Chapter 5
Data Collection Procedures for the Total Station

5-1. General

In the first step of the process, the field survey, the vertical and horizontal angles are measured along with slope distances using the total station. The angle and distances are stored with a point number and description in the data collector. The survey data are then transferred to the microcomputer via a cable connection for data processing and field data storage. The microcomputer is either an in-office desktop system or a laptop model that can be used on site.

a. The data are then processed in the microcomputer to produce a coordinate file which contains point number, point code, X-Y-Z coordinate values, and a point descriptor.

b. Once the data are on the workstation, they are converted into a graphics design file for use in a CADD program such as MicroStation or AutoCad. The program CVTPC, available through the U.S. Army Topographic Engineering Center, can be used to convert the ASCII files into Intergraph design files. Level, label, symbol, and line definitions are assigned to each point based upon point code. The program can transform data into a two-dimensional (2D) or three-dimensional (3D) design file.

c. The 3D file is used to create the digital terrain model (DTM) which is used to produce the contours. The resulting topographic data are then plotted for review. Final editing and addition of notes are completed, yielding topographic data in a digital format or as a plotted map.

d. Uniform operating procedures are needed to avoid confusion when collecting survey data. The use of proper field procedures is essential to prevent confusion in generating a map. Collection of survey points in a meaningful pattern aids in identifying map features.

5-2. Functional Requirements of a Generic Data Collector

The question of field note is an important issue. Some districts require field notes to be kept, while others use a data collector to replace field notes. An important distinction is made if *field notes are not required*, and the data collector is used as an “electronic field book.” Total stations calculate coordinates in situ and can continuously store coordinates, either in their own memory or in a data collector. *If field notes are required*, only specific items are considered in the transfer of data from a data collector to an office computer. The advantage of this method is that a check is provided on field notes. Most field note errors are made by transcription, e.g., writing 12 instead of 21 in the field book. Data transmitted to an office computer, through an RS-232C port, can be listed on an office printer to provide a check for transposition errors in the field notes. If the data collection is bidirectional, then it must receive data from the office computer for stake-out purposes as well as transmit data to the computer. Field notes can again be considered or ignored.

a. Some districts feel that the electronically collected data is the field book required. Other districts still require that a field book be kept for data safeguarding and legal issues. When field books are kept the entries are compared to the files generated by the data collection processing. All data are booked in the format of the standards set by each district or branch. In many cases there are rarely two districts that have a standard format of notekeeping that is identical.

b. Four types of notes are kept in practice: (1) sketches, (2) tabulations, (3) descriptions, and (4) combinations of these. The most common type is a combination form, but an experienced recorder selects the version best fitted to the job at hand. The location of a reference point may be difficult to identify without a sketch, but often a few lines of description are enough. Benchmarks are also described. In notekeeping this axiom is always pertinent: when in doubt about the need for any information, include it and make a sketch. It is better to have too much data than not enough.

c. Observing the suggestions listed here will eliminate some common mistakes in recording notes:

- Letter the notebook owner’s name and address on the cover and first inside page, in India ink.
- Use a hard pencil or pen, legible and dark enough to copy.
- Begin a new day’s work on a new page.
- Immediately after a measurement, always record it directly in the field book rather than on a sheet of scrap paper for copying it.
- Do not erase recorded data.

- Use sketches instead of tabulations when in doubt.
- Avoid crowding.
- Title, index, and cross-reference each new job or continuation of a previous one.
- Sign surname and initials in the lower right-hand corner of the right page on all original notes.

d. Figures 5-1 and 5-2 are examples of sketches in a field book used for digital surveys. Topographic locations are numbered according to data record numbers. Data record numbers (point numbers) depict what type of location and where locations were measured. This helps office personnel improve digital field drawings into final design drawings. More important, blunders and mislabeled feature codes may be caught before costly design errors are made. The finished map and the sketch should be similar. Sketches are not required to be at any scale.

e. Electronic files are sufficient for submittal without identical hand entries from a field book. Video and digital cameras can be used to supplement the field sketch and provide a very good record of the site conditions for the CADD operator, design engineer, and user of the topographic map.

5-3. Data Collection Operating Procedures

Uniform operating procedures are needed to avoid confusion when collecting survey data. The use of proper field procedures is essential to prevent confusion in generating a map. Collection of survey points in a meaningful pattern aids in identifying map features. Experience has resulted in the following steps for collection of field data:

a. Establish horizontal and vertical control for radial survey. This includes bringing control into the site and establishing setup points for the radial survey. Primary control is often brought into the site using the GPS satellite receivers. The traverse through radial setup points can be conducted with a total station as the radial survey is being performed. Experience indicates a separate traverse is preferable. A separate traverse results in less opportunity for confusion of point identification and allows the quality of the traverse to be evaluated before it is used. Elevations are established for the radial traverse points using conventional leveling techniques instead of the trigonometric values determined from the total station.

b. Perform radial surveys to obtain information for mapping.

(1) Set the total station over control points established as described above.

(2) Measure and record the distance from the control point up to the electronic center of the instrument, as well as the height of the prism on the prism pole.

(3) Maintain accuracy. To prevent significant errors in the map elevations, the surveyor must report and record any change in the height of the prism pole. For accuracy, use a suitable prism and target that matches optical and electrical offsets of the total station.

c. Collect data in a specific sequence.

(1) Collect planimetric features (roads, buildings, etc.) first.

(2) Enter any additional data points needed to define the topography.

(3) Define break lines. Use the break lines in the process of interpolating the contours to establish regions for each interpolation set. Contour interpolation will not cross break lines. Assume that features such as road edges or streams are break lines. They do not need to be redefined.

(4) Enter any additional definition of ridges, vertical, fault lines, and other features.

d. Draw a sketch of planimetric features. A sketch or video of planimetric features is an essential ingredient to proper deciphering of field data. The sketch does not need to be drawn to scale and may be crude, but must be complete. A crude sketch is shown in Figure 5-3. The sketch is of an office courtyard. Numbers listed on the sketch show point locations. The sketch helps the CADD operator who has probably never been to the jobsite confirm that the feature codes are correct by checking the sketch.

(1) A detail sketch is shown in Figure 5-4. This information is critical to the design engineer. Detail sketches can be used to communicate complex information directly to the engineer without lengthy discussions.

