ND DEPT OF TRANSPORTATION
SURVEYS & PHOTOGRAMMETRY

DATE: JANUARY 2007
REVISED:

TRAINING MANUAL FOR

Robotic and Conventional Total Stations

NOTE: This manual provides a written account of how certain activities are performed and is designed to guide and assist staff members in performing their functions.
When appropriate, there may be deviations from these written procedures due to changes in personnel, policies, interpretation, law, experimentation with different systems, or simply evolution of the process itself.

This manual may be changed at any time. Staff members are encouraged to review this manual periodically and suggest changes in the manual to keep the manual current and to minimize differences between the manual and actual practices.

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SECONDARY PROJECT CONTROL

All survey equipment, including tripods, tribrachs, prisms, etc. shall be properly maintained and calibrated according to manufacturers' guidelines. The National Geodetic Survey (NGS) calibration baselines established specifically for the checking of Electronic Distance Measuring Instruments (EDMI) may be used for checking the calibration of EDMI's and reflectors. Equipment calibration records and reports (not exceeding one year) shall be maintained by the surveyor and submitted to the Department as requested.
http://www.ngs.noaa.gov/CBLINES/BASELINES/nd

Techniques

Observe temperature and atmospheric pressure and enter this data into the total station to correct the slope distance for atmospheric affects.
Account for prism offset in all distance measurements in the instrument settings.
A backsight of known azimuth should be used.
Measure horizontal angles two times in sets of direct and reverse attitudes (2 direct and reverse (D&R)). The suggested procedure is to:
1. sight the backsight with telescope direct
2. turn the angle right to the foresight
3. plunge the telescope and re-sight the foresight with
the scope reversed
4. turn the angle right to the backsight
This is one D&R.
The sum of the direct and reversed horizontal angles of a single set of angles should not deviate from 360° by more than 5.0 seconds. Re-observe, rejecting sets until two sets agree within this tolerance.
For total station instruments that include the capability, the vertical indexing initialization procedure should be checked at the beginning of each day.
Measure zenith angles used to reduce slope distance to its horizontal component in both the direct and reversed attitudes.
The sum of the direct and reversed zenith angles of a single set of angles should not deviate from 360° by more than 10.0 seconds. Re-observe the rejected sets until the two sets agree within this tolerance.
Measure all baseline distances electronically from both ends of each line.

The slope distances (between adjacent control points) from forward and backward measurements should not differ by more than the amount that the precision of the EDM device allows.

Secondary Vertical Project Control Procedures

Secondary Vertical Project Control shall be established using trigonometric or differential leveling techniques. This should originate and terminate on established primary control in the project corridor.

Network Geometry

Level runs shall begin and end on bench marks of appropriate accuracy classification order. Secondary Vertical Project Control Level Runs will normally begin and end on different Primary Vertical Project Control Stations as established under Chapter 19. Use two different bench marks to begin and end vertical surveys if possible.
When bench marks need to be established on the project site, the bench marks should be incorporated as turning points into a secondary vertical project control level-run using differential leveling techniques described below.

Differential Leveling

Equipment

Use only digital levels with bar code rods. Use a sectional composite or invar bar-code staff.

Techniques

Expend reasonable effort when balancing backsights and foresights. Use subsequent set-ups to make up for deficiencies in balancing. Difference in forward and backward sight lengths should never exceed 10 meters per setup or 10 meters per section. Maximum sight length should not exceed 70 meters. Minimum ground clearance of line of sight should be 0.5 meters.

SECONDARY PROJECT CONTROL

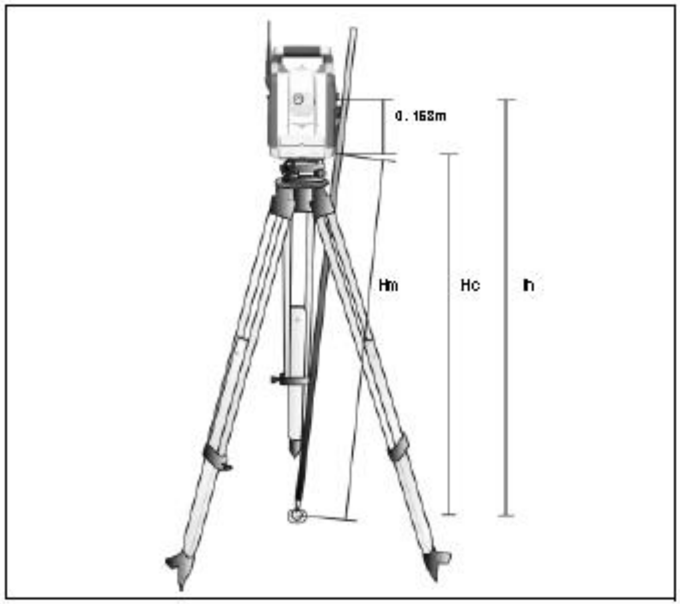
Trigonometric Leveling

Equipment

The total station used for trigonometric leveling should be at least a one-second (angle) and 1mm (distance) least-count instrument with Dual-Axis Compensation. The total station used should have a minimum DIN accuracy of two seconds (angle) and 2mm +2ppm (distance). The total station, tribrachs, prism targets, prism poles, tripods, etc. used for control surveys shall be adjusted properly and maintained in good condition
Account for the correct prism offset in all distance measurements.
Always use a target device with a retro-flector prism. The reflector alone does not make an adequate vertical target.

Techniques

Trigonometric Leveling may be incorporated in to the secondary horizontal project control traverse.
Limit sight distances to about 600 ft. This minimizes the impact of small pointing errors. Longer sight distances may require additional pointings, resulting in a larger sample from which to derive a mean vertical angle.
Take great care in measuring the heights of instruments and targets for each set-up. Make redundant measurements to eliminate the chances of blunders. Make and record measurements at both the beginning and end of each occupation to check for settling, slipping, or misreading. When instruments and targets are exchanged on a tribrach, the HI or HT should be measured again. Never assume that they are the same or that the tripod hasn't deflected differently.



Make reciprocal observations (observations from each end of a line) on all observed lines. Observe each zenith angle with at least two D&R sets. The sum of the direct and reversed zenith angles of a single set of angles should not deviate from 360° by more than 10.0 seconds. Observe, once again, the rejected sets until the two sets agree within this tolerance.
The term reciprocal observations actually denotes zenith angles measured simultaneously from each end of a line. However, achieving simultaneous observations is rarely practical for highway surveying. In this case, zenith angle observations from each end of a line shall be separated by only a minimum amount of time in order to minimize any difference in the atmospheric conditions between stations during the observations. There are instances in which the atmospheric conditions are nearly identical during the times the zenith angles are observed at each end of the line. In these cases the effects of curvature and refraction on the zenith angle observations cancel out. However, there are other instances, in which atmospheric conditions change significantly between the occupation of one point and the next. For best results in these instances repeat all the observations for that baseline.

Reciprocal observations correct distances and zenith angles for the effects of earth curvature and refraction. Automatic curvature and refraction corrections, applied in the instrument settings, usually apply corrections to horizontal distances and vertical changes only and do not affect the slope distances and zenith angles that are collected as part of a raw reciprocal observation. Therefore, automatic curvature and refraction corrections, set at the instrument will have no effect on the reciprocal observation. When a line is observed from only one end, curvature and refraction corrections for determining vertical differences should be applied during processing.
Always try to occupy the known (initial and final) bench marks and all new bench marks, in a trig level run. Reciprocal observations cannot be made to and from a point that is not occupied. If a bench mark

cannot be occupied, set up the total station within 20 meters of it and observe (in direct and reverse) the foresight vertical difference only. The very short distance will minimize the atmospheric effects.

LIMITS OF SURVEY - RTK

As stated in the segment "Primary Control Points" (PCP), the control points are usually set every 2 to 3 miles. With the GPS base set on a given PCP, the extent of survey should NOT extend beyond the next PCP in either direction. In this way, you can cover approximately 5 to 6 miles on each base setup. This also allows for you to leapfrog the base and set on every other PCP. For example, if you were to set the base on GPS2, you would then begin your work by checking GPS1. You could then proceed to survey from GPS1 to GPS3, where you would do another check shot before ending. You could then move your base setup to GPS4, start with a check shot at GPS3 and proceed to survey to GPS5, ending with another check shot, etc., etc.

It is imperative that you do check shots intermittently during the survey time frame. At the very least, do a check shot at the beginning of a session & before the base is shut down at the termination of a session, preferably on 2 different known points. If you are running on the same point all day, you need to do additional check shots throughout the day. We cannot stress enough the importance of doing check shots. CHECK! CHECK! CHECK! & you will save yourself many headaches. Also, be sure to store these check shots as CHK1, CHK2, or whatever the PCP no. because this will be your only permanent record of the validity of your data. If you see a problem with a check shot, don't ignore it and proceed, discover the cause.

A majority of survey issues involve problems associated with elevation critical data (targets, culverts, railroads, bridges, etc.). This is the main purpose in establishing 'limits of survey'.

LIMITS OF SURVEY – TOTAL STATION

Total stations represent a different problem. Because of the trigonometric calculations utilized in total station reductions, elevations are not as accurately obtained using these instruments. Therefore, for elevation critical data, total station measurements should NOT exceed 600 feet from the instrument.

Horizontal data is usually not a problem and can be measured at a much greater distance than vertical data.

Traverses, vertical as well as horizontal, should always be closed, again, preferably between 2 different unknown points. No traverse should ever be left open!

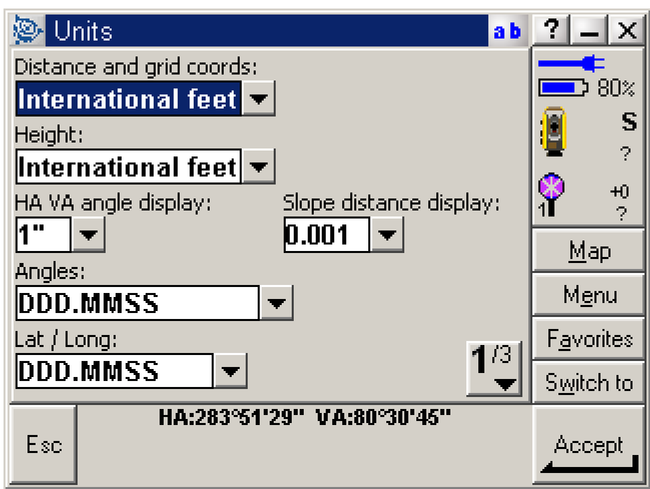
Remember, as in RTK surveying, check shots are absolutely necessary to maintaining the integrity of the data collected and, again, should always be stored as the only permanent record of this fact.

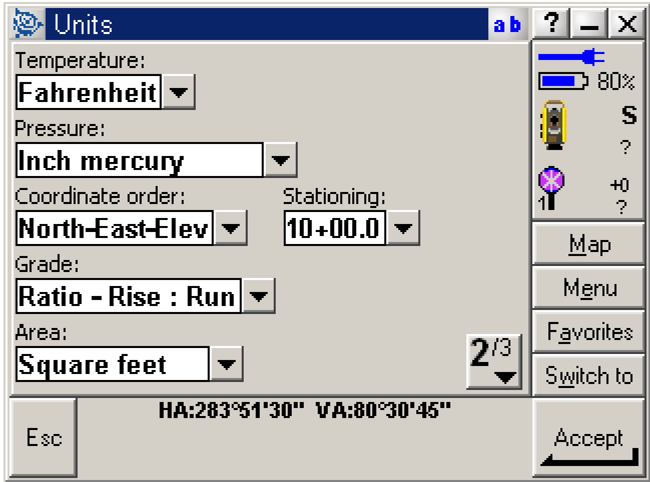
Total Station (Conventional)

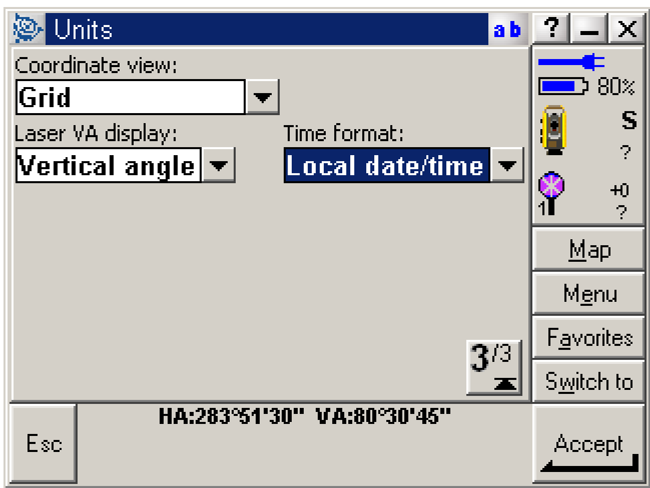
Set-up procedures

A) Level the instrument over the point you are occupying by either the plate level method or by using the electronic level. Make sure that all the screws on the tripod are tight to avoid any play and that you are centered over the occupied point.

