INFORMATION SHEET

II-A-3(IS)
(p. 1 of 11)

ON

THE BUILDER'S LEVEL, TRANSIT LEVEL, AND EQUIPMENT

SUBJECT: Level Instruments; Their Use and Care

INTRODUCTORY INFORMATION:

Level instruments, used properly, provide carpenters and other building trade crafts the opportunity to perform their best work with minimal time expended leveling and plumbing.

In building and construction "leveling" is used extensively to establish and/or verify existing topographical data of building sites; compute requirements necessary to correct topographical conditions to conform with design specifications; set controls and establish new elevations for construction purposes. Simply stated, this means "determine existing grades; calculate necessary cut and fill; establish new grades and elevations for construction purposes."

There are many types and makes of level instruments which vary considerably in design, cost, and accuracy. All are precision measuring devices that operate on the principle of projecting a straight, horizontal line of sight in any direction. The difference lies in the power of the telescope, the acuteness with which angles can be read, and the ability to perform additional functions.

The two instruments most commonly used in building trades are the Builder's Level and the Transit Level. Both are similar in function, setup, and operating procedure.

GENERAL INFORMATION:

Uses of Level Instruments

The Builder's Level is used to:

1. Establish levels in relation to a base (datum) point
2. Determine existing elevations
3. Set grade stakes and future (potential) elevations
4. Run straight lines and establish points on a line
5. Lay out and measure horizontal angles of any degree
6. Lay out lines
7. Level foundation forms; flooring

The Transit Level can perform all of the above in addition:

1. Establish slopes for tile and drainage
2. Plumb walls and uprights
3. Measure Vertical angles
4. Perform complete survey

Parts of Builder's Level

Consists of three major sections: telescope, upper body, lower body.

