System 1200 Newsletter – No. 34
TPS1200 Check & Adjust

THE IMPORTANCE OF CALIBRATION…

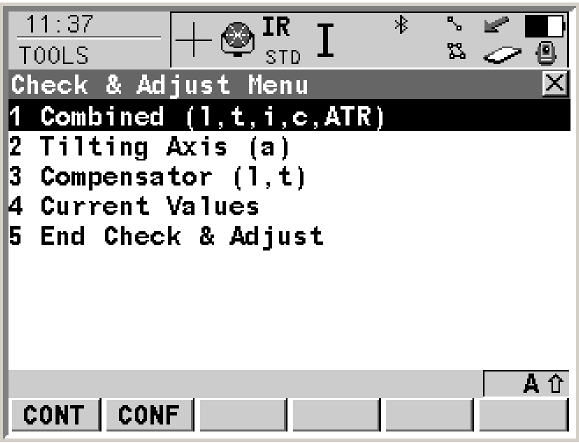
To achieve the highest measurement accuracy from total stations the calibration of the instrument is essential.

A badly calibrated instrument may not measure to its specified accuracy, which may in turn result in points not being measured to the required or expected accuracy.

Accurate measurements with total stations assume that all instrument axes are perfectly perpendicular to each other. This requirement can almost certainly never be attained and certainly never retained over a period of time - this is a mechanical limitation faced by all instrument manufacturers.

This newsletter focuses on the determination of these instrument errors – commonly referred to as the calibration of an instrument.

Within TPS1200 instruments, the calibration routine is called **Check and Adjust** and is found in the **Tools Menu** panel.



The Check & Adjust routine is extremely easy to use and takes only a few minutes – it is even possible to create a logfile of the results of the calibration.

The instrument errors that can be determined using the **Check & Adjust** routine are:

- **c**: Line-of-sight error
- **a**: Tilting axis error
- **l,t**: Compensator index error
- **I**: Vertical Index error
- **ATR Hz** zero-point error
- **ATR V** zero-point error

WHEN TO CALIBRATE?

During the production process of the total station, instrument errors are determined and set to zero – however, the instrument will still need to be calibrated on a regular basis.

In addition to this regular calibration of the instruments, additional calibrations should be made:

- **Before first use** - the instrument may have had a long journey with large temperature differences
- **After long periods of work or after long storage periods**
- **After large temperature difference** - it is strongly advised to recalibrate an instrument if the working temperature differs by more than 10°C (18°F) from the temperature which existed at the previous instrument calibration. This includes re-calibrating if there is a large difference between the storage and working temperature.
- **After rough or long transportation** - mechanical shocks – always take measures to protect the instrument from shocks.
- **Periodically for high accuracy job sites**

WHAT HAS TO BE CONSIDERED WHEN CALIBRATING

Once calibrated, all measured deviations are automatically applied to every measurement. If the calibration routine was therefore inaccurate, this will then adversely affect all subsequent measurements.

So do the calibration properly, accurately and follow the advices below to determine instrument error values precisely:

- **Good atmospheric conditions**, for example, no strong heat shimmer - measure in the morning or with overcast sky.
- **Level** the instrument precisely using the electronic bubble
- The instrument, tribrach and tripod should be **secure and firm**
- Ensure the instrument and tripod are **not exposed to direct sunshine** - this may cause one-sided heating of the instrument or tripod.

Before starting the calibration routine, also ensure that the instrument had enough time to

adapt to the ambient temperature. As a guide, the time for acclimatisation should be at least 20 minutes or 2 minutes per 1°C (1 minute per 1°F) of temperature difference (between storage and working temperature).

A LITTLE THEORY

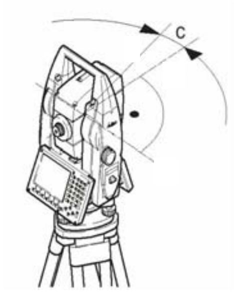
To understand the instrument errors of a total station it is important to know the instrument axes and the essential relationships between them:

- The Line of Sight **L** should be perpendicular to the Tilting axis **T**
- The Tilting Axis **T** should be perpendicular to the Vertical axis **V**
- The Vertical Axis **V** (often referred to as standing or trunnion axis) should be perfectly vertical.

Any imperfections in the conditions above will result in instrument errors which will affect measurement accuracy.

LINE OF SIGHT ERROR (C)

The line-of-sight error (often referred to Hz-collimation error) is caused by the deviation "**c**" between the optical line-of-sight (the direction the crosshairs in the telescope point) and the line perpendicular to the tilting axis.