B) Set up a job if one hasn't already been started.
   a. Create a job name using the last four numbers of the DC serial number.
   b. Under coordinate system select scale factor only / next enter a scale factor of 1.000000 and then store.
   c. Set the units of the job.







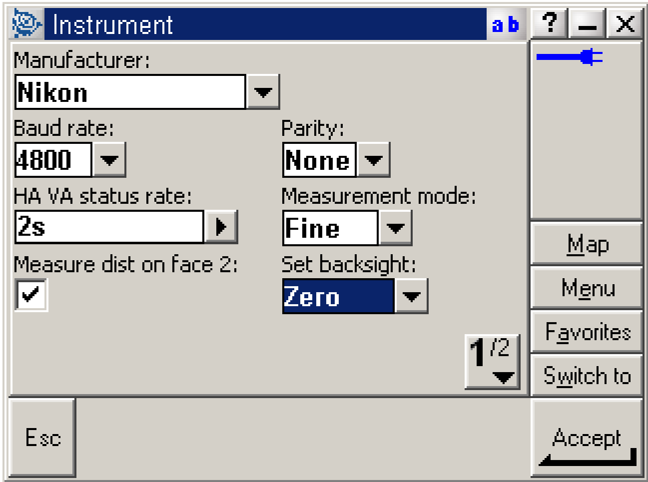
Tap accept to store units and new job.

C) Set up a survey style if one hasn't already been set up.

a. Tap Configuration / Survey Styles and New.

b. Style Name: Name the instrument being used. Example, Nikon-522
Style Type: Conventional
Accept

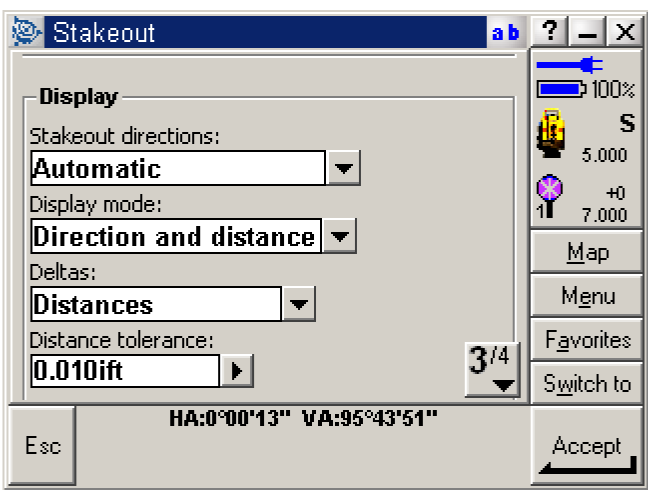
c. Tap Instrument to change settings.

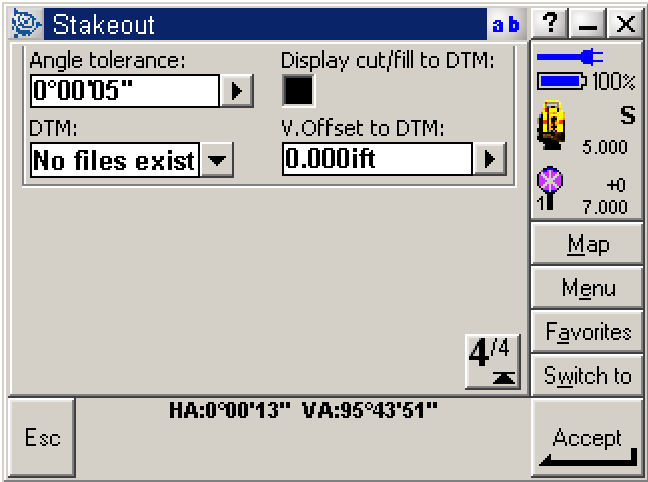


d. Topo point

Measure display: HA HD VD (personal preference)
Auto point step size: 1
View before storage: check to review point details before storing

e. Stakeout





Tip- The data collector will tell you to stake the point when you are within the distance and angle tolerance. Adjust this number according to how accurate the stakeout needs to be. Example: set the distance tolerance to .01 when staking out line for a road. The distances you need to go show up until you get within .01. If you set the angle tolerance to 1 second, the angle that you are off shows up until you are within 1 second.

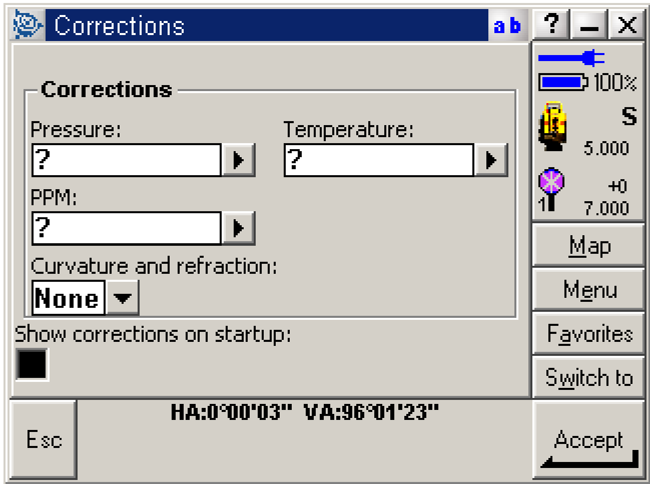
Accept and Store to create style.

D) Configuration Options

Tap Configuration / Options
Check TS surveying & Advanced Geodetic support
Accept

E) Start the survey

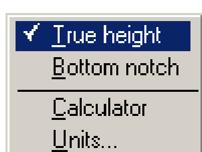
a. Key in known coordinates of points if available.
b. Tap Survey / Nikon-522 (Survey style being used) / Station Setup
c. If you set the corrections for pressure and temperature on the instrument and the settings for curvature and refraction are set in the instrument, then leave the boxes null. Remove the checkmark from <u>Show corrections on startup</u> if you use the instrument to set corrections.



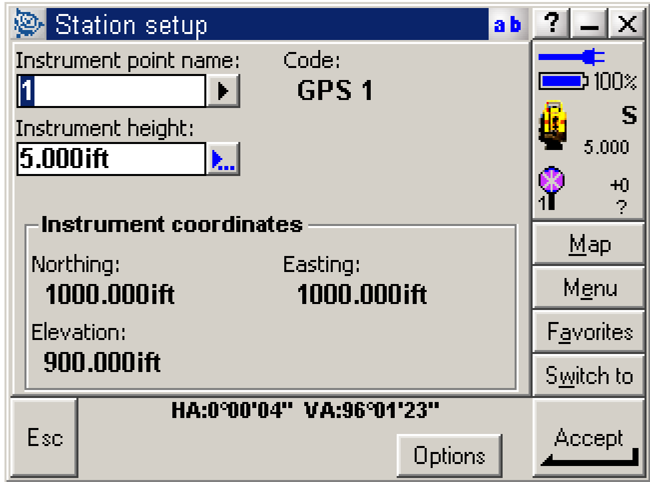
If you want to use the data collector to set corrections, turn the instrument corrections off and place a checkmark on Show corrections on startup.

d. Station setup

1. Type in the point number if known
2. > List allows you to pick a point from the points list
3. > Key in allows you to create Point name, Code, Northing, Easting, and Elevation.
4. Find allows you to enter a number and the DC will find the next free point number.
5. Measure the height of the total station from the occupied point to the horizontal axis indication mark on the side of the instrument and enter it in the Instrument height box. (Make sure True height is checked.)



Leave height box blank if surveying in 2D only.



Tap Accept.

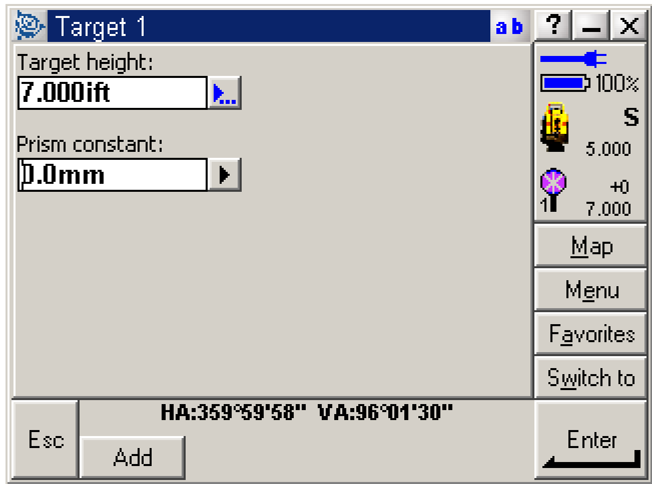
6. Set up targets if none exist. If you are going to use the instrument screen or the measure buttons on the instrument to get or view distances, set the prism constant (typically 30 mm) in the instrument and the target to 0 mm. You cannot enter a prism constant for both the instrument and the data collector.

   If you want to set the prism constant in the data collector, make sure to set the instrument to 0.0 mm. *The measurements that appear on the instrument screen will not be correct.*

   1. Tap on the Target icon below the Instrument icon in the status bar.
   2. To change from Target 1, Target 2, etc. if they exist, just tap which one you want.
   3. To add targets or make changes to targets tap either the target height or the prism type.

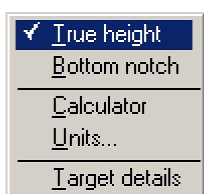
   4. Create a target by tapping Add.

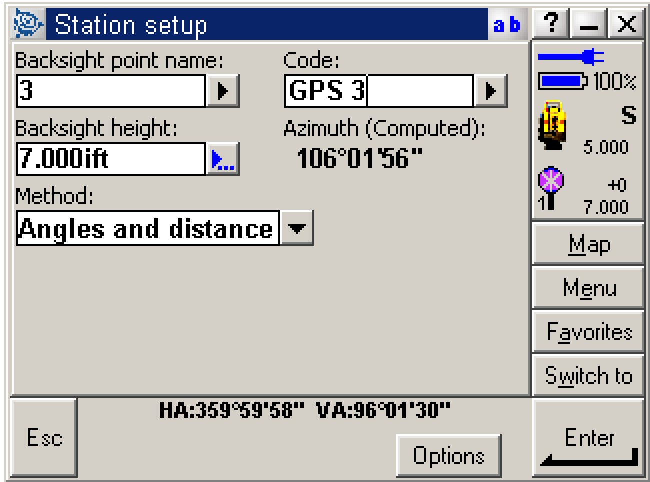


Set the target height and prism constant to 0.0 mm when the prism constant is set in the instrument.

Tap Accept and check the Target icon in the status bar to make sure you have the correct prism and height.

7. Enter backsight point name by typing in if known, > List , or > Key in.
8. Measure the backsight height and make sure true height is checked if measuring to the center of the prism.

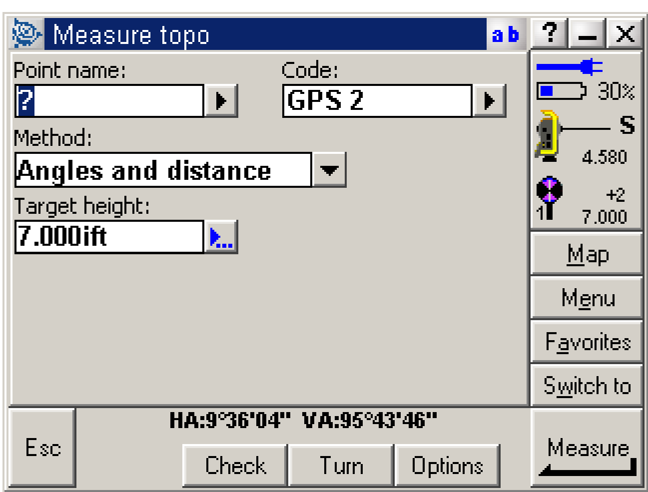




9. Method: Angles and distance
10. Tap Measure and you should be able to see the change in horizontal and vertical. Make sure it is within tolerance and Store to complete station setup. Check the status line on the bottom of the screen to make sure the HA is set to 0 degrees.
    The station setup is completed and you can begin surveying.