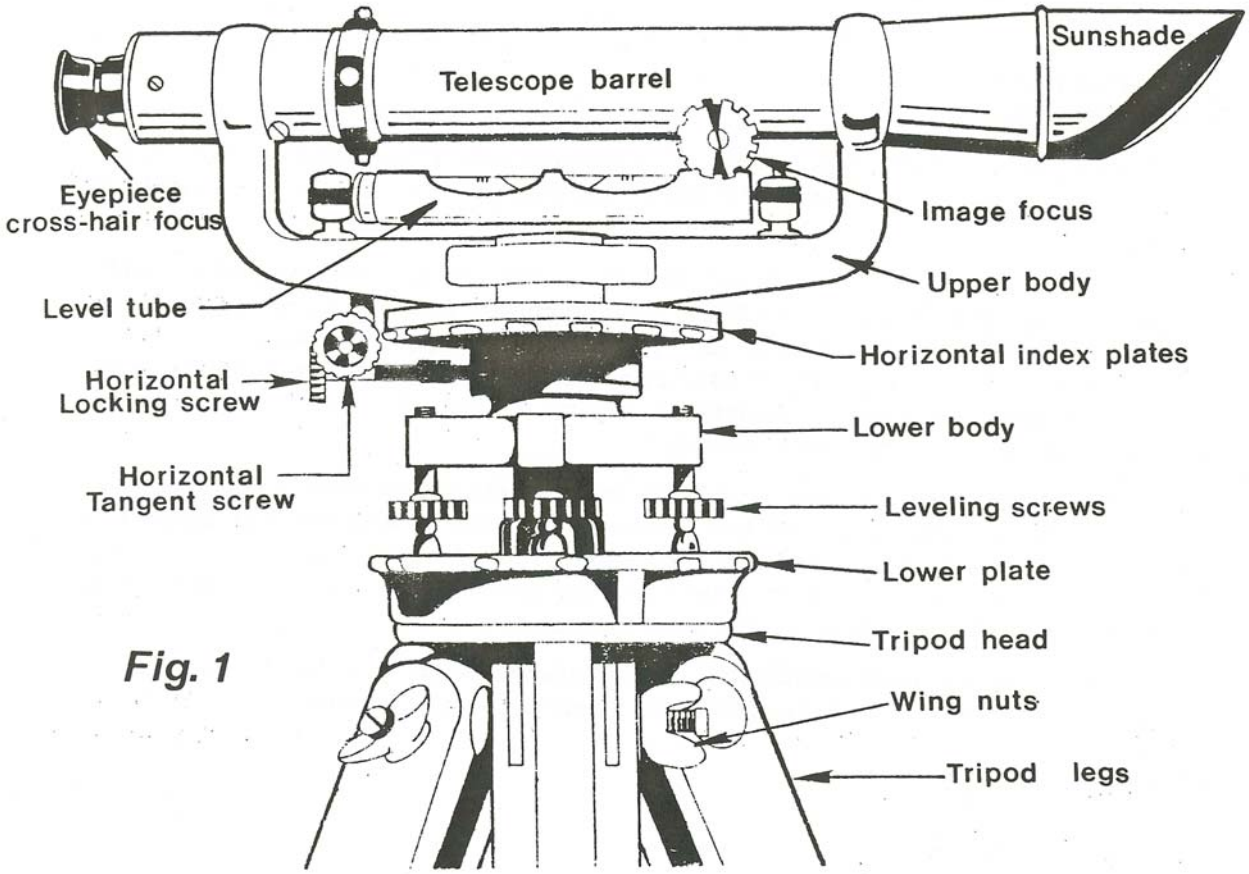


Fig. 1

1. Telescope - is similar to a rifle scope. Consists of:
   a. Barrel - sealed tube containing magnification lenses
   b. Adjustable Eye Piece - to focus cross-hairs
   c. Sun Shield - (optional) on scope end
   d. Image Focus Knob - for object focus
2. Upper body - varies in shape with different makes. Composed of:
   a. Frame - means of support for telescope
   b. Upper Plate - horizontal indexing; contains vernier for reading angles; is supported by tapered center which pivots inside concentric center of lower plate
   c. Level Tube - spirit level; may be attached to telescope or upper body
   d. Horizontal Motion Clamp Screw - clamps upper, lower plates together
   e. Horizontal Motion Tangent Screw - used for fine adjustment

3. Lower Body - Includes:
   a. Lower Plate - horizontal indexing; contains circular graduations (degrees); affixed to tapered center of lower body
   b. Level Head - integral part of lower body; contains leveling screws
   c. Leveling Screws - used to level the instrument
   d. Base Plate - provides uniform surface to receive bearing pressure from leveling screws; contains internal threads for attaching to tripod head
4. Tripod - stand on which instrument is mounted; consists of
   a. Head - ring shaped disc with external threads to mount instrument, and three lugs machined to attach legs
   b. Legs - (3) attach to tripod head at lugs by machine bolts and friction nuts (wing nuts)

Instrument Care

Level instruments are precision measuring devices which must be handled and transported properly if they are to provide lasting and accurate service. The following are suggestions for handling and transporting:

1. Always store instrument in carrying case - place in protected area.
2. Always transport instrument in carrying case when moving to and from job sites.
3. Protect instrument from shock and vibrations.
4. Lift from, and return to, case carefully - do not lift or handle by the telescope.
5. Place loose parts (lens covers, thread cap, plumb bob) in case when not in use to prevent loss.
6. Exercise caution when mounting instrument on tripod - do not cross-thread $3\frac{1}{2}$" diameter threads.
7. Never force or overtighten screws or threads. Finger snugness is the rule.
8. Protect lens from direct sun rays - use sunshade as required.
9. Use lens tissue to clean lens; remove dust with camel hair brush.
10. Never remove lens from telescope.
11. Carrying instrument mounted on tripod; tighten (snug) all clamp screws:
    a. In open country - close legs; place on shoulder with instrument back of head; sling forearm over legs.
    b. In brush and trees - close legs; carry under arm with instrument forward, close to body.
12. Set tripod legs firmly before mounting instrument.
13. Exercise caution moving around a setup instrument.
14. Never leave a setup instrument unattended.

Set Up and Level Instrument

1. Set up Tripod
   a. Unbuckle leg strap and ease leg friction at tripod head - turn wing nuts counterclockwise slightly.
      Note: Some friction (stiff movement) is desirable.
   b. Check leg lenghts if adjustable. Adjust legs evenly to approximate 5' long.
   c. Spread legs evenly 3' - 4' apart and position tripod over desired location.

