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125 years of innovation

Surface Finish Calibration Methods

AMETEK®
ULTRA PRECISION TECHNOLOGIES

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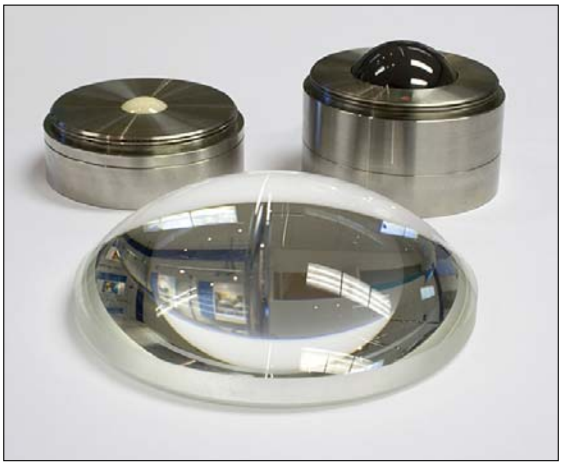
Calibration Balls - Known Radius & Form Error



- Form Talysurf
- PGI 3D

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This method of calibration is used on our Form Talysurf Inductive / PGI and PGI 3D instruments and ensures that the gauge travels through (and therefore, calibrates over) most of its range. Ball calibration is used for calibrating the **gauge** when measurements of form and surface finish are required. The Arcuate corrections, tip corrections, gauge linearity and gain are all calculated from this type of calibration. Any damage to the stylus tip or gauge pivots would be evident using this method of calibration. The measurement data from the calibration routine is fitted to an LS arc and the Pt value, gain correction factor and calibration constants are displayed.

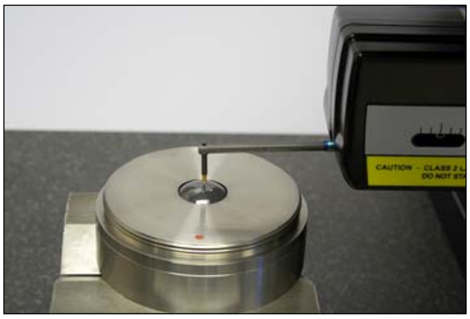
If the Pt value was greater than the maximum permissible form error for the stylus, gauge and calibration standard used, this would indicate an error within the measurement loop.

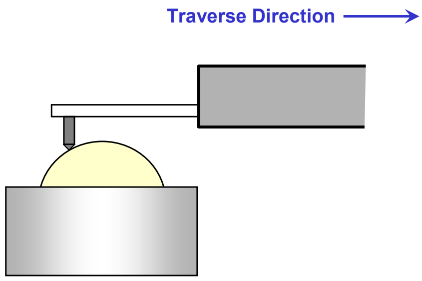
The following should also be checked before calibration:

Dirt adhering to stylus tip / Dirt adhering to cal Ball / Datum bar

Floor vibration / Draughts / Damage to stylus tip

Calibration Balls - Known Radius & Form Error





- Remember to Calibrate in each Gauge Range
- Note variation in Stylus Tip contact position
- Need to fully calibrate over measured range

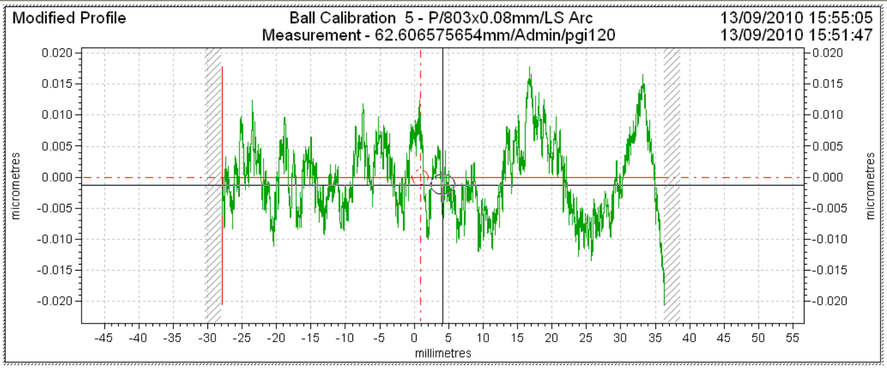
The inductive Form Talysurf instruments have a choice of gauge ranges from 1mm , 200 microns and 40 microns. Depending on the component being measured and the gauge range required to measure the component you should calibrate the correct gauge range and make sure the measurement stays within the calibrated gauge range.