Survey

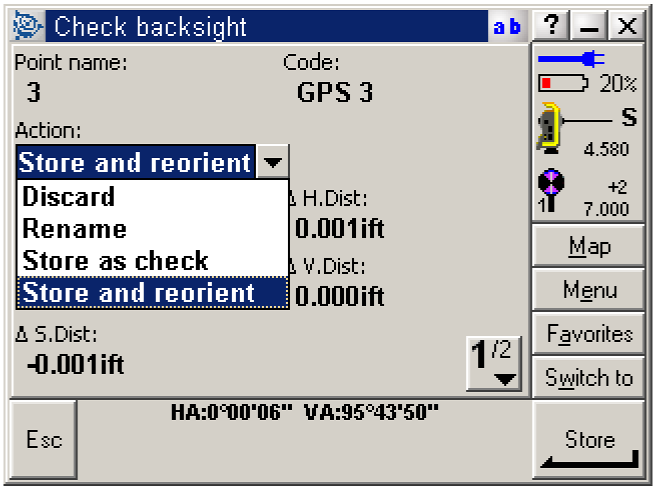
Tap the main menu Survey icon and measure topo.



Typically you will use angles and distance for the method. There are certain situations that you will use other methods.

After your station setup has been performed, tap Check on the bottom of the screen. You have a choice to either check a topo point or a backsight point.

A) Tap the Check BS tab on the bottom of the screen and then measure.



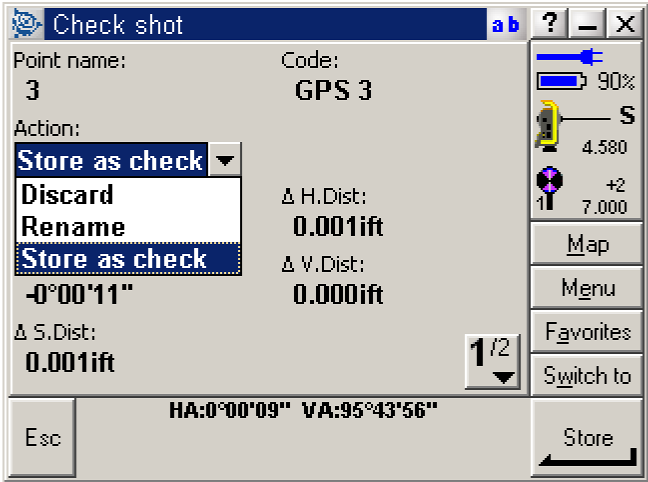
You will be able to see the change in angles and distance on page 1/1 and the change in N E & elevation on page 2/2. You then have a choice of what action you would like to take. If your values are way off, check to see if you are using the correct point and that your instrument and target heights are correct.

Choose Rename and give it a new point name and a code. Example, point name would be the next available number and code would be chk3 for check shot on GPS 3.

Store as check stores the shot under point 3 as a check shot.

Store and reorient is stored as a mean turned angle under point 3. Check your backsight periodically and if the horizontal angle is out of tolerance tap Store and the HA is set to zero degrees. You can also zero the HA on the instrument.

B) To check a topo point, tap Chk topo and enter the point name followed by Measure.



Choose Rename and give it a new point name and a code. Example, point name would be the next available point number and code would be chk3 for check shot on GPS 3.

Store as check stores the shot under point 3 as a check shot.

Tap ESC to exit out of check shots and start measuring topo. Typically, use angles and distance as the method unless another method is needed.

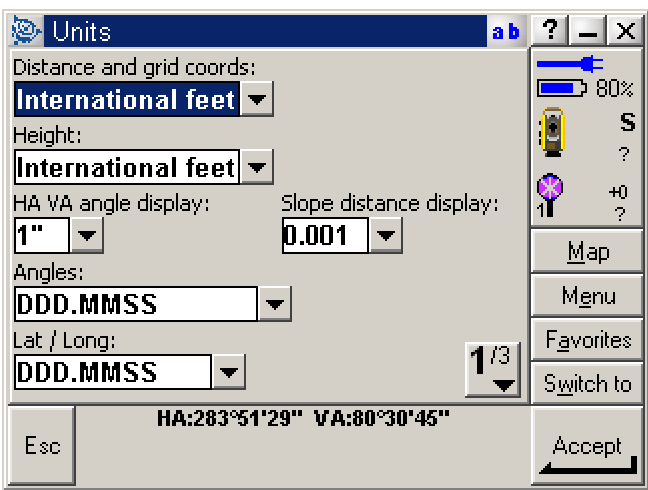
Robotic Total Station
(S Series)

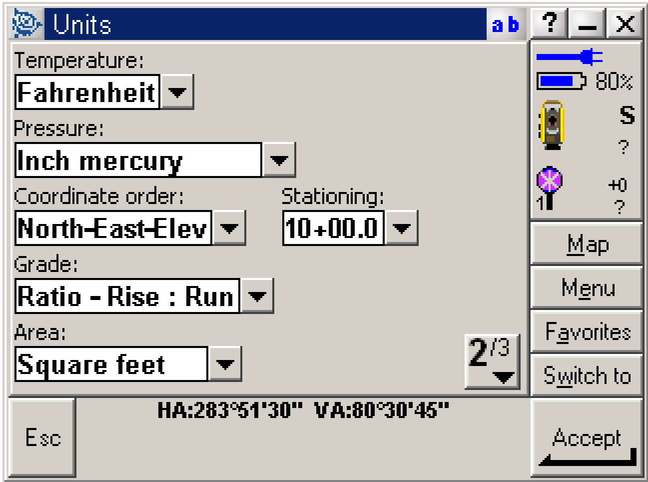
Set-up procedures

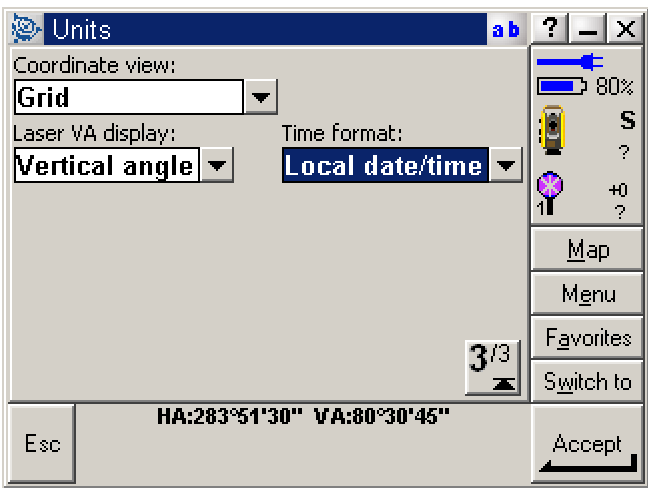
A) Level the instrument over the point you are occupying with the electronic bubble until you are in the circle on the 1:10 or 1:1 scale. Make sure that all the screws on the tripod are tight to avoid any play and that you are centered over the point.

Tip: If you turn the DC on and the robotic connection starts while leveling the instrument, you will lose the leveling screen on the instrument, but you can continue leveling with the data collector. To get the screen back on the instrument to continue leveling, shut the DC off and press the power button on the instrument.

C) Set up a job if one hasn't already been started.
a. Create a job name using the last four numbers of the DC serial number.
b. Under coordinate system select scale factor only / next enter a scale factor of 1.000000 and then store.
c. Set the units of the job.







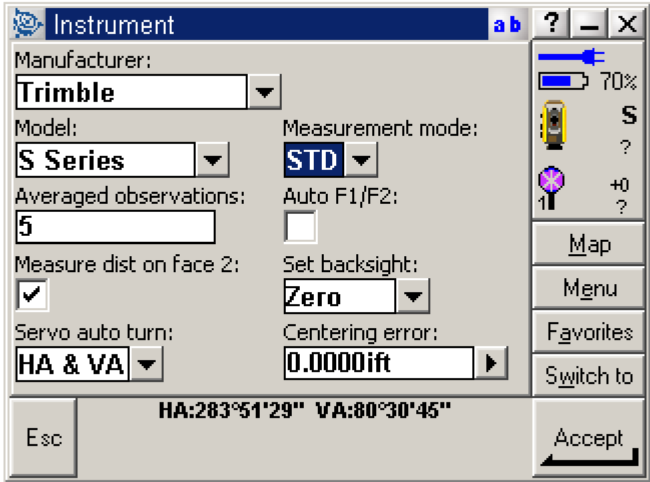
Tap accept to store units and new job.

D) Set up a survey style if one hasn't already been set up.

a. Tap Configuration/Survey Styles and New.

b. Style Name: S Series
Style Type: Conventional
Accept

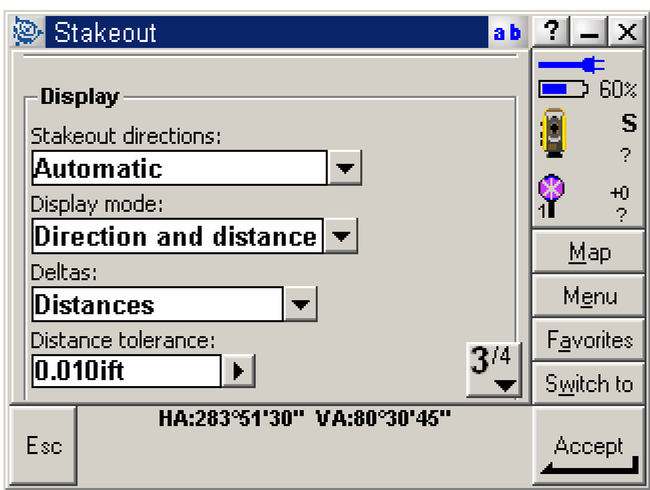
c. Tap Instrument to change settings.



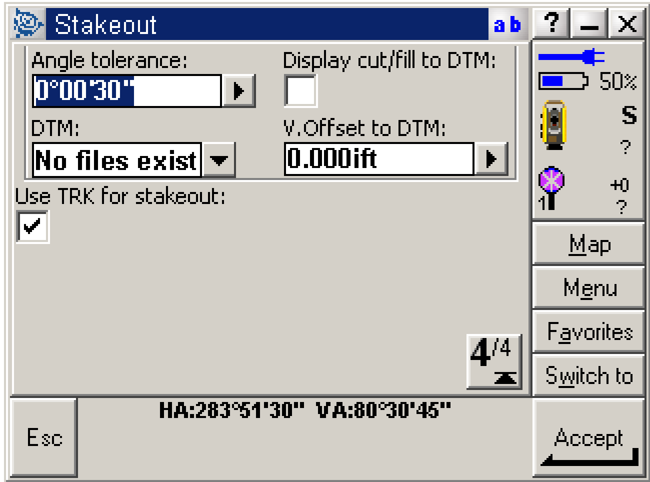
d. Topo point

Measure display: HA HD VD (personal preference)
Auto point step size: 1
View before storage: check to review point details before storing
Offset directions: Automatic

e. Stakeout



Tip – The data collector will tell you to stake the point when you get within the distance tolerance. Adjust this number according to how accurate the stakeout needs to be. Example: set tolerance to .01 when staking out line for a road. The distances you need to go show up until you get within .01.



Check Use TRK for stakeout to continuously measure distances and angles giving you real time measurements.

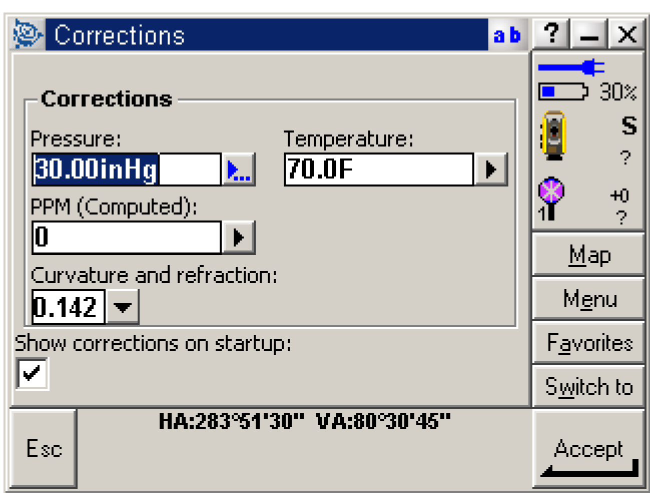
Accept and Store to create style.

