Measurement Standards Laboratory of New Zealand

Calibration Intervals and How to Track the History of Your Instrument or Artefact

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Measurement Intervals

- What factors should be considered when determining measurement intervals?
  - What are the physical processes driving change in the artefact?
  - Does the artefact have an existing measurement history?
  - Are intermediate checks being carried out?
  - Is the measured value combined with its uncertainty close to a critical tolerance?
  - Are there any regulatory requirements for the interval between calibrations?
  - What will the artefact be used for?

Regulatory requirements

- IANZ keeps a table of recommended recalibration intervals which are valid provided the following conditions are met:
  - the equipment is of good quality and of proven stability.
  - the laboratory has both the equipment capability and staff expertise to perform adequate internal checks.
  - if any suspicion or indication of overloading or mishandling arises the equipment will be checked (and recalibrated if necessary) immediately and thereafter at frequent intervals until it can be shown that stability has not been impaired.
  - Where the above criteria cannot be met, appropriately shorter intervals may be necessary.

Drift ….

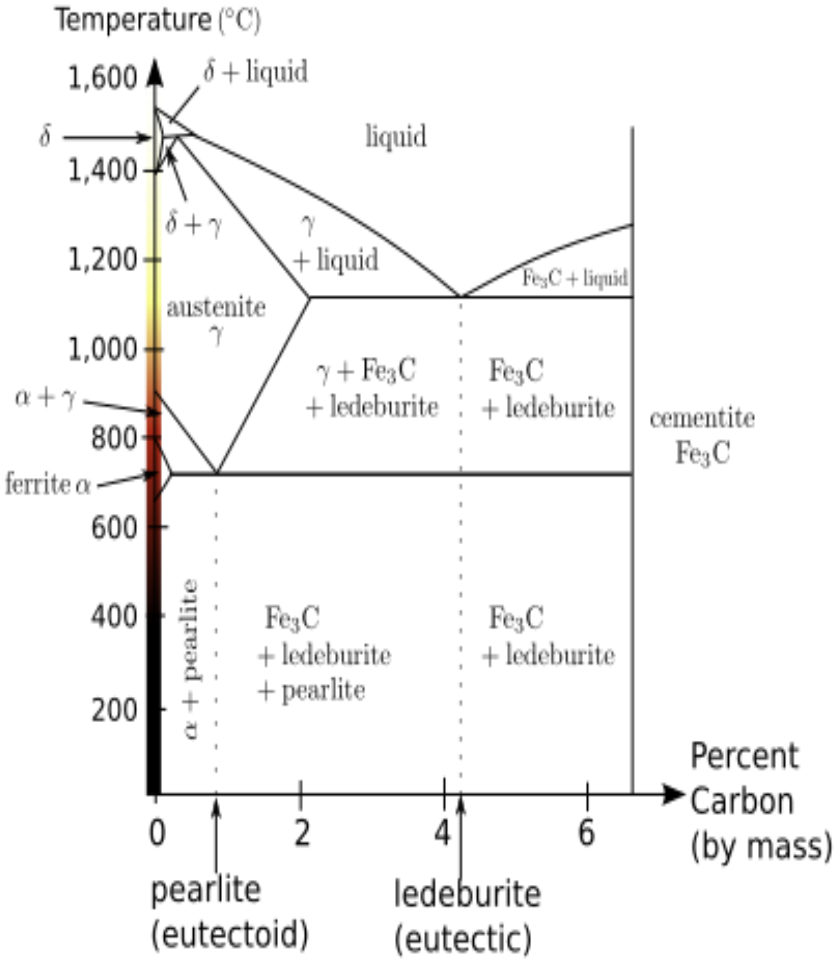
- Drift definition: According to BIPM drift is defined as the continuous or incremental change over time in indication, due to changes in metrological properties of a measuring instrument.
- Drift in the measurand can be random or the measured value can be increasing or decreasing as a function of time.
- Short term drift (< 1 day) in the measurand is usually accounted for in the measurement uncertainty.
- Longer term drift of the order of weeks to years is of critical importance in determining recalibration intervals. We need an understanding of the physical process driving change to get an idea of a realistic recalibration interval. Sometimes it is also appropriate to account for long term drift in the measurement uncertainty.

Physical Process – An Intuitive Example

- The true value of a mass can increase because it has been contaminated.
  - Dirt
  - Deposition of moisture
  - Oxidisation
- The true value of a mass can decrease due to loss of bulk material.
- If the international prototype kilogram changes.

