

Chapter 5

Field Procedures

OBSERVATION PRECAUTIONS

Because of the high standards of accuracy required for second-order observation, constant precautions are necessary to counteract as much as possible all sources of error. The party chief should periodically inspect the performance of all observing parties. A good observer achieves the full potential of his instrument at all times. He precisely bisects signals and targets and consistently obtains very little spread (three or fewer of the smallest increments marked on the micrometer) between his direct and reverse pointings. Proficiency can be attained only by a careful study of all factors affecting the accuracy of theodolite observations. Efforts should be made to eliminate all known sources of error. Observation precautions can be summarized as follows:

Instrument Check

Check the instruments and signals for stability. If an instrument is not stable, all other refinements are useless.

Instrument Adjustment

Pay careful attention to parallax and inclination of the horizontal circle plate. Errors introduced by these cannot be eliminated. Since the effects of an inclined horizontal circle plate increase with the inclination of the line of sight, the plate level of the T-3, or the striding level of the T-2, is read for second-order observations.

Plumb Signals and Targets

Plumb signals and targets directly over the SCP. Carefully aim targets and signals towards the observing station.

Other Precautions

Other operational precautions for accurate observations are —

- Repainting on the initial after each circle setting.
- Checking the plate level frequently.
- Protecting the instrument from wind, sun, and weather, by using an observing tent.

Do not disturb the instrument during observation of a position by releveled or by lateral thrust on a clamp, tangent screw, or electric switches, or by striking the instrument or its support.

When all other known precautions have been taken, one of the principal causes of reobservation is horizontal refraction. Sometimes elevating the signal will reduce the effects of horizontal refraction, but often the only solution without altering the traverse is to reobserve under different atmospheric conditions.

FIELD CHECK PROCEDURES FOR STARTING AND TERMINATING STATIONS

The starting and terminating stations for a traverse are usually recovered and adjusted stations from a previous triangulation or traverse survey. These stations may be established during the current survey by astronomic observations of the appropriate order of accuracy. These stations must be of the same or a higher order of accuracy as that of the traverse being established. When previously established stations are used, they must be positively identified and a line or angle check must be made. The required limits of these checks (ties) to existing stations will depend upon the order of the survey being accomplished.

Distance Check

When only two intervisible stations of the required order can be recovered, their accuracy can be checked by measuring a check distance between the two. The measured distance is reduced to grid and compared to the computed distance between the stations. Measure the distance between the two stations using the method that is prescribed for the equipment being used. The check distance consists of at least two complete measurements: one concentric, the second eccentric (offset). The amount of offset is carefully measured and will not be greater than 0.5 meters. Reduce the measured distance to grid distance and compare with the computed grid distance. If the measured distance compares to the computed distance within the specifications of the project, then the stations are usable.

Angle Check

When three or more intervisible stations of the required order exist, they can be checked by turning check angles between them. The corrected field angles are then compared to the computed angles.

1. With the theodolite pointed at the target and with the horizontal clamp tightened, the circle is set as follows: Set micrometer scales to read the unit minutes and seconds of the given value. Then, using the horizontal circle drive knob, turn the circle until coincidence (or as near as possible) is obtained at the degree and tens of minutes value of the given reading. After setting the circle in this manner, the actual reading is determined. This setting should normally be accurate to $\pm 05.0''$.
2. When measuring a predetermined angle, the instrument is first pointed along the initial line from which the angle is to be measured and the circle is read. The value of the angle is added to the reading to determine the circle reading for the second pointing. Set the micrometer scale to read the unit minutes and seconds of the value to be set on the circle. Then, turn the instrument in azimuth and make coincidence (or as near as possible) at the degrees and tens of minutes value that is to be set. The horizontal slow-motion screw is used to obtain coincidence. After setting the value in this manner, the actual reading is determined. The predetermined value can usually be set on the circle in this way to $\pm 02.0''$.
3. It is seldom necessary to set a predetermined value on the vertical circle, except when adjusting the instrument or when locating a preselected star for azimuth. Set the micrometer scale to the unit minutes and seconds of the given zenith distance. Then the telescope is elevated (or depressed) to make coincidence at the predetermined degrees and tens of minutes value. The telescope clamp and vertical slow-motion screw are used to make this coincidence. After setting the value in this manner, the actual reading is determined. The predetermined zenith distance can usually be set on the circle in this way to $\pm 02.0''$.

TRAVERSE ROUTE SELECTION PROCEDURES

The party chief usually selects a tentative route from a map and aerial photographs, if available, and plots the proposed station on the reconnaissance map. The lines of sight and all previously established controls (both horizontal and vertical) should also be plotted on the map. The final route is selected during the field reconnaissance. The route that will provide the most rapid means of extending the control with the least effort is usually selected. Often this route will bypass some of the required control points and these points

can be connected to the main scheme by separate loop traverses or by side shots if the required order of accuracy is low enough. Full advantage should be taken of previously cleared lines in laying out the traverse. All control stations from previous surveys that exist along the traverse route should be connected whenever possible, to include bench marks.

Reconnaissance Specifications

There are some reconnaissance specifications pertinent to the route selection that are based on the order of accuracy required:

- Minimum distance between stations,
- Maximum number of traverse legs permitted before being required to extend vertical control (direct leveling) from an existing bench mark to the traverse.
- Maximum number of traverse legs permitted before an azimuth check must be made.
- Maximum permitted change in direction of the traverse before an azimuth check must be made, The change in direction is based on the computed deflection angle at the station during the forward run of the traverse.