Set legs firmly in ground with head visually level.
Note: If tripod is on sloping ground, position two legs downhill.

d. Tighten wing nuts at tripod head; remove protective cap from head and store in case.

2. Mount Instrument
   a. Remove instrument from case carefully. Do not lift or hold instrument by telescope. Do not bump or drop instrument.
   b. Position instrument base on tripod head to engage threads. Hold instrument steady with one hand; engage threads handtight (snug) with other hand.
   Note: Do not force or cross threads.
   c. Remove lens covers and store in case. Install sunshade.
3. Level Instrument
   a. Loosen horizontal motion clamp screw and rotate telescope to align over two opposing leveling screws. Tighten clamp screw.
   b. Face side of telescope with level tube - turn the two leveling screws aligned with the telescope in opposite directions simultaneously using the thumb and forefinger of each hand.
   c. Observe the bubble in the spirit level. The bubble will follow the direction of movement of the left thumb. Bring the telescope to the level position (bubble centered between the lines on the level tube.)
   d. Loosen horizontal motion clamp screw and rotate telescope 90^{o} to align over opposite two leveling screws. Tighten clamp screw! Repeat steps b and c above.
   Note: To check instrument level, loosen horizontal motion clamp screw and slowly rotate telescope 360^{o}. Observe bubble in level tube - bubble should not move out of center position (from between lines on the level tube).
4. Set Up Instrument Over A Given Point
   a. Set up tripod and mount instrument similarly as in steps one and two - visually leveled and centered over the given point.
   b. Suspend plumb bob on a cord from the plummet at the bottom of the instrument - point of plumb bob very near the level of the given point (nail in top of stake).
   c. Relocate instrument so that plumb bob is not more than $\frac{1}{4}$" horizontally from the exact point by shifting the tripod legs slightly.
   Note: Maintain visual level of instrument - set legs firmly - tighten wing nuts at tripod head upon relocation.
   d. Position plumb bob directly over given point by loosening two adjacent leveling screws and shifting the instrument on the base plate to the desired position. Tighten leveling screws.
   e. Level instrument as per step three.

Leveling

To better understand the principle of leveling, certain terminology should first be studied and committed to memory.

Vertical line - a line to the center of the earth from any point. A line in the direction

in which gravity works - a plumb line.

Level surface - a spheroidal surface paralleling the surface of the earth's oceans. (The surface of a body of still water - best example).

Level line - any line in a level surface.

Mean sea level - the average height of the surface of the sea. The standard datum for all elevations throughout U.S. Established by taking hourly readings of all stages of the tide over a 19 year period; called Sea Level Datum of 1929.

Datum - reference to an elevation.

Vertical control - a series of points of known elevation established throughout a project.

Bench Mark (BM) - a permanent material object, natural or artificial, bearing a marked point of known elevation.

Temporary Bench Mark (TBM) - a relatively permanent material object whose elevation is established for a particular job.

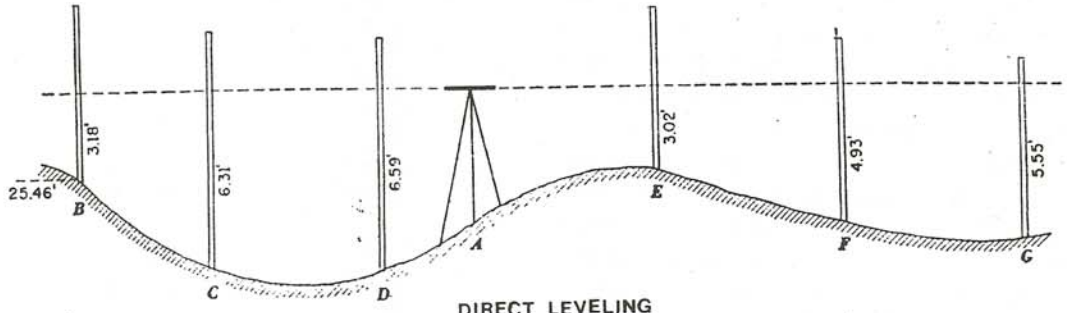
Height of Instrument (HI) - is the elevation at the line of sight of the telescope of a level instrument.