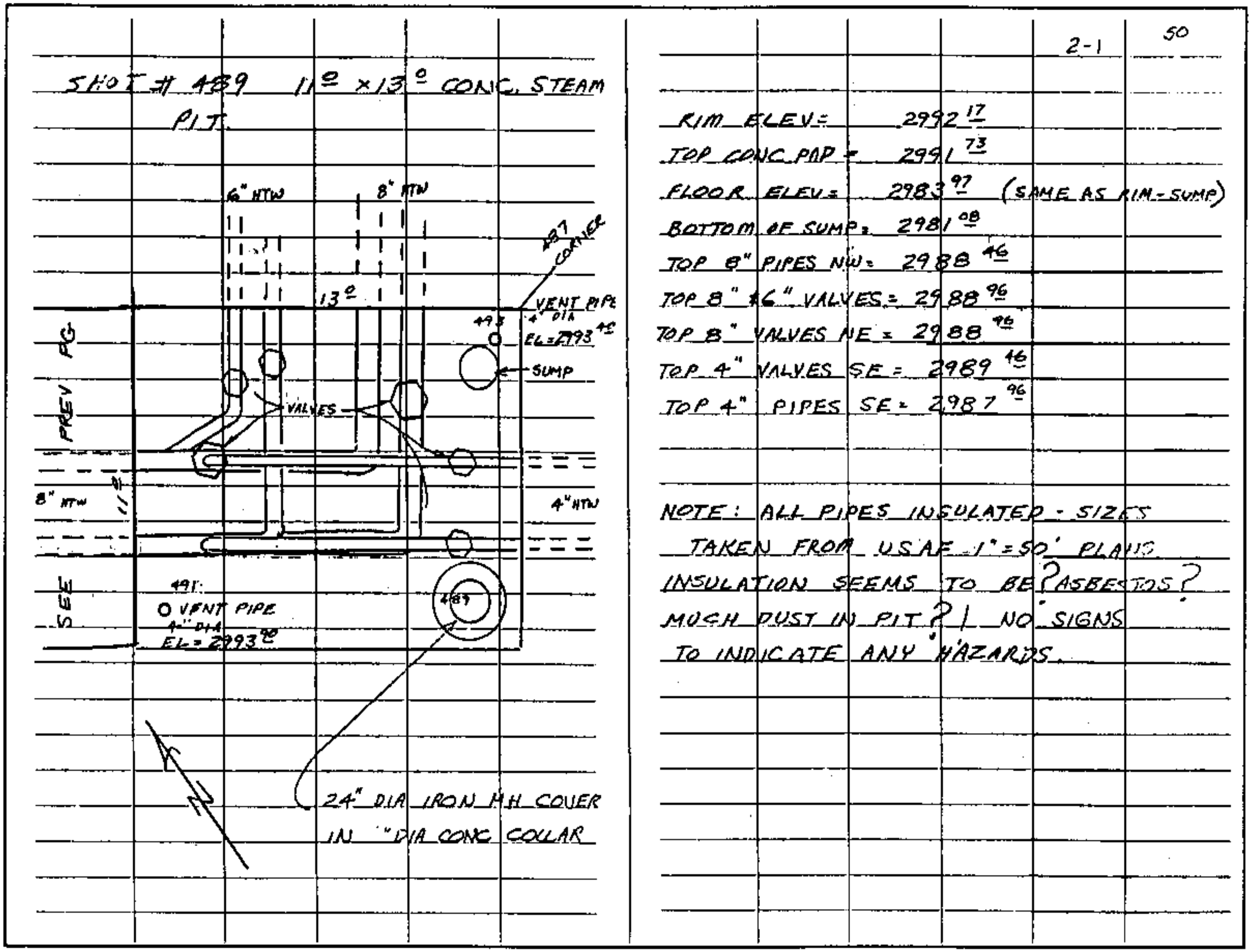

Figure 5-1. Sample of field book sketch used for digital surveys, example 1

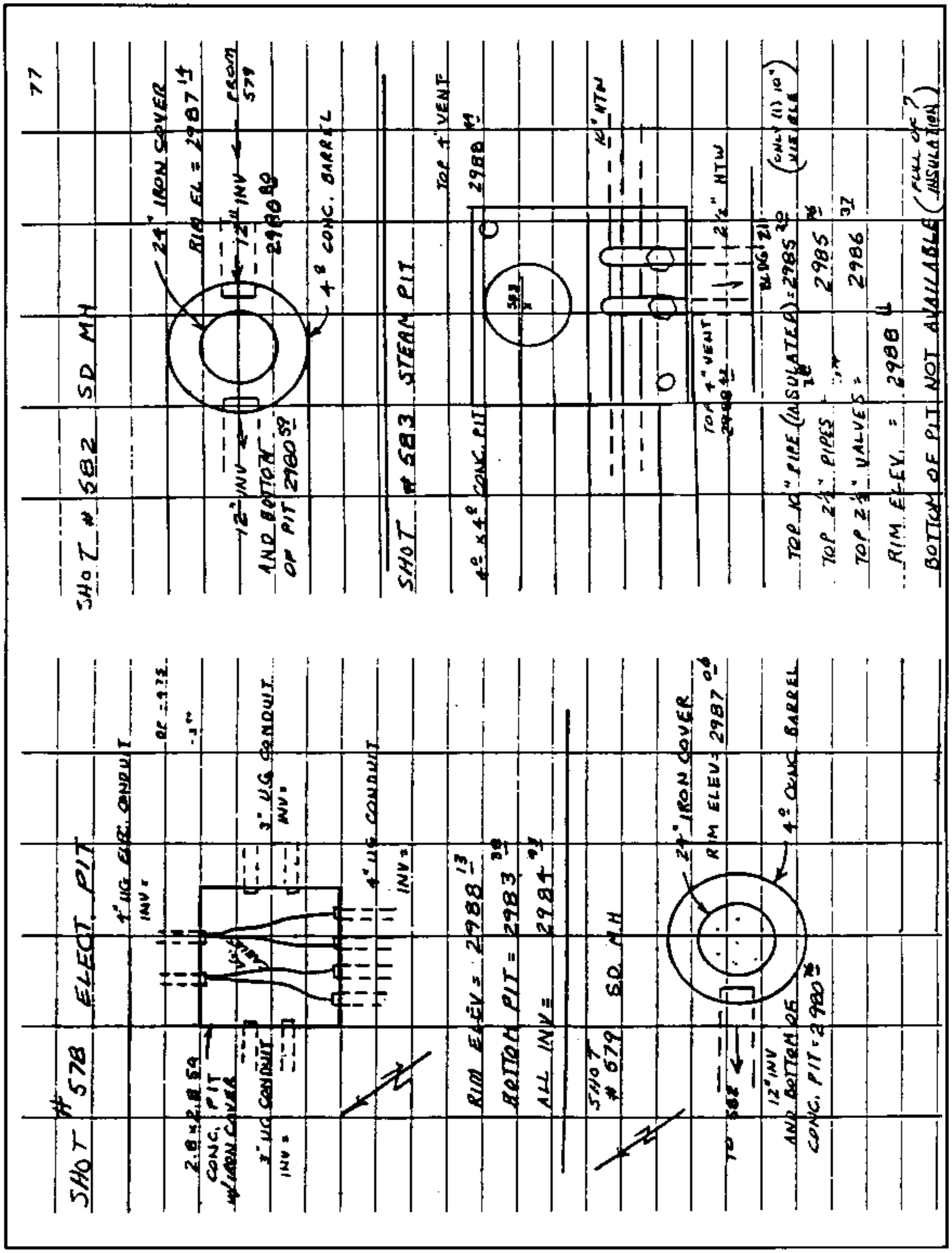

Figure 5-2. Sample of field book sketch used for digital surveys, example 2

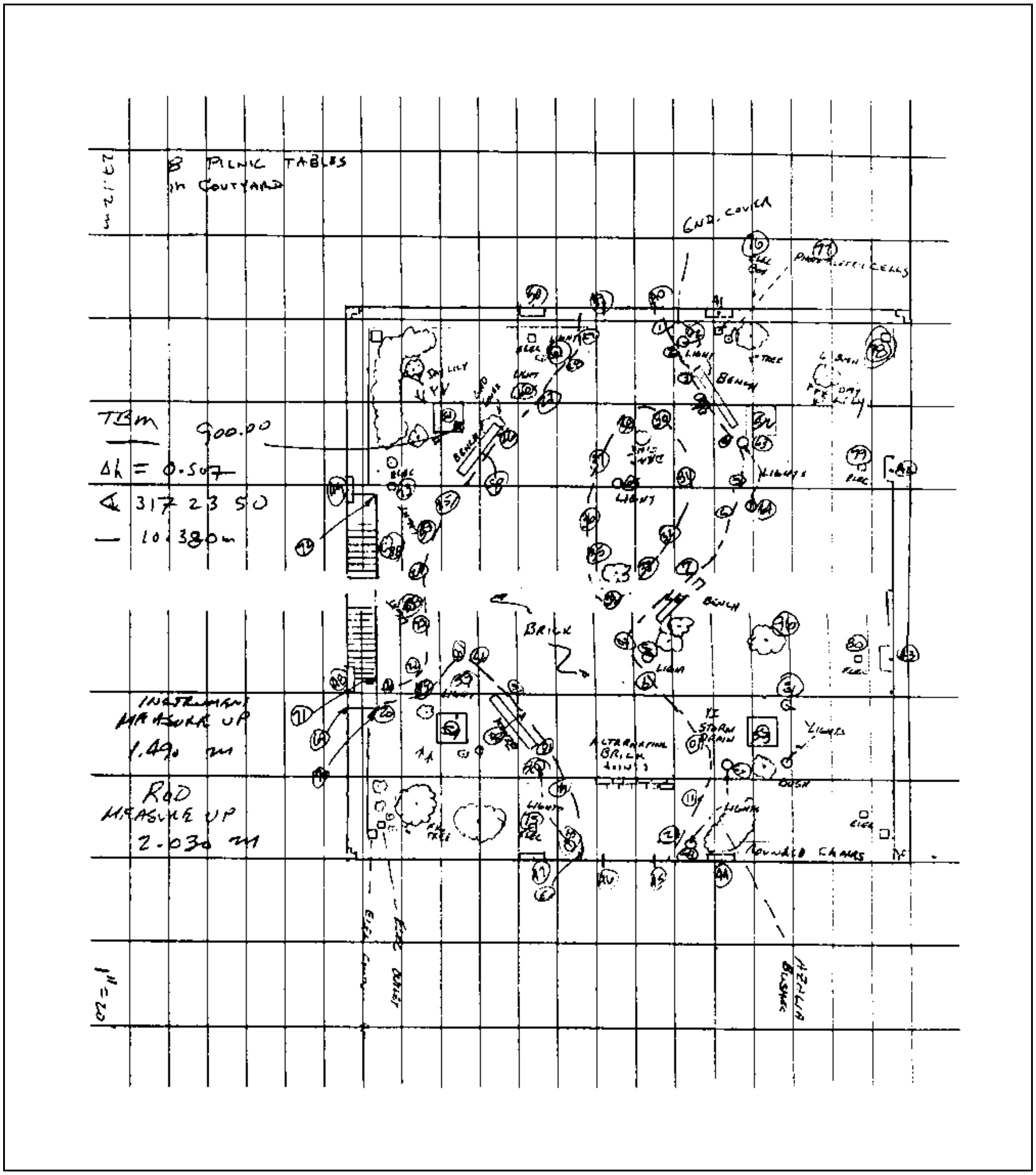

Figure 5-3. Sketch of an office courtyard with point numbers

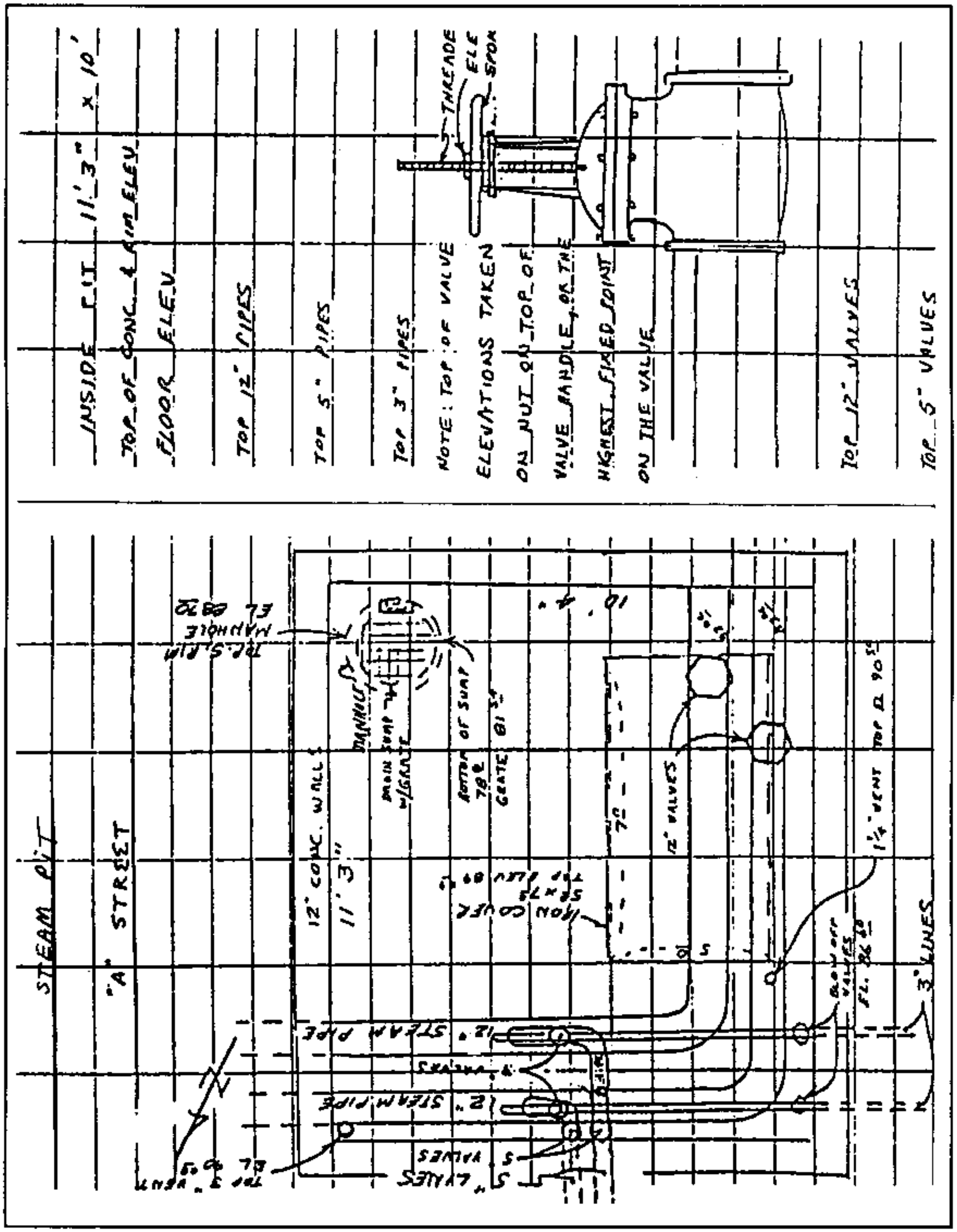

Figure 5-4. Detail sketch

(2) Miscellaneous descriptive notes can also be shown on the sketch for later addition to the design file. These notes are usually clearer and contain more information when shown on the sketch than when entered into the data collector. Figures 5-5 and 5-6 indicate more information than can be typed into a data collector at the present time.

e. Obtain points in sequence. The translation to CADD program will connect points that have codes associated with linear features (such as the edge of road) if the points are obtained in sequence. For example, the surveyor should define an edge of a road by giving shots at intervals on one setup. Another point code, such as natural ground, will break the sequence and will stop formation of a line on the subsequent CADD file. The surveyor should then obtain the opposite road edge.

f. Use proper collection techniques. Using proper techniques to collect planimetric features can give automatic definition of many of these features in the CADD design file. This basic picture helps in operation orientation and results in easier completion of the features on the map. Improper techniques can create problems for office personnel during analysis of