E) Configuration Options

Tap Configuration / Options
Check <u>TS surveying & Advanced Geodetic support</u>
Accept

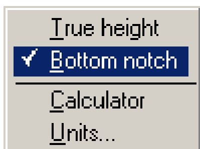
F) Start the survey

a. Key in known coordinates of points if available.
b. Tap Survey / S Series / Station Setup
c. Enter the temperature and pressure and Accept.

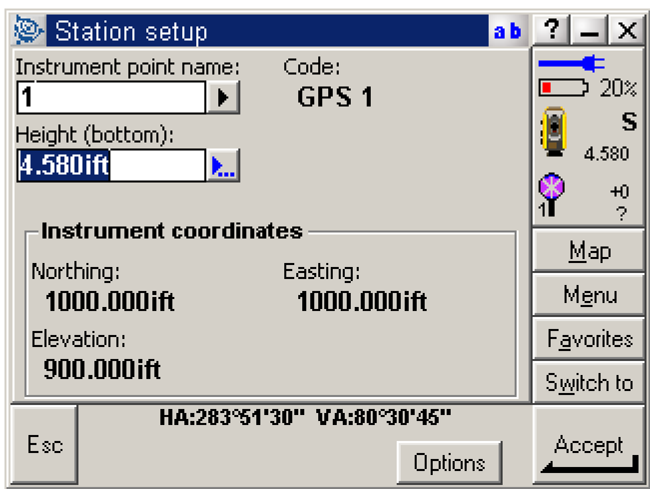


d. Station setup

1. Type in the point number if known
2. > List allows you to pick a point from the points list
3. > Key in allows you to create Point name, Code, Northing, Easting, and Elevation.
4. Find allows you to enter a number and the DC will find the next free point number.
5. Measure the height of the total station from the occupied point to the top ridge of the bottom notch on the S Series total station and enter it in the Instrument height box. (Make sure the bottom notch is checked when using this measurement.)

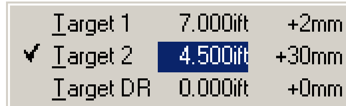


Leave height box blank if surveying in 2D only.

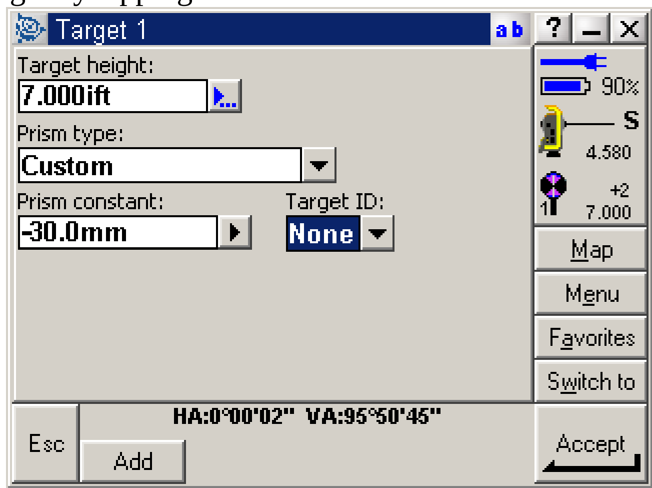


Tap Options if you want to make any changes and then Accept.

6. Set up targets if none exist.
   1. Tap on the Target icon below the Instrument icon in the status bar.
   2. To change from Target 1, Target 2, etc. if they exist just tap which one you want.
   3. To add targets or make changes to targets tap either the target height or the prism type.



4. Create a target by tapping Add.



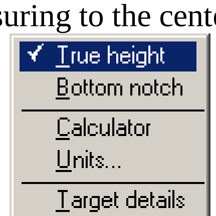
Set the prism type to Custom if it isn't in the drop-down menu under prism type and type in the prism constant. (Typically -30 mm)

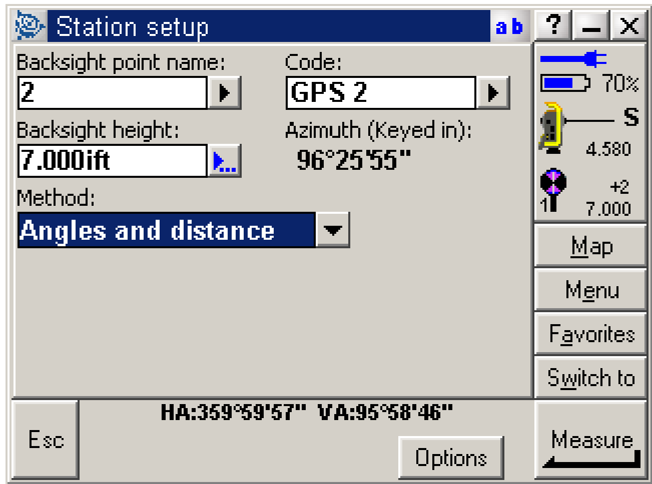
Set the prism type to S Series 360 with a 2 mm prism constant when using the 360 degree robotic prism.

Tap Accept and check the Target icon in the status bar to make sure you have the correct prism and height.

Target ID: If using a target ID make sure that the ID number is the same in the DC and the ID itself.

7. Enter backsight point name by typing in if known, > List , or > Key in.
8. Measure the backsight height and make sure true height is checked if measuring to the center of the prism.

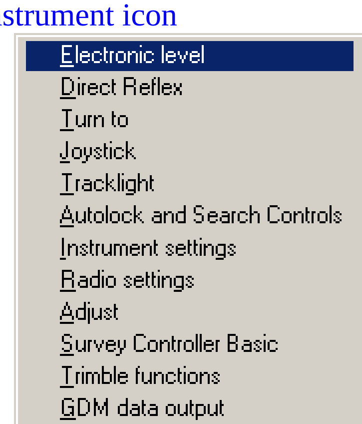




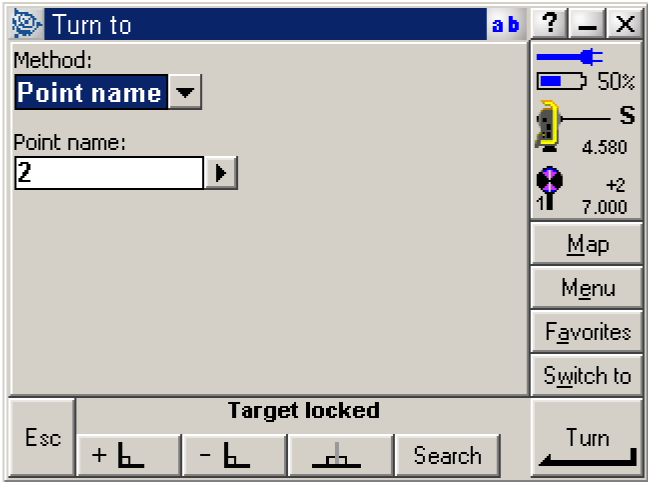
9. Method: Angles and distance
10. Tap Measure and you should be able to see the change in horizontal and vertical. Make sure it is within tolerance and Store to complete station setup. Check the status line on the bottom of the screen to make sure the HA is set to 0 degrees.
11. The station setup is completed and you can begin surveying.

Instrument settings options

Tap Instrument icon



A) Electronic level – Lets you check the status of the instrument.
B) Direct Reflex – Allows you to change settings when using DR
C) Turn to – Used to turn to a specific angle or point

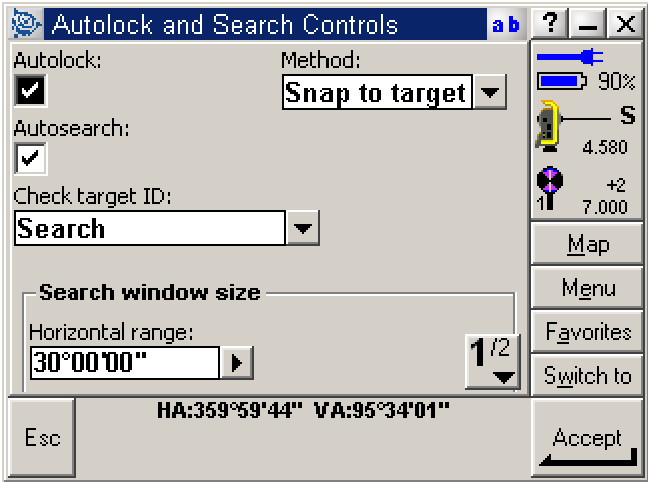


a. Method: Point name allows you to turn to a known point. Search can be initiated if target doesn’t lock.
b. Method: HA & VA allows you to turn to a specific horizontal or vertical angle or both. Search can be initiated if target doesn’t lock.
c. Icons on the bottom of the status line allow you to turn + or – 90 degree increments or 180 degrees.

D) Joystick – Used to turn the instrument. Select either target or instrument perspective and adjust the speed as desired.

E) Tracklight - Used to show that the instrument is locked on to the correct target and also to help aid in locking onto targets.
   a. Select Auto – the tracklight flashes fast when the target is locked and slow if there is no target.
   b. Tip – the rodholder will see a green flashing light if they are to the right of the measuring beam and a red flashing light if they are to the left of the measuring beam. Tilt the rod to the left and right while standing in place to check that the target is locked.

F) Autolock & Search Controls – Locks onto and tracks target



Autolock: Locks onto and tracks target
Autosearch: Automatically performs a horizontal search when target site is lost.
Method: Snap to target – automatically locks on to a remote target if one is detected. It does not check Target ID. Disable snap to target if you are surveying by a high number of reflective objects.
Check target ID: Search- check the ID when a search is initiated
Search & Measure- check the ID when a search is initiated, and when a measurement is initiated
Always- the ID is constantly being checked by the instrument
Predictive Tracking: Allows you to pass behind trees, signs, etc. and the instrument continues to turn, based on the target's horizontal trajectory for a period of time until the target is locked again. You can set it for 1, 2, or 3 seconds. If the target is not found in the specified time, then the instrument will return to the location where sight was initially lost and the predictive tracking began.
Auto Centered Search Window: Uses the current horizontal and vertical angles of the instrument to set the center of the search window. You can set the size of your search window according to your preference.

G) Instrument Settings – View and set specific controls on the instrument

G) Radio Settings – Set the radio channel and network ID to match the instrument.

H) Adjust – Allows you to perform a HA & VA collimation and trunnion axis tilt adjustment and also a autolock collimation adjustment.

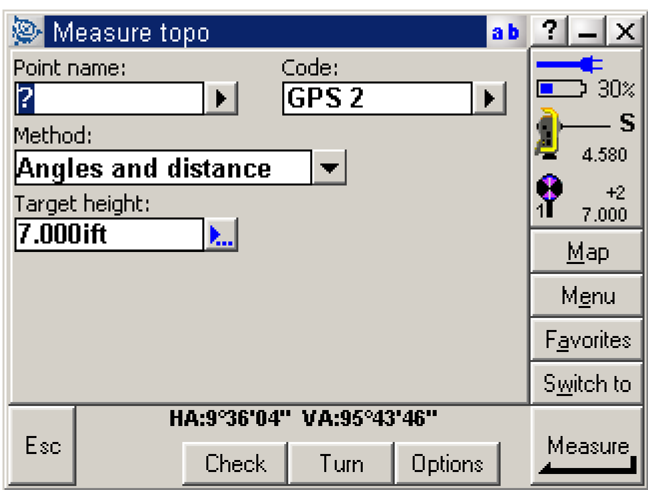
I) Survey Controller Basic – Allows you to view and perform simple distance or angular checks without storing any points. If you want to zero or set the angle you cannot have a station setup defined.

J) Trimble Functions – Access to certain instrument menu functions. The screen can also be brought up by tapping on the instrument icon in the status bar.

Tap and hold on icons to quickly access their menu configuration screens.