Back Sight (BS) - also called "plus sight" (+S) is the reading on a rod held vertical at a point of known elevation.

Fore Sight (FS) - also called "minus sight" (-S) is the reading on a rod held vertical at a point whose elevation is to be determined.

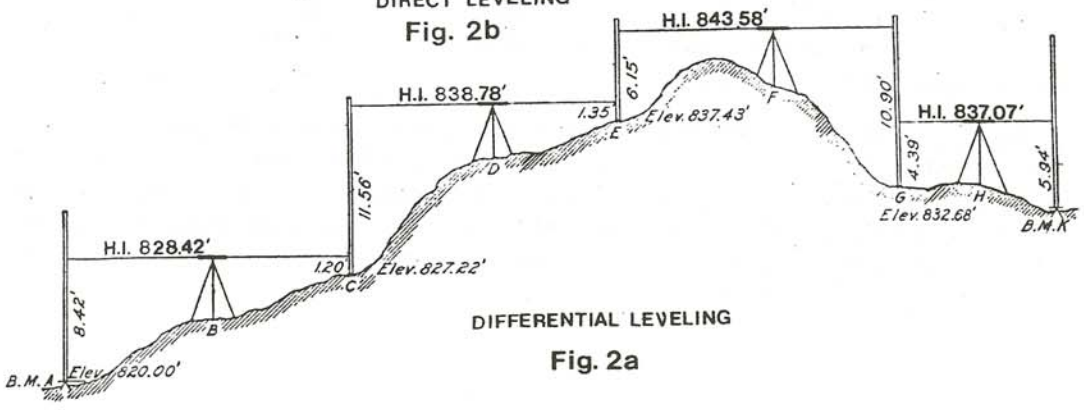
Turning Point (TP) - a stable point, first of unknown elevation, then of known elevation, used to carry forward a line of levels.

Leveling - is the process of determining elevations, or differences in elevations of points. There are several types of "leveling" which are generally named after their function: differential leveling, profile leveling, borrow-pit or cross-section leveling, etc. All leveling operations may be expressed in two equations repeated over and over as necessary.



DIRECT LEVELING

Fig. 2b



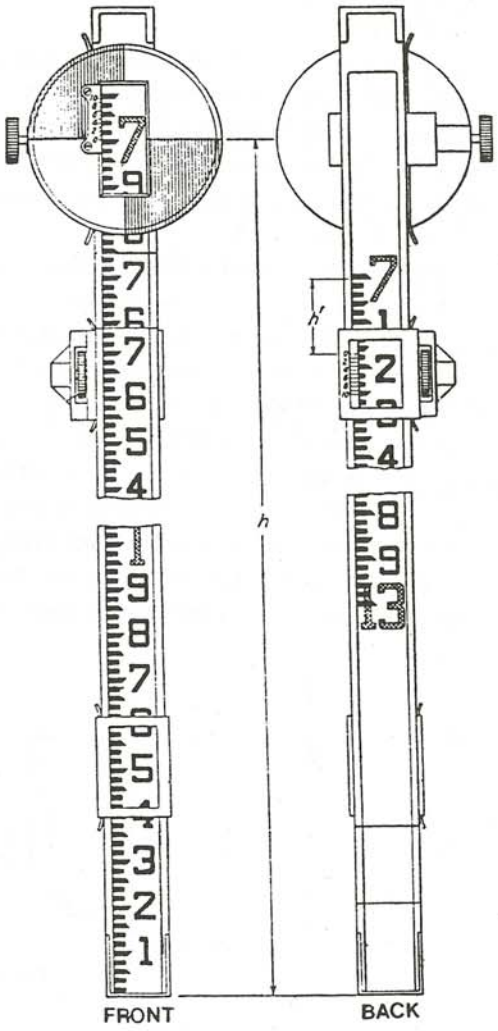
DIFFERENTIAL LEVELING

Fig. 2a

Leveling is performed with the level instrument (mounted on tripod) and the level rod. Leveling requires the coordinated effort of two persons working as a team - communicating through a system of signals. The instrument man sets up, levels, and operates the instrument. He must be able to read the rod accurately and record readings systematically. Leveling rods, generally, are graduated wooden rods. There are several kinds of leveling rods which differ in construction details but not in principle of operation. The two most commonly used are the Philadelphia rod and the California rod.

