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Topographic Surveying Using the Sokkisha SET2 Electronic Total Station With the HP-71B Computer

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CONTENTS

INTRODUCTION

This report discusses the use of the Sokkisha SET2 electronic total station for topographic surveying. The SET2 is a tacheometer, a device which can rapidly measure distance by optical means. The SET2 EDM (electronic distance measurement unit) utilizes an infrared light beam to calculate distance to a reflecting prism. The SET2 also functions as a theodolite measuring azimuth and zenith angles internally. A Hewlett Packard HP-71B hand-held computer is attached to the EDM by means of an interface and transforms distance to the target, and its azimuth and zenith relative to the EDM, into x-y-z coordinates. The use of this equipment greatly simplifies topographic surveying and shortens the amount of time spent in the field.

Preliminary considerations, such as equipment inspection and battery care, are discussed first. Next, operating procedures in the field are explained in detail. The remainder of the report discusses the computer program that drives the EDM and equipment and data storage. The appendices contain diagrams of the EDM parts, a listing of the computer program, and addresses of the equipment manufacturers.

The information in this report has been carefully checked and is believed to be accurate. However, no responsibility is assumed for inaccuracies. Users should read through the SET2 Operators Manual, especially chapter 16 on precautions and maintenance, before using the SET2 for the first time.

PRELIMINARIES

Equipment inspection.

To take full advantage of the "EDM-HP-71B system" bring the equipment listed below into the field.

Sokkisha SET2 EDM with accessories in its carying case
EDM tripod
triple or single prism (or both), prism pole, prism pole tripod
Hewlett Packard 71B computer
Lietz IL interface (to connect HP-71B to EDM)
HP-IL cables

The following equipment is optional but still very important.

AC power supplies for the printer and HP-71B
battery-powered HP 2225B ThinkJet printer
portable disc drive with AC power cable
radio transceivers
extra batteries for HP-71B, EDM, and printer
extra chargers for batteries
altimeter, thermometer

Check the equipment before going into the field. The EDM and HP-71B should be connected together through the interface and turned on to verify that all components are working together properly. It is not necessary to actually take measurements but the HP-71B should be able to control the EDM. Pack all accessories for the EDM, such as the thermometer, altimeter, instructions and tables, with the EDM in the carrying case. Always transport the EDM in the supplied carrying case. The SET2 is an expensive and delicate instrument. Check the prisms for any cracks, broken glass, stripped threads, etc. Examine the EDM tripod and prism pole for stripped threads, broken parts, etc. Also, check all optional equipment, such as the radio transceivers, portable printer and disc drive, for good operating condition. Steinmetz & Brown, Ltd. make a portable disc drive, the SB10161A, which operates on 110V AC current. Hewlett Packard also makes a portable disc drive.

Batteries.

Batteries deserve special attention. Nearly every piece of the electronic field equipment requires a battery for operation. It is particularly important, then, that all batteries should be fully charged before going into the field. Charge the batteries several days before leaving so that if new batteries need to be purchased or other problems resolved, there is time to do so. The battery pack in the portable HP 2225B ThinkJet is rechargeable as are the batteries in the EDM and (typically) the radio transceivers.

The HP-71B uses AAA size batteries that are not necessarily rechargeable. It is important that these batteries should be replaced with new ones if they have been in the HP-71B for a long time (six to twelve months). Place a small piece of paper noting the date of installation and who did it in the computer with the batteries.

If the HP-71B loses power, or if batteries are removed, all memory is lost including any data stored and all programs. Memory loss can be avoided when changing batteries by plugging the HP-71B into a wall outlet using the supplied transformer. Because the HP-71B memory is volatile, store data files and the program EDMXYZ on floppy disc so that they can be retrieved using the portable disc drive. (More on this later in the section *Backing up the Data.*)

Goals.

Clearly state the goals of the topographic survey before leaving the office. One of the first considerations should be the precision required. If the data will be used for map production then discuss the range of map sizes and scales that will be utilized. Minimum width of the plotting pens and map scale decide the resolution attainable in the final product. If the survey data are to be used for geophysical data reduction, then as great an accuracy as possible may be necessary. Though the EDM can measure distance fairly accurately, +/- 3 mm + 2 ppm, the angular measurement is only accurate to 2" of arc, or 10 ppm (10 mm per km). Knowing the information above, the surveyor can determine the amount of time and care that should be devoted to accurate and precise location of field stations.

Unless there is unlimited time and funding, prioritize the field work. Gather the most important and essential data first. Then as time permits, survey the remainder. If survey data will be used by several parties, discuss their individual needs and requirements. Also, allow extra time for bad weather and other delays. A few moments spent planning in the office before the site visit or in the motel room may save hours of wasted or ill-spent time in the field.

FIELD PROCEDURES

Introduction

The EDM can be used in the field in either of two modes, successive measurement or tracking. In the tracking mode, the EDM takes measurements in centimeters, at first after six seconds then every 0.4 to 1 second, as the reflecting prism is moved slowly, but continuously, along a course. In the successive measurement mode, the prism is moved from station to station with a measurement taken at each station. There is a switch on the front panel of the telescope to select the mode.

The most commonly employed mode in topographic surveying is the successive measurement mode, which is the one discussed in the remainder of this report. In general, follow the procedure below when using the Sokkisha SET2 EDM and the HP-71B computer to survey a site. A known point is any station for which the coordinates already are accurately known. A transfer point is the station at which the EDM is set up to take measurements. Refer to figure 1 for a possible surveying situation.

