

Total Station Manual  
For Use With The Leica TC407 Total Station  
CEE121 Introduction to Civil and Environmental  
Engineering Measurements

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## LIST OF SYMBOLS

T.S.	=	Total Station
PtID	=	Point ID
IR	=	Infrared laser
RL	=	Red Laser
Hz	=	Horizontal angle
$\Delta$ Lin	=	Distance down a baseline
$\Delta$ Off	=	Distance off of a baseline
East	=	Easting
North	=	Northing
Height	=	Elevation
E0	=	Station Easting
N0	=	Station Northing
H0	=	Station Elevation
hi	=	Height of instrument as measured from the ground surface to the “tilting” or “Trunion” axis.
hr	=	Reflector height
EDM	=	Electronic Distance Measurement

## **1.0 INTRODUCTION**

This document is meant to serve as a guide and reference for the use of the Leica TC407 Total Station in the CEE 121 Civil and Environmental Engineering Measurements class at the University of Massachusetts Amherst. The general use and operation of the TC407 is discussed as well as the specific operations: 1) a topographic survey, 2) a survey to calculate area, and 3) an “as-built” survey.

## **2.0 EQUIPMENT AND ORGANIZATION**

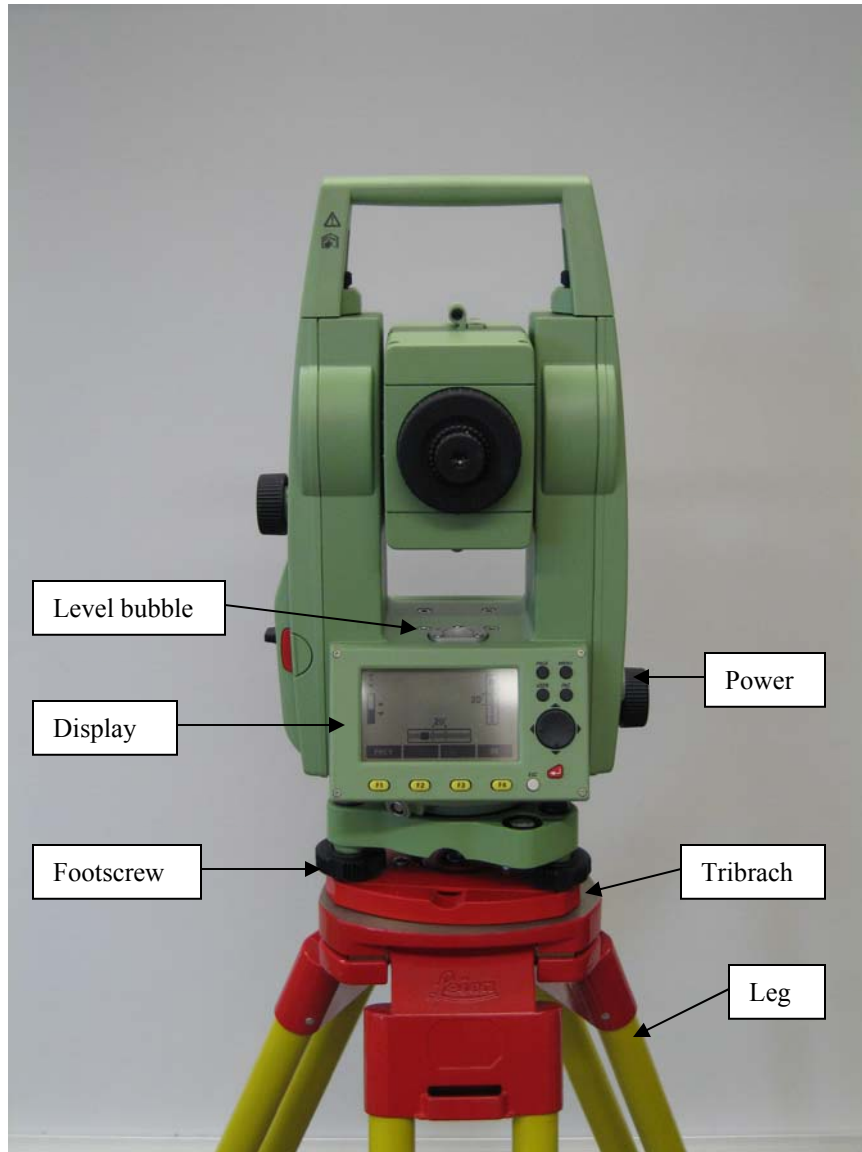
It is important to have a plan for every survey. The goals, methods, and general approach should be discussed before the survey begins. A list of equipment should be compiled, the batteries should be charged, and each member of the survey crew should have an understanding of what is happening and what their specific responsibilities will be during the survey. The method of note taking should also be discussed beforehand, and the note taker and surveyor (if different) should maintain frequent communication and discussion throughout the survey. It may be preferable, for educational reasons, to alternate responsibilities over the course of the survey so that each member of the crew learns the various crew duties.

