Application Note C-012

Assuring balance accuracy

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One of the major requirements of a laboratory balance is that it be accurate. This means that the values given by the balance must be in agreement with nationally accepted standard values. There are two factors involved in assuring that readings given by the balance are truly accurate: calibration and linearity. Generally, the balance user is responsible for the accuracy of calibration and the manufacturer is responsible for the accuracy of linearity.

Calibration

The calibration procedure involves setting two points on the balance scale equal to known values. This is like stretching a rubber ruler to match a standard ruler. One of these points is zero. The setting of this point is accomplished by assuring that the pan is free of any material that is not a permanent part of the weighing system, and then bringing the balance readout to zero (see Fig. 1).

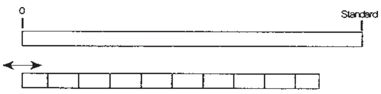

Figure 1: Setting Zero

On mechanical and older type electronic balances, this is accomplished by turning a "zero" control. On today's electronic balances, this is usually done by pressing a "tare" or "zero" button. Since this zero is the starting point for all weighing, always re-zero the balance before each weighing.

The second calibration point is near or at the top of the balance range. A known weight, about equal to the full scale value of the readout, is placed on the pan and the balance

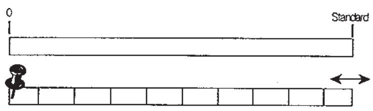

Figure 2: Setting Calibration

readout is adjusted to the calibration value (see Fig. 2).

The method of making this adjustment varies widely from one balance to another. Some balances have their calibration control inside the unit. Others have a more accessible outside control, while a few have an easy to use "calibration" button. Refer to the instrument operating manual for the details of the correct calibration procedure.

The accuracy of this calibration is dependent on the accuracy of the calibration weight. The calibration weights usually supplied with the balance or bought from a laboratory supply firm are guaranteed by the manufacturer to be within a tolerance range. Until about 1975, these tolerance ranges were defined by the National Bureau of Standards Circular 547 and were designated with letters such as M, Si, P, etc. NBS gave this responsibility to American Society for Testing Materials (ASTM) which, in 1980, issued a new tolerance standard E617 with the ranges designated by numbers. The smallest tolerance ranges under the ASTM standard are Class 1.1 and I which replace the NBS Class M. Class 2 and 3 (formally Class S and 5-1) weights are normally used for calibration of laboratory analytical balances.

Today's balances often have resolutions that go beyond the most accurate weight classes. For example, the most accurate standard 200 gram weight has a tolerance of ± 0.5 mg. Using this weight to calibrate a 200 gram balance with a readability of 0.1 mg could leave the last digit in doubt. However, this normally doesn't present a problem as most users are mainly interested in repeatability and desire only reasonable accuracy. If more exact value of the calibration weight is needed, the weight can be certified by a metrology laboratory to a more precise value.

We recommend the following metrology labs:

Troemner, Inc.
6825 Greenway Ave.
Philadelphia, PA 19142
(215) 724-0800

Rice Lake Weighing Systems
230 W. Coleman St.
Rice Lake, WI 54868
(715) 234-9171

Watson Bros.
1328 Grand Central Ave.
Glendale, CA 91201
(818) 247-6711

Another factor to be considered in the calibration of a balance is the portion of the balance range that you will be using. Assuming that you have accurately zeroed the balance, you will get more accurate weight values as you approach zero. Using the 200 gram balance again as an example, assume that your 200 gram calibration weight has an error of 1 milligram. Your weight reading at 100 grams would have an error of 0.5 mg, the reading at 20 grams would only have an error of .1 milligrams, etc. This "error cone" becomes smaller as you approach zero (see Fig. 3). Therefore, if you are only using the low area of your range, you do not have to be as concerned with the accuracy of the calibration weight. Also, this illustrates the reason for using a calibration weight that is near the full scale value of the balance in order to reduce the spread of the error cone.