the collected data. The function performed by the surveyor in determining which points to obtain and the order in which they are gathered is crucial. This task is often done by the party chief. Cross-training in office procedures gives field personnel a better understanding of proper field techniques.

(1) Most crews will make and record 250-400 measurements per day. This includes any notes that must be put into the system to define what was measured. A learning curve is involved in the establishment of productivity standards. It usually takes a crew five to six projects to become confident enough with their equipment and the coding system to start reaching system potential.

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

(3) When the general spacing of the measurements exceeds 50 feet, having a second rod person will increase productivity. A second rod person allows the crew to have a target available for measurement when the instrument operator is ready to start another measurement coding sequence. Once the measurement is completed, the rod person can move to the next shot, and the instrument operator can code the measurement while the rod people are moving. If the distance of that move is 50 feet or greater, the instrument will be idle if you have only one rod person.

(4) Data collection provides a tremendous increase in the speed of field work by eliminating the need to read and record measurements and other information.

(5) On jobs where a large number of shots are needed, the use of two (or more) rod persons has resulted in excellent time and cost savings. Communication between rod person and instrument person is commonly done via T/R radio. The rodmen can work independently in taking ground shots or single features; or they can work together by leapfrogging along planimetric or topographic feature lines. When more than one rod person is used, crew members should switch jobs throughout the day. This helps to eliminate fatigue in the person operating the instrument.

5-4. Field Crew Responsibility

a. Upon the completion of the file transfer, make a backup copy of the raw data. Once this transfer is complete, and ONLY AFTER this transfer is complete, then the data in the data collector can be deleted.

b. Print a copy of the formatted data and check it against the field notes. Check the field input of data against the field notes. Specifically, check the instrument locations, azimuths to backsights, and the elevation of benchmarks. Also scan the data for any information that seems to be out of order. Check rod heights.

c. Edit the data. Eliminate any information that was flagged in the field as being in error. In the system, make a record of any edits, insertions, deletions, who made them, and when they were made.

d. Process the control data. Produce a short report of the data that were collected in the field. Check the benchmark elevation to be certain that the given elevation is the calculated elevation and that the coordinates of the backsights and foresights are correct.

e. To assure that good data are being supplied by the field, make certain that the field crew fully understands the automated processes that are being used and