## **3.0 GETTING STARTED**

Once you are at the location of the survey with all your equipment, it is a good idea to “walk over” the survey site and consider suitable instrument stations. Keep in mind that you will need a clear line of sight from the total station to the prism target that is mounted on top of the prism pole, for each point that will be surveyed. This is a good time to make last minute adjustments to the survey plan, to make a sketch of the site to be surveyed in the field book and to make sure that everybody understands what is going on. After you have agreed upon a plan for the survey, you are ready to set up the instrument over the first station and begin the survey.

### 3.1 PROCEDURE FOR SETTING UP AND LEVELING

- Place the tripod over the station point with the legs evenly spaced and the plate reasonably level and at an appropriate height.
  - *If the first station is a predetermined point*, care must be given to ensure that the instrument is centered above the station point (If the station is not a predetermined point, the benchmark can be located with the laser plummet after the instrument is set up).
  - *If the station is on uneven ground*, two of the legs should be set on ground of about the same elevation and the plate leveled by adjusting the third leg.
  - *If the ground is reasonably level*, consideration should be given to the direction(s) of sights, and the space between two legs arranged to accommodate the surveyor if possible.
- After the tripod is adequately placed, mount the instrument to the tripod plate. Keep a firm grip on the top handle of the instrument while you fasten it to the tripod with the mounting screw in the center of the plate. Be sure that the mounting screw is tight.
- *If you are setting up over a predetermined point*, you should now turn the instrument on by the red power button located on the right side of the instrument and then press [FNC] → [F1] to activate the laser plummet. You may need to adjust the position of the tripod legs while keeping the plate reasonably level at this point.
- Each tripod leg should next be gently, but firmly, set into the ground by pushing on the foot pedestal. Pressure should be applied in the direction of the leg, not directly down. Further adjustment of the leg heights may be necessary after setting the legs. Be sure that all the leg adjustment clamps are tight.
- Now you are ready to level the instrument using the circular bubble. First, use the leg adjustments if necessary to get the instrument near level. Next, use the footscrews on the tribrach (the adjustable base that the instrument is mounted to) to center the bubble in the black circle. The display screen should be parallel to the two footscrews being manipulated, and the two footscrews should be twisted *simultaneously in opposite directions* (this can be thought of as the “side to side” adjustment). After the bubble is centered from “side to side”, the instrument can be leveled from “front to back” by adjusting the back screw independently either up or down as necessary.
- Once the bubble is within the black circle, fine tune the level by the digitally displayed bubbles using the same techniques as for the circular bubble. Note that if the Level/Plummet screen is not displayed, it can be reached at any time by pressing the [FNC] key then the [F1] key.
- *If you are setting up over a predetermined point*, the instrument position can be adjusted a couple of inches by loosening the mounting screw and sliding the instrument on the tripod plate. The instrument should be re-leveled by the digitally displayed bubbles after any adjustment. *Note that the Laser Plummet is only activated when you are on the Level/Plummet dialog screen.*