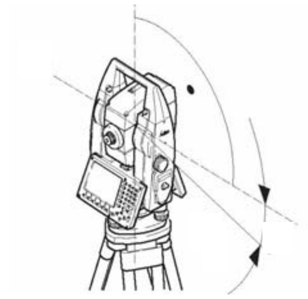
This error will affect all horizontal circle readings and increases with steep sightings. The table below shows the influence of a c=10" line-of-sight error on the horizontal angle for different vertical angles:

Zenith angle	Error in Hz
90°	10"
60°	12"
30°	20"

TILTING AXIS ERROR (A)

The tilting axis error is caused by the deviation "**a**" of the mechanical tilting axis from the line perpendicular to the vertical axis.

The tilting axis error can be observed on a perfectly levelled instrument once the telescope is moved vertically along a vertical line (e.g. an edge of a house) - the crosshair moves from the vertical line even though the instrument is not turned in Hz.



As the Line-of-sight error the Tilting Axis Error effects horizontal angle readings with increasing steepness of the sighting, but other than the Line-of-sight error has no effect on horizontal targets. Again the effect to the vertical angle is very small and is usually ignored.

Shown below is the influence of a a=10" tilting axis error towards the horizontal angle for different vertical angles:

Zenith angle	Error in Hz
90°	0"
60°	6"
30°	17"

VERTICAL AXIS ERROR (V)

The vertical axis error (often referred to as standing axis error) is not an instrument error, but a set-up error. It occurs if the vertical axis is not in truly plumb.

It is important to note that unlike the Line-of-Sight error (c) and Tilting Axis error (a) the Vertical Axis error affects both horizontal and the vertical angle readings and **can not be eliminated by two face measurements.**

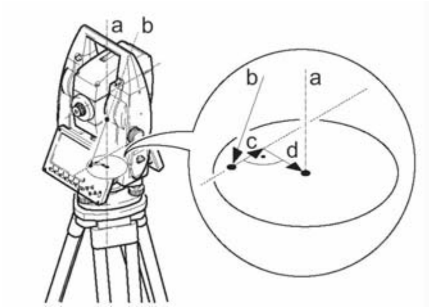
The vertical axis error can be avoided by very carefully levelling the instrument. Alternatively, it can be compensated for with the in-built two axis compensators – this then means the levelling only has to be done roughly as the fine levelling is arithmetically corrected by the compensator.

COMPENSATOR INDEX ERROR (L,T)

The compensator index error is the deviation of the zero point of the compensator from the plumb-line.

With a dual axis compensator the index error of the compensator is divided into two components, one parallel (longitudinal **l**) and the other crosswise (transversal **t**) to the telescope, represented as **c** and **d** in the graph below.

System 1200 Newsletter – No. 34
TPS1200 Check & Adjust



The longitudinal compensator index error "**l**" is similar to the V-index error and affects only vertical angle readings. The transversal compensator index error "**t**" is similar to the tilting axis error and mainly impacts the horizontal angle. The impact on the angle increases with steep sightings.

VERTICAL INDEX ERROR (I)

A vertical index error "**i**" exists if the 0° mark of the vertical circle reading does not coincide with the instrument's mechanical vertical axis.

The v-index error affects all vertical angle readings independent of the steepness of the aiming, but has no impact on the horizontal angle.

ATR COLLIMATION ERROR

The ATR collimation error is the angular divergence between the telescope center (crosshairs) and the center of the ATR camera.

The Hz-component of the ATR collimation error affects the horizontal angle whereas the V component of the ATR collimation error affects the vertical angle.

Always remember that when measuring with ATR, the crosshairs may not be exactly on the prism centre, even if the ATR is newly calibrated. This is **not** an error as the divergence to the centre of the prism is measured by the ATR and the angles are automatically corrected. These "deviations" can be particularly seen when measuring with EDM mode "FAST" - the instrument positions only roughly (to save time) and corrects the remaining divergence by the ATR.

USING TPS1200 CHECK & ADJUST

As already mentioned, before starting the **Check & Adjust** routine ensure that the conditions are appropriate for a calibration to be made and the instrument has acclimatised to the surrounding temperature.

The **Check & Adjust** routine is extremely simple to use – simply follow the instructions on the screen!