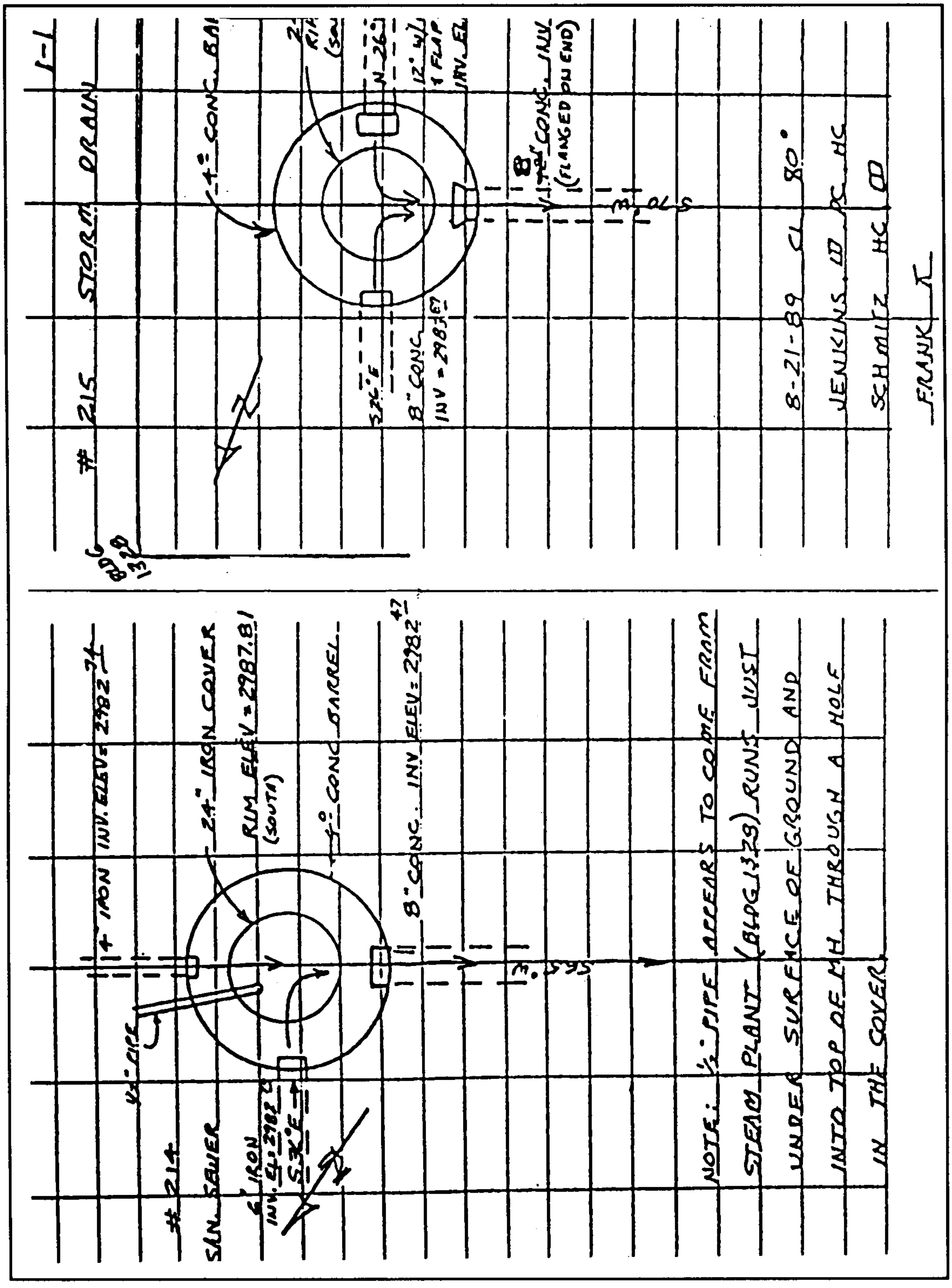

Figure 5-5. Field notes to accompany data collector

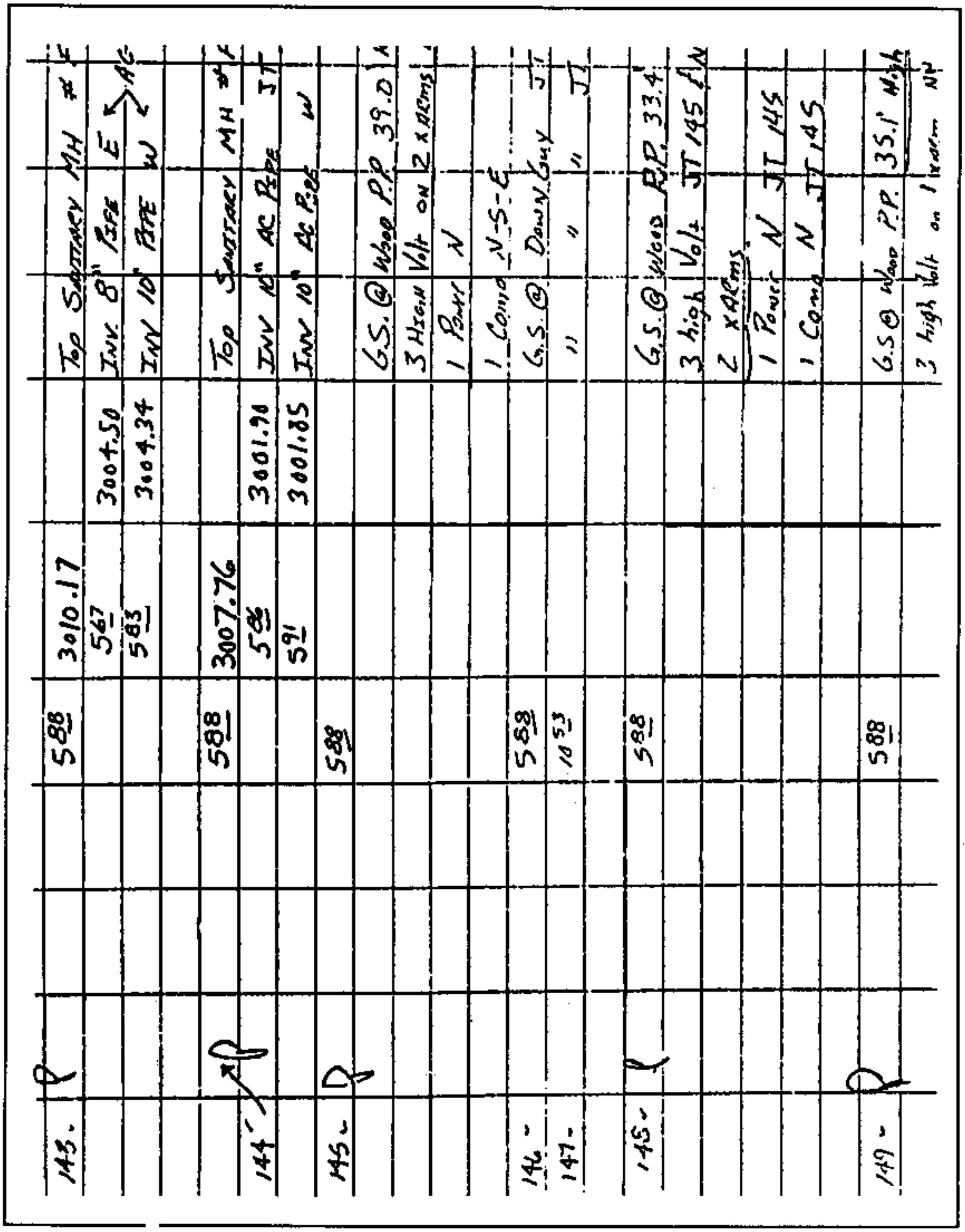

Figure 5-6. Field notes for point locations

that they take care to gather data appropriately. It is much easier and more productive for the field crew to get a few extra shots where they know there will be difficulty in generating a good contour map than it will be for those in the office to determine where certain shots should have been made and add them to the database. Also make sure they pick up all breaklines necessary to produce the final map.

f. The field crew will need to become educated about the contouring package used by the branch. As the data are brought in from the first few projects and periodically thereafter, the crew should observe the product produced by the contouring program. This will help them to understand where and what amount of data may be needed to get the best results.

g. The office staff needs to be aware that in some circumstances the field will have difficulty in getting some information (terrain restrictions, traffic, etc.).

h. The person responsible for the field work should be involved in the initial phase of editing, because he or she will most likely remember what took place. Preferably, the editing should be done the same day the data are gathered, while the field person's memory is still fresh. If it is not possible for someone to walk the site to ensure that the final map matches the actual conditions, then the field person should be the one to review the map.

5-5. Surveyor-Data Collector Interface

For many surveying operations, electronic data collection is routine. However, once the data are collected, most software systems require a large amount of post-processing to produce a map showing planimetrics and contours.

a. Computer interfacing. Many of the benefits of automated data collection are lost if the data stored cannot be automatically transferred to a computer system.

b. Hardware compatibility. Most micro- and minicomputers on the market today are supplied with or have as an option a serial interface board. The serial interface typically supports communications at different baud rates (speed of transmission) and with different parity settings. To control the flow of data, either a hardware or software handshake is used. Cables are connected to the serial interface board using a standard 25-pin connector. Occasionally nonstandard connectors with a different number of pins are used. Every data collector stores data in a different format and the problem is to translate the data from the data collector format into a file with a standard ASCII format. Data standardization will become more important in the future and surveyors should be searching for methods which make system integration easier.