1. Select the origin and x-axis direction for the coordinate system.
2. Set up the EDM on the origin (or other known point) and the prism on the x-axis (or some known point).
3. Start the computer program EDMXYZ and follow prompts. Examples are given later in this report.
4. As necessary, move the prism from station to station and follow computer program prompts. The HP-71B takes measurements directly from the EDM.
5. As necessary, move the EDM to a transfer point and repeat steps 2 through 4.
6. When finished, or as convenient, backup the data by printing out a copy on the portable printer and by copying the files to the portable disc drive.
7. If the project will continue for more than a day, charge batteries over night.

Selecting a coordinate system.

It is important to select a convenient and useful coordinate system, especially if this is the first time that the site will be surveyed. The origin should be a location that is easily found again and somewhat permanent in nature if possible. A USGS benchmark would be ideal. Wells, road intersections, concrete pads also can be used. A metal or wooden stake can be driven into the ground to mark the origin. Likewise, the reference point that establishes the x- or y-axis should also be a feature easily found again and somewhat

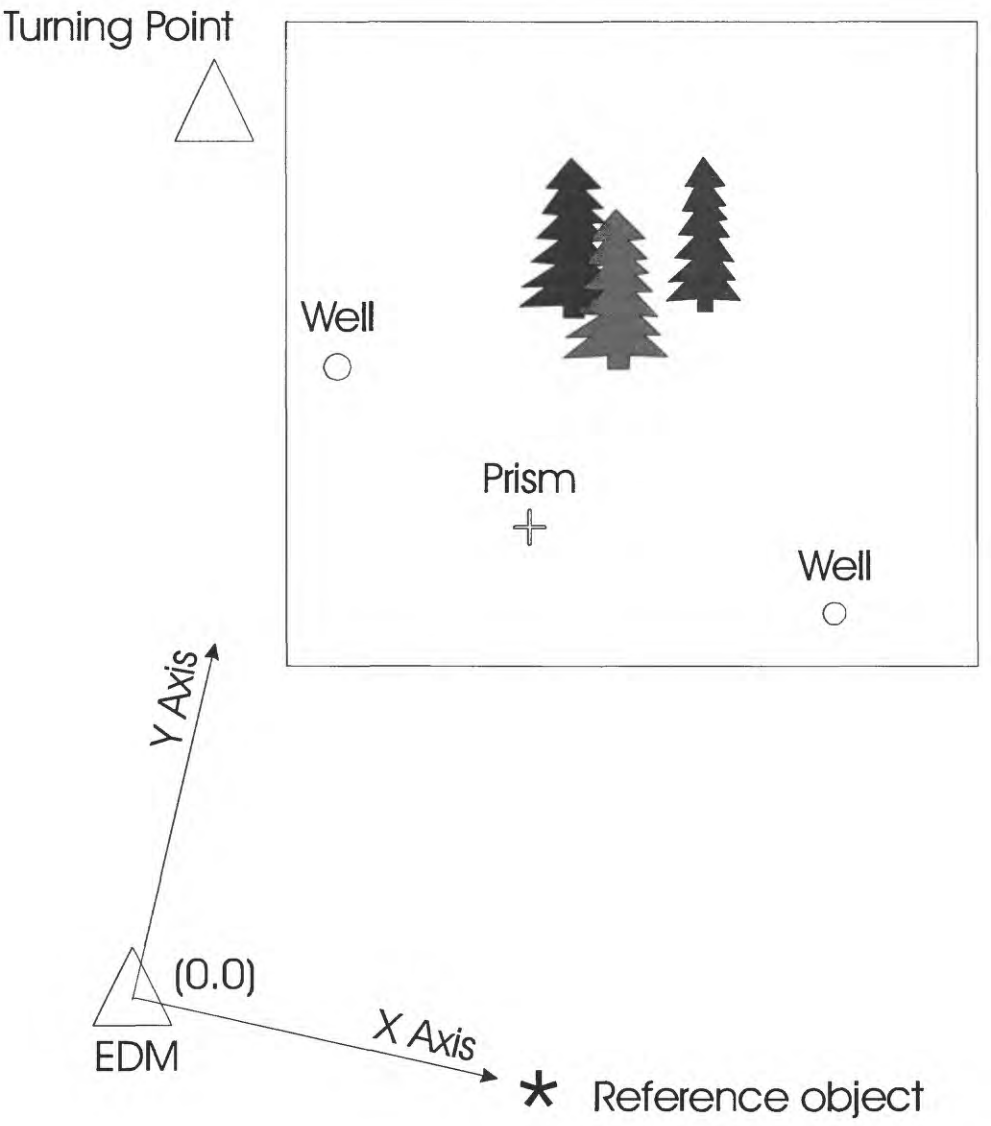

Figure 1. This diagram shows a typical surveying situation. The EDM is set up at an arbitrary but advantageous position to survey in stations inside of a rectangular area. A reference object was determined and the X axis was established in that direction. Two wells are located in or near the survey area. The wells are surveyed to determine their position in the new coordinate system. If the wells are also located in another coordinate system, such as latitude-longitude or UTM, then the new coordinate system established here can be transformed. At least two stations with locations established in another coordinate system are required to transform the new X-Y-Z coordinates. The prism is moved from station to station in the survey area. A few trees are blocking some stations from being seen by the EDM so a turning point must be established. When the EDM is moved to the turning point, the first EDM location, or the wells, can be used as the reference point to keep the coordinate system consistent. The new stations that are surveyed from the turning point will have the same coordinates as the earlier ones.

permanent. It is not necessary that the axes be aligned north-south and east-west because coordinates can be transformed to match any other coordinate system back at the office.

If this is not the first time on the site then the EDM and REFerence stations can be any two locations for which the coordinates are accurately known. If it is not convenient to set up the EDM on a known point, then the EDM can be set up at an arbitrary location (a new origin) and several of the old surveyed points can be re-surveyed. Back at the office the new coordinate system can be transformed to match the old one.

Setting up the EDM.