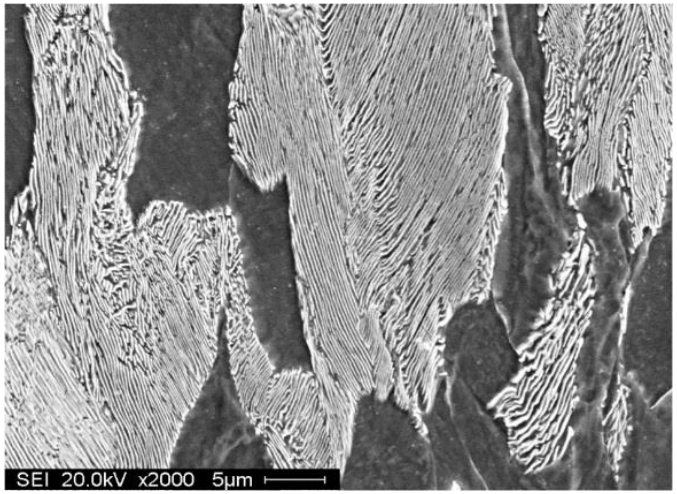
Physical Process – Not so intuitive example

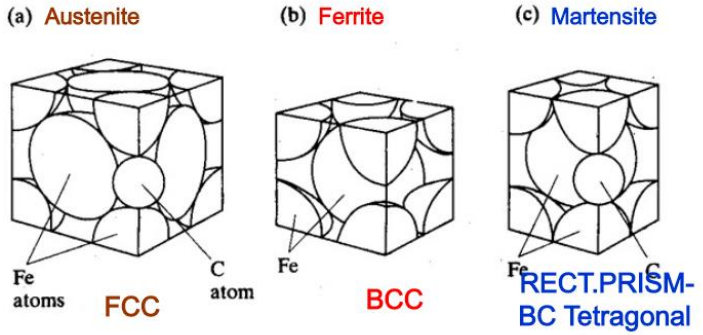
- The true value of the length of a piece of steel is dictated by complicated physical processes.
- The iron-carbon phase diagram is a good starting point for understanding basic unhardened steels.
- Surprisingly increases in length/volume are possible.



Physical Process – example continued

- Pearlite consists of alternating layers of ferrite and cementite (iron carbide). This is the structure of mild steel.
- For metrology applications, particularly gauge blocks we need to harden the steel to make it wear resistant.
- Steel is typically quenched to harden it.
- Tempering is required primarily to relieve strain built up in the martensitic crystal structure.

