensitivity of the weighing device, the application of the load, and the proper zero setting of the device are all operating without question and those elements under the original control of the device manufacturer (i.e., overall design, accuracy readability, sensitivity, drift, and off-center loading characteristics) are within the device’s design specifications. What needs to be determined is the impact of other influences on the uncertainty of test results.

Examining the design of the balance’s installation is a critical step in the use of a precision weighing device and is often overlooked. The installation is the most imperative step in preparing for reliable results. If this area of use is understood and secure, reliable test results are more likely to be achieved.

Electro-Magnetic Force Restoration

In an electro-magnetic force restoration balance, a current is regulated by a servo amplifier in a way that the electro-magnetically generated force and the weight force applied to the platform by the object being weighed are in equilibrium (balanced). Maintenance of the equilibrium is controlled by a small sensor known as a position sensor. If weight is added to the weighing pan, this destabilizes the state of equilibrium and the overweight load causes the force-transmitting lever to move upward into the range of the position sensor. This in turn generates an input signal at the servo amplifier, causing a greater amount of current to flow through the coil and therefore increase the counter force until equilibrium is restored. The current simultaneously flows through a resistor where it causes a drop in voltage proportional to the change in weight on the platform. This voltage drop is digitized in an analog/digital converter so that the result is processed in a digital signal-processing unit (microprocessor), which can then in turn be indicated on a digital display with the appropriate mass indicator.

Leveling the Balance

Most balances available today include a “bubble level” or “bull’s-eye-level” on the device. Along with this feature, two or more of the legs on the balance are adjustable, allowing for adjustment of the horizontal plane of the device to compensate for an out-of-level working surface. Use the bubble level and adjusting legs to insure the balance is properly leveled. An out-of-level balance will add uncertainty to test results.

Room Conditions

Ideally, the laboratory should have the following characteristics at a minimum:

1. Only one door to prevent air drafting.
2. Limited personnel access to prevent drafting and other changes to the environment in the areas of temperature, relative humidity, and atmospheric pressure.
3. A limited number of windows, if any at all. If there are windows, a northern exposure is ideal so that exposure to direct sunlight is limited.
4. The work surface that is dedicated to the balance should be located at a corner of the room, immediately opposite to the wall containing the door. Also, the door should swing inward into the laboratory with a balance table positioned so that the door can act as a shield against drafting from sources external to the laboratory.

Working Surface

Insure that the working surface is clean, firm, and stable. Make sure that it does not feature dual or tandem connection to the floor and a wall. If at all possible, the working surface should be used only for work involving test measurements with the balance.

Ergonomics

Insure that the balance does not need to be moved to meet the various requirements induced by testing and user parameters. Balances are not designed to be relocated between applications, technicians, and laboratories. If a balance is moved after installation, the results of your installation and calibration work are no longer valid. Reinstallation should be performed before the balance is used again.

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Wind Currents

Inherent with the sensitivity of most balances is the ability to be affected by even the slightest of air movements. There are two simple ways to evaluate the impact of air currents surrounding the balance.

Option 1: A simple device known as a smoke tube will generate a harmless trail of smoke that will follow an ambient air current. Although this is a good visual indication, this method is sufficient only for the time that the test is being conducted.

Option 2: Use the balance as a "breeze sensor." To conduct this test, complete the balance installation and set-up following the manufacturer's instructions. Connect the balance to a computer (according to manufacturer's instructions). Configure the balance to interval print every 10 seconds. Configure the computer so that the information from the balance is imported into a spreadsheet, such as Microsoft Excel. Begin the test by activating the print sequence on the balance. Interval printing will continue at 10-second intervals for a set period of time to secure an evaluation of the environment surrounding the balance. Once the test has been completed, turn off the interval testing. Chart the results of the data now resident in your spreadsheet. Evaluate the results to determine if there are factors in the environment that you wish to avoid. An optional breeze-break will modify the unwanted behavior. If you are using an analytical-style balance (those devices with an integral breeze-break), this observation should not be overlooked.

Vibration

This contaminant can result from something as subtle as a person walking by or a constant low-frequency hum of a large piece of manufacturing equipment located several work-areas away from where the balance is located. Anti-vibration pads placed under the feet of the balance can be a low-cost solution.

Magnetism

Magnetic fields within close proximity to the balance may cause weighment errors. Sources of magnetic fields range from small motors, computer displays, and test weights and mass standards. Magnetism in mass standards and test weights cannot be completely eliminated once the device is in the field. The proper care and handling of test weights and mass standards is equally important to minimizing uncertainties as the proper installation and use of a balance.

Powerline Noise

If possible, insure that the balance is connected to a dedicated power circuit. At a minimum, use a conditioned powerstrip to insure against errors in repeatability.

RFI/EMI

Common devices used in work environments can interfere with the proper operation of a weighing system. These include two-way radios, wireless telephones, cordless phones, and wireless LAN communications. With the balance operating and presenting a stable zero reading, use a two-way radio, cell phone, or any other electronic device within close and various proximity to the balance. Any sudden change in reading may indicate some level of interference and corrective action should be considered. Another option is to contract a professional experienced with detecting, measuring, and compensating for RFI and EMI.