NOTE: There is the option to use longer styli for both the inductive and PGI instruments this will increase the gauge range accordingly and choice of calibration ball might change.

Consider also the possibility of stylus tip contact position – the incorrect choice of calibration ball, stylus length and gauge range could cause stylus flanking which would be visible on the calibration result.

Calibration Balls - Calibration Result

- Check Pt Value and Z1 Value



Pt	0.0384	µm	Radius	79.5080	mm	Range	8	mm
Z1	0.98372		Z2	0.002319		Z3	-0.0000007	
X1	-0.31043		X2	0.009102		X3	-0.0000460	

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This shows a typical calibration result from calibrating a Ball standard.

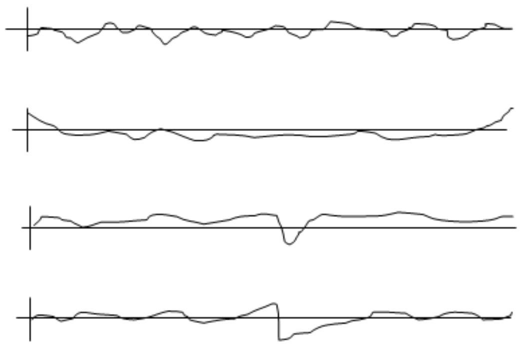
The operator should check the Pt value is within the allowed form error for the chosen stylus, gauge range and ball standard.

The Z1 value is the Gain correction value this is typically 1 ± 10%

The Z2, Z3, X1, X2 and X3 values are the calibration constants correcting for arcuate and none linearity errors.

Calibration Balls - Calibration Form Errors

- The Pt should be within the allowed form error for the chosen stylus, gauge range and ball standard.
- If not the profile can indicate possible errors within the measuring loop



- The shape is even, acceptable calibration
- The shape is uneven, unacceptable - pivot bearing damage or sticking - settings, stylus tip form issues / damage.
- The shape is uneven, unacceptable – as above
- The shape is uneven, unacceptable – as above

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The calibration results are the confidence for the operator that the system is working correctly and will give correct and repeatable results. If there are issues with the system the calibration results can give a good indication to were the problem lies, although further tests would need to be done to highlight the exact cause.

Typical unacceptable calibrations can be due to the following:

Incorrect choice and configuring of stylus within the software

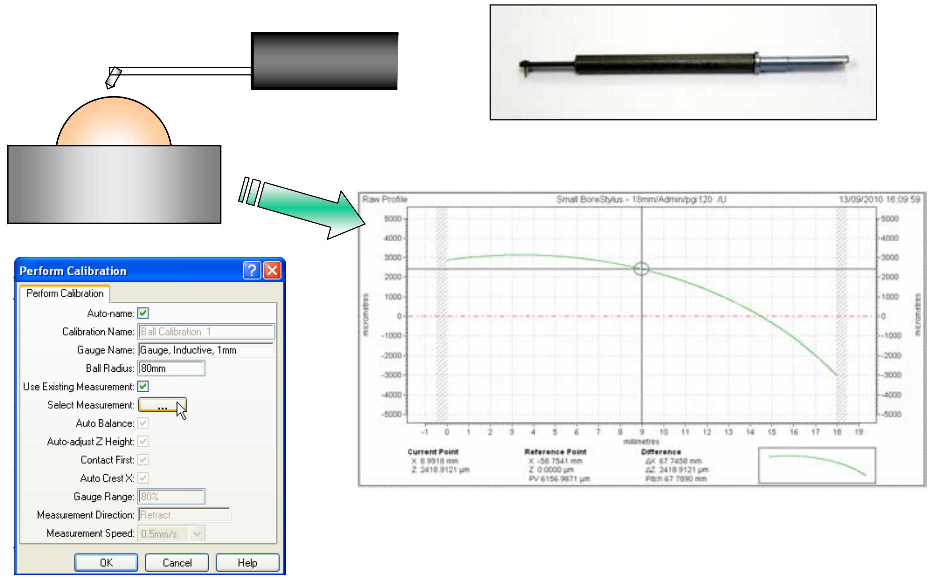
A damaged or missing tip on the stylus

Pivot bearings sticking or damaged

None linearity of the gauge

Datum bar dirty – dependant on calibration position.