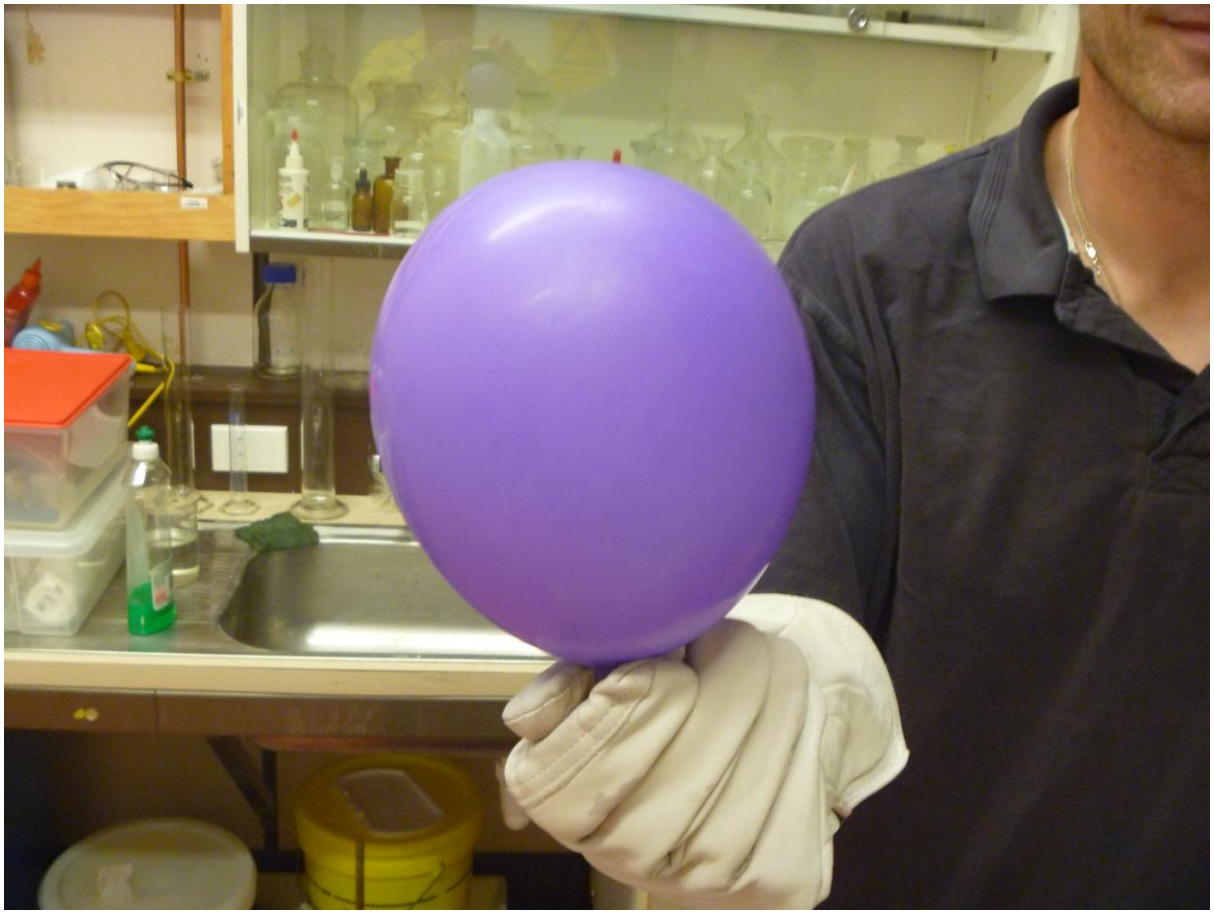


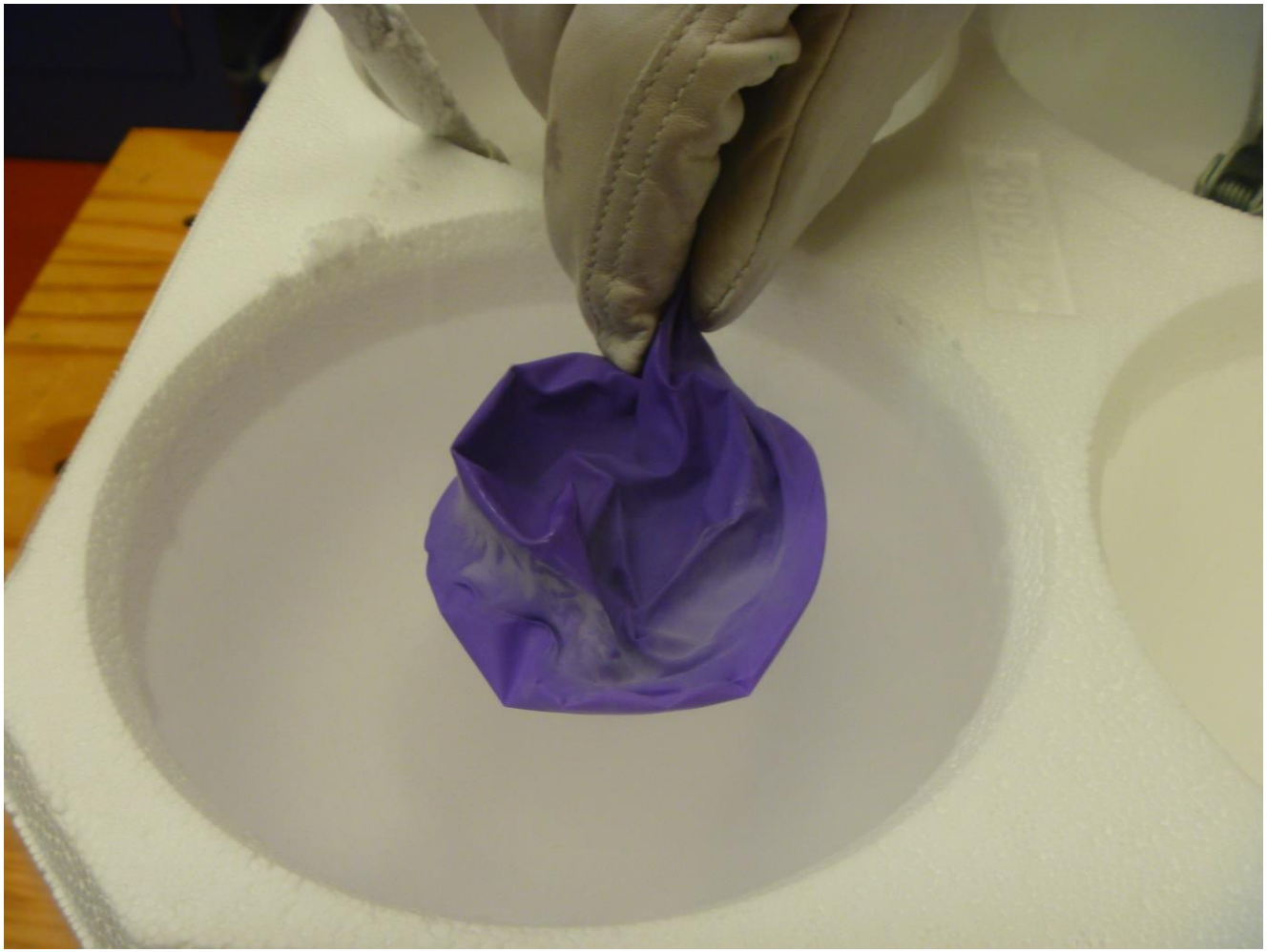


Physical Process – example continued

- When austenite is quenched at a rate of greater than 430 °C/s carbon atoms do not have enough time to defuse out of the crystal structure to form cementite. Instead a new highly strained crystal structure is formed called martensite.
- Tempering relieves some of the strain by allowing the excess carbon atoms diffuse out of the martensitic lattice. This tends to reduce the overall volume of the crystal structure.
- During quenching not all austenite is transferred to martensite. There is usually some residual austenite left over in the martensitic lattice. Austenite to martensite transformation tends to cause an increase in volume at room temperature.
- Both the above processes can occur at room temperature, an are particularly prominent where limited tempering has been done.

