photograph, and figure 11-3 shows the line map made by the use of overlays.

BASIC SURVEYING INSTRUMENTS

Most fieldwork done by an Engineering Aid (especially at the third- and second-class levels) is likely to consist of field measurements and/or computations that involve plane surveying of ordinary precision. This section describes the basic instruments, tools, and other equipment used for this type of surveying. Other instruments used for more precise surveys will also be described briefly.

Surveying instruments come in various forms, yet their basic functions are similar; that is, they are all used for measuring unknown angles and distances and/or for laying off known angles and distances.

MAGNETIC COMPASS

A magnetic compass is a device consisting principally of a circular compass card, usually graduated in degrees, and a magnetic needle, mounted and free to rotate on a pivot located at the center of the card. The needle, when free from any local attraction (caused by metal), lines itself up with the local magnetic meridian as a result of the attraction of the earth's magnetic North Pole.

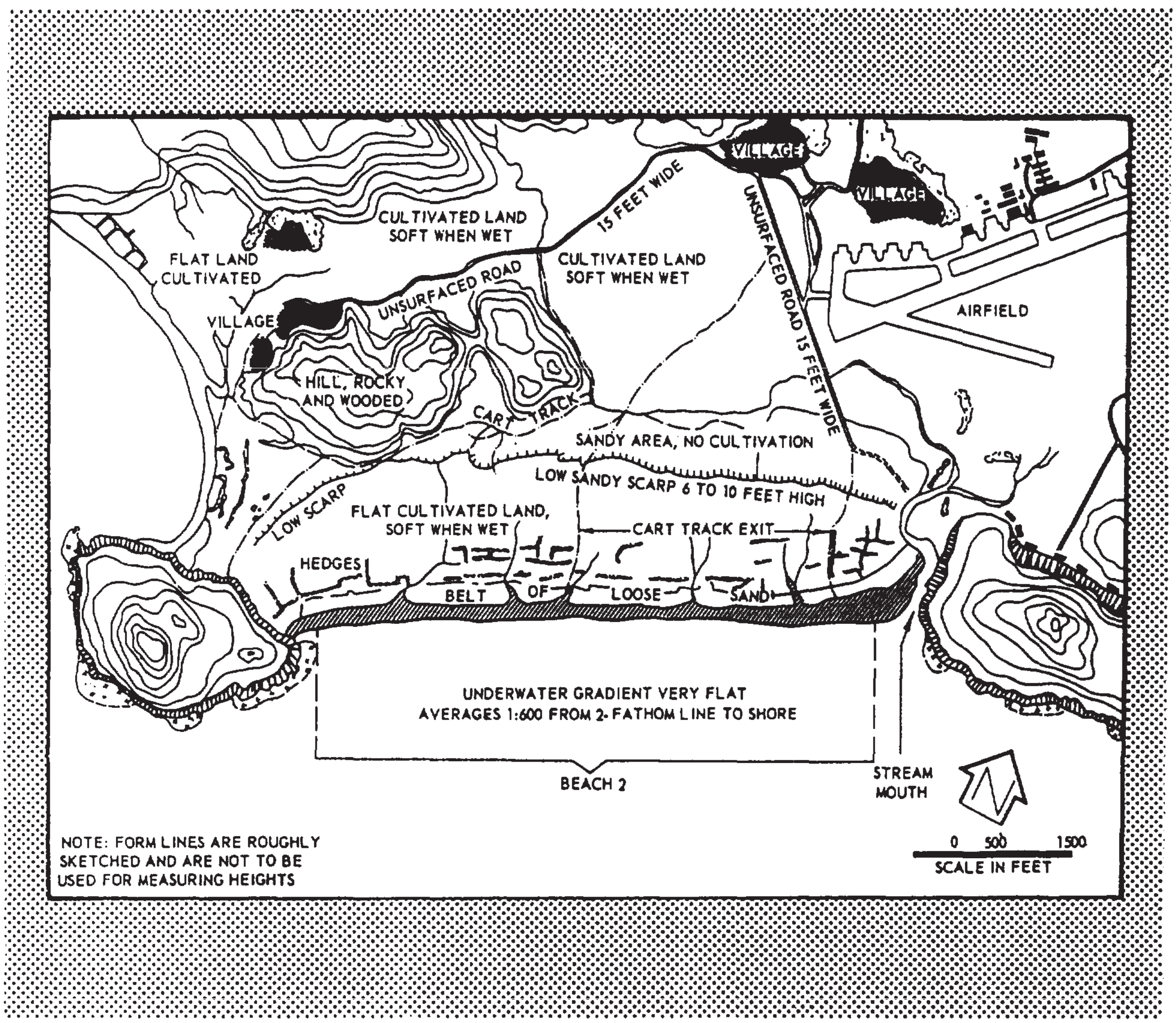

Figure 11-3.-Line map made by overlays from the aerial photograph in figure 11-2.

The magnetic compass is the most commonly used and simplest instrument for measuring directions and angles in the field. This instrument has a variety of both civilian and military applications. The LENSATIC COMPASS (available in your Table of Allowance) is most commonly used for SEABEE compass courses, for map orientation, and for angle direction during mortar and field artillery fires.

In addition to this type of compass, there are several others used exclusively for field surveys. The ENGINEER'S TRANSIT COMPASS, located between the standards on the upper plate, is graduated from 0° through 360° for measuring azimuths, and in quadrants of 90° for measuring bearings (fig. 11-4). Notice in figure 11-4 that the east and west markings are reversed. This permits direct reading of the magnetic direction.

The compass shown in figure 11-5 is commonly called the BRUNTON POCKET TRANSIT. This instrument is a combination compass and clinometer. It can be mounted on a light tripod or staff, or it may be cradled in the palm of the hand.

Other types of compasses can also be found in some surveying instruments, such as the theodolite and plane table.

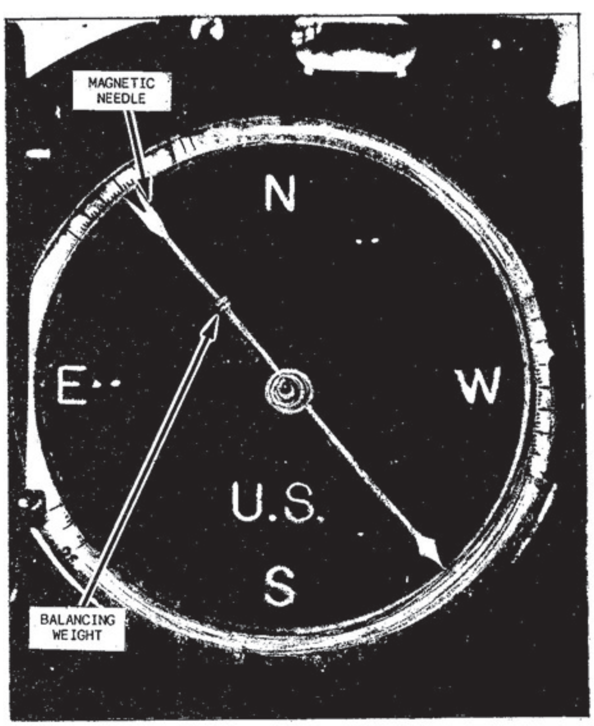

Figure 11-4.-Engineer's transit compass.

ENGINEER'S TRANSIT

A primary survey fieldwork consists of measuring horizontal and vertical angles or directions and extending straight lines. The instruments that can perform these functions have additional refinements (built-in) that can be used for other survey operations, such as leveling. Two types of instruments that fall into this category are the engineer's transit and the theodolite. In recent years, manufacturing improvements have permitted construction of direct-reading theodolites that are soon to replace the vernier-reading transits. However, in most SEABEE construction, the engineer's transit is still the major surveying instrument.

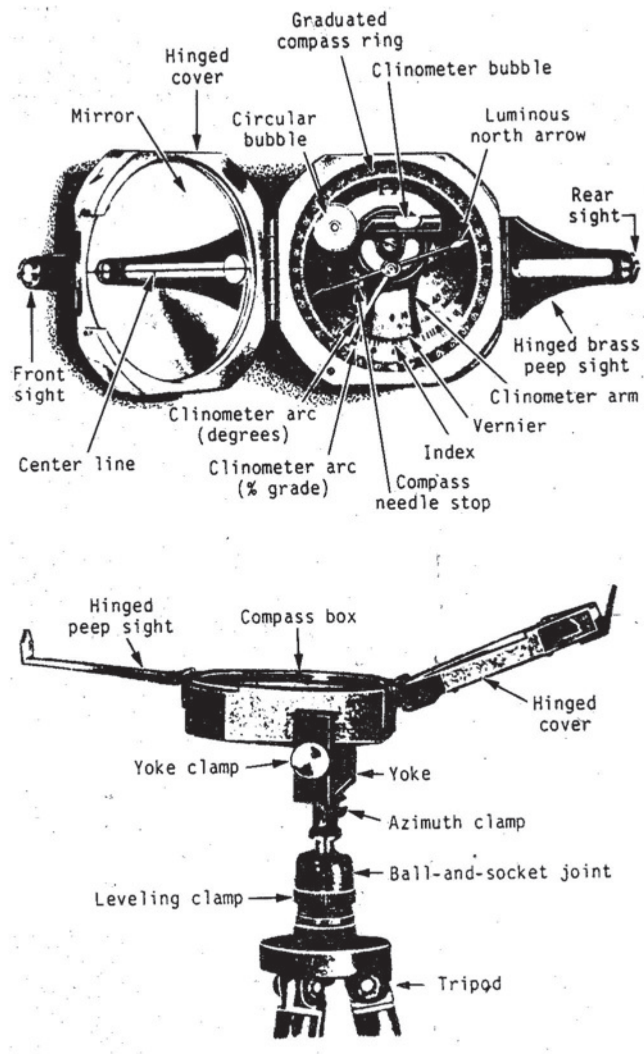

Figure 11-5.-A Brunton pocket transit.

The transit (fig. 11-6) is often called the universal survey instrument because of its uses. It may be used for measuring horizontal angles and directions, vertical angles, and differences in elevations; for prolonging straight lines; and for measuring distances by stadia. Although transits of various manufacturers differ in appearance, they are alike in their essential parts and operations.

The engineer's transit contains several hundred parts. For-descriptive purposes, these parts may be grouped into three assemblies: the leveling head assembly, the lower plate assembly, and the upper many plate or alidade assembly (fig. 11-7).

Leveling Head Assembly

The leveling head of the transit normally is the four-screw type, constructed so the instrument can be shifted on the foot plate for centering over a marked point on the ground.

Lower Plate Assembly

The lower plate assembly of the transit consists of a hollow spindle that is perpendicular to the

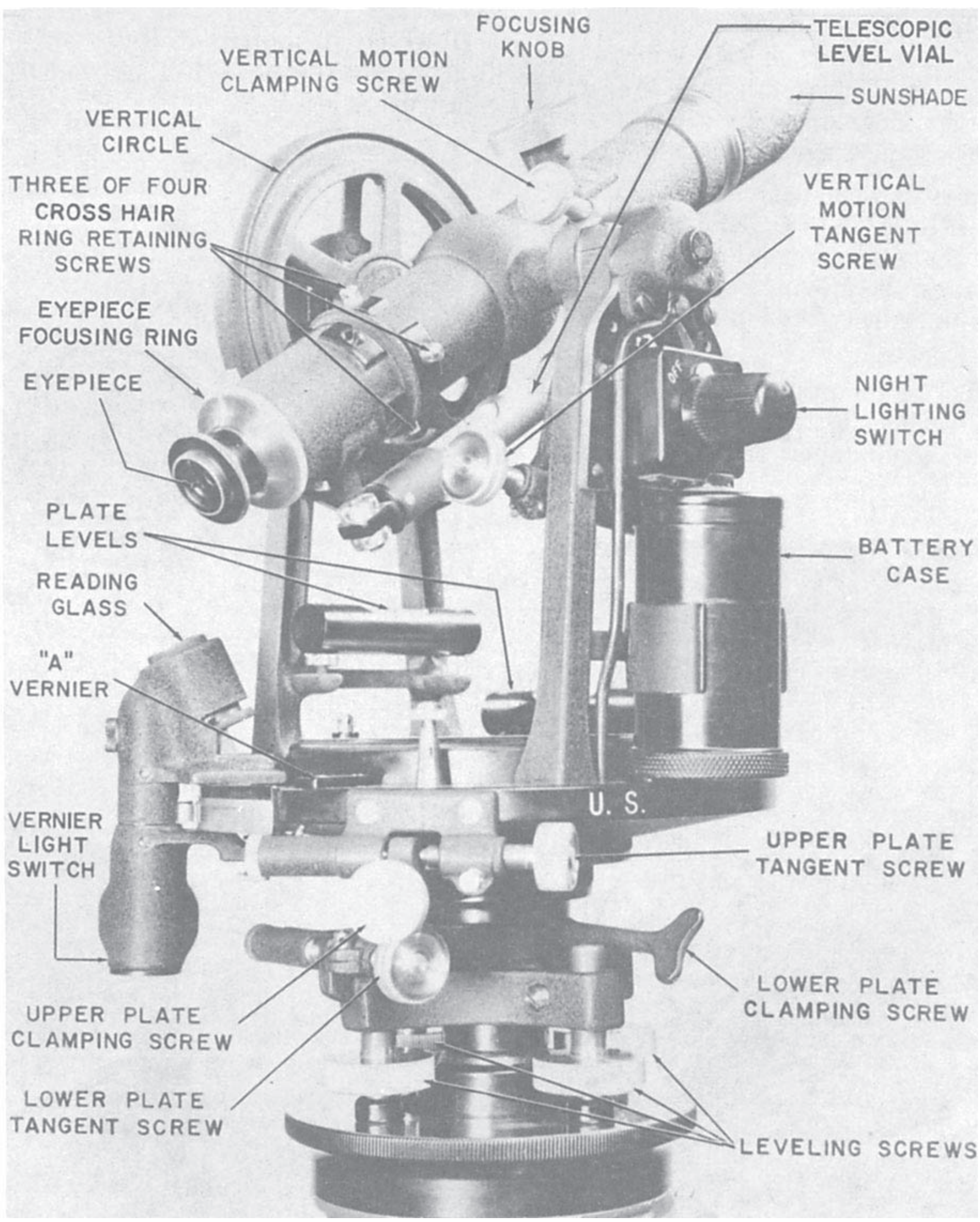

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Figure 11-6.-An engineer's transit.

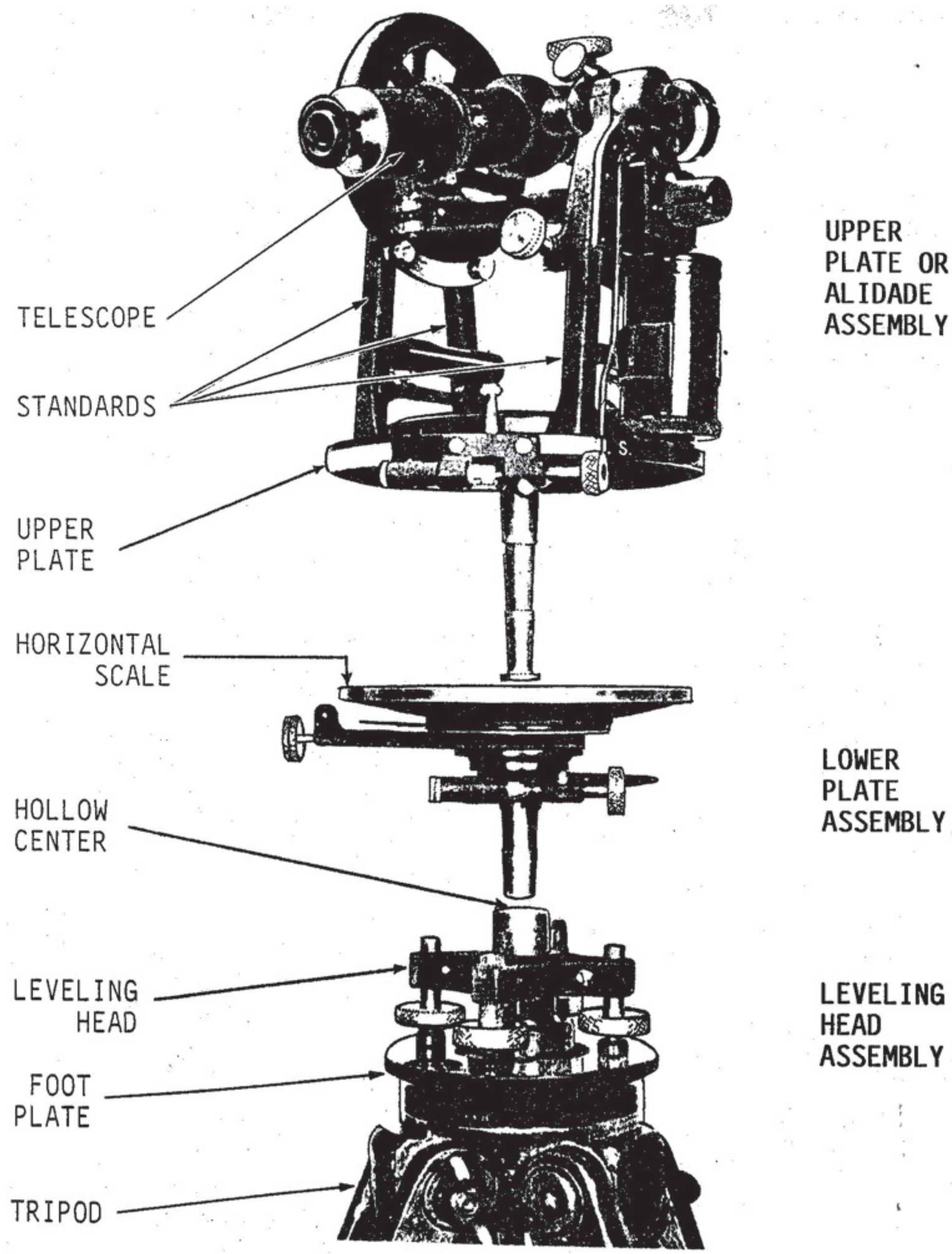

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Figure 11-7.-An engineer's transit, exploded view.

center of a circular plate and accurately fitted the socket in the leveling head. The lower plate contains the graduated horizontal circle on which the values of horizontal angles are read with the aid of two verniers, A and B, set on the opposite sides of the circle. A clamp controls the rotation of the lower plate and provides a means for locking it in place. A slow-motion tangent screw is used to rotate the lower plate a small amount to relative to the leveling head. The rotation accomplished by the use of the lower clamp and tangent screw is known as the LOWER MOTION.

Upper Plate or Alidade Assembly

The upper plate, alidade, or vernier assembly consists of a spindle attached plate to a circular plate carrying verniers, telescope standards, plate-level vials, and a magnetic compass. The spindle is accurately fitted to coincide with the socket in the lower plate spindle. A clamp is tightened to hold the two plates together or loosened to permit the upper plate to rotate relative to the lower plate. A tangent screw permits the upper plate to be moved a small amount and is known as the UPPER MOTION. The standards support two pivots with adjustable bearings that hold the horizontal axis and permit the telescope to move on a vertical plane. The vertical circle moves with the telescope. A clamp and tangent screw are provided to control this vertical movement. The vernier for the vertical circle is attached to the left standard. The telescope is an erecting type and magnifies the image about 18 to 25 times. The reticle contains stadia hairs in addition to the cross hairs. A magnetic compass is mounted on the upper plate between the two standards and consists of a magnetized needle pivoted on a jeweled bearing at the center of a graduated circle. A means is provided for lifting the needle off the pivot to protect the bearing when the compass is not in use.

LEVEL VIALS.— Two plate level vials (fig. 11-6) are placed at right angles to each other. On many transits, one plate level vial is mounted on the left side, attached to the standard, under the

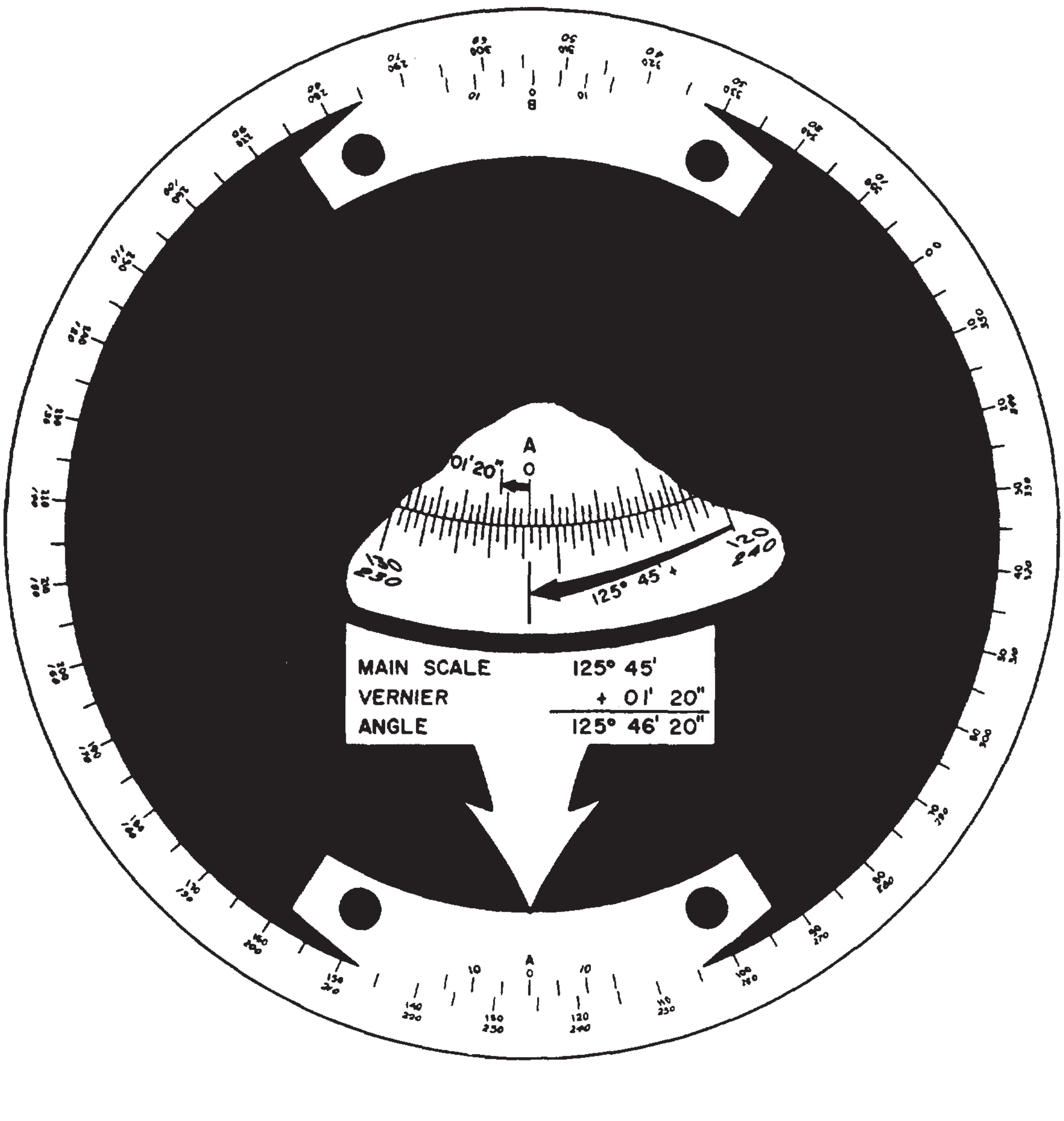

Figure 11-8.-Horizontal scales, 20 second transit.

vertical circle vernier. The other vial is then parallel to the axis of rotation for the vertical motion. The sensitivity of the plate level vial bubbles is about 70 sec of movement for 2 mm of tilt. Most engineer's transits have a level vial mounted on the telescope to level it. The sensitivity of this bubble is about 30 sec per 2-mm tilt.

CIRCLES AND VERNIERS.— The horizontal and vertical circles and their verniers are the parts of the engineer's transit by which the values of horizontal and vertical angles are determined. A stadia arc is also included with the vertical circle on some transits.

The horizontal circle and verniers of the transit that are issued to SEABEE units are graduated to give least readings of either 1 min or 20 sec of arc. The horizontal circle is mounted on the lower plate. It is graduated to 15 min for the 20-sec transit (fig. 11-8) and 30 min for the 1-min transit (fig. 11-9). The plates are numbered from 0° to 360°, starting with a common point and running both ways around the circle. Two double verniers, known as the A and B verniers, are mounted on the upper plate with their indexes at circle readings 180° apart. A double vernier is one that can be read in both directions from the index line. The verniers reduce the circle graduations to the final reading of either 20 sec or 1 min.

