Standard Test Method of Testing Top-Loading, Direct-Reading Laboratory Scales and Balances[1]

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INTRODUCTION

This method is designed to test commonly used laboratory scales that read the entire range of weight up to the capacity without manual operation. In essence, the entire reading range is on-scale and no manipulation of weights, riders, or dials is required; except some scales with optical reading devices may require the operation of a micrometer dial to interpolate the final one or two significant figures.

1. Scope

1.1 This test method covers the determination of characteristics of top-loading, direct-reading laboratory scales and balances. Laboratory scales of the top-loading type may have capacities from a few grams up to several kilograms. Resolution may be from 1/1000 of capacity to 1/1 000 000 or more. This method can be used for any of these instruments and will serve to measure the most important characteristics that are of interest to the user. The characteristics to be measured include the following:

1.1.1 warm-up,

1.1.2 off center errors,

1.1.3 repeatability, reproducibility, and precision,

1.1.4 accuracy and linearity,

1.1.5 hysteresis,

1.1.6 settling time,

1.1.7 temperature effects,

1.1.8 vernier or micrometer calibration, and

1.1.9 resistance to external disturbances.

1.2 The types of scales that can be tested by this method are of stabilized pan design wherein the sample pan does not tilt out of a horizontal plane when the sample is placed anywhere on the pan surface. The pan is located generally above the measuring mechanism with no vertical obstruction, except for draft shields. Readings of weight may be obtained from an optical scale, from a digital display, or from a mechanical dial. Weighing mechanisms may be of the deflecting type, using gravity or a spring as the transducer, or may be a force-balance system wherein an electromagnetic, pneumatic, hydraulic, or other force is used to counterbalance the weight of the sample. Other force-measuring devices may be tested by this method as long as a sample placed on a receiving platform produces an indication that is substantially a linear function of the weight of the sample.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Method

2.1 Throughout this method, the instrument is used in the manner for which it is intended. One or more weights are used to test each of the characteristics, and the results are expressed in terms of the least count or ultimate readability of the display.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*[2]

3.1.1 *accuracy*—the degree of agreement of the measurement with the true value of the quantity measured.

3.1.2 *capacity*—the maximum weight load specified by the manufacturer. In most instruments, the maximum possible reading will exceed the capacity by a small amount.

3.1.3 *full-scale calibration*—the indicated reading when a standard weight equal to the full scale indication of the scale is placed on the sample pan after the device has been correctly zeroed. Usually some means is provided by the manufacturer to adjust the full scale indication to match the weight of the standard.

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[2] ANSI/ISA S51.1 "Process Instrumentation Technology". Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

3.1.4 *linearity*—the degree to which a graph of weight values indicated by a scale vs. the true values of the respective test weights approximates a straight line. For a quantitative statement of linearity errors, the concept of terminal-based non-linearity is recommended, such as, the maximum deviation of the calibration curve (average of the readings at increasing and decreasing test load, respectively) from a straight line drawn through the upper and lower endpoints of the calibration curve.

3.1.5 *off-center errors*—differences in indicated weight when a sample weight is shifted to various positions on the weighing area of the sample pan.

3.1.6 *hysteresis*—difference in weight values indicated at a given test load depending on whether the test load was arrived at by an increase or a decrease from the previous load on the scale.

3.1.7 *repeatability*—closeness of agreement of the indicated values for successive weighings of the same load, under essentially the same conditions, approaching from the same direction (such as, disregarding hysteresis).

3.1.8 *reproducibility*—closeness of agreement of the indicated values when weighings of the same load are made over a period of time under essentially the same conditions but not limited to the same direction of approach (such as, hysteresis errors are included).

3.1.9 *precision*—the smallest amount of weight difference between closely similar loads that a balance is capable of detecting. The limiting factor is either the size of the digital step of the indicator readout or the repeatability of the indicated values.

3.1.10 *standard deviation*—used as a quantitative figure of merit when making statements on the repeatability, reproducibility or precision of a balance.

3.1.11 *readability*—the value of the smallest unit of weight that can be read without estimation. In the case of digital instruments, the readability is the smallest increment of the least significant digit (for example, 1, 2 or 5). Optical scales may have a vernier or micrometer for subdividing the smallest scale division. In that case, the smallest graduation of the vernier or micrometer represents the readability.

3.1.12 *standard weight*—any weight whose mass is given. Since weights are not always available with documented corrections, weights defined by class may be used if the class chosen has sufficiently small limits and there is an understanding that errors perceived as being instrumental in nature could be attributed to incorrectly adjusted weights.

4. Significance and Use

4.1 This method will enable the user to develop information concerning the precision and accuracy of weighing instruments. In addition, results obtained using this method will permit the most advantageous use of the instrument. Weaknesses as well as strengths of the instrument should become apparent. It is not the intent of this method to compare similar instruments of different manufacture, but to enable the user to choose a suitable instrument.