**Figure 1. Leveling Diagram**

#### **4.0 INTERFACING WITH THE TC407**

Navigating your way around the TC407 display (see Figure 2) may be a little different than what you are used to. There are a few things that you should keep in mind:

- First of all, you can always press the [ESC] key to go back a screen. If you press [ESC] repeatedly you will scroll back through the active screens you have progressed. [ESC] will also get you out of an edit mode and restore the previous value.
- At the top of any display will be the title of the display and the page number of the total pages, such as:

MENU 1/3

This means that you are at the Menu dialog on page 1 of 3. You can scroll through the pages by pressing the **[PAGE]** key.

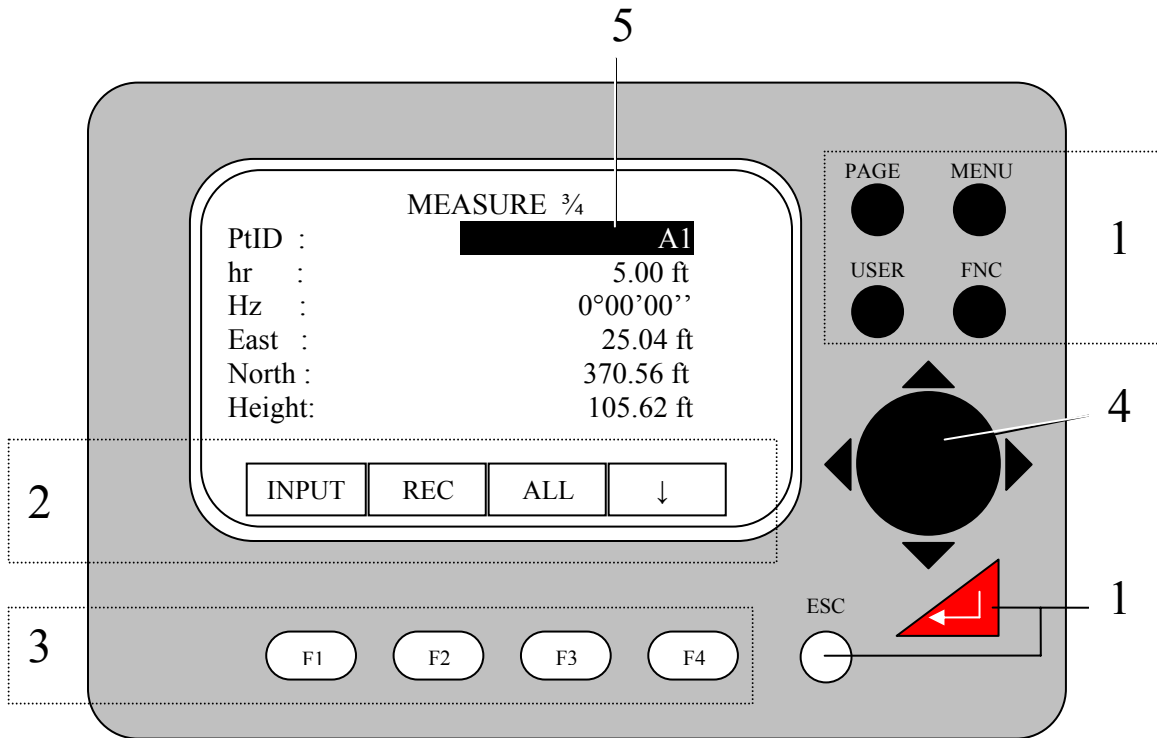
- The **[FNC]** key gets you to the Functions dialog where you can level the instrument, turn the display light on and off and change your units, etc. To exit FUNCTIONS press **[ESC]** and you will return to where you left off in the Measure dialog.
- The **[MENU]** key gets you to the Menu dialog where you can do things like start a new program, transfer data and initialize the memory. To exit MENU and return to where you left off in the Measure dialog, press **[ESC]** .
- The Measure dialog automatically creates a new point display after you press the **[REC]** or **[ALL]** softkeys (record the point measurements to memory). The new point ID (PtID) is the old point plus 1, so after recording a PtID “DEFAULT”, the automatic new PtID would be “DEFAULT1”, or after recording PtID “12”, the automatic new PtID would be “13”.