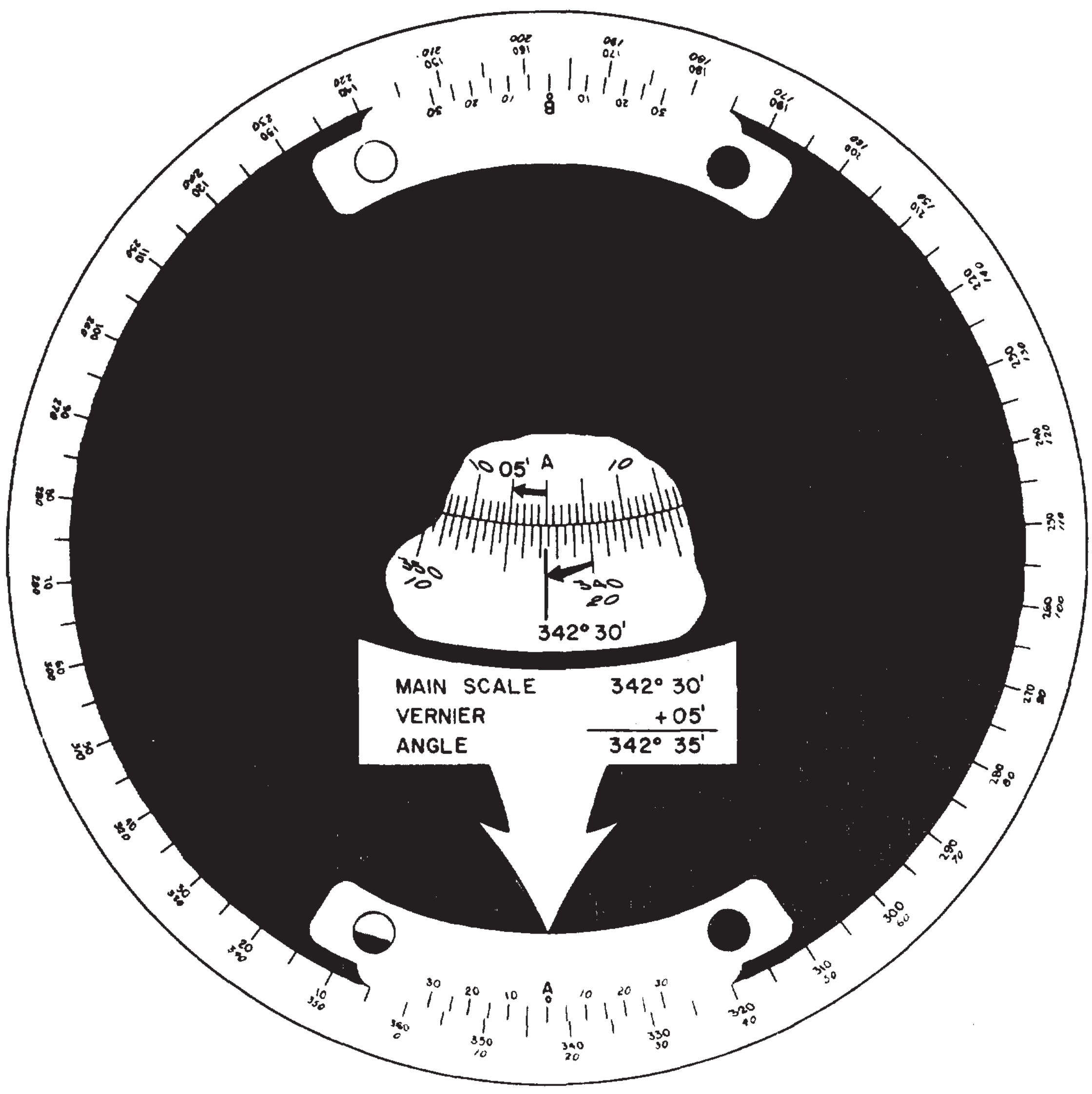

Figure 11-9.-Horizontal scales, 1-minute transit.

The A vernier is used when the telescope is in its normal position, and the B vernier is used when the telescope is plunged.

The VERTICAL CIRCLE of the transit (fig. 11-10) is fixed to the horizontal axis so it will rotate with the telescope. The vertical circle normally is graduated to 30´ with 10° numbering. Each quadrant is numbered from 0° to 90°; the 00 graduations define a horizontal plane, and the 90° graduations lie in the vertical plane of the instrument. The double vernier used with the circle is attached to the left standard of the transit, and its least reading is 1´. The left half of the double vernier is used for reading angles of depression, and the right half of this vernier is used for reading angles of elevation. Care must be taken to read the vernier in the direction that applies to the angle observed.

In addition to the vernier, the vertical circle may have an H and V (or HOR and VERT) series of graduations, called the STADIA ARC (fig. 11-10). The H scale is adjusted to read 100 when the line of sight is level, and the graduations decrease in both directions from the level line. The other scale, V, is graduated with 50 at level, to 10 as the telescope is depressed, and to 90 as it is elevated.

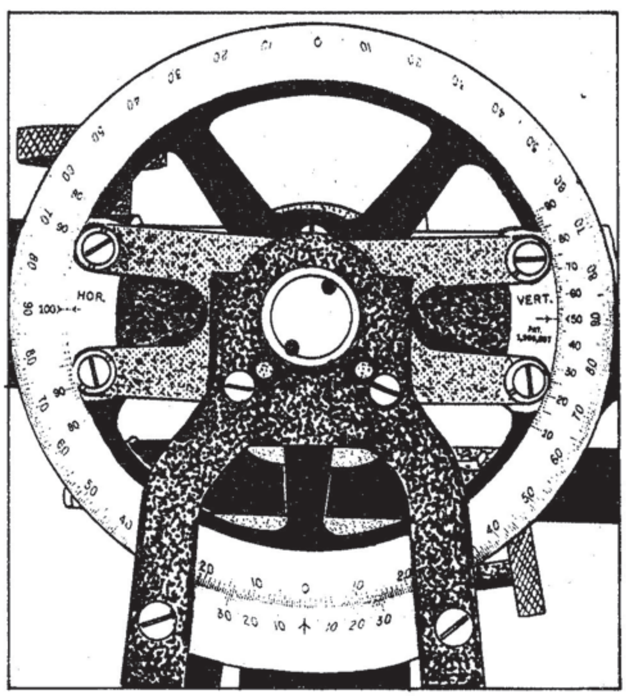

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Figure 11-10.-Vertical circle with verniers, scales, and stadia arc.

The VERNIER, or vernier scale, is an auxiliary device by which a uniformly graduated main scale can be accurately read to a fractional part of a division. Both scales may be straight as on a leveling rod or curved as on the circles of a transit. The vernier is uniformly divided, but each division is either slightly smaller (direct vernier) or slightly larger (retrograde vernier) than a division of the main scale (fig. 11-11). The amount a vernier division differs from a division of the main scale determines the smallest reading of the scale that can be made with the particular vernier. This smallest reading is called the LEAST COUNT of the vernier. It is determined by dividing the value of the smallest division on the scale by the number of divisions on the vernier.

Direct Vernier.— A scale graduated in hundredths of a unit is shown in figure 11-11, view A, and a direct vernier for reading it to thousandths of a unit. The length of 10 divisions on the vernier is equal to the length of 9 divisions on the main scale. The index, or zero of the vernier, is set at 0.340 unit. If the vernier were moved 0.001 unit toward the 0.400 reading, the Number 1 graduation of the vernier shown in figure 11-11, view A, would coincide with 0.35 on the scale, and the index would be at 0.341 unit. The vernier, moved to where graduation Number 7 coincides with 0.41 on the scale, is shown in figure 11-11, view B. In this position, the correct scale reading is 0.347 unit (0.340 + 0.007). The index with the zero can be seen to point to this reading.

Retrograde Vernier.— A retrograde vernier on which each division is 0.001 unit longer than the 0.01 unit divisions on the main scale is shown in figure 11-11, view C. The length of the 10 divisions on the vernier equals the length of the 11 divisions of the scale. The retrograde vernier extends from the index, backward along the scale. Figure 11-11, view D, shows a scale reading of 0.347 unit, as read with the retrograde vernier.

Vernier for Circles. — Views E and F of figure 11-11 represent part of the horizontal circle of a transit and the direct vernier for reading the circle. The main circle graduations are numbered both clockwise and counterclockwise. A double vernier that extends to the right and to the left of the index makes it possible to read the main circle in either direction. The vernier to the left of the index is used for reading clockwise angles, and the vernier to the right of the index is used for reading

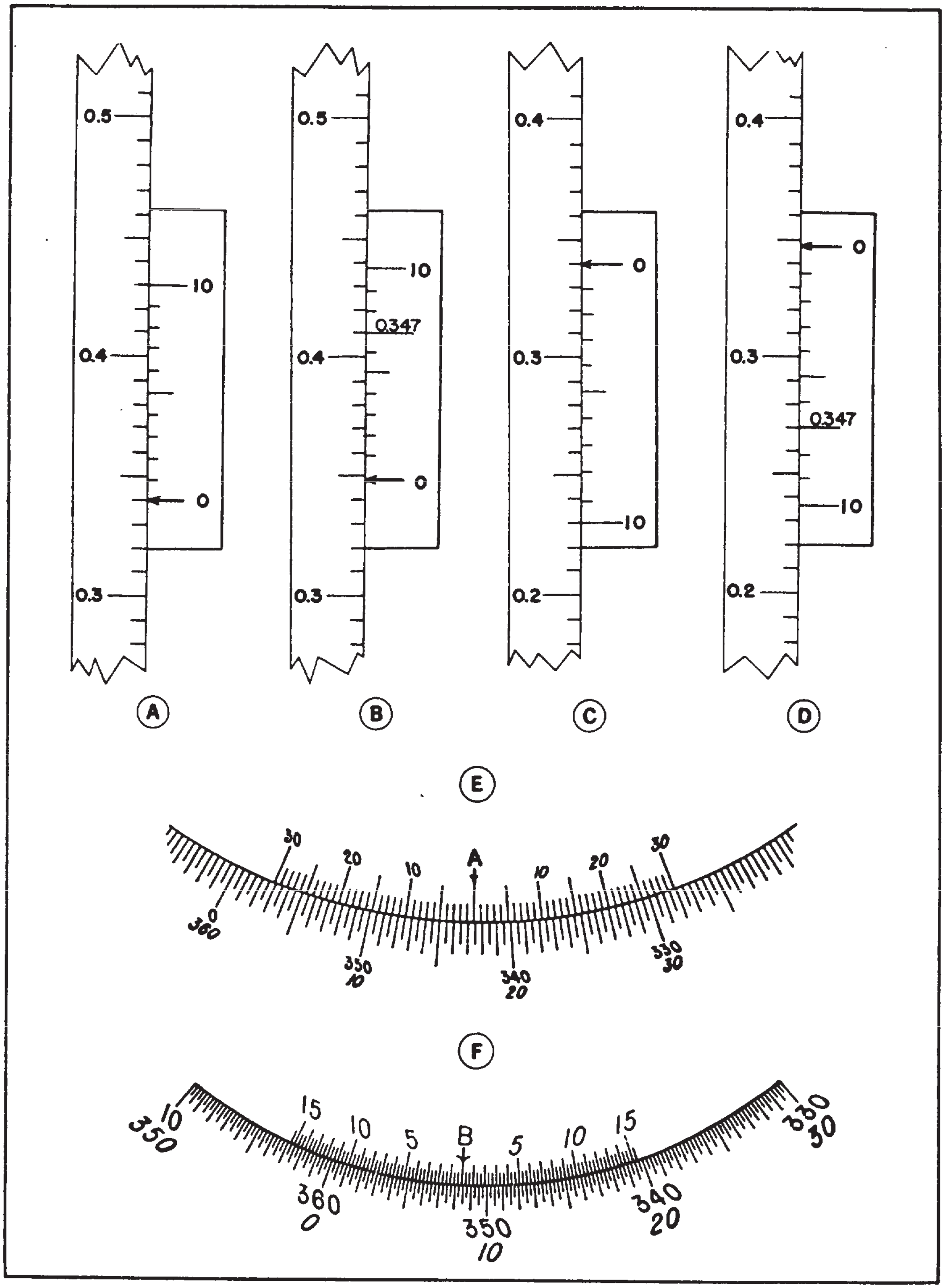


Figure 11-11.-Types of verniers.

counterclockwise angles. The slope of the numerals in the vernier to be used corresponds to the slope of the numerals in the circle being read. Care must be taken to use the correct vernier. In figure 11-11, view E, the circle is graduated to half degrees, or 30 min. On this vernier, 30 divisions are equal in length to 29 divisions on the circle. The least reading of this vernier is 30 min divided by 30 divisions, or 1 min. The index (fig. 11-11, view E) is seen to lie between 342°30´ and 343°. In the left vernier, graduation Number 5 is seen to coincide with a circle graduation. Then, the clockwise reading of this circle is 342°30´ plus 05´, or 342°35´. When the right vernier is used in the same way, the counterclockwise reading of the circle is 17°00´ plus 25´, or 17°25´. In figure 11-11, view F, the circle is graduated in 15-min divisions and each half of the double vernier contains 45 divisions. The least reading on this vernier is 20 sec. The clockwise reading of the circle and vernier is 351°30´plus 05´40" or 351°35´40". The counterclockwise reading is 8°15´ plus 9´20", or 8°24´20".

THEODOLITE

A theodolite is essentially a transit of high precision. Theodolites come in different sizes and weights and from different manufacturers. Although theodolites may differ in appearance, they are basically alike in their essential parts and operation. Some of the models currently available for use in the military are WILD (Herrbrugg), BRUNSON, K&E, (Keuffel & Esser), and PATH theodolites.

To give you an idea of how a theodolite differs from a transit, we will discuss some of the most commonly used theodolites in the U.S. Armed Forces.

One-Minute Theodolite

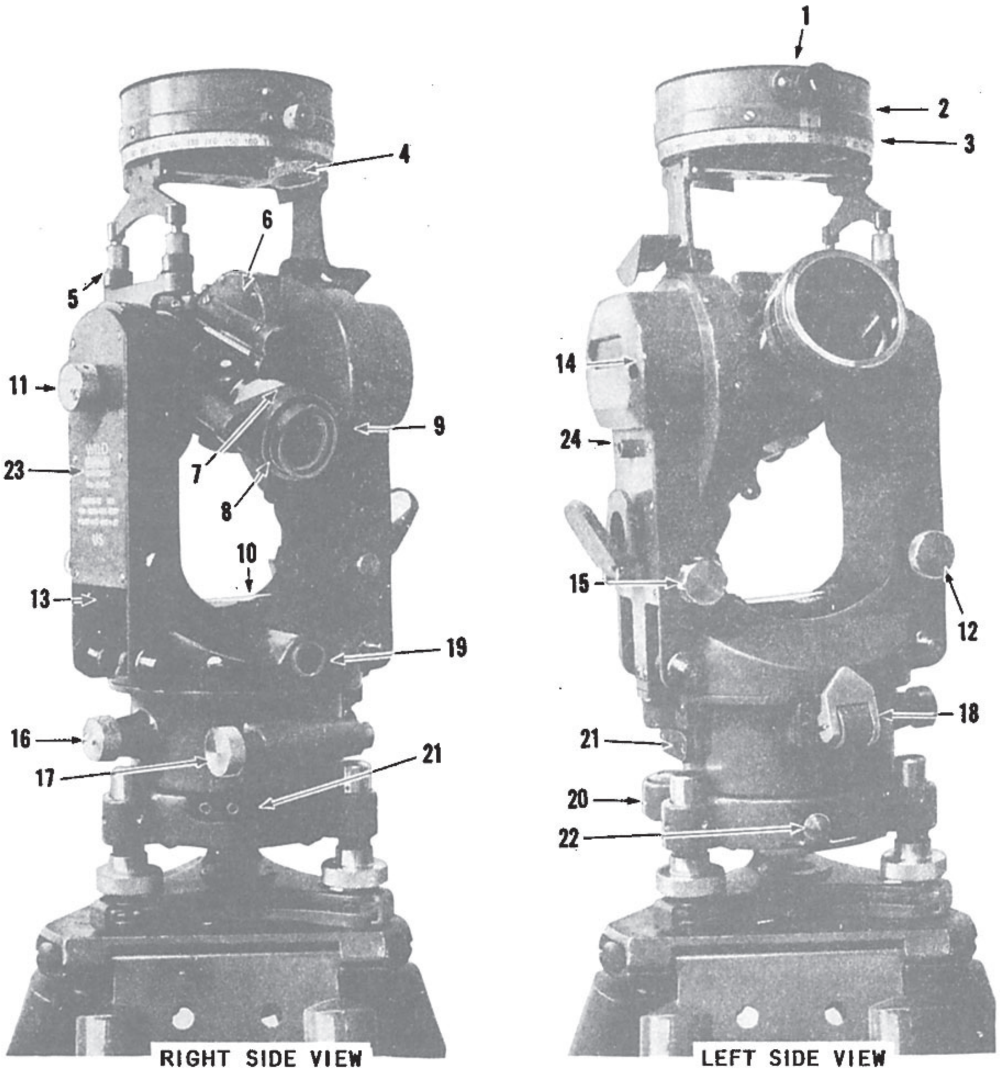
The 1-min directional theodolite is essentially a directional type of instrument. This type of instrument can be used, however, to observe horizontal and vertical angles, as a transit does.

The theodolite shown in figure 11-12 is a compact, lightweight, dustproof, optical reading instrument. The scales read directly to the nearest minute or 0.2 mil and are illuminated by either natural or artificial light. The main or essential parts of this type of theodolite are discussed in the next several paragraphs.

HORIZONTAL MOTION.— Located on the lower portion of the alidade, and adjacent to each other, are the horizontal motion clamp and tangent screw used for moving the theodolite in azimuth. Located on the horizontal circle casting is a horizontal circle clamp that fastens the circle to the alidade. When this horizontal (repeating) circle clamp is in the lever-down position, the horizontal circle turns with the telescope. With the circle clamp in the lever-up position, the circle is unclamped and the telescope turns independently. This combination permits use of the theodolite as a REPEATING INSTRUMENT. To use the theodolite as a DIRECTIONAL TYPE OF INSTRUMENT, you should use the circle clamp only to set the initial reading. You should set an initial reading of 0°30´ on the plates when a direct and reverse (D/R) pointing is required. This will minimize the possibility of ending the D/R pointing with a negative value.

VERTICAL MOTION.— Located on the standard opposite the vertical circle are the vertical motion clamp and tangent screw. The tangent screw is located on the lower left and at right angles to the clamp. The telescope can be rotated in the vertical plane completely around the axis (360°).

LEVELS.— The level vials on a theodolite are the circular, the plate, the vertical circle, and the telescope level. The CIRCULAR LEVEL is located on the tribrach of the instrument and is used to roughly level the instrument. The PLATE LEVEL, located between the two standards, is used for leveling the instrument in the horizontal plane. The VERTICAL CIRCLE LEVEL (vertical collimation) vial is often referred to as a split bubble. This level vial is completely built in, adjacent to the vertical circle, and viewed through a prism and 45° mirror system from the eyepiece end of the telescope. This results in the viewing of one-half of each end of the bubble at the same time. Leveling consists of bringing the two halves together into exact coincidence, as



1 Compass eyepiece
2 Compass
3 Circle ring
4 Caging knob
5 Compass leveling screw
6 Telescope level
7 Focus drive
8 Microscope eyepiece
9 Telescope eyepiece
10 Plate level
11 Vertical clamp
12 Vertical slow-motion screw
13 Vertical slow-motion adjusting screw
14 Collimation level
15 Collimation slow-motion screw
16 Horizontal clamp
17 Horizontal slow-motion screw
18 Horizontal circle clamp
19 Optical plumb eyepiece
20 Circular level
21 Electric plugs
22 Tribrach clamp lever
23 Right cover
24 Left cover

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Figure 11-12.—One-minute theodolite.

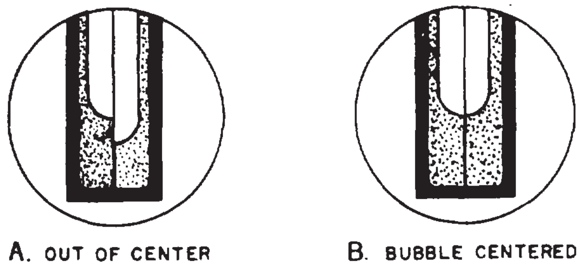

Figure 11-13.-Coincidence- type level.

shown in figure 11-13. The TELESCOPE LEVEL, mounted below the telescope, uses a prism system and a 45° mirror for leveling operations. When the telescope is plunged to the reverse position, the level assembly is brought to the top.

TELESCOPE.— The telescope of a theodolite can be rotated around the horizontal axis for direct and reverse readings. It is a 28-power instrument with the shortest focusing distance of about 1.4 meters. The cross wires are focused by turning the eyepiece; the image, by turning the focusing ring. The reticle (fig. 11-14) has horizontal and vertical cross wires, a set of vertical and horizontal ticks (at a stadia ratio of 1:100), and a solar circle on the reticle for making solar observations. This circle covers 31 min of arc and can be imposed on the sun's image (32 min of arc) to make the pointing refer to the sun's center. One-half of the vertical line is split for finer centering on small distant objects.

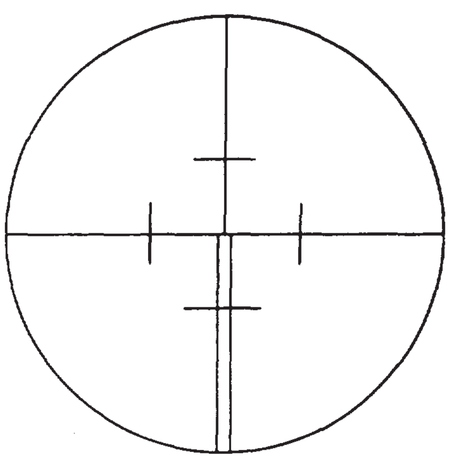

Figure 11-14.-Theodolite reticle.

The telescope of the theodolite is an inverted image type. Its cross wires can be illuminated by either sunlight reflected by mirrors or by battery source. The amount of illumination for the telescope can be adjusted by changing the position of the illumination mirror.

TRIBRACH.— The tribrach assembly (fig. 11-15), found on most makes and models, is a detachable part of the theodolite that contains the leveling screw, the circular level, and the optical plumbing device. A locking device holds the alidade and the tribrach together and permits interchanging of instruments without moving the tripod. In a "leapfrog" method, the instrument (alidade) is detached after observations are completed. It is then moved to the next station and another tribrach. This procedure reduces the amount of instrument setup time by half.

CIRCLES.— The theodolite circles are read through an optical microscope. The eyepiece is located to the right of the telescope in the direct position, and to the left, in the reverse. The microscope consists of a series of lenses and prisms that bring both the horizontal and the

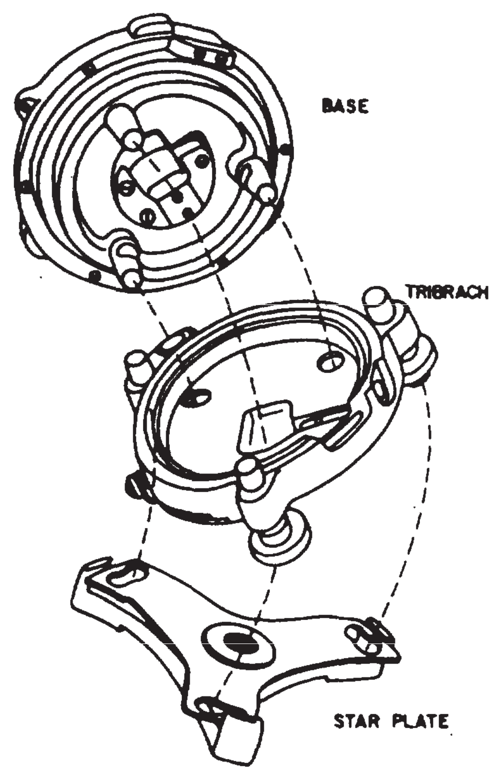

Figure 11-15.-Three-screw leveling head.

vertical circle images into a single field of view. In the DEGREE-GRADUATED SCALES (fig. 11-16), the images of both circles are shown as they would appear through the microscope of the 1-min theodolite. Both circles are graduated from 0° to 360° with an index graduation for each degree on the main scales. This scale's graduation appears to be superimposed over an auxiliary that is graduated in minutes to cover a span of 60 min (1°). The position of the degree mark on the auxiliary scale is used as an index to get a direct reading in degrees and minutes. If necessary, these scales can be interpolated to the nearest 0.2 min of arc.

