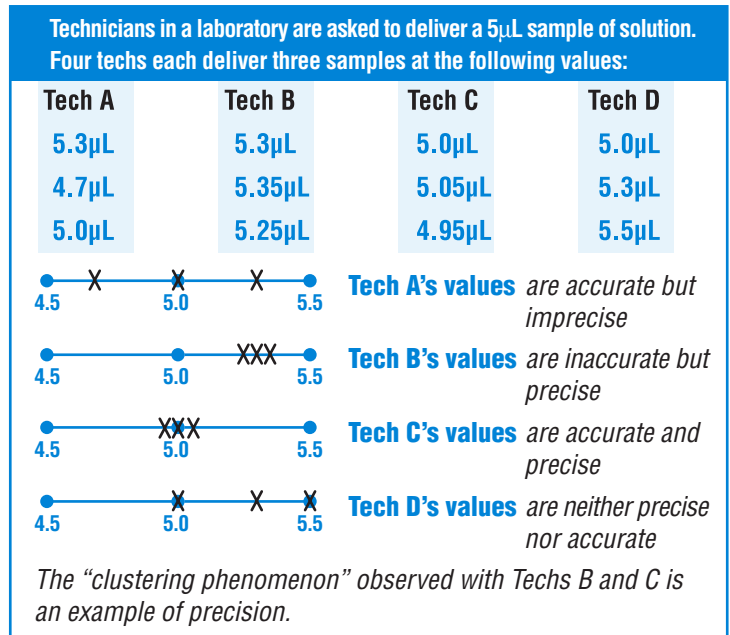# Defining *accuracy & precision*

> "Specifications for stable imprecision and inaccuracy are incomplete and inadequate if they fail to consider QC...If you perform QC, that's evidence...the assumption of perfect method stability is wrong."[1]

ARTEL

Increased usage sometimes causes definitions to become tainted. In the laboratory, two terms which are often used interchangeably are accuracy and precision, or inaccuracy and imprecision. These, in fact, are different terms with very distinct meanings. Knowing the true definition, influences upon, and importance of each is critical to the development of a sound quality control program in the laboratory. A sound quality control program assures the reliability of your results, allows the interchangeability of results between laboratories, reduces the likelihood of expensive repeat testing, and, in a worst case scenario, could prevent failed inspection or the questioning of vital research data.[2]

What are inaccuracy and imprecision?

Inaccuracy is the deviation of a measurement from a standard value or true quantity. In a group of values, inaccuracy would be the deviation of the mean ($\bar{x}$) of the group of values from a standard value. Inaccuracy is measured in terms of absolute error **AE**.

Imprecision, on the other hand, is concerned with the closeness of two or more measurements to each other, rather than to a standard value. It is measured in terms of standard deviation **s**

Technicians in a laboratory are asked to deliver a 5µL sample of solution. Four techs each deliver three samples at the following values:

Tech A	Tech B	Tech C	Tech D
5.3µL	5.3µL	5.0µL	5.0µL
4.7µL	5.35µL	5.05µL	5.3µL
5.0µL	5.25µL	4.95µL	5.5µL

Tech A's values *are accurate but imprecise*

Tech B's values *are inaccurate but precise*

Tech C's values *are accurate and precise*

Tech D's values *are neither precise nor accurate*

The "clustering phenomenon" observed with Techs B and C is an example of precision.

or as coefficient of variation **CV** *(see For the Mathematically Inclined).* It is possible for a group of values to be precise without being accurate *(see chart above).*

What influences accuracy and precision?

Three types of errors affect accuracy and/or precision:

■ **Errors affecting precision:**
Random, or **indeterminate errors**, are not predictable. The amount of random error can be greatly increased or decreased by a variety of factors including the number and complexity of steps in a method, the skill of the analyst, and the quality of materials and apparatus.[3] Random errors can affect accuracy, however, if a limited number of data

points are taken. Good statistical practice requires a number of data points sufficient to reflect the true mean.

■ **Errors affecting both accuracy and precision:**
Gross errors are usually large, easily detectable, and preventable if a method is carefully followed. Examples of gross errors include misreading, careless observation of methods, and character transposition.[4] Because gross errors result in outliers *(please see Q&A)*, which in turn influence $\bar{x}$, gross errors affect both accuracy and precision.

