Traceability and Uncertainty

Measurement today is more valuable than ever. We depend on measurement for almost everything – from time keeping to weather forecasts, from DIY work at home to heavy-duty manufacturing, industrial research and medical science. Since measurement plays such a fundamental part in our lives, it is important that the accuracy of the measurement is fit for purpose, i.e. it fully meets the requirements of the application. Every measurement is inexact and therefore requires a statement of uncertainty to quantify that inexactness. The uncertainty of a measurement is the doubt that exists about the result of any measurement. One way of ensuring that your measurements are accurate is by tracing them back to national standards. This method of guaranteeing a measurement's accuracy through an unbroken chain of reference is called traceability.

Accurate measurement enables us to:

- Maintain quality control during production processes
- Comply with and enforce laws and regulations
- Undertake research and development
- Calibrate instruments and achieve traceability to a national measurement standard
- Develop, maintain and compare national and international measurement standards

> "When you can measure what you are speaking about and express it in numbers you know something about it; but when you can not express it in numbers your knowledge is of a meagre and unsatisfactory kind."
>
> Lord Kelvin, British Scientist (1824 – 1907)

There are many factors that can cause inaccuracy:

Environmental effects

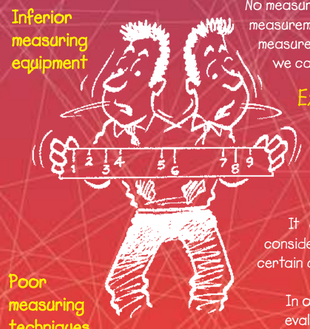
Successful measurement depends on the following:

- **Accurate** instruments
- **Traceability** to national standards
- An understanding of **uncertainty**
- Application of **good measurement practice**

In the United Kingdom, the **National Measurement System** (NMS) is in place to enable measurements to be traced back to their national standards. As the UK's national standards laboratory, NPL is at the pinnacle of this system guaranteeing the accuracy of physical measurments for the nation and abroad.

What is uncertainty?

No measurement is ever guaranteed to be perfect. Uncertainty of measurement is the doubt that exists about the result of any measurement. By quantifying the possible spread of measurements, we can say how confident we are about the result.



Inferior measuring equipment

Expressing uncertainty

A measurement result is only complete when accompanied by a statement of its uncertainty. A statement of uncertainty is required in order to decide if the result is adequate for its intended purpose and consistent with other similar results.

It does not matter how accurate a measuring instrument is considered to be, the measurements made will always be subject to a certain amount of **uncertainty**.

In order to express the **uncertainty** of a measurement, we need to evaluate as accurately as possible the errors associated with that particular measurement.

Poor measuring techniques

For example – we might say that a particular stick is 200 centimetres long, plus or minus 1 centimetre, at a 95% confidence level. This is written:

200 cm ±1 cm at a level of confidence of 95%

This means we are 95% sure that the length of the stick is between 199 centimetres and 201 centimetres.

Why does uncertainty matter?

Calculating and expressing **uncertainty** is important to anybody wishing to make good quality measurements.

It is also crucial where **uncertainty** can influence a pass or failure in a particular test and must therefore be reported on a calibration certificate.

> **Don't confuse the terms Error and Uncertainty**
>
> **Error** is the difference between the *measured value* and the *true value* of the object being measured.
>
> **Uncertainty** is the quantification of the doubt about the measurement result.

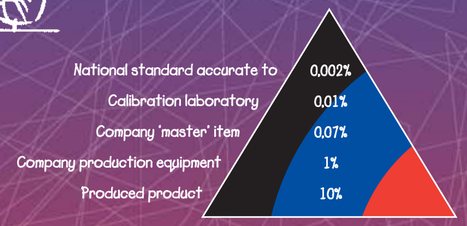
There are established rules for the evaluation of **uncertainty**. [More information can be found in NPL's Good Practice Guide (011) *'A Beginner's Guide to Uncertainty of Measurement'*.] Of course, we must all make every effort to 'control' the uncertainty in our measurements. This is done by regular inspection and calibration of our instruments, careful calculation, good record-keeping.