Calibration Balls - Calibrating Using an Existing Measurement



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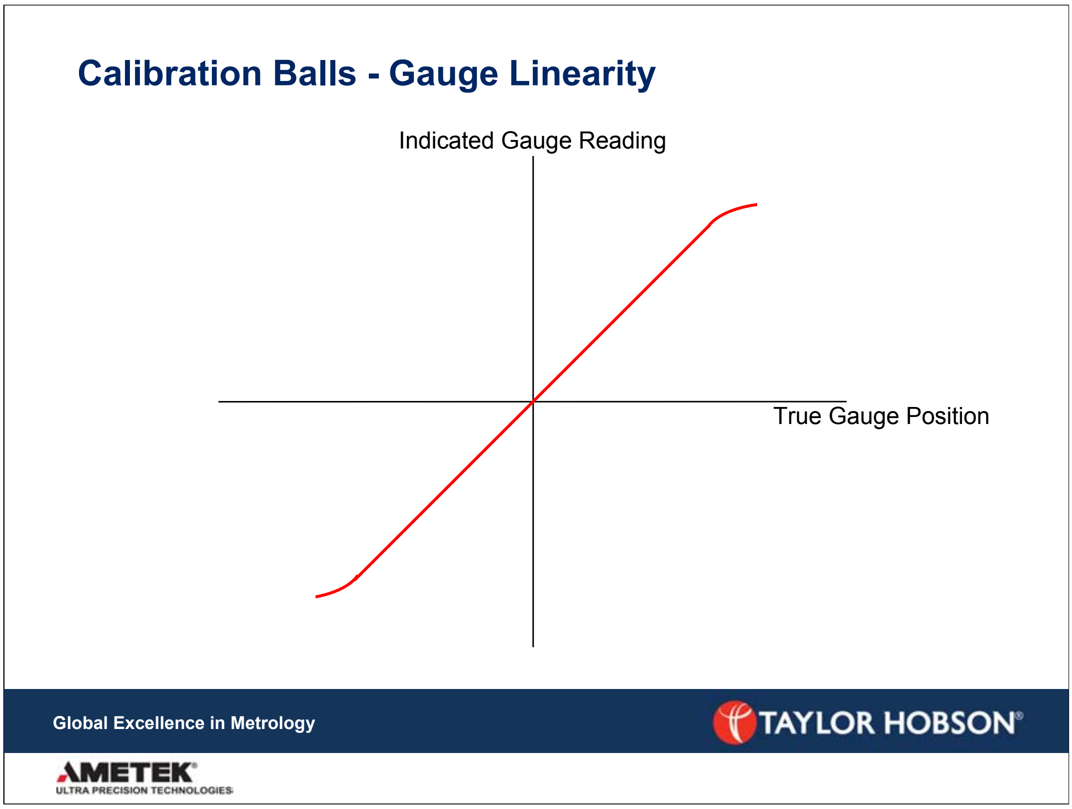
Some special styli cannot be calibrated using the normal symmetrical ball calibration routine due to the geometry of the stylus tip and possible flanking on the left hand side of the ball.

This does not mean we cannot calibrate a suitable gauge range for the stylus – you choose a suitable calibration ball and measure the maximum window from the left of crest without flanking; moving down to the lowest point on the right side of the ball again without flanking.

An example is shown of a front pointing small bore stylus – typical of injector nozzle measurements on the seat angle.

The operator has to do a measurement outside the calibration routine and select the measurement within the calibration menu.



Form Talysurf PGI or inductive gauges are very linear within 80% of their gauge range.

Taylor Hobson's Ultra software uses the 80% default gauge range during calibration due to inherent none linearity's towards the end of the gauge travel.

This can be seen on the chart above showing a straight line between indicated gauge reading and True gauge position up to 80% total range, then a slight tail off for the final 10% at the furthest positive and negative movement of the gauge.

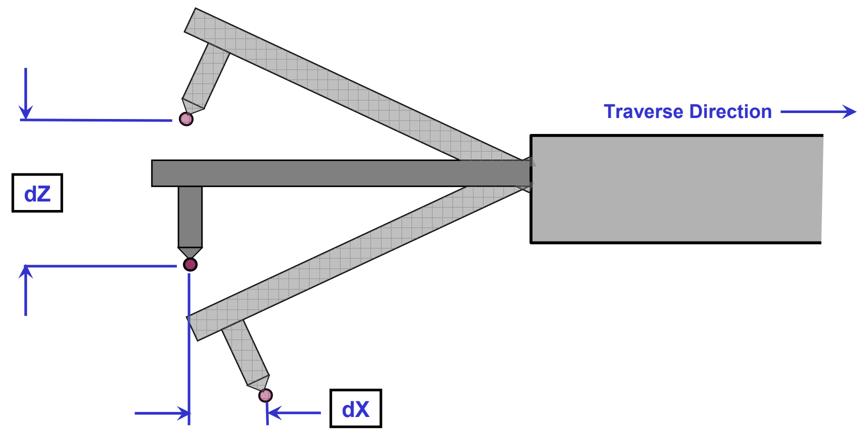
For example a PGI 1240 has a 12.5mm available gauge range which we only calibrate 80%