#### 4.1 THE KEYS OF THE TC407

There are three types of keys on the TC407, “fixed keys”, “function keys” and “softkeys” (see Figure 1). The softkeys change from screen to screen. They are total station functions that can be called upon by the function keys located below the display screen (**F1**, **F2**, **F3** and **F4**). The softkeys are usually displayed as a “softkey bar” at the bottom of the screen directly above their corresponding function keys (Figure 1); However, you should note that the softkeys are sometimes displayed as a list of functions following their corresponding function key, for example, on the MENU 1/3 display:

F1 Programs
F2 Settings
F3 EDM Settings
F4 File management

# Keypad



1) Fixed keys

2) Softkey bar

3) Function keys

4) Navigation pad

5) Focus bar

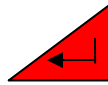
**Figure 2.** TC407 Display Screen

## 4.2 LIST OF FIXED KEYS

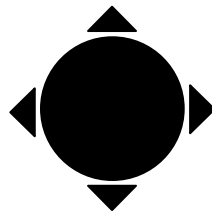
The Fixed keys (Figure 1) are the keys located to the right of the screen. They are:

- [PAGE]** Scrolls to next page when a dialog consists of several pages.
- [MENU]** Accesses programs, settings, the data manager, adjustments, communication parameters, system information and data transfer.
- [USER]** Is a user defined key, programmable from the Function menu.
- [FNC]** Quick access to measurement supporting functions.
- [ESC]** Quit a dialog or quit the edit mode.

The red arrow key is the ENTER key. It is to confirm an input and continue to the next field. It also enters input/edit mode for the data field where the focus bar is located.



There is also a navigation pad:



The navigation pad moves the “focus bar” (the highlighted field) in a way similar to how a TV remote works. It can also be used to control the cursor when you are in input or edit modes; where ▼ deletes, ▲ adds a space, ◀ and ▶ move the cursor.

Located on the right side of the instrument are the power button and measurement trigger. The measurement trigger can be a little tricky, especially if you hit it by mistake and end up with an extra measurement. It has three settings (ALL, DIST, OFF) that are programmable in the settings menu. I recommend leaving the trigger key off.

### 4.3 LIST OF GENERAL SOFTKEYS

<b>[ALL]</b>	Initiates distance and angle measurements and saves all measured values.
<b>[DIST]</b>	Initiates distance and angle measurements without saving the measured values.
<b>[REC]</b>	Saves displayed values without initiating a distance measurement.
<b>[INPUT]</b>	Deletes current value in the display and enables the manual input of a new value.
<b>[ENH]</b>	Opens the coordinate input mode.
<b>[LIST]</b>	Displays the list of available points.
<b>[FIND]</b>	Starts a search for the point entered.
<b>[EDM]</b>	Displays EDM settings.
<b>[IR/RL]</b>	Toggles between infrared and reflectorless measurement modes.
<b>[PREV]</b>	Back to last active dialog.
<b>[NEXT]</b>	Continue to next dialog
<b>[STATION]</b>	Displays station data for input/edit.
<b>[SetHz]</b>	Displays the horizontal (Hz) angle for input/edit.
<b>[Hz=0]</b>	Sets the current instrument bearing as 0.
<b>[SecBeep]</b>	Displays the sector beep settings for edit (on or off).
<b>[   ←]</b>	Returns to highest softkey level.
<b>[↓]</b>	To next softkey level.
<b>[OK]</b>	Sets displayed message or dialog and quits dialog.