A Brief Interlude – An Excuse to Play

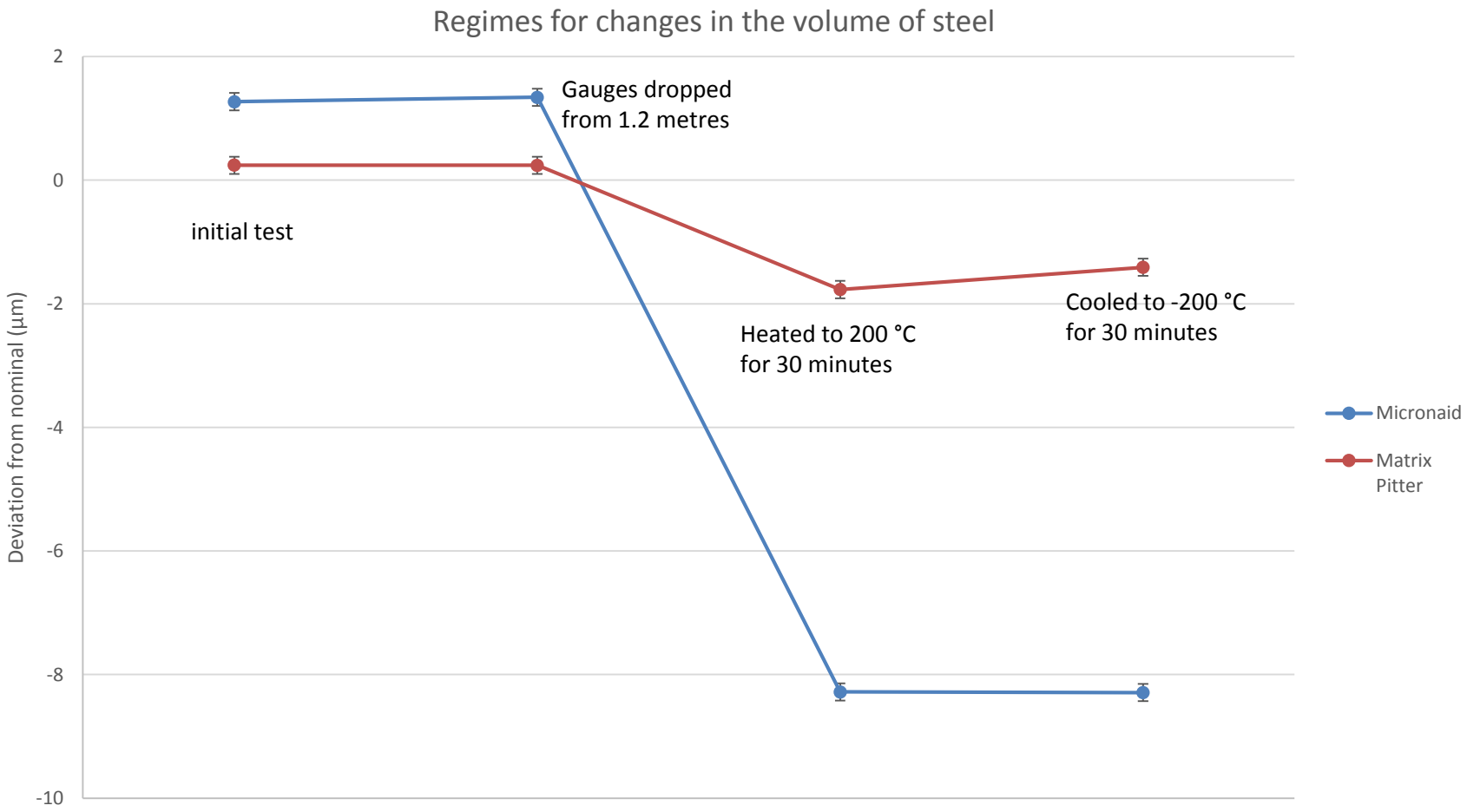




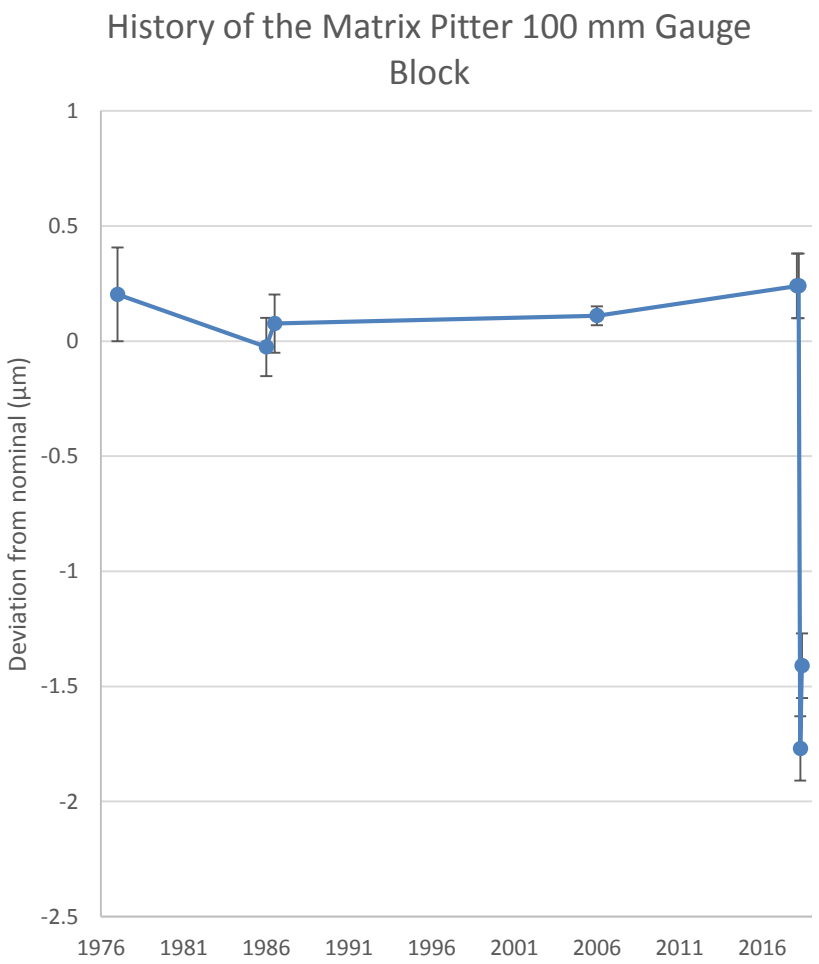
Physical Process – Gauge block experiment