Survey

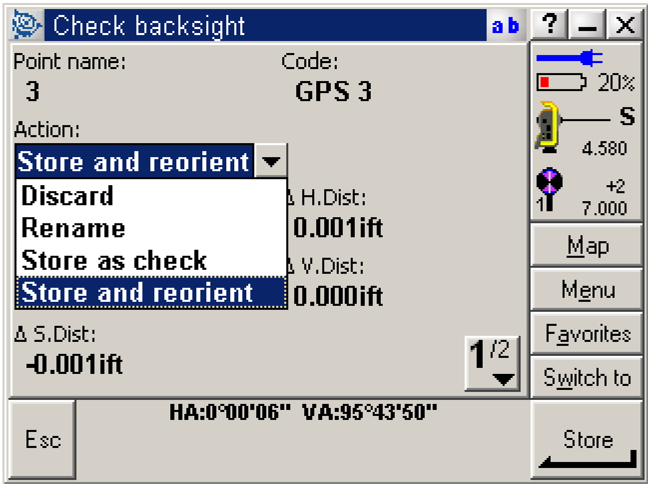
Tap the main menu Survey icon and measure topo.



Typically you will use angles and distance for the method. There are certain situations that you will use other methods.

After your station setup has been performed, tap Check on the bottom of the screen. You have a choice to either check a topo point or a backsight point.

A) Tap the Check BS tab on the bottom of the screen and then measure.



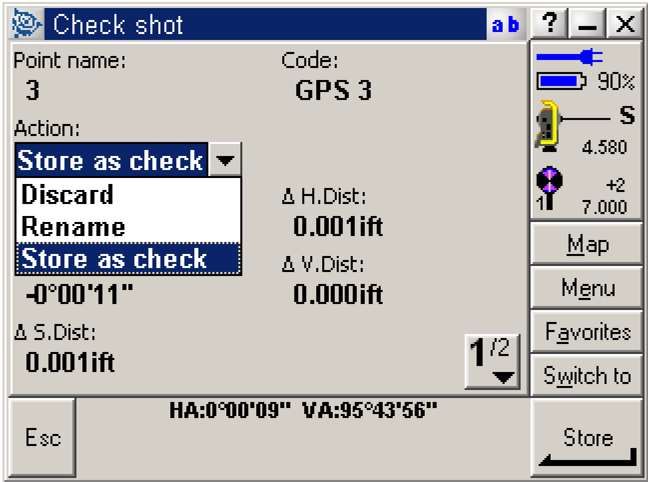
You will be able to see the change in angles and distance on page 1/1 and the change in N E & elevation on page 2/2. You then have a choice of what action you would like to take. If your values are way off, check to see if you are using the correct point and that your instrument and target heights are correct.

Choose Rename and give it a new point name and a code. Example, point name would be the next available point and code would be chk3 for check shot on GPS 3.

Store as check stores the shot under point 3 as a check shot.

Store and reorient is stored as a mean turned angle under point 3. Check your backsight periodically and if the horizontal angle is out of tolerance tap Store and the HA is set to zero degrees.

B) To check a topo point, tap Chk topo and enter the point name followed by Measure.



Choose Rename and give it a new point name and a code. Example, point name would be the next available point number and code would be chk3 for check shot on GPS 3.

Store as check stores the shot under point 3 as a check shot.

Tap ESC to exit out of check shots and start measuring topo. Typically, use angles and distance as the method unless another method is needed.

Additional Information

- When surveying with the 360 degree prism and a high degree of accuracy is needed, make sure to face one of the prisms directly at the instrument or the distance measurement can be up to .15 off.

- When using the Target ID make sure it faces the instrument or the ID will not be detected.
  - Press the On/Mode button to choose <u>timer mode</u>, (ID stays on for 60 seconds to allow target verification during search and then shuts off), or <u>On</u> to continuously stay on. Use the timer mode to save battery life, especially during cold weather.

- After performing an update on the S6 or the TSC2, make sure you set the radio channel and network ID so that they are the same on the S6 and the TSC2. If you cannot start a robotic connection, this is probably what is wrong.

- Try to set up the instrument on high ground so that you can minimize the obstructions between the instrument and the target. If you are in heavily traveled areas and continuously loose sight of the target, it might be best to turn autolock off and have someone manually sight the instrument to the target.

- When you are using 2 or more different prisms make sure to change your targets or your data will be wrong. If you are using a -30 mm prism for a backsight, make sure to change the rod target to the 2mm 360 degree prism if that is what you are using to collect data. The targets can be changed under review current job if you forget, but it is easier to make the change right away.

- When taking measurements in the field, you can choose between standard and track under the trimble functions menu.
    - Standard- Measurement takes place only when initiated by you. It allows you to enter a set number of averaged observations before storing a point. Typically used to measure topo.
    - Track- Continuously measures the distance and angle from the instrument to the target giving real time information. Typically used during stakeout.

- You can program certain functions to the 2 soft keys on top of the TSC2 between the OK and Windows tabs. On the right side of the screen tap Favorites / Customize / Assign a command to App Button 1, you can then choose an application used frequently like Search or Joystick. Repeat steps to Assign a command to App Button 2.

- If the data collector locks up, try doing a soft reset by holding the power button for approximately 10 seconds. If this doesn't work, try doing a hard reset by holding the cntrl and power buttons at the same time. If nothing happens you might have to unscrew the battery and disconnect it for a short period of time.

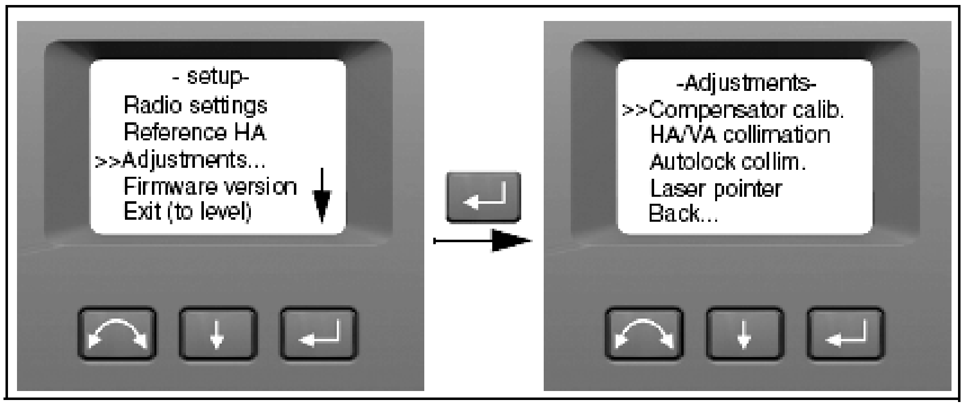
Instrument Adjustments

Perform adjustments and calibrations periodically, especially before you take precise measurements.

Adjustments menu

The adjustments menu contains all the instrument collimation and calibration routines.

- Press to scroll to Adjustments and then press .



Compensator calibration

The compensator is calibrated when the instrument is in perfect balance, then the compensator sensor will compensate for any unbalance introduced later. For this reason the instrument has to have low unbalance when the compensator calibration is done.

To minimize unbalance in the instrument:

- Do not have the Control Unit mounted on the instrument.
- Internal battery must be fitted.
- Handle must be mounted.
- The instrument will automatically position the distance unit for best balance.

To start the compensator calibration:

1. Level the instrument. The instrument will automatically check if the compensator is within range before the calibration is started.
2. Press to scroll to Compensator calib. and then press .
3. Follow the instructions in the display. figure 4.26.

***Note** – Trimble recommends that you regularly carry out a compensator calibration, particularly when measuring during high temperature variations and where high accuracy is demanded.*

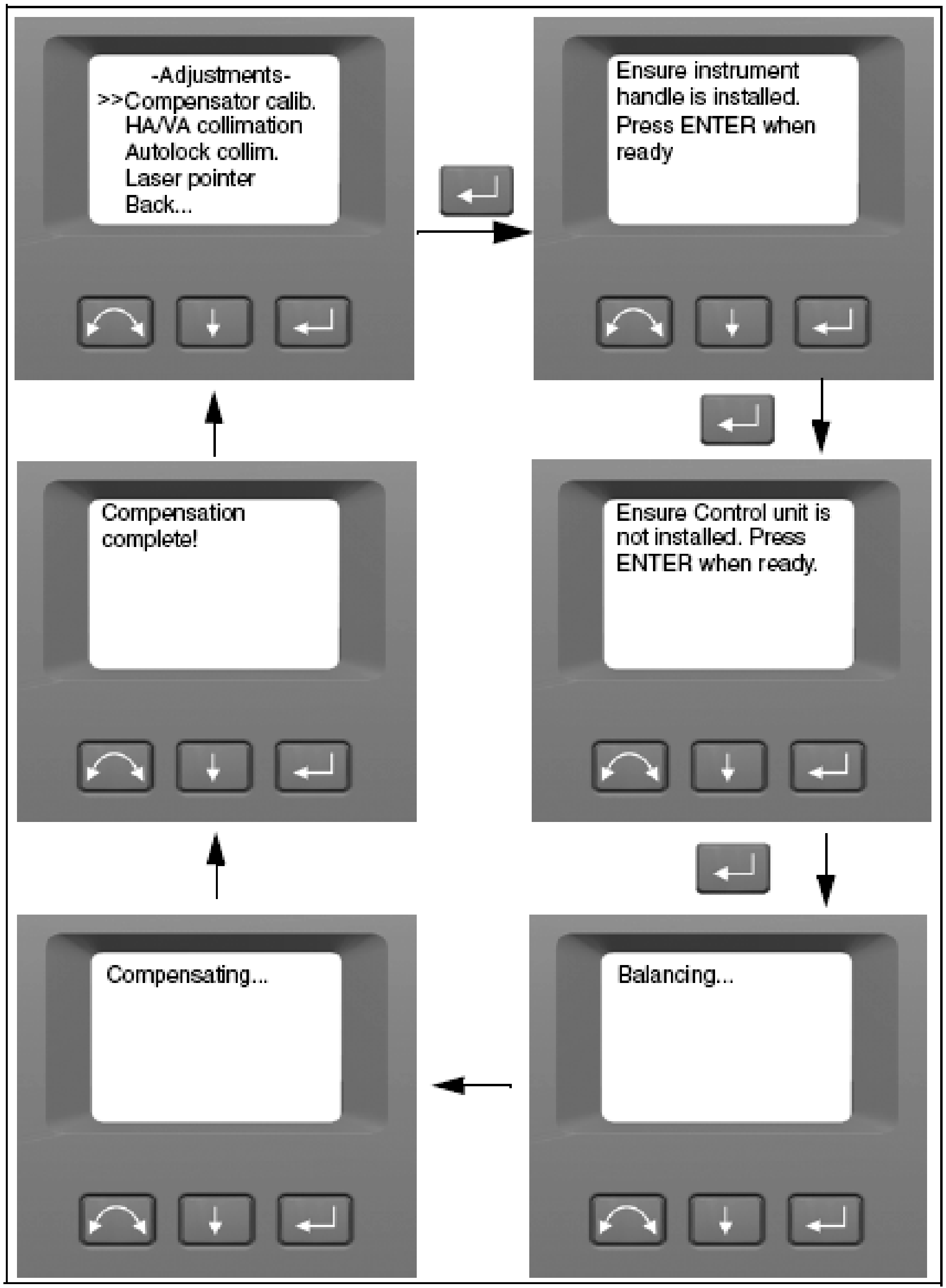


Figure 4.26 Compensator calibration routine

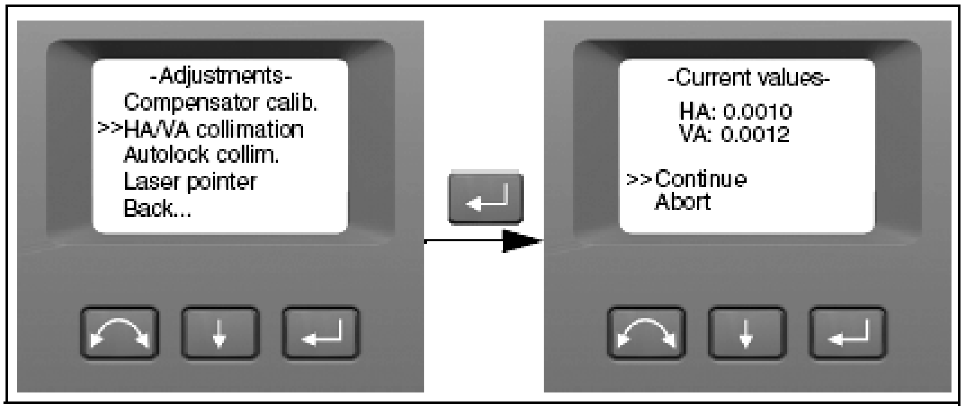
HA/VA Collimation and trunnion axis tilt

The collimation routine consists of the HA/VA collimation and then the trunnion axis tilt.