The Philadelphia rod consists of two longitudinal sections held together with brass sleeves and clamps which allow the rear section to slide causing the rod to be extended. The front face of the two sections are graduated in feet, tenths of a foot, and hundredths of a foot. The graduation marks themselves are painted .01' wide with .01' spaces between. The .10' and .05' graduations are emphasized by spurs extending the marks. Tenths are indicated by black numbers, and feet by bolder red numbers centered on their respective marks. When the rod is closed, called a "short rod," heights to 7'-0" can be read. When the rod is extended fully, called a "long rod," the graduations are arranged continuously to read heights to 13'-0". The back of the upper rod is marked from 7'-0" downward to 13'-0 in the same manner as the front. On distant shots a target is set at 7'-0 and the rod raised to the level of the telescope. The target is generally a circular shaped plate painted red and white in alternate quadrants to assimilate the telescope cross-hairs. It contains a window in its center for reading the rod. When the correct level is reached the instrument man signals the rodman who takes the reading through a fixed window on the back attached to the lower rod. A rod partially extended is referred to as an "open rod."

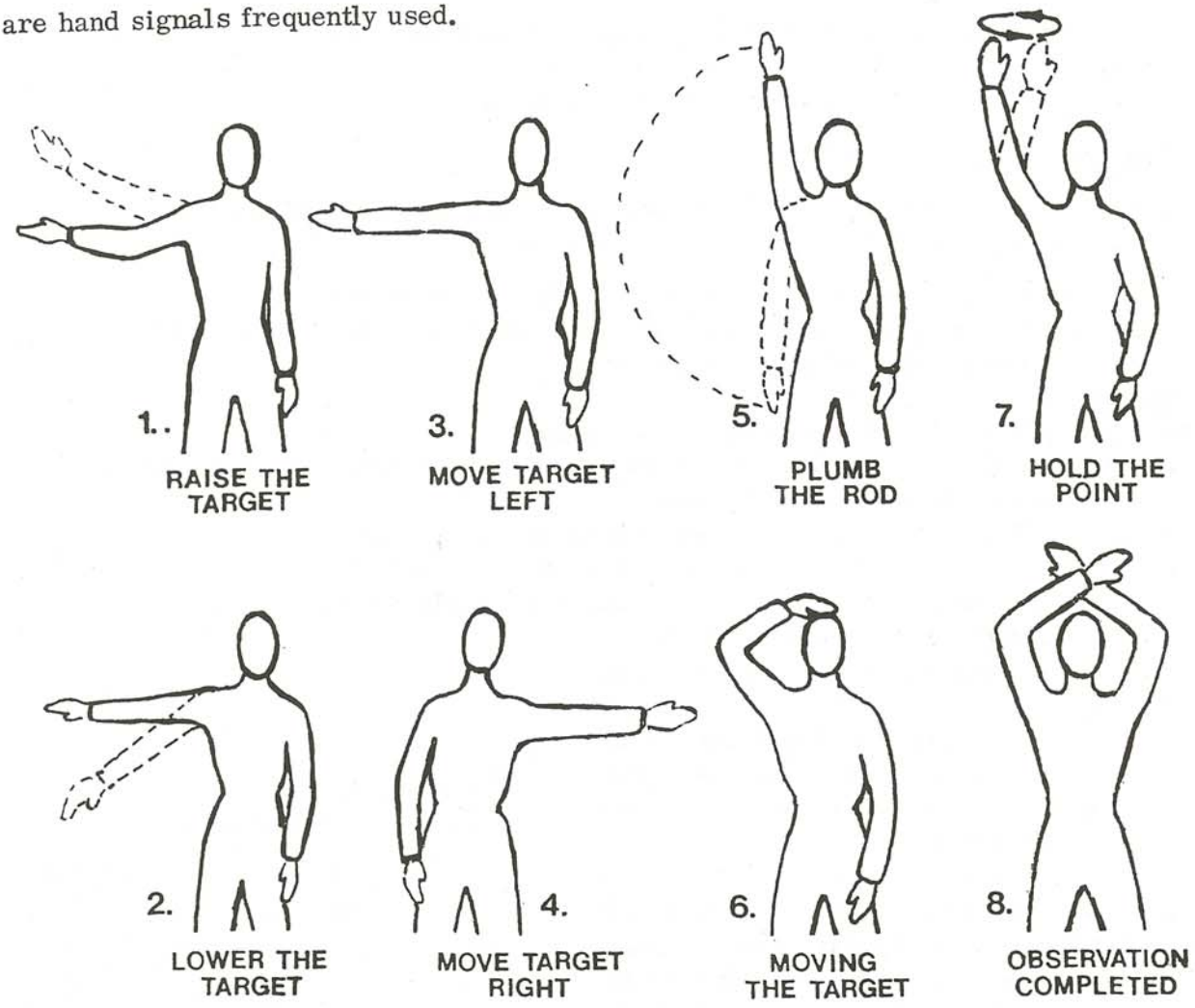
Fig. 3



Philadelphia Rod

Hand signals are used to communicate instructions between the instrument man and the rodman. Often working several hundred feet apart renders verbal instructions inadequate. As the rod must be plumb with the instrument cross-hairs -- a rod leaning in any direction will cause inaccurate readings--the instrument man must signal instructions to the rodman who positions and holds the rod accordingly. Following

are hand signals frequently used.



1. Raise the Target - right arm outstretched to side with palms up; slowly raise arm until target is positioned.
2. Lower the Target - right arm outstretched to side with palm down; slowly lower arm until rarget is positioned.
3. Move Target Left - extend right hand in direction rod is to be moved. A long sweeping motion indicated a long distance; a short quick motion indicates a short distance.
4. Move Target Right - opposite of "move target left."