## 4.4 INPUT AND EDIT MODES

To manually input a value or alphanumeric label, first be sure that the “focus bar” is located on the appropriate data field (remember that the focus bar can be manipulated by the navigation pad). Then, press either the **ENTER** fixed key or the **[INPUT]** softkey to activate the cursor. When the cursor is activated a new set of softkeys will become available at the bottom of the screen. These are the alphanumeric/numeric input characters. They are arranged in groups of four characters per softkey which you can scroll through by pressing **[F4]** (the **[>>>]** softkey). Once a four character softkey is selected (one character of which is the desired character), another set of softkeys will appear at the bottom of the screen. This is the four character group you just selected, from which you can select the desired character. It’s a little complicated at first, but you’ll get the hang of it. Remember: **[ESC]** exits input/edit mode and replaces the previous value, and the **ENTER** key enters or exits input/edit mode.

## 5.0 AS-BUILT SURVEY

An “as-built” survey is where existing structures and features are surveyed relative to a baseline to create a site plan or an “as built” plan. The TC407 has a convenient program for such an application, called the *Construction* program. This allows you to set up on a station, remotely define a baseline with the total station, and take all your measurements from that single point. The total station then gives you the coordinates of the measured points relative to the established baseline. Instead of Northing and Easting, the coordinates are given as  $\Delta Lin$  and  $\Delta Off$  for the distance down the baseline and the perpendicular distance off of the baseline. Negative values of  $\Delta Off$  denote a position to the side of the baseline that the instrument is set up on, and positive values denote a position to the opposite side of the baseline.

- Start from the MENU Display.
  - From MENU select **[F1]** for Programs.
  - Scroll to page 2 of 2.
  - Select **[F4]** for Construction.
  - If you need to set a new job, press **[F4]** to select from a list of jobs or to enter in a new job.
    - Press **[F1]** (the **[NEW]** softkey)
    - Now fill in the Job name, operator initials, and remarks (if necessary) data fields. When finished, press **[F4]** (the **[OK]** softkey) and you should return to the *CONSTRUCTION: Start* screen.
  - Select **[F3]** to establish a new construction line.
- You will be prompted to “measure line-start point”. Sight the line-start point and press **[F3]** (the **[ALL]** softkey) to record the point.
- You will be prompted to “measure the line-end point”. Sight the line end point and press **[F3]** (the **[ALL]** softkey) to record the point.

- There are two kinds of Construction program surveys on the TC407: the *LAY-OUT* mode and the *As-BUILT* mode. *LAY-OUT* is the default mode, so you will need to select **[F2]** (the **[As-BUILT]** softkey) in order to switch from the *LAY-OUT* to the *As-BUILT* mode.
- Now you should be on the “As-BUILT CHECK” display, and you can start taking measurements. Sight the required point and press **[F3]** (the **[ALL]** softkey) to record the point. Remember that the PtID data field will have a default alphanumeric label of the last PtID + 1. I recommend changing this to a sensible starting PtID that will make sense for your survey. You can use the default PtID characteristic (last PtID + 1) to save you time if you shoot and label points consecutively. For example, start with point A1, and then shoot point A2.
- Repeat the last step until all the points are recorded. Note that if you need to move the T.S. to another station, just re-establish the same baseline and your coordinates will match the coordinates from the previous station. Keep in mind, however, that if you set up on the other side of the baseline the  $\Delta$ Off signage will be reversed.

I recommend recording measurements in your field notebook as you take them, that is, for each ptID number write in your field notebook what that point is, e.g., edge of curb, center of manhole, etc. However, when you are finished recording all the points you can go back and review the recorded measurements from the MENU dialog.

- From MENU 1/3 select **[F4]** for “File management”.
- Select **[F3]** for “Measurements”.
- The focus bar will be on the Job data field. Scroll to the Job you want with the navigation pad (**◀**, **▶**).
- Select **[F4]** to “Show all measurements”. (You can also select **[F3]** to search for a specific point).