Setting up the EDM involves three things: centering the EDM vertically over the station, leveling the EDM, and initializing the EDM. Refer to the figures in Appendix A for descriptions of the EDM parts. It is assumed that the internal switches and prism constant are set correctly. (See the SET2 operator's Manual.)

Start by separating the legs of the tripod so that it will stand securely and center it over the station. Place the bracket for the Lietz interface on the tripod head and add the brass extension screw to the base plate knob. Attach the EDM securely to the tripod head, centering the EDM base plate on the tripod. Tighten the base plate knob. The leveling screws on the EDM should be in the middle of their adjustment range. Use the sight (optical plumb) on the side of the EDM to position it over the station. There is a focusing ring on the eyepiece. Move the tripod legs as necessary. Look at the circular level on the tribrach of the EDM to see if it is roughly leveled. Adjust tripod legs accordingly. When close to being centered, the tripod shoes should be pushed firmly into the ground to avoid settling that will disturb the level. It may take several tries to get it right, but leveling the EDM is one of the most important steps in surveying. The EDM must be level and set up exactly over the station to get the most precise and accurate results. The center of the station should be well marked so that the EDM can be positioned to within millimeters.

To level the EDM, first use the circular level on the tribrach, moving the tripod legs as necessary to keep the EDM centered over the station. Adjust the tripod legs and leveling screws as necessary. Next use the tubular plate level, which is much more sensitive, to "fine tune" the level. Place the plate level parallel to any two leveling screws. Bring the bubble to the center of its run by turning the two screws by the same amount but in opposite directions. Turn the instrument 90° and use the third screw to bring the bubble back to the center of its run. Repeat these two steps until the bubble remains centered (or close to it) in both positions. If the EDM is now slightly off center of the station, loosen the base plate knob a little and carefully slide the EDM to the correct position and tighten the knob. Recheck the level. The figure below from Section 13.1.1 in the Sokkisha SET2 Operator's Manual illustrates the relationship of the plate level and the movement of the leveling screws.

13. CHECKS AND ADJUSTMENTS

The SET2 may be affected by sudden changes in weather conditions and excessive vibration. This can result in inaccurate surveying. Therefore, IT IS IMPORTANT TO CHECK AND ADJUST THE SET2 BEFORE AND DURING USE in the following order.

13.1 ANGLE MEASURING FUNCTION

13.1.1 Plate level
13.1.2 Circular level
13.1.3 Index error of the tilt angle sensor
13.1.4 Reticle
13.1.5 Perpendicularity of the reticle to the horizontal axis
13.1.6 Coincidence of the distance measuring axis with the reticle
13.1.7 Optical plummet

13.1.1 Plate level

The glass tube of the plate level is sensitive to temperature change or shock. Be sure to check the plate level ⑱ before use.

1) See Figs. 13.1 and 13.2 for relation between bubble movement and rotation of the levelling screws.

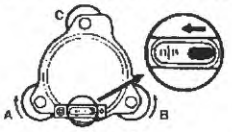

Fig. 13.1

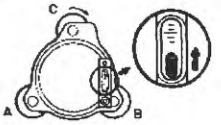

Fig. 13.2

2) Turn the upper part of the SET2 until the plate level is perpendicular to a line between levelling screws A and B. Then centre the bubble using the levelling screw C.

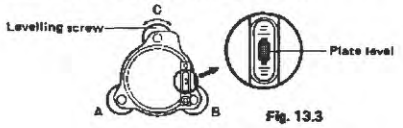

Fig. 13.3

3) Turn the upper part 90° (100gon) until the plate level is parallel to the line between levelling screws A and B. Then centre the bubble by turning levelling screws A and B by the same amount and in the opposite direction.

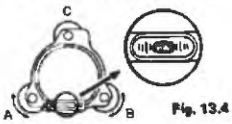

Fig. 13.4

4) Turn the upper part 180° (200gon). Correct the bubble deviation, if any, by half amount with levelling screws A and B, as in 3) above.

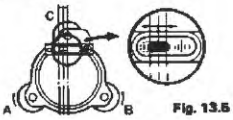

Fig. 13.5

5) Correct the remaining half deviation by turning the plate level adjusting screw ⑱ with the adjusting pin.

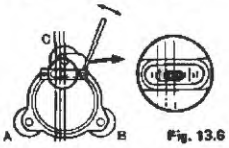

Fig. 13.6

6) Repeat 2) to 5) above until the bubble remains centred for all the positions of the upper part.

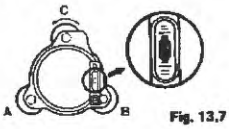

Fig. 13.7

To initialize the EDM, turn it on. (Note: when installing a battery in the EDM, be sure that the power switch is off.) Loosen both the vertical and horizontal clamps. Do not loosen the lower clamp. In fact, never loosen the lower clamp or adjust its fine motion screw when surveying using the methods described in this report. This will cause loss of azimuthal referencing. Using the telescope plunging knob, rotate the telescope so that the objective lens crosses the horizontal plane. This indexes the vertical circle (zenith angle) so that 0^{o} is straight up, 90^{o} is horizontal and 180^{o} is down. An audio signal is given when the vertical circle is indexed.

Set the atmospheric correction factor by adjusting the part per million (ppm) switch on the telescope. The correction factor can be found from the atmospheric correction chart supplied with the EDM using the current temperature and barometric pressure. Use the real barometric pressure, not the corrected-to-sea-level value given in weather reports. The barometric correction for elevation is approximately 25.4 mm (one inch) of mercury (Hg) for every 305 m (one thousand ft) above sea level. Temperature and pressure control the refractive index of air which is inversely proportional to the velocity of light through the atmosphere. The exact values for temperature and pressure are not critical, but to maintain an accuracy of 2 ppm, temperature must be measured to within 1^{o} C (1.8^{o} F) and pressure to within 5 mm (0.2 in) Hg. Adjust the atmospheric correction factor during the day if there is a substantial change in temperature or barometric pressure.