5. Plumb the Rod - extend either arm above head - move arm slowly in direction top of rod must move to align with telescope vertical cross-hair - stop arm motion when plumb.
6. Moving the Target or Rodman has moved the Target - extend arm up at 45^{o} angle with body and place palm of hand on head (used by rodman).
7. Hold the Point (used to signal the level is going to be moved; the rod must not be

moved until new backsight has been taken) - extend right hand above and wave in a circle.

8. Observation Completed - extend both arms above head and cross.

Shooting And Recording Levels

Certain procedures should be followed when shooting and recording levels in order to produce the most accurate results with least effort.

Direct Leveling - is used in areas where all readings can be taken from one HI setting.

Example: Setting grade stakes on a building site which has a gentle change in topography and is moderate in size.

Procedure:

1. Study the job at hand! From blueprint plot plans:
   a. Study grade contours and topography. Note contour elevations; topographical features which may obstruct vision.
   b. Locate BM, potential TBM, best location to set up level.
   c. Determine grid system for setting grade stakes; size of plot; spacing of grids.
   d. Make grid drawing on plot plan or plot plan overlay to same scale. Locate and identify all grid intersections.
2. Lay out and stake grid system according to drawing:
   a. Locate property rront boundary or other base line for grids - lay out grid intervals as per grid drawing - set 2" x 2" x 6 lg. stake flush with ground at each point.
   b. Lay out perpendicular line to base and set grid stakes similar as base line.
   c. Lay out intermediate grid points using intersecting tapes from appropriate points and mark with stakes as others.
3. Set up instrument at chosen station point:
   a. Visually check lines of sight - to BM or TBM, to distant points of plot.
   b. Set up and level instrument.
   c. Recheck lines of sight using telescope and level rod (adjust station point as necessary).
   d. Establish HI and record.
4. Shoot elevations systematically and record.

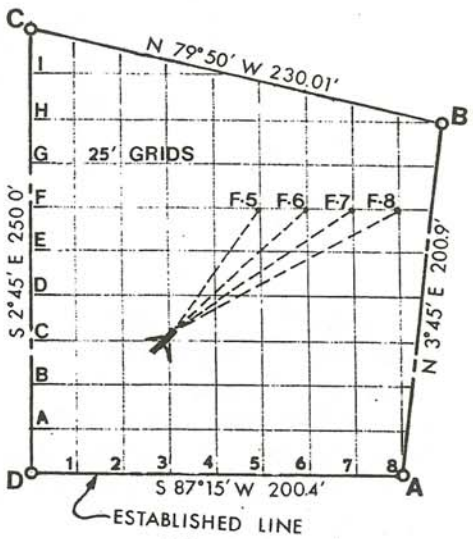


Fig. 5

Differential Leveling - often called "a line of levels" is used when the distance between two points is too great, or the elevation between two points is too great to determine with one setting of the instrument.

