

Balance Verification Using Calibrated Weights

The following is an example of how to use test weights with the appropriate pedigree to calibrate and verify an electronic weighing device such as an electromagnetic force restoration balance. Manufacturer's operating and maintenance instructions should always be referenced prior to performing a test or making adjustments. Pay exceptional attention to the manufacturer's discussion on the environment suitable for the device. At the end of these procedures, refer to page 251 for information regarding weighing influence factors. Failure to consider these specifications and conditions will invalidate this procedure. Please contact us if you cannot locate the operating instructions for your device. We may be able to provide a duplicate.

Equipment Required:

- Balance
 - Accessory printer (to document calibration changes and results*)
 - Cotton gloves
 - Tweezers
 - Tongs (as appropriate to handle the test weights)
 - Test weight calibration certificate, or traceable certificate.
1. Using the manufacturer's operating instructions, set up the balance in the environment in which it is intended for use. Allow the balance to "soak" in the environment for a minimum of 24 hours prior to any testing. This is a critical step. Many of the mechanical structures in a balance are affected by the changes in environment. To ensure a proper test with definable results, the device must be allowed to equalize within its environment.
 2. If the balance is equipped with an internal calibration feature, activate that feature and allow the printer, if so equipped, to document the results.
 3. If the balance is not equipped with an internal calibration feature, use an external electronic balance calibration weight and, following the manufacturer's recommendations, calibrate the balance. Many electronic balances deployed in the field allow you to select the size of calibration weight you wish to use. To minimize the impact of hysteresis on linearity, it is strongly recommended that you use a weight that represents 100% of the rated capacity of the device.
 4. Weight Selection Criteria. Selecting the appropriate size and class of an electronic balance calibration weight is not a difficult process.

Option 1: Refer to the instructions provided by the manufacturer of the balance or other weighing device. Generally, the size (capacity) and class of the recommended test weight will be included for your reference.

Option 2: Manually calculate the test weight needed based on the best performance from a device with a specific capacity and readability.

- a. Record the capacity of the balance
- b. Record the minimum increment (readability) of the balance
- c. Divide the result from step 2. above by a factor of four. This number results in the appropriate tolerance for the test weight required. For example, if the balance in question has a capacity of 120 g and a displayed resolution of 1 mg (0.001 g), the result of the calculation would be 0.25 mg (0.00025 g).
- d. Refer to the ASTM Weight Tolerance Table on page 230.
- e. In the column titled "Metric Denomination" find the weight value closest to the capacity of the balance. If the exact number is not available, select the next smallest value. For example, a balance has a capacity of 120 g. The closest value but smaller than the rated capacity of the balance is 100 g.
- f. Read across the table to the right to locate the tolerance that is closest to, but smaller than the value of 0.25 mg calculated in step three. The first value that meets this criteria is 0.13 mg, Class 0
- g. To assure the most error-free results, an ASTM Class 0 test weight should be used for this calibration exercise. However, because the value in the next column is .025 mg exactly, an ASTM Class 1 device could be selected with satisfactory results.
- h. Now we know that every test weight we purchase for this device must be a minimum of ASTM Class 1.

Option 3: Manually calculate the test weight based on the tolerance of the procedure or methodology.

- a. Given - your balance has a capacity of 120 g
- b. Given - your balance has a readability of 0.0001 g (0.1 mg)
- c. Given - you wish to check your balance at weighing capacities of 5 g, 10 g, and 15 g.
- d. To get the proper results, weights with the following capacities are required: 1 ea 5 g, 1 ea 10 g

You will be able to use the 5 g test weight alone to test the device at 5 g; the 10 g weight alone to test the device at 10 g; and the 5 g and 10 g test weights together to test the device at 15 g.

- e. Given ~ the tolerance you are looking for in your procedure is 0.5 mg
- f. Divide your tolerance of 0.5 mg by a factor of 4. This results in a tolerance of 0.125 mg
- g. Refer to the ASTM Weight Tolerance Table on page 251.
- h. Because more than one weight is being used to accomplish this test, cumulative tolerance will need to be applied considering the tolerances of both a 5 g and 10 g test weight together to insure that they do not exceed 0.125 mg.
- i. Find the first 10 g weight value in the column titled "Metric Denomination". Read across the chart to find the value that is closest to but smaller than the calculated tolerance of 0.25 mg from step 4c above. This would be the value of 0.074 under ASTM Class 2. ASTM Class 3 cannot be used since that value 0.25 mg is larger than the calculated tolerance of 0.125 mg.
- j. Follow the ASTM Class 2 column until you are across from the 5 g test weight, which is the next test weight being used. As listed on the chart, the tolerance for a 5 g ASTM Class 2 test weight is 0.054 mg.
- k. Add this to the tolerance of the 10 g ASTM Class 2 test weight from step 4 above. The result is 0.74 mg + 0.054 mg = 0.128 mg. This value is larger than the stated tolerance of 0.125 mg. Because of this, tolerances for ASTM Class 1 need to be used to improve performance.
- l. The tolerance for an ASTM Class 1 10 g test weight is 0.050 mg. The tolerance for an ASTM Class 1 5 g test weight is 0.034 mg. When combined, the total accumulated tolerance of 0.084 mg of is well within the stated tolerance of 0.125 mg. Therefore, for this procedure, ASTM Class 1 test weights should be used.