The vertical circle reads 0° when the theodolite's telescope is pointed at the zenith, and 180° when it is pointed straight down. A level line reads 90° in the direct position and 270° in the reverse. The values read from the vertical circle are referred to as ZENITH DISTANCES and not vertical angles. Figure 11-17 shows how these zenith distances can be converted into vertical angles.

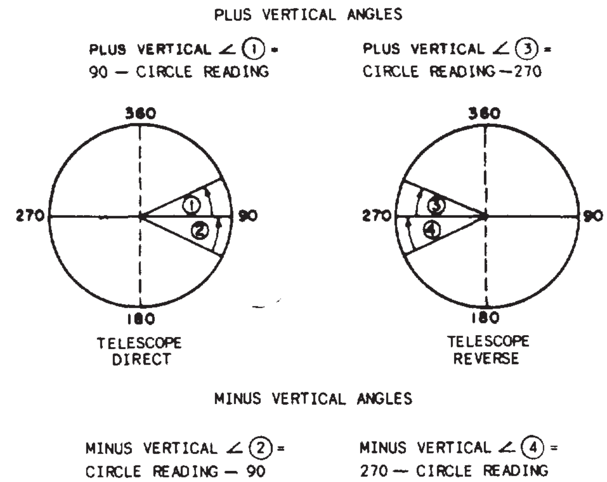

Figure 11-17.-Converting zenith distances into vertical angles (degrees).

In the MIL-GRADUATED SCALES (fig. 11-18), the images of both circles are shown as they would appear through the reading microscope of the 0.2-mil theodolite. Both circles are graduated from 0 to 6,400 mils. The main scales are marked and numbered every 10 mils, with the

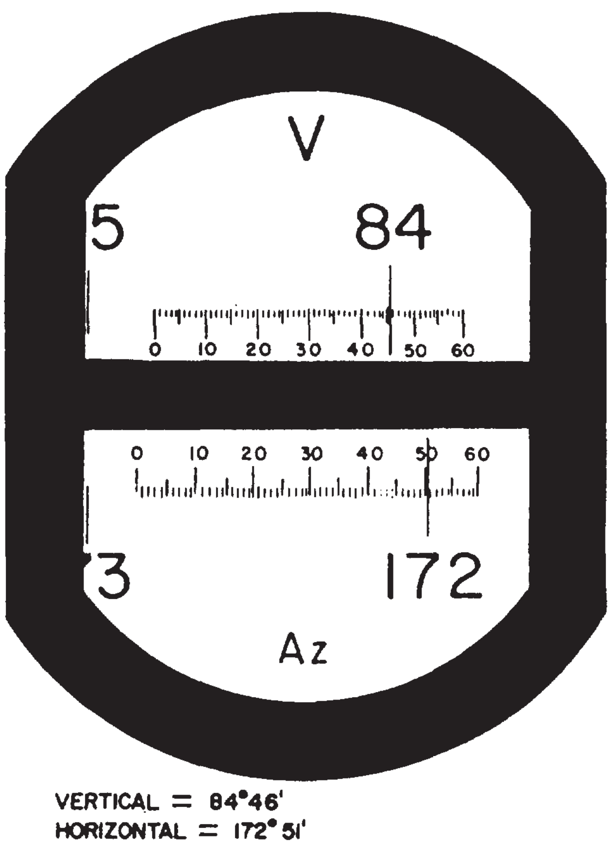

Figure 11-16.-Degree-graduated scales.

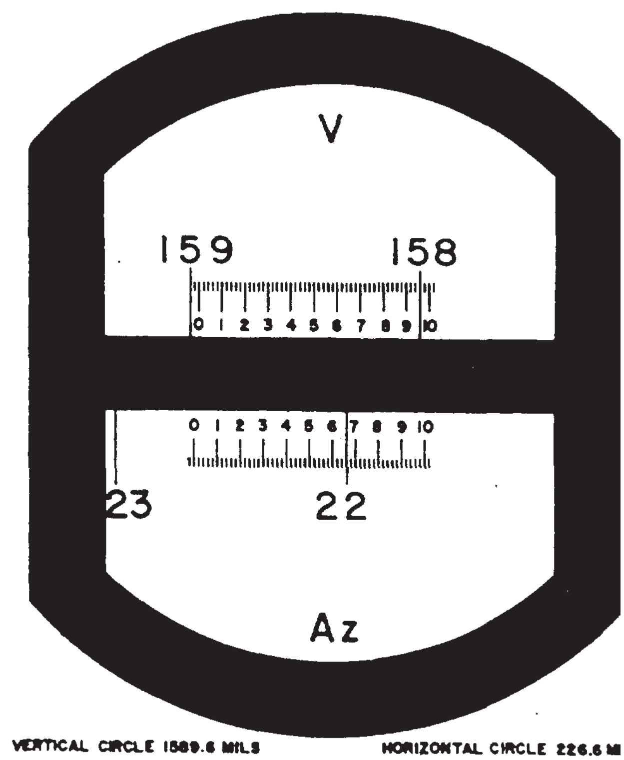

Figure 11-18.-Mil-graduated scales.

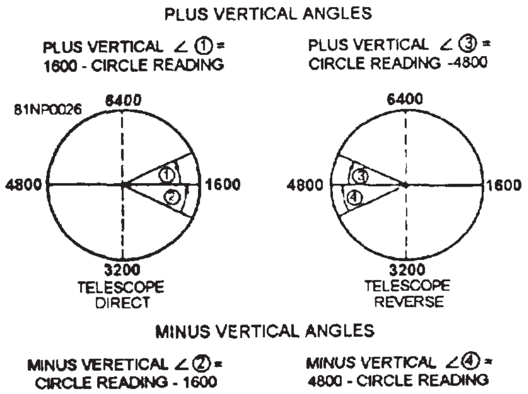

Figure 11-19.-Vertical angles from zenith distances (mils).

last zero dropped. The auxiliary scales are graduated from 0 to 10 roils in 0.2-mil increments. Readings on the auxiliary scale can be interpolated to 0.1 mil.

The vertical circle reads 0 mil when the telescope is pointed at the zenith, and 3,200 mils when it is pointed straight down. A level line reads 1,600 roils in the direct position and 4,800 roils in the reverse. The values read are zenith distances. These zenith distances can be converted into vertical angles as shown in figure 11-19.

One-Second Theodolite

The 1-sec theodolite is a precision direction type of instrument for observing horizontal and vertical directions. This instrument is similar to,

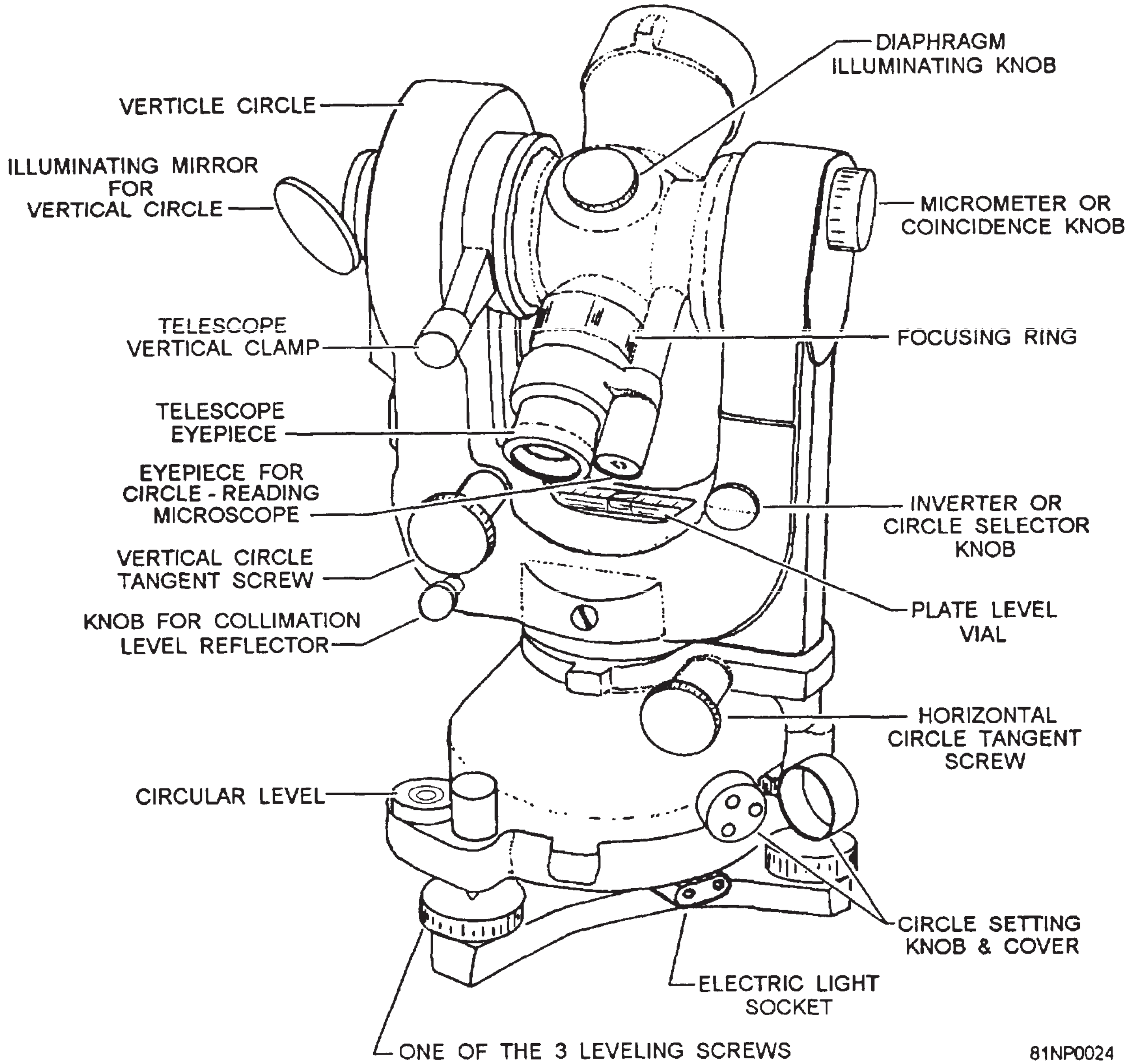

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Figure 11-20.-A 1-second theodolite.

but slightly larger than, the 1-min theodolite. The WILD theodolite shown in figure 11-20 is compact, lightweight, dustproof, optical reading, and tripod-mounted. It is one spindle, one plate level, a circular level, horizontal and vertical circles read by an optical microscope directly to 1 sec (0.002 roil), clamping and tangent screws for controlling the motion, and a leveling head with three foot screws. The circles are read using the coincidence method rather than the direct method. There is an inverter knob for reading the horizontal and vertical circles independently. The essential parts of a l-see theodolite are very similar to that of the 1-min theodolite, including the horizontal and vertical motions, the levels, the telescope, the tribrach, and the optical system shown in figure 11-21. The main difference between the two types, besides precision, is the manner in which the circles are read.

The CIRCLE to be viewed in the 1-see theodolite is selected by turning the inverter knob on the right standard. The field of the circle-reading microscope shows the image of the

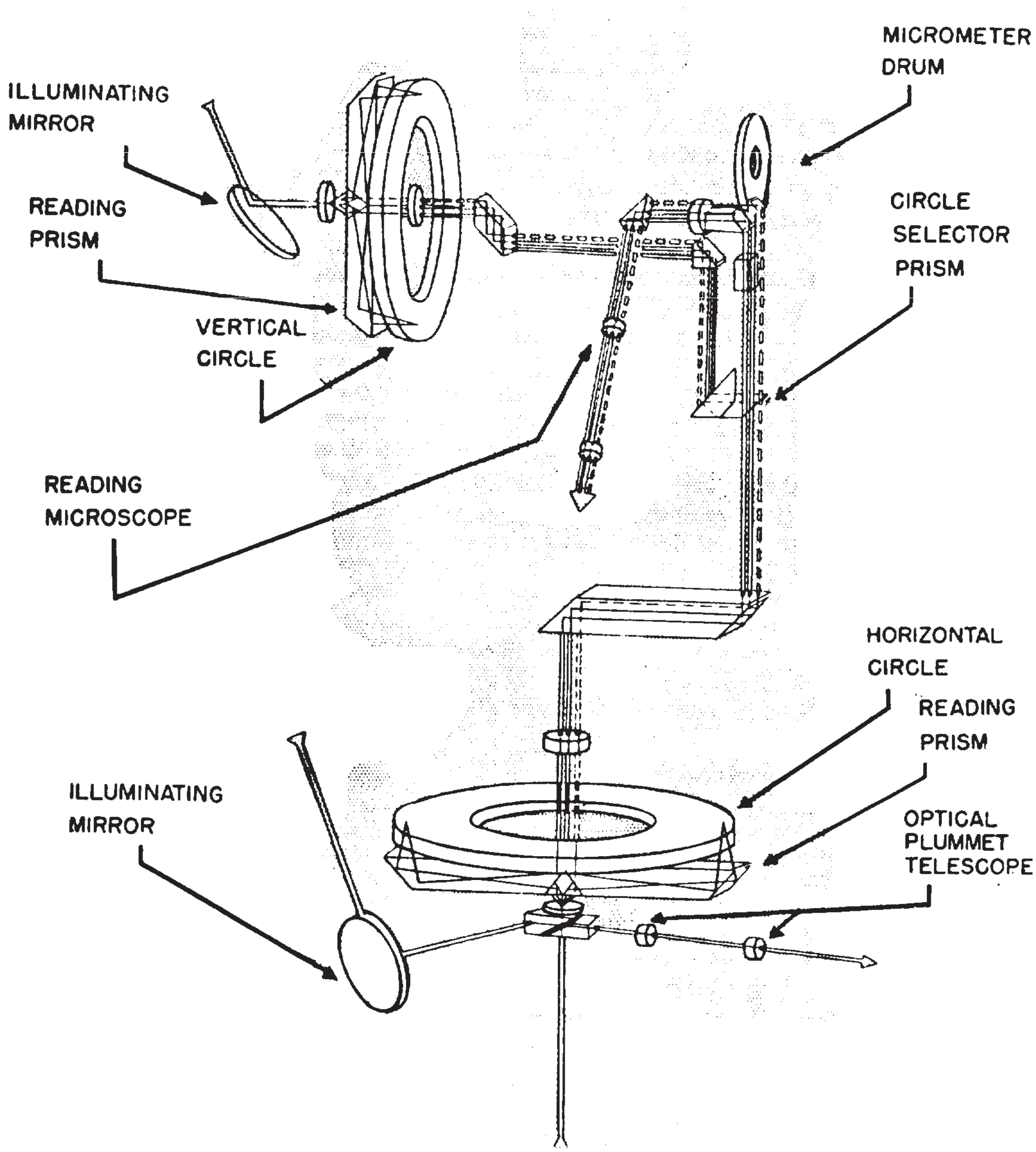

Figure 11-21.-Circle-reading optical system.

circle (fig. 11-22) with lines spaced at 20-min intervals, every third line numbered to indicate a degree, and the image of the micrometer scale on which the unit minutes and seconds are read. The numbers increase in value (0°to 360°, clockwise around the circle. The coincidence knob on the side of, and near the top of, the right standard is used in reading either of the circles. The collimation level and its tangent screw are used when the vertical circle is read.

The circles of the theodolite are read by the COINCIDENCE METHOD in which optical coincidence is obtained between diametrically opposite graduations of the circle by turning the MICROMETER or COINCIDENCE KNOB. When this knob is turned, the images of the opposite sides of the circle appear to move in opposite directions across the field of the CIRCLE-READING MICROSCOPE. The graduations can be brought into optical coincidence and appear to form continuous lines crossing the dividing line. An index mark indicates the circle graduations that are to be used in making the coincidence. The index mark will be either in line with a circle graduation or midway between two graduations. The final coincidence adjustment should be made between the graduations in line with the index mark or when this index mark is halfway between the two closest graduations.

HORIZONTAL CIRCLE.— To read the HORIZONTAL CIRCLE, turn the INVERTER or CIRCLE-SELECTOR KNOB until its black line is horizontal. Adjust the illuminating mirror to give uniform lighting to both sections of the horizontal circle; the micrometer scale is viewed through the circle-reading microscope. Focus the microscope eyepiece so that the graduations are sharply defined. The view through the microscope should then be similar to figure 11-22, view A. From this point, continue in the following way:

1. Turn the coincidence knob until the images of the opposite sides of the circle are moved into coincidence. Turning this knob also moves the micrometer scale. The view through the microscope now appears as shown in figure 11-22, view B.

2. Read the degrees and tens of minutes from the image of the circle. The nearest upright number to the left of the index mark is the number of degrees (105). The diametrically opposite number (the number ± 180°) is 285. The number of divisions of the circle between the upright 105 and inverted 285 gives the number of tens of minutes. In figure 11-22, view B, there are five divisions between 105 and 285; and the reading, therefore, is 105°50´. The index may also be used for direct reading of the tens of minutes. Each graduation is treated as 20 min. Thus, the number of graduations from the degree value to the index mark multiplied by 20 min is the value. If the index falls between graduations, another 10 min is added when the tens of minutes is read directly.

3. Read the unit minutes and seconds below from the image of the micrometer scale. This scale has two rows of numbers below the graduations; the bottom row is the unit minutes and the top row, seconds. In figure 11-22, view B, the unit minutes and seconds are read as 7'23.5"

4. Add the values determined in Steps 2 and 3 above. This gives 105°57'23.5"as the final reading.

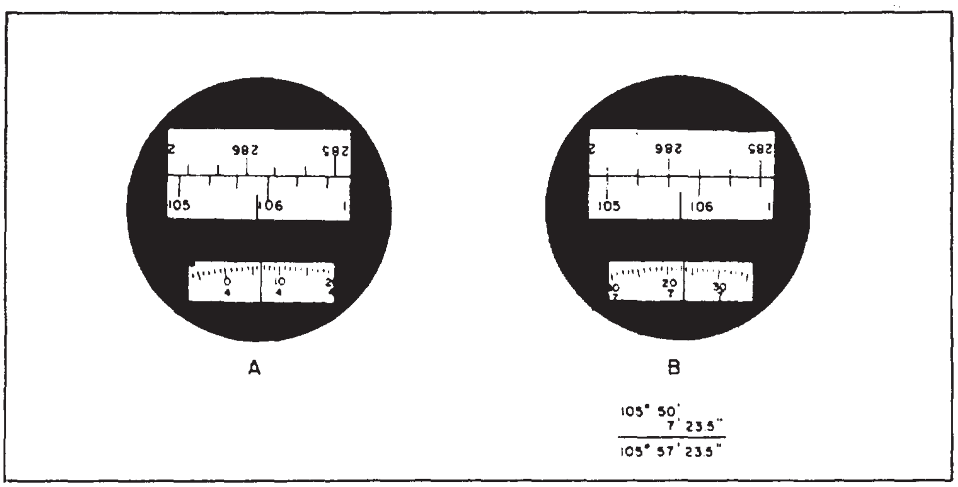

Figure 11-22.-View of a 1-second theodolite circle.

VERTICAL CIRCLE.— When reading the VERTICAL CIRCLE, turn the circle-selector knob until its black line is vertical. Adjust the mirror on the left standard and focus the microscope eyepiece. You then go on in the following way:

1. Use the vertical circle tangent screw to move the collimation level until the ends of its bubble appear in coincidence (fig. 11-23) in the collimation level viewer on the left standard.
2. Read the vertical circle and micrometer scale as described before. Be sure to have proper coincidence before you take the reading.
3. The vertical circle graduations are numbered to give a 0° reading with the telescope pointing to the zenith. Consequently, the vertical circle reading will be 90° for a horizontal sight with the telescope direct and 270° for a horizontal sight with the telescope reversed. Figure 11-23 shows the view in the circle-reading microscope for direct and reversed pointings on a target. These readings are converted to vertical angles as follows:

	Telescope Direct	Telescope Reversed
Circle Reading	86°17′43.5″	273°42′21.5″
Zenith Distance	86°17′43.5″	86°17′38.5″
Mean Zenith Distance...	86°17′41.0″	
Mean Vertical Angle	+3°42′19.0″	

There are two separate occasions for setting the horizontal circle of the theodolite. In the first case, the circle is set to read a given value with the telescope pointed at a target. With the theodolite pointed at the target and with the azimuth clamp tightened, the circle is set as follows: Set the micrometer scale to read the unit minutes and the seconds of the given values. Then, with the circle-setting knob, you turn the circle until coincidence is obtained at the degree and tens of minutes value of the given reading. This setting normally can be made accurately to plus or minus 5 sec. After the circle is set in this manner, the actual reading should be determined.

In the second case, the circle is set to a value of a given angle. When a predetermined angle is measured, you first point the instrument along the initial line from which the angle is to be measured and read the circle. Add the value of the angle to the circle reading to determine the circle reading for the second pointing. Set the micrometer scale to read the unit minutes and the seconds of the value to be set on the circle. Then, you turn the instrument in azimuth and make coincidence at the degrees and tens of minutes value that is to be set. The predetermined value can usually be set on the circle in this way to plus or minus 2 sec.

ENGINEER'S LEVEL

The engineer's level is a widely used instrument for leveling operations. Its sighting device is a 30 ± 3 variable power telescope, with a maximum length of 18 in. and with an erecting eyepiece. Some models use internal focusing, while others use external focusing objective

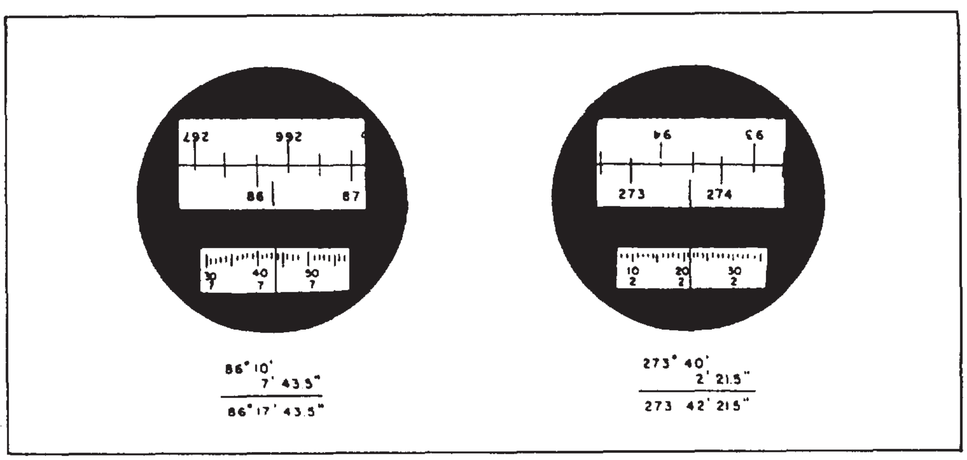

Figure 11-23.-View of a vertical circle for direct and reversal pointings.

assemblies. The reticle has two cross hairs at right angles to each other, and some models have stadia hairs. The telescope and level bar assembly is mounted on a spindle that permits the unit to be revolved only in a horizontal plane. It cannot be elevated or depressed. A clamp and tangent screw acts on this spindle for small motions to permit accurate centering. The spindle mounts in a four-screw leveling head that rests on a foot plate. The foot plate screws onto the threads on the tripod. When the instrument is properly leveled and adjusted, the line of sight, defined by the horizontal cross hair, will describe a horizontal plane.

The two distinct types of engineer's levels, classified according to their support, are the wye level and the dumpy level. The WYE LEVEL (fig. 11-24) is so called because its telescope is supported by a pair of wye rings. These rings can be opened for the purpose of turning the telescope or rotating it around its horizontal axis. The bubble tube (vial) can be adjusted, either vertically or laterally, by means of adjusting nuts at the ends of the bubble tube. All these features are provided for the purpose of making fine adjustments. The DUMPY LEVEL (fig. 11-25) has its telescope rigidly attached to the level bar, which supports an adjustable, highly sensitive level vial. During visual leveling operations and observations, both types handle similar basic operations. Their cross hairs are brought into focus by rotation of the eyepiece, and their target, into clear focus by rotation of the focusing knob. Their telescope can be exactly trained on targets by lightly tightening the azimuth clamp and manipulating the azimuth tangent screw.