The Horizontal and Vertical collimation and the trunnion axis tilt correction have been measured and stored in the instrument at the factory.

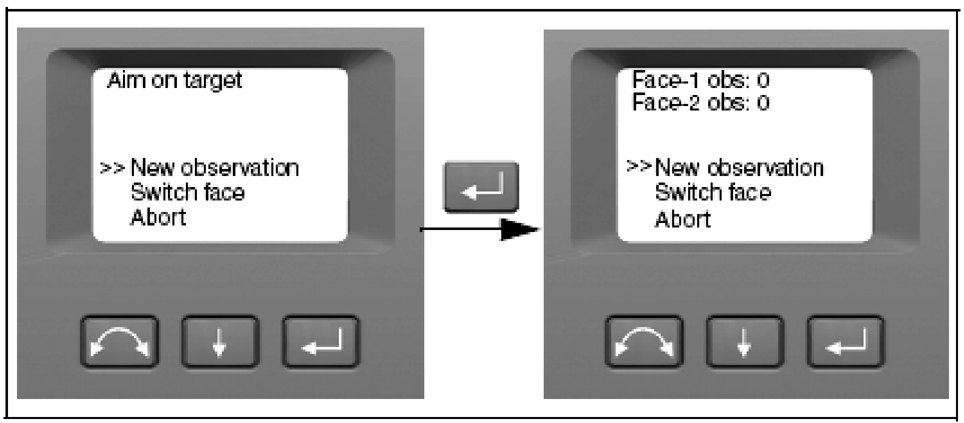
Note – Trimble recommends that you regularly carry out a test measurement of the HA/VA collimation and trunnion axis tilt, particularly when measuring during high temperature variations and where high accuracy is demanded.

1. Press to scroll to HA/VA collimation and then press .



The current collimation values appears.

2. Press to scroll to one of the following:
   - Continue Then press to continue the HA/VA collimation test.
   - Abort. Then press to return to the *Adjustments* menu.



If you select Continue:

3. Press to scroll to one of the following:
   - New observation. Then press to continue the HA/VA collimation test.
   - Switch face. Then press to change between face 1 and 2.
   - Abort. Then press to return to the *Adjustments* menu.

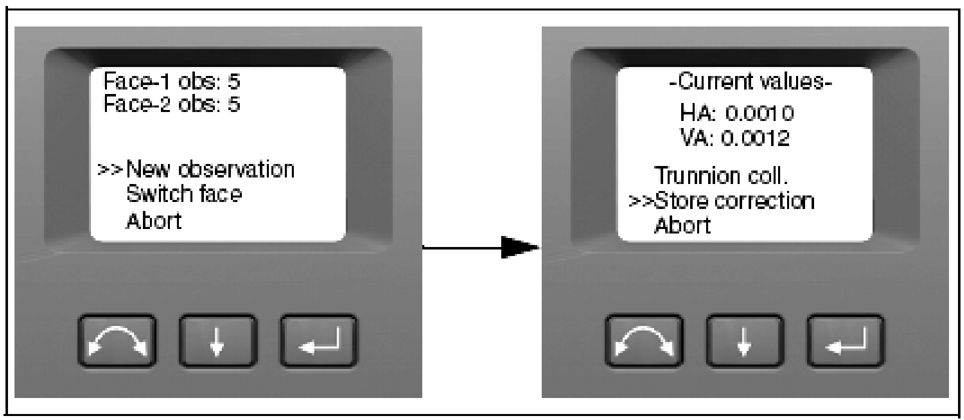
If you select New observation:

a. Aim accurately in face 2 towards a point near the horizon at max. ±5 grads (± 4.5 degrees) at a minimum distance of 100 m (328 ft.).
b. Press to measure and record angles.
c. Repeat point a and b about 5 times.
d. Press to scroll to Switch face. Then press to change face.
e. Aim accurately towards the point.
f. Press to measure and record angles.
g. Repeat point e and f the same number of times as was made at point a and b.

As observations are made on the first face (either face 1 or face 2), the angle values are stored and the counter increases. When one or more observations have been taken on each face, and the number of observations on each face are the same.

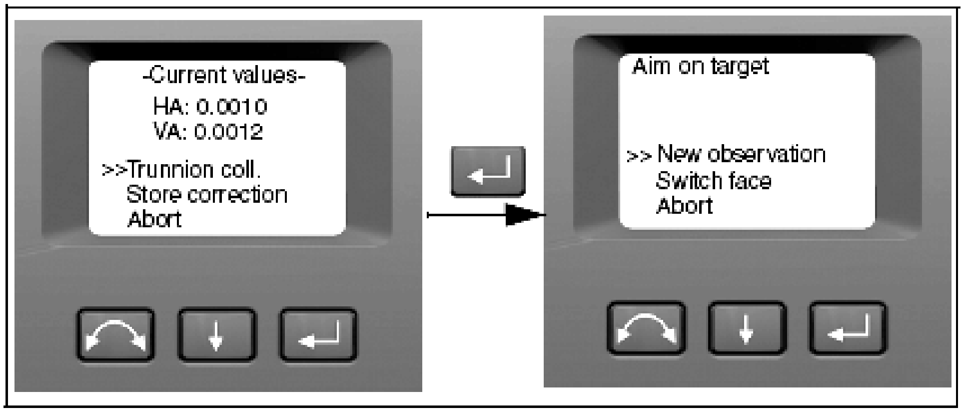
The software calculates and displays the new horizontal and vertical collimation values.

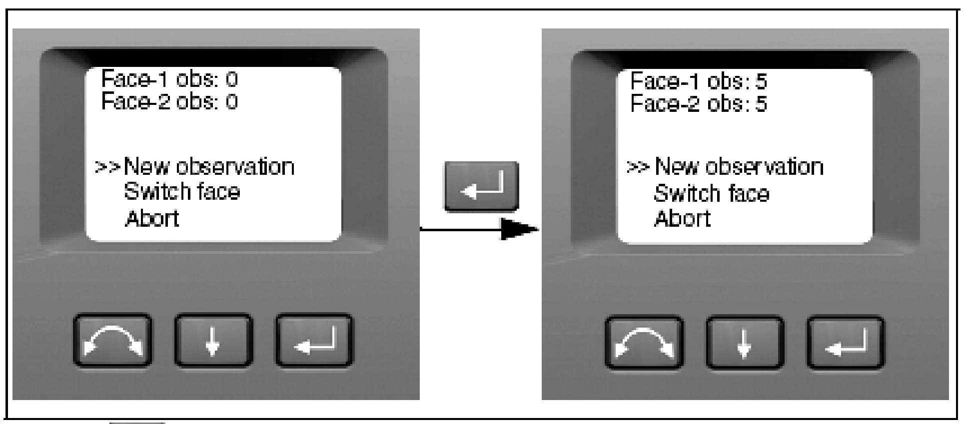
4. Press to scroll to one of the following:
   - Trunnion coll. Then press to continue to Trunnion collimation.
   - Store correction. Then press to accept and store the new collimation values.
   - Abort. Then press to return to the *adjustments* menu.



Select Trunnion coll. to continue with trunnion axis tilt collimation.

5. Press to scroll to Trunnion coll. Then press to continue the Trunnion axis tilt collimation test.





6. Press to scroll to one of the following:

- New observation. Then press to continue the trunnion axis tilt test.
- Switch face. Then press to change face.
- Abort. Then press to return to the adjustments menu.

If you select New observation the number of observations in both faces appears:

a. Aim accurately in face II towards a point at least 15 grads (13.5 degrees) above or below the point where the collimation test was made at a minimum distance of 30 m (66 ft.).

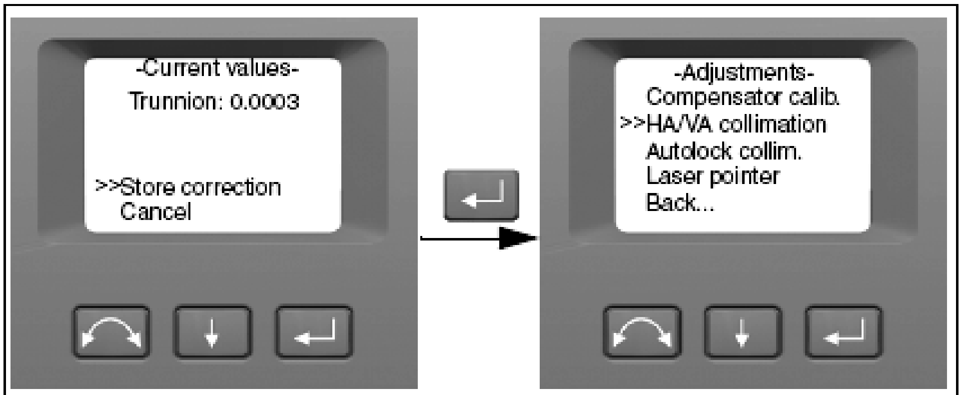
b. Press to measure and record angles.

c. Press to scroll to Switch face. Then press to change face.

d. Aim accurately towards the point.

e. Press [enter] to measure and record angles.

As observations are made on the first face (either face 1 or face 2), the angle values are stored and the counter increases. When one or more observations have been taken on each face, and the number of observations on each face are the same, the software calculates and displays the new trunnion axis tilt value.



7. Press [down] to scroll to one of the following:

- Store correction. Then press [enter] to accept the new trunnion axis tilt value. The *Adjustments* menu appears.
- Cancel. Then press [enter] to return to the *Adjustments* menu.

Note *– The instrument will prohibit a trunnion axis tilt test if it is made towards a point with an angle less than 15 grads (13.5 degrees) from the point where the collimation test was made. The trunnion axis tilt accuracy will improve with a steeper angle towards the measured point. The minimum distance for the trunnion axis tilt measurement is 30 m (66 ft.).*

Note *– If the trunnion axis tilt correction factor is greater than 0.05 grads (0.045 degrees), the message* Fail Remeasure? *appears. Press Yes and then repeat the measurement procedure. If the factor is greater than 0.05 grads (0.045 degrees) and you answer No to the re measurement message, the instrument uses the correction factor previously stored in the instrument. If the factor is greater than 0.05grads (0.045 degrees), then the instrument must be mechanically adjusted at the nearest authorized Trimble service center.*

Autolock collimation (Only on instruments with Autolock technology)

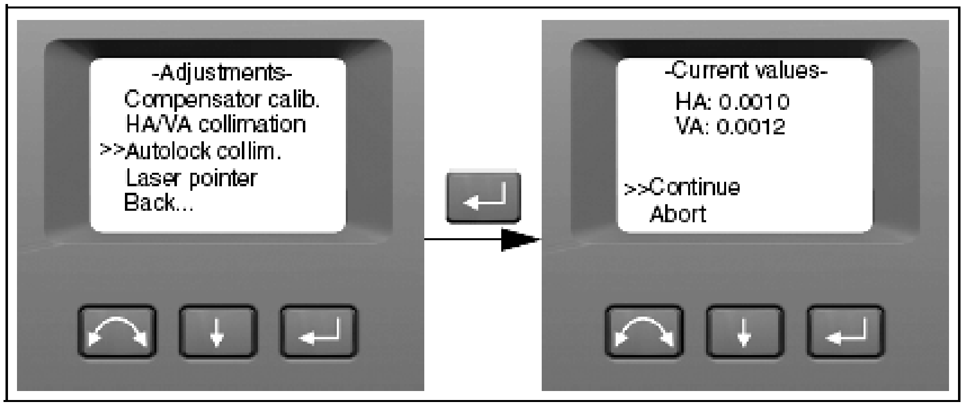
The Autolock technology that directs the instrument when configured for Autolock, remote, and robotic surveying can receive collimation errors in the same way as the optical system. Therefore, you should regularly test measurements and store the new values. If possible, perform the test over a similar distance as that you will be working on, but at least 100 m.