Example: Establish a TBM from a distant BM

Procedure:

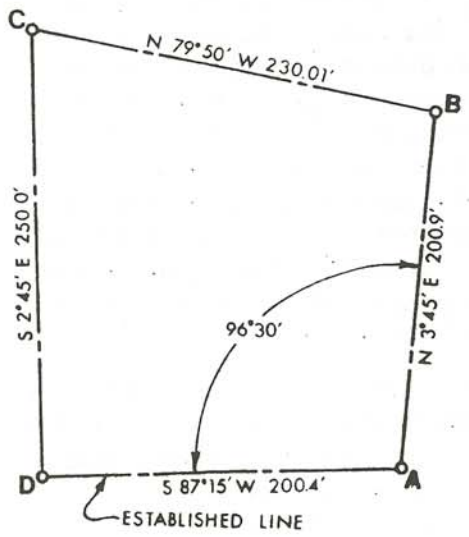
1. Study the job at hand! Become familiar with the topography, grade contours, variations in elevation.
2. Locate BM; establish desired TBM; select appropriate number of intermediate points between which:
   a. are approximately the same distance apart.
   b. can be read with a BS and a FS of the instrument set up between each two points.

   Notes: Points do not have to be in a straight line. The distances between the instrument and each two points should be approximately the same. This may be accomplished by pacing off the distances.
3. Set up and level instrument equidistant between BM and TP-1. Take BS with rod held vertical at BM. Take FS with rod held vertical at TP-1. Record all readings.
4. Repeat step #3 between TP-1 and TP-2, 2 and 3 etc. until arriving at the TBM.
5. Total the BS readings; total the FS readings. The difference in totals equals the difference in BM and TBM elevations. If BS totals are greater than FS totals the TBM is higher than BM.
6. To check accuracy of work, run a second line of levels from the TBM back to the BM.

DIFFERENTIAL LEVELING
FIELD NOTES

STA.	B.S.	H.I.	F.S.	ELEV.	DIST.
B.M.	8.42			820.0	
		828.42			270'
TP-1	11.56		1.20	827.22	
		838.78			258'
TP-2	6.16		1.35	837.43	
		843.58			285'
TP-3	4.39		10.90	832.68	
		837.07			261'
TBM			5.94	831.13	

Turning Horizontal Angles



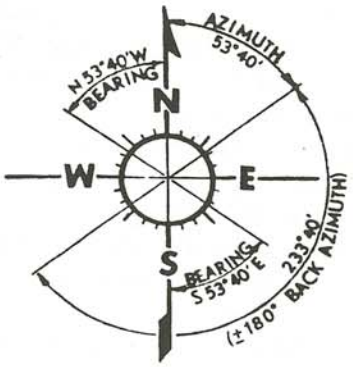
1. Set up instrument over the vertex of the angle (point A) at which the two sides meet:
   a. position instrument using the plumb bob.
   b. level the base and the telescope.
2. Sight the telescope along the first side (AD) of the angle:
   a. edge of rod held plumb at a point on line AD (may be point D).
   b. telescope vertical cross-hair aligned with edge of rod.
3. Tighten the clamp screw to hold the telescope in position and set the circular scale on the 0^{o} indicator or 0^{o} of vernier.