PRECISION LEVEL

Other types of leveling instruments have been incorporated into the SEABEE units. In fact, the self-leveling level has now become standard

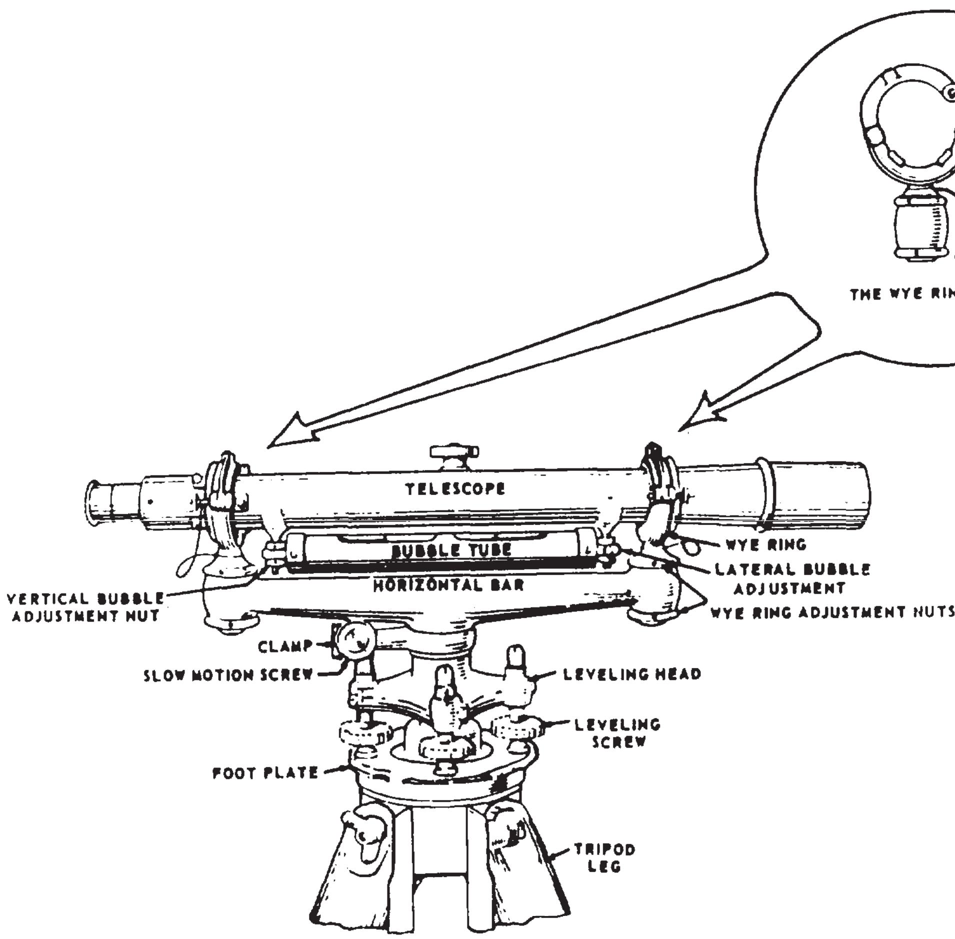

Figure 11-24.-A wye level.

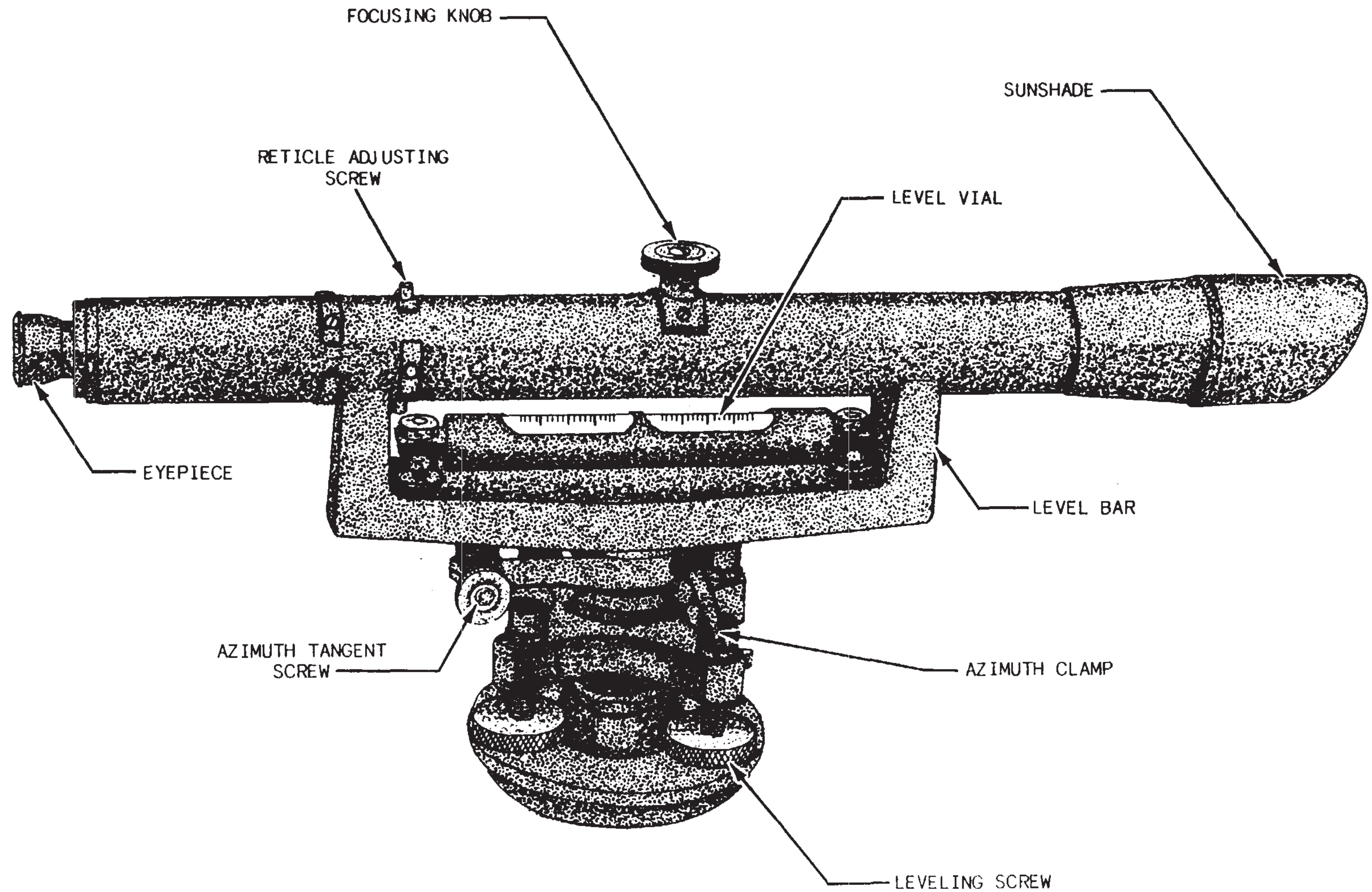

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Figure 11-25.—A dumpy level.

equipment in the Naval Construction Force Table of Allowance (TOA). These precision instruments are essentially like the conventional levels except for added features.

A precision level is one that is equipped with an extra-sensitive level vial. The sensitivity of a level vial is usually expressed in terms of the size of the vertical angle the telescope must be moved to cause the bubble in the level vial to move from one graduation to the next.

The sensitivity of the level vial on an ordinary level is about 20 sec. On a precise level, it is about 2 sec. The telescope level vial on an ordinary transit has a sensitivity of about 30 sec.

The more sensitive the level vial is, the more difficult it is to center the bubble. If the level vial on an ordinary level had a sensitivity as high as 2 sec, the smallest possible movement of the level screw would cause a large motion of the bubble.

For this reason, a precise level is usually also a tilting level. On a tilting level, the telescope is hinged at the objective end so the eyepiece end can be raised or lowered. The eyepiece end rests on a finely threaded micrometer screw that can be turned to raise or lower the eyepiece end in small increments. The instrument is first leveled, as nearly as possible, in the usual manner. The bubble is then brought to exact center by the use of the micrometer screw.

Military Level

The military level (fig. 11-26) is a semi-precise level designed for a more precise work than the engineer's level. The telescope is a 30-power, 10-in.-long, interior-focusing type with an inverting eyepiece and an enclosed fixed reticle. The reticle is mounted internally and cannot be adjusted as in other instruments. It contains cross wires and a set of stadia hairs. The objective is focused by an internal field lens through a rack and pinion, controlled by a knob on the upper right-hand side of the telescope. The telescope and level vial can be tilted through a small angle in the vertical plane to make the line of sight exactly horizontal just before the rod reading is made. The tilting is done by a screw with a graduated drum located below the telescope eyepiece. A cam is provided to raise the telescope off of the tilting device and to hold it firmly when the instrument is being moved and during the preliminary

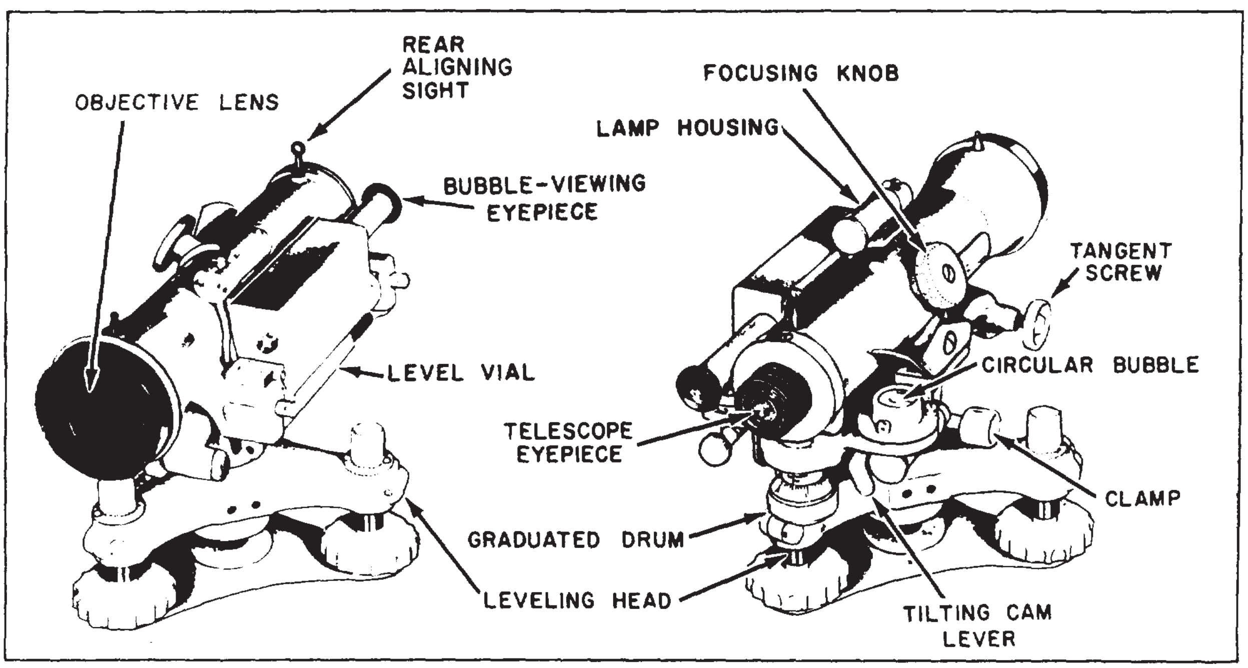

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Figure 11-26.-A military level.

leveling. An eyepiece, located to the left of the telescope, is used for viewing the bubble through the prism system that brings both ends of the bubble (fig. 11-13) into coincidence.

The level vial is located directly under the telescope, but to the left and below, directly in line with the capstan screws under the bubble-viewing eyepiece. The level vial's sensitivity is given as 30 sec per 2-mm spacing. A circular bubble that is viewed through a 45° mirror is provided for the first approximate leveling before the long level vial is used. For night work, battery-powered electric illumination lights the long bubble, the reticle, and the circular level. The clamping screw and the horizontal motion tangent screw are located on the right-hand side; the former near the spindle and the latter below the objective lens. The instrument has a three-screw leveling head. The tripod for this level has a non-extension leg to add rigidity and stability to the setup.

Self-Leveling Level

The self-leveling level (also called automatic level) shown in figure 11-27 is a precise, time-saving development in leveling instruments. It did away with the tubular spirit level, whose bubble takes time in centering as well as in resetting its correct position from time to time during operation.

The self-leveling level is equipped with a small bull' s-eye level and three leveling screws. The leveling screws, which are on a triangular foot plate, are used to center the bubble of the bull's-eye level approximately. The line of sight automatically becomes horizontal and remains horizontal as long as the bubble remains approximately centered. A prismatic device called a compensator makes this possible. The compensator is suspended on fine, nonmagnetic wires. The action of gravity on the compensator causes the optical system to swing into the position that

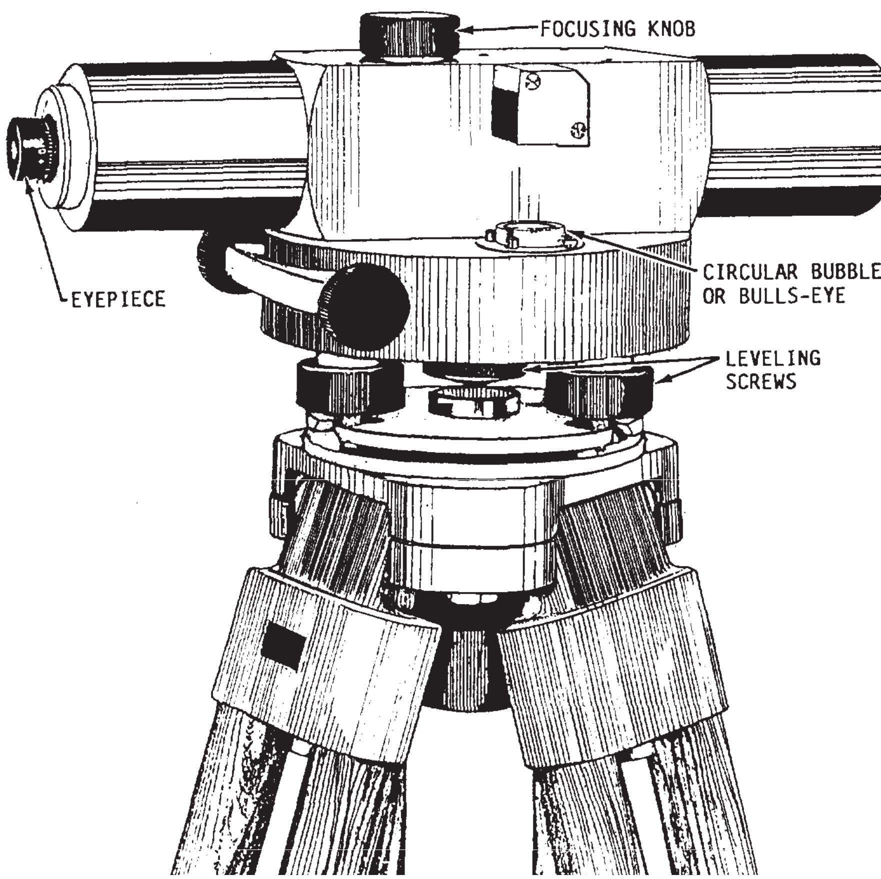

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Figure 11-27.-An automatic level.

defines a horizontal sight. This horizontal line of sight is maintained despite a slight out of level of the telescope or even when a slight disturbance occurs on the instrument.

HAND LEVEL

The hand level, like all surveying levels, is an instrument that combines a level vial and a sighting device. It is generally used for rough leveling work. In a cross-sectional work, for example, terrain irregularities may cause elevations to go beyond the instrument range from a setup. A hand level is useful for extending approximate elevations off the control survey line beyond the limits of the instruments.

Figure 11-28, view A, shows a LOCKE HAND LEVEL; view B shows an ABNEY HAND LEVEL. For greater stability, both hand levels may be rested against a tree, rod, range pole, or on top of a staff. A horizontal line, called an index line, is provided in the sight tube as a reference line. The level vial is mounted atop a slot in the sight tube in which a reflector is set at a 45° angle. This permits the observer, while sighting through the tube, to see the landscape or object, the position of the bubble in the vial, and the index line at the same time.

The distances over which a hand level is sighted are comparatively short; therefore, no magnification is provided for the sighting.

The Abney hand level is more specialized than the Locke type. It has a clinometer for measuring the vertical angle and the percent of grade. The clinometer has a reversible graduated arc assembly mounted on one side. The lower side of the arc is graduated in degrees, and the upper side, in percent of slope. The level vial is attached to the axis of rotation at the index arm.

When the index arm is set at zero, the clinometer is used like a plain hand level. The bubble is centered by moving the arc and not the sighting tube as is the case in the plain hand level. Thus, the difference between the line of sight and the level bubble axis can be read in degrees or percent of slope from the position of the index arm of the arc. The 45° reflector and the sighting principle with its view of the landscape, bubble, and index line are the same as in the plain hand level.

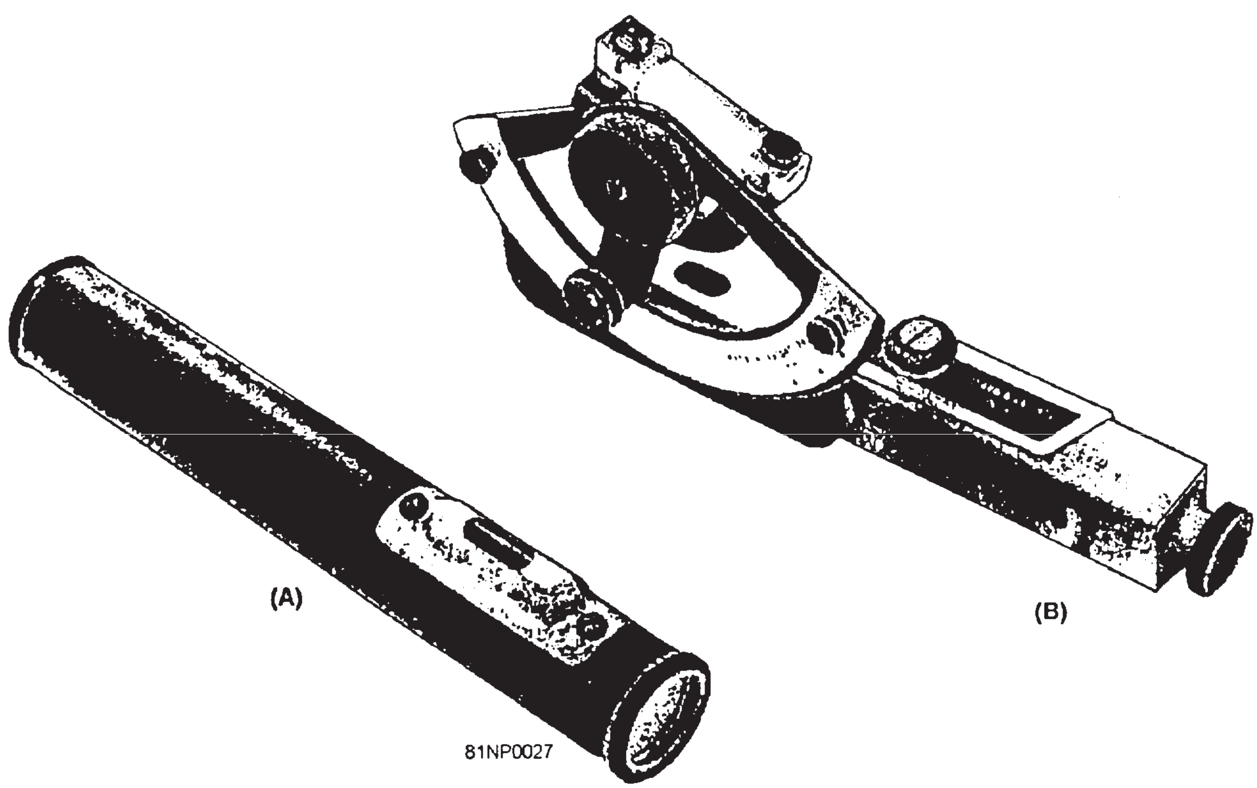

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Figure 11-28.-Types of hand levels.

When combined with the stadia board or Philadelphia rod, the plane table are used in what is generally known as plane table surveys. Which these instruments, the direction, the distance, and the difference in elevation can be measured and plotted directly in the field. The plane table opration produces a completed sketch or map manuscript without the need for further plotting or computing.

A plane table (fig. 11-29) consists of a drawing board mounted on a tripod with a leveling device designed as part of the board and tripod. The commonly used leveling head is the ball-and-socket type. The cross section of a plane table with the tripod head is shown in figure 11-30. The board (G) usually is either 18 by 24 in. or 24 by 31 in. and has an attached recessed fitting that screws onto the top of the spindle (A). A wingnut (B) controls the grip of parts C and D on cup E. By releasing the wingnut (B), you can tilt the drawing board in any direction to level it. Another wingnut (F) acts only on the spindle and, when released, permits the leveled board to be rotated on azimuth for orientation. The tripod is shorter than the transit or level tripods and, when set up, brings the plane table about waist high for easy plotting. One precaution must be observed in attaching the plane table to the tripod head. A paper gasket should be placed between the fittings to prevent sticking or "freezing" of the threads.

The plane table is setup over a point on the ground whose position has been previously plotted, or will be plotted, on the plane table sheet during the operation. The board is oriented either by using a magnetic compass for north-south orientation or by sighting on another visible point whose position is plotted. The board is clamped and the alidade is pointed toward any new, desired point using the plotted position of the setup ground station as a pivot. A line drawn along the straightedge that is parallel to the line of sight will give the plotted direction from the setup point to the desired point. Once the distance between the points is determined, it is plotted along the line to the specified scale. The plotted position represents the new point at the correct distance and direction from the original point. By holding the plane table orientation and pivoting the alidade around the setup point, you can quickly draw the direction to any number of visible points. The distance to these points is determined by any conventional method that meets the requirements for the desired accuracy and can be plotted along their respective rays from the setup point. Thus, from one setup, the positions of a whole series of points can be established quickly. For mapping, the difference in elevation is also determined and plotted for each point. The map is completed by subdividing the distances between points with the correct number of contours spaced to represent the slope of the ground.

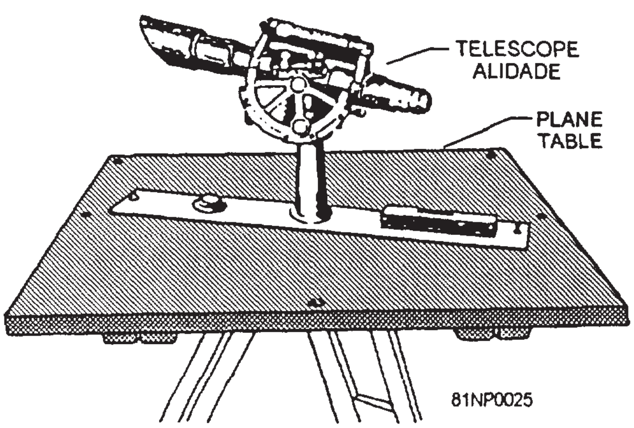

Figure 11-29.-Plane table.

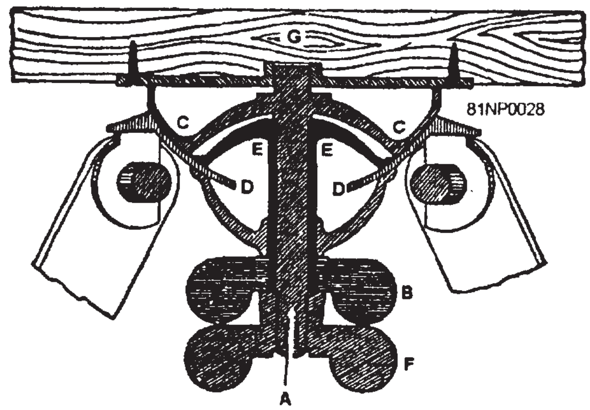

Figure 11-30.-Cross section of a plane table tripod bead.

The alidade (fig. 11-31) is a straightedge with a sighting device parallel to the edge. The more precise types have telescopes for sighting, special retitles for measuring distance, and graduated arcs for measuring vertical angles. A new version also includes a self-leveling, optical-reading system with enclosed graduated arcs.

1. The open-sight alidade (fig. 11-31, view A), which is very useful in sketching small areas, has a collapsible open sight attached to a straightedge. A level bubble is mounted on the straightedge for keeping the alidade level. A trough compass is also furnished for attaching to the sketch board. By sighting through the peep sight, the operator can determine a level line and the slope from the sighting point. No magnification is provided, so the sight lines are kept comparatively short. The distances can be estimated by pacing or can be measured with a tape if more accuracy is required. A 10-mil graduation that is numbered every fifth tick mark from 0 to 40 runs up on the right edge and down on the left edge of the front sight for determining slopes.

2. The telescopic alidades (fig. 11-31, views B and C) consist of straightedges with rigidly mounted telescopes that can be rotated through a vertical angle of $\pm 30^{\circ}$. One type has a telescope set on a high standard or post to raise it above the table. This permits direct viewing through the telescope, which is at a comfortable height. The other type has the telescope mounted close to the straightedge. A right-angle prism is attached to the eyepiece and permits viewing through the telescope by looking down into the eyepiece prism.