5-6. Digital Data

The fact that survey data collected by computer is in digital form has until recently been of interest only to surveyors themselves. Since the final product delivered to the clients were drawings, surveyors have needed to invest in only the computer equipment and software they needed to get the digital data collected and plotted as a scaled drawing. Now the situation is changing. The proliferation of computer graphics used by architects, engineers, and developers has meant that surveyors are asked, even required, to deliver survey information in digital format. These demands can pose thorny technical problems for those who did not consider this eventuality when they acquired their computer systems. The time and expense to work out the technical details of digital data delivery can be prohibitive to those who consider themselves as surveyors, not computer experts.

5-7. Digital Transfer

There are two ways to transfer survey information digitally: as numeric data or as graphic files. The first is simpler from the surveyor's point of view. It begins with a text file--the sort of data that can be produced using a word processor. Text files are easiest to transfer between computers, but the clients want data that computer software can interpret to produce drawings, not raw field notes.

a. Again, if the surveying software permits the output of the appropriate information in a text file, reformatting that information is, at worst, a minor programming task and may be possible simply through the global replacement feature of a word processing package. However, surveyors who use word processors to edit text files should be sure to use the "ASCII" output option that is available in most word processors. This creates a "generic" text file without embedded control or formatting characters.

b. Most CADD systems require digital deliverables and graphics files compatible with their particular system. This is a more problematic request because, unlike COCO tables which are uniform no matter which vendor's version of COCO is being used, every CADD system has a unique and proprietary graphic data format. This means, for example, that graphic data produced in AutoCad cannot be loaded onto an Intergraph system without some sort of intermediary "translation." Thus, even when data collectors are interfaced with a major CADD package, the diversity of CADD systems being used in the United States today virtually guarantees there will be clients using different systems and unable to load the graphic file directly.

c. Translation of graphics data can be handled in two ways, by direct translation or through a neutral format. A direct translator is a computer program that reads graphic data in one specific CADD system's format and outputs the same graphic information in a second CADD system's format. Although this is generally the quickest and most foolproof way to perform translation, it is often the most expensive. Since direct translation programs only address the problem of translation between two specific systems, several different translation programs may be necessary to provide data that meet the compatibility requirements of all the surveyor's clients.

d. Since all CADD vendors regard their data formats as proprietary, this process generally requires programmers who are intimately familiar with both CADD systems to write translation software.

e. It may be hard to locate all the programs required. Software prices are high because there is little competition in this market. And there is a limited number of buyers who need to communicate between any two specific CADD systems. Finally, most CADD vendors release at least one, and sometimes two, new versions of their software each year. Many releases include changes in graphic data format, so direct translation software can have a life of a less than a year.

f. Users may purchase software maintenance contracts. Like hardware maintenance, these generally charge a monthly fee to guarantee users that the software will be upgraded when either CADD system changes its data format. Users can purchase each updated version as it becomes available.

g. The second way to tackle graphic data translation is through neutral format translators. A neutral format is a nonproprietary graphic data format intended to facilitate transfer of graphic information between CADD systems. Documentation is made available to the public. One such format, the Initial Graphic Exchange Specification (IGES), is an ANSI standard, and documentation is available through the National Technical Information Service in Washington. Other neutral formats have been designed by specific CADD vendors to facilitate data exchange with their systems. The two most frequently used are Auto Desk's Drawing Interchange Format (DXF) and Intergraph's Standard Interchange Format (SIF). The neutral format most commonly used a few years ago was SIF, but DXF now appears to be more generally accepted, particularly among PC-based CADD users. (The other format in which graphic data are sometimes transferred between CADD systems is a plot format, typically CalComp or Hewlett-Packard.)

h. Neutral format translation requires two steps. First, the originator of the data, in this case the surveyor, translates the graphic information from a CADD system's proprietary format into the neutral format. This is the format in which the data are delivered to the client. The client must then translate the data from the neutral format to a CADD system's proprietary format.

i. A major inconvenience of this approach is that it takes at least twice as long as direct translation. With a large survey, it can eat up time on both the surveyor's and the user's systems. Another problem is that users may need to purchase translation programs between the neutral format and their CADD systems if vendors do not provide them as part of the CADD software purchases.

j. Finally, programs do not always execute properly. This can be due to an error in the software or a mistake on the part of the user. Translation programs, whether direct or neutral format, are no exception. The added difficulty with the neutral format approach is that it is difficult to pinpoint where the failure occurred--at the surveyor's end or at the user's. The situation is particularly frustrating when a client who has had painful experiences with unsuccessful and costly graphic data translations may demand that the data be delivered in their CADD system's format.

k. New computer products are being made available every day. Often there is a trade-off between the enhanced degree of functionality in state-of-the-art software packages and their limitations in translation capability. If a software package proves to be truly exceptional and finds a large number of users, translation software will almost surely follow. If the software has limited appeal, either because it is extremely special-purpose or because it is not well marketed, compatibility problems will most likely persist.

l. Requests for digital data deliverables will certainly become more frequent. Large users like the USACE have recently made major commitments to move to a computer-based design and documentation process. This means that not only will the Corps be requesting

CADD deliverables, but increasing numbers of consultants will convert their operations to CADD to be able to satisfy the Corps' requirements. Surveyors currently looking at new computer systems or considering an upgrade should make data exchange capability a major criterion. They should contact major clients to determine their CADD preference and quiz prospective software vendors about their translation software capabilities. If the necessary translation software is available but too expensive, the vendor may be able to recommend service bureaus that provide translation services.

m. Surveyors who have computer systems and are generally pleased with their software's functionality, but who are encountering requests for digital deliverables, should do a quick survey of their major clients to determine what CADD equipment they are using. They should then contact their software vendor to see what solutions they suggest. There may, in fact, be a translation program already available, either through vendor or through a third party. If not, the more requests the vendor gets for translation capability, the more viable a translation program will appear as a new software product.

n. Another good source of information is a software users group, if one exists. Finally, the surveyor can contact CADD service bureaus in the area to see what data translation services they are able to perform. Fortunately, many service bureaus have invested heavily in translation software and are becoming expert in CADD data translation into a number of formats.

o. One caution: be sure to test data translation software using "real life" data. Also ask for references who are surveyors or civil engineers. Graphic data translation is tricky, and a translation program that works wonderfully for 2D architectural floor plans may be totally incapable of handling 3D survey data.

p. A final concern in the delivery of digital data is the media on which the data will be transferred. CADD files are relatively large and extremely cumbersome to transfer via modem. Much preferable and more reliable is the physical transfer of a diskette, magnetic tape, or tape cartridge. When surveyors discuss CADD deliverable with clients, they should explore the question of which media the clients use. Those with large computers probably prefer 1/2-inch 9-track magnetic tape. Those using micros will want diskettes or cartridge tapes. Whereas the large magnetic tape specification is standard, both diskettes and cartridges come in a variety of sizes and formats: high density, double density, etc. The surveyor may decide to forgo a 3-1/2-inch floppy drive if existing clients use 5-1/4-inch high-density diskettes.

q. Figure 5-7 depicts the basic requirements of a generic data collector.

