A. Purpose

This chapter provides general guidance on the use of total stations on topographic surveys. This chapter includes information on reflector less/robotic systems and prism-only systems. Use and operation of internal and external data collectors with a total station are covered. Additional examples of total station applications on Corps military and civil projects are provided in appendices to this manual.

Wild TC-1010 Total Station with TDS-HP48GX Data Collector
1998 Levee Survey at Bayou Segnette (New Orleans District)

B. Total Stations

Total stations combine electronic theodolites and EDM into a single unit. They digitally observe and record horizontal directions, vertical directions, and slope distances. These digital data observations can be adjusted and transformed to local X-Y-Z coordinates using an internal or external microprocessor. Various atmospheric corrections, grid and geodetic corrections, and elevation factors can also be input and applied. The total station may internally perform and save the observations or (more commonly) these data may be downloaded to an external data collector. With the addition of a data collector, the total station interfaces directly with onboard microprocessors, external PCs, and software. Electronic theodolites operate in a manner similar to optical theodolites. Angles can be electronically encoded to one arc-second with a precision down to 0.5 arc-second. Digital readouts eliminate the uncertainty associated with reading and interpolating scale and micrometer data. The electronic angle-measurement system minimizes some of the horizontal and vertical angle errors that normally occur in conventional theodolites. Angular measurements are based on the reading of an integrated signal over the surface of an electronic encoder that produces a mean angular value and completely eliminates the inaccuracies from eccentricity and circle graduation. These instruments also are equipped with a dual-axis compensator, which automatically corrects both horizontal and vertical angles for any deviation in the plumb line.

Leica TCR-705 Reflectorless Total Station (Geodetic Services, Inc.)

Trimble TSC and HP48 Data Collectors

The development of the total station has made it possible to accurately gather enormous amounts of survey measurements quickly. In the last 20 years, total stations and data collectors have become common field equipment, and have largely replaced the traditional survey methods that utilized transits, theodolites, and alidades. Digital theodolites and EDM instruments were perfected during the 1970s. In the early 1980's the surveying instrument manufacturers introduced what has become the total station, redefining the term by creating an entirely electronic instrument that combined the heretofore separate digital theodolites and EDM devices. Directly storing direction and distance observations to a microprocessor helped eliminate many of the reading errors that can occur with an optical theodolite or traditional EDM where observations are hand recorded. Along with the advent of the electronic theodolite came the electronic data collector, thus minimizing both the reading errors and the writing errors. Modern total stations can measure a distance to an accuracy of better than 5 millimeters plus 1 part per million, with some variation depending on the type of reflecting surface or prism used. Electronic angles can be resolved to about one-half arc second, although models used for construction may have a resolution of only 30 seconds. In most land surveying situations, the normal crew size can be reduced to two persons when equipped with a standard total station, and one person when using robotic total stations.

Traditionally, surveying has used analog methods of recording data. Digital data collection methods using electronic total stations are far more efficient. Total stations have dramatically increased the amount of topographic data that can be collected during a day and are well suited for topographic surveys in urban landscapes and busy construction sites. Modern total stations are also programmed for construction stakeout and highway centerline surveys. When proper procedures are performed, total stations have made trigonometric leveling nearly as accurate as many of the differential level techniques in areas possessing large relief landforms. Total station instruments and associated data collectors can quickly transfer 3D coordinates and are capable of storing unique mapping feature codes and other parameters which in the past could only be recorded on paper media such as field books.

C. Total Station Features and Operation

There are less than a dozen manufacturers of total stations that commonly market in the US. Each manufacturer may have varied models, with optional features that can be tailored to local operating conditions, such as accuracy requirements, project size (EDM distances), and available crew size.

a. General operation. Total station surveys are performed similarly to transit-stadia or plane-table-alidade surveys. Total stations are set up over control points similarly to traditional transits, theodolites, or EDM. Most employ a three-screw, forced-centering Wild-type tribrach mount to fasten and align the total station with the tripod. Heavy wooden or fiberglass tripods are best for supporting total stations. Leveling over a point is performed no differently than traditional instrument methods. The tribrach is roughly centered over the point first using the standard tripod leg adjustment technique. The total station is then mounted in the three-pin tribrach and internally leveled using either level vials or electronic dual-axis methods, depending on the type of instrument. Either optical or laser plummets are used for final centering over a point. Some total stations provide out of level warnings to the operator. All plummets, optical or digital, should periodically be checked, adjusted, and calibrated. A conventional plumb bob provides such a check if used in ideal conditions.

b. Prism poles. A variety of target poles are used for the remote rod to which topographic observations are made. Both adjustable and fixed height poles are common. A standard rod level is used to plumb the prism pole over a point. Many poles have built-in rod levels to facilitate plumbing the prism.