3. The telescope for the high standard is 16 power; for the low standard, 12 power. Both are the inverting type with internal focusing. The prismatic eyepiece inverts the image top to bottom, so that it appears erect but reversed side to side. The line of sight through the telescopes in a level position is parallel to the straightedge on the base. The telescope reticle has horizontal and vertical cross hairs and a set of stadia hairs. As you already knew, the stadia hairs are used to measure distances. The vertical distance between the upper and lower stadia hairs is carefully read and multiplied by the stadia interval factor. This value is the straight-line distance between the instrument and the rod.

4. A circular bubble and a magnetic compass needle are attached to the base. These are used to level the plane table and orient it to its proper position. Since the ball-and-socket head does not permit as fine a movement as the leveling screw, the bubble is centered as accurately as possible. Then, the wingnut (fig. 11-30, view B) is set firmly but not tightly. When the plane table is tapped lightly on the proper corner, the operator can refine the leveling and then properly tighten the wingnut. To orient the plane table, loosen wingnut F and rotate the table. It is a good practice to draw a magnetic north line on the cover sheet or on two pieces of tape attached near the edges of the board. The straightedge is set on this line during orientation. When the plane table is rotated to face north, the magnetic needle is released and will have room to swing in its case without hitting the sides.

5. The telescopic alidades have two other important features used for plane table surveying. These are the detachable striding level and the

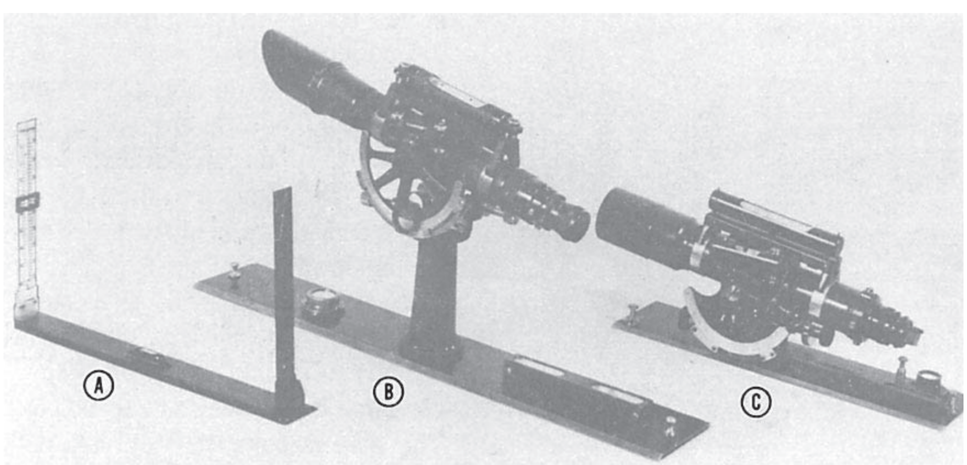

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Figure 11-31.-Types of alidades.

stadia arc. The striding level contains a long bubble, and when attached, permits accurate leveling of the line of sight. The bubble is mounted on a metal tube with V-fittings on each end. The fittings are placed astride the telescope and bear on built-in polished brass rings on each side of the center post. A spring clip on the level grips a center pin on top of the telescope and keeps the level from falling or being knocked off during operation. A button on the side of the level releases the clip for removing the level. For checking and adjusting, the level is reversible. The striding level normally is used to establish a horizontal line of sight and to use the alidade as a level. The stadia arc assembly consists of a vertical arc mounted on the end of the left trunnion and a vernier attached to the left bearing by an arm. A level vial is attached to the upper end of the arm; a tangent screw controls the movement of the vial. Once adjusted, this vial establishes a reference from which vertical angles can be measured even if the plane table is not exactly level. The stadia arc is a vertical scale attached to the alidade. With the stadia arc, it is possible to determine horizontal distances and differences in elevation by the stadia method.

6. A new model telescopic alidade is the self-leveling, optical-reading instrument. Instead of the exterior arc and level bubble, a prism system with a suspended element and enclosed arcs is used. As long as the alidade base is leveled to within one-half degree of horizontal, the suspending element (or pendulum) will swing into position. Then the vertical arc index that is attached to it will assume a leveled position. The scales are read directly through an optical train. This combination permits faster operation. In addition, there is no chance of forgetting to index the arc bubble and introducing errors into the readings.

Some of the auxiliary equipment used with a plane table consists of a coated plastic or a paper plane table sheet on which the map or sketch is drawn, drawing materials (scribing tools for coated plastic or pencils for the paper), scales for plotting distances, triangles, waterproof table covers, umbrella, and notebook. The plane table sheet is attached to the board by flatheaded, threaded studs that fit into recesses in the table and do not obstruct the alidade's movement.

FIELD EQUIPMENT

The term *field equipment,* as used in this training manual, includes all devices, tools, and instrument accessories used in connection with field measurements.

FIELD TOOLS

If you are running a survey across rough terrain, the essential equipment you will need are various types of tools used for clearing the line; that is, for cutting down brush and other natural growth as necessary.

Surveying procedures usually permit the bypassing of large trees. Occasionally, however, it may be necessary to fell one of these. If heavy equipment is working in the vicinity, an EO may fell the tree with a bulldozer. The next best method is by means of a power-driven chain saw. In the absence of a chain saw, a one-man or two-man crosscut saw may be available.

The machete and brush hook (fig. 11-32) are used for clearing small saplings, bushes, vines, and similar growth. Axes and hatchets (fig. 11-32) are used for felling trees and also for marking trees

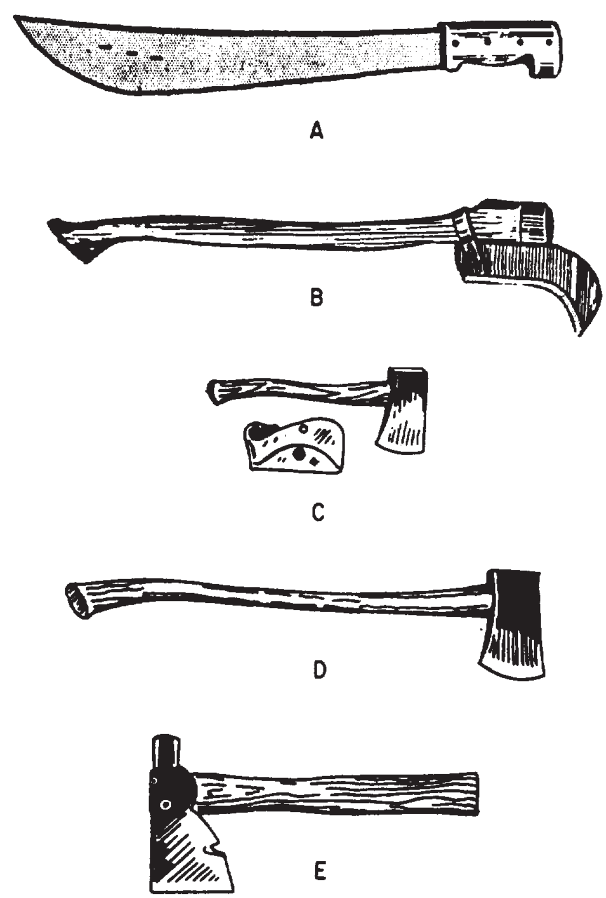

Figure 11-32.-(A) Machete; (B) Brush hook; (C) Single-bit belt ax; (D) Single-bit ax; (E) Half hatchet.

by blazing. Files and stones are usual items of equipment for sharpening the edges of tools.

Hubs, stakes, pipe, and other driven markers are often driven with the driving peen of a hatchet or a single-bit ax. A sledgehammer, however, is a more suitable tool for the purpose. A double-faced, long-handled sledgehammer is shown in figure 11-33. It is swung with both hands. There are also short-handled sledgehammers, swung with one hand. A sledgehammer is classified according to the weight of the head; common weights are 6, 8, 10, 12, 14, and 16 lb. The 8- and 10-lb weights are most commonly used.

When the ground is too compact or too frozen to permit wooden stakes and hubs to be driven directly, the way for a stake or hub is opened by first driving in a heavy, conical-pointed steel bar, 10 to 16 in. long, called a bull-point. One of the heavy steel form pins, used to pin down side forms for concrete paving, can be used as a bull-point; however, the pyramidal pavement-breaker bit on a jack hammer (pneumatic hammer used to drive paving breaker bits, stone drills, and the like) makes a better bull-point. Because a jack hammer bit is made of high-carbon steel, it is liable to chip and mushroom when subjected to heavy pounding. Do not use a bull-point with a badly damaged head; it should be refinished by grinding or cutting off before being used to avoid injury to personnel.

In searching for hidden markers, you may need a shovel like the one shown in figure 11-34 for clearing top cover by careful digging. In soft ground, such as loose, sandy soil, you may prefer to use a square-pointed shovel or a probing steel rod to locate buried markers.

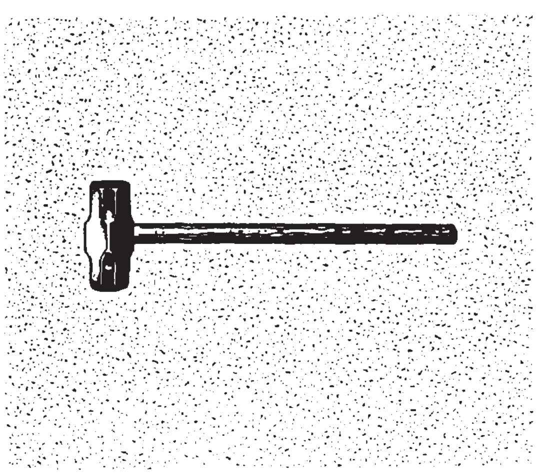

Figure 11-33.-A double-faced sledgehammer.

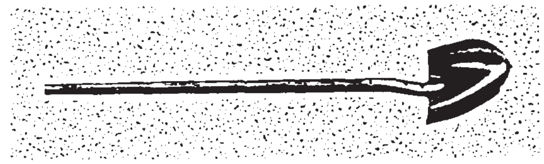

Figure 11-34.-Long-handled shovel.

A pick (fig. 11-35) may be required to chip bituminous pavement off of manhole covers and for levering up covers. Sometimes a crowbar is needed for levering manhole covers.

Buried metal markers may be located with the help of a magnetic device called a dip needle or a battery-powered instrument, similar in principle to a mine detector, commonly called a pipe finder. These instruments are used in engineering surveys to locate utility pipelines, buried manhole and valve box covers, and the like. These instruments can generally be borrowed from the utilities division of the public works department (PWD) of the larger shore stations.

SURVEYING TAPES

Tapes are used in surveying to measure horizontal, vertical, and slope distances. They may be made of a ribbon or a band of steel, an alloy of steel, cloth reinforced with metal, or synthetic materials. Tapes are issued in various lengths and widths and graduated in a variety of ways.

Metallic Tapes

A metallic tape is made of high-grade synthetic material with strong metallic. strands (bronze-brass-copper wire) woven in the warped face of the tape and coated with a tough plastic for

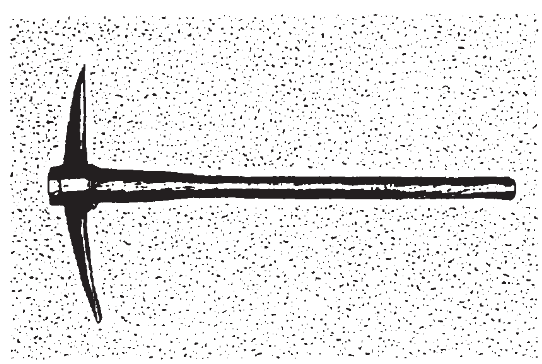

Figure 11-35.-Pick.

durability. Standard lengths are 50 and 100 ft. Some are graduated in feet and inches to the nearest one-fourth in. Others are graduated in feet and decimals of a foot to the nearest 0.05 ft.

Metallic tapes are generally used for rough measurements, such as cross-sectional work, road-work slope staking, side shots in topographic surveys, and many others in the same category.

Nonmetallic tapes woven from synthetic yarn, such as nylon, and coated with plastic are available; some surveyors prefer to use tapes of this type. Nonmetallic tapes are of special value to power and utility field personnel, especially when they are working in the vicinity of high-voltage circuits.

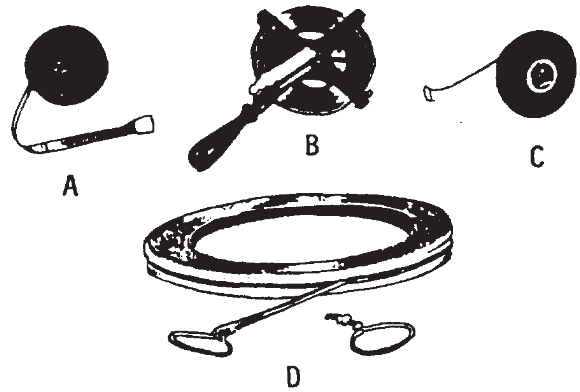

Figure 11-36.-Surveying tapes.

Steel Tapes

For direct linear measurements of ordinary or more accurate precision, a steel tape is required. The most commonly used length is 100 ft, but tapes are also available in 50-, 200-, 300-, and 500-ft lengths. All tapes except the 500-ft one are band-types, the common band widths being 1/4 and 5/16 in. The 500-ft tape is usually a flat-wire type.

Most steel tapes are graduated in feet and decimals of feet, but some are graduated in feet and inches, meters, Gunter's links, and chains or other linear units. From now on, when we discuss a tape, we will be talking about one that is graduated in feet and decimals of a foot unless we state otherwise.

Some tapes called engineer's or direct reading tapes are graduated throughout in subdivisions of each foot. The tape most commonly used, however, is the so-called chain tape, on which only the first foot at the zero end of the tape is graduated in subdivisions, the main body of the tape being graduated only at every 1-ft mark.

A steel tape is sometimes equipped with a reel on which the tape can be wound. A tape can be, and often is, detached from the reel, however, for more convenient use in taping.

Various types of surveying tapes are shown in figure 11-36. View A shows a metallic tape; view B, a steel tape on an open reel; view C, a steel tape or, a closed reel. View D shows a special type of low-expansion steel tape used in high-order work; it is generally called an Invar tape or Lovar tape.

Invar Tapes

Nickel-steel alloy tapes, known as Invar, Nilvar, or Lovar, have a coefficient of thermal expansion of about one-tenth to one-thirtieth (as low as 0.0000002 per $1^{\circ}F$) that of steel. These tapes are used primarily in high-precision taping. These tapes must be handled in exactly the same manner as other precise surveying instruments. The alloy metal is relatively soft and can be easily broken or kinked if mishandled. Ordinarily, Invar tapes should not be used when a steel tape can give the desired accuracy under the same operating conditions. Invar tapes are used for very precise measurements, such as those for base lines and in city work. When not in use, the tape should be stored in a reel, as shown in figure 11-36, view D. Except for special locations where the ground surface is hard and flat, such as roadways or railroads beds, the Invar tape is used over special supports or stools and is not permitted to touch the ground.

SURVEYING ACCESSORIES

Surveying accessories include the equipment, tools, and other devices used in surveying that are not considered to be an integral part of the surveying instrument itself. They come as separate items; thus, they are ordered separately through the Navy supply system.

When you run a traverse, for example, your primary instruments may be the transit and the steel tape. The accessories you need to do the actual measurement will be the following: a tripod to support the transit; a range pole to sight on in line; a plumb bob to center the instrument on the point; perhaps tape supports if the survey is of high precision; and so forth. It is important that you become familiar with the proper care of this equipment and use it properly.

Tripod

The tripod is the base or foundation that supports the survey instrument and keeps it stable during observations. A tripod consists of a head to which the instrument is attached, three wooden or metal legs that are hinged at the head, and pointed metal shoes on each leg to be pressed or anchored into the ground to achieve a firm setup. The leg hinge is adjusted so that the leg will just begin to fall slowly when it is raised to an angle of about 45°. The tripod head may have screw threads on which the instrument is mounted directly, a screw projecting upward through the plate, or a hole or slot through which a special bolt is inserted to attach to the instrument.

Two types of tripods are furnished to surveyors: the fixed-leg tripod and the extension-leg tripod. The fixed-leg type is also called a STILT-LEG or RIGID tripod, and the extension-leg tripod is also called a JACK-LEG tripod. Both types are shown in figure 11-37. Each fixed leg may consist of two lengths of wood as a unit or a single length of wood split at the top, attached to a hinged tripod head fitting and to a metal shoe. At points along the length, perpendicular brace pieces are sometimes added to give greater stability. The extension tripod leg is made of two sections that slide longitudinally. On rough ground, the legs are adjusted to different lengths to establish a horizontal tripod head or to set the instrument at the most comfortable working height for the observer. A leg may be shortened and set as shown in the extreme right view of figure 11-37.

The fixed legs must be swung in or out in varying amounts to level the head. Instrument height is not easily controlled, and the observer must learn the correct spread of the legs to get the desired height.

WIDE-FRAME tripods, like those shown in figure 11-38, have greater torsional stability and tend to vibrate less in the wind.

You should grip the surveying instrument firmly to avoid dropping it while you are mounting it on the tripod. Hold the transit by the right standard (opposite the vertical circle) while you are attaching it. The engineer's level should be held at the center of the telescope, while theodolites and precise levels should be gripped near the base of the instrument. The instruments should be screwed down to a firm bearing but not so tightly that they will bind or the screw threads will strip.

In setting up the tripod, you should be sure to place the legs so that you achieve a stable setup. On level terrain, you can achieve this by having each leg form an angle of about 60° with the ground surface.

Loosen the restraining strap from around the three legs, and secure it around one leg. An effective way to set the tripod down is to grip it with two of the legs close to the body while you stand over the point where the setup is required. By using one hand, you push the third leg out away from the body until it is about 50° to 60° with a horizontal. Lower the tripod until the third leg is on the ground. Place one hand on each of the first two legs, and spread them while taking a short backward step, using the third leg as a

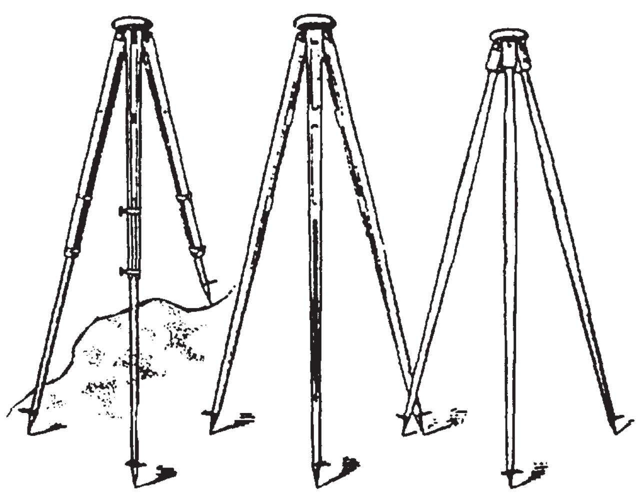

Figure 11-37.-Types of tripods.

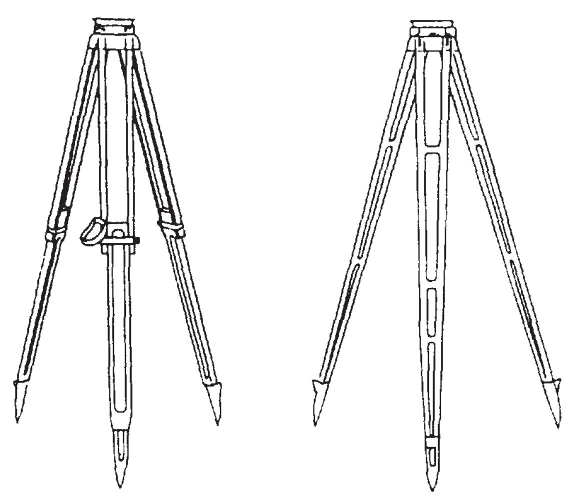

Figure 11-38.-Wide-frame tripods.

pivot point. When the two legs look about as far away from the mark as the third one and all three are about equally spaced, you lower the two legs and press them into the ground. Make any slight adjustment to level the head further by moving the third leg a few inches in or out before pressing it into the ground.

On smooth or slippery paved rock surfaces, you should tighten the tripod legs hinges while setting up to prevent the legs from spreading and causing the tripod to fall. You should make use of holes or cracks in the ground to brace the tripod. In some cases, as a safety factor, you should tie the three legs together or brace them with rock or bushes after they are set to keep them from spreading. If setups are to be made on a slippery finished floor, rubber shoes may be fitted to the metal shoes, or an equilateral triangle leg retainer may be used to prevent the legs from sliding.

When you are setting up on steeply sloping ground, place the third leg uphill and at a greater distance from the mark. Set the other two legs as before, but before releasing them, check the stability of the setup to see that the weight of the instrument and tripod head will not overbalance and cause the tripod to slip or fall.

Proper care must be observed in handling the tripod. When the legs are set in the ground, care must be taken to apply pressure longitudinally. Pressure across the leg can crack the wooden pieces. The hinge joint should be adjusted and not overtightened to the degree that it would cause strain on the joint or strip or lock the metal threads. The machined tripod head is to be kept covered with the head cover or protective cap when not in use, and the head should not be scratched or burred by mishandling. When the tripod is in use, the protective cap is to be placed in the instrument box to prevent it from being misplaced or damaged. Any damage to the protective cap can be transferred to the tripod head. Mud, clay, or sand adhering to the tripod has to be removed, and the tripod is to be wiped with a damp cloth and dried. The metal parts should be coated with a light film of oil or wiped with an oily cloth. Foreign matter can get into hinged joints or on the machined surfaces and cause wear. Stability is the tripod's greatest asset. Instability, wear, or damaged bearing surfaces on the tripod can evolve into unexplainable errors in the final survey results.

Range Pole

A range pole (also called a lining rod) is a wood or metal pole, usually about 8 ft long and about 1/2 to 1 in. in diameter; it is provided with a steel point or shoe and painted in alternate bands of red and white to increase its visibility. Figure 11-39 shows a variety of range poles. The range pole is held vertically on a point or plumbed over a point, so the point may be observed through an optical instrument. It is primarily used as a sighting rod for either linear or angular measurements. For work of ordinary precision, chainmen may keep on line by observing a range pole. A range pole may also be used for approximate stadia measurement.

Plumb Bob, Cord, and Target

A plumb bob is a pointed, tapered brass or bronze weight that is suspended from a cord for the general purpose of determining the plumb line from a point on the ground. Common weights for

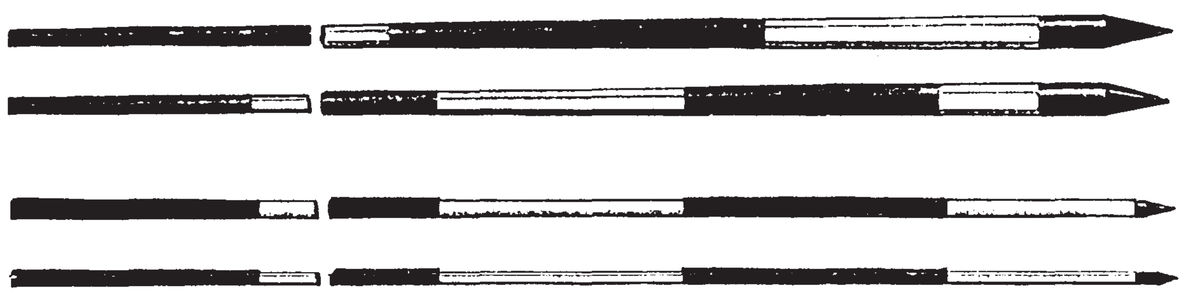

Figure 11-39.-Range poles.

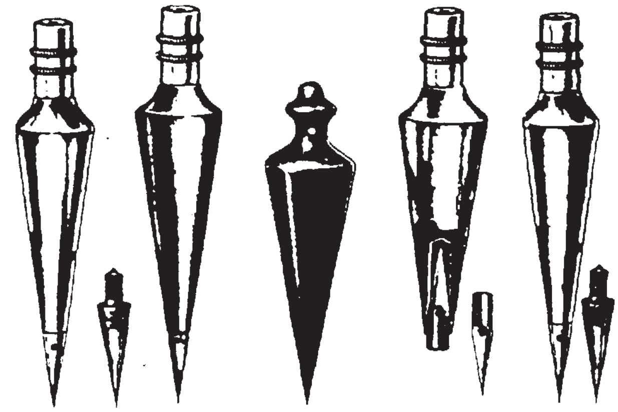

Figure 11-40.-Types of plumb bobs.