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5. When external (preferred) or internal calibration has been successfully accomplished, select a verification weight that is representative of a typical sample used on a daily basis. If the weighing device is used for samples of exceptionally different values, consider the number of transactions with each typical sample. Develop a representative sample size for this test. The test weights you use for this test should not only be representative of the sample size, but also have the appropriate laboratory documentation and traceability to ensure test validity.
6. Tare or zero the balance and verify that the display reads a stable zero value
7. With the device reading zero, apply the sample test weight to the balance.
8. Wait until the balance indicates that it is no longer "in-motion."
9. Write down the reading on the display.
10. Remove the test weight from the balance.
11. Wait until the balance is no longer "in motion" and the display has returned to a stable 0 value.
12. Repeat steps 5-10 20 times.
13. Using the results from step 11, calculate a standard deviation
14. Multiply the answer in step 13 by 3. This is the random error that is expected for the balance with a 99% confidence level. This number now becomes the upper and lower limits for the performance verification. In other words, the balance is performing satisfactorily when the results of a balance reading compared to the practical test weight (PTW) are no more than $PTW + STDV$ and no less than $PTW - STDV$.
15. It is important to now verify the results of the standard deviation against the repeatability specification for the weighing device under test. If the standard deviation value is greater than the repeatability factor of the balance under test consider the following.

Recheck the installation parameter of the balance. Be acutely aware of environmental influences on the balance under test as these can have a significant impact on the device's performance. If you are confident that all preventative measures have been taken to insure optimal

balance performance, contact the manufacturer of the device for additional recommendations.

16. Determine the correction value from the laboratory documentation that accompanies the test weight used to calibrate the balance at 100% from step 3. The correction value is the error that was introduced into the balance mechanism and algorithms when the balance was calibrated in step 3. The calibration function in most electronic balances of recent manufacture compensates and sets the linearity of the device from the point in the weighing range representing the calibration load down through and including zero. It is critical that the calibration be performed as close as possible to 100% of the balance's rated capacity. Perform balance calibration with an external calibration test weight since the linear error cannot be deduced by using an internal calibration weight. If the balance was calibrated at 100% of its rated load, 100% of the error in the calibration weight was also introduced at that point. This error is reduced to half its original value at the 50% load point. It is further reduced to 75% at the 25% load point. It is possible to make an estimation of the linear error of the calibration by the equation in figure 2.
 - A. LE = Linear Error
 - B. ECW = Rated Error of the Calibration Weight
 - C. L = Load
 - D. CL = Calibration Load
17. A study of the points presented so far explains the fallacy of attempting to calibrate a balance at less than 100% of its rated capacity. Failure to do so can make the device's performance completely theoretical and destroy the intent of uncertainty budgets.
18. Using all of this information, it is now possible to determine the anticipated result for the verification process.
19. Using the laboratory documentation for the test weight that represents the typical sample weight, determine the error or correction of the weight. Also, check the uncertainty of the weight that you will use for this process. The uncertainty must be no greater than 25% of the random error of the balance being examined from step 15. If the uncertainty of the weight is greater than 25% of the random error of the balance, select a test weight of equivalent value but with a higher accuracy class. In the

event that the correction on your laboratory documentation is a negative number, the weight in question is below nominal value by that amount. A positive value means the weight is heavier than nominal by that amount.

20. Calculate the anticipated value for performance verification using the following formula where:

- EV = Expected Value;
- AMV = Actual Mass Value and
- LE = Linear Error (from step 14)

$$AMV = (NV + LE)$$

$$\sqrt{\frac{n\sum x^2 - (\sum x)^2}{n(n-1)}}$$

Figure 1

$$LE = \frac{(-1)x(ECW \times L)}{CL}$$

Figure 2

Balance Verification Using Calibrated Weights (continued)

Where AMV = Actual Mass Value; NV = Nominal Value and AM = Apparent Mass vs. 8.0 correction in the following formula:

$$EV = (AMV + LE)$$

21. Verification: Zero the balance and place the verification weight on the balance. If the actual reading is within the random error range established in the calculation of the anticipated value, the verification passes.