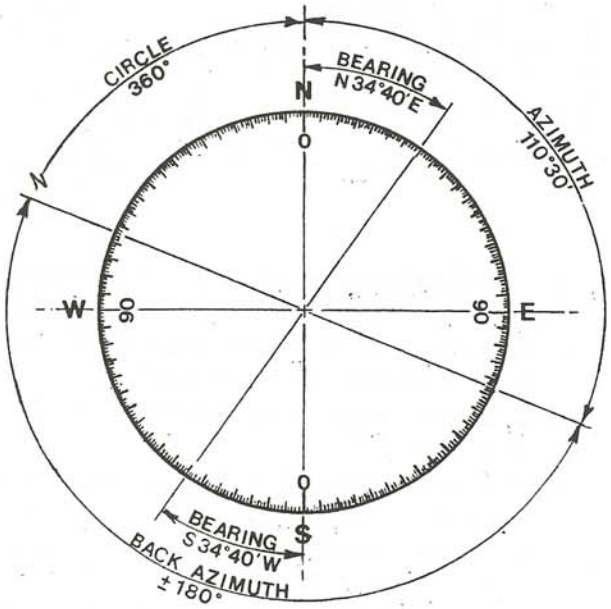
Note: Different model instruments vary in sequence of alignment and orientation. Steps 2 and 3 may be reversed on some models.

4. Set the telescope on the desired angle:
   a. swing telescope in direction to form angle.
   b. read circular scale to approach, but not pass desired angle.
   c. set final angle with tangent (fine adjustment) screw for accuracy.

Reading Angles:

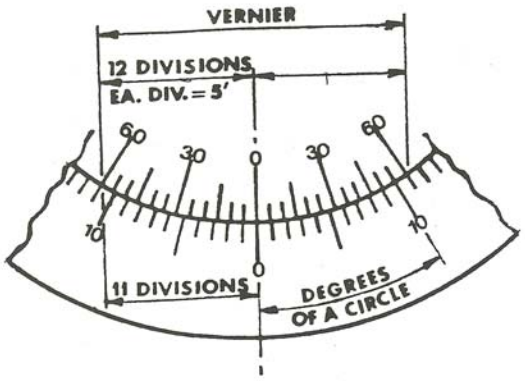
1. "Metes" in surveying means "directions." Compass directions given in terms of an angle generated from a point on a north-south line. These directions are given in degrees, minutes, and seconds. There are 360 degrees in a circle; 60 minutes in each degree; and 60 seconds in each minute. Directions are referred to as either azimuths or bearings. An azimuth is an angle generated from north as 0^{o} in a clockwise direction. A bearing is an acute angle (less than 90^{o}) generated from either north or south as 0^{o}, in either an east or a west direction.

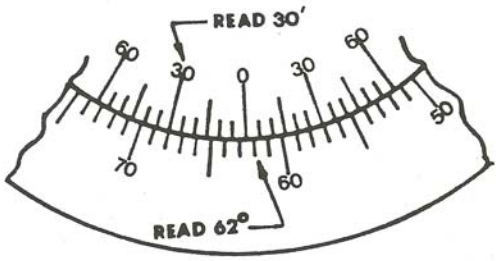




2. The circular scale is calibrated into 360 equal divisions. Each division represents one degree of a circle. The circular scale is also divided into four quadrants. Each quadrant measures 0^{o} to 90^{o} with the 0^{o} marks (2) on opposite sides of the circle. When 0^{o} are aligned with a north-south line this allows bearing angles to be easily generated and/or read. The circular scale 0^{o} may be oriented to any line of known direction over a known point and angles generated or determined in the same manner although an angle being generated must first be calculated from known data (bearings and azimuths of lines forming the angle).

3. The vernier scale allows angles to be read accurately within minutes or seconds of a degree. The vernier is tangent to, and opposite of the graduations of the circular scale. A vernier, popular among building contractors, allows angles set or read accurately to one-twelfth of a degree-or five minutes.





This vernier scale is composed of a 0^{o} mark with twelve equal graduations on each side of 0. Each graduation of the vernier represents five minutes of a degree (5' x 12 = 60' or 1^{o}). A twelve-unit arc on the vernier is equal to an eleven-degree arc of the circular scale.

To read the circular scale and vernier:

1. Always read in the direction of the increasing angle.
2. Read degrees when the vernier 0^{o} mark lines up with a degree mark on the circular scale.
3. Read degrees and minutes when the vernier 0^{o} mark passes a degree mark:
   a. locate a "five minute" calibration on the increasing side of the vernier which aligns with a degree mark on the circular scale.
   b. read minutes from the vernier 0 to the aligned marks on the vernier scale.