NCPTT

Coordinate Measurement of Ships and Smallcraft | 1999-06

Mystic Seaport Museum, Inc.

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Coordinate Measurement of Ships and Smallcraft

A Cooperative Project Among Mystic Seaport Museum, HABS/HAER and South Street Seaport

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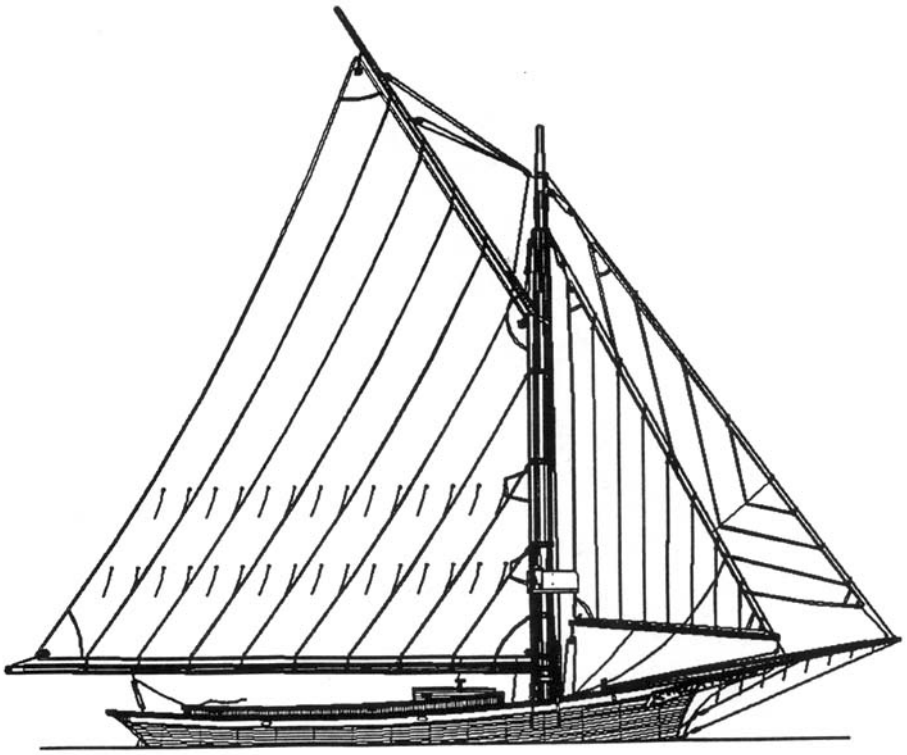

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PURPOSE OF THIS MANUAL

This manual is meant to help the operator through the measurement of watercraft using the Sokkia total station. The vessels to be measured can vary in size from small boats to full sized ships. The key to the total station is that it is collecting full three-dimensional coordinate data. The Sokkia total station is a surveyor's tool. Its native language is that of a land surveyor. In adapting it for use in the maritime field, it is only necessary to change the language used to understand the workings of the machine. A historic vessel can be described as an unusual piece of topography; the measurer is creating a topographic map of a peculiar area. The advantages of the Sokkia total station in the field are both its speed and accuracy in three-dimensional coordinate measurement. The total station also allows the operator a certain amount of freedom in the measurement process, not commonly found in traditional methods used to document boats.

This section of the manual is intended to take the operator through the actual physical use of the machine itself. Later chapters deal with the way in which a vessel can be measured with the total station to produce a set of lines for the boat. The Sokkia total station comes with a set of manuals that describe how the machine operates when used for surveying. As this is a foreign language to the maritime field, this manual will provide the translation needed for non-surveyors. This manual will not deal with surveying as done on land in this text, but will cover a few of the features that may be of interest outside the field of vessel documentation. Interest in the surveying field will have to be accommodated through the use of the Sokkia manuals themselves. This manual will present a systematic process that the operator can follow to successfully measure a historic boat using the Sokkia total station. It will always be beneficial for the new operator to get a day of training at Mystic Seaport Museum in the use of the machine, and then use this manual as a way of refreshing what was learned there. This may not always be possible, however, and thus the creation of this manual.

Description Of The Sokkia Total Station

The total station chosen for this project is a Sokkia PowerSet 3000. This total station is capable of simultaneously measuring both horizontal and vertical angles as well as measuring the distance to a reflective target. It can then reduce this information into plain coordinate points having an X, Y and Z value. All of these calculations are carried out onboard the total station itself. The total station package as delivered comes with:

1) Sokkia 630030 PowerSet 3000 Total Station -Serial #011275
2) 635009 SCR2 Card Reader
3) 35001 EDC21A Power Supply
4) 35012 SCR2 Cable
5) 35033 Computer Cable
6) 14503 COMMS PLUS Software
7) 5/8” x11” tripod, Wooden Extension leg 42”-72”
8) SECO 5101-s 8.5’ SUR_LOC Precise Prism Pole, .01’/10mm
9) OMNI 1600 25.4mm Prism JR. Complete assembly
10) 30-10nmix10mm stick-on reflective targets
11) Two Batteries for the PowerSet 3000
12) Battery Charger for above
13) Waterproof Carrying case for PowerSet 3000
14) Three Sokkia manuals: *Getting Started, Advanced Operations* and the *Software Reference Manual.*
15) Mystic Seaport’s *Coordinate Measurement of Ships and Smallcraft Manual.*

The total value of the package for insurance purposes is $13,532.25. This equipment must be covered by the borrowing institution for complete replacement cost due to damage or loss. Before the system can be sent, proof of insurance must be sent to:

Mark Starr
H. B. DuPont Preservation Shipyard
Mystic Seaport Museum, Inc.
75 Greenmanville Ave, P.O. Box 6000
Mystic, CT 06355-0990

Tel: (860) 572-0711, extension 5092
Fax: (860) 572-5344
E-mail: marks@mysticseaport.org

This package is a self-contained unit- nothing else is required to set it up and measure a vessel.

The Sokkia total station was chosen for this work for two specific reasons. While all total stations produce the same type of information and perform the same type of functions, the Sokkia total station was designed to layout large manmade objects, from milling machines to ships. To accommodate this type of work, the Sokkia total station can use, in addition to the standard surveyor's prism, reflective stick-on targets as small as 10mm square. In the measurement of objects other than landforms, these targets become indispensable. Unlike the large and cumbersome surveyor's targets, the 10mm targets can always be placed on the hull of a ship exactly where required. This frees the operator from having to add corrections to every shot that is made with standard surveyor's prisms.

The Sokkia total station also has an onboard storage capacity of two thousand points. This means that the operator does not need to carry around a bulky data collector when gathering measurements. The information measured in the field can be stored in the total station's memory. In addition, no information can be accidentally erased from the total station's memory by accident in the field. The operator can only delete information from the system if it has previously been downloaded to another computer or to the system memory card.

General Specifications:

The Sokkia total station has an angle accuracy of 3" (1mgon) and a distance accuracy of ±(2 +2ppm x D)mm. Its measurement range runs from 3' to 10,800'. It has an automatic, dual axis, liquid tilt compensator that will correct for up to 3' of arc in two directions, and an automatic third axis collimation correction. Its two keyboards are 120x64-alphanumeric/graphic dot matrix LCD screens, with a back light for low light level situations. The unit is powered by Ni-MH rechargeable batteries. Each battery can run the machine for

approximately 500 points, or four and one half-hours. The quick charger that comes with the total station recharges these batteries in seventy minutes. The unit itself weighs 12.6 pounds, and measures W7.4” x D6.5” x H13.6” without the tripod. For a more complete description of the machine, please see the included Sokkia manuals.

The total station also has an onboard memory card that the operator can write the files to while in the field. This is a sealed non-contact magnetic coupling system that writes to a card that can be taken from the unit and placed into a card reader attached to the host computer for downloading. In addition, the total station itself can download directly into the computer via a serial cable provided with the machine.

A Word Of Caution

The Sokkia total station is a high precision, delicate machine, and should be treated as such by the operator in the field. Its replacement cost is significant. The operator should be careful never to use force when operating the total station. It is manufactured to high tolerances, and a delicate touch is all that is required to perform all of its functions. Rough use or weather conditions such as rain and snow can damage it. It should not be used in such weather. If the machine gets wet in the field, it should be brought inside and wiped dry with a soft cloth. Putting the total station away in a wet case will cause the machine to pull moisture into the telescope, and possibly into the keyboard screen itself. The case should be dried out and left open for twenty-four hours to allow all humidity to escape before locking it shut on the total station. The operator should never attempt to lubricate the total station with any type of lubrication. Only authorized dealers should perform this task. If care is used by all of the operators, the machine should be available for use for a very long time.

Setting Up The Tripod And Leveling The Total Station

The Sokkia total station should always be mounted securely to its tripod while taking measurements. It should never be used to take measurements while resting on a flat surface. The heavy-duty tripod included with the system is generally set up on bare ground. It can be set up on different types of floors with some modifications. On a hard surface such as concrete or tile, the operator can either put the total station on a large piece of carpet to keep the feet from sliding out, or set each foot on a rubberized pad of some sort. Three blocks of wood tied together so they can't spread will also do the trick. Remember that the total station can not move during the measurement process once it has begun, so it is important for the feet to remain where they are. Do not physically alter the tripod to accommodate floor conditions.

After unbuckling the tripod's legs, spread them out into an equilateral triangle with the legs approximately three and a half feet apart to maximize stability. Loosen the thumbscrews on each leg and set the unit up to the proper height, locking the thumbscrews so that the legs do not slip. Try to set the top of the tripod roughly level by eye before taking out the total station. Each leg should be firmly planted into the ground by stepping on the small footrest on each leg. The yellow plastic cap that is screwed to the top of the tripod can be removed and hooked to the top of a tripod leg using the plastic tab cut into it. Once the tripod is firmly set, open the carrying case for the total station and take out the unit.

The Sokkia total station should always be carried with two hands. One hand on the handle on top of the unit, and one underneath the tribrach (the roughly triangular bracket that the unit fastens to the tripod with on the bottom of the machine.) Set the total station on top of the tripod with the legs of the triangle of the tribrach lined up with the legs of the triangle on the top of the tripod. Fasten the tripod to the total station by using the tripod screw attached to the tripod. This should be tightened enough to assure that it won't slide, but not overly tightened so that it distorts the tribrach or tripod head. This does not require much force!

Two locking adjustments on the Sokkia total station keep the unit from swiveling freely on the tripod. One is a vertical adjustment that

allows the scope to swing through vertical angles. The other is a horizontal adjustment that allows the total station to swing 360 degrees around the tripod horizontally. Both of the adjustments have a black rubberized fine adjustment knob and a locking screw on them. In order for the scope of the total station to swing, the locking screw for these adjustments must be free. **Do not swing either the scope or unit if there is any resistance.** This will damage the total station and render it inoperable. Always loosen the locking screws by turning them counter-clockwise first. If they are both free, the total station should swing without any resistance in all directions. This allows the operator to rough aim the unit at the desired location. Once the unit is roughly aimed at the target, the locking screws can be lightly set to keep the unit from spinning. At this point, all of the rest of the aiming is done by turning the fine adjustment screws on each of the adjustment knobs. The locking screw gives the fine adjustment screws something to turn against. If these locking screws are not set, the fine adjustment screws will not work. *Again, it is extremely important that these locking screws are only very lightly tightened for each shot, and released before the unit is swiveled to its next target.* This is where the most damage is generally done to these instruments by beginning users.

Once the total station is fastened to the tripod, the tripod needs to be rough leveled. On the base of the total station, just above one of the three black leveling screws, is a small circular leveling bubble. By slowly adjusting the tripod legs, one at a time, level the tripod so that the bubble is fairly close to the center of the bubble level. This is accomplished by adjusting the bubble so that it is directly opposite one of the other tripod legs. Adjust the leg that is opposite the bubble by loosening the thumb screw while holding onto the moving part of the leg and either letting the leg slide up or down to move the bubble towards the center of the level. Although this takes a few tries to get used to, with a little practice it becomes routine. Don’t worry about getting this level perfect by shifting the leg length of the tripod. When the bubble is close, use the three black leveling screws to make the final adjustment. These screws either are turned clockwise or counter clockwise to make the final adjustments. Note that the three leveling screws have a scribed center mark on their posts. Before adjusting the tripod in any way, make sure that this scribe mark is at the top of each screw. This should assure that the screws have plenty

of adjustment room for the following operations. If the screw bottoms out, simply thread it back down to the center and begin leveling again.

After the circular level has been set, it is time to do the final leveling of the total station. Above the keypad and below the telescope portion of the unit is a long and highly accurate bubble level used to fine tune the level of the total station. Swivel the unit so that this level is running straight between two of the black adjusting screws. Using only these two adjusting screws, turn them so that the bubble is centered in its vial exactly. Once this has been accomplished, swivel the unit until the level is running straight between one of those original adjusting screws and the last adjusting screw. Now adjust the bubble to the center of the vial by *only turning the new screw.* Do not turn the screw that is common to both sets of screws. Leave this one alone for the rest of the adjustments and it will go more quickly. Once this has been leveled, rotate the unit back to the first orientation and use only the screw that is new again to adjust the bubble again. Repeat this process until the unit is level over both sets of screws. When the bubble settles into the center in both directions, the unit is fine leveled. The unit is now ready to be turned on.

Before turning on the total station, make sure that the battery is installed. These batteries should not be stored on the machine when the total station is put away for storage. They can be found in the carrying case in the left bottom corner. They are put into the machine with the thickest part of the battery up. Place them into the total station by inserting the bottom of the battery first, and then swinging the top in until it clicks into place. To remove the battery at the end of the session, simply push the gray **UNLOCK** button and slide the catch with the arrow on it down. The battery should swing freely out. Run each battery out completely before recharging it to assure maximum life span. They have a memory that will shorten their usable life in the field if they are recharged without being completely drained first. The battery life in the field is approximately 500 shots, or about four and a half-hours of time. The battery charger will fully charge a battery in 70 minutes, so it is not normally a problem to measure vessels all day, as long as there is 110v power available for the charger.

Configuring The Total Station - Setting The Correct Parameters

The total station is now ready to be powered on. Simply push the **ON** button on the keypad at the top left of the screen. Wait for a few seconds for the screen to come up and the machine to display this message:

H 0 set
V 0 set

The total station is waiting for the operator to break the horizontal and the vertical angles. This is accomplished by rotating the unit horizontally around its axis until a beep is heard, and then by swinging the telescope vertically until a beep is heard. This will clear this message and present the operator with a screen that looks like this:

SET3000
No.011275
Expert
Ver. 04-20
139-00-04
139-10-08
© 1996 SOKKIA

This screen is simply the opening information screen. To get to the next screen, the operator can push either the **ESC** (escape) key or the **FNC** (function) key. The next screen that should appear looks like this:

P.C. mm 0
ppm 0
2
H.obs 245°13'14"
V.obs 88° 24' 09'
S.Dist <null>
1 Read PPM CNFG REC

This screen provides the operator with some information about the total station and its settings. The first line gives the prism constant-**P.C. mm.** This correction is automatically added to every shot to compensate for the thickness of the prism used in the field. The types of prisms that surveyors use in the field may need a 30mm correction added to them to get the actual distance to the target being measured. In the measurement process for ships and watercraft, we will generally be using the flat stick on targets. The thickness of this target can be entered as the Prism Constant if desired. This is entered on a later screen.

The second line is letting the operator know that there are no corrections being added for atmospheric conditions. This correction is in parts per million, or **ppm**. The operator can add corrections to shots taken for both temperature and pressure. Since the near infrared light beam the total station uses to measure the distance to a target is affected by the atmosphere it is traveling through, long distance shots that surveyors use can be affected by these variables. For the measurement of watercraft, where the distance traveled is usually less than one hundred feet, this is seldom a concern. The correction can generally be left at 0 for our purposes. If the operator still wishes to apply the known temperature and pressure, it can always be changed. This is also done at a later screen.

The third line has a picture of the battery and its charge left. The numbers go from one to three, with three being fully charged. Again, do not charge the battery until it has completely run out. The total station will warn you that it is about to run out. At most, the operator will only lose the point being taken when the battery died. After losing power, simply remove the drained battery and install a charged one. After turning on the total station again and breaking the horizontal and vertical set of the instrument, the machine will return to the same point at which the battery died. That is to say, the operator can continue the measurement process without having to go through any of the initial set-up of the machine.

The next line will show **H.obs**, or the Horizontal angle the machine is currently pointing to. The **V.obs** is the vertical angle observed. The next line shows the **S.Dist**. This will read **<null>** if a reading off a target has not been taken. If a distance has been read, it

will show that distance in decimal feet or meters, depending on the units setting.

The bottom line of the total station screen appears in a darkened blue color. On some screens, there will be no choices on this bottom line. In other screens, only a few choices will appear in the dark blue color. These choices are activated by pushing one of the four **F**-keys just below them. These are **Fl, F2, F3,** and **F4.** On this particular screen, the operator would push the **Fl** key to have the machine measure the distance to a target. By pushing the **F3** key, the operator would be sent into the configuration screen. Notice the bottom left corner of these darker choices. The number **1** that appears in the left corner indicates that the operator is in screen **1** of that type. By pressing the **FNC** (function) button on the total station, the operator will cycle to screen number **2**. Pressing the FNC button again brings the operator back to the first screen. We will now proceed through the screen choices that are useful in the measurement of watercraft one at a time.

Starting with this same screen, the operator can push the **Fl** key, thereby asking the total station to take a measurement. If there is no target that the unit is focused on, the machine will indicate that the signal is off. Depending on the settings, it may stop after one attempt to acquire the target, or it may continue to cycle and find a target. If it finds one, it will display a screen with the horizontal and vertical angles shown, as well as a slope distance to the target. If this key was hit accidentally, pressing the **ESC** (Escape) key will return the operator to the previous screen.