COMBINED ADJUSTMENT

The combined adjustment simultaneously determines

- **l,t**: Compensator index error determination
- **i**: V-index error determination
- **c**: Line-of-sight error
- ATR zero-point error determination

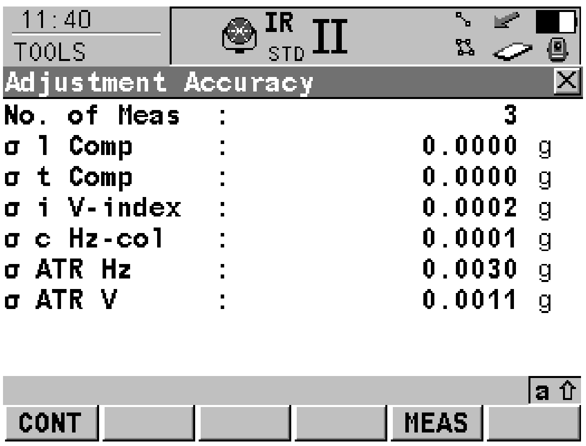
This is done by measuring to any point located approximately 100m away which is at approximately the same level – this is to avoid influences of the tilting axis error when determining the line-of-sight error.

If the instrument does not have an ATR, or if it is not necessary to determine the ATR corrections then the remote target need not be a prism.

However, if the ATR is being calibrated, then the target must be a standard round prism (such as the GPR1) – this is even if a 360° prism or any other prism is being used for measurement work.

Always take greatest care when manually aiming at the target!

Within the Combined Adjustment, the target has to be aimed at in both faces several times in order to average the aiming errors. From the second repetition onwards the standard deviation of the measurements is displayed for quality control.



DETERMINING THE TILTING AXIS ERROR

Since the tilting axis error has only an effect on steep sightings it can only be determined with observations to targets located either significantly below or above the level of the instrument.

System 1200 Newsletter – No. 34
TPS1200 Check & Adjust

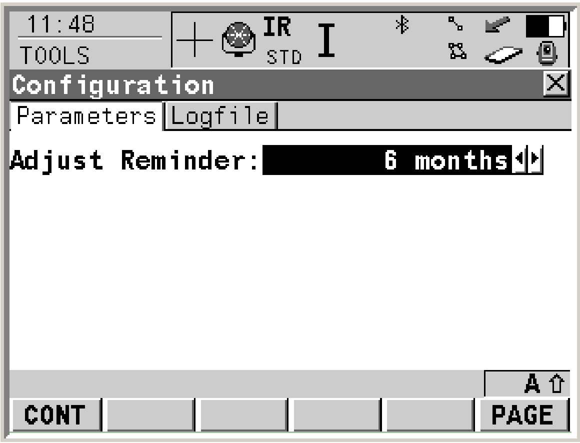
To avoid influences from the line-of-sight error, the combined adjustment has to be run prior to the tilting axis calibration.

The tilting axis error determination does not need a prism or target plate being aimed at. This means that this adjustment can be made at any time - select any recognisable point which is as far away from the instrument as possible and is well above or below the instrument (maybe a detailed point on a high building) – ensure this point can be accurately aimed at twice.

CHECK & ADJUST CONFIGURATION

Remember, it is possible to create a logfile for the **Check & Adjust** routine – select the appropriate format file as for any other application.

Additionally, it is also possible to configure the instrument to remind the user to perform a regular calibration at regular intervals – press **F2(CONF)** in the **TOOLS Check & Adjust Menu** panel. As a default, this reminder is set to 6 months.



The reminder period is only reset once both the **Combined** and **Tilting Axis** calibration routines are completed.

MECHANICAL ADJUSTMENT

In addition to the instrument errors mentioned above, some adjustments cannot be arithmetically corrected and therefore have to be adjusted mechanically:

- Circular bubble on instrument and tribrach
- Visible red laser beam (RL EDM)

For the mechanical adjustments please refer to the TPS1200 user manual.

It is worth to note, that particularly when measuring with the reflectorless EDM to edges or inclined planes a divergence of the visible red laser beam from the line-of-sight can lead to measurement errors – this is because the RL EDM will not measure exactly to where the instruments cross-hairs are being pointed. The red laser beam must therefore be periodically adjusted.

OTHER INFLUENCES TO ACCURACY

Careful calibration and adjustment is certainly required to achieve the most accurate measurements - but does not guarantee them.

There are many additional factors, which can affect the measurement accuracy:

- One sided instrument and tripod warming (e.g. from sunlight) ⇒ use an umbrella
- Heat shimmer and unpredictable refraction
- Instrument has not acclimatised to surrounding temperature
- …

In addition when the highest precision measurements are required it is strongly recommended that two-face measurement techniques are used.

Two-face measurements eliminate most instrument errors (also inaccurate determined instrument errors) through averaging the measured angles.

AND FINALLY

Always remember - a total station is at the end of the day a high precision instrument that must be handled with great care.