Total stylus movement 12.5mm

Calibrated range = 80% of 12.5mm = 10mm

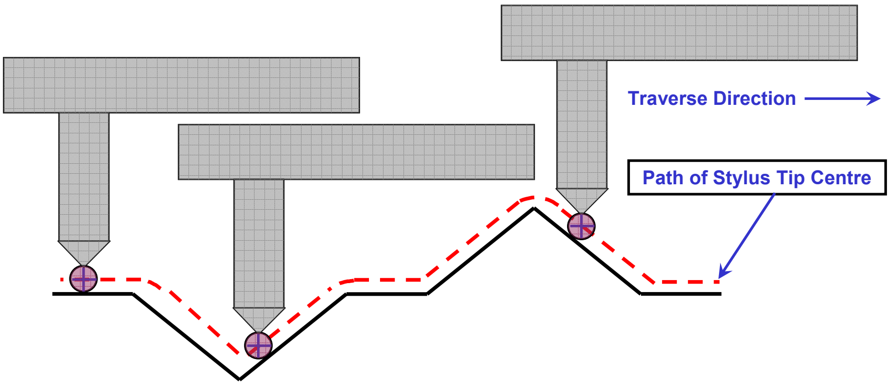
Subsequently all measurements should be carried out within this ±5mm gauge range

Software Corrections - Arcuate Errors



As the stylus pivots the effective beam length of the stylus is shortened giving rise to arcuate errors. These errors are taken account of by using a set of Calibration Constants in the software that compensate for arcuate errors and other non-linearity errors. There are five orders of Z correction and three orders of X correction used in the Form Talysurf Series. Use of appropriate constants will correct for all the main non-linearity's in the system providing the instrument has been correctly calibrated.

Software Corrections - Stylus Tip Errors



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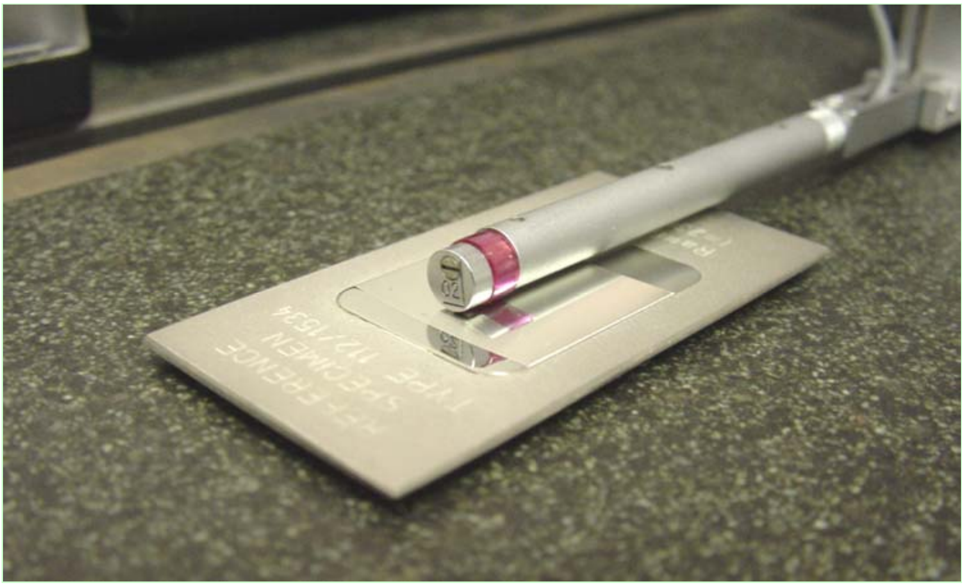
Actual measurement data is taken from the centre of the tip of the stylus.

Software corrections are made to the raw data by taking into account the radius of the stylus tip in order to get a true representation of the surface. These corrections are calculated at the time of calibration and applied to subsequent measurement data.