The last item to initialize is the horizontal angle or azimuth. Line up the telescope on the center of the reference target. Use the peep sight on top to find the target. Often, the prism can be the target positioned at the reference location. However, any object will do. Press the SET button on the EDM. This references the horizontal angle to zero at this position of the telescope.

Finally, press the CA button on the EDM to put it in the proper mode to take measurements. The displays on the EDM should clear. The EDM is now ready to take measurements using the HP-71B.

Note: to extend battery life, turn the signal audio switch to off.

Taking measurements.

If the HP-71B and Lietz IL interface are not attached, do so now. Plug the HP-IL cables into the HP-71B and into the Lietz interface. Attach the computer to the interface. Fold up the extra cable and tuck between the computer and interface. The interface clips onto the support bracket. Plug the interface cable into the "DATA OUT" connector on the EDM. Turn on the HP-71B and type RUN EDMXYZ <endline> to start the program. "<endline>" indicates that the user should press the ENDLINE button after typing in the command.

The following are the correct responses to the program prompts concerning the REFerence and EDM if the coordinate system is being set up for the first time (see figure 1). The HP-71B prompts are capitalized and in quotes and suggested responses follow the double dashes.

"REF COMMENT?"--something appropriate to identify the station

"REF X?"--some positive value, true value not needed
"REF Y?"--0, the reference is on the x-axis
"REF Z?"--any value, true value not needed

"EDM COMMENT?-- something appropriate to identify the station

"EDM X?"--0, or the known value
"EDM Y?"--0, or the known value
"EDM Z?"--0, or the known value

"EDM HEIGHT?"--the measurement from the benchmark or landmark to the instrument height mark on the EDM standard opposite the battery (this is the center of the telescope pivot)

"PRISM HEIGHT?"--the measurement from the base of the pole to the middle of the prism

Only for the initial visit to a site is it not necessary to supply true values for the REFerence location. In the calculation of x-y-z coordinates, only the direction to the REFerence is needed, not the actual location. Because the EDM is set up on the origin and the REF on the x-axis, the true values for x and z are not needed (y, of course, must be equal to zero). However, if the EDM and REF are not at these initial locations, then the true values are required.

After the above information is entered, the program is ready to start taking measurements. Place the prism pole on the first station. Use the circular level on the pole to hold the prism vertically above the station. Loosen the vertical and horizontal clamps on the EDM and sight the telescope on the prism. There is a peep sight on top of the telescope to aim it in the general direction. There is an adjusting ring on the telescope eyepiece to focus the cross hairs. Use the telescope focusing ring to focus on the prism. Tighten the clamps and use the vertical and horizontal fine motion screws to sight directly on the prism center. Again, be careful not to disturb the lower clamp or lower fine motion screw as this will cause loss of horizontal angle indexing. Follow the prompts on the computer screen. See the following section (THE COMPUTER PROGRAM EDMXYZ) for a more detailed description of the program.

Moving the prism from station to station.

When the EDM is finished taking a measurement and the results are displayed on the computer screen, signal the prism pole operator to move to the next station. If the stations are more than a few tens of meters from the EDM, radio transceivers makes communication between parties much easier. If the height of the prism pole must be changed to get a measurement, enter PSM at the 'START' prompt (see the section THE COMPUTER PROGRAM EDMXYZ for details) to change the prism height in the program before taking the next measurement. Be sure to change the height back in the program when the normal prism height is restored. Assign each station a unique ID string. A unique identifier string facilitates searching through the data file and reduces confusion if a large number of stations are measured.

Moving the EDM.

Eventually it may be necessary to move the EDM to survey more stations. When this time comes, the prism pole operator should select an advantageous site to set up the EDM. The site should be accurately marked using a stake, pin or even a rock. Use a pen to mark the center of the station. The prism operator should inform the EDM operator that this station will be the next transfer point (or turning point) so that it can be noted in the ID string for that station. Likewise, a reference point can be selected, carefully marked, and the EDM operator informed so appropriate comments can be made in the computer file. If it is convenient, the present EDM station can be used as the REF for the next EDM station. But this is not required. It is only necessary that the EDM and REF (the prism) be at known points. It may be convenient to write down the transfer point coordinates so that they don't have to be searched for using the program.

After the new EDM location and REF points are surveyed, move the EDM. Turn off both the computer and the EDM. It is not necessary to stop the program. It will go into the SUSP mode when the HP-71B is shut off. If the move is not far, check that the base plate knob is tight then pick up the EDM, tripod and all, collapse the legs and walk to the transfer point. (This method of transport is not recommended in the SET2 Operator's Manual.) If the move is not short then detach the EDM from the tripod and return the EDM to the carrying case. Repeat the setup procedures discussed above. Be sure that the EDM is positioned exactly over the "X" marking the center of the transfer point to get the most accurate and precise measurements.

Initialize the EDM as discussed above, except this time, true values must be used for the REF and EDM locations.

When the HP-71B is turned on type CONT START <endline>. If you didn't write down the coordinates, instead of "STA" enter "SEARCH" at the prompt to find the coordinates for this new EDM station. Enter "EDM" after the coordinates have been found and the values will be assigned to the EDM coordinates. Repeat the search for the REF station except enter "REF" after the coordinates have been found. When the program returns to the "START" prompt, enter "REF" so that you can double check that the correct values were used and to enter the new EDM and PSM (prism) heights.

If a hardcopy was printed out during this move the values can be typed in. Instead of using the SEARCH command and the procedure above, enter "REF" after the "START" prompt and supply the requested values.

You will see that as the size of the data file increases it also takes longer to find stations at the end of the file. Start new files after about every hundred stations or as convenient. Give meaningful names to the files.