The **F2** key below the dark text **PPM** brings the operator to the setting screen for temperature and pressure. If desired, the temperature and pressure for the day can be set. As previously mentioned, this is of no real concern for shots that under a few hundred feet. If you are measuring a vessel that is eight thousand feet away during a winter hurricane, you may want to change these parameters. Other than that, leaving the **PPM** correction at **0** is sufficient for the measurement of watercraft. If the operator does want to enter new values for these two corrections, the arrow keys will get him or her down to the setting to be changed. The new values may be entered by using the alphanumeric keypad and then stored by hitting the **Enter** key. By hitting the **Enter** key (the light gray large key with the left pointing arrow on it, between the **F4** key and the **Y**

key on the alphanumeric keypad) the operator will store the new values or keep the old values if no new numbers were entered. The machine will then return to the previous screen.

The next key is the **F3** key. This will activate the **CNFG** screen. This is the Configuration screen for other parameters on the Sokkia total station. After pressing the **F3** key, the operator is faced with this screen:

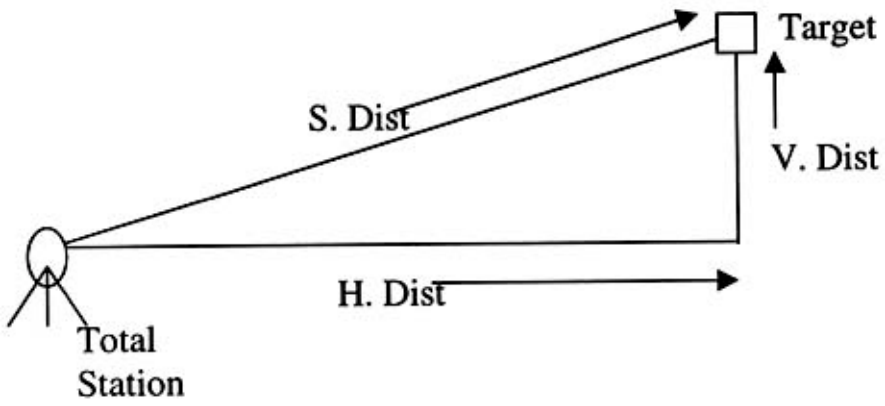
Distance mode	**S.Dist**
H.obs	**Right**
V.obs	**Zenith**
Meas mode	**Fine**
Meas repeat	**No**
Reflector type	**Sheet**
P.C.mm	**0↓**

This is the first page of this screen, as indicated by the little down-arrow just after the **0** on the bottom line. If the operator arrows down through the choices, the screen will jump to the next page after going by the **P.C. mm** field. The second page continues with these parameter settings:

Tilt cm	**Yes**
Collimation cm	**Yes**
H indexing	**Auto**
V indexing	**Auto**
Reticle	**Bright**

The first item on the first page is **Distance mode.** For the measurements that we will generally be doing we want to leave this in the **S.Dist** (slope distance) mode. There are two other choices available. These are made active by using either the right or left arrow key. The other two choices are **H.dist or V.dist.** The **H.dist** is for Horizontal distance. In this mode, the total station will return the horizontal distance between the unit itself and the target. This is only the same as the slope distance measurement if the target is at the same elevation as the total station. If the target is on top of a ten story building ten feet away from the total station, the machine will record a horizontal distance of only ten feet. If **V.dist** is used, the machine

will only record the change in elevation between the target and the unit itself. Thus, if the target is one thousand yards away and three feet higher, the machine will only record three feet as the **V. dist** distance to the target. Since we are primarily interested in coordinate measurements, the operator should leave this setting on **S.dist**. This is the actual distance from the center of the total station to the target in a straight line.



The next line is the **H.obs** setting. This is generally set to **Right.** This means that the total station will measure horizontal angles by starting at zero and counting up to three hundred and sixty degrees when the total station is rotated horizontally to the right when looking down on it. That is to say, a clockwise rotation. The other option is **Left,** which forces the total station to count the angles in a counterclockwise fashion. Although we do not generally care how this is done in the measurement of watercraft, the **Right** option is the most commonly used and may help to avoid confusion with those used to this convention.

The next line is the **V.obs** setting. This is generally left to **Zenith**. This means that **0°** is set vertically to be at the zenith. When the scope is pointing straight up, the digital readout for the vertical angle is **0°.** The operator can also set this to **Horiz** to set **0°** at the horizon**.** Once again, this does not really affect our measurements, but since the standard is vertically above, the operator might as well leave it set to **Zenith.**

Meas mode is the next setting. This can be changed to one of three values: **Fine**, **Rapid and Track.** The **Fine** mode is the most

accurate method, and the operator generally leaves this option set to this. The **Rapid** mode allows for quicker and slightly less accurate measurements. This mode may be used if there is limited battery life as the measurements taken are generally short-range measurements. The **Tracking** mode is used when the operator is trying to find a target at a great distance and cannot actually see the target. This is useful in dense woods where vegetation may obscure the target. The total station will emit a series of sounds that let the operator know that the target is getting closer to the center of focus as the target comes into range. As all of the boat measurements are short range, it would be rare for the operator to use this function.

The next setting is **Meas repeat.** If this is set to **No**, the Sokkia total station will try to read the target only once. If it fails to acquire the target on the first attempt it will stop and let the operator know that it has failed by displaying the words **Signal Off.** This setting can be set to allow the total station to keep trying to acquire the target even if it misses on the first attempt. This can be handy in certain situations where it is difficult to hold a target steady because the target is on the end of a long stick or the target holder is on top of a large ladder and won't risk both hands for the project. The danger in setting this to continually search for a target is that it will wear out the battery quickly if the operator isn't aware that it is still searching for a target.

Reflector type refers to the type of target that the operator of the total station is using. The Sokkia total station comes with two types of targets. The one most commonly used for the measurement of boats is the Sheet type reflector. These are 10mm square stick-on targets. These targets need to be held so that their reflective face is normal to the scope of the Sokkia total station. This will assure that the total station can read the target. If the angle of incidence is too large, the total station will display a message saying that the signal is off. In this case, the target person merely needs to rotate the target into as square a position as possible and then let the operator of the total station re-shoot the target. It should be noted that the operator of the gun should be pointing the unit at the part of the target that is actually in contact with the hull of the vessel. It is often helpful if the person holding the target tells the total station operator where on the target the operator should be focusing.

The other type of reflector that comes with the unit is a prism type reflector most commonly used by surveyors. This prism is generally mounted on top of the prism pole. This type of prism is generally not used in the measurement of boats because it is difficult to place it exactly where required on the hull of a boat due to its size and shape. It can be used on boats; however, corrections will have to be added to account for the size of the prism. The one supplied with the machine is 30mm deep, so in most cases this 30mm would have to be added onto each measurement taken. While this is done automatically by the gun through the **P.C.** function, this type of reflector is generally not very handy for the measurement of watercraft. It is included in case other types of surveying need to be done. The advantage of this type of prism is that it can be used for very long distances. Where the sheet type 10mm reflector is used for up to 300', the surveyor's prism can be used for distances up to thousands of feet.

The next line on the settings screen is the **P.C. mm** setting. This is where the thickness of the target used can be entered so that it is automatically added onto each shot as it is taken. In the case of the pole prism, 30 mm would be added to the shot by entering this value into this field. Since the smallest value that can be entered in this field is 1mm, it is generally left at zero if the sheet style target is being used. These targets are less than a third of a millimeter thick and thus the error would be greater if the correction were added. In general practice when measuring a vessel with the Sokkia total station, the operator uses a sheet type target stuck on a stick, rather than constantly sticking targets onto the vessel. This means very few targets are used to measure the vessel and so costs are kept down (the targets are about $120 per sheet,) and no paint is accidentally removed from the vessel. This is also a much quicker way to measure the vessel. The operator could stick the target onto a stick whose thickness plus the thickness of the target add up to one millimeter and then put in a correction here of 1mm to get a more exact measurement of the object. In general, this method is used in the measurement of watercraft.

The next value that the operator comes to is the **Tilt crn** line. This is on the second page of the configuration screens. The operator gets to this page by arrowing down through the previously discussed values until the second screen of values appears. There are three values for this field: **yes**, **no** and **x only**. This correction is where the

liquid tilt sensor built into the total station will automatically compensate for up to three minutes of arc of tilt in the unit. This will take care of any small shifts of the tripod during the measurement of a vessel. This can happen as the tripod's feet sink further into the earth or tar. It can easily happen on frozen ground that thaws as the sun hits it during the day. This correction is in the X and Y plane. While this function is operating, the total station will also inform the operator of the unit that the machine is out of level if the tilt goes past three minutes of arc in any direction. The operator will then have to stop and re-level the unit before being allowed to continue the measurement process.

If this option is set to **Yes**, the unit will automatically correct for both directions. If it is set to **No**, it will not correct or warn the operator that a shift out of level has occurred. If it is set to **X only**, it will only correct for errors along this axis. The operator should generally leave this option left on **Yes**, as these automatic corrections will only improve the accuracy of the points taken.

The only case where this function may want to be shut off is if the total station has been set aboard a floating ship to measure something like the deck. In this case, the motion of the vessel may keep the total station from operating as it constantly shuts down due to an out of level error. The operator can shut off this function before starting and try to measure the vessel on a calm day to avoid problems.

The next configuration value is the **Collimation crn.** This is a correction automatically applied to the measurements taken in the third axis. This function, however, is based on inherent machining inaccuracies in the construction of the total station. As the telescope of the machine swings through the 360° of arc vertically, it should stay in one exact Z plane. In reality, however, there is a minute wobble due to the machining of the instrument. This is corrected for, however, by the collimation correction. Therefore, the operator should leave this function on all the time to enhance the accuracy of the measurements taken. The two choices for this line are **Yes** and **No**.

H. Indexing

V. Indexing Auto, manual

The last option in the configuration settings is the **Reticle** setting. The two settings for this option are **Dim** and **Bright**. This is the illumination level inside the scope itself. It is generally left on **Dim**

to save battery life, but can be set to bright for use of the machine indoors in low level light conditions. In practice, there seems to be little difference between the two settings. This is the end of this configuration menu. By hitting the **Enter** key all of the changes made during the configuration of the machine are saved. They will remain the default settings until changed at a later date. Once set, the operator should be free from having to redo this information every time that a new vessel is to be measured. The Sokkia total station will come to you previously set with the correct parameters, but the operator should feel free to change any options deemed necessary.

The REC Option – F4

The last of the dark-blue screen choices available to the operator on the first screen is **REC**, just above the **F4** soft key. This stands for record, and by pushing the **F4** key the operator will end on another screen of choices. These choices are where all of the actual measuring and surveying work will be done and recorded. This screen looks like this:

07-Oct-97 13:27:48

Job
Stn
BS pt
3

Free Recs 1117
FUNC SURV COGO ROAD

The date and time are displayed across the top of the screen. This setting may not be corrected each time the total station is turned on. Since the battery is not stored in the unit when it is in its case, the date and time may be lost. This is easily reset to the appropriate dates and time if desired and this will bed explained shortly. For most cases, if the operator is not interested in this detail, it can be ignored.

The next line is **Job**. If the operator is currently in a job the name of the job will appear to the right. In this case, since no job has been

opened yet, the name space appears blank. The next line gives the station number (**STN**) of the location of the total station. Once again, since nothing has been determined yet, this value is also blank. The next line, **BS pt,** is the number of the back sight taken. In the measuring of watercraft we do not take back sights, and so this field is also blank. The next line of the screen shows a picture of the battery, with the remaining battery life. In this case, the battery is at three, and is fully charged. **Free recs** shows the number of free records in memory, each point measured being one complete record. In this case, there are **1,117** free records left.

The next line contains the dark blue choices activated by using the **F** keys below them. We will start with the first choice in this menu, the **Fl** key below **FUNC**. After pressing the **Fl** key, the operator is faced with this new screen:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

Fl- The Job Function

The first choice on this screen is **JOB.** This is where the operator, by selecting this option once it is highlighted by pressing the **Enter** key, can actually begin to define a job to be done. After selecting this option, a new screen appears that will show the operator existing jobs - if there are any. If the operator wishes to continue with one of these existing jobs, he or she can arrow down to the choice and press the **Enter** key. That job and all of its parameters will then be loaded and the operator will be returned to the previous screen. If a new job is to be started, the operator pushes the **Fl** key below the dark blue text that says **NEW**. A new screen pops up and looks like this:

Create Job

Job	**<no text>**	
S.F.	**1.00000000**	
Point Id Numeric		**(4)**
Record elev	**Yes**	
Atmos crn	**no**	
C and R crn	**no ↓**	
	A	

The operator can type in a name for this particular job. This can be the name of the vessel, an accession number, or anything else meaningful. This can be with letters or numbers, using up to fifteen spaces at the most. Notice at the bottom of the screen the letter **"A".** This stands for alphabet and means that the alphabetic keyboard is active. When the operator types on the keyboard, she or he will only get letters. By pushing the **ALPHA** key on the lower right corner of the keypad, the operator can see that the **"A"** changes to an **"N".** This sets the keypad into the numeric mode, which allows the operator to enter numbers onto the screen. The Sokkia total station will switch to the appropriate mode whenever possible. The operator will never be allowed to enter a letter into a field that always contains numbers, or vice-versa. If the screen is in the wrong mode, the operator only needs to press the **BS** key below the **FNC** key to backspace over mistakes or changes to be made.

After typing in the job name, the operator has a few other choices that can be made. The next line, **S.F.** is set to **1** and should be left this way. This is a plane scale factor that is used for transverse Mercator projections. Although this does not concern us with the measurement of watercraft, this setting *must be left on **1*** to give the operator a 1:1 ratio in the measurements taken.

The next line, **Point Id Numeric**, is where the operator decides what the points will be called. This is generally left in numeric mode, with a setting of 4. Set this way, the total station will automatically enter a value for each point starting with one and progressing by one until the end of the data collection. The four means the points will start at 1000, and progress to 1001, 1002, 1003 and so on. This field can be switched to an alphabetic note of 14 characters if desired, but this leaves the operator to label each shot taken, a very time

consuming process. In general, it is beneficial to have ascending values for points taken, as it helps the operator sort out the information later during the drawing process.

The next line should always be set to yes during the measurement of watercraft. This is the **Record elev** line. If this option is set to **no,** the total station will assume that all points taken lie on a plane.

The next three lines can all be left to **No**. As discussed before, these are the temperature and pressure corrections as well as the sea level correction that are normally entered by surveyors for long distance work. These are generally ignored for the measurement of boats or other manmade objects. The **C** and **R crn** corrections are for curvature and refraction. If you feel the curvature of the earth will impede your measurements you can add these corrections, but they are generally ignored when measuring boats.

Notice that the little arrow on the bottom of the screen indicates that there is a second page of choices, available to the operator if she or he arrows down to them.

After these options have been addressed (and generally the operator will only be entering a new job name and then pressing the **Enter** key) the operator pushes the **Enter** key and is shown a **Note** screen. Here the operator can choose to type in any information that is desired. If no note is desired, the operator presses the **Enter** key again to move on. If the operator chooses to type in some notes and then presses the **Enter** key, he or she will be given another **Note** screen as well. By pressing the **Enter** key again, the operator is moved into the previous screen where the **Job** function was originally selected. All of the parameters have been saved and the operator can now move into the data collection phase.

The Instrument Setting Functions

Returning to the screen where the Job was set up from:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

We see that the next choice is the **Instrument** setting. By arrowing down once to this choice and pressing the **Enter** key, the operator is then given this screen:

Instrument	**SET**
EDM desc	**Set3000**
EDM S/N	**011275**
V.obs	**Zenith**
Reflector type	**Sheet**
P.C. mm	**0**
Orient	**Azimuth**

This screen is an information only screen, with the only exception being the last line of the screen. All of the other lines can not be changed, or can not be changed from this screen. This merely allows the operator to double-check his settings without having to return to the other screens in earlier menus while working on a job. The first three lines simply describe the unit used to do the measuring. The instrument is a **SET3000 EDM** with the serial number of **#011275.** The next line lets the operator know that the vertical angles **(V.obs)** are based on the Zenith, or straight up, being zero (0). The type of reflector the total station is expecting is the stick on **Sheet** type. The correction for the thickness of the target **P.C. mm** is set to 0. The only line that can be changed is the last line of the screen. This is the **Orient** line. This can be set to **Azimuth, Zero** or **None**. This should be left at the standard setting of **Azimuth**, although it will not make any difference in the measurement of watercraft. By hitting the **Enter** key, the operator returns to the previous screen:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

The Job Settings Function:

The next line down is the **Job settings** function. By choosing this option, the operator is presented with this new screen:

Job settings
Job NAME
Atmos crn no
C and R crn no
Sea level crn no
A

This screen allows the operator to change some of the settings for this particular job. The first line simply lets the operator know which job she or he is changing. The name of the job appears on the first line. The next three lines show that there are no corrections being applied for atmospheric conditions (temperature and pressure), no corrections applied for the curvature of the earth or refraction, and that no sea level corrections have been added to the measurements taken or to be taken. The operator can choose to change these values in this screen to **YES**. If the operator chooses to do this, he or she will be given the opportunity to type in the values desired for these corrections. As stated before, these will not be used during the measurement of watercraft, and so there is no need to change these values. By hitting the **Enter** key or the **ESC** key the operator is returned to the previous screen:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

The Configure Reading Function:

The next line is the **Configure reading** function. Once again this is a screen where the operator can change the settings for the total station. After selecting this option, the operator will see this screen:

Auto pt num	**1000**
Topo view stored	**obs**
Combine F1/F2	**No**
# dist rdgs	**1**
Meas mode	**Fine**
Meas repeat	**No**
Code list active	**Yes↓**
	N

Once again, it will not be generally necessary for the operator to set all of these settings each time the unit is used to measure a boat. Once set, the total station will store and use the values previously assigned. This means that the process of setting up for each vessel is actually quite quick, as there are only a few things that need to be set each time a new boat is measured.

This screen is important, however, in first setting up the Sokkia total station. The first line of this screen allows the operator to simply tell the total station where to start assigning numbers for each point measured. On this screen, it is set to begin at point number 1000, and then number the points consecutively upward. The operator can choose at this location to start from point number 1 if

desired. This does not affect the measurements in way. These point numbers will appear in the printed out notes of the measurements taken, and are simply a way to track which measurement is which. The operator can also recall a specific point by calling up its number.