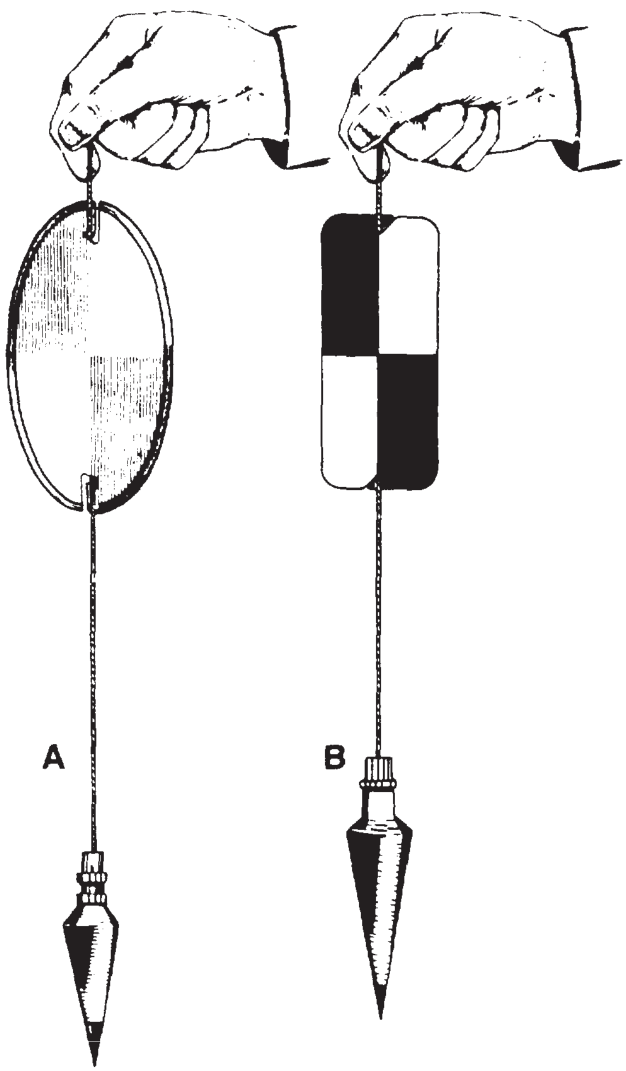

Figure 11-41.-Plumb bob, cord, and target.

plumb bobs are 6, 8, 10, 12, 14, 16, 18, and 24 oz; the 12- and the 16-oz are the most popular. Typical plumb bobs are shown in figure 11-40.

A plumb bob is a precision instrument and must be cared for as such. If the tip becomes bent, the cord from which the bob is suspended will not occupy the true plumb line over the point indicated by the tip. A plumb bob usually has a detachable tip, as shown in figure 11-40, so if the tip becomes damaged, it can be renewed without replacing the entire instrument.

Each survey party member should be equipped with a leather sheath, and the bob should be placed in the sheath whenever it is not in use.

The cord from a plumb bob can be made more conspicuous for observation purposes by the attachment of an oval form aluminum target (fig. 11-41, view A). The oval target has reinforced edges, and the face is enameled in quadrants alternately with red and white. Also, a flat rectangular plastic target may be used (fig. 11-41, view B). It has rounded corners with alternate red and white quadrants on its face. These plumb bob string targets are pocket size with approximate dimensions of 2 by 4 in.

Optical Plumbing Assembly

The optical plumbing assembly, or plummet, is a device built into the alidade or the tribrach of some of the instruments to center the instrument over a point. Its working principle is shown in figure 11-42. The plummet consists of a small prismatic telescope with a cross wire or

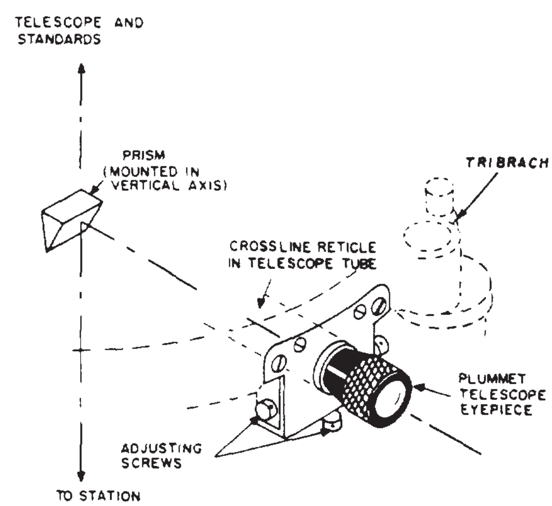

Figure 11-42.-Optical plumbing assembly.

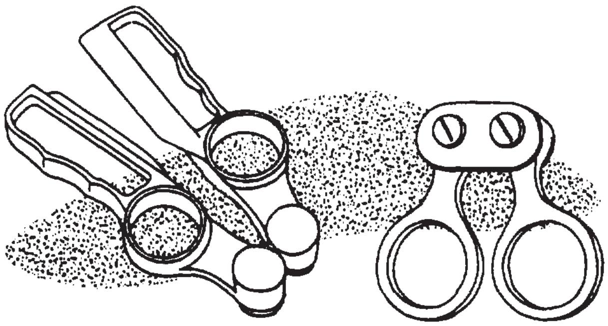

Figure 11-43.-Types of tape clamp handles.

marked circle reticle adjusted to be in line with the vertical axis of the instrument. After the instrument is leveled, a sighting through the plummet will check the centering over a point quickly. The advantages of the plummet over the plumb bob are that it permits the observer to center over a point from the height of the instrument stand, and it is not affected by the wind. The plummet is especially useful for work on high stands. A plumb bob requires someone at ground level to steady it and to inform the observer on the platform how to move the instrument and when it is exactly over the point. With the plummet, the centering and checking is done by the observer.

Tape Accessories

There is usually a leather thong at each end of a tape, by which the tape can be held when the full length is being used. When only part of the tape is used, the zero end can be held by the thong, and the tape can be held at an intermediate point by means of a tape clamp handle, like those shown in figure 11-43.

When a tape is not supported throughout—that is, when it is held aboveground between a couple of crew members—a correction must be applied for the amount of sag in the tape. To make this correction, you apply a certain amount of tension. Figure 11-44 shows two devices for applying a given amount of tension.

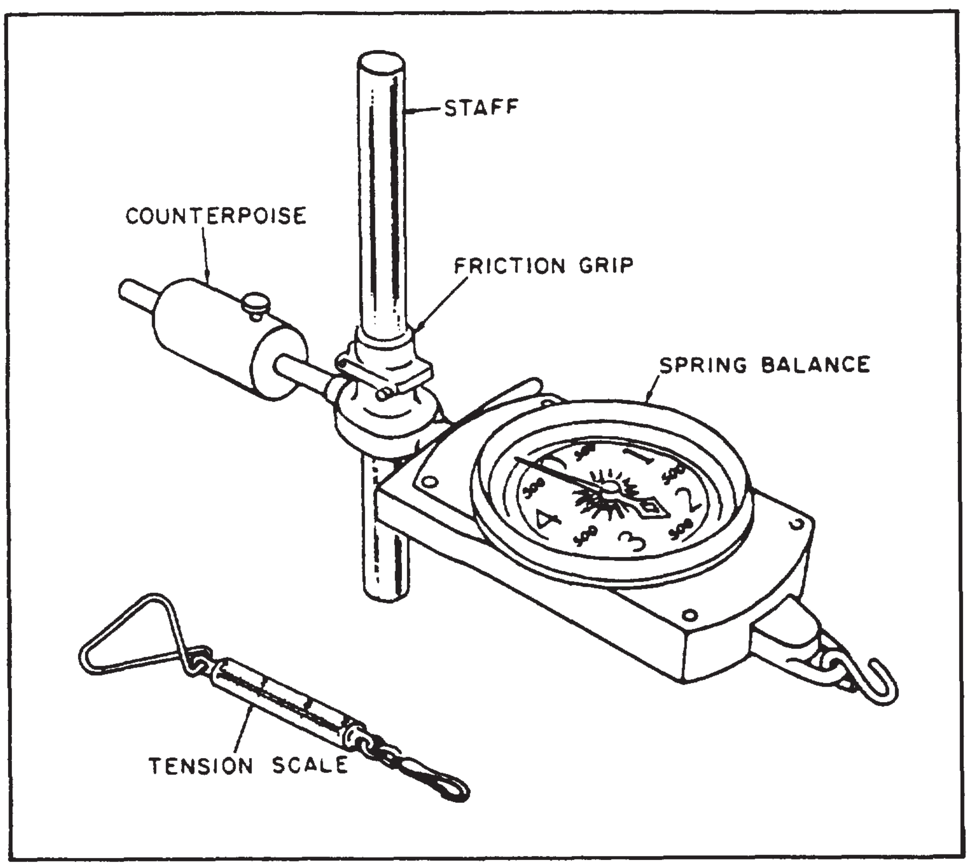

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Figure 11-44.-Tension scale and spring balance.

The tension scale is graduated in pounds from 0 to 30. It is clipped to the eye at the end of the tape, and the tension is applied until the desired reading appears on the scale. A pair of staffs can be used' to make the work easier. The rawhide thongs are wrapped around the staff at a convenient height and gripped firmly. The bottom end of the staff is braced against the foot (fig. 11-45) and the upper end tucked under the arm. Tension is applied by using the shoulder and leaning against the poles. The spring balance is used in a similar fashion for work of higher precision.

The stool device in figure 11-45 is called a tapping stool or chaining buck and is used in high-precision work. It is a metal three-legged stand with an adjustable sliding head and a handwheel-operated device for locking the plate (the top surface of the sliding head) in any desired position. A line is scribed on the plate. During taping operations, the head is moved until the scribed line is directly under a particular graduation on the tape; the handwheel is then used to lock the head. When the tape is shifted ahead to measure the next interval, the graduation is held exactly over the line until the next stool is adjusted and locked. The basic purpose of taping stools is to furnish stable, elevated surfaces on which taped distances can be marked accurately. When stools are not available, 2 by 4s or 4 by 4s are often driven into the ground for use as chaining bucks.

The length of a tape varies with the temperature, and the precision of a survey may require the application of corrections for this. For work of ordinary precision, you can assume that the

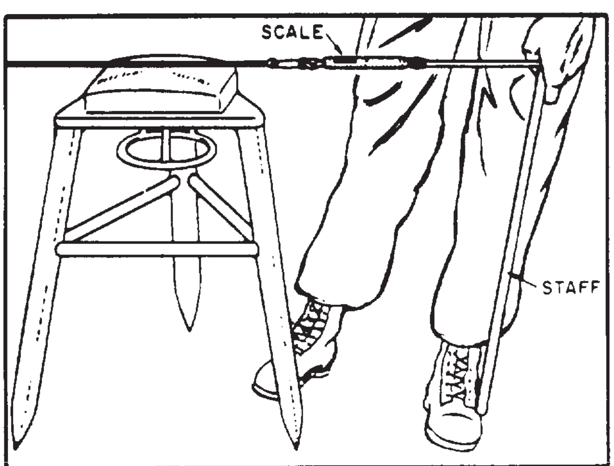

Figure 11-45.-Applying tension to tape.

Figure 11-46.-Tape thermometer.

temperature of the tape is about the same as that of the air. For work requiring higher precision, a tape thermometer, like the one shown in figure 11-46, is attached to the tape. For very precise work, two thermometers, one positioned at each end, may be used. If the two indicate different temperatures, the mean between them is calculated and used.

Chaining Pin

A chaining pin (also called a taping arrow) is a metal pin about 1 ft long. It has a circular eye at one end and a point for pushing it into the ground at the other (fig. 11-47). These pins come in sets of 11 pins, carried on a wire ring passed through the eyes in the pins or in a sheath called a quiver.

Chaining pins can be used for the temporary marking of points in a great variety of situations, but they are used most frequently to keep count of tape increments in the chaining of long distances.

Leveling Rod, Target, and Rod Level

A leveling rod, in essence, is a tape supported vertically and is used to measure the vertical distance (difference in elevation) between a line

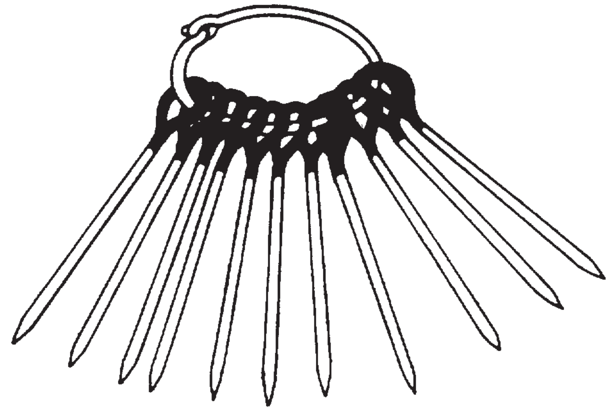

Figure 11-47.-Taping arrows or chaining pins.

of sight and a required point above or below it. This point may be a permanent elevation (bench mark), or it may be some natural or constructed surface.

There are several types of leveling rods. The most popular of all is the Philadelphia rod, as shown in figure 11-48. it is a graduated wooden rod made of two sections and can be extended from 7 to 13 ft. In view A, each foot is subdivided into hundredths of a foot. Instead of each hundredth being marked with a line or tick, the distance between alternate ones is painted black on a white background. Thus, the value for each hundredth is the distance between the colors; the TOP of the black, EVEN values, the BOTTOM of the black, ODD values. The tenths are numbered in black, the feet in red. This rod may be used with the level, transit, theodolite, and with the hand level on occasion to measure the difference in elevation.

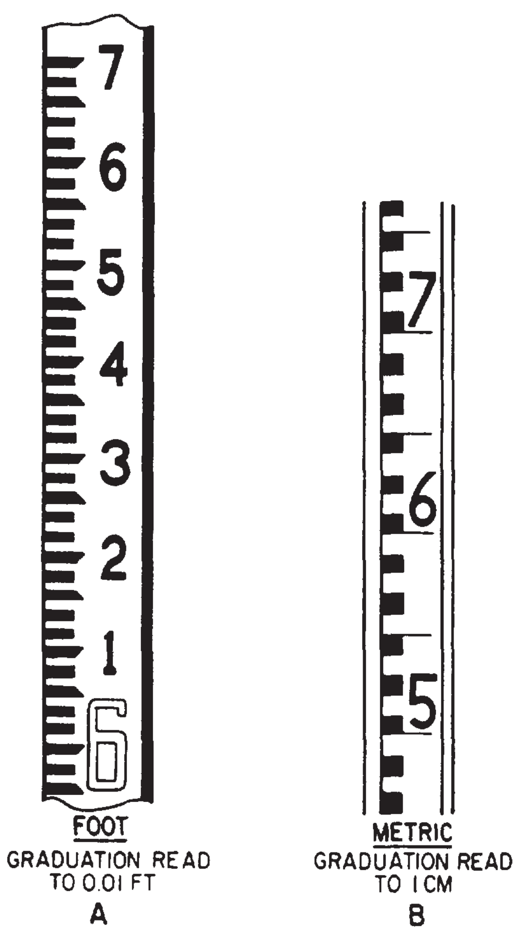

Figure 11-48.-Philadelphia rod.

The leveling rod may be read directly by the instrumentman sighting through the telescope, or it may be target-read. Conditions that hinder direct reading, such as poor visibility, long sights, and partially obstructed sights, as through brush or leaves, sometimes make it necessary to use targets. The target is also used to mark a rod reading when numerous points are set to the same elevation from one instrument setup.

Targets for the Philadelphia rod are usually oval, with the long axis at right angles to the rod, and the quadrants of the target painted alternately red and white. The target is held in place on the rod by a C-clamp and a thumbscrew. A lever on the face of the target is used for fine adjustment of the target to the line of sight of the level. The targets have rectangular openings approximately the width of the rod and 0.15 ft high through which the face of the rod may be seen. A linear vernier scale is mounted on the edge of the opening with the zero on the horizontal line of the target for reading to thousandths of a foot. When the target is used, the rodman takes the rod reading.

The other types of leveling rods differ from the Philadelphia rod only in details. The Frisco rod, for direct reading only, is available with two or three sliding sections. The Chicago rod is available with three or four sections that, instead of sliding, are joined at the end to each other like a fishing rod. The architect's or builder's rod is a two-section rod similar to the Philadelphia but is graduated in feet and inches to the nearest one-eighth in. rather than decimally. The upper section of the Lenker self-computing rod has the graduations on a continuous metal belt that can be rotated to set any desired graduation at the level of the height of the instrument (HI). To use the rod, you set the rod on the bench mark and bring the graduation that indicates the elevation of the bench mark level with the HI. As long as the level remains at that same setup, wherever you set the rod on a point, you read the elevation of the point directly. In short, the Lenker rod does away with the necessity for computing the elevations.

View B (fig. 11-48) shows the rod marked with metric measurements; the graduations of the rod are in meters, decimeters, and centimeters. The targets that are furnished with the metric rod have a vernier that permits reading the scale to the nearest millimeter. The metric rod can be extended from 2.0 to 3.7 meters.

For high-precision leveling, there are precise leveling rods as well as precise engineer's levels. A Lovar rod is usually T-shaped in cross section

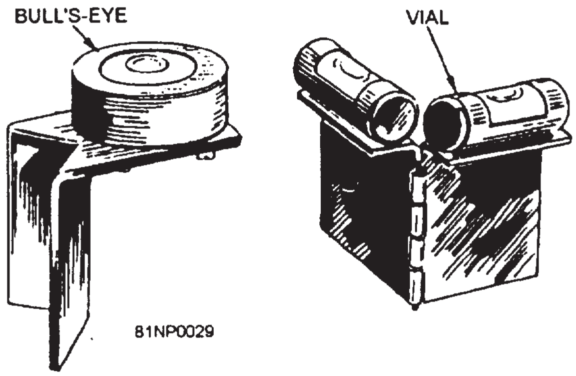

Figure 11-49.-Types of rod levels.

and has the scale inscribed on the strip of Lovar metal. A precise rod usually has a tapering, hardened steel base. Some are equipped with thermometers, so temperature correction can be applied. Precise rods generally contain built-in rod levels.

When a rod reading is made, it is accurate only if the rod is perfectly plumbed. If it is out of plumb, the reading will be greater that the actual vertical distance between the HI and the base of the rod. Therefore, to ensure a truly plumbed leveling rod, use a rod level.

Two types of rod levels that are generally used with standard leveling rods are shown in figure 11-49. The one at the left is called the bull's-eye level, and one on the right is the vial level. Figure 11-50 shows the proper way of using the bull's-eye level; the vial level is attached in the same manner.

Proper care should be taken of leveling rods. The care consists of keeping them clean, free of sand and dirt, unwarped, and readable. They must be carried over the shoulder or under the arm from point to point.

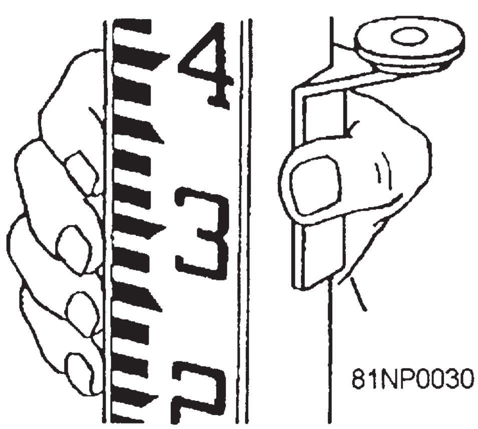

Figure 11-50.-Proper attachment of a bull's-eye rod level to the rod.

Dragging them through the brush or along the ground will wear away or chip the paint. When not in use, the leveling rods should be stored in their cases to prevent warping. The cases are generally designed to support the reds either flat or on their sides. The rods are not to be leaned against a wall or to remain on damp ground for any extended period, since this can produce a curvature in the rods and result in unpredictable random and systematic errors in leveling.

Stadia Boards

In determining linear distance by stadia, you observe a stadia rod or stadia board through a telescope containing stadia hairs, and note the size of the interval intercepted by the hairs. Atypical stadia board is shown

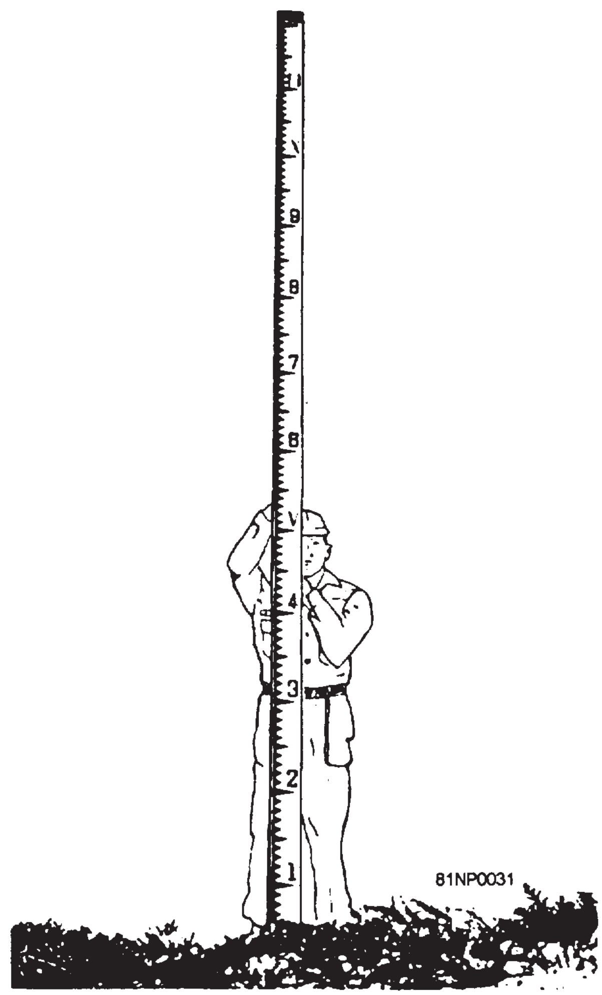

Figure 11-51.-Nadia board.

in figure 11-51. Note that it is graduated in a manner that facilitates counting the number of graduations intercepted between the hairs. Each tenth of a foot is marked by the point of one of the black, saw-toothed graduations. The interval between the point of a black tooth and the next adjacent white gullet between two black teeth represents 0.05 ft.

Other types of graduations on stadia rods or boards are shown in figure 11-52.

Turning-Point Pins and Plates

The point on which a leveling rod is held between a foresight and the next backsight while the instrument is being moved to the next setup is called a TURNING POINT. It must be sufficiently stable to maintain the accuracy of the level line. Where either proper natural features of man-made construction is not available, a turning-point pin, a turning-point plate, or a wooden stake is used. These not only furnish the solid footings but also identify the same position for both sightings. Normally, the pins or plates are used for short periods and are taken up for future use as soon as the instrument readings are completed. Wooden stakes are used for longer periods except when wood is scarce or local regulations require their removal.

A turning-point pin is shown in figure 11-53, view A. It is made of a tapered steel spike with a round top with a chain or a ring through the shaft for ease in pulling. The pin is driven into the ground with a sledgehammer. After a turning pin has served its purpose atone point, it is pulled and carried to the next turning point.

Turning-point plates (fig. 11-53, view B) are triangular metal plates with turned-down corners or added spikes that form prongs and have a projection or bump in the center to accept the rod. The plates are devised for use in loose, sandy, or unstable soils. The

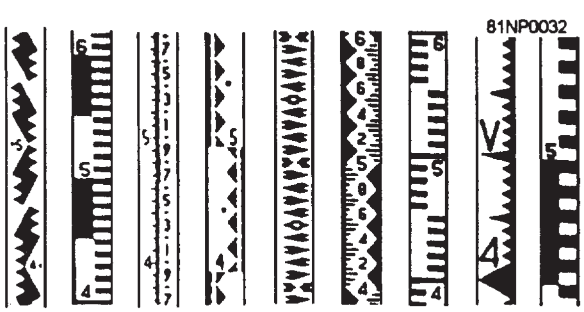

Figure 11-52.-Types of graduations on stadia boards.

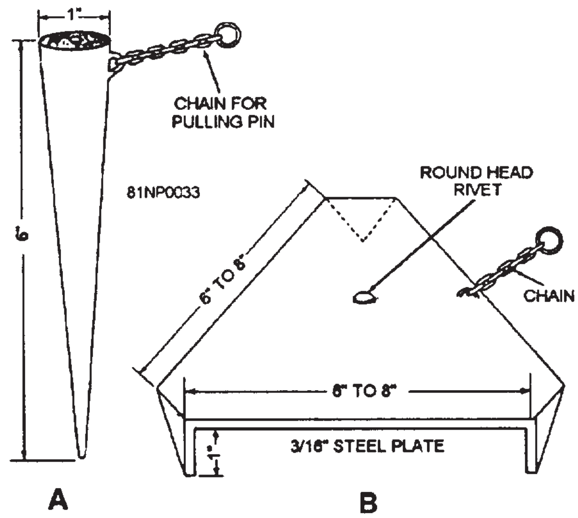

Figure 11-53.-Turning-point pin and plate.

plate is set by placing it on the ground, points down, and stepping on it to press it to a firm bearing. After use, it is lifted, shaken free of dirt and mud, and carried forward to the next turning point.