Survey the REF station and compare the coordinates with those stored in the program. If the results are different (by more than a few millimeters) then double check that the correct values were entered for the REF and EDM coordinates, and also that the prism is indeed set on the REF point and the EDM on the transfer point.

Backing up the data.

The principle advantage of using the computer-controlled EDM is rapid and accurate data acquisition. The data are stored in volatile memory in the HP-71B computer rather than recorded by hand. It is very important, then, that the data are not lost. At every convenient opportunity, a hardcopy of the data should be obtained by connecting the Hewlett Packard 2225B ThinkJet to the HP-71B. This printout is handy for referring to previous stations when moving the EDM and for assigning station IDs. If a power source is available, the files should be copied to the portable disc drive for more permanent storage. In the event that power is lost to the HP-71B, the files can be copied back to the HP-71B memory from the

disc drive. If no electricity is available in the field, the data should be copied to floppy disc at the motel room or office at the end of the day.

Both the printer and disc drive are connected to the HP-71B using two HP-IL cables (Hewlett Packard interface loop). These can be the same two cables that connect the HP-71B to the Lietz IL interface. First disconnect the HP-71B from the HP-IL cables and the Lietz interface. Disconnect the HP-IL cables from the interface if a spare set is not available. Turn the HP-71B off before connecting to the printer or disc drive. Connect the HP-71B to the printer or disc drive using the HP-IL cables. Turn on the printer or disc drive, then turn on the HP-71B. When the HP-71B is turned on, it searches for devices connected to the interface loop and gets the address of the device.

To get a printout of a file, RUN the program EDMXYZ or enter 'CONT PRINT' (if EDMXYZ is already "loaded" and "attached") and follow the prompts. NOTE: when the file is done printing, the HP-71B screen goes blank. IT IS NOT OFF!

To copy a file to the Steinmetz & Brown disc drive enter the command, COPY filename TO filename:SB10161 <endline>. Catalog the disc to verify the copy by entering the command, CAT :SB10161 <endline>.

When finished, turn off the printer or disc drive and turn off the HP-71B. Disconnect the HP-IL cables. Re-attach the HP-71B to the Lietz interface. RUN the program EDMXYZ to reset the interface loop and continue surveying.

During the course of the day, comments should be recorded in a note book concerning station locations, errors in prism or EDM height, etc. At the end of the work day good hardcopies of the survey data should be printed out and annotated with these comments.

Recharging batteries.

Charge all batteries over night so that they will be fresh for use the next day. Observe the battery charging precautions listed in the EDM operator's manual. Follow the instructions on the individual chargers. The batteries in the HP-71B are not rechargeable unless they are the commercially available alkaline batteries.

THE COMPUTER PROGRAM EDMXYZ

The Hewlett Packard 71B hand-held computer controls the EDM using the program EDMXYZ. A program listing is in Appendix B. EDMXYZ uses input from the user to establish an x-y-z coordinate system. If the positive y-axis is straight ahead, the positive x-axis is to the right and positive z is up -- the right hand rule. The program commands the EDM to take measurements at the user's signal. The HP-71B receives slope distance, vertical angle (zenith) and horizontal angle (azimuth) and transforms these values into x-y-z

coordinates. The data file is automatically updated to include these new coordinates and the program returns to prompt the user for the next instruction. Now for more detail.

The EDM is turned on. The HP-71B is connected to it using the Lietz IL interface and HP-IL cables. The EDM has been initialized. Turn the HP-71B on. If the message "SUSP" appears in the right side of the display then type

STOP <endline> then press RUN.

Alternatively, you can type

CONT START <endline>

and respond to the prompt by typing:

REF <endline>.

If there was no message when the HP-71B was turned on then type

RUN EDMXYZ <endline>.

If the program is already "loaded" then pressing "RUN" is sufficient. The program prompts for the filename to store the data in. Verify that this is the correct file and press ENDLINE or change the name and press ENDLINE. It then asks if you want to erase the file. "N" for "no" is the usual response; press ENDLINE. If there are no values for the REFerence and EDM coordinates the program prompts for those coordinates, their ID strings and the height of the EDM and prism (see the explanation of "REF" below). Otherwise, the program beeps and prompts you to enter a string from the list shown below that is only partially displayed on the computer screen.

xxx.xxx PTS/Left DISP PRINT SEARCH REF PSM XYZ OR STA?STA

To see more of the list press the "<" and ">" keys next to the RUN key. Pressing the ON key once clears the suggested response. Pressing it again suspends the program. This prompt is after the 'START' line label (at line 280) in the program. The first part of the prompt (PTS/Left) informs you of how many more data entries can be stored in the computer. Select your response chosen from the list and press ENDLINE. Herw is a brief description of each choice. Any other response branches to 'START' and repeats the prompt sequence.

Response	Line	Comment
DISP	790 'DISP':	Display the X,Y,Z coordinates for the last measurement.
PRINT	610 'PRINT':	Print a file on attached printer.
SEARCH	650 'FND':	Asks which file to search and which comment string to search

		for. The X,Y,Z coordinates are returned with the original slope distance and angular measurements. Then it asks if the user wants to use these coordinates for new REFerence or EDM coordinates or neither (NON).
REF	150 'REF':	Modify the REFerence point (a station comment, x, y, and z values), the EDM (a station comment, x, y, and z values) and heights of the EDM and prism (PSM).
PSM	240 'PSM':	Modify PSM height.
XYZ	450 'XYZ':	Recalculate the coordinates for the last measurements, store them in the current file and display\ the results.
STA	320 'STA':	default; take measurements for a new station.

"STA" is the default response and prompts the user to take another measurement. After pressing ENDLINE, the next prompt asks for a station comment. This short comment should be unique and meaningful. The display after that indicates that the user should press ENDLINE to take data from the EDM. After the new coordinates are displayed press ENDLINE to return again to 'START' and the above prompt sequence.