The next line tells the operator the format used to store the information gathered in the field. Surveyors use a variety of formats to record the information they are collecting, depending upon the reason for gathering it in the first place. In practice, it does not really matter how this function is set. The total station records all of the necessary data no matter how this is set. The total station will convert this data to any of the other formats at any time. Even if this is not set to the particular format desired, it can later be converted into the proper format for the measurement of boats. The choices for this particular screen choice are as follows: **OBS, MC, RED** and **POS. OBS** stands for Observed view. This is the data stored in its rawest form. This will include northing, easting and elevation data, as well as all of the corrections added. This is the form most generally accepted by surveyors, and the form that the machine should be left in. The **M.C.** format stands for measurement corrected. This is the data gathered with all of the corrections applied, such as orientation, collimation, instrument and target height, atmospheric corrections and the curvature of the earth corrections. The **RED** format is a reduced format. This means that all of the information has been reduced to a flat plane for surveying purposes such as the production of a map. This format is clearly not what is desired in the measurement of watercraft. The last choice is the **POS** format. This format is finally downloaded from the total station into the host computer for the production of lines plans or other drawings. This is the position format, and is the information gathered reduced into plain coordinate points- or (X,Y,Z) values. As mentioned before, the machine is generally set the format **OBS** and then downloaded into the computer in the **POS** format. The reason for this is that the information taken will need to be parsed (that is separated into neat columns where all similar information is lined up) after loading into the computer. By using these particular formats, the parsing goes much easier. Therefore, the operator should leave this field in the **OBS** format.

The next line is the **Combine Fl/F2** option. As you have probably noticed, the Sokkia total station has two faces with screens on them. These are Facel/Face2. In surveying, the operator will often

backsight his last location to check his or her new position. This can be done by revolving the scope one hundred and eighty degrees and sighting from the second face of the instrument (that is the face opposite from the large bubble-level used to fine-tune the instrument). This gives the total station a chance to measure the angle twice and divide the difference in the scope to assure accuracy. This is the **Combine F1/F2** option, where these revolved scope sightings will be taken or not. Again, this is not a functioned used in the measurement of boats. This option can be left to the **No** setting.

The next choice is the **# dist rdgs**, currently set to the value of 1. This number represents the number of distance readings the machine will take each time a target is shot. If set for more than one, it will take more readings and then average them. This is generally not worth the extra time and drain on the battery, but can be used if desired for higher accuracy.

The next setting is **Meas mode**, and can be set to three different choices by using the right arrow key to toggle between them. The three choices are **Fine, Rapid** and **Tracking**. This setting affects the way in which the signal is put out. Fine is the setting generally used in the measurement of boats and ships. This is the most accurate signal sent and received. The Rapid signal is used for coarser work in the surveying field, such as the laying out of topography. While it will conserve battery strength, it is not recommended for our purposes. The **Tracking** mode is used to set out points at known angles and distances from the Sokkia total station. In this mode, the total station sends out a continuous signal that sounds different tones as the target is moved into sight of the pre-aimed scope. This can be handy for targets that are very far away or somewhat obscured by vegetation. This generally does not concern the operator documenting boats, although I have seen vessels with trees growing right through them. The operator should leave this setting in the fine mode.

The next line is the **Meas repeat** setting. This simply allows the machine to keep sending out the signal to measure the distance to a target. This setting should be left at **No**. It is very costly in terms of batter life to have the total station keep sending out the signal. It is better to have the unit shut down and give the warning message that the signal is off. In this way, the operator can check to be sure the target has not moved, or is still fairly normal to the scope on the unit.

The next line is **Code list active.** This is a YES/NO toggle, and simply turns on or off the availability of the code list. This is a list of notes typed into the total station before any boats are measured, and is used as a means of speeding up the measurement process. While taking shots of the vessel the operator will type in descriptive notes with each shot to remind him or her later what those points were. To help avoid having to type notes in with that small keyboard, standard notes can be pre-entered and simply picked from an alphabetized list in the field. If this choice is left **YES**, this list will work and the operator can pick from it. If left at **NO**, the operator will have to type in each new note from scratch. It should be noted, however, that the last note typed in carries over into the note field in the next shot taken. Therefore, if the operator is shooting the sheer line of the vessel and has the word *sheer* for the note, she or he will only have to type it once for all of the shots taken. Only when switching to another type of shot, such as the *keel,* will the operator have to type in the word "keel". This will then appear in every note section until a new note is typed in. There is a list of notes already in the machine that may or may not be of some use in the measurement of boats and ships. This list can be modified, erased or a separate list can be created by each operator to best suit his or her needs. This is discussed under **Code Lists**. This screen only allows the operator to turn the function on or off.

This screen is a two page screen, as there is a down arrow at the bottom of the screen indicating that there is more to follow by arrowing down past the last line. After doing this, this new screen appears:

Info blocks	**0**
Code Fields	**0**
Recip Calc	**Prompted**

The first two fields allow the operator to break notes down into separate fields of their own, where sub-field notes can be recorded. While handy in surveying it is not generally very useful for the measurement of ships. For a description of this feature, please see the Sokkia manual itself.

The **Recip Cal** setting has three possible settings: **Prompted, Always** and **Never**. This function is not used in the measurement of

boats. It is used in surveying when the operator needs to take a backsight at a station previously occupied. This function will then do a reciprocal calculation to help refine the new stations' elevation. This can then be set to any of these choices. The total station will only activate this function if a backsight occurs; it will not affect the measurement of boats. This is the end of the **Configure Reading** function. After hitting the **Enter** key, the operator is returned to the previous screen:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURY COGO ROAD

The Tolerances Function

The next field is the **Tolerances** section. After selecting this option**,** the operator is given a screen that looks like this:

Tol H.obs	**00° 00' 30"**
Tot V.obs	**00° 00' 30"**
Edm tol (mm)	**5**
Edm tot (ppm)	**3**
Angle resolution	**1"**

N

The tolerances set here will not generally affect the type of measuring we are using the Sokkia total station for. These limits are used when the machine is doing surveying work. In surveying, the operator is constantly referring back to known points. The machine expects these to be in a specific orientation to its current location. If

it detects that the new shot is beyond the listed tolerances (i.e. something is rotten in the topography of Denmark) it will warn the operator and mark the new shot with an asterisk. Since there are generally no backsights in ship work, these functions do not come into play, and these fields can be left as they are. The last line merely indicates what resolution the angles measured will be. At 1”, it is set to its finest resolution, and should remain there. After hitting the Enter key to record any changes that have been made, the operator is returned to the previous screen:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

The Units Function

The next line brings up the **Units** settings screen. This is where the type of units displayed by the **total station will** be set. After picking this line the screen jumps to this one:

Angle	**Degrees**
Dist	**US Feet**
Pressure	**mmHg**
Temp	**Farenht**
Coord	**N-E-Elev**
Other grades	**%**
Sideslope grade	**1:↓**

If the operator continues to arrow down, the second screen appears:

Sta...ing	**10+00**
Decimals shown	**3**
Zero Azimath	**North**

The first option is how the angles will be displayed on the screen and in the printout of the information. It should be noted that the total station can display any of the measurements taken in any format at a later time. If you measure in English units and then want to look at them in metric units, there is no need to re-measure. By changing the unit type before opening the job, the job will then be displayed in the new units. Under **Angle** there are four choices including **Degrees, Quad brng, Gons and Mills.** For the measurement of watercraft, it is generally easiest to leave this in Degrees. The operator can feel free to change this to whatever type of unit she or he feels comfortable working with.

The Dist setting records the operator's choice for distance units. The unit choices available are: **US Feet, Meters** or **Feet.** The standard for our work is either US Feet or Meters.

The next two lines deal with corrections that are not usually applied to boat documentation, the temperature and pressure corrections. If the operator wishes to apply these corrections, however, this is the place where the units desired are set.

The next line **Coord**, deals with the way in which the information is recorded. As all of our measurements are relative, it doesn't really make a difference which of the two choices we pick: **N-E-Elev** or **E-N-Elev.** Simply leave this at the first choice, as it is the standard for other work.

The next two lines allow surveyors to describe slopes in topography either as a percentage or as a ratio. This is not used in the measurement of boats.

The first line of the next page apparently gives the operator the way stationing values are displayed. This is the **Sta…ing** function**.** The manual says nothing beyond this, and so we are left partially in the dark.

The next line allows the operator to set the number of decimal places displayed on the screen when measuring an object. This is not the number of stored decimal places, as that remains constant. Three places are generally adequate for viewing.

The last line in this settings screen is the **Zero azimuth** setting. **North** is the standard, and the machine can be left with this value. **South** is the other choice; this will not affect the way in which the boats are measured. This is the end of the settings, and by hitting the

Enter key, the operator's changes are recorded and the previous screen returns:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

The Date and Time Function

The next group of settings allows the operator to set the correct date and time on the machine. While this does not affect the measurement process, if it is properly set it can be helpful later as this is printed out with the other information taken with the Sokkia total station. After picking this line the operator is presented with a new screen:

Date format DDMMYY
Date 11-Dec-97
Time 09:22:31

Time out 10
Timestamp 10
N

The first line shows the order in which the day, month and year are entered. By highlighting the first line and using the right arrow key, the operator can change the order of these three variables to suit his or her personal preference. The operator enters the correct date on the second line. The third line is for the correct time. Note that these values may be incorrect if the machine has been left for a few days as the battery is not stored on the machine when not in use, and thus without power the setting is lost.

The next line is the **Time out** function. This is where the machine is set to turn itself off after a certain amount of time if not in use. This is to save battery life if the operator walks away from the machine for a while. It is currently set to ten minutes. It is important to note that if the machine is shut off automatically, no information is lost. The operator simply turns the machine back on, and after breaking the **H. Set** and the **V. Set**, the machine will be exactly where it was when it self-powered down, ready to continue collecting information.

The last line is the **Timestamp** function: this is set to a thirty-minute increment. This function simply stamps the time into the measurement record (which will be printed out with all of the data collected) every thirty minutes to allow the operator later to tell when the measurements were taken. This is of little use unless the operator is interested in the duration of the job. After setting these values, the operator presses the **Enter** key to record the new values or the **ESC** key to discard the new values and return to the previous screen. By then hitting the down arrow key, the next screen of these choices is presented:

Job deletion ↑
Feature code list
Hardware
Communications
Card Menu
Language
SURV COGO ROAD

The Job Deletion Function

The first choice of this second page is **Job deletion.** The operator should exercise caution here, although as a safety feature it is impossible for a job to be deleted without first downloading it to a computer or the memory card. This prevents accidental erasure in the field of completed jobs. Once the job has been transferred from the machine, it can be deleted to free up memory in the total station.

After highlighting and selecting **Job deletion,** the operator is given a new screen that looks like this:

Select jobs
Select roads
Select templates
Select all data

By picking the first option, the operator will be given a complete list of jobs currently stored in memory on the total station. Any of these jobs with the symbol **N/A** after them can not be deleted, in that they have never been downloaded from memory to the card or a computer. The other jobs will have the word **No** after them. The operator arrows down to the job to be deleted, and presses the **right arrow** key to switch the **No** to a **Yes**. After picking all of the jobs to be deleted, or by pushing the **Fl** key to automatically select all of the jobs that can be deleted, the operator pushes the **Enter** key to delete them. The operator will be given one last chance to abort the operation before the jobs are actually deleted, but once that road is crossed, the information is gone from the machine forever.

The next line under the **Job deletion** function deletes Roads from memory. If you have used the total station to lay out roads, you would delete them from here. The same methods apply to delete them as did for the deletion of **Jobs**. This is also true for the deletion of Templates, the next choice. The last choice is the most powerful. It will automatically group all of the information in memory in one location for deletion. This is the **Select all data** option. Again, the same rules apply.

After having completed the job deletion, the operator is returned to the previous screen of choices:

Job deletion ↑
Feature code list
Hardware
Communications
Card Menu
Language
SURV COGO ROAD

The Feature Code Function

The next line is the **Feature code list.** This function, while not required to do the job at hand, can significantly speed up the measurement process in the field. This list is a predefined list of words that the operator will use to describe the points taken in the field during the measurement process. These words appear in the notes field for each point taken. The way this works is this: the operator takes a measurement on the vessel, say the rabbet line of the boat. After taking the first shot of the rabbet line, she wishes to type in **Rabbet** in the note section to remind her later what that particular point was. She could arrow to the note section and type in the word **Rabbet**, and then continue to measure the rabbet line. This note will automatically show up on all subsequent shots until replaced with new text. Instead of having to type in the entire word in the note section, however, the feature code list can eliminate the need to hunt and peck for letters on the alphanumeric list. With this function active (it can be turned on or off if desired) the operator hits the first letter of the word she wants and an alphabetically arranged predefined list pops up on the screen. The operator can then arrow down to the word rabbet and hit the **Enter** key to enter this word into the note section automatically. This allows the operator to enter larger descriptions into the note field without having to type them in every time. If the word desired does not show up on the list the operator simply keeps typing the word and the machine will return to the note section of the measurement screen. The operator can add or delete any words from the feature code list at any time, or make up several different lists from which to choose. The total station has a predefined list in it specific to the measurement of watercraft, and the operator should feel free to use or change this list to suit.

By selecting this choice, the operator is given a screen that looks like this:

Ship

Cd	**aftkeelref**
Cd	**aftvertref**
Cd	**fwdkelref**
Cd	**fwdvertref**
Cd	**keelprofile**

ADD DEL EDIT

The three F keys, **Fl, F2** and **F3** at the bottom of the screen allow the operator to add new words to the list, delete old words on the list, or edit the existing list. After selecting one of these F keys, the operator can change the word in the desired way. Notice also that there are other options. These are Attributes, and they form a subgroup to the feature code list. I have not found them useful measuring boats, but other operators may. They are intended to further breakdown categories described by the main feature code list. Surveyors use this to further define objects in the field. The feature code list word may be TREE. The operator can pick this code from the list, then go into the Attributes list, and pick a further description of the tree from a list of words like maple, oak, pine, ash or any other description desired. In the measurement of watercraft however, there are not that many descriptions needed to cover the points taken, and so this extension of the function can probably be ignored. The operator can consult the Sokkia manuals for further description of this feature if desired.

The Hardware Function

Next on the list of choices is Hardware. This screen looks like this:

Hardware

Battery	**2**
Backup	**Good**
Backlight	**Off**
Reticle	**Dim**

SYSTE SET VERSION

This function provides the operator with some information on the machine's status. By selecting it, information on the **Battery** level is displayed **(1,2** or **3** is displayed, with 3 being the most battery life left), the status of the backup memory card is displayed (either **Good** or **Bad),** the status of the **Backlight** (either **On** or **Off**) and lastly the status of the **Reticle** illumination (either **Bright** or **Dim).**

The bottom of this screen gives the operator three F key choices as well. By pressing the **Fl** key, this screen of information appears:

System

PC BIOS	**139-00-04**
Avail TPA	**636**
Drive Size	**125k**
	68K free

This information gives the BIOS information, the available TPA, the amount of memory installed in the machine and the amount of free memory left for the storage if point data. By pressing the **F2** key, the operator is given this information:

SET

EDM S/N	**011275**
SET	**SET 3000**
EDT BIOS	**139-10-08**

This lists the serial number of the total station, the model number and the BIOS installed. This information is used when dealing with the factory or in troubleshooting problems. The **F3** key simply gives the version of the software currently installed on the total station:

Version

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V04-04.20

After viewing this information and making any changes necessary, the operator is returned to this screen:

Job deletion ↑
Feature code list
Hardware
Communications
Card Menu
Language
SURV COGO ROAD

The Communications Function

Communications is the next option. The screen that pops up after selecting this looks like:

Communications

Data Format SDR

OPTNS COM SEND RECV

There is one active field and four choices of F keys. The two choices for the **Data Format** field are **SDR** or **Printed.** This can be left on **SDR**, as all of the information will be downloaded into a computer or the memory card, and probably never directly to a printer. By pushing the Fl key for **OPTNS**, the operator is given yet another list of options. This new list looks like this:

Send records in

Current view	**Yes**
OBS view	**No**
MC view	**No**
RED view	**No**
POS view	**Yes**
Send partial job	**No . ↓**

In addition, the next page's last choice is:

Send all as POS	**No**

These choices allow the operator to send the information gathered in the field in a variety of formats to the computer. In the measurement of watercraft, where all of the information is reduced to coordinate values for entering into a CAD program of one sort or another, the only way that the operator will want to send information will be in the POS view (position view). The other types of information are used for surveying purposes, and will give the operator values of Northing, Easting and elevation for each shot taken. It should be noted however, that the operator can send the information later in any format desired. The basic information is always retained to output any format chosen by the operator as long as it has not been deleted from the machine or the Sokkia software on the host computer.