- Two 100 mm gauge blocks, one with a long period of stability and one with a long period of instability.
- If the gauge blocks were properly manufactured they should have been tempered at 200 °C and possibly cryocooled to -196 °C. Both these processes play a role at reducing interstitial carbon and retained austenite.
- The gauge with the history of instability should have either more interstitial carbon or more retained austenite than the gauge with a history of stability.

Physical Process – Gauge block experiment



Does the Artefact Have an Established History?



- An established history helps us determine appropriate calibration intervals.
- If we are calibrating an instrument or artefact for the first time we do not have any evidence of stability. However, we can use our knowledge of the underlying physical process to infer an appropriate calibration interval.
- A good history also gives us a way to see if something unexpected has happened.

The measured value combined with its uncertainty is close to a critical tolerance.

In certain cases there is some critical tolerance. These are usually found in regulatory examples

- Water quality testing – rivers, lakes, beaches, drinking water.
- Asbestos testing
- Blood testing – Warfarin levels
- Weigh station “levelness”
- Manufacturing processes. e.g Timken deep groove bearing clearance.

What will the artefact/instrument be used for?

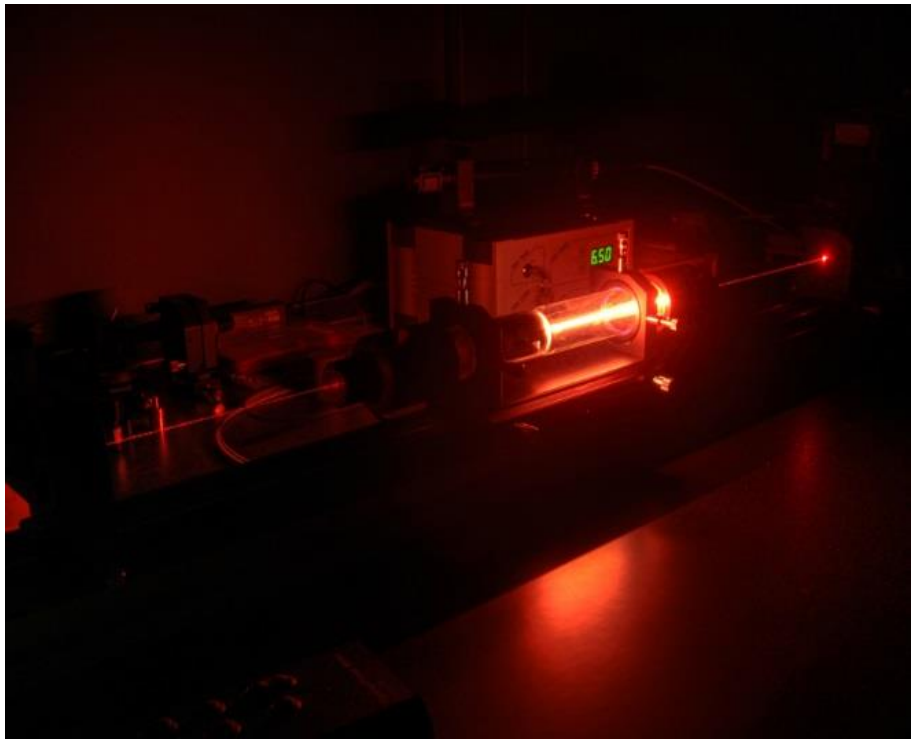
The type of application/environment your artefact will be used in may have a bearing on what calibration interval is appropriate.

- Calibration laboratories provide critical services to industry because they are the bodies that disseminate the standards. The economic risk in this case is not easily quantified, but it is assumed to be high.
- Other areas in industry may have more quantifiable risks e.g critical aviation parts, drinking water quality, medical equipment.
- Usually if the economic risk is well established or quantifiable we can make cost/benefit type decisions about appropriate calibration intervals, or perhaps in some cases, the need for calibration at all.