5-8. Data Collector Requirements

The data collector is vital to large surveys using the total station. Assumptions or oversights made at the time of equipment purchase can force a survey operation into equipment problems on the job for the economic life of the equipment. Below are listed some options to consider for the data collector:

- Weatherproof, designed for rugged/durable field use.
- Nonvolatile memory ensures data safety.
- Allow the storage of at least 1,000 points.
- Full search and edit routines immediately on the spot.
- Automatic recording with electronic theodolites.
- Manual entry and recording capability with the hardware that measures angles and distances.
- Formatting must be very flexible for manual entry, even for various CADD leveling tasks.
- Capability to use two files in the collector: one file for collection, the other file for processed data for stakeout tasks.
- Data collector must communicate with the electronic theodolite.
- All the features of the total station should be usable with the data collector purchased.
- The data collector must be compatible with the software you purchase or plan to use.
- Mixing brands should not cause a service problem.

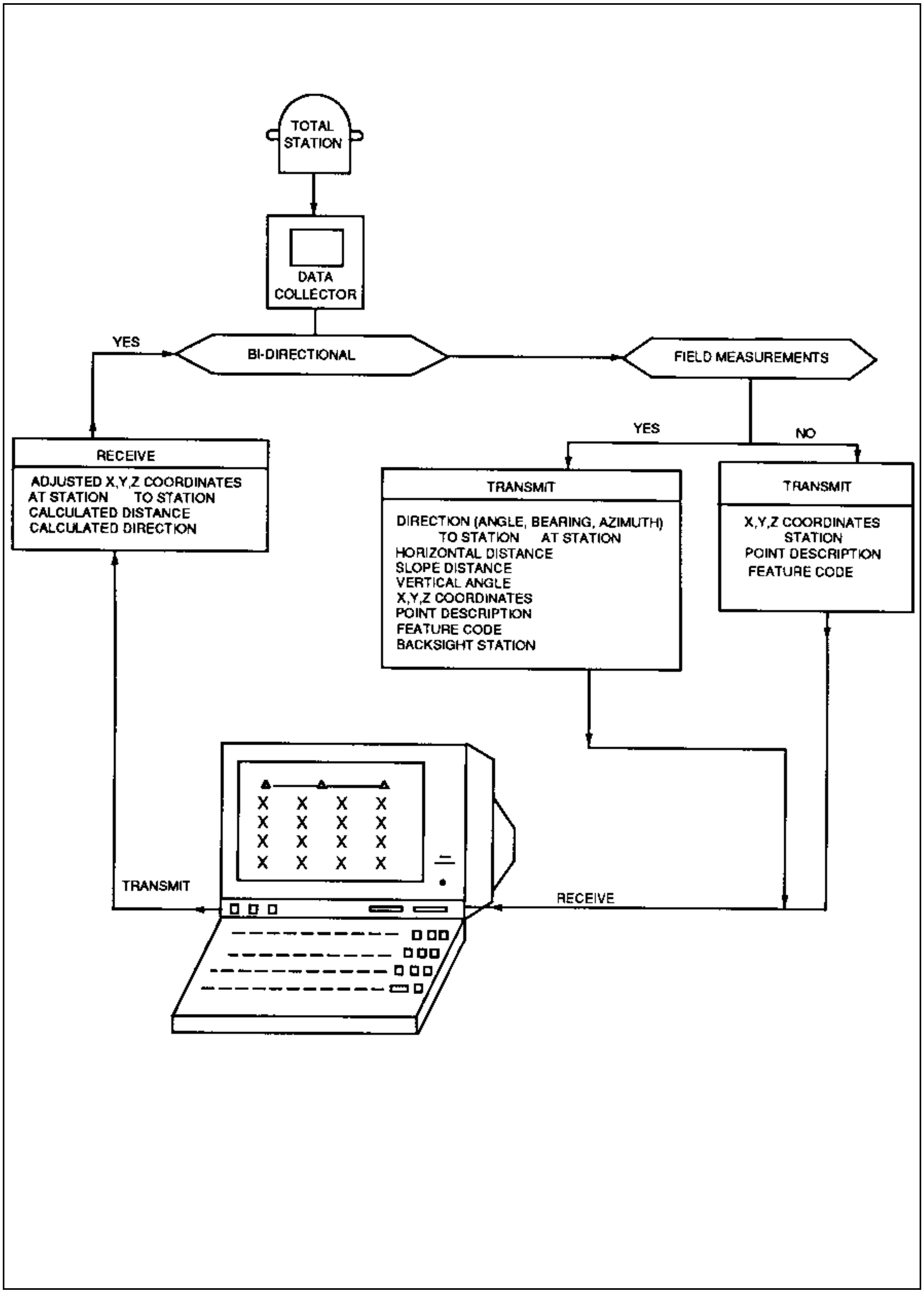

Figure 5-7. Functions of generic data collector

5-9. Coding Field Data

Whether data are recorded manually or electronically, one of the most time-consuming survey operations is the recording of a code or description to properly identify the point during processing. For example, in a topographic or planimetric survey, identification points which locate the position of curbs, gutters, center lines, manholes, and other similar features are essential for their correct plotting and contour interpolation.

a. Especially in topographic or planimetric surveying, many surveyors have wished for some way to speed up the process. For the most part, surveyors tolerate the time-consuming coding process, because it is the only way of ensuring an accurate final product.

b. In spite of this slow coding process when using data collectors available today, the advantages heavily outweigh the disadvantages. These advantages include collection blunder-free numeric data from electronic total stations virtually at the instant they are available and the error-free transfer of these data to an office computer system without the need for manual entry.

c. Field coding allows the crew to become the drafter and provide a more logical approach, as the field crew can virtually produce the map from the field data and eliminate the need for many field book sketches. They can also eliminate office plotting, editing by connecting the dots, etc., to produce a final product. The coding scheme is designed so the computer can interpret the recorded data without ambiguity to create a virtually finished product.

d. Although most of the codes required for survey operations will be found in the following pages, from time to time additional codes may be required.

e. Either numerical point codes or alpha-numeric point codes can be entered into the total station. This identification will vary from district to district, but the descriptor should be standardized throughout the Corps of Engineers.

f. Whenever districts require specialized point codes, then the attribute file may be edited to include these changes.

5-10. Summary of Total Station FIELD-TO-FINISH Procedures

a. Gather field data and code the information.

b. Off-load the data to computer and process the information using equipment-specific software.

c. Create the ASCII Coordinate File containing point number, X coordinate, Y coordinate, Z coordinate, standardized descriptor, and any additional notes.

d. Import the ASCII coordinate file into a CADD program and create a graphics file.

e. Use the CADD program to develop a final map with topographic, planimetric information, including contours, utility information, etc.

f. Edit map.

g. Plot map.

This procedure is illustrated in Figure 5-8.

5-11. Data Collectors

a. Geodimeter 126/400 Series. Geodimeter has integrated most, if not all, of the features of its established Geodot 126 series data collector into the 400 series. The 126 data collector is still available for those users that may have older Geodimeter equipment.