The settings for this screen should always be as shown above to simplify the parsing of data once it comes off the machine. When the operator downloads the information taken in the field with the total station in the **POS** view, the information can be read into a word processor. It comes up looking like this:

```
00NMSDR20     V03-05000014-Nov-97 08:29 121211
"
10NMSchooner Etta
"
13CPSea level crn: N
"
13CPC and R crn: N
13CPAtmos crn: N
06NM1.00000000
13OOPOS
13TS13-Nov-97 13:32
13JS10000
13TS13-Nov-97 13:32
01NM:SET3000         011275                 0000003
0.00000000
13PCP.C. mm Applied: 1.000
02TP00010.000000000.000000000.000000000.00000000
03NM0.00000000
08TP10007.1699313043.19696211.38947969pt1
08TP1001-20.413625-70.460473-0.5434425pt2
08TP10027.00161699-11.12053112.0211167pt3
08TP100313.32478186.5928335214.8318824sta5
08TP100413.05672406.4123648011.0707695sta5
08TP100513.02126126.4678235910.8811588sta5
08TP100613.00285166.4284490510.8764789sta5
08TP100712.96089266.506372509.45084546sta5
08TP100812.87649466.390080127.97724023sta5
08TP100912.87031456.308197186.83637724sta5
13TS13-Nov-97 13:43
08TP101012.89931176.199087295.65960904sta5
08TP101113.20923186.410497424.08403219sta5
08TP101213.54588416.309355262.99310199sta5
08TP101314.05094876.045561741.94895449sta5
08TP101414.69715015.812173331.05736440sta5
08TP101515.69493185.643561880.20426474sta5
08TP101616.81985545.31646180-0.5917741sta5
08TP101717.86946544.96170616-1.1314047sta5
08TP101818.82725914.63584048-1.6537532sta5
08TP101919.89712544.19701204-2.1661007sta5
08TP102021.08614403.79811225-2.7402329sta5
08TP102121.98794193.46025931-3.1476051sta5
08TP102222.90955933.22222040-3.7059800sta5
08TP102323.64297362.92393782-4.1972000sta5
08TP102424.37136262.64231715-4.7492890sta5
08TP102510.3444148-1.695095814.4231978sta5
08TP102610.2627379-1.799697913.4200372sta6
08TP102710.0930122-1.589949710.6933281sta6
08TP102810.0558093-1.537208410.4866481sta6
08TP102910.0386824-1.39645499.15807675sta6
08TP10309.95329819-1.44192787.60689156sta6
08TP103110.0199877-1.26887896.51691583sta6
08TP103210.0912827-1.18550295.27855068sta6
08TP103310.3488983-1.24431163.57664557sta6
```

In this format the information is aligned, more or less, into (X,Y and Z) values. The header to the file shows information on how the machine was set in terms of corrections added to the measurement, the name of the job and the time it was measured. Note the time stamp in ten-minute intervals placed between the shots of the vessel. This setup makes it easy to parse the information using a spreadsheet such as Excel into this format:

Schooner ETTA - Starboard Side	x	y	z	
0	7.1699313	43.1969621	1.38947969	pt1
1	-20.413625	-70.460473	-0.5434425	pt2
2	7.00161699	-11.120531	12.0211167	pt3
3	13.3247818	6.59283352	14.8318824	sta5
4	13.056724	6.4123648	11.0707695	sta5
5	13.021 2612	6.46782359	10.8811588	sta5
6	13.0028516	6.42844905	10.8764789	sta5
7	12.9608926	6.5063725	9.45084546	sta5
8	12.8764946	6.39008012	7.97724023	sta5
9	12.8703145	6.30819718	6.83637724	sta5
10	12.8993117	6.19908729	5.65960904	sta5
11	13.2092318	6.41049742	4.08403219	sta5
12	13.5458841	6.30935526	2.99310199	sta5
13	14.0509487	6.04556174	1.94895449	sta5
14	14.6971 501	5.81217333	1.0573644	sta5
15	15.6949318	5.64356188	0.20426474	sta5
16	16.8198554	5.3164618	-0.5917741	sta5
17	17.8694654	4.96170616	-1.1314047	sta5
18	18.8272591	4.63584048	-1.6537532	sta5
19	19.8971254	4.19701204	-2.1661007	sta5
20	21.086144	3.79811225	-2.7402329	sta5
21	21 .9879419	3.46025931	-3.1476051	sta5
22	22.9095593	3.2222204	-3.70598	sta5
23	23.6429736	2.92393782	-4.1972	sta5
24	24.371 3626	2.64231 715	-4.749289	sta5
25	10.3444148	-1.6950958	14.4231978	sta5
26	10.2627379	-1.7996979	13.4200372	sta6
27	10.0930122	-1.5899497	10.6933281	sta6
28	10.0558093	-1.5372084	10.4866481	sta6
29	10.0386824	-1.3964549	9.15807675	sta6
30	9.95329819	-1.4419278	7.60689156	sta6
31	10.0199877	-1.2688789	6.51691583	sta6
32	10.091 2827	-1.1855029	5.27855068	sta6
33	10.3488983	-1 .2443116	3.57664557	sta6
34	10.5980833	-1.4876821	2.62827551	sta6
35	11.1417628	-1.6790664	1.5956994	sta6
36	11.8396364	-1.8991696	0.67547399	sta6
37	12.9432011	-2.3643022	-0.2630998	sta6

In this format, the information is now easily read into a CAD program as coordinate points where the operator can begin to draw the vessel measured. If the operator is using the total station for surveying rather than for the measurement of vessels, then he or she may want to send the information in its raw or reduced form for surveying purposes, and not as coordinate values.
After setting this screen and pressing the **Enter** key to save the changes, the operator is returned to this screen:

Communications
Data Format **SDR**

OPTNS **COM** **SEND** **RECV**

The **F2** key brings up this screen:

Device	**COM**
Baud rate	**1200**
Word length	**8**
Parity	**Not set**
Stop bit	**1**
Output delay	**0**

This is where the communications protocol is set. This must match the settings on the computer receiving the information. This is done on the computer through the Sokkia Software that comes with the total station package, and will be discussed later.
The first choice should always be set to **COM,** and not **LPT.** This means it will be transferred over the serial port COM 1 or Com2 and not through the parallel port LPT1 or LPT2. This is because the only cable available with this setup is a serial cable. The **Baud rate** can be

left at 1200, unless it proves too fast for older computers. This only affects the speed at which the transfer of data occurs. **Word length** chops the file name to 8 letters to avoid problems with the old DOS limitation on file name length. **Parity** should be left to **Not set, Stop bit** left at **1**, and **Output delay** left on **0**. After setting these values and pushing the **Enter** key, the operator is brought back one screen:

Communications
Data Format **SDR**

OPTNS COM SEND RECV

If the operator presses the **F3** key under **SEND**, she or he will get this list:

Select jobs
Select Roads
Select templates
Select all data

These functions operate exactly as the **DELETE** functions previously discussed. By highlighting the **Select jobs** line and hitting the **Enter** key, the operator will be able to pick the jobs he or she wants transferred. Once these have been chosen and the **Enter** key has been pressed, the information will be sent to the host computer. This is assuming, of course, that the computer and the total station are connected and the software on the host computer is ready to receive the information. This is discussed later in this manual. After the information has been sent, the total station beeps and shows a Complete screen. The operator then presses any key to return to the previous screen of choices:

Communications
Data Format SDR

OPTNS COM SEND RECV

The last choice is above the F4 key- RECV. In surveying, this is used to upload old jobs to the total station so that more work can be done on them. This is not used in the measurement of watercraft, and so will not be discussed here. The interested operator can look up this aspect of the machine's operation if desired in the Sokkia manuals that accompany the total station. From here the operator is backed out to this screen:

Job deletion ↑
Feature code list
Hardware
Communications
Card Menu
Language

SURV COGO ROAD

The Card Menu Function

The next round of functions deals with the memory card that is attached to the total station. This allows the operator to save the information gathered in the field to a card that can be read from into the host computer. This card is much like a diskette used on a computer. Information can be written to it or retrieved from it. By highlighting this option and pressing the **Enter** key the list of options dealing with the memory card are displayed:

Format card
Mem to card
Card to mem
Check card
Delete card file

SURV COGO ROAD

Like a diskette for a computer, this memory card can be formatted. This will erase permanently any information on the card. After choosing this option, the operator has one last chance to back out before the card is erased.
If the **Mem to card** option is picked, the operator is given a way to pick which information will be written to the card. This works in the same way as the **Delete** and **Communication** functions work in terms of picking what information is to be saved. The **jobs** or **roads** or

templates are highlighted with a **Yes** and then sent to the card, where they can then be downloaded to a computer or uploaded back into the total station. Note that the jobs are not removed from the total station's memory simply because they have been downloaded to the memory card. They remain in memory until deleted through the **Delete Job** function.
The Check card function reports the status of the memory card itself. The information that it provides looks like this:

Check card

Type	**Data**
Size (k)	**128**
Format	**DOS**
Battery	**Good**
Free memory	**122880**
Write protect	**off**

This information shows us that the card in the machine is a data type card of 128k, is DOS formatted, has 122880 bytes of free memory, a good battery, and is not currently write protected. The battery in this case is the battery inside the card that keeps the information stored on the card. This card, like a diskette, can be write protected to keep accidents from occurring.
The last option in dealing with the memory card is the **Delete Card File** option. Rather than re-formatting the card to erase information, the job can simply be deleted from the card using this function. Unlike the delete used on the total station's built-in memory, the card delete will delete a file that hasn't previously been downloaded to a computer. The operator should be careful not to download to the card and then accidentally delete it from both locations unwittingly. Note that the three F keys **F2, F3** and **F4** will take the operator directly back into **SURV, COGO** and **Road** if desired.

The Language Function

After the menu dealing with the memory card, there is the **Language** choice. Actually, there really is no choice. The language

is **English US** and no other language can be loaded without a language card. After hitting the ESC key the operator returns to this screen:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

F2 - The SURV Function:

Most of the work to be done measuring boats with the total station will be accomplished with the **SURV** function button. While applications can be found where the **COGO** and **ROAD** functions could be used, they primarily deal with surveying of land, and are not easily modified to serve the measurement process used in recording watercraft. The operator pushes the **F2** key below the **SURV** text in dark blue to again bring up a new menu of choices. This two-page menu looks like this:

Topography
Traverse adjustment
Resection
Set collection
Set review
Building face survey
Collimation ↓
FUNC COGO ROAD

By arrowing down, the second page looks like this:

Tilt offset ↑
Remote offset
Keyboard input

FUNC COGO ROAD

The **Topography** mode is where most of the measuring will be done, as in effect, the operator is taking a topographic survey of the hull of the vessel. After highlighting the **Topography** choice and pressing the **Enter** key, the operator is faced with a screen that must be filled out before continuing:

Stn
North <null>
East <null>
Elev <null>
Theo ht <null>
Cd <no text>
N

The total station has switched automatically to numeric mode, as it will only accept numbers for the first five answers. The first line, **Stn**, is where the operator enters the station number that he or she wants to assign to the location of the total station itself. Generally, this is the number one, as a zero is not allowed. After typing in "1", the operator arrows down to **North, East, Elev** and **Theo ht.** These next four values can all be zeroed out. That is to say, the value of "0" can be entered for all of them. These values are used by surveyors to locate the total station in a pre-existing grid. As the location of the vessel on the earth is generally not considered important when measuring the vessel, the "0" values will not effect our measurements. The **North** and **East** values are northing and easting numbers entered by surveyors. **Elev** is where the operator could enter a known

elevation above sea level. This does not matter to us, nor does **Theo ht,** or the **theodolite** height. This height is the height of the unit measured from a point directly under the total station to the center of the blue plastic line found on the side of the unit just below the words **POWERSET**. Since all of our measurements are relative, we can ignore these values. Note that some value must be entered for the **STN** and the **Theo ht** fields or the operator will not be allowed to continue. Technically the operator can skip the other fields entirely and be allowed to progress.

After pressing the **Enter** key, the operator is given a chance to **Confirm orientation** on the next screen. This is where a surveyor may enter a backsight point by typing in its location or using the total station to measure the point if visible. This does not concern the operator measuring boats, and the operator can simply push the **Enter** key to jump to the next screen.

This next screen looks like this:

Avoid BS

Confirm?

YES **NO**

Since the operator does not wish to take a backsight, she or he should push the Fl key to enter the value **YES** in the dark blue text at the bottom of the screen. Finally, the operator has finally reached the measurement screen and can begin working on the vessel. This screen, where the operator will spend most of the time, looks staggering similar to this:

Take a reading
Stn 0001

Topo
H. obs 349° 10’ 42”
V. obs 128° 52’ 36”

1 READ OFS ANGLE CNFG N

The total station is now waiting for the operator to aim the unit and shoot an actual target. The method used to quickly aim, focus and shoot a target will be somewhat individualized. However, there are a few tips that may be of some help.

To begin with, *the operator should not swivel the unit unless the locking screws for the horizontal and vertical adjustments are loose.* On top of the Sokkia total station is a small black tube with a white triangle inside of it. This is the rough spotting scope for the unit. The operator should get used to using this scope to rough sight the instrument, by noting where this triangle needs to be placed in relation to the target so that when looking through the full scope the target is very near to the center of the crosshairs. This takes a little practice, but shortly the operator will be able to hit the target very accurately with it, thereby increasing the speed at which measurements are taken. It is generally easiest if the operator concentrates on only one of the two axes at a time. Swing the unit horizontally until the triangle is in line with the target horizontally, and then *gently* lock the horizontal locking screw. Next, swing the scope vertically until the target is in line vertically, and then *gently* lock the vertical locking screw. From here on, unless the target is very far away from center and the operator wants to loosen and swing in either the vertical or horizontal direction again, all of the adjustments are made by turning the fine adjustment screws on either knob. Note that each of these fine adjustment screws have a centering mark on the shaft they are on. This is a line that runs around the shaft. If the operator keeps turning these fine adjustment screws in one direction only, they will eventually bottom out. The

operator should then just turn them until they reach the center mark again before aiming the unit at the next target. This is also true with the leveling screws on the base of the total station. If all of the screws start out in the middle of their shaft at the scored line, the operator will not genially run out of threads during the leveling operation. Generally, the operator checks these center marks between shots as the target person moves to a new location.

The other adjustments for the unit are the two focusing rings on the scope itself. The operator should first focus the crosshairs so that they are sharp. This is done by turning the small focusing ring on the eyepiece itself. Each operator will find it necessary to adjust this focus to his or her eyesight. Once this is in focus, the operator can focus the instrument on the target itself by turning the large rubber focusing ring on the scope until the target is in sharp focus. Turning this ring counterclockwise brings objects farther away into focus, and turning it clockwise brings objects closer in into focus. Note that there is an infinity symbol oo and a directional arrow on the scope to remind the operator which way to turn the focus ring for objects farther away. Once the cross hairs are on the exact part of the target desired (this may not necessarily be the center of the target, but may be a specific corner or edge of the target) the measurement is taken by pressing the **Fl** key under the dark blue text that says **READ**. The total station beeps and begins measuring the distance to the target. It then beeps when it has measured the distance and both the vertical and horizontal angles to the target. These will now appear on the screen, which will now look like this:

Code

<No text>

Pt 1000
Target ht <null>
H. obs 264° 43’ 22”
V. obs 81°22’ 13”
S. Dist 14.350
READ OFS ANGLE CNFG A

The total station is now waiting for further instructions. The first text line is where the operator can place a note about the point taken.

If the first shots taken are all to be on the sheerline of the vessel, the word **sheer** might be enough of a description. It should be noted that all of these field notes will appear on the printout later and make a handy reference tool for the draftsman when drawing the vessel. The text that the operator types into this section will carry forward into the next shot. This saves the operator from typing in the same note every time. The operator may then shoot all of the rest of the sheer line before moving on to the next thing, such as the stem profile. When reaching a point that requires a new note, the operator can simply backspace over the old note and type in a new one. The operator can use both the alpha and the numeric keys in this field.

The next line down shows the number assigned to the first point taken. This is set to run from 1000 on up. The numbers will be 1001, 1002, 1003 and so on. The operator can not change this field. The operator can go back and look at specific points if desired by using this number as a reference later, however. The next field, **Target ht,** needs to be filled out for the first shot only. This can be any value, as again all of the measurements are relative. The total station wants to know what the constant height of the target is. Generally this value is entered as **zero**. Arrow down to this field and type in "**0**" and the process is complete. The data has not been permanently stored at this point however. By pressing the **Enter** key, the data is permanently stored and the screen jumps to the next **Take a reading** screen. From now on, all the operator has to do is to focus and shoot the next target, adding any notes in the text block that are needed. It should be mentioned that the operator does not need to push the **Enter** key to save the data taken after each shot. After focusing and pushing the **Fl** key, the total station reads the angles to the new target, beeps, and then returns the distance to the new target. At this point, the operator can swing the total station to a new target, focus on it, and then push the **Read** or **Fl** key again. This will now do two things. First, it will beep and display the message **Input accepted,** meaning it saved the last point taken, and then it will go into the search mode for the new target by displaying a **Searching**... message. It will beep when it has acquired the target and then display the new angles and distance to the target. This allows the operator to more quickly aim and shoot targets, one after another.

The other lines give the operator the horizontal angle measured, the vertical angle measured, and the slope distance to the target. The

person running the total station should consistently check to make sure all of these values are returned. If the gun should go out of level beyond the 3” of arc, it will tell the operator that there is a problem and stop functioning. It does this with a note and a beep, which sounds just like the normal beep of information being accepted into memory. It is therefore possible for the operator to continue with the measurement process thinking that all is well and not actually be recording all of the information necessary. By simply looking at this screen periodically, the operator can not go too far off course.

There are other functions available to the operator at the bottom of the screen in dark-blue text besides the **Fl-Read** key. The **F2** key activates an offset function. Surveyors use this when they want to work along a line offset to something they may not be able to get next to directly. This may be a line ten feet out from a building. They can then use this function to work along this line. This has little use in the measurement of smallcraft.

The **F3** key reads angles only. If for some reason the operator wishes to know the angle between two points, he or she can swing the gun to the new target and get the new target angles, without the distance. This is handier in the surveying world than it is in the documentation of boats. These points are taken and stored just as any others are, but can not be reduced into coordinates due to the missing distance to the target needed to resolve the problem.

The **F4** key allows the operator to enter the configuration field and make any changes needed during the measurement process. This is seldom changed during the measurement of a boat.

Once the measurement team has taken all of the shots needed, the operator can push the **Enter** key and save the last point shot. By hitting the **ESC** escape key four times, the operator should be backed out to the opening Sokkia screen, where the unit may then be powered off by pushing simultaneously both the **ON** button and the light button on the top left corner of the screen. The battery can then be removed, and the unit returned to its case for transportation. It should be mentioned at this point that the unit should never be moved to a new location by leaving it attached to its tripod. Always remove the unit first, and then move and reset the tripod in the new location.

The Traverse Adjustment Function

If the operator returns to the previous screen, she or he will see that the next function is **Traverse adjustment.**

Topography
Traverse adjustment
Resection
Set collection
Set review
Building face survey
Collimation ↓
FUNC COGO ROAD

A traverse in surveying is a set of observations running across a plot of ground. In taking these measurements in the field there is always going to be some error introduced into the system, and this traverse adjustment function provides a way to mathematically quantify the error of the traverse. As this function is not useful in the measurement of watercraft, it will not be discussed further in this manual. Interested operators should consult the Sokkia operating manuals for further information on this subject.

