GLP 9

Good Laboratory Practice for Rounding Expanded Uncertainties and Calibration Values

A calibration is not complete until the expanded uncertainty associated with the calibration is determined and reported. Each Standard Operating Procedure (SOP) includes information regarding the calculation of uncertainties. The expanded uncertainty is generally reported with approximately a 95 % confidence interval (95.45 %). The confidence interval is determined by multiplying a coverage factor (often 2, but based on the degrees of freedom or effective degrees of freedom) times the combined uncertainty, u_c; the combined uncertainty is usually the root sum square of properly combined Type A and Type B evaluated components according to the calibration procedure and rounded according to this GLP, ISO/IEC Guide to the Expression of Uncertainty in Measurement (GUM, 2008), Section 7, and ISO 80000-1:2009, *Quantities and units, Part 1*. Three Options for rounding presented in this GLP that are all commonly used by calibration and testing laboratories. The laboratory should document which method(s) will be used.

Note: do not round intermediate calculations; rounding intermediate values can cause rounding errors in the final results and should only take place after the final expanded uncertainty has been determined.

1 Rounding Steps. The steps for reporting corrections and uncertainties are as follows:

1.1 Identify the first two significant digits in the expanded uncertainty. Moving from left to right, the first non-zero number is considered the first significant digit. Zeros, which follow a decimal point, when there are only zeros ahead of the decimal point, are not considered significant figures.

1.2 Round the expanded uncertainty following Option A, B, or C.

1.3 Round the reported measurement result, correction, or error to the same number of decimal places as the least significant digit of the uncertainty with both value and uncertainty being in the same units. Both the measurement result and uncertainty will be rounded to the same level of significance.

2 Rounding Methods

2.1 Option A. Even/Odd Method[1].

2.1.1 Use the following rules to round measurement data using the even/odd rounding rules, consistent with the level of significance:

[1] This is the historical method used in this GLP. Where statistics matter, and where numbers that end with the 5 are common, this method is preferred, because it avoids asymmetry due to rounding up. Normally there are 5 situations when you round up (0.5 to 0.9) but only 4 to round down (0.1 to 0.4). By using the even/odd method you introduce more balance in the final results that may avoid bias in mean values over the long term.

2.1.2 When the digit next beyond the one to be retained is less than five, keep the retained figure unchanged. For example: 2.541 becomes 2.5 to two significant figures.

2.1.3 When the digit next beyond the one to be retained is greater than five, increase the retained figure by one. For example: 2.453 becomes 2.5 to two significant figures.

2.1.4 When the digit next beyond the one to be retained is exactly five, and the retained digit is even, leave it unchanged; conversely if the digit is odd, increase the retained figure by one (even/odd rounding). Thus, 3.450 becomes 3.4 but 3.550 becomes 3.6 to two significant figures.

2.1.5 When two or more figures are to the right of the last figure to be retained, consider them as a group in rounding decisions. Thus, in 2.4(501), the group (501) is greater than 5 while for 2.5(499), (499) is less than 5.

2.2 Option B. Standard Spreadsheet Rounding.

Use standard rounding practices that are used in spreadsheet software such as Microsoft Excel and by following the steps for rounding shown above. (This will generally round up. Do not use truncations.)

2.3 Option C. Round Uncertainties Up.

Round uncertainties up to the next larger value when there are any digits beyond the second significant digit. This conservative approach may be used for reporting uncertainties, for evaluating compliance of the uncertainties against maximum permissible errors (mpe), tolerances, or risk assessments (including guard banding) and may also be used when reporting values on an accreditation Scope. Follow the steps for rounding shown above.

3 Examples of Rounding

Several examples to illustrate the proper method of reporting corrections and uncertainties follow. The number of significant digits will be identical for these examples for all three options.

3.1 Example 1

Suppose the correction for a weight is computed to be 1.357 8 mg and the uncertainty is 0.577 5 mg. First, round the uncertainty to two significant figures, that is, 0.58 mg. Then state the correction as 1.36 mg. Notice that the uncertainty and the correction express the same number of decimal places. Report the correction as 1.36 mg ± 0.58 mg. This result will be identical for Options A, B, and C.

3.2 Example 2

The volume of a given flask is computed to be 2000.714 431 mL and the uncertainty is 0.084 024 mL. First, round the uncertainty to two significant figures, that is, 0.084 mL. (Do not count the first zero after the decimal point.) Round the calculated volume to the same number of decimal places as the uncertainty statement, that is, 2000.714 mL. Report the volume as 2000.714 mL ± 0.084 mL. Options A and B follow this example. Option C will round the uncertainty to 0.085 mL since it rounds up for evaluation. The result for Option C will be 2000.714 mL ± 0.085 mL.

3.3 Example 3

The correction for a weight is computed to be 4.3415 mg and the uncertainty is 2.0478 mg. First, round the uncertainty to two significant figures, that is, 2.0 mg. (Notice that two significant figures are shown. The zero is a significant figure since it follows a non-zero number.) Then, round the correction to the same number of decimal places as the uncertainty statement, that is, 4.3 mg. Report the correction as 4.3 mg ± 2.0 mg for Options A and B. Option C will be 4.3 mg ± 2.1 mg since any value after the 0 in 2.0 will cause it to be rounded up to 2.1.

3.4 Example 4

The correction for a weight is computed to be 285.41 mg and the uncertainty is 102.98 mg. Because this uncertainty is a large number, we first convert both values to the next larger commonly reported unit (i.e., 0.28541 g and 0.10298 g respectively). First, round the uncertainty to 0.10 g. (The first nonzero digit (1) is the first significant figure and the remaining digits are rounded to the nearest number following the first nonzero digit.) Then, round the correction to the point where the rounding occurred in the uncertainty statement. Round the correction to 0.29 g. Report the correction as 0.29 g ± 0.10 g (290 mg ± 100 mg) for Options A and B. Option C will be reported as 0.29 g ± 0.11 g (290 mg ± 110 mg).

3.5 Example 5

The correction for a weight is computed to be 285.41 mg and the uncertainty is 33.4875 mg. First, round the uncertainty to two significant figures, that is 33 mg. Then, round the correction to the same number of decimal places as the uncertainty statement, that is, 285 mg. Report the correction as 285 mg ± 33 mg for Options A and B. Report the correction as 285 mg ± 34 mg for Option C.

3.6 Example 6

The length of a calibrated interval is computed to be 9.999 455 8 ft and the uncertainty is 0.003 561 7 in. First, make sure both values are reported in the same unit (i.e., convert the uncertainty to ft, 0.000 296 808 ft.) Then, round the value to two significant figures, that is, 0.000 30 ft. Then, round the length of the interval to the same number of decimal places as the uncertainty value, that is, 9.999 46 ft. Report the length of the interval as 9.999 46 ft ± 0.000 30 ft. This result will be identical for Options A, B, and C.

Rather than stating the uncertainty value with each correction, it is also proper to place the correction values in a column headed by the words "Correction" or "Error," etc., and place the uncertainties (without plus-minus signs, ±) in a column headed "Expanded Uncertainty".