Magnifying Glass

A magnifying glass is used mainly to aid the instrumentman in reading graduations that are provided with verniers, such as the horizontal and vertical circle of a transit. Although these graduations can be read with the naked eye, the use of a magnifying glass makes the reading easier and decreases the chance of reading the wrong coincidence.

Two types of magnifying glasses that you will generally find in the transit box are shown in figure 11-54. They are usually called pocket

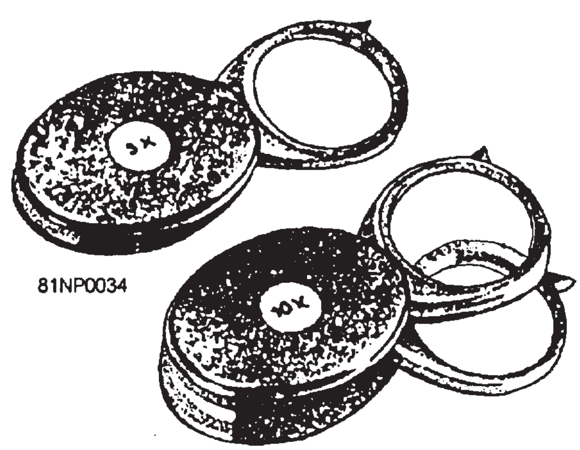

Figure 11-54.-Types of pocket magnifying glasses.

magnifying glasses. To avoid unknowingly dropping a magnifying glass in the field, you should attach it to a loop of string. The instrumentman puts his head through the loop, retaining the string around the neck, and carrying the magnifying glass in a pocket. At the end of each day's work, it is a good practice always to return the magnifying glass to its proper place in the instrument case.

Adjusting Pins

Surveying instruments are built in such a way that minor adjustments can be performed in the field without much loss of time while the work is in progress. The adjustments are made by loosening or tightening the capstan screws that are turned by the use of adjusting pins. These pins are also included in the instrument box. They come in various sizes that depend upon the type of instrument and the hole sizes of its capstan screws. Use the pin that fits the hole in the capstan head. If the pin is too small, the head of the screw will be ruined.

Replacements for these pins are generally given free of charge by surveying instrument dealers. Like the magnifying glass, adjusting pins should be carried in the pocket and not left in the instrument box while a survey is in progress. This will save a lot of valuable time when the pins are needed. Do not use wires, nails, screwdrivers, and the like, as substitutes for adjusting pins.

Tape Repair Kit

Even though you handle the tape properly and carefully during field measurements, some tapes still break under unforeseen circumstances. During chaining operations, when the area is quite far from the base of operations, the surveyor should always be sure to have a tape repair kit (fig. 11-55) with him so that he can rejoin any broken tape in the field, or if the surveyor has brought an extra tape, he can take the broken tape back to the office to be repaired.

The tape repair kit usually contains a pair of small snips, the tape sections of proper size and graduations, a hand punch or bench punch with block, an assortment of small rivets, a pair of tweezers, a small hammer, and a small file. Before reusing a repaired tape, always compare it with an Invar or Lovar tape to check it for accuracy.

FIELD SUPPLIES

Field supplies consist principally of a variety of materials used to mark the locations of points in the field. For example, pencils, field notebooks, and spare handles for sledgehammers

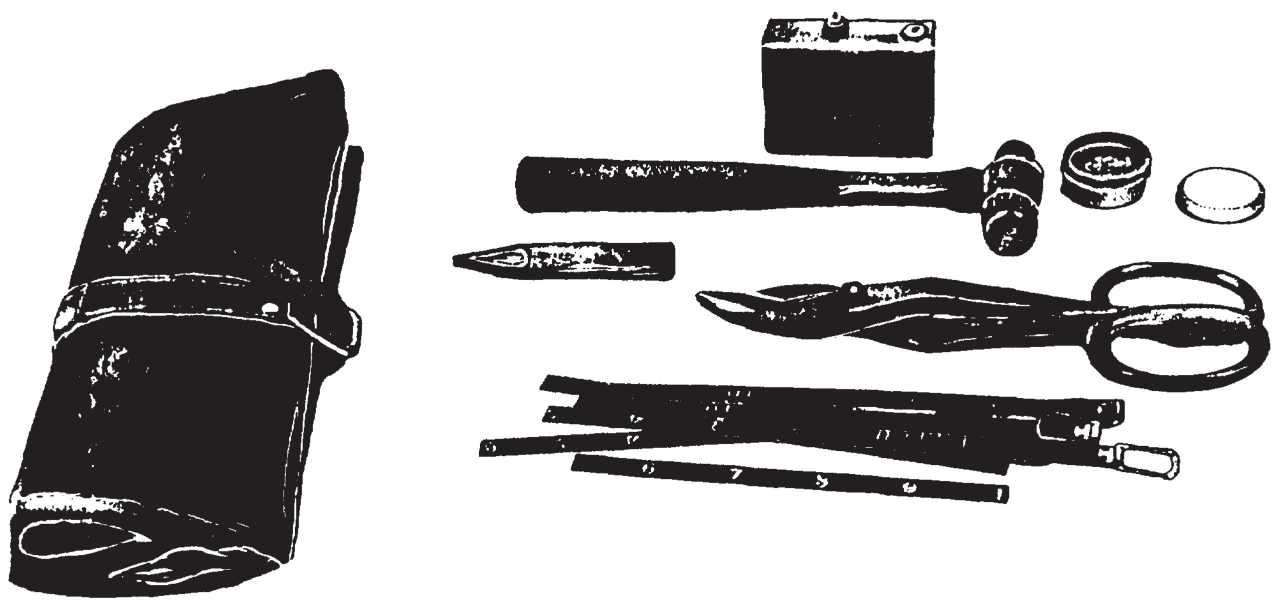

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Figure 11-55.-Tape repair kit.

are generally classified as field supplies. Because SEABEEs operate in so many different places and under such varied conditions, we have not tried to list in this training manual the supply requirements for every location. From your own experience and with the aid of your leading petty officer, you can easily make a list of supplies necessary for a projected survey mission. Those items generally required for a mission are described in this section.

SURVEY POINT MARKERS

The material used as a SURVEY POINT MARKER depends upon where the point is located and whether the marker is to be of a temporary, semipermanent, or permanent character. For example, a wooden stake can be easily driven to mark the location of a point in a grassy field, but it cannot be used to mark a point on the surface of a concrete highway. Similarly, though a wooden stake may be easily driven in a grassy field to mark a property line corner, a marker of this kind would not last as long as a piece of pipe or a concrete monument.

Most of the material commonly used as semipermanent or permanent markers of points in the field is described in the following sections. For purely temporary marking, it is often unnecessary to expend any marking materials. For example, a point in ordinary soil is often temporarily marked by a hole made with the point of a plumb bob, a chaining pin, or some other pointed device. In rough chaining of distances, even the mere imprint of a heel in the ground may suffice. A point on a concrete surface may be temporarily marked by an X drawn with keel (lumber crayon), a pencil, or some similar marking device. A large nail serves well as a temporary point in relatively stable ground or compacted materials.

Semipermanent Markers

Wooden hubs and stakes are extensively used as semipermanent markers of points in the field. The principal distinction between the two is the fact that a hub is usually driven to bring its top flush with, or almost flush with, the ground surface. A hub is used principally to mark the station point for an instrument setup. It is usually made of 2- by 2-in. stock and is from 5 to 12 in. long. The average length is about 8 in. Shorter lengths are used in hard ground, longer lengths in softer ground. A surveyor's tack, made of galvanized iron or stainless steel with a depression in the center of the head, is driven into the top of the hub to locate the exact point where the instrument is to be plumbed.

Stakes improvised in the field may be either cylindrical or any other shape available. However, manufactured stakes are rectangular in cross section because the faces of a stake are often inscribed with data relevant to the point that the stake is marking. A stake that marks a bench mark, for instance, is inscribed with the symbol that identifies the bench mark and with the elevation. A stake that marks a station on a traverse is inscribed with the symbol of the particular station, such as 2 + 45.06. A grade stake is inscribed with the number of vertical feet of cut (material to be excavated) or of fill (material to be filled in) required to bring the elevation of the surface to the specified grade elevation.

Figure 11-56 shows typical dimensions for an average-sized hub and stake. These dimensions, however, may be modified as situations arise, such as material limitations.

Permanent Markers

Permanent station markers are used to mark points that are to be used for a long period of time. Horizontal and vertical control stations are

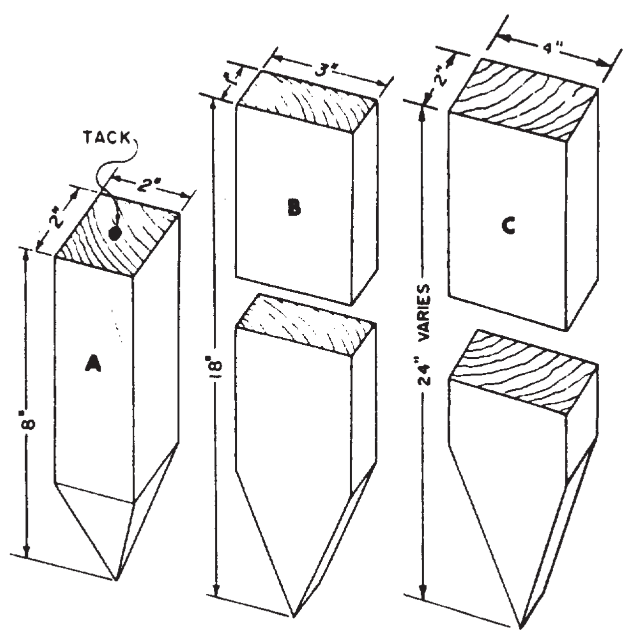


Figure 11-56.-Hub and stakes.

generally marked with permanent markers. These markers could be in the following forms:

- A bronze disk set in concrete
- An iron pipe filled with concrete
- A crosscut on an existing concrete structure or on a rock outcrop
- A hole drilled in concrete and filled with lead or a metal rod driven into the ground with a center-punched mark to designate the exact point

All permanent survey station markers should be referenced so they can be replaced if disturbed. Methods of referencing points are discussed later in this training manual.

Surveyor's tacks, spikes, and nails are often driven into growing trees, bituminous, or other semisolid surfaces as permanent markers. A nail will be more conspicuous if it is driven through a bottle cap, a washer, a plastic tape, or a "shiner." A shiner is a thin metal disk much like the top or bottom of a frozen fruit juice can.

A SPAD is a nail equipped with a hook for suspending a plumb bob. It is driven into an overhead surface, such as the top of a tunnel. The plumb bob will locate on the floor the point vertically below the point where the spad is driven.

Points on concrete or stone surfaces are often marked with an X cut with a hammer and chisel. Another way to do this is to cut holes with a star drill and then plug them with lead.

A much more durable form of marker is made of a length of metal pipe—usually called iron pipe regardless of the actual metal used. Lengths run from about 18 to 24 in. Sawed-off lengths of pipe have open ends; pipes cut with a shear have pinched ends and are called pinch pipe. There are also manufactured pipe markers, some of which are T-shaped rather than cylindrical in cross section. A commercial marker may consist of a copper-plated steel rod. All commercial markers have caps or heads that permit center punching for precise point location and stamping of the identifying information.

A still more durable form of marker is the concrete monument. A short length of brass rod is often set in the concrete to mark the exact location of the point. Concrete monuments that are used as permanent markers by various federal survey agencies have identifying disks set in concrete, like those shown in figure 11-57.

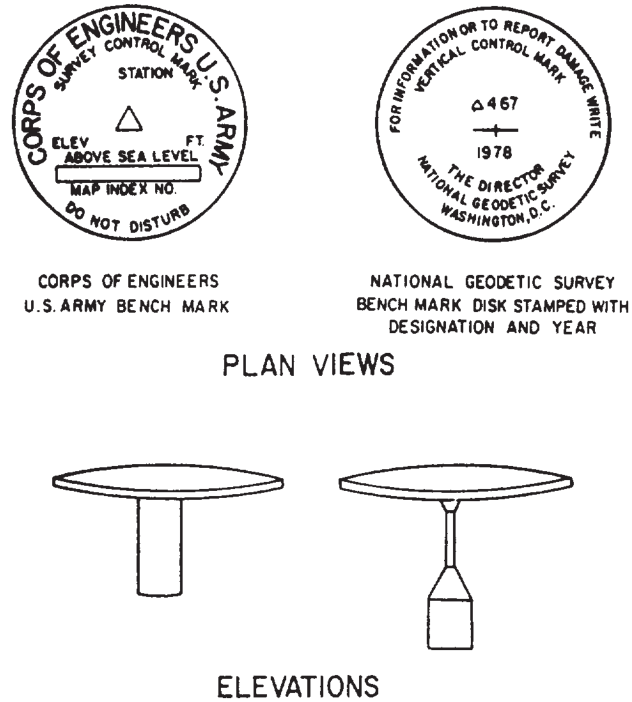


Figure 11-57.-Various types of federal marking disks.

Points on concrete or masonry surfaces may be permanently marked by setting lengths of cylindrical brass stock into holes plugged with lead or grout. Brass stock markers set in pavement are commonly called coppers. Manufactured brass disks, similar to the ones shown in figure 11-57, may be set in grouted holes in street pavements, sidewalks, steps, or the tops of retaining walls. Points on bituminous surfaces maybe marked by driving in pipe, railroad spikes, or case-hardened masonry nails, commonly called PK nails. A center punch for marking a precise location on metal stock or metal caps is a common item of equipment for a surveyor.

MARKING MATERIALS

KEEL, or LUMBER CRAYON, is a thick crayon used for marking stakes or other surfaces. Common marking devices that contain a quick-drying fluid and a felt tip are also popular for marking stakes. All of these types of graphic marking materials come in various colors.

In addition to keel, paint is used to mark pavement surfaces. Paint may be brushed on or sprayed from a spray can. To make the location of a point conspicuous, use a circle, a cross, or a triangle. Identification symbols, such as station or traverse numbers, may also be painted on. For a neater job, stencils are sometimes used.

FLAGGING

Colored cloth bunting or plastic tape is often used to make stakes conspicuous so they will be easier to find or to warn Equipment Operators away. Flagging may also be used for identification purposes. For example, traverse stakes may be marked with one color, grade stakes with another. Red, yellow, orange, and white are the most popular colors of flagging.

NOTE-KEEPING MATERIALS

Field notes are usually kept in a bound, standard field notebook. Sometimes loose-leaf notebooks are used but are not generally recommended because of the chance of losing some pages. Notebooks are classified as ENGINEER'S or TRANSIT FIELD BOOKS, LEVEL BOOKS, CROSS SECTION BOOKS, and so forth, depending on their use.

In a transit book, the left-hand side of the page is used for recording measurement data, and the right-hand side of the page, for remarks, sketches, and other supplementary information. The other field books generally follow the same pattern of usage. Different types of field books and inside pages are shown in figure 11-58. Note how each type is lined or gridded. Actually, a transit or a level book may be used for recording any type of survey. You may add or modify the column headings to suit the required data you desire to record.

PERSONAL PROTECTIVE AND SAFETY EQUIPMENT

In addition to the necessary field supplies and equipment, a field party must carry all necessary items of personal protective equipment, such as containers for drinking water, first-aid kits, gloves, and foul weather gear, as needed. A field survey party is usually working a considerable distance away from the main operational base. If, for example, you happen to be chaining through a marsh filled with icy water, you would not have a chance to return to the base to get your rubber boots.

You are required to wear a hard hat whenever you work in a construction area where the assigned personnel are regularly required to wear hard hats. Do NOT get caught-flat-footed in any situation. To avoid this, you should study the situation in advance—considering both the physical and environmental conditions.

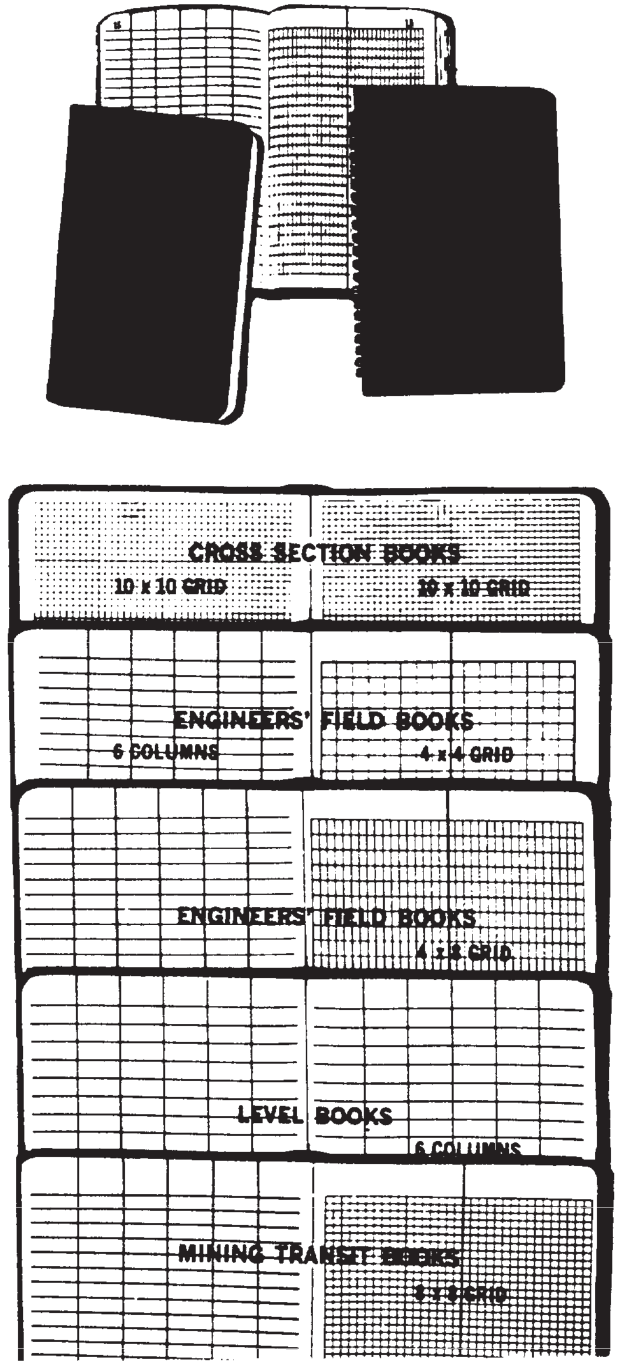


Figure 11-58.-Diffferent types of field books.

CHAPTER 12

DIRECT LINEAR MEASUREMENTS AND FIELD SURVEY SAFETY

This chapter covers the various duties, the techniques, and the skills a chaining crew member must learn thoroughly concerning chaining operations and some of the devices used in chaining itself. DIRECT LINEAR MEASUREMENTS, as used in this chapter, are methods used for measuring horizontal distances with a tape (or chain) and/or with electronic distance-measuring instruments presently available in the military.

As a crew member, you should be concerned not only about the task at hand but also about the potential hazards to which you may be exposed in the field. It is important, therefore, that you recognize the precautions and safety measures applicable to the survey field crew. In this chapter we shall discuss these precautions and safety measures and also additional duties normally performed by the crew.

DUTIES OF A CHAINING CREW MEMBER

During a typical chaining operation, it is possible that many and varied duties other than the actual chaining itself are to be undertaken as part of the whole process. To prepare the field chaining party for the task ahead, we shall present some of these duties, as applicable. In some cases, these duties can be modified or tailored, contingent upon the mission, terrain features, and other conditions that may affect the speed and accuracy of the operation.

GIVING HAND AND VOICE SIGNALS

During fieldwork, it is essential that you communicate with the other members of the survey party over considerable distances. Sometimes you may be close enough to use voice communication; more often, you will use hand signals. Avoid shouting; it is the sign of a beginner. Standard voice signals between chainmen must be used at all times to avoid misunderstanding. There are also several recommended hand signals, most of which are shown in figure 12-1. Those shown are recommended, but any set of signals mutually agreed upon and understood by all members of the party can also be used. It is important to face the person being signaled. Sometimes, if it is difficult for you to see the other person, it helps to hold white flagging in your hand when giving signals. When signals are given over snow-covered areas, red or orange flagging is more appropriate.

Explanations of the hand signals shown in figure 12-1 are as follows:

1. ALL RIGHT. The “all right” is given by the instrumentman when the alignment is OK for a plumb line, a range pole, a stake, a hub, or any other device used as a target, or when the instrumentman has finished all activities at your location.

   It is given by waving both arms up and down while extending them out horizontally from the shoulders. If the instrumentman, in aligning a target, extends both arms out horizontally from the shoulders without waving them, the signal means that the target should be held steady while a quick check of its position is being made.

2. MOVE RIGHT OR LEFT. This signal is given by the instrumentman when lining in a target on a predetermined line. It is given by moving the appropriate hand outward from the shoulder. A slow motion of the hand means that you must move a long distance; a quick, short motion means that you must move a short distance.

3. GIVE ME A BACKSIGHT. This signal is given when the instrumentman wants a target held at a previously located point. It is given by extending one arm upward with the palm of the hand forward.

4. GIVE ME A LINE OR THIS ISA HUB. This signal, given by the rodman or the chainman, is intended to indicate a hub or to ask for a line on the point indicating the exact location.

   It is given by holding a range pole horizontally overhead, then moving it to a vertical

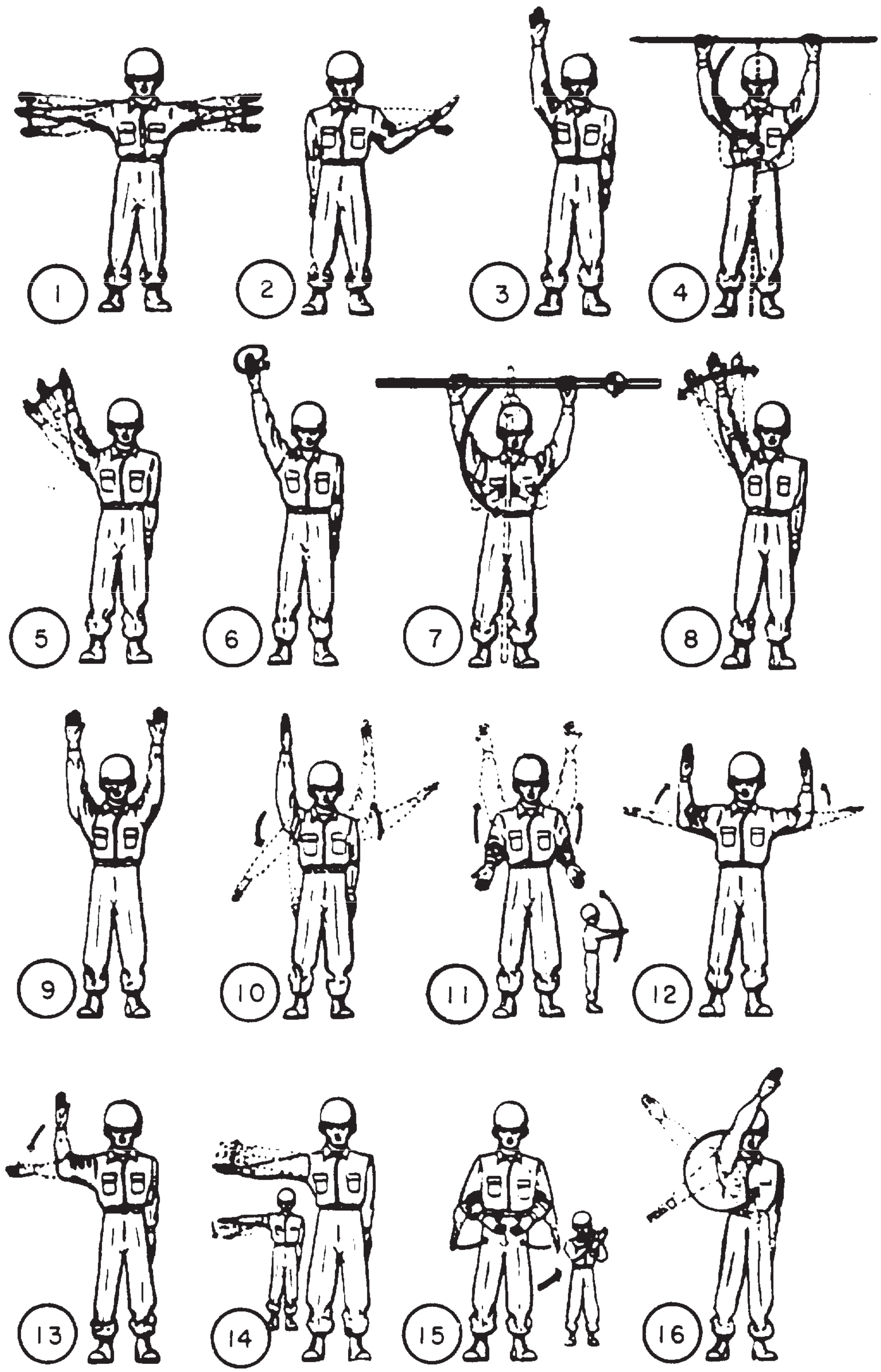


Figure 12-1.-Surveyor's hand signals.

position in front of the body. Sometimes the range pole tip is set on the ground to serve as a pivot. Then the pole may be swayed slowly to the left and/or right until the instrumentman picks up the signal.