Scroll through the points with the navigation pad (**◀**, **▶**). Remember to use the **[PAGE]** key to view all the pages available for each point. Note that this dialog uses a **▼** symbol in the upper right corner of the screen to denote that there are numerous pages.

## 6.0 TOPOGRAPHIC SURVEY FROM A KNOWN POINT

The total station can give directly reduced coordinates of surveyed points (Easting, Northing and elevation) if you input the station coordinates (E0, N0, H0), height of instrument (hi), and initial orientation of the instrument (hz) before you begin. You will also need to input the reflector height (hr) of measured points. Note that the TS refers to the prism target as the “reflector”.

- First of all, I am going to make the assumption that you have already staked out a grid of survey points relative to a base line (although it is not necessarily required to have points to be surveyed on an established grid). If all the points of the grid are visible from one corner of the grid (and the maximum distance between any two points is less than the  $\pm 1800$  meter range of the EDM), you can shoot all the points from that corner; however, you may need to have multiple stations.

- Now you are set up on a corner of the grid (preferably the (0+00, 0+00) corner) with an established elevation (a temporary benchmark) and the instrument is leveled. You need to select the program and set the job.
  - Go to the menu dialog by pressing [MENU] or [ESC].
  - Select [F1] for “Programs”
  - Select [F1] for “Surveying”
  - Select [F1] for “Set Job”
  - Press [F1] (the [NEW] softkey)
  - Fill in the Job name, operator initials, and remarks (if necessary) data fields. When finished press [F4] (the [OK] softkey) and you should return to the SURVEYING screen.
- Next you will need to “Set station”.
  - Select [F2] for “Set Station”.
  - You should be prompted to enter the station number. Do so, and after you have identified the station press [F4] (the [ENH] softkey) in order to enter the station coordinates.
  - You should be prompted to enter the point coordinates. Let’s assume this corner is 0.00, 0.00 for Easting and Northing, and you will need to enter the elevation of the station (what the T.S. calls “Height”).
  - Then press [F4] (the [OK] softkey).
  - You should be prompted to enter instrument height (hi). This is measured manually from the ground to the indent on the side of the instrument that represents the “Tilting axis” which is the horizontal rotation axis of the telescope (also called the Trunion axis). After you enter the instrument height press [F4] (the [OK] softkey) and your station will be set.
- Next you will need to “Set orientation”.
  - Select [F3] for “Set orientation”
  - Select [F1] for “Manual angle setting”
  - Align the instrument with the “Y-axis” of the grid by sighting to the appropriate other corner. Note that you are operating within an established grid and that for this operation the northing and easting coordinates are relative only to that grid, not to any other established coordinates.
  - Once the instrument is aligned, press [F1] (the [Hz=0] softkey) to set that bearing as 0°00’00”.
  - Then press [F3] (the [REC] softkey) to set the orientation.
- Now that you have the Job, Station, and Orientation set, you can start the survey.
  - Select [F4] for “Start”.
  - This brings you to SURVEY 1/3. Remember this means the Survey dialog on page 1 of 3. Remember also that the PtID data field will have a default alphanumeric label of the last PtID + 1. I recommend changing this to a sensible starting PtID that will make sense with your grid layout. Also, you can use the default PtID characteristic (last PtID + 1) to save time if you shoot and label points consecutively. For example, start with point A1, and then shoot point A2.

