Measurement Quality Matters   June 2023

In this issue we revisit the important matter of how to make valid conformity (Pass/Fail) statements as a result of measurements. This topic is often misunderstood, and some people confuse specifications with tolerances and measurement uncertainty.

Firstly, let's define those three terms, informally as

Specification – the specified parameters that shall be met by a product. Example – Height of a desk 760 mm. This specification is absolute, it does not depend or rely on your measurement ability.

Tolerance – allowable variation to a specification limit. A bigger tolerance often allows cheaper or quicker manufacturing techniques. In the height of a desk example this might be 760 mm +/- 30 mm which may be expressed as height of table to be 730 mm minimum, 790 mm maximum.

Measurement Uncertainty (MU) – this is an estimate or evaluation of the doubt you have about your measurement ability. Expressed in the parameter of the measurement or a percentage of that, it describes how confident you are about the measurement result being correct.   If you can have confidence that your measurements are within 1 mm of the true value then your MU might be described as MU = 1 mm at 760 mm. This description of your ability also requires a confidence level to be stated with the MU. We shall not address that complication today, but it is usually expressed at k=2 which is approximately 95%.   So the measurement of the desk height might be stated as 760 mm with an MU of 1 mm at 95% confidence.

PASS/FAIL Statements -

What is the issue?   We may be asked to say if the desk passes or fails the specification. Our result may depend on how well we can make the measurement. If the measured value is close to the specification limit then the size of our MU affects how confident we can be about our pass or fail statement. The real-world reality is that no-one wants to make a product much "better" than it needs to be to meet a specification because that costs more materiel or time. Furthermore, from a laboratory point of view, no-one wants to make a more expensive test or calibration measurement because that too requires more expensive equipment or more time to make the measurement. The customer often wants the cheapest test or calibration. Broadly speaking, a Pass/Fail statement made when a measured value is within uncertainty of a Pass/Fail figure, then that statement cannot be considered reliable. Where this does not matter, where no safety issues or no high failure cost is involved then the customer may be happy. It is essential that the customer understands and accepts the risk involved.

To properly handle these factors we need to develop a decision rule and agree that with the customer. This is now required by the latest version of the testing and calibration competence standard ISO/IEC 17025:2017 and is beginning to appear in specifications and requirements.

Decision Rule – a rule that describes how measurement uncertainty is accounted for in making statements of conformity.

This may be provided in a specification or standard, required by legislation, specified by the customer or by established practice in an industry.   In all other cases, where a statement of conformity is made there must be an agreed decision rule that explains how MU is accounted for in making the pass/fail statement.

Common Decision Rules include:

> Offsetting the pass/fail by the measurement uncertainty. This is called "Guardbanding" and gives a very safe conformity statement but may involve wastage by false rejection of some results.
>
> Offering the pass/fail statement together with a figure for likelihood of false accept or reject. Commonly provided as "Pass with n% PFA" where PFA (potential false accept) represents the likelihood of false acceptance. The fail equivalent is PFR.
>
> "Simple Acceptance" is where the MU is not used in any calculation of pass/fail but the customer must then be made aware of the risk involved when the measurement uncertainty is too large to give a confident result. I would recommend using the PFA arrangement described above in that case but there are other ways of describing the risk, which could reach 50% in some cases.

Customers often do not understand measurement uncertainty (MU) and it is essential that they are given to understand sufficiently to make good use of the test or calibration results.

The components of MU include anything that when varied could alter a result. As shown in Fig 1 this typically involves environmental factors such as temperature, the calibration of measuring equipment, skill of staff, the method including number of repeated readings and sometimes more features.

Some uncertainty components give rise to random variations and the effect can be reduced by using an average of repeated measurements. Some are more systematic, maybe a constant bias of the result which would not vary when repeated. Fig 2 shows "precision" and "accuracy" as they might appear on a dartboard. The true value is the bullseye. Our results are shown by the red, green and blue darts on the board. The triangles represent the average of each set of three darts.