Prism pole (Portland District)

c. EDM range and accuracy. Ranges with standard prisms and reflectorless models vary widely between manufacturers. Both infrared and laser EDMs are used. Distance resolution is either pulsed (low accuracy) or phase comparison (typical ± 2 to ± 5 mm accuracy). One and three array prism ranges can vary from one mile to over 5 miles. Ranges of reflectorless total stations are specified relative to 90% and 18% Kodak grey cards, and can vary from 300 ft to over 3,000 ft.

Reflector less accuracies are not as good as prism accuracies given the variability of the reflecting terrain, and may therefore may not be suitable for more accurate surveys.

d. Instrument controls. Focus and plate control tangent and locking screws vary widely between total station brands. A 30X optical zoom is common on most total stations. These controls should be operated in accordance with the manufacturer's instructions.

e. Cost. Total station costs obviously will vary with the accuracy and added features. A simple digital theodolite (no data collection) will cost less than $1,500. A basic total station survey package (including tripod and prism pole) will cost about $7,500 and reflectorless or robotic units can cost upwards of $20,000. A data collector and software must be purchased separately--a $1,500 to $4,000 additional cost. A field laptop computer will run $2,000 to $3,000. Miscellaneous survey equipment can easily exceed another $3,000--e.g., extra tripods, total station batteries, 25-ft telescoping rod, additional prisms, magnetic locater, etc.

f. Angular accuracy. Angle standard errors range from ± 1" to ± 5" based on a Direct and Reverse set. Less accurate models are available for construction layout application--e.g., 1-minute instruments.

g. Other features. Other factors to be considered in the selection of a particular total station include: robotic search controls, measurement time, integrated laser scanners, integrated GPS, internal digital camera, internal data storage capacity, compatibility with existing data collector (if not purchased with the total station), weight (including batteries and battery life), ease of operation, and training needs.

D. General Total Station Operating Procedures

- A set routine should be established for a survey crew to follow. Standard operating procedures should require that control points be measured and noted immediately on the data collector and/or in the field book after the instrument has been set up and leveled.
- This ensures that the observations to controlling points are established before any outside influences have had an opportunity to degrade the setup. In making observations for an extended period of time at a particular instrument location, re-observe the control points from time to time.
- This ensures that any data observed between the control shots are good, or that a problem has developed and appropriate action can be taken to remedy the situation.

- As a minimum, require survey crews to observe both vertical and horizontal control points at the beginning of each instrument setup and again before the instrument is picked up.
- One of the major advantages of using a total station equipped with data collection is that some errors previously attributed to blunders (e.g., transposition errors) can be minimized or eliminated. Even if the wrong reading is set on the horizontal circle in the field or the wrong elevation is used for the bench, the data itself may be precise.
- To make the data accurate, many software packages will allow the data to be rotated and/or adjusted as it is processed. The only way to assure that these corrections and/or observations have been accurately processed is to compare the data to control points.
- Without these observations in the recorded data, the orientation of that data will always be in question.
- The use of a total station with a data collector can be looked upon as two separate and distinct operations.

The following procedure is typical of most total stations and data collectors:

a. Total Station

- If EDM is modular, mount it on instrument.
- Connect data collector.
- Set up and level instrument.
- Turn on total station.
- Set atmospheric correction (ppm). This should be done in the morning and at noon.
- Set horizontal circle.
- Set coordinates.
- Observe backlights (check whether azimuth to backlights is 180 degrees from previous reading).
- Observe backlights benchmark (obtain difference in elevation). This may require factoring in the height of reflector above benchmark.
- Compute relative instrument height (benchmark elevation +/- difference in height). Note height of rod (HR) and note computations in field book.
- Input Z (elevation) value in instrument or data collector.
- Observe backsight benchmark (check elevation).
- Invert and repeat (check elevation).

b. Data Collector

- Record date and job number.
- Record crew number and instrument serial number.
- Record field book number and page number.
- Record instrument location (coordinates).
- Record backsight azimuth.
- Record standard rod height.
- Record height of instrument.