These specifications are spelled out in the Federal Geodetic Control Committee's publication, *Standards and Specifications for Geodetic Control Networks*, and will be strictly adhered to when supporting National Geodetic Survey or its Control Networks. In all other cases, comply with the project requirements of the using organization while observing correct surveying procedures.

Type of Distance Measuring Equipment

Consideration must be given to the type of distance measuring equipment when planning a traverse route. In most cases, EDM is available and the distances between intervisible stations are limited only by the maximum effective range of the EDM. If taping must be used, limit the distances between the stations to ten lengths of the tape. The ten-length limit will minimize alignment, leveling, and taping errors.

PROCEDURAL SPECIFICATIONS FOR THIRD-ORDER TRAVERSE SURVEY

The following procedures will be performed when extending horizontal control by traverse methods and third-order accuracy is to be obtained:

ALL third-order traverses will have **TWO station angles** observed at each occupied SCP. The sequence for observing station angles is as follows:

1. The observer places the instrument in the direct position (vertical circle on the observer's left) and points the instrument at the rear station. The observer bisects the rear target, sets the initial plate setting (if required), and reads the micrometer.
2. In the direct position, the observer turns the instrument clockwise to the forward station, bisects the target, and reads the micrometer.
3. The observer plunges the telescope, and turns the instrument clockwise to the forward station, with the vertical circle on the observer's right (reverse position). The observer bisects the target, and reads the micrometer.
4. In the reverse position, the observer turns the instrument clockwise until the instrument is pointing at the rear station, bisects the target, and reads the micrometer.

Steps 1 through 4 constitute the **first station angle**.

5. The instrument remains in the reverse position and pointed at the rear station. The observer bisects the target, advances the horizontal plates to the new initial plate setting (if the theodolite so requires), and reads the micrometer.
6. In the reverse position, the observer turns the instrument clockwise until the instrument is pointing at the forward station, bisects the target, and reads the micrometer.
7. The observer plunges the telescope and turns the instrument clockwise until the instrument is pointing at the forward station in the direct position. The observer bisects the target and reads the micrometer.
8. In the direct position, the observer turns the instrument clockwise until the instrument is pointing at the rear station, bisects the target, and reads the micrometer.

Steps 5 through 8 constitute the **second station angle**.

ALL third-order traverses will have **TWO explement angles** observed at each occupied SCP. The sequence for observing explement angles is the same as the sequence for station angles, except that the explement angles are initiated on the forward station.

The **mean of the station angles** will be shown on the recording form.

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The **horizon closure** will be calculated and shown on the recording form. The horizon closure is the sum of the mean station angle and the mean explement angle.

The **error** will be shown on the recording form. The error is the horizon closure minus 360 degrees. The error will not exceed $\pm 05.0''$.

The **corrections** will be shown on the recording form. The corrections are the error divided by two, and the algebraic sign reversed. When a 1-second theodolite is used, the corrections will be rounded to 0.1 second. If one correction is rounded up, the other correction will be rounded down. The larger correction will be applied to the larger angle.

The **corrected mean station angle** will be calculated and shown on the recording form (see Figure 6-1, page 6-2).

Traverse lines (legs) will have zenith distances observed **in both directions** within one hour. Reciprocal zenith distances are mandatory for compliance with third-order traverse specifications.

SPECIFICATIONS FOR THIRD-ORDER DIFFERENTIAL LEVELING

The terms differential leveling, direct leveling, geodetic leveling, and spirit leveling describe the same activity: the determination of differences in elevation by direct observation. The terms will be interchangeable in this publication. When performing differential leveling and third-order accuracy is to be obtained, the following procedures will be adhered to:

1. Each day, just before the leveling begins, and immediately following any instance when the level is subjected to unusual shock, the error of the level (C factor) must be determined. The C check will be recorded and kept in the records of the project.
2. The leveling will start from and end on bench marks of third-order accuracy or higher.
3. The method of observation will be three-wire readings.
4. No observation will be made closer to the ground than one-half (0.500) meter. No observation will be made on the rod or precise meter board higher than project specifications require.
5. The rods will be leapfrogged forward.
6. There will be an even number of setups between the starting and ending bench marks.
7. The sequence of observing the rods will be the red rod first sequence: rod # 1 or A of a matched pair of rods will be marked (the foot of the rod is painted or flagging is attached to the rod) to distinguish it from the other rod. The marked rod will be observed and the readings recorded first for each setup.
8. Sections will be double run: from the first bench mark out to the next bench mark and return.

9. The maximum allowable disclosure will be the lesser of the two computed values:
 - Twelve millimeters times the square root of the shorter distance run between the bench marks in kilometers, or;
 - Twelve millimeters times the square root of the perimeter of the loop (front and back runs combined) in kilometers.
10. Actions not specified above will comply with the specifications set forth by the Federal Geodetic Control Committee.
11. In no instance will proper leveling methodology and procedures be abandoned. Procedures 1 through 10 will be complied with at all times unless the customer sets forth specific methodology, standards, and specifications for performing the differential leveling in his request for survey support.