Traceability

Traceability is a method of ensuring that a measurement (even with its uncertainties) is an accurate representation of what it is trying to measure.

What is traceability to national standards?

The simple and basic concept behind calibration is that measuring equipment should be tested against a standard of higher accuracy.



It should be possible to demonstrate an unbroken chain of comparisons that ends at a national standards body such as NPL. This demonstrable linkage to national standards with known accuracy is called **'traceability'**.

National standards laboratories such as NPL also routinely undertake international comparisons in order to establish worldwide consensus on the accepted value of fundamental measurement units.

Representatives of seventeen nations signed the **Convention of the Metre** (Convention du Mètre) on 20th May 1875 in Paris. This diplomatic treaty provided the foundations for the establishment of the *Système International d'Unités* (International System of Units, international abbreviation SI) in 1960. Since then, national standards laboratories have cooperated in the development of measurement standards that are traceable to the SI.

Any organisation can achieve traceability to national standards through the correct use of an appropriate traceable standard from NPL.

Who is who in the measurement world?

International Committee for Weights and Measures
(CIPM – Comité International des Poids et Mesures) the world's highest authority in the field of measurement science.

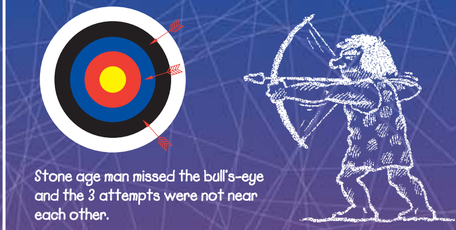
International Bureau of Weights and Measures
(BIPM – Bureau International des Poids et Mesures) co-ordinating body for international metrology, based in Sèvres, France.

National Physical Laboratory
(NPL) is the UK's national standards laboratory, a world-leading centre in the development and application of highly accurate measurement technology and material science.

What is the difference between ACCURACY and PRECISION?

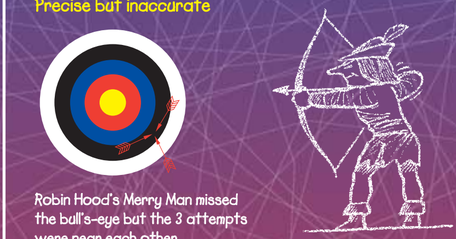
The difference between accuracy and precision is illustrated below by 4 different archers... each with varying degree of ability. The bull's-eye in the target represents the true value of a measurement.

Inaccurate and imprecise (unrepeatable)



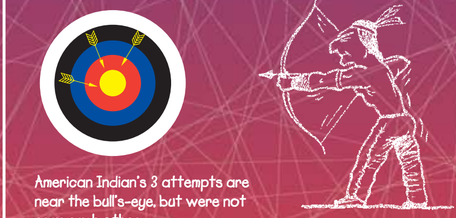
Stone age man missed the bull's-eye and the 3 attempts were not near each other.

Precise but inaccurate



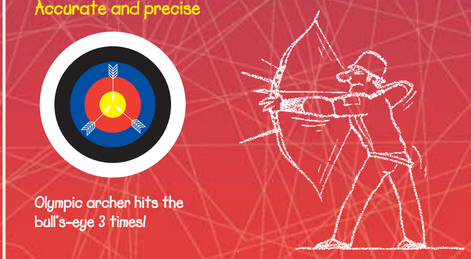
Robin Hood's Merry Man missed the bull's-eye but the 3 attempts were near each other.

Accurate but imprecise



American Indian's 3 attempts are near the bull's-eye, but were not near each other.

Accurate and precise



Olympic archer hits the bull's-eye 3 times!

Accuracy is a qualitative term relating the mean of the measurements to the true value, while precision is representative of the spread of these measurements. Even when we are precise and accurate, there will still be some uncertainty in our measurements. When the uncertainty of a measurement is evaluated and stated, then the fitness of purpose for a particular application can be properly understood.

If you have a measurement-related scientific question contact us on: telephone 020 8943 6880
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