Ra & Rz Roughness Standards



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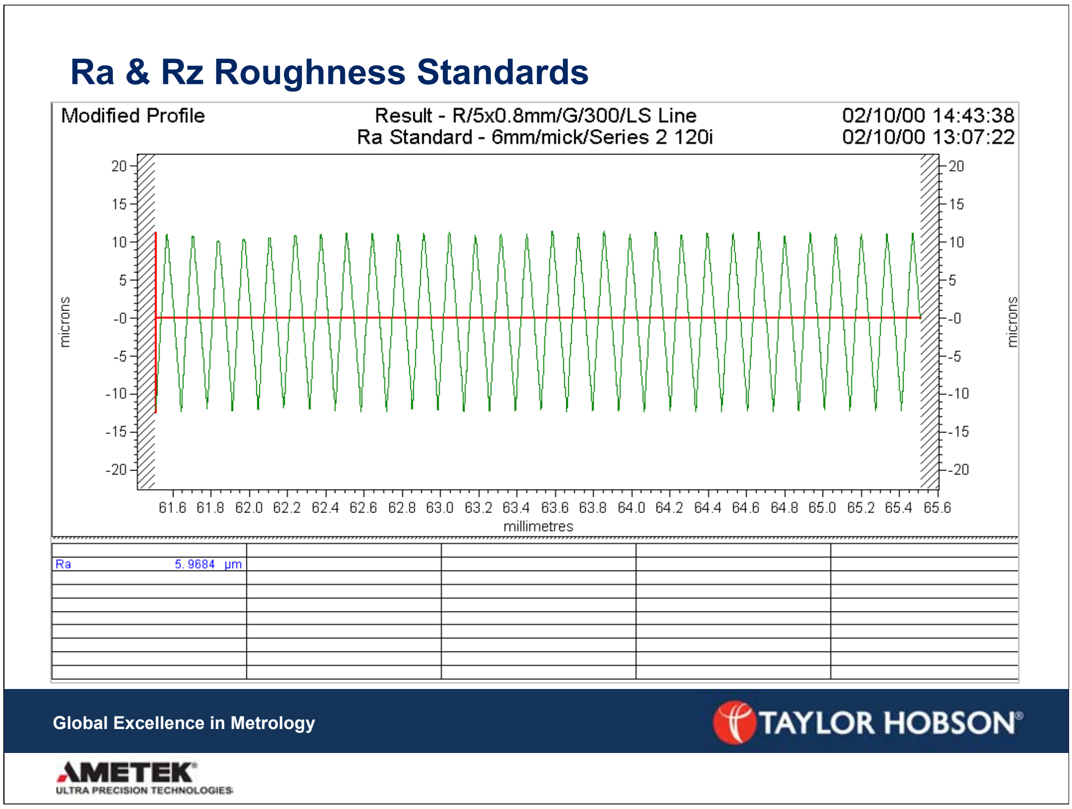
These standards comprise of a waveform etched or machined on to metal or glass surfaces.

The Surtronic 25 and Surtronic Duo are portable hand held units which are calibrated using this standard.

The Waveform is usually a sinusoidal shape although square wave and sawtooth forms can also be used.

These type of standards can be used with or without a skid, but if a skid is used then the radius must big large enough to make any skid errors negligible.

The gain of the instrument is adjusted with respect to the calibrated value of the Standard.

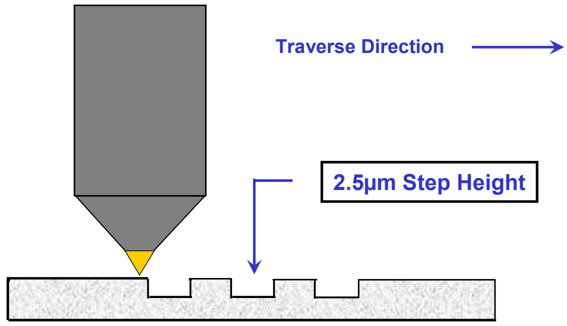


This slide shows the result obtained using an Ra/Rz Calibration Standard having a Sawtooth waveform.

Typical Ra value for the Taylor Hobson supplied metal patch is nominally 6 µm

If customers are measuring surfaces with Ra values subsequently smaller than 6 µm we would recommend they purchase a traceable standard nearer to this value to calibrate their instrument.