Calibration weights can change their values with time. They usually increase in weight due to accumulation of oils and particles of dust. In order to maintain a constant standard, many users choose one weight or a set of weights (they need not be certified) which are used a primary standards for the lab. These weights are very carefully handled and usually kept in a locked compartment under

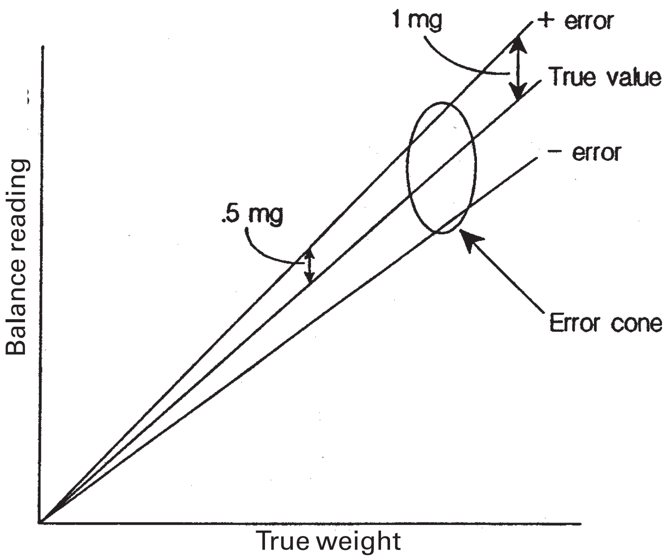

Figure 3. Error Cone

the control of the laboratory director. The working calibration weights are recalibrated against these primary standards every three to six months or as needed. Then, the working calibration weights are used to recalibrate the balances daily or weekly. Carefully used, this method will give the desired constancy over a period of many years.

Linearity

Accurately calibrating a balance does not assure accurate weigh values. Though the two end points are accurate, poor linearity will produce inaccurate readings between these points. For example, if a 100 gram balance is calibrated at the 0 and 100 gram points, but an accurate 50 gram

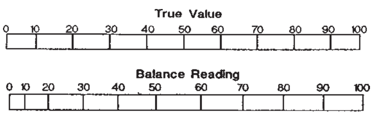

Figure 4: Non-linearity

weight produces a reading of 57 grams, then the balance is inaccurate due to very poor linearity (see Fig. 4). Linearity is dependent upon the design and the condition of the balance. The manufacturer usually will detail the limits of the linearity in the balance specifications. Since linearity is as measure of quality, this specification should be checked when shopping for a new balance. Also, linearity should be tested periodically since it can deteriorate in time due to balance wear or abuse.

The tests for linearity involve weighing individual parts of a sample and comparing the sum of the parts to the weight of the total sample. For this test, calibration weights are not required, nor does the balance have to be calibrated. Switch on the balance and allow the recommended warm up time. Use four individual weights with values about one-fourth the full scale value of the balance. For our examples of this test procedure, we will assume the balance has a full scale value of 200 grams. Therefore, we will select four metal pieces with weights about 50 grams. Identify each piece with a letter A, B, C or D. Do not make any mark on the pieces that could cause them to change weight. Carefully zero the balance before each of the following weighing. To account for repeatability of the instrument, several weighing (ideally ten) should be made and the mean used for each reading.

Test no.1: Midpoint

1. Weigh all four pieces together. Record this reading as the "full scale value".
2. Weigh pieces A and B together. Then weigh C and D together. Add these two values and call the sum "weight sum".
3. If the balance is linear at the midpoint, the weight sum will equal the full scale value. If the two differ, divide the difference by two because two measurements were made at this point. The result is the balance non-linearity at the midpoint.

Test no 2: 25% Point

1. Assuming the "full scale value" has been determined, weight all four pieces individually. Add their weights together, and call the sum "weight sum".
2. If the balance is linear at the 25% point, the weight sum will equal the full scale value. If the two differ, divide the difference by four. This is the balance non-linearity at the 25% point.

Test no 3: 75% Point

1. Divide the pieces into the following groups:
   Group no1: pieces A, B, C
   Group no2: pieces A, B, D
   Group no3: pieces A, C, D
   Group no4: pieces B, C, D
2. Weigh all four groups individually. Add their weight values together and call the result "weight sum". However, this time, multiply the full scale value by three and call it "75% full scale value".
3. If the balance is linear at the 75% point, the weight sum will equal the 75% full scale value. If the two differ, divide the difference by four. This is the balance non-linearity at the 75% point.

Most balances have a non-linearity that follows a bow curve (see Fig. 5). For these balances, only a midpoint check will be needed to determine the maximum non-linearity. However, if you get a very small non-linearity at the midpoint, the balance may have a non-linearity that follows a "S" curve. In this case, you should check the 25% and 75% points. About 5 to 10% of the balances have this "S" type non-linearity.

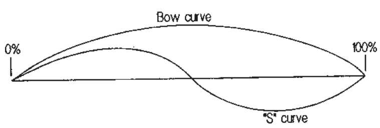

Figure 5. Non-linearity Curves

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