The Resection Function

The **Resection function,** the next selection on the list, is a function that is actually performed in the measurement of watercraft where not all the information can be gathered from one location with the total station. To surveyors, a resection is the calculation of the coordinates of an unknown location through the observation of a number of known coordinates. If a surveyor wants to set up the total station on a new site and relate his or her new measurements and location to previous measurements taken, he or she would use a resection to establish the new relative position. This is what the operator does when she or he moves the total station from one location on the side of a vessel to another location. This is often done on large vessels

where the bow and the transom can not be seen from one location due to the size of the vessel. It can often happen if the total station needs to be moved several times during the measurement process due to other obstructions in the way of the measurement process. In a surveyed resection however, the accuracy of the resection is dependant upon certain measurements taken with a tape measure (this is the theodolite height). The accuracy of the resection is then dependant upon a set of these measurements taken off the ground. In surveying practice, the error of the height of the machine is always going to be very small in relation to the shots taken to new locations thousands of yards away. The error is of no real consequence. This error is less acceptable in the measurement of watercraft. I have developed a system of reference triangles, discussed in the chapter the **Measurement of Ships and Smallcraft with a Sokkia Total Station**, that uses the accuracy of the machine to relocate itself once it has been moved in relation to the first set of coordinate data taken. In effect, the machine does all of the calculations and measurements in this resection. This seems to provide a more accurate way of linking multiple sets of data together than the resection performed by the total station. This manual will not go into further detail on resections. Interested operators can consult the Sokkia operating manuals for further information on this subject if they feel it would be beneficial to their measurement procedures.

The Set Collection Function

The next function on the screen is the **Set collection** function.

Topography
Traverse adjustment
Resection
Set collection
Set review
Building face survey
Collimation ↓
FUNC COGO ROAD

This function is primarily used by surveyors. It provides them with a method of observing a series of points from different locations and using both faces of the total station to refine the overall accuracy of their measurements by having the total station compare them automatically. In surveying, this is very important. In the measurement of watercraft, this is not useful. Out in the field surveyors may be checking less than a dozen points over great distances. In the measurement of boats, the operator may have hundreds of points taken that are not marked and so can not be re-measured later. This function will not be further described in this manual. A thorough discussion of this can be found in the Sokkia manuals.

The Set Review Function

The Set review function allows the operator to review all of the information taken as sets with the total station during the measurement process. Since the measurement process for watercraft does not involve sets, this function will not be used. As always, the Sokkia manuals describe this function in detail if individual operators are interested.
In terms of review of data taken with the total station, however, there is one simple function that may be of so the use to the operator. This is the View key, located on the alphanumeric keypad on the bottom row to the right of the **Enter** key (this is also the Y key). During the measurement process, the operator can press the View key to look at any point taken with the total station in that particular set of measurements. After pressing this key, the total station switches to a screen that looks like this:

Fl 10561↑
Fl 1057
Fl 1058
Fl 1059
Fl 1060
Fl 1061
Fl 1062
SRCH SHFT PREV NEXT

The column on the right lists the point numbers previously shot. The arrows pointing up or down in that column indicate that the operator can scroll up or down to view other points in the set. This can be done by arrowing up or down with the arrow keys. This will move the highlighted section up or down one point at a time. If the operator needs to move long distances through the list, two methods are provided to help with this task. The **Fl** key at the bottom of the screen is for searching the database for a known point or point code (note added during the measurement process). If the operator wants to jump to point **#1022** from point **#11199,** it would be much faster to push the **Fl SRCH** key, backspace through the number showing for **PT,** and then type in the new number **#1022**. Once this number is typed in, the operator presses the **Enter** key, and the database jumps to the number desired. Note that the operator must backspace out the number that exists on the screen when she or he goes into the **SRCH** mode. Otherwise, if the operator simply starts typing in the new number the search will fail, as the new number typed in is being added to the number already on the screen. The total station will then jump to that point number in the database.

The second method of quickly going through the database list is to push the **F2** key labeled **SHFT.** Before pushing this key, the **F3** and **F4** keys allow the operator to jump to the **PREV** (previous) point or the **NEXT** point in the list. By pressing the **SHFT** key, the **PREV** and **NEXT** change to **PGUP** and **PGDN**- page-up and page-down. This allows the screen to jump by pages, rather than by points.

Once the operator has highlighted the point that is to be reviewed, he or she pushes the right arrow key to call up the recorded information on that point. The screen for a point will look like this:

OBS	**F1←**
Stn	**0001**
Pt	**1032**
H.obs	**20°53’20”**
V.obs	**94°22’ 15”**
S.Dist	**30.110**
Cd	**sheer at deck**

MC RED POS

The first line shows that the operator is looking at information stored in the **OBS** (observed) mode. Note that the **F** keys on the bottom of the screen allow the operator to view the information in any of the standard formats. Pressing the **F4** key would give the operator the x, y and z values that will eventually be exported from the total station to the computer. The second line shows that the information was shot from Station 0001. Following that line are the Horizontal and Vertical angles observed for that particular point, as well as the Slope distance to the target. The last line gives the note or code entered for that point. To return to the database list, the operator presses the left arrow key once. From there, another point may be picked for viewing.

Although not used very often during the measurement process, there are occasions where this function is handy. Every now and again the operator may hit the wrong key and be unsure if the machine has recorded a point properly. The operator can then go into the View mode to check this past point. It can also be used to check to see if the machine has been accidentally bumped during the measurement process. By re-shooting a reference triangle target, the operator can then compare the first time the target was shot with the last time it was shot to see if the machine has moved by comparing the measurement information recorded. To return to the measurement process from the View mode, the operator just pushes the **ESC** key.

The Building Face Survey Function

The next function on the list is the **Building face survey function.** While not used very often on maritime vessels, this function is very useful in the historic preservation field. For this reason, how this function works will be described in this manual.

As is apparent by its title, this function is used to measure planer faces of structures such as buildings. The beauty of this system is that the operator can set up the total station in one location, take three measurements with the targets on the building, and then measure the rest of the building without leaving the total station. This makes the measurement of very large or tall buildings much quicker and safer, as there are no ladders or scaffolding involved.

The general principal behind this function is simple. Once the total station has been set up in front of the building, the operator places three targets on the building face and shoots them with the total station. Since the total station reads the angles and distances to these targets, it can completely establish the plane of the building's face. Note that the planer face does not have to be vertical in relationship to the ground. It can be the planer face of a pyramid if desired. From there, the operator simply aims the total station at the points of interest on the building's face. These might be the corners of the windows, doors, additions, porches and details, as well as the roofline at the peak and eaves. By adding notes to the points taken the operator can refresh his or her memory when the points are transferred to the CAD program for production of the drawing of the building. While the operator may not wish to measure small things with the total station, such as the window itself, it is very useful for establishing the large-scale parameters of the structure. The smaller details can be measured by hand and placed into the drawing in the proper location using the reference points shot with the Sokkia total station.

After highlighting and pushing the **Enter** key for this option, the operator is given this screen:

Create Job

Job <no text>
S.F. 1.00000000
Point Id Numeric (4)
Record elev Yes
Atmos crn No
C and R crn No

A

And on the next page if the operator arrows past the **C and R crn:**

Sea level crn No

Here the operator fills out the new job's name and then presses the Enter key if no other changes are to be made. The next screen sets up the location of the total station using the screen used previously for the same purpose:

Stn
North <null>
East <null>
Elev <null>
Theo ht <null>
Cd <no text>

N

As before, if the operator is not trying to tie this face survey into an existing land survey job, the fields can be filled out with the value of **1** for **Stn**, and **0** for all of the other values. After filling these out and pressing the **Enter** key, the operator will get this next screen:

Confirm orientation

Stn 001
BS pt
N

By hitting the **Enter** key again, the operator will be asked if the backsight should be avoided:

Avoid BS

Confirm?
YES NO

After pushing the **F1** key to avoid a backsight, the operator gets to the planer definition screen which looks like this:

Define a plane

Pt 1
Pt 2
Pt 3

Local coords Yes
Type 3D

Read N

At this point, the total station is waiting for the operator to give it three points with which it can define the planer surface of the structure to be measured. This can be done by having the total station read three targets stuck on the plane itself. After placing three targets

on the surface (note- these should be spaced as far apart as possible to increase the accuracy of the plane) the operator presses the **F1** key above the **READ** in dark blue highlight at the bottom left of the screen. The total station then jumps to a measurement screen like this:

Take a reading

Stn 001

Pt1
H.obs 33°47’22’
V.obs 48°15’36’

READ OFS ANGLE CNFG N

By pressing the **Fl** key again, the total station measures the distance and angles to the target and presents the information to the operator in a screen where she or he can add notes and a target height if desired:

Code
(No text)
Pt 1000
Target ht (Null)
H. obs 33°47’22’
V. obs 48°15’36’
S.dist 34.86

READ OFS ANGLE CNFG

After typing in a note if desired, and assigning **0** to the target height, the operator hits the Enter key to record point number 1, and returns to the previous screen. The process is then repeated for points numbered two and three. After this is finished, the plane has been defined. The screen will now look like this:

Define a plane

Pt 1 1000
Pt 2 100l
Pt 3 1002

Local coords Yes
Type 3D

Read N

If the line **Local Coords** does not read **Yes,** arrow down to it and switch this value to **Yes** by pressing the **right-arrow** key to toggle it to **Yes**. If this is left to **No**, the measurements taken will be in terms of Northing, Easting, and elevation. If it is set to **Yes** for local coordinates, the total station will assume the first point taken is the origin (0,0,0) and the information gathered can be plotted as is to draw the building.

When the operator is happy with the points taken and the information on the screen, he or she presses the **Enter** key to advance to the measurement process. This new screen appears:

Take a reading
Stn 0001

Building face survey
H. obs 33°47'22'
V.obs 48°15'36'
Angle-only

1 READ ANGLE CNFG

The operator now aims the total station at whatever point she or he wants to locate and then pushes the **F1** key to read and store the information on that point. Using the two angles, horizontal and vertical, and knowing the location of the plane that the new point lies on, the total station will automatically calculate the position of the

new point. The operator continues shooting points of interest and typing in notes until finished with the job. Note that the operator can also get the angle to a point of interest on the plane in relation to the first point shot by aiming the total station at it and pushing the **F3** key below the word **ANGLE**. This means that the operator may wish to set his or her three initial targets carefully to begin with. Picking a vertical edge, such as the corner of the building for two of the targets, and the other edge of the building for the last point will make things clearer in the end. Once the job has been finished, the operator can hit the **ESC** key twice to back out into the **SURV** screen again:

Topography
Traverse adjustment
Resection
Set collection
Set review
Building face survey
Collimation ↓
FUNC COGO ROAD

By arrowing down, the second page looks like this:

Tilt offset ↑
Remote offset
Keyboard input
FUNC COGO ROAD

The Collimation Function

This brings us to the next function on the list, the collimation function. Briefly, the collimation function allows the operator to minimize error in the readings taken by averaging out measurements taken of the same points from both faces of the total station. The reason for two working faces on the total station is that surveyors will

take backsights to the previous location of the total station using the second face of the machine. In swinging the scope 180° to shoot from the second face, there is some error introduced due to machining tolerances. The collimation function allows the operator to repeat this process multiple times over various points. It stores all of the information and then averages out the readings to come up with a correction that can be added during the measurement process to further refine its accuracy. As this function depends upon the operator to aim the total station exactly at the same point time and time again, it is in effect a measure of the operator's ability with the machine more than it is a measure of the tolerances of the machining of the total station. In practice, the error detected is around one second of arc, which measures how difficult it is to refocus repeatedly on the same point at any distance. For this reason, it is recommended that this correction be skipped. It does not appear to be numerically significant. For more information on this function, see the original Sokkia manuals.

The Tilt Offset Function

The next function on the list is the **Tilt Offset Function.** This function, like the collimation correction, is designed to improve the accuracy in measurements taken by averaging multiple shots of the same point from both faces of the machine. As the original Sokkia manuals do not describe this feature in detail, it can not be determined how it differs from the previous collimation function. This function is performed in the exact same manner as the collimation function, and suffers from the same problem. It actually measuring the operator's ability more than the machine's. For this same reason, it is recommended that the operator ignore this function during the measurement of watercraft. If the operator is interested in this function, the procedure is outlined in the original Sokkia manuals.

The Remote Elevation Function

The remote elevation function may be of some use in the documentation of historic structures, although of limited use on watercraft. This function allows the operator to establish the height of a very tall object without having to climb the object itself. This is handy in the measurement of tall buildings, steeples, bridges, radio towers or even trees.

The principal behind this function is this: the operator sets up the total station some distance away from the object to be measured. She or he then places a reflective target on the object and shoots the target with the total station. Now, knowing the distance to the object, the total station can calculate any height on the object by simply knowing the vertical angle to that point of the object. The operator therefore swings the scope vertically up to the point of interest, and the total station reads out the height in feet or meters to that point by doing the geometry. By adding to this the height of the original target above the ground, the total height of the object is determined.

To use this function, the operator highlights this option and presses the **Enter** key to get to this screen:

Take a base reading
Stn 0001

Remote elevation
H.obs 31°56’ 52”
V.obs 90°21’ 32”

1 READ OFS ANGLE CNFG N

The operator places a target on the base of the object to be measured and shoots the target by pressing the **F1** key. The total station returns the angles and the distance to the target. After pressing the **Enter** key to accept the values displayed, the operator gets this new screen:

Remote elevation

Cd	**<No text>**
Pt	**10l5**
H.obs	**31°56’ 52”**
V.obs	**90°21’ 32”**
Height	**0.000**
Elev	**3.211**

STORE **A**

The machine is displaying the angles to the target, and the height and elevation of the target. Note that the **Height** of the target has been set to **0**, but the elevation of the target above horizontal as measured at the machine is **+3.211**. This shows the target is 3.211 feet above the height of the total station itself. The height of the target above the ground itself would have to be added to the final reading to get the total height of the object measured. As the operator rotates the scope vertically, the machine begins to change the **Height** from **0** to the height of the location at which the scope is pointed. The total station is merely doing the geometry necessary to calculate this for the operator. By pressing the **F1** key, the operator can store this height in the machine’s database to be included in the printout later.

The Keyboard Input Function

The next set of functions on the list are used by surveyors in the field to enter known data. While this could be useful for some forms of historic documentation, it again depends upon human accuracy in terms of setting up the total station to achieve final accuracy, and thus is not used in the measurement of watercraft. This function allows the operator to enter known coordinates from previous shots or maps, as well as azimuths, distances and observations. For further information on this function, please see the Sokkia manuals.

The F-3 Key - COGO

The **F3** key at the bottom of the screen activates the **COGO** menus. These are the coordinate geometry layout functions that the total station is capable of performing. With these options, the operator is able to describe geometry to be set out using the total station. For instance, the operator can set out a third point from two other points at any angle or distance desired. The operator can set out a line through the woods, and arc in a parking lot, find the intersection of two imaginary lines projected through space, or calculate the area of a geometric shape. The **COGO** function allows the operator to take cross-sectional measurements of landforms to produce topographical maps. Again, these features may be very useful during the documentation of historic landscapes, but have very little to do with the documentation of historic boats. Although the resection function (which takes slices through topography) seems similar to what the operator may be doing when she or he measures a boat, it is not a practical method for recording hull forms. While this manual will not go into the functions found under **COGO,** the operator may wish to look at the original Sokkia manuals at this particular section as some of it may be useful for other historic applications.

The F-4 Key - Road

The **F4** key opens the **Roading** functions available to surveyors. As its name implies, it is used in the field to set out roadwork to be done. This allows the operator to locate the edges and center of the road, the amount of fill that needs to be removed or added to obtain the appropriate grade, and many other complicated geometric tasks, such as setting out vertical parabolic curves over a distance. As these functions are well beyond the scope and intention of this manual, they will not be discussed further here. As before, the operator can refer to the Sokkia manuals for help with these functions if desired.

Transferring Data From The Total Station

Once the data has been gathered in the field, the operator will generally download the information to a computer for analysis. There are two methods for doing this. The Sokkia total station can be linked directly to the computer with a serial cable supplied with the unit. On one leg of the tribrach of the total station are two round sockets. One is labeled **6V** and is the connection for six-volt power to the machine, rather than the batteries. There is no six-volt power capacity included with this machine, however, so the operator will not use this connection. The other connection is the **Data Out** connection. This connection is a serial port that connects the total station to the host computer, and allows for the transfer of data to and from the total station. To use this port, the operator sets the total station on the desk next to the computer and plugs in the appropriate cable. This cable snaps into the total station in one direction only. The operator rotates the cable until the locking collar clicks into place on the total station. The other end of the cable is then plugged into one of the serial ports on the host computer. Software on the total station and in the host computer allows the two machines to communicate with each other.

The total station also has a magnetic card reading and writing capacity that allows the operator to write information in the field onto the card. This data is transferred later using a card reader rather than plugging the total station itself directly into the computer. This memory card built into the total station allows the operator in the field to write the information gathered to another source for backup reasons. In addition, if the operator finds that the onboard storage capacity has been reached, she can download some of the jobs to the card and free some of the storage capacity.

There is no preferred method for transferring data from one machine to another, although the direct connection method seems to be the fastest. The advantage of the card reader is that the total station does not need to be set up on the desk every time a job must be downloaded. The card reader can be left hooked up to the computer and the card removed from the total station when the information is to be transferred. Information stored on the total station cannot be accidentally erased from memory before it has been

downloaded. After downloading the information, it is possible for the operator to erase the job from the system and regain space for future jobs.

The system comes with disks containing the Sokkia Comms Plus Software that can be loaded onto the host computer. This program is a DOS program, but it can be run within Windows 95. There is no Macintosh version available. To load the software on the host computer, the operator should follow these instructions:

1) Place the installation diskette into the appropriate drive.
2) At the system prompt, change to the drive where you put the installation disk and type *install.* Press the **Enter** key. The installation screen will appear.
3) Follow the instructions on the screen. By simply pressing the **Enter** key, the defaults will be assigned to the choices to be made. When the installation is complete, the program will offer to run Comms Plus. The operator can run the program by pressing any key, or exit by pressing the **Escape** key. To run the program later from DOS, the operator would simply change the directory to the Sokkia directory (C:\sokkia) and type in the word comms and press the **Enter** key. This will launch the program. To exit the program, the operator simply goes to the File/Exit option.
4) To launch the program from Windows 95, the operator can go into the Sokkia directory through Explorer, and double click on the file **comms.exe.** This file is found under the Comms folder. This will bring up a window with the program running. To Exit from Windows 95, the operator goes to **File/Exit**, and then presses the **CTRL** and the **C** key at the same time.