[Note: All the above information may also be recorded in a field book if necessary]

- Observe and record measurement to backsight benchmark.
- Enter alpha or numeric descriptor of above point into data collector.
- Observe and record measurement backsight benchmark or check benchmark (if setting benchmark, note in field book and repeat with instrument inverted).
- Enter alpha or numeric descriptor of above point into data collector.
- Observe and record measurement to backsight.
- Enter alpha or numeric descriptor of above point into data collector.
- Invert and repeat the above two steps.
- Observe and record measurement to foresight.
- Enter alpha or numeric descriptor of above point into data collector.
- Invert and repeat the above two steps.
- Observe and record measurement to side shot.
- Enter alpha or numeric descriptor of above point into data collector (repeat the above two steps as needed).
- When setup is complete, or at any appropriate time, repeat shots on vertical and horizontal control. Observe the displays and record in data collector.

***c. Precautionary guidance and recommendations on total stations*.**

The following guidance from the CALTRANS *Surveys Manual*

(CALTRANS Surveys Manual 2001-2004) is applicable to total station operation.

- Never point the telescope directly at the sun as the sun’s rays may damage the diodes in an electronic distance measuring instrument (EDMI).
- If possible, shade the instrument from direct sunlight as excess heat may reduce the range of the sender diodes in the EDMI.
- To maintain maximum signal return at longer ranges, shade prisms from direct sunlight.
- Avoid multiple unrelated prisms in the same field of view; this can cause blunders in distance observations.
- Do not transmit with a two-way radio near the total station during EDMI measurements.
- Most total stations are equipped to detect and correct various instrumental errors. If such errors exceed program limits, error codes will indicate the error. Consult the operator’s manual for exact procedures and error codes.
- Do not carry tripod-mounted instruments over the shoulder.
- Whenever possible, select instrument setup locations to minimize the exposure of the instrument operator, other members of the crew, and the instrument to danger. Select stable ground or footing for the tripod feet. Do not set an instrument directly in front of or behind a vehicle or piece of construction equipment that may suddenly move.
- Don't leave instruments unprotected or unattended.
- In the event that the instrument or any personnel are required to be in an area subject to traffic, protection procedures must be followed.

Total Station Job Planning

An often-asked question when using a total station with a data collector is “How do I plan a project?” To answer this question, first examine the productivity standards expected of field crews.

a. Most crews will make and record hundreds of observations per day. This includes any notes that must be put into the system to define what was measured. When creating productivity standards keep in mind that a learning curve is involved. Usually it takes a crew some four to five projects to become familiar with the equipment and the coding system to start reaching the potential productivity of the system.

b. A two-person crew is most efficient when the nominal spacing of the measurements is less than 50 feet. When working within this distance the average rod person can acquire the next target during the time it takes the instrument operator to complete the measurement and input the codes to the data collector. The instrument operator usually spends 20 seconds (±) sighting a target, recording a measurement, and another 5-10 (or more) seconds coding the measurement.

c. When the general spacing of the data exceeds 50 feet, having a second rod person will significantly increase productivity. A second rod person allows the crew to have a target available for measurement while the first rod person is moving. If the distance of the move is 50 feet or greater, the instrument will be idle with only one rod person.

d. When dealing with strip topographic situations, it may be necessary to acquire data every 3 feet along the length of the job. In urban areas the data may seem to be denser, but the rights-of-way are generally wider. Some feel that one measurement for every 3 feet of linear topography works very well for estimating purposes. Using this estimate, an average field crew can make and record between 350-500 measurements or 1,000-1,500 feet of strip topography per day. A two-person crew equipped with recording total station and data collector can pick up 1,250 feet a day. Depending on the office/field reduction software being used, these data can produce both the planimetric and contour maps as well as transfer the data to an engineering design package with very little additional manipulation.

Reference:
Chapter 8: Total Station Topographic Survey Procedures

http://140.194.76.129/publications/eng-manuals/em1110-1-1005/toc.htm
http://140.194.76.129/publications/eng-manuals/em1110-1-1005/c-8.pdf