3 Line (Step Height) Standard



- Remember to Calibrate in each Gauge Range
- Note variation in Stylus Tip contact position
- Need to fully calibrate over measured range

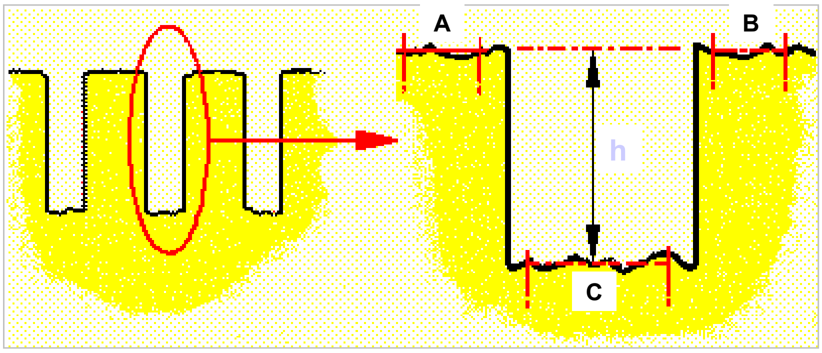
The three line standard is used for calibrating only a very small part of the gauge range and is normally used when only surface finish measurements of a level surface are required.

Typically this standard was used on our earlier instruments which relied on operators adjusting the gain of the system to obtain a correct pen movement on the Chart type recorder which was the only output of the measurement results.

Calibration is typically carried out using the smallest of the available gauge ranges of the instrument.

This method of calibration does not calculate any arcuate or tip corrections and is therefoe not suitable if form measurement is required.

3 Line (Step Height) Standard



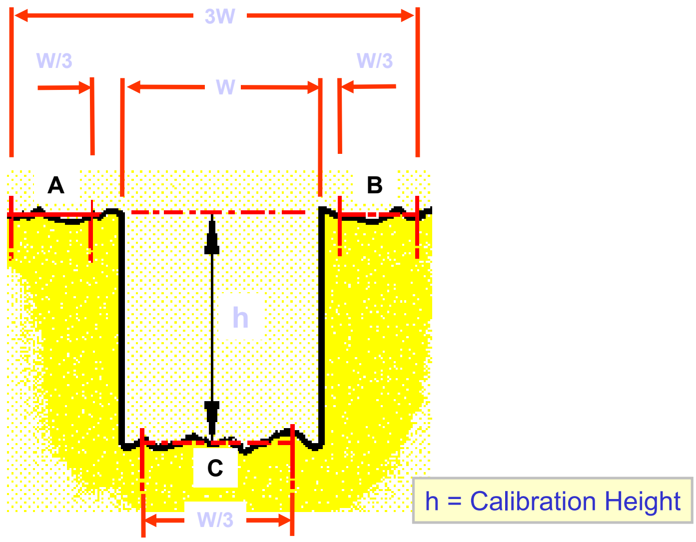
A = Mean Line

h = Calibration Height

The purpose of this method of calibration is to accurately set the direct gain of the stylus displacement, to achieve this it is necessary to determine a stable average value of the middle step of the standard. (The Pt value used for calibration is an unstable parameters). This is done as follows:

On either side and at the bottom of the central step of the standard, the average of the gauge positions is determined. The difference between the upper and lower values is taken to be the calibration height (this is not the Pt value).

3 Line (Step Height) Standard



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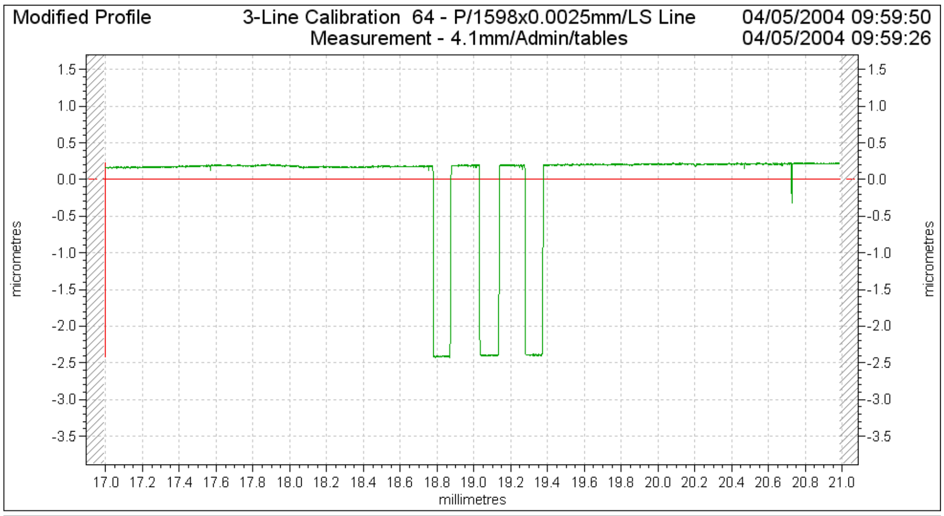
The diagram shows the method of calculating the Calibration Height of a (Type A1) 3 Line Calibration Standard. A continuous least squares line equal to 3 times the width of the groove is placed centrally on the top surface of the groove and levelled. Another Least Squares line equal to a third of the groove width is placed centrally in the base of the groove (C). To avoid any influences caused by the rounding of corners the upper surface of each side of the groove is ignored for a length equal to a third of the groove width. The portions used to calculate the 3 Line Calibration Height are A, B and C.