There are only a few commands in the Comms software that the operator will actually be using, since the majority of the commands are for surveyors. This manual will only deal with the commands needed to extract the information gathered from the total station.

After launching the program, the Comms screen comes up like this:

COMMS

SOKKIA COMMS Plus

File Edit SDR Card SETB/E/6F Options Help

Many of the commands are standard commands found in most software today. These are under the **File, Edit** and **Help** drop-down menus. The commands that are used in the measurement of boats are found under the **SDR** menu. This drop down menu has three options:

Receive, *Send* and *Setup.* The *Send* option is for uploading information from the computer to the total station, and is generally not used in the measurement of watercraft. The operator should first go to the *Setup* option under the **SDR** list to set the communications protocol. This assures the proper handshake between the total station's software and the computer's software. By clicking on the *Setup* option, the operator is given this screen:

SDR Setup

Port	Baud Rate	Parity	Data Bits
( ) Com1	( ) 300	(•) None	( )7
(•) Com2	( ) 600	( ) Even	( ) 8
( ) Com3	( ) 1200	( ) Odd	
( ) Com4	( ) 2400		Stop Bits
	( ) 4800		(•) 1
	(•) 9600		( )2
	( ) 19200		
	( ) 38400		

≤ OK ≥ < Cancel >

The operator can set these parameters from this screen. These must also be set to match on the Sokkia total stations so that the information can be transferred correctly. The values set above are the values that should be used, except perhaps for the Com port value. If you are connected to a Com port other than Com2, check the appropriate box. The baud rate set to 9600 works well. When all of

the appropriate choices have been made, the operator clicks the **OK** on the bottom of the screen to accept the new defaults.
The next step is to set the computer up to receive the data. Under the **SDR** list, again, is the choice *Receive.* This screen looks like this:

Receive From SDR
PC Filename: [ ]
Directory: C :\SOKKIA\COMMS
[X] Use Job Name
≤ Receive ≥ < Cancel >

This screen allows the operator to rename the files as they come off of the total station if desired. Generally, they can be left with the same name as found on the total station. If this is the case, the operator checks off the box that says *Use Job Name.* If the operator wishes to change the name of the file to be downloaded, he or she can type that name into the first line of the screen. Once she or he is satisfied with the name of the new file, he or she clicks on *Receive.* The computer will then go into the receive mode, and wait for the total station to begin sending information. *This must be preset before the send button on the total station is pressed.*

The next step is to set the total station itself to the same parameters and then send the information to the computer. The operator accomplishes this by going to the **Communications** menu on the total station (this is a sub menu to the **FUNC** menu.) Please refer to the previous section on communications for information on this function.

Formatting The Data Gathered.

Once the information has been gathered in the field and downloaded into the host computer, it is up to the operator to put it into the form that is deemed most useful. This form is going to

depend upon the software that the draftsman will use. At Mystic Seaport Museum, Inc., the form most commonly used is a simple text format. The information gathered during the measurement process is stored in two basic formats. One is a plain text file that generally be read into any computer's word processor, and the other is an Excel file that is useful for parsing out the data into neat rows and columns. The software used at the museum can generally read in this type of information as coordinate data. The operator is going to have to determine exactly what format is needed based on the type of software that the information will eventually go into. If it is to be read directly into a CAD program, the format may be a tab delimited form or a space delimited form. The measurements taken are only coordinate geometric points taken in space, and therefore can be read into most programs as points in space. If the information is stored in the simplest form possible, it increases the likelihood that the software of the future will be able to access it. Leaving it in some obscure form only means that it will be more difficult later to use the same information.

MEASUREMENT OF SHIPS AND SMALLCRAFT WITH A SOKKIA TOTAL STATION

This section of the manual is intended to address the application of the Sokkia total station technology to the measurement of ships and smallcraft. For the technical aspects of running the total station, please review the manual on the use of the Sokkia total station itself.

The Sokkia total station is a machine generally used by surveyors in the measurement of land, not ships. It is therefore set up to do that specifically, and all of the terminology and the machine's functions are geared towards that goal. The total station is capable of doing far more than what is required for the measurement of ships. This manual will not go into details on the surveying functions that have no direct relationship to this particular project. These topics can be found in the regular Sokkia handbooks that come with the total station if the operator is interested in these other functions. Some of the functions that surveyors use are similar to the methods described in this manual, and some methods would give surveyors pause. The operator should feel free to experiment at any point along the way with new methods that improve on the methods described here.

Traditionally, when watercraft are measured, a certain routine is followed. The boat to be measured is set up very carefully to be both plumb and level. This can be a significant chore if the vessel is large, and even time consuming with a small boat. Once the vessel is set up in this attitude, and locked into place for the duration of the measurement process, a grid system is then constructed around the vessel to aid in the measurement of the boat. The vessel is divided up into stations, or sections to be measured. These stations are two-dimensional cuts taken athwartships, usually running from the rail to the bottom of the keel of the boat. These sectional cuts are made square to the center-plane of the vessel. Enough cuts are taken throughout the vessel to adequately define the shape of the hull. In general, more cuts are taken at the extreme ends of the vessel where most of the radical change in shape occurs. The mid-section of the hull, where the shape changes slowly, generally required fewer measurements. Once all of these measurements have been taken, and related to a baseline, they are then transferred to a sheet of paper in scale format. The sections are then laid out in relation to each other,

and the work begins to relate them three dimensionally through the use of two other two dimensional views.

The Sokkia total station does not release the measurement team from taking as many measurements as a team using traditional methods. The surface to be captured remains the same, and in fact, more measurements may be taken due to the speed and ease of the measurement process. There are differences, however, in the two processes. The initial difference is that the vessel to be measured does not need to be set up prior to the measurement procedure. The only requirement is that the area to be measured be visible from a location that the total station can be set upon. This allows most boats to be left as they are. Boats have been measured sitting up on racks, leaning over on the ground, or as hauled on marine railways or docks. The coordinate data is gathered with the vessel at its current attitude. After it has been loaded into the computer software, it can be rotated on the screen into a plumb and level attitude for the rest of the work. Therefore, there is no need to move the vessel around as long as the side to be measured is at least visible from one or more locations.

The second major difference is in the lack of a need to measure the vessel squarely to the center-plane of the vessel. That is to say, the sectional measurements can run at any vertical angle to the ground below the ship. While it is nice to have plumb cuts through the vessel, it is not required. It is not technically even required that the points taken be in a straight line, although it certainly looks better to have them so when the data is worked with later on the computer screen. This is not to say that the Sokkia total station can not be used to gather information in the traditional way in terms of station cuts. The total station can be set up on stations and can be used to take vertical cuts through the hull. This method will only be slower in the field. If the data is to be reduced later by hand, however, this may be the method of choice. This system does not require it.

The final difference, and a major one from the older system, is in the development of the lines plan of the vessel using sophisticated three-dimensional modeling software. Since all of the coordinate data is gathered in three dimensions, it makes the most sense not to reduce it to two dimensions until ready to print the final paper plans. The software of choice, *MultiSurf,* by AeroHydro, will read in directly the information gathered with the Sokkia total station and plot the points as three-dimensional coordinate points. Since *MultiSurf is*

parametrically based software, any changes made to the hull is automatically reflected in all of the views at the same time, eliminating the need to constantly redraw the three views of two dimensions as drawn on paper.

The advantages then of this system then are 1) It eliminates the need to set up the vessel to be measured in any specific way. 2) It makes the measurement of the vessel faster and more accurate, and all in three dimensions. 3) It allows a quick method to draw up the lines plans, as well as obtaining basic hydrostatic information on the vessel described. There are some differences in the measurement process used with this electronic system that need to be explained. Most of the differences have to do with the software that the information will be fed to. Different shapes will require different data sets to fully capture the shape of the vessel. Listed below are some of the methods used at Mystic Seaport Museum to capture these shapes. Other techniques can be employed. The operator of the system should certainly feel free to experiment and come up with new methods for tackling the problem at hand.

Setup of the Sokkia Total Station

This is the general method used to set up to measure a specific ship or boat. The vessel to be measured must be stationary for the period that it is measured. Once the measurements have begun, neither the object to be measured nor the total station should be moved without previous planning. With large ships, this is generally not a problem. The mass of the vessel keeps it still. Smallcraft, however, are easily bumped and shifted if they are light enough. When measuring a small boat such as a canoe, it is generally easier on the operator to place the boat on a set of wooden work horses, propping the boat up so that the entire side of the boat can be easily seen from the total station location. In this way, the person holding the target does not have to constantly bend over to place the target. The total station itself is also easily disturbed by accidentally tripping on its tripod legs, so that some care is required by the total station operator. Larger vessels may require that the total station be moved from one location to another to obtain a full set of measurements. This is often the case if the total station cannot be set far enough back

from the hull due to space constraints, or the shape of the ends of the vessel will not allow all of it to be seen from one location. In these cases, the total station may be moved to as many different stations as required to complete the measurements. After the total station and the boat are set up and the operator is ready to begin the measurements, the first thing to be done is to establish a base triangle of targets.

SETTING OUT THE REFERENCE TRIANGLE

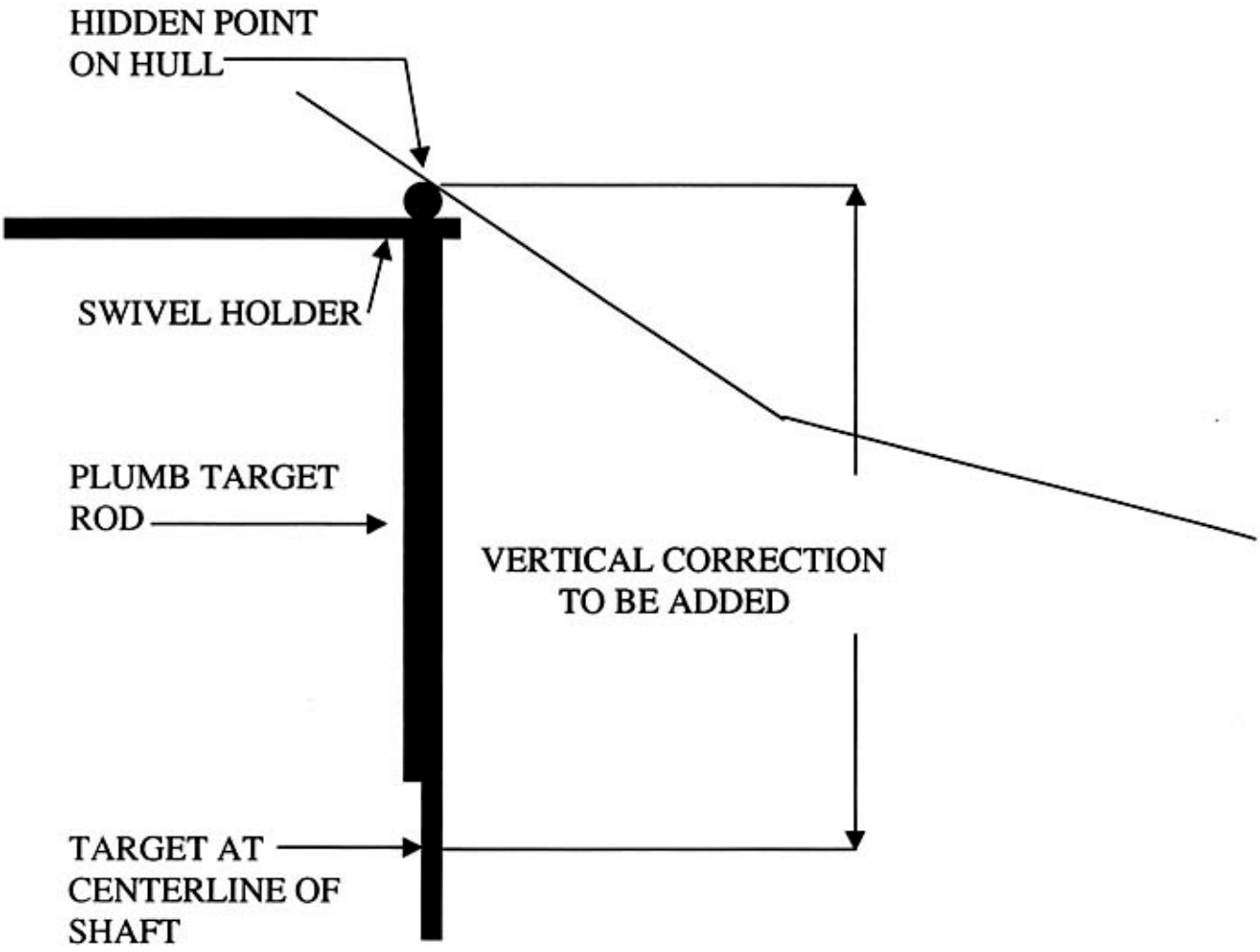
It is always preferable to measure a vessel from one location if possible. This merely reduces the chance for error and increases the accuracy of the measurements. This is not, however, always possible. In these cases, it is therefore necessary to set up a reference triangle. The reference triangle is a set of three targets set before beginning the actual measurement of a vessel. The triangle is not required to measure a boat, and is only intended to help prevent accidental loss of data should either the boat or the total station move during the measurement session. This reference triangle is often not used in the measurement of small boats, as the measurement process for them is short and not much time would be lost if the process had to be started over again. It is highly recommended, however, in the measurement of vessels that will take more than a half an hour to measure or that will be difficult to measure (i.e. the vessel is laying over in a mud flat and you need to beat the tide!). The triangle *is required* if the total station needs to be set up in more than one location to fully document the vessel.

The triangle of targets allows the operator to tie together sets of measurements taken from different locations. These locations may be from one end of the ship to the other, or they may be in the same approximate location after the tripod has been kicked and re-leveled. With three points common to all sets of measurements, a single universal coordinate system can be found and all of the coordinate data can be put into its proper relation with each other, producing one final master data set. The way in which this works is this: Three stick-on targets are set out such that they can be seen from all possible locations the total station may be set during the measurement session. The three targets should be placed as far apart from each other as possible, and as close to an equilateral triangle as they can

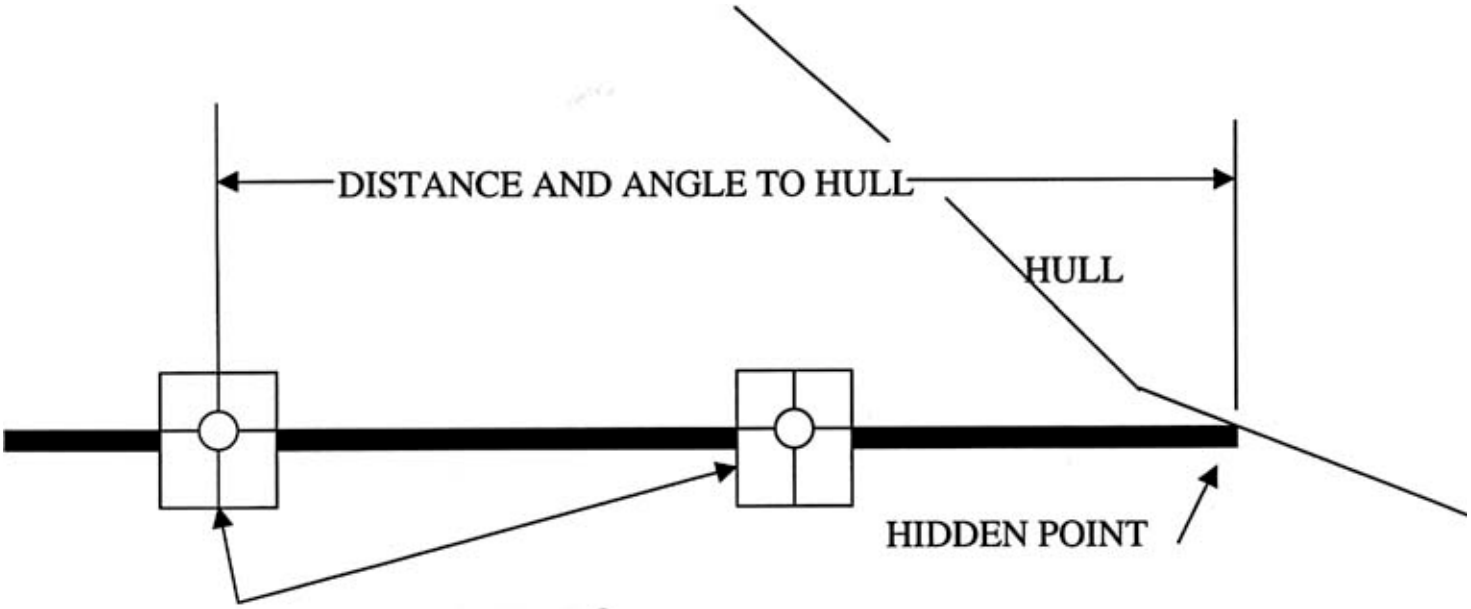
be. Usually one target is placed on the hull itself, while the other two targets are placed on any object out from the ship that will remain stationary through the measurement process.

These targets become the first three shots made with the total station, and are generally labeled with a descriptor that identifies them later. This can be simply *triangle, triangle and triangle.* At any time throughout the measurement process if the Sokkia total station is moved, a new set of these three points is taken as the first step at the new location. Similarly, if the boat shifts by accident or the tripod is kicked, a new set of coordinate data can be started by first re-shooting the triangular reference points first. In this way, hours of measurements are not lost due to an accident. Using this concept of coincident points, other sets of measurements of the vessel can be related to the hull shots. For instance, the total station can be set up on the deck and major construction details can be shot, like the location of deckhouses, masts, hatches or companionways. These can then be located properly with respect to the other measurements.