The red set show that all three darts land close to each other; they have good repeatability but bad (average) accuracy as that appears far away from the bullseye. The distance from their average to the bullseye represents a bias (systematic component).

The green set have worse precision, but the average is closer to the bullseye. A smaller bias and repeated measurements which handle the random component giving a better accuracy.

The blue set show small bias and small scatter so these results have higher precision and higher average accuracy.

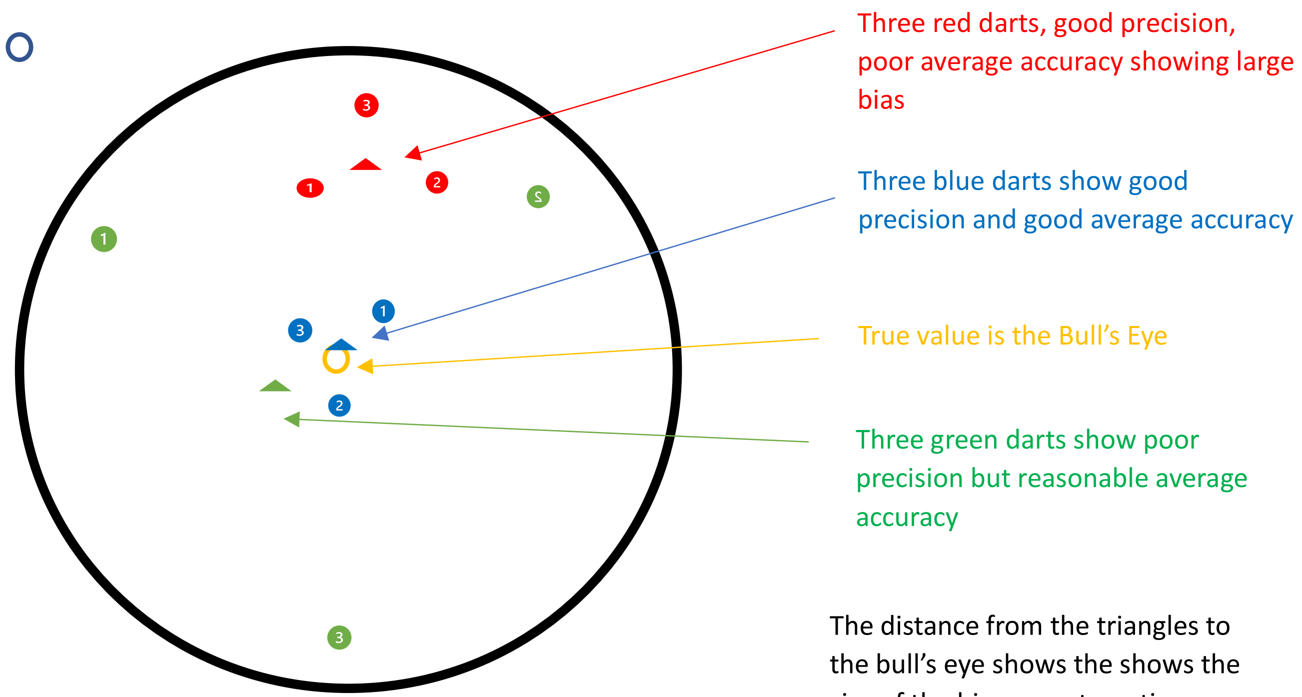
Enumeration of the bias needs external attention such as good traceable calibrations and participation in proficiency testing regimes or interlaboratory comparisons. These are topics for another time.

The ultimate reference about measurement uncertainty is the free "Guide to the expression of Uncertainty in Measurement" published by B.I.P.M. Simpler documents are available from NPL, ILAC and UKAS.

Trevor Thompson retired from the United Kingdom Accreditation Service and now offers training, mentoring and consultancy in metrology, accreditation and related ISO/IEC 17025 matters at www.bestmeasurement.com.

Fig 1

Fig 2



The distance from the triangles to the bull's eye shows the shows the size of the bias or systematic component of the MU