- You will also need to input the reflector height (hr). I recommend setting the prism pole to an even increment like 5.00 ft. and leaving it there throughout the survey if possible. *Note that the T.S. will keep the previous reflector height (hr) value for consecutive points unless you change it manually.*
- Once you have input the PtID and hr, you can measure the distance, horizontal direction (Hz) and record the point to memory.
  - Sight the prism.
  - Press the **[F3]** (the **[ALL]** softkey) to measure the distance and horizontal direction and to record the point to memory.
  - Now scroll to page 3/3 by pressing the **[PAGE]** key. The East, North and Height coordinates should be displayed. *A common source of confusion is that the previously recorded distance measurement information (including Easting, Northing and elevation) is displayed until a new point is recorded by pressing the **[ALL]** or **[REC]** softkeys, even though the PtID data field is displaying the next PtID.*
- Record the rest of the grid points in the same manner. Remember that you can review the recorded points after the survey is complete from MENU → “File management”, as described above.

## 7.0 SURVEY TO OBTAIN AREA

The area of an irregular polygon (or any shape with at least three non-intersecting sides) can be calculated directly by the TC407 by surveying the corner points with the “Area (plan)” program. You will need to set up on a station from which you will be able to sight all the corner points from a single position. *The station is not a corner point of the polygon.* Also keep in mind that this is a “plan view” survey and you will be able to disregard changes in elevation (the T.S. takes care of that automatically); therefore, you need not enter starting elevation (height), height of instrument (hi), and reflector height (hr).

- Start from the MENU display.
  - From MENU select **[F1]** for Programs.
  - Scroll to page 2 of 2.
  - Select **[F2]** for “Area (plan)”.
  - If you need to set a new job, press **[F4]** to select from a list of jobs or to enter in a new job.
    - Press **[F1]** (the **[NEW]** softkey)
    - Now fill in the Job name, operator initials, and remarks (if necessary) data fields. When finished press **[F4]** (the **[OK]** softkey) and you should return to the *Area* screen.
- You will need to “set station”
  - Select **[F2]** for “Set Station”.

- You should be prompted to enter the station number. Do so, and after you have identified the station you can enter the station coordinates by pressing **[F4]** (the **[ENH]** softkey).
  - You have to press **[F4]** (the **[ENH]** softkey) in order to continue the dialog; however, you do not have to enter values into the data fields to obtain an area with this survey.
- You should be prompted to enter the point coordinates. Let's assume this point is 0.00, 0.00 for Easting and Northing, and you will *not* need to enter the elevation of the station (what the T.S. calls Height).
- Then press **[F4]** (the **[OK]** softkey).
- You should be prompted to enter instrument height (hi). The default value of 0.00 ft can be left as is by pressing **[F4]** (the **[OK]** softkey).
- Next you will need to “Set orientation” only if you will need to know the coordinates of the recorded points.
  - Select **[F3]** for “Set orientation”
  - Select **[F1]** for “Manual angle setting”
  - Align the instrument with the Y-axis of your grid or with North by sighting to the appropriate bearing.
  - Once the instrument is aligned, press **[F1]** (the **[Hz=0]** softkey) to set that bearing as 0°00'00”. (You can also sight to a known bearing and enter that value.)
  - Then press **[F3]** (the **[REC]** softkey) to set the orientation.
- Now that you have the Job, Station, and Orientation set, you can start the survey.
  - Select **[F4]** for “Start”.
  - You should be prompted to “Measure to target”. Sight the first corner and press **[F3]** (the **[ALL]** softkey) to record the point to memory.
  - The point will be recorded and the next PtID will be displayed. Repeat the last step until all the corner points are recorded.
- Once all of the corner points are recorded, you can press **[F2]** (the **[Result]** softkey) to display the result of the survey.
  - Remember that you can review the recorded points from MENU → “File management”, as described above. *The recorded point coordinates are only available when viewed this way.*

## CONCLUSION

I hope that this document proves to be a useful tool for your endeavors in surveying with a total station. There are, of course, many more things you can do with the TC407 total station such as: lay out points from a station, determination of a station's coordinates by sighting known coordinates, creation of a new reference line from an established baseline, remotely measuring points from an offset distance, and much more. The total station is certainly an important tool in surveying today and one that is well worth spending the time learning how to use.

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