5. Apparatus

5.1 *Manufacturer's Manual.*

5.2 *Standard Weights*—A set of weights up to the capacity of the scale with sufficient subdivisions of weight so that increments of about 10 % of the capacity up to the capacity can be tested.

5.3 *Thermometer,* room temperature, with a resolution of at least 1 °C.

5.4 *Stop-Watch,* reading to ⅕ s.

6. Preparation

6.1 Make sure that the scale and weights are clean.

6.2 Place the standard weights near the instrument.

6.3 Place the thermometer on the bench in such a position that it can be read without being touched.

6.4 Allow the instrument and the weights to sit undisturbed for at least 2 h with the balance turned off. Monitor the temperature during this time to make sure that there is no more than approximately 2°C variation over the last hour before beginning the test.

6.5 Read the manufacturer's instructions carefully. During each step of the test procedure, the instrument should be used in the manner recommended by the manufacturer. Know the location of any switches, dials, or buttons as well as their functions.

7. Test Procedure

7.1 *Warm-up Test:*

7.1.1 If it is required in the normal operation of the scale to turn it "on" as an operation separate from weighing, perform that operation simultaneously with the starting of the stopwatch.

7.1.2 If a zeroing operation is required, do it promptly. Record the temperature.

7.1.3 At the end of 1 min, read and record the indication with the pan empty.

7.1.4 At the center of the sample pan place a standard weight nearly equal to but not exceeding 98 % of the capacity of the scale. If the scale allows no weight readings above the stated nominal capacity, then this test should be performed with standard weights equal to 90 % of capacity. When the indication is steady, record the indication and remove the weight from the pan.

7.1.5 At the end of 5 min, repeat steps 7.1.3 and 7.1.4 without rezeroing.

7.1.6 At the end of 30 min, repeat again.

7.1.7 At the end of 1 h, repeat again. Record the temperature.

7.1.8 Compute for each measurement as follows:

$$k_t = W/(I_w - I_o) \quad (1)$$

where:

I_w = indication with the standard weight on the pan,
I_o = indication with pan empty,
W = known or assumed value of the standard weight, and

k_t = calibration factor for time t.

7.1.9 Plot the values of k_t against the time (1 min, 5 min, 30 min, and 60 min). The time at which k_t apparently no longer drifts in one direction can be assumed to be the warm-up time required.

7.1.10 If there is a user-adjustable full-scale calibration procedure recommended by the manufacturer, this adjustment should be made after the warm-up time determined in 7.1.9.

7.1.11 If the calibration cannot be adjusted by the user, the factor k_t can be used as a multiplier for an indicated weight to correct to true weight.

7.1.12 Plot I_o as a function of time to determine the zero drift. For individual measurements of weight, the zero can be monitored or corrected prior to a weighing. However, if the change in weight of a sample as a function of time is of importance, and if the sample cannot be removed for zeroing, it is also important to know the course of the zero as a function of time.

7.2 *Off-Center Errors*—The geometry of the stabilizing mechanism for the sample pan determines whether or not the scale is sensitive to the position of the load on the pan. This effect is measured by placing the load in various positions on the pan and observing any difference in indication. Place the standard weight (100 % or 90 % of capacity, as per 7.1.4) in 5 positions on the pan, noting the indication for each position: center-front-back—right-left; or center and corners. The difference between the lowest and the highest indication is the maximum off-center error.

7.3 *Repeatability*—A computation of the standard deviation (σ) of a series of observations at the same load apapproached from the same direction provides a measure of precision. The computation of 3σ will indicate with a high degree of assurance that any single measurement will fall within that limit of error, providing hysteresis is negligible. A control chart can be generated by periodically remeasuring the standard deviation and plotting it as a function of time (perhaps by date). Any time that the standard deviation falls outside of a pattern of values (control limits) there may be a reason to investigate the instrument or the measuring technique to determine whether adjustments may be required.

7.4 *Hystersis*—Balances do not usually have problems with hysteresis. Nevertheless the test for hysteresis is simple and should be performed on newly-acquired balances. Perform the test as follows:

7.4.1 Zero the balance,

7.4.2 Place a weight or weights equal to about one-half the balance capacity on the pan and record the reading once it is stable,

7.4.3 Add more weights to the balance pan until 90 % to 100 % of full capacity is reached. Wait for a stable reading, although the actual value need not be recorded.