Often it is difficult to set up a triangle when space is limited around the vessel to be measured. In this case, we have used special target holders that consist of a base weight with a hole drilled through it. Into this hole is inserted a round shaft that sticks up about 8 inches, and has a flat spot ground through the shaft to the centerline of the shaft. The flat spot should be at least as tall as the 10mm targets. One of these targets is then applied to the flat spot, which places the target at the center of the shaft. This is then placed on the ground and is used as a one of the triangular targets. It has the advantage that the shaft can be rotated to face the total station no matter which end of the ship the total station is located. Since the target is in the center of the shaft, its location does not shift during rotation. Other types of specialized targets allow for the taking of slightly hidden points of interest on the hull. By creating a target glued to a centerline flat spot, ground out of a small shaft, and hanging from this shaft like a plumb-bob from the hidden point such that the target is in view, the operator can merely add a vertical correction to the target location to get the hidden point, as the correction will only need to be added in one direction:



Another method can be used to pick up hidden points, such as using a long shaft with a pointed end that is placed on the hidden point. On the other end of the shaft, two targets are applied down the shaft, in view of the Sokkia total station. By shooting the two visible targets, and knowing the distance from the targets to the point of the shaft, the location can be worked out for the hidden target:



TWO TARGETS THAT CAN BE SEEN FROM THE TOTAL STATION

The operator of the total station should experiment and come up with other solutions to measurement problems.

Measurement of the Vessel Itself

After the triangular reference targets have been recorded, the operator begins to measure the vessel itself. The measurements that he is generally interested in are similar to the measurements that he would take doing it in any other fashion. The order that the measurements are taken does not really matter, as all of the coordinate data will appear in the correct relationship to each other in the final data set. However, there are certainly reasons to collect the information in as logical a manner as possible when measuring the boat. The first reason, of course, is that measurements required for the completion of the lines plans are less likely to be missed in an organized procedure. The other reason is that all of the coordinate data will be assigned a number in the software that deals with the points. When working with the data later it is easier to identify points with specific locations on the hull if the are in a logical numeric sequence. This is, fortunately, a natural way to measure a vessel anyway.

The actual measurement of the hull should always include a few specialized shots that help the operator to plumb and level the vessel on the computer screen later. I have made up a set of special field note sheets to help the operator remember to take all of the

information needed while measuring a vessel. These sheets look like this:

DATA COLLECTION SHEET SHEET #_____ OF____ DATE___/___/___
VESSEL NAME: MEASURED BY:_____
SIDE MEASURED: STARBOARD___ PORT___

POINT #	X	Y	Z	CORRECTIONS ADDED	DESCRIPTION
					(0,0,0) 1ST POINT
					FWD KEEL REF.
					AFT KEEL REF.
					FWD.VERT.REF. 1
					FWD.VERT.REF 2
					AFT VERT.REF.1
					AFT VERT.REF. 2
					WATERLINE FWD
					WATERLINE MIDSHIP
					WATERLINE AFT
					(0,0,0) LAST POINT
					MEASURED THICKNESS OF SHEAtHING
				FIRST SET	TRIANGLE REF. A
					TRIANGLE REF. B
					TRIANGLE REF. C
				SECOND SET	TRIANGLE REF. A
					TRIANGLE REF. B
					TRIANGLE REF. C
				THIRD SET	TRIANGLE REF. A
					TRIANGLE REF. B
					TRIANGLE REF. C
				FOURTH SET	TRIANGLE REF. A
					TRIANGLE REF. B
					TRIANGLE REF. C

DATA COLLECTION SHEET SHEET #_____ OF____ DATE___/___/___
VESSEL NAME: MEASURED BY:_____
SIDE MEASURED: STARBOARD___ PORT___

POINT #	X	Y	Z	CORRECTIONS ADDED	DESCRIPTION

Separate sheets should be maintained for each vessel, and each vessel should at least have the first sheet filled out. Although the Sokkia total station will accept notes along with each of the points taken in the field, in practice there are often notes that the operator forgets to add in at the time that the shot is taken. This paper version allows the operator to add these later to the information gathered. These sheets are to help clarify questions later at the drafting session, where all of the data is reduced. Quick field notes on specific points taken in the field go a long way in speeding up the work at the desk later. Not every point taken needs clarification. Most of the data will be sectional data taken that will require no special notice. There are special points taken, however, that will be within the main body of points, and will be more readily identified with these field sheets. An explanation of what the sheet means is as follows:

The top block of information is self explanatory. Any other known information about the vessel may be filled out on the back of the sheet for easy reference later, or in another field notebook. As the operator uses the total station to collect coordinate data, each point shot is assigned a number. The first column of the sheet, **Point #,** is where the operator would place this number for later reference. The columns **X, Y** and **Z** are where the coordinate location of that specific point can be recorded if desired, although in practice very few coordinates are hand recorded. It is handy, however, to write down the coordinates of the reference triangle down the first time they are shot. After this, if there is any time when the operator feels that something has changed during the measurement process, such as a bumped tripod, all the operator needs to do is to re-shoot the reference triangle and check the new reading with the initial readings to see if there is any change. The **Corrections Added** column is where notes on corrections can be made. This would only be used with targets that are specially made, and in most cases can be ignored. The **Description** column is merely a place to note what the special point may be. This may be an easy place to note that a point was a waterline, the location of a major construction detail, the center of a porthole, or any other critical point that may not appear as obvious once it is mixed in with four hundred other points.

Under the **Description** column there are pre-entered point descriptions on the first page. These are points that the operator is generally going to want to take with every boat measured, and are

written in to keep the operator from forgetting to take them. The first entry is **(0,0,0) 1st Point.** This is a point that can be used to check periodically to see if the vessel or the Sokkia total station has moved during the measurement process. If the coordinates are written down on paper after shooting the target, it can then be shot later on to make sure nothing has shifted. The next two rows **are FWD KEEL REF,** and **AFT KEEL REF**. These are two shots along either the centerline of the keel if possible, or along a side of the keel parallel to the centerline of the ship, spaced as far apart as possible. They allow the operator to quickly align the coordinate data with the X axis once it has been loaded into the software for processing, since it is traditional to have the keel run down the X axis while drawing the vessel. The next two points to be gathered are called the **FWD.VERT.REF.1** and **FWD.VERT.REF.2**. These are two points located on the centerline of the stem of the vessel, and like the keel reference lines, are used to line the coordinate data up vertically later while the points are being reduced. This line quickly determines how to plumb the vessel up. If this line is running at a 4 degree slope, i.e. the vessel when measured was at a 4 degree list, the operator merely needs to rotate the data set minus four degrees to have the vessel standing straight vertically. This is why the vessel to be measured does not need to be set up previously to the measurement session.
The points **AFT VERT.REF.1 and AFT VERT.REF.2** perform the same task as the forward reference marks. I have also found that they provide one more service. Comparing the forward vertical reference line with the aft vertical reference line gives the operator an immediate feel for the amount of twist present in the vessel. In almost all of the cases of wooden boats that I have measured electronically, I have found twist in the hull. Some of it is minor, and some of it is quite pronounced. Often this twist is not discovered with conventional methods.

The next three points to be gathered somewhere along the measurement process are the points that pick out the waterline of the vessel. These points are the **WATERLINE FWD., WATERLINE MIDSHIP,** and **WATERLINE AFT.** This can be the floating waterline if known, the painted waterline, or probably in a best case scenario, both waterlines. These points are used to tilt the vessel into the proper attitude on the computer once the data set has been entered into the computer.

The **(0,0,0) LAST POINT** is a re-shoot of the first point taken, and is only there to assure the operator that nothing has moved during the measurement process by comparing it to the written down coordinates of the first shot.

The last of the pre-recorded points are the triangle reference shots that are usually taken during the procedure. They are listed as **TRIANGLE REFERENCE POINTS A,B** and **C**, and there are four sets of them on the data sheet if needed. The other blank areas on the sheet are to record other points of interest that have special meaning. These may be locator points for structural details that you want to include in the final drawing, such as the center of every porthole down the side of the ship, the location of a deckhouse, or the angle that the chain-plates hit the hull. It is often easier to write quick paper notes while measuring than to type them into the Sokkia total station.

After these initial shots have been taken the actual measurement of the ship begins. The information to be gathered for the production of final lines plans is based on the needs of the software that the information will be downloaded into, or by the needs of the draftsman that will be handling the information in the end. This system is assuming that the software will be *MultiSurf*, by AeroHydro. The first set of points that are usually gathered are the measurements that make up the outboard profile of the vessel. These are often at the edge of the stem, keel and sternpost of the vessel, running from one end to the other in sequence. The centerline of the keel can be taken if visible, but this is generally handled more quickly by a simple measurement of the thickness of the keel and noted on the paper field note for the vessel.

Once again, the sequence of the shots does not really matter in the long run, but has the advantage of being faster in the field to take. The operator of the Sokkia total station must aim and focus the gun at every point to be acquired. Large changes in distance or angle from the previous shot require a larger amount of re-focusing and adjustment on the part of the total station operator, and thus more time in the field. If the operator of the gun needs to make short swings with the instrument, the re-focusing and aiming of the gun is much quicker. If the vessel is large and the target person needs to be up on a ladder, it is often better to shoot out of sequence so that the ladder does not need to constantly be moved back into the same area

it had previously occupied. Each vessel will have a different shooting sequence depending on the size and degree of difficulty; the operator should feel free to measure in what ever order makes sense.

The next set of points to be gathered for the software is the rabbet line of the vessel. These points will form the edge of the main surface to be created in *MultiSurf.* Although you will only use the rabbet points on the stem and the stempost to create the *MultiSurf model*, I generally shoot the entire rabbet line anyway. This allows for more control and checks later in the drafting process. As the operator begins a new set of shots, he should enter into the note field the proper description, such as RABBET LINE, STEM PROFILE, KEEL EDGE etc., etc.. These will be printed out when the information is downloaded onto a computer, making the jumble of points easier to understand.

The next set of shots are generally the station cuts through the hull, running from the top to the keel. The operator will have to decide how high the first points will go. These may be the top of a gunwale, the bottom edge of a covering board, the deck line or any location that makes sense in terms of drawing the vessel. The method for taking off the station cuts is vastly different as done with the Sokkia total station than it is utilizing traditional methods, and bears some explanation.

Traditionally, when a vessel is measured, the length of the boat is divided evenly up into stations that are perpendicular to the keel line of the boat. Measurements are taken normal to the keel, with more sections possible taken at either end of the vessel to account for greater changes in shape. These two dimensional cuts are then transferred to paper and arranged in the order that they appear on the vessel. The three dimensional relationship of the section cuts is then worked out in two other views - the plan view and the profile view. Because of the way the three dimensional information is worked out, it is necessary to take the sectional information squarely to the keel line in order to keep the relationships clear. Any biased cut through the hull produces the need for the draftsman to work with projections to establish the true relationships of all of the parts. This is due to the fact that the vessel, a three dimensional object, is being represented on two dimensional paper. With the advent of three dimensional surface modeling software, however, this need no longer exists.

All of the information gathered with the Sokkia total station is in three dimensions, and is transferred to the computer later in this format. All of the points gathered maintain their real-world relationship with each other. There is no need for any projection work to be done. This means that any points gathered on the surface of the hull can help define the surface of the hull. What this means to the operator is that the need to carefully align himself with exact stations and carefully set up the measurements to be taken no longer exists. The total station generally only needs to be set up in one location to shoot the entire boat, and the sections taken no longer need to be normal to the keel. All that is required for *MultiSurf is* enough cuts through the surface to adequately define the shape. In this way, it is no different from traditional needs. When taking sectional cuts, the person holding the target on the hull merely needs to run down the hull, spacing the points close enough to adequately capture the curvature in that area, in roughly a straight line till reaching the rabbet. Often it is convenient to follow a row of fastenings or other suitable marks along the hull in order to keep the points lined up. Other marks may be temporarily applied to the hull to give the target person a line to follow. These marks may be a chalked line, a strip of tape or a piece of string stretched out over the boat. It is not necessary that they be in a perfectly straight line, but the straighter the better for the final product.

The points taken with the total station are going to be used to define the surface of the vessel's hull. After this surface is created, it can then be sliced in any fashion desired for the production of the final lines plans. This is when the vessel will be cut into nice station cuts square to the keel, or waterline cuts or buttock cuts. This means that the operator does not have to worry initially about squareness when taking station cuts. The cuts only need to be square in the final product.

The sectional cuts are then measured with the total station, spacing them by eye down the length of the vessel. They should be placed often enough to fully capture the change in shape in the hull, with special care going to capturing the extreme ends of the vessel where this shape change is the most dramatic. It is easiest to imagine the points that need to be gathered by thinking of them as the points needed to draw out that same curve on a mold loft floor with a wooden batten. If there are not enough points taken the batten will be

either too flat or too rounded when sprung into the shape. On the other hand, too many points will cause the batten to kink in some areas. As a general method of practice, it is always better to take more than enough points during the measurement of a boat rather than end up with than too few. These extra points do not need to be used when drawing the vessel but can remain on the screen to assure the operator that the curves he or she is fitting are correctly defining the shape measured. The number of measurements taken will become more obvious as the operator gets used to the software and its requirements. This generally means that the first vessels measured will have more points taken that necessary for the strict production of lines. In any case, however, the operators of the total station will generally want to take as much information as time allows, as the opportunity may not present itself at a later date.

In the measurement of boats that may not be seen again, it is also a very good idea to bring along at least a 35mm camera and some rolls of film to photograph the vessel during measurement. This aids the draftsman immensely later when reducing the data. A picture brings back immediately all of the complexity of the vessel and jogs the memory while drafting. This is particularly important if the data is not to be reduced till a later date or the draftsman will not be able to walk over and take another look at the ship. Things that seemed so obvious in the field are quickly lost to time.

Once all of the sectional measurements have been taken, the transom area needs to be recorded. This is generally the most difficult area of any vessel to record, and great care should be taken to capture enough information in this section of the boat. This is the area that is also the most difficult to surface model from a drafting standpoint. The transom areas that prove to be the most difficult to handle are the ones with large overhangs. These require careful planning while taking off the measurements in the field. Transoms with no overhang or double ended craft are generally quite easy to handle. Once again, after the operator becomes more familiar with the software that the measurements are used in, the data that needs to be collected in the field will become more obvious.

BREAKING THE PROCESS INTO JOBS

If the vessel to be measured is large and more information than the information required to draw the lines of the vessel is going to be taken, the operator should consider breaking up the shoot into differing job names. This means that the operator will shoot one type of information at a time, such as sectional cuts by themselves, the profile by itself, deck structures by themselves, etc.. All this means in the field is that the operator simply starts a new job name as she or he moves to a new type of information. This does not require any new setup time, but breaks the information down so that it can be individually loaded into a CAD program and thus easily placed onto separate layers or be given different colors to help the draftsman tell the points apart. Drafting in three dimensions can be a very tricky thing, as the computer screen still is a two dimensional screen. This means that points that seem in lie in one plane can be very far off when viewed in the other two planes. Any kind of visual help such as color can give the operator extra information while drafting, and allows the separate information to be turned off when not needed. While taking the measurements, the operator should take the extra time required to type in quick notes for the points taken. This drastically speeds up the drafting process later as a screen full of unidentified points can become quite confusing.

BEYOND LINES TAKING

The data described above is the information necessary to construct a basic set of lines for the vessel measured. It is not, however, the only information that the operator may wish to gather. The total station may be used to gather other information that may be used to produce a more complete set of drawings beyond the lines plan. This may include points that locate major construction features such as the location of portholes, rigging features, rails, hardware, carvings, sheathings, or plank lines. Some of this information can be incorporated as the initial work is done. Often the operator can take a shot at each plank seam as each sectional cut is made. In this way, two birds are taken with the same shot. The operator can later draw in the planking lines without having to go back for additional

measurements by simply connecting the planking points fore and aft with the appropriate curve.

The Sokkia total station may not always be the best machine for the job at hand when drawing out the structures that are to be place on the vessel. For instance, the measurement and drawing of a hatch assembly may be best if measured with a standard ruler, and then entered into the drawing later. In this case, it may only be located in the proper position on the ship by a single shot with the total station to locate one corner of the structure. This relieves the operator from having to take detailed measurements by hand on the deck of a large vessel to try and properly locate an object. If the total station is set up on deck to measure out the layout of the vessel, the operator can tie the set of measurements to the hull measurements by once again shooting three common points to each set, or by referencing both to a object common to both sets.

MONITORING CHANGES IN A VESSEL'S SHAPE

The Sokkia total station, due to its inherent accuracy, can also be used to monitor changes occurring over time in a vessel or object. This information may be used to detect problems with the structure ahead of the time when it may become obvious in other ways. This may be done by placing permanent locators on the hull of the vessel that can be measured periodically. For instance, bronze screws with heads the same size as the 10mm targets could be placed into the sheerstrake of a vessel and targets could be held over the heads and shot with the total station every six months. The information from each subsequent set of shots could then be compared quantitatively to monitor change over time in the hull. Any points that can be relocated exactly each time the vessel is measured can be used for this type of analysis.

The one thing to remember is that the vessel can not be moving during the measurement process unless the total station is on the vessel and is moving with it at the same rate. It is possible to set the total station on the vessel and take measurements if the vessel is relatively still. The Sokkia total station has internal compensaters that act to keep the unit level despite small shifts in the tripod. This is to account for the legs of the unit settling into the dirt while on land, but can also accommodate small angles of heel in the vessel (up to

three minutes of arc) in two axis. As long as it is a relatively still day, this should present no real problem. If the three minutes of compensation is exceeded, the operator is warned by the machine and the operator is not allowed to continue without re-leveling the total station. Once the information has been collected, it can be downloaded into a CAD (computer aided design) package for comparison.

USING THE TOTAL STATION TO MEASURE OTHER OBJECTS

The Sokkia total station was not originally constructed to measure boats or ships. Its primary function is in land surveying. It can, of course, be used to measure any object of a large enough size. By this I mean that it would not be the appropriate machine to use for the documentation of ship models. It can be used in other historic documentation fields to capture both two or three dimensional information as desired.