Example:

- Balance specification – 100 g x 0.1 mg
- Calibration load – 100 g (100% of rated capacity)
- Test weight specifications
 - 100 g Class 1 electronic balance calibration weight with a correction of + 0.10 mg
 - 10 g Class 1 electronic balance calibration weight with a correction of + 0.010 mg
- Typical sample value – 10 g

Following the instructions above (step 14), 20 measurements are taken and the standard deviation is found to be 0.3 mg. Applying a factor of 3 (3 x 0.3 mg), the value calculates to 0.9 mg.

To calculate the Linear error =

$$LE = \frac{(-1) \times (ECW \times L)}{CL} \quad \text{OR} \quad 0.01 \text{ mg} = \frac{(-1) \times (1 \text{ mg} \times 10 \text{ g})}{100 \text{ g}}$$

Expected value =

$$EV = (AMV + LE) \quad \text{OR} \quad 9.99999 = 10 + (-0.01 \text{ mg})$$

Verification range = 9.99999 g +/- (-0.9 mg)

The actual verification is performed and the reading on the balance results in a value of 10.0003 grams. Since this value is within the control limit, the results of the test is a “pass,” as relative to a “pass/fail” rating system.

Refer to the chart below.

22. In the chart below, the methodology explained in this section has been followed. A weight of 10 g is applied to the balance. The reading on the balance is 10.00010. This

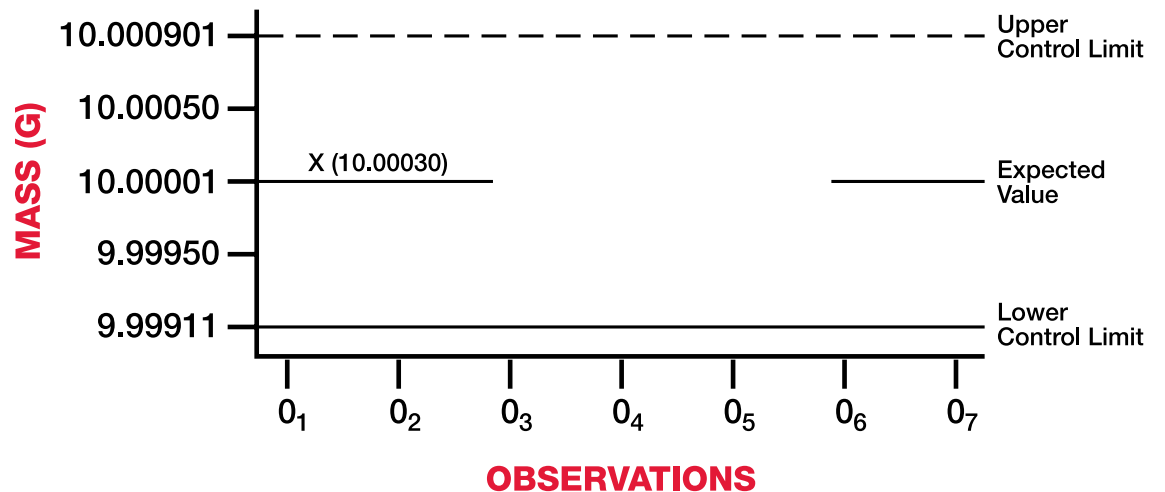
value has been plotted on the chart as X. It falls within the upper and lower limits and therefore, this verification observation passes.

Further Suggestions

- Perform verifications at different times of the day. If you notice that the results are significantly different at these different times, it may suggest that the environmental conditions within the work space are changing and may have unforeseen impact on the work being conducted.
- Constantly monitor the condition and weight value of your test weights. Under the auspices of NIST H-150, laboratories providing recalibration services are prohibited from recommending or establishing scheduled recall dates without your explicit instructions. To learn more about how to determine when and if a weight is due for recalibration, please contact us. We will be happy to discuss the process with you.
- Keep a constant running record of your test results and chart these results using a program such as Microsoft® Excel. This record can help you understand the data being recorded as well as help you gain additional insight into your laboratory conditions.

- From time to time, recalculate the random error to see if your balance is performing consistently.
- Have your balance serviced according to the manufacturer’s instructions or recommendations by your dealer to ensure it maintains optimum operational parameters.

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