If the EDM is not turned on or is not correctly attached, the program will proceed to the "manual" mode and the user may enter the data (slope distance, slope angle, and horizontal angle) by hand.

If the HP-IL has not been reassigned to the EDM then the following message will appear after the HP-71B attempts to talk to the EDM

HPIL ERR L390: Loop Broken

and "SUSP" appears in the right side of the display. If this happens, turn off the HP-71B (be sure the EDM is on) then turn it on and press RUN. Re-survey this station.

Several problems may develop while using the HP-71B. These generally will be system lockups and errors. The two most common errors are the "Loop Broken" error mentioned above and the following error:

ERR L520: Chn1# Not Found .

This error sometimes occurs after connecting the computer to another device then reconnecting to the EDM. It means that at line 270 or 510 the channel opened to the data file cannot be found. The program should be started over to correct this. Press RUN.

The other common problem is system lockup. This occurs for some unknown reason occasionally when the computer is trying to talk to the EDM. The message "TAKING DATA" appears on the display but nothing is happening. The EDM is not beeping. The display does not change. To correct this situation, simply press the ON button several times to clear the display and suspend the program. Ignore any error message, and type:

CONT START <endline>.

The program will continue with the 'START' prompt above. Re-survey this station. If some other error or problem develops that the solution to is not immediately obvious, turn the computer off then back on and press RUN, or just press RUN while the program is running.

EQUIPMENT STORAGE

Place the equipment in the appropriate storage cases when transporting. A specially molded plastic case is supplied with the EDM. The prisms come with foam padded nylon bags. There is a protective plastic cover that screws onto the top of the EDM tripod (now missing). The prism tripod goes into a cardboard tube (now missing). The printer and disc drive fit into a high-impact plastic case lined with foam. Place foam between these two units.

After returning from the field, inspect the equipment for good condition, clean if necessary and return to the appropriate storage areas. Fully charge all batteries before storage. Report any problems with the equipment and take appropriate action. Double check that all data files have been backed up onto disc.

COMPUTER DATA STORAGE

There are two main reasons for acquiring topographic data. The first is to construct maps of the project site. The second is to use the data to make topographic corrections to the geophysical survey data. In both cases, the topographic data will be stored in a computer for easy access and manipulation. In our office, we transfer data files from the LIF-formatted disk (5 ¼ inch floppy, DS DD, from the Steinmetz & Brown disk drive) using a utility program called LIFUTIL.EXE. Contact the author for further information.

CONCLUSION

This report has presented only one way in which the SET2 EDM can be utilized for topographic surveying. The EDM is capable of providing much more information from its measurements, such as slope reduction, remote elevations, northing and easting coordinates, horizontal distance and height difference between two target points and stake out by distance or coordinates. The SET2 Operator's Manual contains examples of how to use these and other features.