Fluctuations in Temperature

Ideally, lab temperature does not change over the course of a normal 24-hour period more than one to two degrees Celsius. Realistically, however, many factors prevent this ideal except in the most controlled environments. To compensate for this, many balances have an internal automatic temperature-sensitive calibration. It is important to purchase and use devices with this feature. When a change in temperature that could affect the outcome of a weighment is detected, the operator is notified that recalibration is required, or, on some units, the device's own internal calibration routine automatically compensates for the temperature change.

The laboratory should be as free from windows and direct sunlight as possible. If such a consideration is impossible, keep weighing areas away from windows, direct sunlight, and heat and refrigeration sources. The ideal humidity range for most balances is between 45% and 60% non-condensing RH.

To maintain the balance's optimal internal thermal equilibrium, the balance should not ever be turned off. When using a balance with an enclosed weighing chamber, always use a tweezers or other mechanical gripping device to place things in or remove things from the weighing chamber. When choosing a container to hold a weighing sample, select one with a small surface area.

NOTE: If using a device with an integral breeze-break, note the difference between the environment inside and outside the weighing chamber. If unsure about the weight vs. temperature properties of the commodities being tested, prepare two "identical" samples of the commodity. These "identical" samples should have the same weight value. Leave one sample outside the weighing chamber next to the balance. Place the other sample inside the weighing chamber, but not on the weighing platform. Add the second sample inside the chamber to equalize to the weighing chamber's temperature. Weigh the sample inside the weighing chamber once it has equalized to the chamber temperature. Immediately weigh the sample that was outside of the weighing chamber. If there is any difference in weight, you will need to achieve temperature equilibrium between the sample and the weighing chamber before making future weighing transactions.

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Sample Conditions

The weight of a sample will increase or decrease depending on its exposure to volatile substances. Similarly, the sample will behave differently dependent on the evaporation of water or the absorption of moisture by the sample itself. Always use clean and dry weighing containers to hold the sample(s) under test. Keep the weighing platform and/or weighing chamber clean and free from foreign substances that may interfere with the testing results. Use weighing containers with as narrow an opening as possible and keep these containers covered unless direct and specific work is being done with the samples.

Condition of Electro-static Discharges

ESD usually demonstrates itself in one of two ways:

1. Repeated weighments of the same sample return dissimilar results.
2. The reading on the weight display is unusually unstable even though all other environmental concerns seem to be accounted for.

   The following procedures can help counteract ESD. In some instances, following more than one of these procedures may be necessary:

   a. Avoid weighing vessels made of plastic. Glass is preferable.

   b. Ground the device. This can be achieved by running a wire from the chassis of the device to a direct ground connection.

   c. Ground the technician. These solutions include ESD wrist straps, ESD-proof laboratory coats, anti-static hand soap, etc.

   d. Use anti-static brushes to discharge ESD within the weighing chamber.

   e. Discharge ESD in the balance's immediate environment.

   f. There are a number of solutions that provide a constant stream of neutralized ion air that eliminates anti-static build-up.

   g. If the above procedures fail to correct the ESD problem, consider using only metal sample containers.

Installation

Who is doing the installation? There are basically three types of "installers" for precision weighing equipment: laboratory technicians, maintenance staff, or a dealer technician. If you have purchased your balance directly from one of the major catalog suppliers, your options for installation and maintenance are limited to either a laboratory technician or the in-house maintenance staff. Find the individual with the most experience and insure they thoroughly follow the instructions that come with the device. If you have purchased your balance from a local scale or balance dealer, you have the benefit of requesting installation by a dealer technician. This is the preferable option. A scale or balance dealer's technician is a trained professional, who, by definition, is sensitive to all of the factors that we have discussed in this article. Additionally, you have the benefit of being able to call them back and troubleshoot either the device or the environment if you have difficulty.

Operator Training and Certification

Who is going to use the balance? Operator training and certification on a weighing device cannot be overstated. Operator errors are not only a result of individuals being inadequately trained, they also add untold degrees of uncertainty to valuable test results. Every operator should have at least a background in weighing technology, even if it is limited only to the device in question. Additionally, they should have a thorough understanding of the test process and the necessity to correctly record data thus preventing an erroneous influence in the significant process evaluation.

In summary, careful planning and/or suitable corrective action will minimize and possibly even eliminate many sources of uncertainty within your weighing process. It is possible that you will determine the need to test the balance at its planned location, and perhaps other alternative working sites in order to arrive at the best performance parameters. This will exclude influences of the surroundings or the operating personnel. By controlling the optimum performance of the balance based on its location and proper installation, you can significantly reduce uncertainties in your weighing processes.

With all of these factors under control, you should be able to proceed now using good laboratory weighing practices to determine the standard deviation of your device, as well as the uncertainty of your process.

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