3 Line (Step Height) Standard



Pt	2.6606	µm	Slope	-0.0219	°	Range	1.04	mm
Z1	1.01277							

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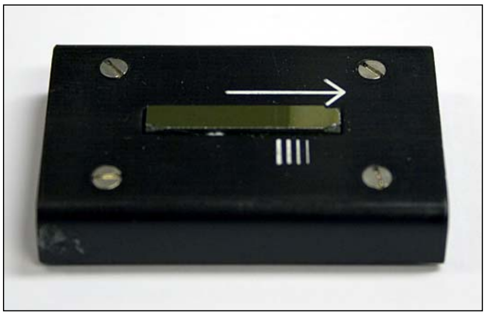
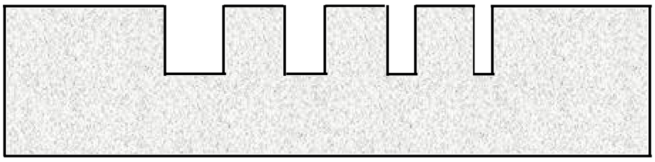
This shows a typical calibration result from calibrating a
3 Line (Step Height) Standard
The operator should check the Pt value is within the uncertainty of the calibrated value supplied with the standard.
The Z1 value is the Gain correction value this is typically 1 ± 10%

Wear Gauge





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One method of checking the stylus tip geometry and size would be using some form of optical system such as a microscope using a magnification of several hundred times. This method is rather time consuming and impractical for most industries. A more practical and dynamic method of checking the stylus is by using a Stylus Wear Gauge. Each of the groove widths normally corresponds to a typical stylus width, e.g: 20µm,10µm, 5µm, 2µm. Using this gauge it is possible to determine the tip size, shape and angle.

Wear Gauge

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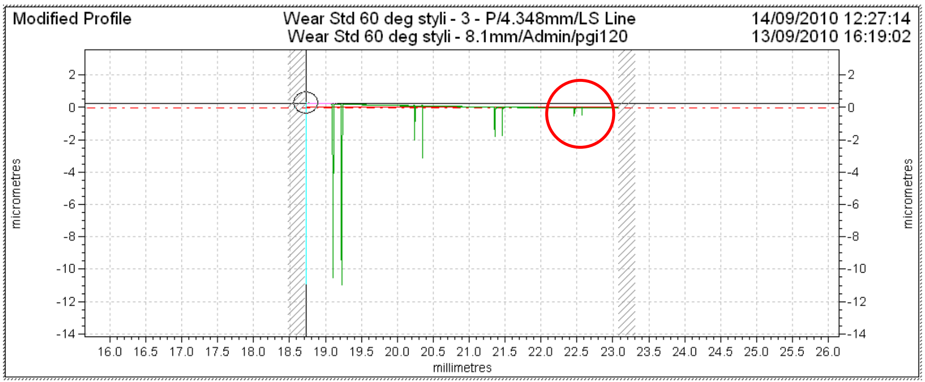
A truncated pyramid tip stylus will increase in width as it wears, therefore, if the nominal 2µm tip width increases to 3µm it will be unable to penetrate a groove width of 2µm.

Wear Gauge

- Measurement across the wear gauge using a 2 micron conisphere stylus. The results shows the 2 micron radius tip has measured the 2 micron groove width indicating the tip is still attached.



Measurement across the wear gauge using a 2 micron conisphere stylus.
The results shows the 2 micron radius tip has measured the 2 micron groove width indicating the tip is still attached.