Note *– The adjustment between the two optical axes, i.e. the Telescope and the Tracker, may differ. See Aiming on page 105*

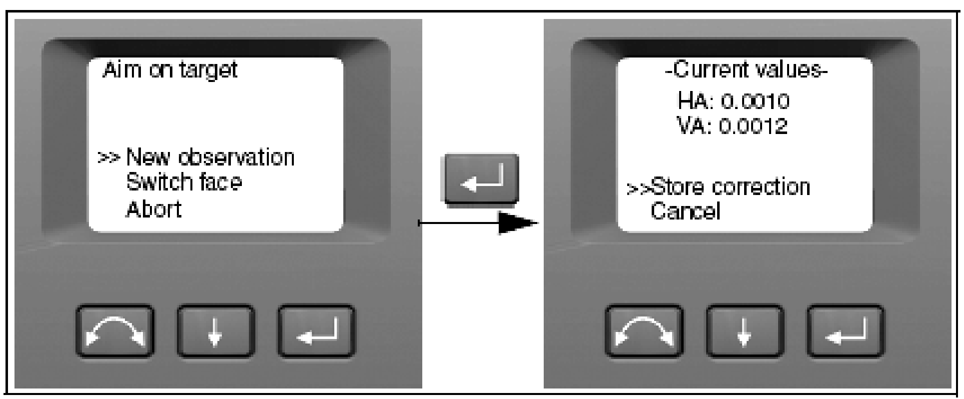
The target must be very still during the test (Trimble recommends that you use a tripod) and must be in clear sight without any obstructing traffic.

The instrument is calibrated to Horizontal and Vertical collimation errors, which can be stored and used to correct the measured points. The measured values are in effect until you carry out a new test measurement:

1. Press to scroll to Autolock collim then press .



2. Accurately aim towards a prism.
3. Press to scroll to New observation and then press .



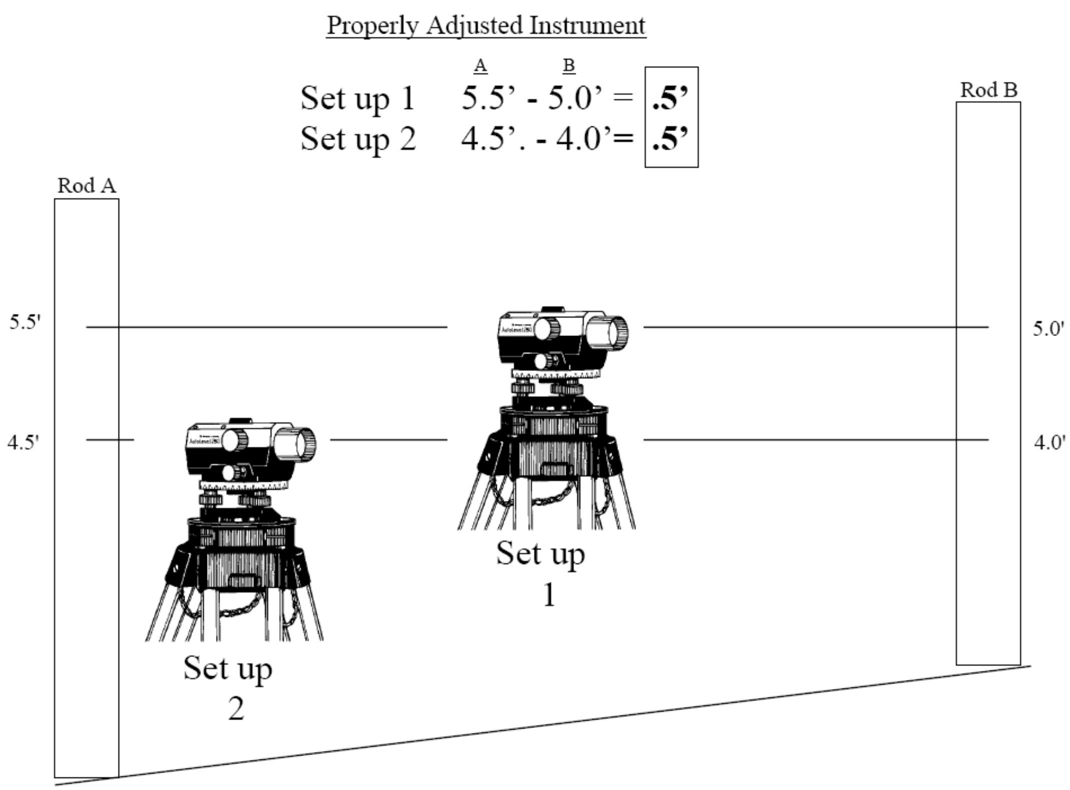
4. The instrument will measure to the target in both faces automatically and then display the current values.
5. Press to scroll to one of the following:
   - Store correction. Then press to save the correction values.
   - Cancel. Then press to return to the Adjustments menu
6. Once the instrument has stored the correction values, the *Adjustments* menu appears.

Appendix

The "Two Peg Test"

The "Two Peg Test" is the most common means of checking an instrument in the field, and can be done for both optical & laser levels. Here is how it works:

1) Set up two rods approximately 150 to 200 feet apart.
2) Set up and level the instrument at the approximate midpoint of the two rods and take a reading on each rod. In the diagram below, these two readings would be 5.5' on Rod "A" and 5.0' on rod "B". The instrument is now set up and leveled at a point as close to rod "A" as is practical, 6 feet or less is recommended.
3) Intentionally change the height of the tripod so there is an offset in the two setup heights. Again readings are taken on both rods.
4) If the calculated difference is the same from both setups, the instrument is shooting level. **If the calculated difference in elevation is not the same, the instrument is not shooting level, and is in need of service.**



STATE OF NORTH DAKOTA BASE LINE DESIGNATION

BASE LINE DESIGNATION	STATE	COUNTY	QUAD
BISMARCK CBL (1990) REMEASURED	NORTH DAKOTA	MORTON	N461004
DICKINSON	NORTH DAKOTA	STARK	N461031
WILLISTON CBL	NORTH DAKOTA	WILLIAMS	N481033

US DEPARTMENT OF COMMERCE - NOAA   CALIBRATION BASE LINE DATA
QUAD: N461004
NOS - NATIONAL GEODETIC SURVEY   BASE LINE DESIGNATION: BISMARCK CBL
NORTH DAKOTA
ROCKVILLE MD 20852   PROJECT ACCESSION NUMBER: 16542

MORTON COUNTY

NEAREST TOWN: HUFF

LIST OF ADJUSTED DISTANCES (JULY 20, 1990)

FROM STATION	ELEV.(M)	TO STATION	ELEV.(M)	ADJ. DIST.(M) HORIZONTAL	ADJ. DIST.(M) MARK - MARK	STD. ERROR(MM)
0	504.400	150	504.365	149.9922	149.9922	0.2
0	504.400	430	504.134	430.0002	430.0003	0.3
0	504.400	1400	504.683	1400.0494	1400.0495	0.4
150	504.365	430	504.134	280.0080	280.0081	0.2
150	504.365	1400	504.683	1250.0572	1250.0573	0.3
430	504.134	1400	504.683	970.0492	970.0493	0.2

A TAPE CALIBRATION MONUMENT WAS SET AT THE 100 FOOT POINT OF THE BASE LINE. THE REDUCED MARK TO MARK DISTANCE IS 100.00 FT.

DESCRIPTION OF: BISMARCK BASE LINE
YEAR MEASURED: 1980
YEAR REMEASURED: 1990
CHIEF OF PARTY: LPB

THE BASE LINE IS LOCATED ABOUT 16.1 KM (10.0 MI) SOUTHEAST OF MANDAN, 14.5 KM (9.0 MI) SOUTH OF BISMARCK,
AND 9.7 KM (6.0 MI) NORTH OF HUFF IN AN ABANDONED RAILROAD BED ALONG THE EAST SIDE OF STATE HIGHWAY 1806.

THE BASE LINE IS A NORTH-SOUTH LINE WITH THE 0-METER POINT ON THE NORTH END. IT CONSISTS OF THE 0, 150, 430, AND 1400 METER POINTS WITH A 100-FOOT TAPE CALIBRATION STATION LOCATED SOUTH OF THE 0-METER POINT.

TO REACH THE 0-METER POINT FROM THE JUNCTION OF MAIN STREET (BUSINESS LOOP INTERSTATE 94) AND STATE HIGHWAY 1806 (6TH AVENUE EAST) IN MANDAN, GO SOUTH ON HIGHWAY 1806 1.1 KM (0.7 MI) TO A BRIDGE. CONTINUE SOUTH FOR 6.6 KM (4.1 MI) TO THE ENTRANCE TO THE FORT LINCOLN VISITOR CENTER ON THE LEFT. CONTINUE SOUTH FOR 1.3 KM (0.8 MI) TO A CONCRETE FLOOD GATE. CONTINUE SOUTH FOR 6.68 KM (4.15 MI) TO THE 0-METER POINT ON THE LEFT.

THE 0-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK STAMPED "0 M" SET IN THE TOP OF A 84 CM (33 IN) DIAMETER CONCRETE POST PROJECTING 23 CM (9 IN) ABOVE THE SURFACE OF THE GROUND. IT IS 3.0 M (9.8 FT) WEST OF THE CENTERLINE OF THE RAILROAD BED, 1.2 M (3.9 FT) EAST OF A FIBERGLASS WITNESS POST, 1.1 M (3.6 FT) WEST OF A METAL WITNESS POST WITH REFLECTOR, AND 1.0 M (3.3 FT) SOUTH OF A METAL WITNESS POST WITH REFLECTOR.

THE 150-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK STAMPED "150 M" SET IN THE TOP OF A 76 CM (30 IN) DIAMETER CONCRETE POST PROJECTING 13 CM (5 IN) ABOVE THE SURFACE OF THE GROUND. IT IS 3.0 M (9.8 FT) WEST OF THE CENTERLINE OF THE RAILROAD BED, 1.0 M (3.3 FT) WEST OF A METAL WITNESS POST WITH REFLECTOR, AND 1.0 M (3.3 FT) EAST OF A FIBERGLASS WITNESS POST.

THE 430-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK STAMPED "430 M" SET IN THE TOP OF A 71 CM (28 IN) DIAMETER CONCRETE POST PROJECTING 18 CM (7 IN) ABOVE THE

SURFACE OF THE GROUND. IT IS 3.2 M (10.5 FT) WEST OF THE CENTERLINE OF THE RAILROAD BED, AND 0.2 M (0.7 FT) WEST OF A FIBERGLASS WITNESS POST.

THE 1400-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK STAMPED "1400" SET IN THE TOP OF A 79 CM (31 IN) DIAMETER CONCRETE POST PROJECTING 18 CM (7 IN) ABOVE THE SURFACE OF THE GROUND. IT IS 2.7 M (8.9 FT) WEST OF THE CENTERLINE OF THE RAILROAD BED, 0.7 M (2.3 FT) WEST OF A METAL WITNESS POST WITH REFLECTOR, AND 0.4 M (1.3 FT) WEST OF A FIBERGLASS WITNESS POST.

1THE 100-FOOT TAPE CALIBRATION STATION IS A STANDARD NGS REFERENCE MARK DISK STAMPED "100 FT" SET IN THE TOP OF A 79 CM (31 IN) CONCRETE POST PROJECTING 18 CM (7 IN) ABOVE THE SURFACE OF THE GROUND. IT IS 30.48 (99.99 FT) SOUTH OF THE 0-METER POINT, 3.0 M (9.8 FT) WEST OF THE CENTERLINE OF THE RAILROAD BED, AND 1.2 M (3.9 FT) EAST OF A FIBERGLASS WITNESS POST.

THE 100-F00T SECTION WAS REMEASURED BY EDMI METHOD AND FOUND TO BE 99.99 FEET (30.478 M) MARK-TO-MARK.

USER NOTES: CBL USERS SHOULD TAKE CARE IN PLUMBING OVER ALL POINTS. ELEVATIONS ARE FOR CBL USE ONLY.