■ **Errors affecting accuracy:**
Absolute (AE) or determinate errors fall into three categories: *personal error, method error, and instrumental error*[3] *(see following table).*

When should accuracy and precision be investigated?

A laboratory should investigate the accuracy and precision of a method when: the method is new, the method is questioned because of external quality control data, or the validity of the results is questionable.

How should requirements for accuracy and precision be determined?

To determine how important accuracy and precision are to a method, you will have to take a close look at the intended use of your results, your sources of error, and how those errors will affect your results. A three step analysis is involved:

1. establish the limits of acceptable error in results
2. determine each predominant source of error in the method
3. do a statistical analysis of the impact of these errors upon your results

This analysis will tell you whether random error or absolute error will be the bigger source of error in your results. If random error is the principal contributor, you will need to control imprecision; if absolute error is the principal contributor, you will need to focus on controlling inaccuracy.

Which should be determined first?

Precision studies should be done first. The level of precision will reveal the reproducibility of a method[5], the method's inherent variability, and the ability to maintain a consistent mean from month to month or run to run.[2] You can then develop and perform accuracy control studies.

Type of error	example	corrective action
personal error	incorrectly determining endpoints during a titration because of subjectivity	use an objective method like a pH meter and/or retrain technician
method error	using a variable volume pipette at the bottom of its range	use a pipette sized such that the set volume is in the top half of its range
instrumental error	delivering inaccurate volume because of a corroded pipette piston	clean and check pipettes regularly

For the mathematically inclined:

To determine inaccuracy:

$AE = [\mu - \bar{x}]$ where $\bar{x}$ is the mean of enough experimental runs to ensure a meaningful average and μ is the standard value.

To determine imprecision:

$$s = \sqrt{\frac{\mathcal{E}(\bar{x} - x_i)^2}{N - 1}}$$

$\bar{x}$ = mean or average value
x_i = any single value
N = total number of observed values

When a method is less precise, the standard deviation is greater. For example, s for the values obtained by Tech A in our example would be:

$$\sqrt{\frac{(5.0-5.3)^2 + (5.0-4.7)^2 + (5.0-5.0)^2}{N-1}}$$

or 0.3.

The s for Tech B, whose values are more precise, would be 0.05.

To express imprecision as a percentage, use CV

$$CV = \left(\frac{s}{\bar{x}}\right)100$$

Again, for Tech A:
$CV = (0.3/5.0)(100) = 6$
A low CV indicates good precision.

References:

[1] Westgard, Westgard Quality Corporation, www.westgard.com

[2] Kaplan, Szabo, *Clinical Chemistry: Interpretation and Technique.*

[3] Tietz, *Fundamentals of Clinical Chemistry*, second edition.

[4] Tietz, *Textbook of Clinical Chemistry.*

[5] www.umassd.edu/chemistry 167 (statistics)

[6] Snedecor and Cochran, *Statistical Methods*, eighth edition.

Questions & Answers

When can a method be considered reliable?

A method is reliable if it has maintained a steady state of accuracy and precision over a considerable period. The reliability can only be established by checking the method, using appropriate primary standards and control specimens.[3]

What is an outlier?

Outliers, or aberrant values, are extreme cases which can strongly influence statistical calculations.

A suspect value should be investigated. Sometimes an inquiry will reveal the correct value for the observation. The correct value can then be used in analysis. Sometimes, although a gross error was most certainly made, there is no way to find the correct value. In this case, the outlier would be omitted and the data would be analyzed without that value. The investigator should also analyze the data with the outlier present to learn which conclusions are affected by the absence or presence of the outlier.[6]

There are several tests to determine if an extreme value is in fact an outlier.[4] The simplest such test, the range test, applies if there is only one outlier: if the difference between the extreme value and the next highest or lowest value is greater than one third of the range of the entire set of values, then the extreme value is an outlier.

How many data points should I take?

The number of data points will vary depending upon your laboratory's needs, and whether you are testing for accuracy or precision. Please reference ARTEL Lab Report, Issue One, *How Many Data Points.*