APPENDIX A

Computer Program Listing
The following program is written in HP-71B BASIC.

```
10 ! EDMXYZ  G.OLHOEFT FEB-86/J.LUCIUS FEB-87
20 DESTROY C$,Q$,R$,R1$,R2$ @ PWIDTH 80 @ DIM Q$[160],C$[80],
   R1$[80],R2$[80] @ FIX 3 @ DEGREES
30 INPUT "Filename?",F$;F$
40 DISP "Erase "&F$; @ INPUT "?","N",C$
50 IF C$[1,1]="Y" THEN DISP "New File "&F$ @ PURGE F$
   @ DESTROY X0,Y0,Z0,X1,Y1,Z1,H0,H1
60 GOSUB 'EOF'
70 L=-1 @ ON ERROR GOTO 'START'
80 RESTORE IO @ RESET HPIL @ REMOTE
90 L=DEVADDR("LIETZ1A")
100 OUTPUT :L ;"SB8;ST17;SP19"
110 OUTPUT :L ;"RV"
120 CFLAG -23
130 ENTER :L ;R$
140 GOTO 'START'
150 'REF': INPUT "REF COMMENT? ",R1$;R1$
160 INPUT "REF X? ",STR$(X0);X0
170 INPUT "REF Y? ",STR$(Y0);Y0
180 INPUT "REF Z? ",STR$(Z0);Z0
190 'EDM': INPUT "EDM COMMENT? ",R2$,R2$
200 INPUT "EDM X? ",STR$(X1);X1
210 INPUT "EDM Y? ",STR$(Y1);Y1
220 INPUT "EDM Z? ",STR$(Z1);Z1
230 INPUT "EDM HEIGHT? ",STR$(H1);H1
240 'PSM':INPUT "PRISM HEIGHT? ",STR$(H0);H0
250 'REFSTORE': Q$="REF XYZ: "&R1$& " "&STR$(X0)&" "&STR$(Y0)&
   " "&STR$(Z0)&" "
260 Q$=Q$&"EDM XYZ: "&R2$&" "&STR$(X1)&" "&STR$(Y1)&" "&
   STR$(Z1)&" "
270 Q$=Q$&"Hed: "&STR$(H1)&" Hpr: "&STR$(H0) @ PRINT #1;Q$
280 'START': OFF ERROR @ IF X0+Y0+Z0+X1+Y1+Z1=0 THEN 'REF'
290 BEEP @ DISP MEM/70;" PTS/Left DISP PRINT SEARCH REF PSM
   XYZ or STA"; @ INPUT "?","STA";Q$
300 Q=POS("NUL REF PSM STA XYZ SEARCH  PRINT   DISP",Q$) DIV
   4+1
310 ON Q GOTO 'START','REF','PSM','STA','DISPXYZ','FND','START',
   'PRINT','START',  'DISP'
320 'STA': INPUT "Station Comment? ",C$;C$
```

```
330 IF LEN(C$<1) THEN 'START'
340 DESTROY R$,V$,H$
350 IF L<0 THEN 'MANUAL'
360 BEEP @ DISP "To Take Data, Press ENDLINE"; @ INPUT "";Q$
370 DISP "TAKING DATA"
380 'MEAS': OUTPUT :L ;CHR$(17)
390 TRIGGER :L
400 CFLAG -23
410 ENTER :L ;R$,V$,H$
420 IF R$="" THEN 'MEAS'
430 OUTPUT :L ;CHR$(19)
440 RESTORE IO
450 'XYZ': R=VAL(R$)/1000
460 V=VAL(V$[1,3])+VAL(V$[4,5])/60+VAL(V$[6,7])/3600
470 H=VAL(H$[1,3])+VAL(H$[4,5])/60+VAL(H$[6,7])/3600
480 Z=R*COS(V)+H1-H0+Z1 @ H2=R*SIN(V) @ B=ATN((Y0-Y1)/(X0-X1))+
   ((X0-X1)<0)+180
490 X=X1+H2*COS(B-H) @ Y=Y1+H2*SIN(B-H)
500 Q$=C$&" X="&STR$(X)&" Y="&STR$(Y)&" Z="&STR$(Z)&" ("&
   STR$(R)&" "&V$&" "&H$" )"
510 PRINT #1;Q$
520 'DISPXYZ': DISP USING "#,K,3(4DZ.3D)";"Press ENDLINE ",
   X,Y,Z, @ INPUT "";Q$ @ GOTO 'START'
530 'MANUAL': INPUT "SLOPE DISTANCE?";R
540 R$=STR$(IP(1000*R))
550 INPUT "SLOPE ANGLE?","DEGMMSS";V$
560 INPUT "HORIZONTAL ANGLE?","DEGMMSS";H$
570 GOTO 'XYZ'
580 'EOF': DISP "Preparing to Store Data in "&F$ @ ASSIGN #1 TO
   F$ @ ON ERROR GOTO 'RETEOF'
590 'DSE': READ #1;Q$ @ GOTO 'DSE'
600 'RETEOF': RETURN
610 'PRINT': INPUT "Print what file?",F$;F$ @ DISP "Printing "
   &F$
620 ASSIGN #1 TO F$ @ PRINTER IS :PRINTER @ PRINT CHR$(27)&
   "&I1L"
630 ON ERROR GOTO 'STOP' @ PRINT F$
640 'PRT': READ #1;Q$ @ PRINT Q$ @ GOTO 'PRT'
650 'FND': INPUT "Search what file?",F$;S$
660 C$="" @ ASSIGN #1 TO S$ @ INPUT "Search for...?";C$
670 DISP "SEARCHING" @ ON ERROR GOTO 'NOTFND'
680 'SLOOP': READ #1;Q$ @ IF POS(Q$,C$)=0 THEN 'SLOOP'
690 BEEP @ DISP "FOUND: "&Q$; @ INPUT "";C$
700 P=POS(Q$,"X=") @ IF P=0 THEN 'SLOOP'
710 C$=Q$[1,P-1] @ Q$=Q$[P] @ X=VAL(Q$[3])
```

```
720 P=POS(Q$,"Y=") @ Y=VAL(Q$[P+2]) @ P=POS(Q$,"Z=") @
  Z=VAL(Q$[P+2])
730 INPUT "Put this XYZ into: REF or EDM or NON? ","NON";C$
740 IF C$="REF" THEN X0=X @ Y0=Y @ Z0=Z @ GOSUB 'EOF' @ GOTO
  'REF'
750 IF C$="EDM" THEN X1=X @ Y1=Y @ Z1=Z @ GOSUB 'EOF' @ GOTO
  'EDM'
760 GOTO 780
770 'NOTFND': BEEP @ DISP C$;" NOT FOUND" @ BEEP @ WAIT 2
780 GOSUB 'EOF' @ GOTO 'START'
790 'DISP': INPUT "Disp what file? ",F$;F$
800 DISP "Press ENDLINE to step through file."
810 ASSIGN #1 TO F$
820 ON ERROR GOTO 'STOP'
830 'DSP': READ #1;Q$ @ DISP Q$; @ INPUT "";Q$ @ GOTO 'DSP'
840 'STOP': DISP @ END
```

APPENDIX B

Parts of the EDM (copied from the Sokkisha SET2 Operator's Manual).