Limits?

In rare cases there are physical limits for the operation of the artefact.

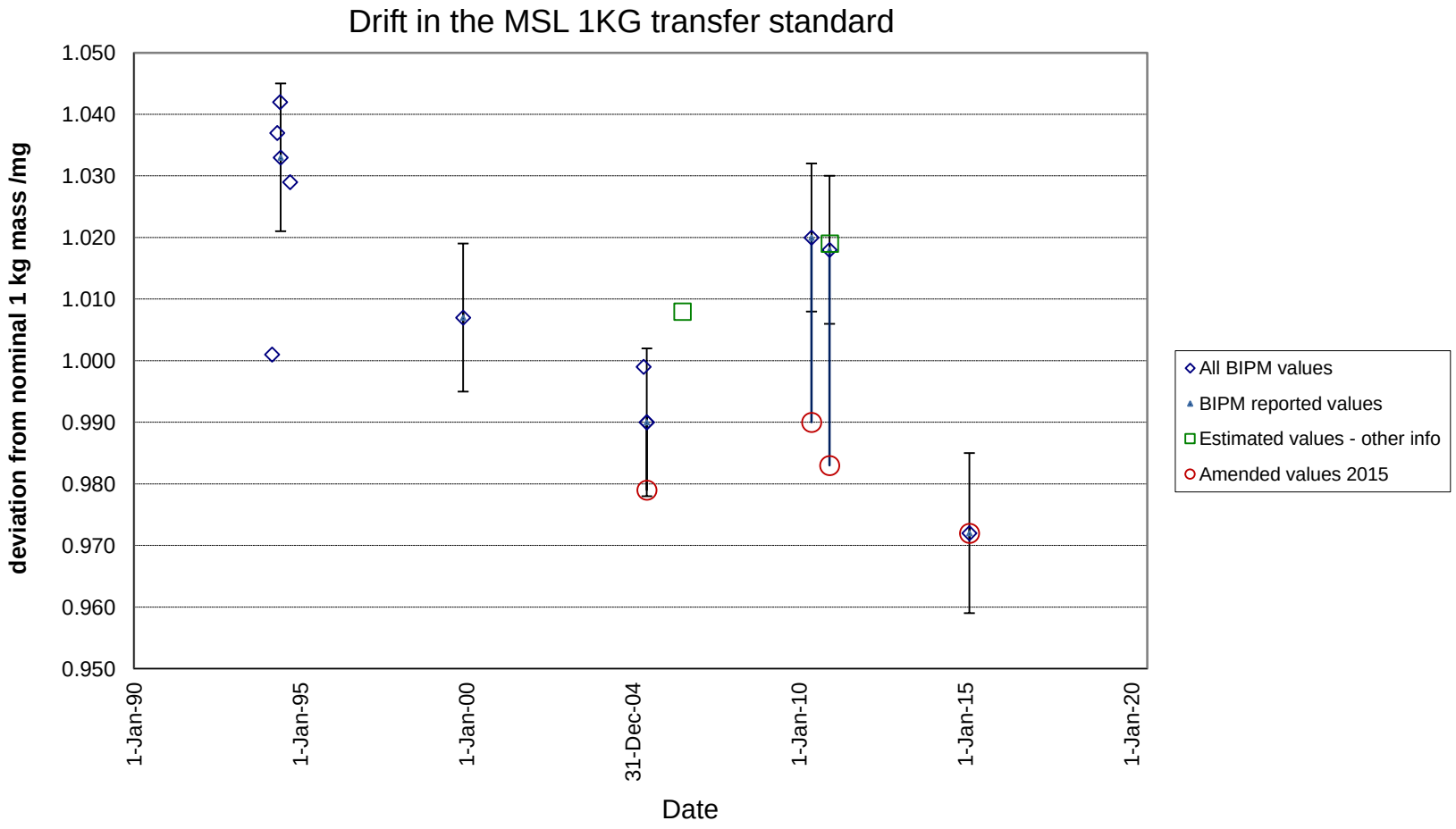
- Helium neon laser as a frequency standard. There are only a narrow range of possible frequencies at which a helium neon laser can operate.