Prism Standard - Angle Verification

This comprises a glass artefact that has the profile of a truncated pyramid.

The standard is measured using as much of the available CALIBRATED gauge range as possible coming up the nominal 35 degree slope onto the top land.

The analysis will show the resultant slope difference between the two least squares lines fit, which should be within the uncertainty of the calibrated value.

X Axis Datum – Straightness Correction

- System Requirements for Calibration
  - Excellent Gauge Resolution
  - Excellent Gauge Linearity
  - Low Noise
  - Good Environment
  - Good Inherent Traverse Straightness
  - Repeatable Straightness Before Calibration

Traverse Straightness Correction is available on Taylor Hobson's PGI PLUS Systems which are available for Aspheric Measurements and for high precision bearing measurement.

The system is calibrated as normal using a calibration ball. A very high quality glass flat is measured in order to reveal the straightness error in the Traverse Datum. This error is saved in the PC and subtracted from future measurements.

After correction, the system is calibrated again using a calibration ball, but this time with the corrections 'switched on'.

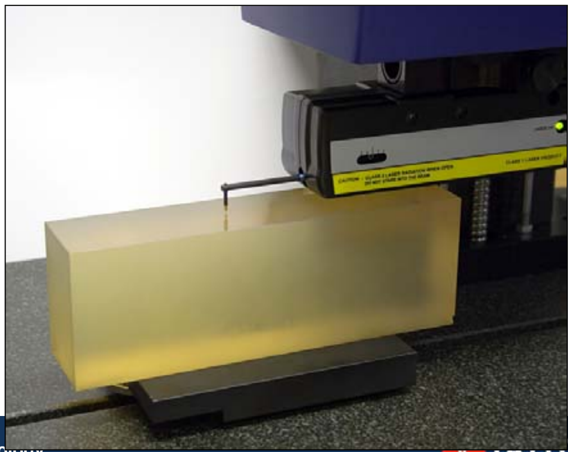
The system is then ready to use.

After correction, Traverse Straightness errors as low as 30nm over 120mm have been achieved!

As we are dealing with such small errors, the correction procedure needs to be done on a regular basis before measuring.

X Axis Datum – Straightness Correction

- Form Talysurf PGI Datum Correction set up. Levelling table used to align the glass flat parallel to the datum bar within 5 µm



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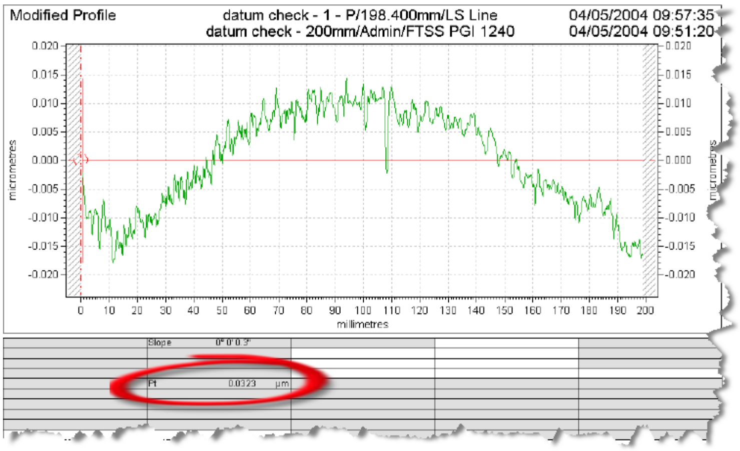
The picture shows the Optical Glass flat supplied by Taylor Hobson sitting on a manual levelling table which is used to align the glass flat parallel to the datum bar within 5 µm.

X Axis Datum – Straightness Correction

- Corrected straightness typically Pt - 0.03 – 0.07µm



Typical X axis datum corrections on a 200mm traverse unit can be in the order of 0.03 – 0.07µm

A similar process of Straightness correction can be applied to the Steinmeyer Y stage – including alignment of the stage perpendicular with the stylus traverse.

Contact us

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or call: +44 116 276 3779

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Instrument Training
Without question, the benefits of training are exponentially greater than the cost. When your operators, inspectors and engineers are well versed in the theory and application of metrology they are more confident, more efficient, better informed and more likely to avoid mistakes or misrepresentation of results.

Technical Support
Manned by a team of Experienced Metrologist's, we provide a Case Study or Measurement Report Service alongside a Contract Measurement Service, to help in the correct selection of our metrology systems.