The total station can be used to gather archeological information on a dig. For the operator to capture the three dimensional information of objects recovered during a dig, the total station can be set up and each find located with a single shot taken as the object is uncovered. The information in test pits spread over wide areas can be tied together using the total station.

The total station can be used to measure buildings using its FACE SURVEY function. This function allows the operator to measure the face of a large structure without having to resort to getting out scaffolding or ladders to reach points high above the ground. The operator sets up the total station at a convenient location and shoots three points located on the face of the building to be surveyed. This allows the machine to establish the plane of the face. From there, the operator aims and shoots the points of interest on the face of the building. The total station will calculate the location of the points shot by turning the horizontal and vertical angles and calculating the distance to the plane at that point: This is especially handy for the measurement of tall structures or very large structures. Once again, it may be best to gather some of the information to be included in the drawing by hand, while locating the object on the structure with the total station. The operator may choose to measure and draw the

windows using a ruler, and then locate the bottom left corner of all of the windows with the Sokkia total station. As with the measurement of ships and boats, the information taken in the measurement of any object is generally going to be the same as would be taken by traditional methods. In some cases it may not be the correct tool for the job, or it may be the correct tool for part of the job. It will be up to the individual operator's discretion to determine which tool to use.

REFERENCES FOR THE DOCUMENTATION OF VESSELS

There are several good reference works that can be consulted on the documentation procedures used to record vessels of all sizes. The only shortcoming of these books are their information on computer aided measurement and drawing. As the authors are generally used to traditional methods, they have very outdated information on electronic methods. However, the general information that they provide is invaluable as a reference tool. I will list the two works that I am familiar with, realizing that there are many others out there:

Anderson, Richard. K., *GUIDELINES FOR RECORDING HISTORIC SHIPS*, Second Edition, 1995. For Historic American Buildings Survey/Historic American Engineering Record, National Parks Service, U.S. Dept. Of The Interior. Washington, D.C.

Lipke, Paul/Spectre, Peter/Fuller, A.G. Editors, *BOATS: A MANUAL FOR THEIR DOCUMENTATION.* American Association of State and Local History and the Museum Smallcraft Association, 1993.

Quick Start Directions

These directions are to get the measurement team set up and measuring a vessel as quickly as possible. They assume some familiarity with the process and the total station. These instructions also assume that the configuration of the instrument has been preset. They are basically quick notes to remind the operators of certain procedures.

1) Set up and rough level the tripod on firm ground. Remove the total station from its case and screw to the tripod.
2) Roughly level the Sokkia total station using the small bubble level on the mounting unit. Once this is done, fine level the unit, using the large bubble level on the gun itself.
3) Turn on the total station by pushing the ON button. Wait for this screen to appear:

H 0 set
V 0 set

4) Making sure that the horizontal locking screw and the vertical locking screw are both loose, swivel the unit horizontally and vertically until it beeps once in each direction and the above screen disappears. The next screen should look like this:

SET3000
No.011275
Expert
Ver. 04-20
139-00-04
139-10-08
© 1996 SOKKIA

5) Push the **ESC** escape button once to jump to this screen:

P.C. mm **0**
ppm **0**
2
H.obs **245°13’14”**
V.obs **88° 24’ 09’**
S.Dist **<null>**

1	**Read**	**PPM**	**CNFG**	**REC**

6) Push the **F4** key under the word **REC** in dark blue letters. If you get a screen that says:

Discard changes
ppm
...Press any key...

then press any key to jump to the next screen, which should look like this:

07-Oct-97 **13:27:48**

Job
Stn
BS pt
3

Free Recs **1117**
FUNC SURV COGO ROAD

7) Press the **Fl** key under the word **FUNC** in dark blue letters. The screen should look like this:

Job
Instrument
Job settings
Configure reading
Tolerances
Units
Date and time ↓
SURV COGO ROAD

The word **JOB** should be highlighted in blue. If not, highlight it by using the arrow keys to get to it and press the **Enter** key.

8) Press the **Fl** key under **NEW** to start a new job. The next screen should look like this:

Create Job
Job **<no text>**
S.F. 1.00000000
Point Id Numeric **(4)**
Record elev **Yes**
Atmos crn no
CandRcrn no ↓
A

9) Type in the name of the vessel or some identification for the **Job** name.
10) Press the **Enter** key.
11) If a note is desired type it into the **Note** screen and press the **Enter** key. You will get **a** second screen **to type** notes on. Press the **Enter** key again. If no notes need to be added, simply hit the **Enter** key. You are returned to this screen:

Job
Instrument
Job settings
Configure reading
Tolerances

Units
Date and time ↓
SURV COGO ROAD

12) Press the **F2** key under the word **SURV** in dark blue letters. The next screen is this:

Topography
Traverse adjustment
Resection
Set collection
Set review
Building face survey
Collimation ↓
FUNC COGO ROAD

13) The word **Topography** should be highlighted. If not, use the arrow keys to highlight it and press the **Enter** key. The next screen should look like this:

Stn
North <null>
East <null>
Elev <null>
Theo ht <null>
Cd <no text>

N

14) Type in the number (1) for the first line **STN**.
15) Type in the number (0) for the line **North**.
16) Type in the number (0) for the line **East.**
17) Type in the number (0) for the line **Elev**.
18) Type in the number (0) for the line **Theo ht.**
19) Press the Enter key. The next screen looks like this:

Confirm orientation

Stn **0001**
Bspt

N

20) Press the **Enter** key.
21) The next screen asks you to confirm avoiding the back sight. Press the **Fl** key to answer **YES.**
22) Aim and focus the total station on a target. Push the **Fl** key to take a reading. This the total station will beep and then return a screen that looks like this:

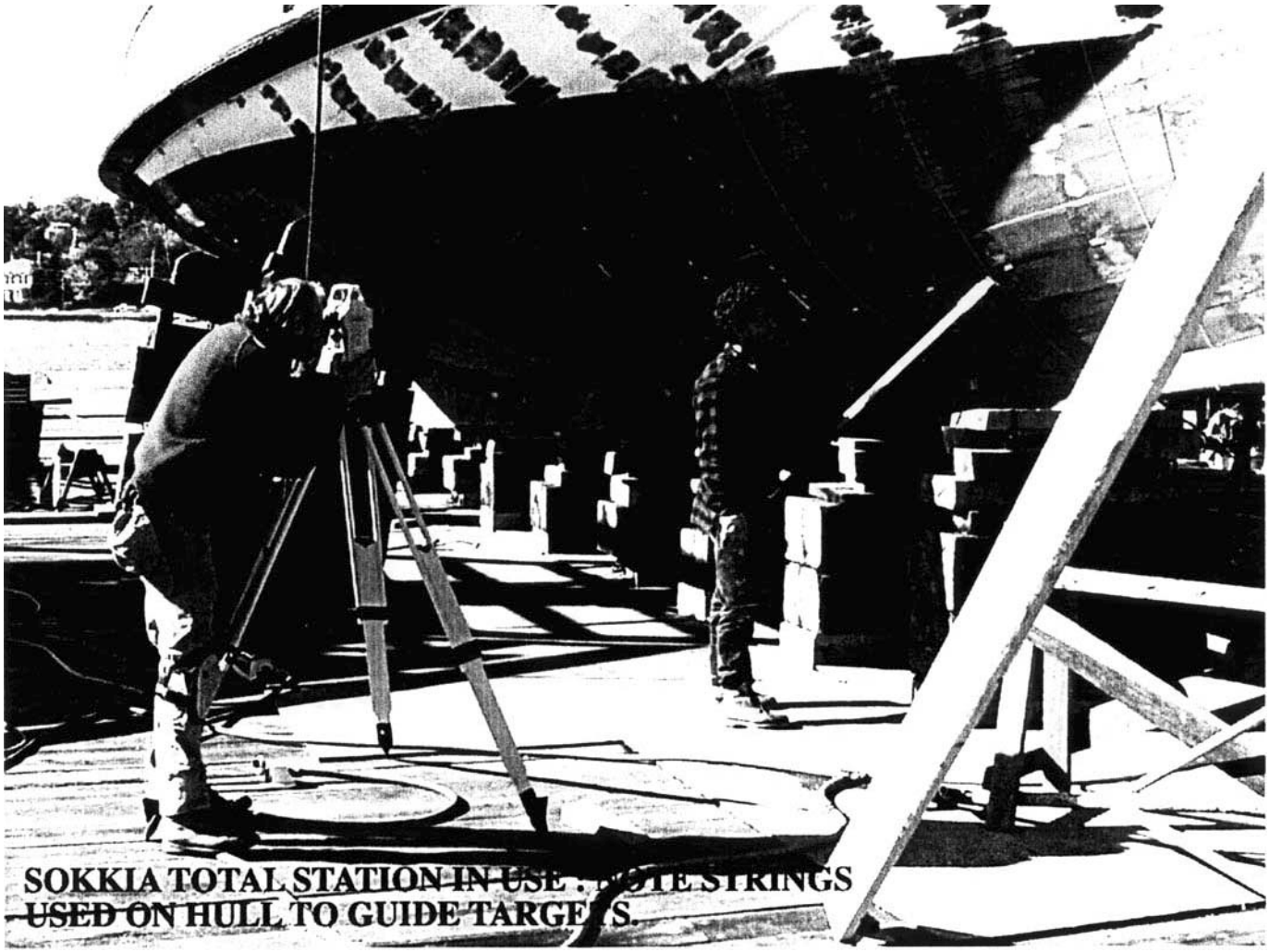
Code

<No text>
Pt **1000**
Target ht **<null>**
H. obs **264° 43’ 22”**
V. obs **81°22’ 13”**
S. Dist **14.350**
READ OFS ANGLE CNFG A

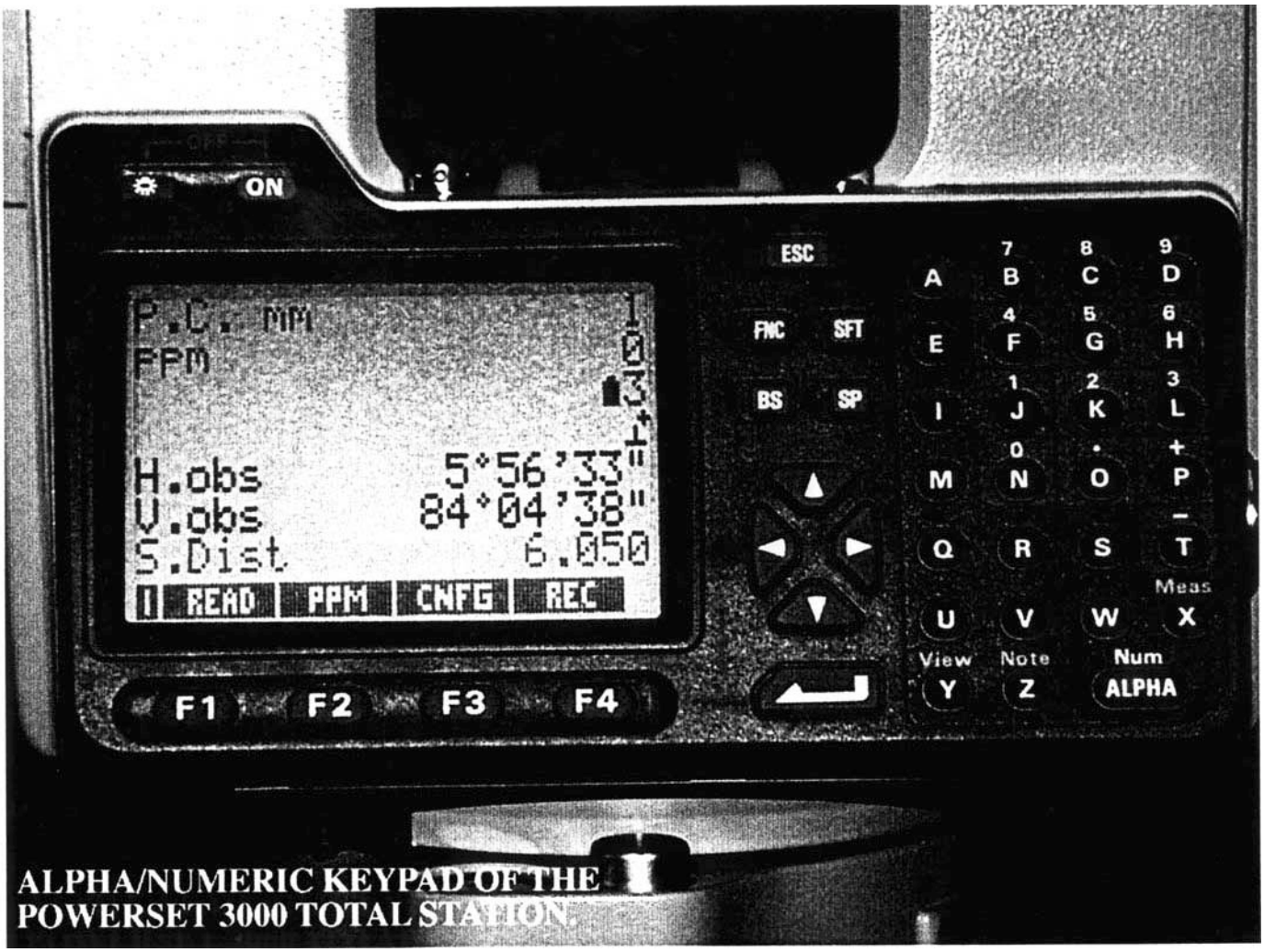
23) Type in a name for this first point if desired where it says **<no text>.**
24) Arrow down to the line **Target ht**. Enter (0) for a value here. Press the **Enter** key.
25) The station is now set to take repeated measurements. Aim and focus the total station on the next point and push the **Fl** key to read the next target. Continue in this fashion until done.
26) After shooting the last point, press the **Enter** key to store the last point.
27) Press the **ESC** or escape key four times to return to the **Set3000** screen. Turn off the total station by simultaneously pressing the **ON** button and the button with the light on it to the left of the **On** button. Remove the battery from the total station and pack the unit back into its shipping case.

OPERATOR HOLDING REFLECTIVE TARGET AGAINST THE HULL OF THE VESSEL.

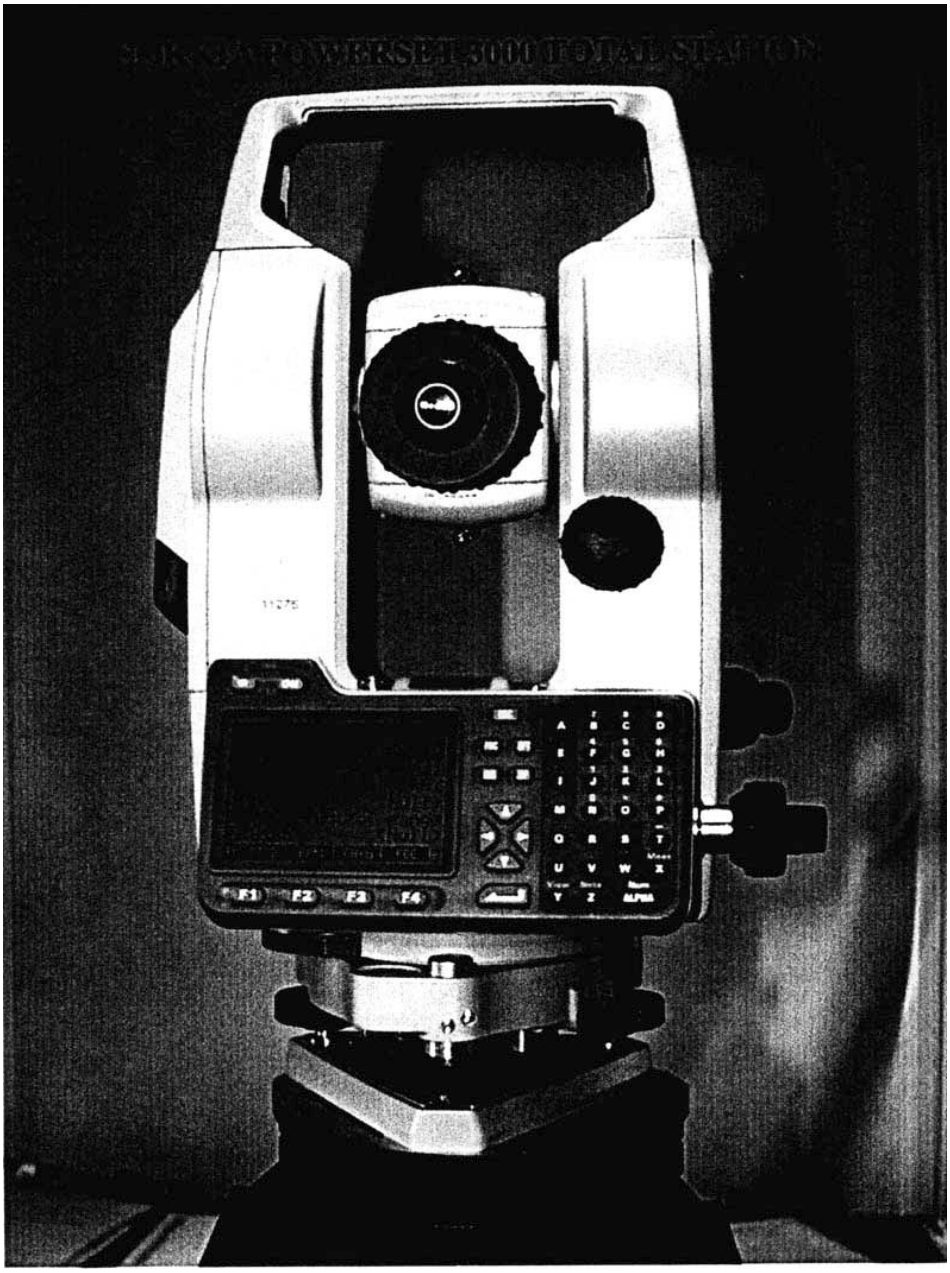
OPERATOR SIGHTING A TARGET



SOKKIA TOTAL STATION IN USE : NOTE STRINGS USED ON HULL TO GUIDE TARGETS.



ALPHA/NUMERIC KEYPAD OF THE POWERSET 3000 TOTAL STATION


F1
F2
F3
F4