Tracking the History of your artefact

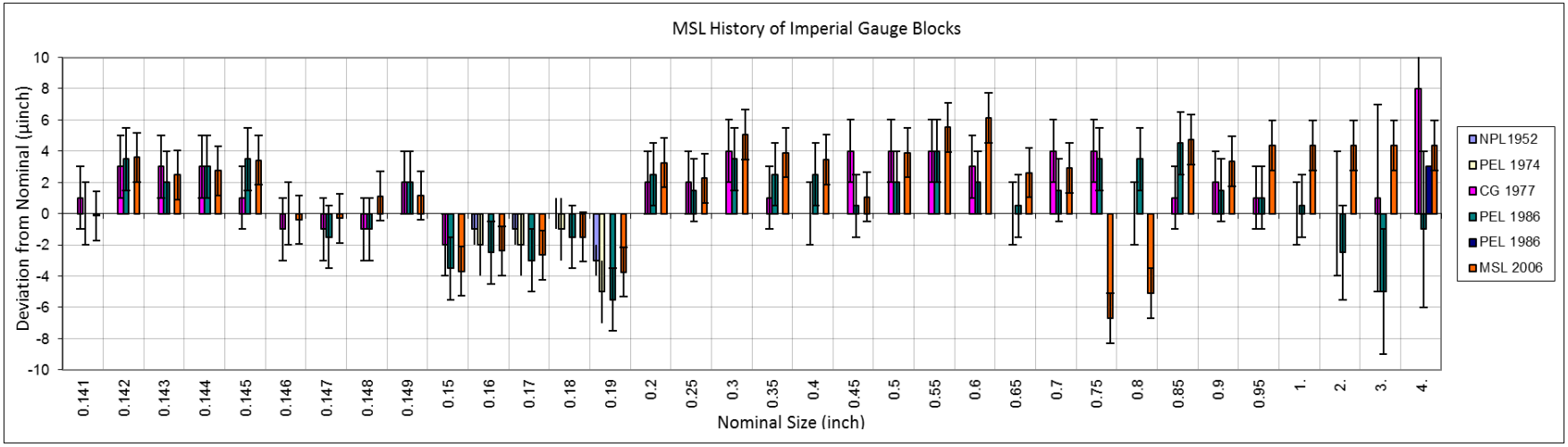
- When it comes time to measure your artefact:
  - Usually a starting point is to plot the data on a graph with uncertainty bars. This gives us a visual way of interpreting historical changes in and artefact.
  - Mathematically we can evaluate change in the artefact by determining En values.
  - Intermediate checks can be included a history analysis.
  - A control chart can be used to monitor performance – usually used with instrumentation.

Plot the data so you can see what's happening visually!



What if we have lots of data?

- Sometimes we have a lot of data and we need a better and easier way of determining whether there has been any changes of significance during the time interval between calibrations.



The En Value

To calculate the En value we first figure out what the difference is between two measurements on the same artefact. Often when we are looking at historical measurements the two measurement points are taken years apart.

$$\mathrm{d} = m_a - m_b$$

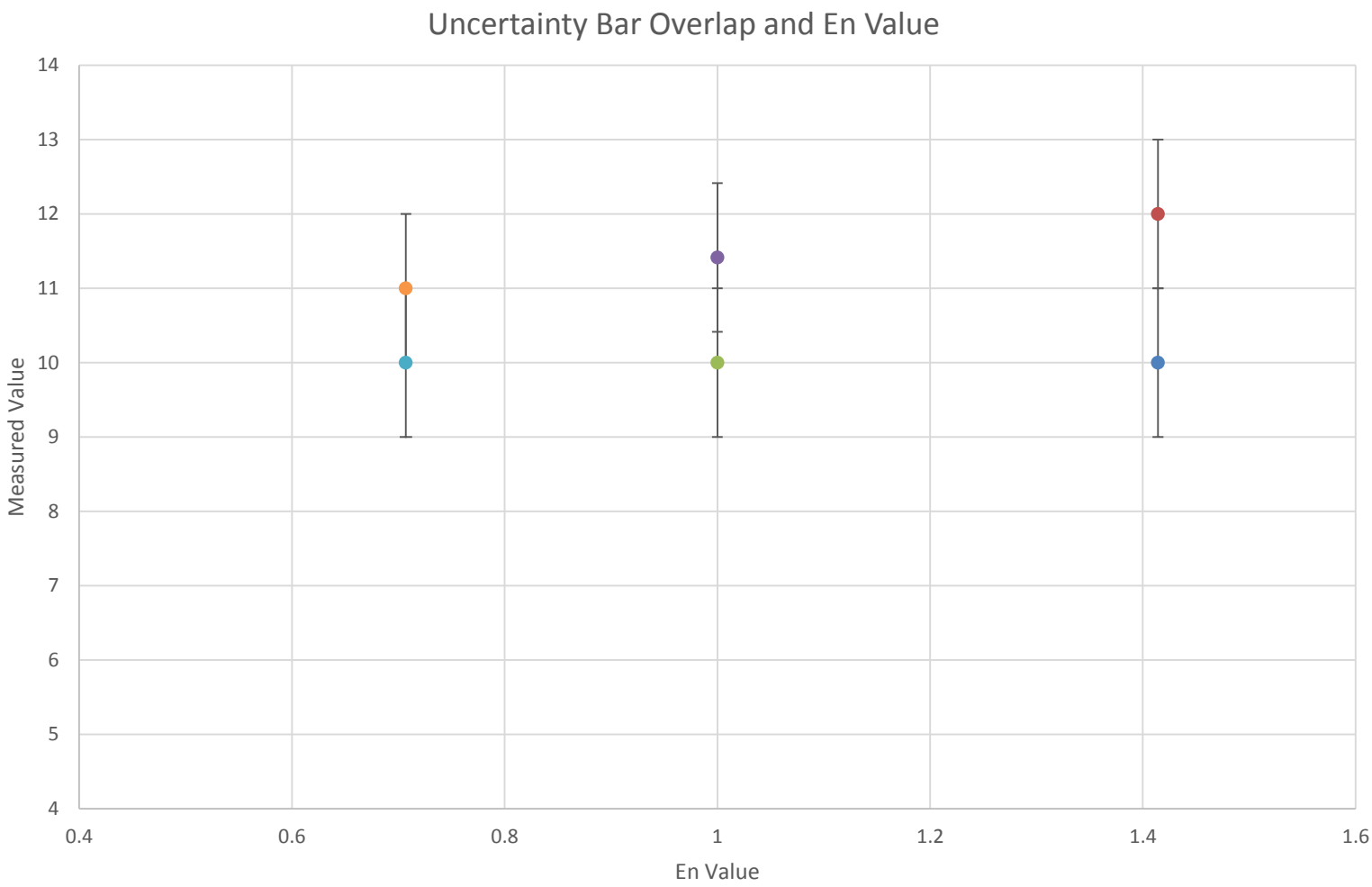
We also need to calculate the combined expanded uncertainty of the two measurements.