1. PARTS OF THE INSTRUMENT

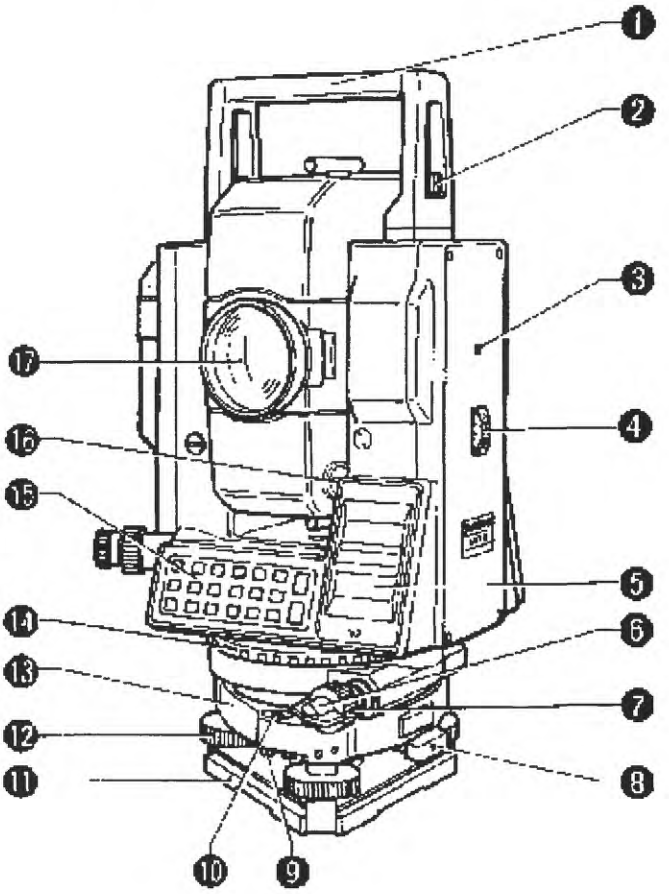

Fig. 1.1

1. Handle
2. Handle securing screw
3. Instrument height mark
4. Internal switch cover
5. Display
6. Lower clamp
7. Lower fine motion screw
8. Tribrach clamp
9. Circular level adjusting screw
10. Circular level
11. Base plate
12. Levelling screw
13. Tribrach
14. Circle positioning ring
15. Keyboard
16. Prism constant cover
17. Objective lens

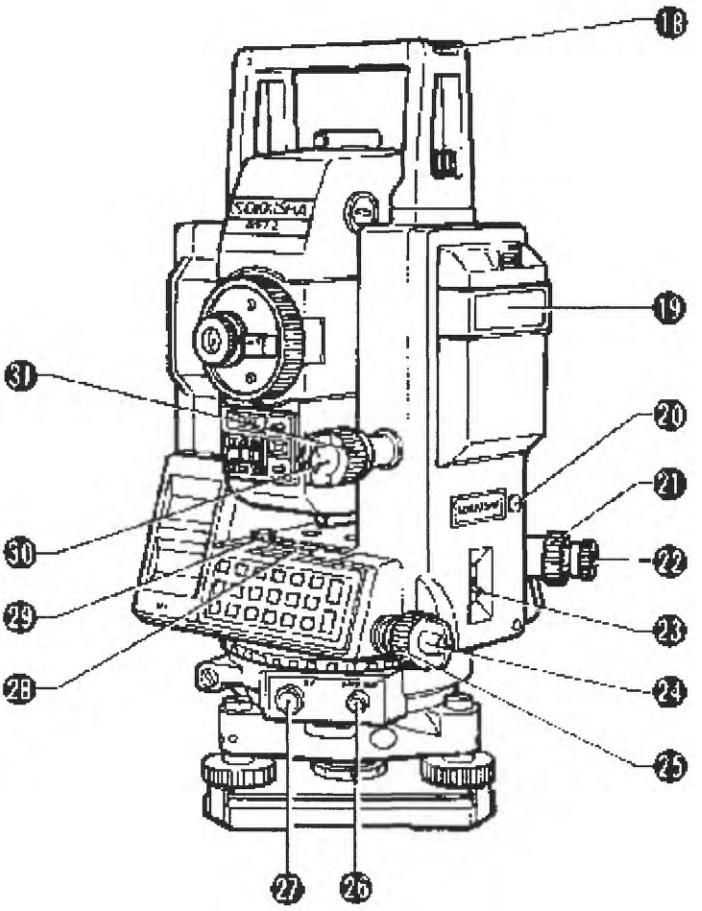

Fig. 1.2

⑱ Tubular compass slot
⑲ Battery, BDC18
⑳ Sensor index adjustment cover
㉑ Optical plummet focussing ring
㉒ Optical plummet eyepiece
㉓ Power switch
㉔ Horizontal clamp
㉕ Horizontal fine motion screw
㉖ Data output connector
㉗ External power source connector
㉘ Plate level
㉙ Plate level adjusting screw
㉚ Vertical clamp
㉛ Vertical fine motion screw

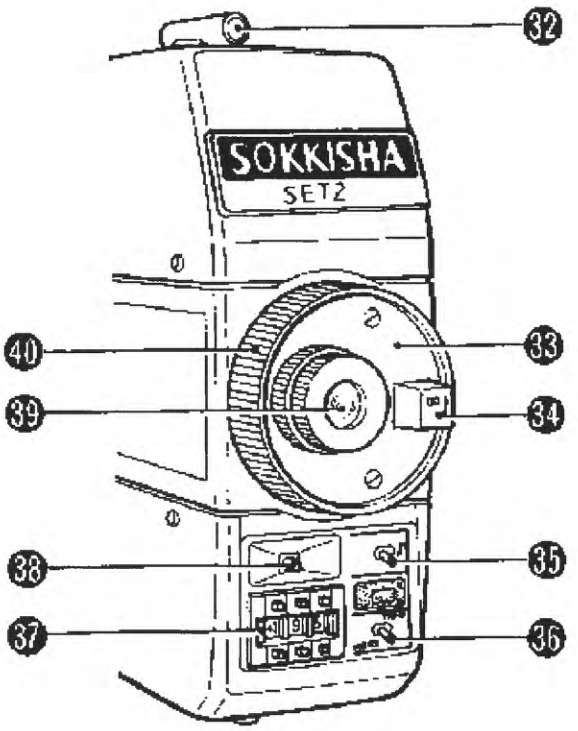

Fig. 1.3

32 Peep sight
33 Telescope reticle adjustment cover
34 Telescope plunging knob
35 Return signal audio switch
36 Measure/track switch
37 ppm switch
38 Return signal lamp
39 Telescope eyepiece
40 Telescope focussing ring

APPENDIX C

List of Manufacturers

SOKKISHA CO., LTD.
Keio Yoyogi Building 5th Floor, No. 1,1,1-chome
Tomigaya, Shibuya-ku, Tokyo, 151 Japan
Telex: J28518SURSOK
Fax: 03-465-5203
Phone: 03-485-2501

HEWLETT-PACKARD COMPANY
Portable Computer Division
1000 N.E. Circle Blvd.
Corvalis, Oregon 97330
U.S.A.