(1) The power source for the Geodot 126 is four nickel cadmium rechargeable batteries which give a life of 15 to 20 hours between charges. The 400 series uses the on-board power supply of the instrument. Data integrity is provided by a lithium battery.

(2) The systems will operate at temperatures between 15 to 122 degrees F which is somewhat higher than most systems and should be considered by those working in the northern areas.

(3) Data storage is described as 900 points for the 400 and 1,500 points for the 126. Both systems allow for additional (optional) memory. Both systems also allow data to be down-loaded to an external data storage device through the HPIL that is integral to both systems.

(4) The Geodot 400 and the Geodot 126 will only support Geodimeter systems.

(5) Both systems support a number of calculating functions as well as northings, eastings, and elevations of points measured in the field.

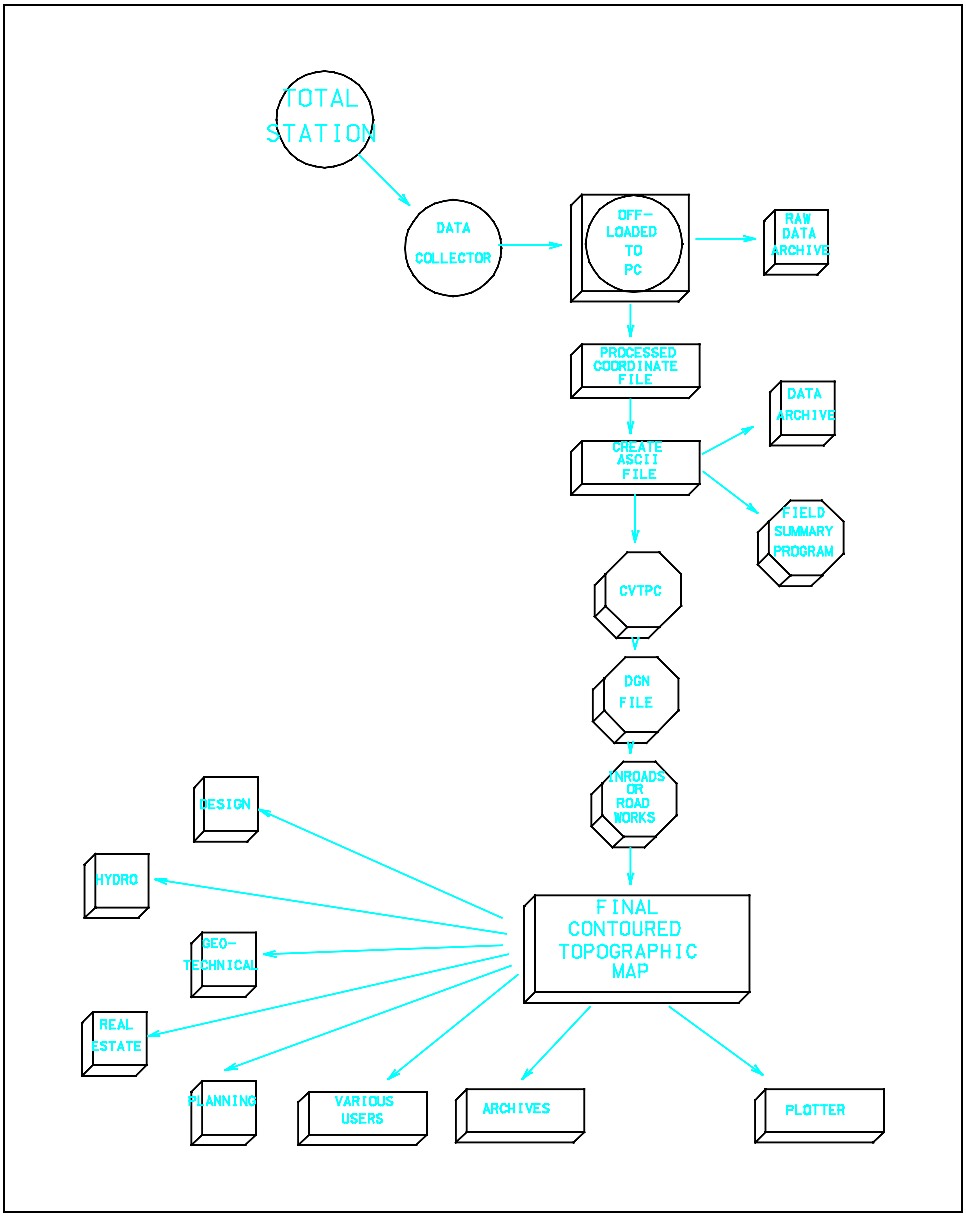

Figure 5-8. Data flow process for mapping

b. Lietz SDR series. The Lietz SDR series of data collectors has a number of features that may be of interest.

(1) The system uses four AA batteries. The operating life is 120 hours. Data integrity is protected should the battery run down.

(2) The SDRs can operate in a temperature range of 4 to 122 degrees F.

(3) The data storage capacity is 32K for the SDR 20, 64K for the SDR 22, and 128K for the SDR 24.

(4) The SDR 24 will support total stations other than Lietz.

(5) Built-in programs handle many coordinate geometry functions.

(6) The data collector is programmable. These programs must be down-loaded from the computer.

c. Topcon FC-4.

(1) The Topcon FC-4 contains an on-board rechargeable nicad battery with sufficient power to operate the unit for 8 hours. The data are protected with a lithium battery which will assure the integrity of data for up to 6 months. The FC-4 will allow the use of an external battery when operating for extended periods.

(2) The system will operate at temperatures from -4 to 122 degrees F. With the optional water and dust cover, the unit is waterproof.

(3) Data storage capacity is 256K with additional storage available for disk and tape. In addition, a unique RAM disk makes it convenient for the field crews to store excess data.

(4) The FC-4 will support 39 models of instruments in the Topcon line and has the capability to support instruments of other manufacturers.

(5) The FC-4 has the common complement of coordinate geometry functions.

(6) The data collector is programmable. User-defined prompts can be input from the data collector keyboard. Custom programs can be done on the computer and down-loaded to the FC-4. The FC-4 does not allow for programming from the keyboard.

(7) Topcon no longer manufactures the FC-1 and the PROPAC HA3 data collectors, but these data collectors remain in the inventory of many satisfied users.

d. Wild GRE and REC series.

(1) The GRE system uses rechargeable nickel batteries and can be powered from external batteries. When used with an external power source, the GRE can run with the on-board battery removed. The REC module operates from the instrument battery. Data integrity is preserved with a lithium battery contained in the REC module.

(2) The systems can operate at temperatures that range from 4 to 122 degrees F. They are “splashproof.”

(3) The data storage capacity of the current line of GRE data collectors is 128K. The older GRE 3 models range from 16K to 128K. The REC module is a 16K module.

(4) The GRE and GRM 10 will support only the Wild instruments.

(5) Built-in programs handle many coordinate geometry functions.

(6) The data collector is programmable. For all practical purposes, these programs must be completed on a PC and down-loaded to the data collector.