7.4.4 Remove the weights which were added in 7.4.3 and record the balance reading once it is stable.

7.4.5 Remove the rest of the weights from the balance and record the reading as soon as it is stable. The five operations can be shown in tabular form:

Operation	Weight on Pan	Balance Reading
1	nil	0
2	½ capacity	W1
3	full capacity	W2
4	½ capacity	W1'
5	nil	Z

If the quantity $W1 - W1' + Z/2$ differs significantly from zero, the difference can be attributed to hysteresis. The test may be repeated several times and the results averaged to reduce measurement scatter.

7.5 *Precision*—To calculate the balance precision, combine the uncertainties due to lack of repeatability and to hysteresis.

7.6 *Accuracy and Linearity*—These tests are made together because they represent the same thing. Since accuracy represents the proximity to true value, the nonlinearity is a point-by-point measure of accuracy if the zero point and the full-scale calibration point have been set true. Set the zero and full-scale indications as described in 7.1.10 if possible. Place weights on the pan in increasing increments of about 10 % of the capacity and observe the indications. Plot the indicated values against the known or assumed value of the weight. The difference at any point is the inaccuracy. Keep in mind that the accuracy cannot be better than the precision and that every observation includes an uncertainty of as much as 3σ so that specifying a higher accuracy may be misleading. However, a procedure that includes multiple observations at each point and which minimizes any hysteresis effects and off-center errors can improve the precision, and therefore produce an accuracy measurement which is more significant.

7.7 *Settling Time*—The time for an indication to reach a stable value after the application of a load is a measure of how soon an indication may be read. This time is controlled by several factors including the moment of inertia of the system, the degree of damping or, in the case of digital instruments, the time-constant of the digital conversion rate. In addition, some digital designs may permit a flicker between two or more digits because of hunting in a servo loop. A knowledge of the time required may prevent a reading in error. Zero the scale in accordance with the manufacturer's instructions. Place a standard weight equal to the capacity of the scale on the pan simultaneously starting the stop-watch. Stop the watch when it appears that the indication is steady. Record the elapsed time. Repeat several times to ensure that there is reasonable correlation between measurements.

7.8 *Temperature Effects*—The ambient temperature may have an effect on the zero as well as the full-scale calibration. If means are available to test the instrument at various temperatures, such a test can be valuable, especially if the location in which the instrument is used is subject to variable temperature. Precaution should be taken to avoid moving the instrument from one location to another in order to take advantage of different existing temperatures. Moving the instrument may introduce other effects which could mask the variability with temperature.

7.9 *Vernier or Micrometer Calibration*—Some optical scales are equipped with a device for subdividing the smallest increment of the main scale. In order to subdivide correctly, the full range of the subdividing device must exactly equal one scale graduation. In the case of a vernier, this can be accomplished by carefully zeroing the instrument and observing the coincidence of the first and last line of the vernier with the corresponding lines on the main scale. Usually, if the first (zero) line of the vernier is coincident with the zero line of the main scale, the last line of the vernier should be coincident with the line of the main scale which is one less than the number of graduations on the vernier (for example, 10 graduations on the vernier corresponding with 9 graduations on the main scale). In the case of a micrometer which may subdivide a scale division into 100 parts, this test is not as simple because the micrometer usually is limited to 99 subdivisions in order to avoid ambiguities in reading. Therefore, the range of the micrometer cannot be examined by turning it through its entire range. One test which can be performed is to set the micrometer to read 00. Zero the instrument to some scale line higher than zero. Operate the micrometer to read 99. It should not be possible to bring the next lower line of the main scale into coincidence with the cursor. If possible, check the micrometer more precisely by using a test weight equal to 99 readable units. Combinations of small weights can be used to make up this value. Zero the instrument. Place the weights on the pan and operate the micrometer to bring the cursor into coincidence. Observe the displayed weight and compare with the true value of the weights on the pan. If the displayed weight is in error by more than one readable unit, adjust the display if such an adjustment is recommended by the manufacturer.

7.10 *Resistance to External Effects*—Some digital devices can show disturbances in the display due to RFI (radio frequency interference). Quantitative testing is difficult but operating a citizens band radio transmitter near the instrument can give some information about the susceptibility to RFI. Electromagnetic force-balance instruments may have insufficient shielding and may, therefore, react to the influence of strong magnetic fields nearby. Passing a small permanent magnet around the instrument and observing changes in display will give information about this effect. Moving the instrument from a metal topped bench to one which is nonmagnetic and observing a difference in full-scale calibration will give some qualitative information about any sensitivity in this area.

8. Interpretation of Results

8.1 Each of the tests listed are designed to give pertinent information about the instrument. The importance of any one test will depend on the needs of the user. If the tests are to be used for qualifying an instrument for a procedure, those tests which are pertinent to that procedure should, obviously, be performed.

9. Precision and Bias

9.1 For statements on precision and bias, refer to 7.5 and 7.6.

10. Keywords

10.1 balances; direct reading; laboratory; scales; top-loading