$$U_{a,b} = \sqrt{{U_a}^2 + {U_b}^2}$$

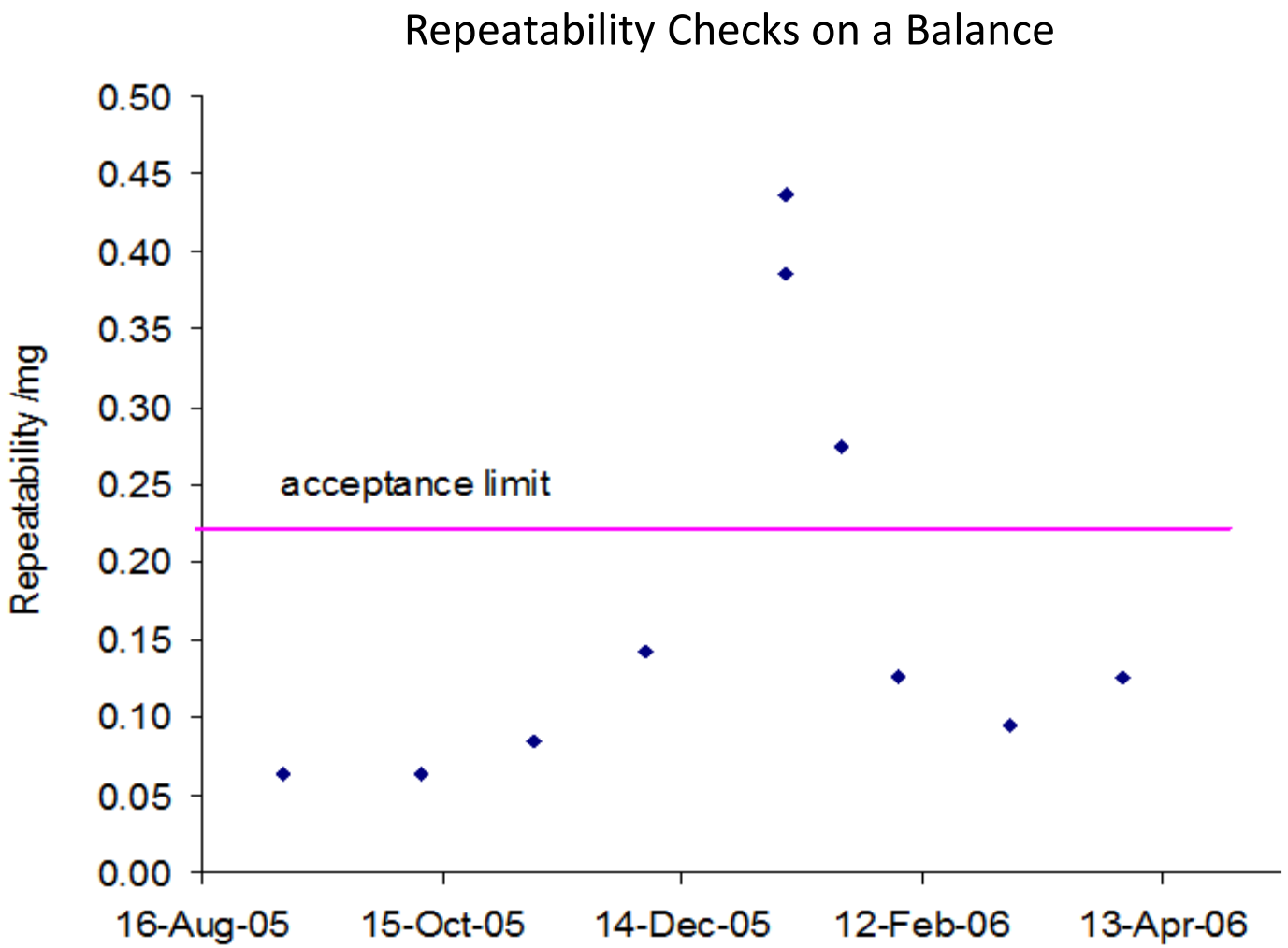
The En value is then simply.

$$E_n = \frac{d}{U_{a,b}}$$

A Common Misconception?



Control Chart for Performance Checks



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