

Pi Technical Note 110

Accuracy, Precision, Reproducibility Repeatability & Resolution. What do they mean?

Introduction

When purchasing online instruments such as pH, chlorine, and ozone analysers, buyers often ask the question "which analyser is the most accurate?". This question when applied to online instrumentation, is not as valid as people may think. In order to choose the best analyser and understand what is truly being measured it is important to consider all of the following concepts; Accuracy, Precision, Reproducibility, Repeatability, Resolution and Drift and if necessary, change our question.

What is Accuracy?

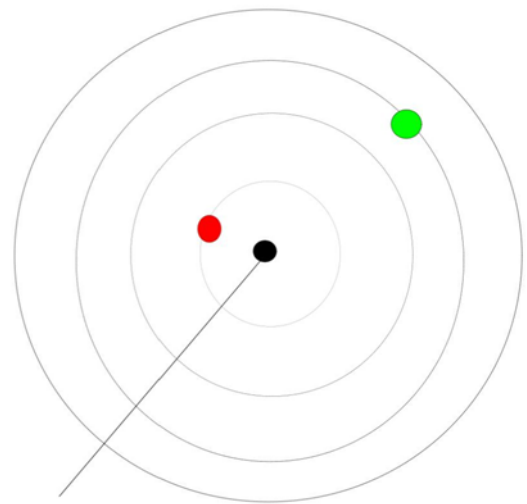
The "accuracy" of a measurement refers to how close a measurement is to a "true" (actual) value or a value accepted as being true¹. The accuracy of most instrumentation, is dependent on the accuracy of the device, or method used for calibration, therefore most online instruments cannot be quoted for accuracy as they may only be as "accurate" as their calibration. The engineer asking how accurate an analyser is, is normally asking how accurate will the analyser be over time, as all analysers are 100% accurate at the point of calibration.

What is Precision?

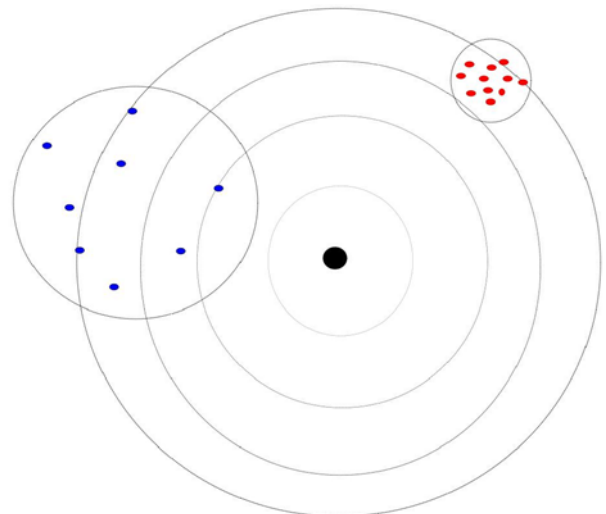
Precision is a measure of the spread of different readings. Precision and accuracy are unrelated to each other, meaning that you can be very PRECISE but not ACCURATE or vice versa. In practical terms precision is often more relevant to an online analyser than accuracy. Precision is also used as a synonym for the resolution of the measurement e.g. a measurement that can distinguish the difference between, 0.01 and 0.02 is more precise (has a greater resolution) than one that can only tell the difference between 0.1 and 0.2 even though they may be equally accurate or inaccurate.

What is Resolution?

Resolution refers to the smallest change that a sensor can detect in the quantity it is measuring. Resolution of an online instrument can be affected by the sensor itself, the manner of digitisation and the capability of the display. In the past the resolution was limited by the display (a small analogue gauge), so 'resolutions' were often reported as the ability to read a gauge. The development of digital displays, means that the display is no longer the limiting factor, but is often still used to define the resolution. Quoting a resolution which is better than the precision is quite misleading. For example quoting to a resolution of the display of an online pH meter at 0.001 is misleading if the sensor precision is 0.1.



This is the Actual value. Accuracy is the distance of the measurement from the Actual value. The Red is more accurate than the Green.



The Red is more precise than the Blue. Both the Red and the Blue are equally accurate.

What is Drift?

Drift is possibly the most important and overlooked term relevant to online process instruments. Drift defines how much the signal would change over a given time-scale e.g. 1% per month. It is important to understand what the percentage refers to, for example, does it refer to the current reading or the full scale? In the majority of cases it refers to the full scale.

What is Repeatability/Reproducibility?

Reproducibility is the degree to which an experiment or study can be accurately reproduced, or replicated, by someone else working independently, and is one of the main principles of the scientific method. For the vast majority of people/situations reproducibility equals repeatability. The extent to which reproducibility applies to an instrument is dependent on whether it is a continuous or continual online instrument. With a continual online instrument a series of samples are analysed repeatedly, therefore repeatability applies between each sample. For continuous online instruments the sample is analysed continually (all the time), therefore reproducibility does not apply. For an online instrument reproducibility is a useful measure, that is, if there are 2 or more of the same instrument calibrated at the same time on the same sample, what will the agreement be?

Conclusions

For online instruments like pH, chlorine, ozone, chlorine dioxide etc.:

Accuracy: is set by the calibration method and so depends on the accuracy of the device used to calibrate the sensor. No manufacturer should quote accuracy for an online analyser that needs to be calibrated, and yet many do!

Resolution: is a useful measure if it is a true figure, but typically it is the resolution of the display that is quoted and so is worthless.

Drift: the gradual change of the signal from a measuring instrument over time is probably the most useful measure of how good an instrument really is, as the accuracy of all online instruments is 100% at the time of calibration.

Repeatability: can be a useful measure of the agreement between instruments.

Reproducibility: has no real relevance to most online instruments.

Quoting for accuracy and reproducibility are not useful for online instruments. When choosing an instrument, drift is what really counts, which is often overlooked completely! In some cases precision (be careful it isn't the resolution of the display that you are buying!), can also be a useful measure, along with repeatability.

References

1. ISO 5725-1:1994, Accuracy (trueness and precision) of measurement methods and results - Part 1: General Principles and Definitions.