THIS CALIBRATION BASE LINE WAS ESTABLISHED IN CONJUNCTION WITH THE MISSOURI RIVER CHAPTER OF THE
NORTH DAKOTA SOCIETY OF PROFESSIONAL LAND SURVEYORS AND BISMARCK STATE COLLEGE. FOR MORE INFORMATION CONTACT MR. ALAN ERICKSON, ULTEIG ENGINEERS INC, P.O. BOX 2041, 1701 SOUTH 12TH STREET, BISMARCK, NORTH DAKOTA 58502. TELEPHONE (701) 258-6507. OR CONTACT MR. MIKE WICKSTROM, ENGINEERING DEPARTMENT, BISMARCK STATE COLLEGE, SCHAFER STREET, BISMARCK, NORTH DAKOTA 58501. TELPHONE (701) 224-5458.

US DEPARTMENT OF COMMERCE - NOAA — CALIBRATION BASE LINE DATA
QUAD: N461031
NOS - NATIONAL GEODETIC SURVEY — BASE LINE DESIGNATION: DICKINSON
NORTH DAKOTA
ROCKVILLE MD 20852 - OCTOBER 29, 1986 — PROJECT ACCESSION NUMBER: G16542

STARK COUNTY

LIST OF ADJUSTED DISTANCES (AUGUST 28, 1986)

FROM STATION	ELEV.(M)	TO STATION	ELEV.(M)	ADJ. DIST.(M) HORIZONTAL	ADJ. DIST.(M) MARK - MARK	STD. ERROR(MM)
0	800.000	150	801.287	149.9814	149.9869	0.1
0	800.000	430	804.050	429.9529	429.9719	0.3
0	800.000	1400	815.646	1399.8818	1399.9692	0.5
150	801.287	430	804.050	279.9715	279.9851	0.3
150	801.287	1400	815.646	1249.9003	1249.9828	0.4
430	804.050	1400	815.646	969.9288	969.9981	0.3

DESCRIPTION OF DICKINSON BASE LINE
YEAR MEASURED: 1986
CHIEF OF PARTY: JNL

THIS BASE LINE IS LOCATED ABOUT 4.0 KM (2.5 MI) WNW OF BELFIELD, NORTH DAKOTA.

TO REACH THIS BASE LINE FROM THE JUNCTION OF INTERSTATE HIGWAY 94 AND STATE HIGHWAY 85, GO NORTH ON STATE HIGHWAY 85 FOR 0.9 KM (0.55 MI) TO THE JUNCTION OF HIGHWAY 85 AND A GRAVEL ROAD. TURN LEFT AND HEAD WEST FOR 3.2 KM (2.0 MI) TO THE JUNCTION OF A FIELD ROAD. TURN RIGHT ONTO THE FIELD ROAD AND RIGHT AT THE FENCE CORNER WHERE YOU WILL FIND A WIRE

GATE. PASS THRU THE GATE, THEN TURN LEFT AND GO WNW FOR 0.2 KM (0.1 MI) TO THE 0 METER POINT.

THE BASE LINE IS AN EAST-WEST LINE WITH THE 0 METER POINT ON THE EAST END. IT IS MADE UP OF MARKS AT THE 0, 150, 430, AND 1400 METER POINTS. ALL MARKS ARE IN LINE AND A 100 FOOT POINT WAS SET WEST OF THE 0 POINT.

THE 0 METER POINT IS A STANDRD NGS BASE LINE DISK STAMPED---0---SET INTO THE TOP OF AN IRREGULAR MASS OF CONCRETE FLUSH WITH THE GROUND. IT IS LOCATED 122.0 M (400.5 FT) WEST OF THE NORTH-SOUTH FENCE LINE, 36.0 M (118.0 FT) NORTH OF THE EAST-WEST FENCE LINE, AND 1.0 M (3.3 FT) NNW FROM THE WITNESS POST.

THE 150 METER POINT IS A STANDARD NGS BASE LINE DISK STAMPED---150---SET INTO THE TOP OF AN IRREGULAR MASS OF CONCRETE FLUSH WITH THE GROUND. IT IS LOCATED 0.95 M (2.9 FT) NNW OF THE WITNESS POST.

THE 430 METER POINT IS A STANDARD NGS BASE LINE DISK STAMPED---430---SET INTO THE TOP OF AN IRREGULAR MASS OF CONCRETE FLUSH WITH THE GROUND. IT IS LOCATED 0.88 M (2.7 FT) NNW OF THE WITNESS POST.

THE 1400 METER POINT IS A STANDARD NGS BASE LINE DISK STAMPED---1400---SET INTO THE TOP OF AN IRREGULAR MASS OF CONCRETE FLUSH WITH THE GROUND. IT IS LOCATED 0.76 M (2.5 FT) NNW OF THE WITNESS POST.

THIS BASE LINE WAS ESTABLISHED FOR AND IN CONJUNCTION WITH THE UNITED STATES FOREST SERVICE. FOR FURTHER INFORMATION CONTACT CURT GLASOE, C/O UNITED STATES FOREST SERVICE, RT. 6, BOX 131 B, DICKINSON, NORTH DAKOTA 58601. TELEPHONE (701) 225-5151.

US DEPARTMENT OF COMMERCE - NOAA CALIBRATION BASE LINE DATA
QUAD: N481033
NOS - NATIONAL GEODETIC SURVEY BASE LINE DESIGNATION: WILLISTON CBL
NORTH DAKOTA
ROCKVILLE MD 20852 PROJECT ACCESSION NUMBER: 16542

WILLIAMS COUNTY

NEAREST TOWN: WILLISTON

LIST OF ADJUSTED DISTANCES (NOVEMBER 14, 1989)

FROM STATION	ELEV.(M)	TO STATION	ELEV.(M)	ADJ. DIST.(M) HORIZONTAL	ADJ. DIST.(M) MARK - MARK	STD. ERROR(MM)
0	564.800	150	564.311	149.9746	149.9754	0.1
0	564.800	430	564.831	429.9483	429.9483	0.4
0	564.800	1400	565.483	1399.9933	1399.9935	0.5
150	564.311	430	564.831	279.9737	279.9741	0.4
150	564.311	1400	565.483	1250.0186	1250.0192	0.5
430	564.831	1400	565.483	970.0450	970.0452	0.4

A TAPE CALIBRATION MONUMENT WAS SET AT 100 FOOT POINT OF THE BASELINE. THE REDUCED MARK TO MARK DISTANCE IS 100.00 FT.

DESCRIPTION OF WILLISTON BASE LINE
YEAR MEASURED: 1989
CHIEF OF PARTY: LPB

THE BASELINE IS LOCATED JUST NORTH OF WILLISTON, ABOUT 1.6 KM (1.0 M) NORTHEAST OF SLOULIN FIELD AIRPORT IN WILLISTON.

THE BASELINE IS A NORTH-SOUTH LINE WITH THE 0-METER POINT ON THE SOUTH END. IT CONSISTS OF THE 0, 150, 430, AND 1400 METER POINTS WITH A 100-FOOT TAPE CALIBRATION STATION LOCATED NORTH OF AND ON LINE WITH THE 0-METER POINT.

TO REACH THE 0-METER POINT FROM THE INTERSECTION OF 2ND AVENUE WEST AND 26 STREET WEST AND THE DAKOTA PARKWAY (U.S. HIGHWAYS 85 AND 2 BYPASS) ON THE NORTH SIDE OF WILLISTON, GO NORTH FOR 1.6 KM (1.0 MI) ON 2ND AVENUE WEST TO THE INTERSECTION OF 42ND STREET WEST. TURN RIGHT ONTO 42ND STREET WEST AND GO EAST FOR 1.46 KM (0.9 MI) TO A SWEEPING RIGHT CURVE. INSTEAD OF CURVING, CONTINUE STRAIGHT ONTO A SMALL GRAVEL ROAD AND GO EAST FOR 0.12 KM (0.07 MI) TO AN INTERSECTION WITH A SMALL GRAVEL ROAD AND THE 0-METER POINT ON THE LEFT. TO REACH THE OTHER MONUMENTS, TURN LEFT ONTO THE GRAVEL ROAD AND GO NORTH FOR 0.15 KM (0.09 MI), 0.43 KM (0.27 MI), OR 1.4 KM (0.87 MI) RESPECTIVELY.

THE 0-METER POINT IS A STANDARD NGS CALIBRATION BASELINE DISK STAMPED "0 M 1989" SET IN THE TOP OF A 15 CM (5 IN) CONCRETE POST FLUSH WITH A SURROUNDING MOUND OF DIRT 1.5 M (4.9 FT) HIGHER THAN THE GENERAL LAY OF THE LAND. IT IS 15.0 M (49.2 FT) NORTH OF THE CENTERLINE OF A GRAVEL ROAD, 12.6 M (41.3 FT) WEST OF THE CENTERLINE OF A GRAVEL ROAD, 7.3 M (23.9 FT) WEST OF A FENCE CORNER POST, AND 1.5 M (4.9 FT) EAST OF A FIBERGLASS WITNESS POST.

THE 150-METER POINT IS A STANDARD NGS CALIBRATION BASELINE DISK STAMPED "150 M 1989" SET IN THE TOP OF A 15 CM (5 IN) CONCRETE POST FLUSH WITH A SURROUNDING MOUND OF DIRT 0.3 M (1.0 FT) HIGHER THAN THE GENERAL LAY OF THE LAND. IT IS 11.9 M (39.0 FT) WEST OF THE CENTERLINE OF A GRAVEL ROAD, 7.8 M (25.6 FT) WEST OF A THREE-STRAND FENCE, AND 1.5 M (4.9 FT) EAST OF A FIBERGLASS WITNESS POST.

THE 430-METER POINT IS A STANDARD NGS CALIBRATION BASELINE DISK STAMPED "430 M 1989" SET IN THE TOP OF A 15 CM (5 IN) CONCRETE POST FLUSH WITH A SURROUNDING MOUND OF DIRT 0.3 M (1.0 FT) HIGHER THAN THE GENERAL LAY OF THE LAND. IT IS 12.4 M (40.7 FT) WEST OF THE

CENTERLINE OF A GRAVEL ROAD, 8.1 M (26.6 FT) WEST OF A THREE-STRAND FENCE, AND 1.5 M (4.9 FT) EAST OF A FIBERGLASS WITNESS POST.

THE 1400-METER POINT IS A STANDARD NGS CALIBRATION BASELINE DISK STAMPED "1400 M 1989" SET IN THE TOP OF A 15 CM (5 IN) CONCRETE POST FLUSH WITH A SURROUNDING MOUND OF DIRT 1.5 M (4.9 FT) HIGHER THAN THE GENERAL LAY OF THE LAND. IT IS 13.7 M (44.9 FT) WEST OF THE CENTERLINE OF A GRAVEL ROAD, 9.5 M (31.2 FT) WEST OF A THREE-STRAND FENCE, AND 1.5 M (4.9 FT) EAST OF A FIBERGLASS WITNESS POST.

THE 100-FOOT TAPE CALIBRATION STATION IS A STANDARD NGS CALIBRATION BASELINE TAPING DISK STAMPED"1OO FT 1989" SET IN THE TOP OF A 15 CM (5 IN) CONCRETE POST FLUSH WITH A SURROUNDING MOUND OF DIRT 0.3 M (1.0 FT) HIGHER THAN THE GENERAL LAY OF THE LAND. IT IS 30.48 M (100.0 FT) NORTH OF THE 0-METER AND 1.5 M (4.9 FT) EAST OF A FIBERGLASS WITNESS POST. THE 100-FOOT PUNCH MARK IS LOCATED IN THE "T" OF THE WORD "CALIBRATION" ALONG THE NORTH EDGE OF THE DISK.

USER NOTES: CBL USERS SHOULD TAKE CARE IN PLUMBING OVER ALL POINTS. ELEVATIONS ARE FOR CBL USE ONLY.

THIS CALIBRATION BASELINE WAS ESTABLISHED IN CONJUNCTION WITH THE BUREAU OF LAND MANAGEMENT AND MONUMENTED BY THE MISSOURI BREAKS CHAPTER OF THE NORTH DAKOTA SOCIETY OF PROFESSIONAL LAND SURVEYORS. FOR MORE INFORMATION CONTACT LEO HORGAN AT ROUTE 2, BOX 93, WILLISTON, ND 58801, 701-572-7326; OR ALVIN LAMBERT AT ROUTE 3, BOX 24, WILLISTON, ND 58801, 701-572-6352; OR TREVOR OAKLAND AT ROUTE 3, BOX 79, WILLISTON, ND 58801, (701) 572-9144.