5. PLUMB THE ROD. The signal to plumb the rod to the desired direction (right or left) is given by extending the appropriate arm upward and moving the hand in the direction the top of the rod must be moved to make it vertical.

6. ESTABLISH A TURNING POINT. This signal is given when the instrumentman wants a turning point established during traversing or leveling operations. It is given by extending either arm upward and making a circular motion.

7. THIS IS A TURNING POINT. The rodman gives this signal to indicate a turning point. This is done using a leveling rod and applying the method described in 4.

8. WAVE THE ROD. This signal, given by the instrumentman to the rodman, is important to get the lowest stadia reading. The instrumentman extends one arm upward, palm of the hand forward, and waves the arm slowly from side to side. The rodman then moves the top of the leveling rod forward and backward slowly about a foot each way from the vertical.

9. FACE THE ROD. To give this signal, the instrumentman extends both arms upward to indicate to the rodman that the leveling rod is facing in the wrong direction.

10. REVERSE THE ROD. The instrumentman gives this signal by holding one arm upward and the other downward, and then reversing their positions with full sidearm swings.

11. BOOST THE ROD. The instrumentman gives this signal by swinging both arms forward and upward, palms of the hands upward. This signal is used when the instrumentman wants the leveling rod raised and held with its bottom end at a specified distance, usually about 3 ft, above the ground.

12. MOVE FORWARD. The instrumentman gives this signal by extending both arms out horizontally from the shoulders, palms up, then swinging the forearms upward.

13. MOVE BACK. The instrumentman gives this signal by extending one arm out horizontally from the shoulder, hand and forearm extended vertically, and moving the hand and forearm outward until the whole arm is extended horizontally.

14. UP OR DOWN. The instrumentman gives this signal by extending one arm out horizontally from the shoulder and moving it upward or downward. This directs the rodman to slide the target up or down on the rod.

15. PICK UP THE INSTRUMENT. The party chief gives this signal by imitating the motions of picking up an instrument and putting in on the shoulder. The party chief or other responsible member of the party gives this signal, directing the instrumentman to move forward to the point that has just been established.

16. COME IN. The chief of party gives this signal at the end of the day's work and at other times, as necessary.

Two additional hand signals are shown in figure 12-2. Their meanings are given in the next two paragraphs.

RAISE FOR RED. The instrumentman gives this signal in a leveling operation to ascertain the immediate whole-foot mark after reading the tenths and hundredths of a foot. This usually happens when the rodman is near the instrument or if something is in the way and obscures the whole-foot mark.

EXTEND THE ROD. The instrumentman gives this signal when there is a need to extend an adjustable rod. This happens when the height of the instrument becomes greater than the standard length of the unextended adjustable level rod.

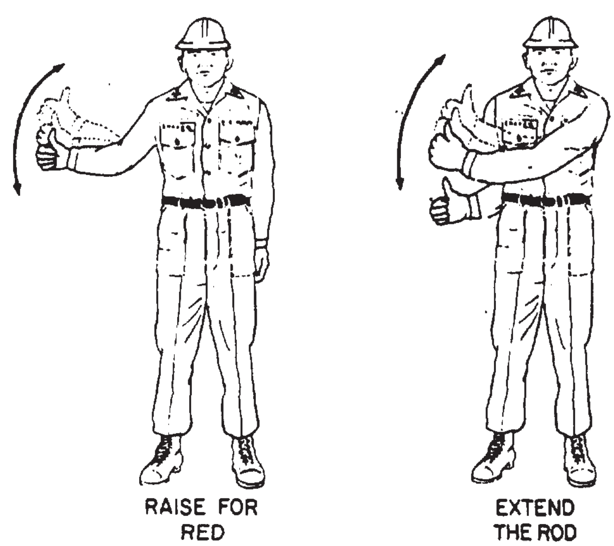


Figure 12-2.-Additional hand signals.

SIGNALS FOR NUMERALS. Figure 12-3 shows a simple system for numerals.

ONE—Right arm extended diagonally down to the right from the body

TWO—Right arm extended straight out from the body

THREE—Right arm extended diagonally up and out from the right shoulder

FOUR—Left arm extended diagonally up and out from the left shoulder

FIVE—Left arm extended straight out from the body

SIX—Left arm extended diagonally down to the left from the body

SEVEN—Both arms extended diagonally down and out from the body

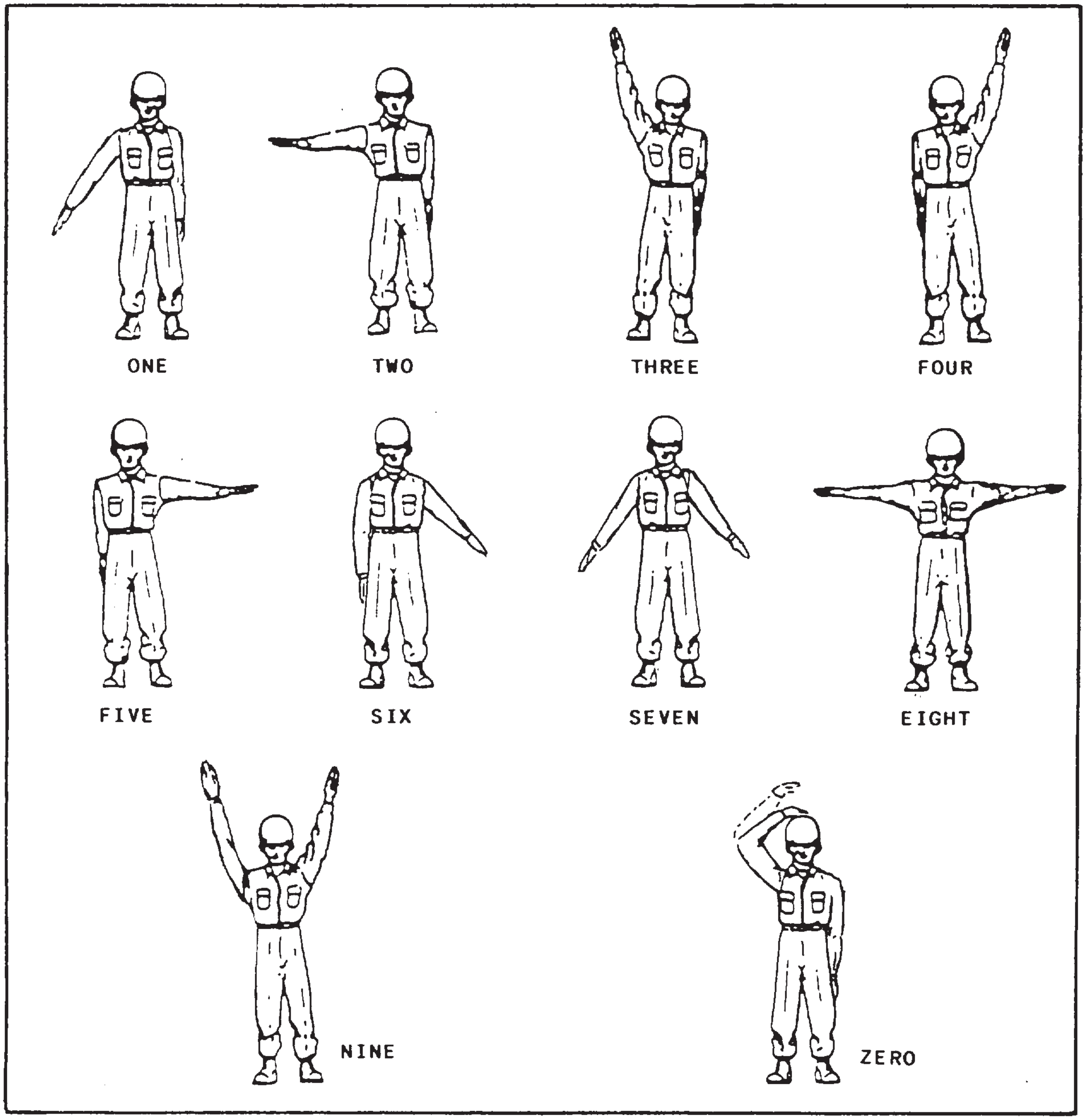


Figure 12-3.-Hand signals for numerals.

EIGHT—Both arms extended straight out from the body

NINE—Both arms extended diagonally up and out from the body

ZERO—Hitting the top of the head with an up-and-down motion of the palm

A decimal point should be indicated by using a signal that maybe easily distinguished from the other signals.

Make sure to orient yourself properly when receiving signals for Number 1 through Number 6; your left is the right of the signalman. The other numerals can be read without thinking of right or left. Use numeral signals only when necessary. Mistakes can easily result from misinterpreted signals.

It is important to remember that, if hand signals are used, they should be used consistently. It is important that every member of the survey party be completely familiar with them.

CLEARING THE LINE

A line must be cleared ahead when a crew is chaining (or taping) across brush-covered country. Specific tools, such as those presented in chapter 11, for the kind of job assigned must be used and handled with care. Before you start to swing, make sure that no one is within range.

You may cut ordinary scrub growth in unsettled areas more or less as needed. If, however, you encounter large trees or shrubs that may be of value, you should consult your party chief for advice. Even though a tree or shrub lies directly on the chaining line, it is never absolutely necessary that it be cut down. If it is desirable that it be preserved, you can always triangulate around it or bypass it by some other method, as described in a later chapter.

The principle technical problem in clearing the line is keeping on the line. When possible, this is accomplished by the use of natural foresights; that is, by the use of bearings taken on natural objects (or, perhaps, on artificial objects) lying ahead.

Suppose there is no distinctive object lying on the line of bearing ahead. In this case, you may be able to keep on the line by BLAZING ahead. To do this, you set up the compass and sight ahead on a tree lying as far ahead as possible. You then mark this tree by blazing. (A blaze is a scar notched on a tree with a hatchet or machete.) You could also use red or white flagging as markers. You then clear a line toward the tree.

Suppose the growth is too high and thick for you to sight ahead. In this case, you'll have to work ahead by looking back and aligning yourself on a couple of markers on the line already covered.

GIVING BACKSIGHTS AND FORESIGHTS

To run a line by instrument from a point of known location A to point B, for example, and given a distance and direction ahead, the instrumentman usually proceeds in the following manner:

1. Sets up the instrument (usually a transit) over point A.

2. Trains the telescope on the given direction of the line to B.

3. Sights through the telescope to keep the chainmen on line for as many consecutive foresights as can be observed from that particular instrument setup.

Suppose, for example, that the chainmen are using a 100-ft tape. After the instrument has been trained along the line of direction, the head chainman walks away with the zero-foot end of the tape, while the rear chainman holds the 100-ft end on the point plumbed by the instrument. After the head chainman has walked out the whole 100 ft, a plumb bob is dropped on a cord from the zero-foot mark to the ground.

The instrumentman sights along the line and thus determines the direction in which the head chainman must move to bring the plumb bob on to the line. The "move right" or "move left" signal is given, if needed. When the head chainman has been brought by signal to the vicinity of the line, the instrumentman signals for the final placement of the plumb bob by calling out, "To you!" (meaning "Move the plumb bob toward yourself!") or "Away!" (meaning "Move the plumb bob away from yourself!"). When the plumb bob is exactly on the line, the instrument man calls out, "Good!" or "All right!" The head chainman then marks the point indicated by the plumb bob in the correct manner. The first 100 ft have now been measured on the given line of direction.

If the distance to be measured is long, the chainmen will eventually proceed beyond the scope of the instrument as it is then set up. The instrument must then be shifted ahead to the last point marked by the head chainman. When the instrument has been set up over this point, the telescope must be reoriented to the line of direction. To do this, the instrumentman usually plunges the telescope (rotates it vertically) and backlights on a point on the line already laid off. In taking backlights, the instrumentman is guided by the rear chainman who holds on, or plumbs over, the point. When the telescope has been trained on the backsight point, it is again plunged. The telescope is now again trained in the desired direction.

Holding on a Point

If the point on the ground can be sighted through the telescope, the chainman may simply hold on the point; that is, hold a pencil point, chaining pin point, plumb bob point, or some other appropriate indicator on the point (fig. 12-4). Whatever the indicator may be, it is essential that it be held in an exactly vertical position. For short sights, it is also essential that the shaft of the indicator be relatively slender so that the vertical cross hair can be aligned with sufficient exactness.

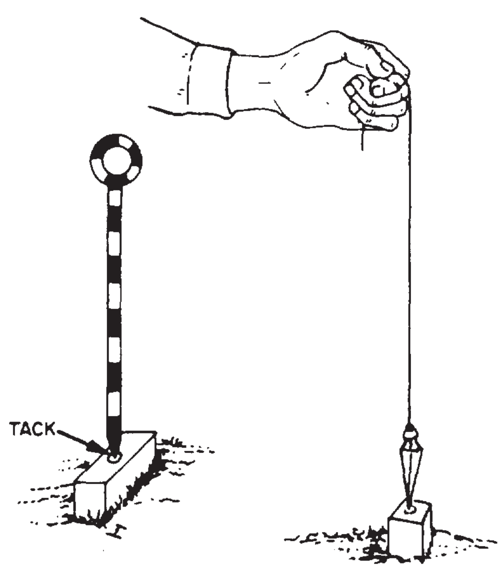


Figure 12-4.-Indicators used for short sights.

Plumbing over a Point

If intervening low growth or some other circumstance makes it impossible for the instrumentman to sight the point on the ground, the chainman must plumb over the point, using the plumb bob and cord. If the distance is too far for observation of the plumb bob cord, the cord should be equipped with a plumb bob target, or a range pole may be used. In the absence of a target when using the plumb bob, you may tie a piece of colored flagging to the cord, or you may use a handkerchief, as shown in figure 12-5.

Some chainmen prefer to hold the plumb bob and cord with the cord running over the forefinger. Others prefer to have the cord running over the thumb. If you are plumbing high (that is, required to hold the cord at chest level or

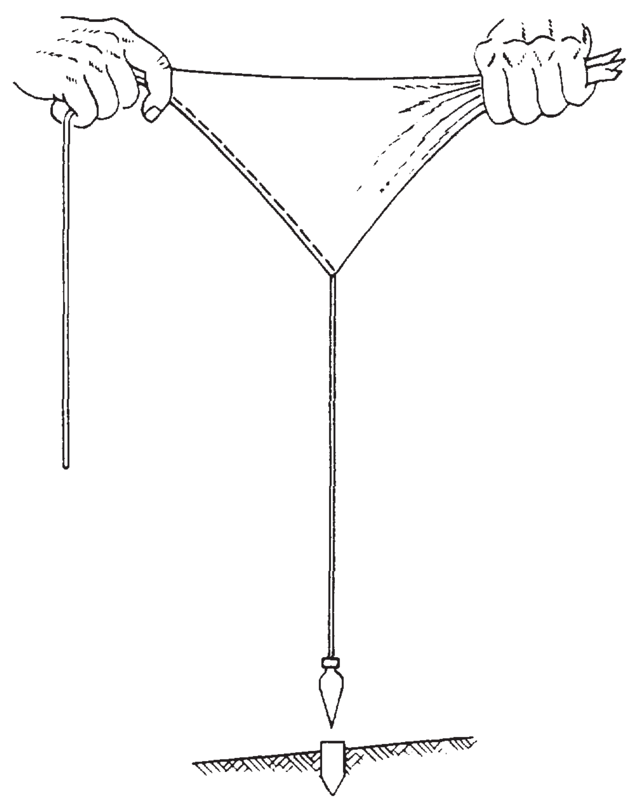


Figure 12-5.-Using a handkerchief as a substitute for a target on a plumb bob cord.

above), you need to learn to brace your holding arm with your other arm, and against your body or head or both, to avoid unsteadiness and fatigue. When there is a wind, you may find it difficult to hold the plumb bob suspended over a point. The plumb bob will tend to swing back and forth. You can overcome this problem by bouncing the point of the plumb bob slightly up and down on the point.

For a long sight, it is much better to plumb over a point with a range pole. For a short sight, however, the shaft of a range pole is too thick to permit exact alignment of the vertical cross hair.

For long sights, or for sights on a point that is to be sighted repeatedly, it is often desirable to construct a semipermanent target. There are no definite rules that can be stated for constructing targets because they usually must be built from materials at hand. Use your ingenuity; but make the target high enough to be seen, strong enough to withstand prevailing winds, and plumb over a point. Several types of semipermanent targets are shown in figure 12-6.

MARKING CONTROL POINTS, REFERENCE POINTS, AND MONUMENTS

In general, control surveys deal with established points. To define these points, surveyors have to mark them. Certain points are made permanent; on the other hand, others are temporary. A line that will be used for a long period of time, for example, may be marked at each end with a bronze disk set in concrete, or with a center-punched metal rod driven flush with the ground. For less permanent control points, wooden stakes or hubs with nails, shiners, and flaggings can be used.

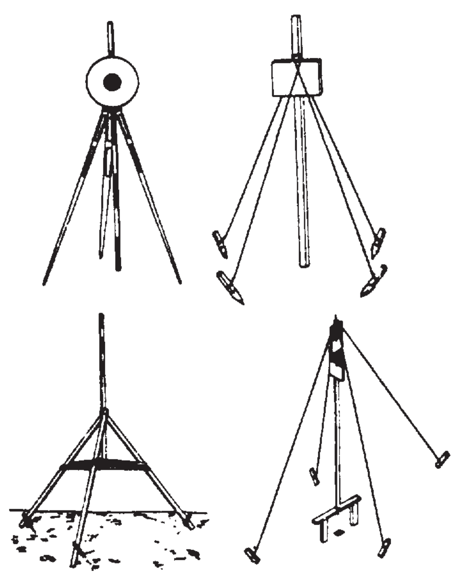


Figure 12-6.-Field-constructed semipermanent targets.

Placing Driven Markers

A DRIVEN MARKER must be set exactly vertically on the point it is supposed to mark. If it is driven on a slant, the top of the marker will not define the correct location of the point. To drive the marker vertically, first align it vertically; then, using a sledgehammer or other type of driving implement, strike each blow squarely on the flat end of the hub or stake.

A wooden hub is normally driven to mark the exact horizontal location of a point, usually for the purpose of plumbing an instrument over the point. Consequently, it is not normally necessary for the top of a hub (or other markers used for the same purpose) to extend much above the ground line. The precise location of the point is marked by a hub tack, punch mark, or other precise marker driven or set in the top of the hub. For work on asphalt roads or runways, you'll find it easier to use flagging or a soda pop top and a nail as a marker; in concrete and other hard surfaces, you can use orange paint or a star-drilled hole plugged with lead. The choice of markers to be used depends on the surveyor's judgment as well as the purpose of the survey.

In frozen or otherwise extra hard ground, use a bull-point to start a hole for a stake or hub. Remember that the stake or hub will follow the line of the opening made by the bull-point. Therefore, if the bull-point is not driven vertically, the stake or hub will not be vertical either.

Placing Monuments

In surveying, a MONUMENT is a permanent object or structure used where a point or station must be retained indefinitely for future reference. It may simply consist of a conspicuous point carved on an outcrop of a ledge rock or otherwise constructed in concrete. Figure 12-7 shows common types of concrete monuments. The top of the monument should have an area large enough to include the required point and any necessary reference data. The depth of the monument should be sufficient to extend below the frost line. If the depth of the frost line is unknown, a minimum depth of 3 ft is generally accepted. Other factors, such as soil condition and stability of foundation, may also affect the depth of the monuments. The area should be checked out for soil stability to provide an adequate foundation. A monument settles in the same manner as any other structure if an adequate foundation is not provided.

The exact location of the point on a monument may be marked by chiseling an X on the surface or by drilling a hole with a star drill and hammering in a lead filler or grouting in a length of brass stock (often called a COPPER). When grouting a copper, you should use neat cement grout because a fluid grout would flow into and fill the small space around the copper. If the point can be placed at the same time as the monument is being cast in place, the copper can be pushed down into the surface of the monument before the concrete begins to harden. If you are near an armory, you may be able to obtain large, expended brass shell casings. The primer end of a shell casing makes an excellent survey point marker when it is embedded in a concrete monument.

With a little imagination and ingenuity, you can easily design and construct adequate survey monuments when they are required.

Identifying Points

A point is marked with the information required to identify the point and with any other relevant data. Temporary identification marks can be made with keel. More permanent marks can be made with paint. An even more permanent mark consists of a metal plate set in concrete.

A. point that indicates a traverse station is marked with the symbol or number of the station, such as STA. B or STA. 21. A point on a stationed traverse is marked with the particular station, such as 2 + 87.08. Frequently, a point will serve as a traverse station and a bench mark. A bench mark is marked with an identifying symbol and usually with the elevation. In marking such an elevation, do not use a decimal point, as in 317.22 ft. Instead, raise the figures that indicate the fractional part and underline them; for example, $317^{\underline{22}}$ ft.

Referencing Points

All control points should be tied in or referenced. The ties or reference points are

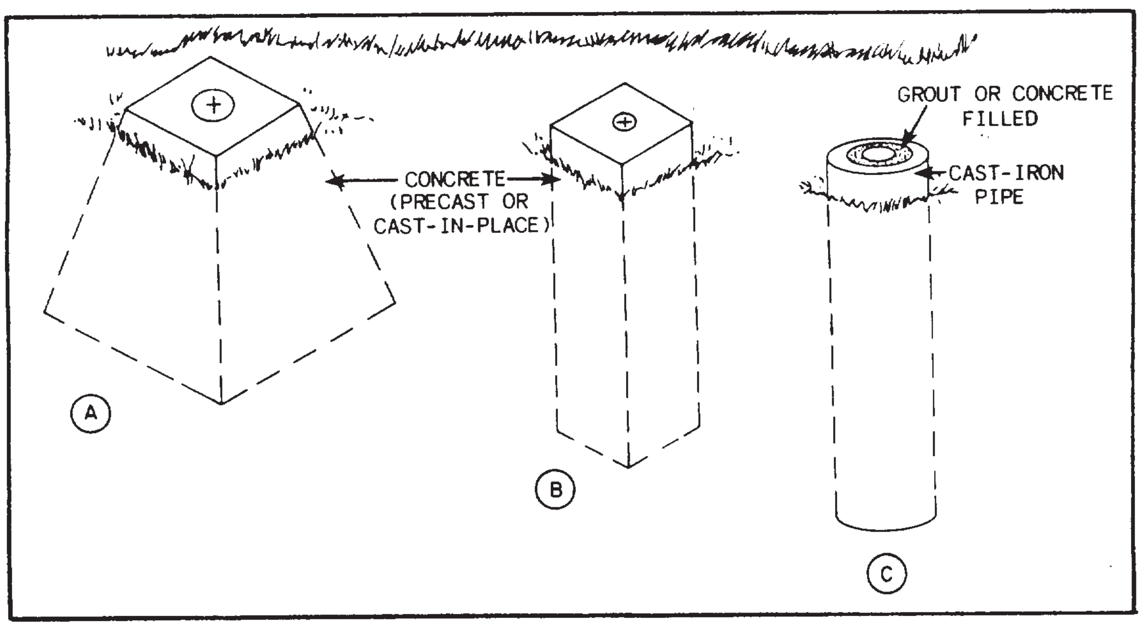


Figure 12-7.-Common types of survey monuments.

recorded in the field book as they are established in the field. The record may be done either by sketch, by work description, or by the combination of the sketch and notes. The control point must be referenced to some permanent type of object in its vicinity; if no such objects exist, REFERENCE HUBS are driven at points where they are unlikely to be disturbed. These ties are important in recovering control points that have been covered or otherwise hidden or in reestablishing them accurately if they have been removed.

The reference location of a particular point is recorded on the remarks page of the field book by sketches like those shown in figures 12-8 and 12-9. For a permanent control point, such as a triangulation point, monument, or bench mark, a complete "Station Description" is individually prepared for each station. The field offices of the National Oceanic and Atmospheric Administration or the National Geological Survey have these station descriptions on separate cards. This is done so they can easily run a copy for anyone requesting a description of a particular station. They also maintain a vicinity map on which these

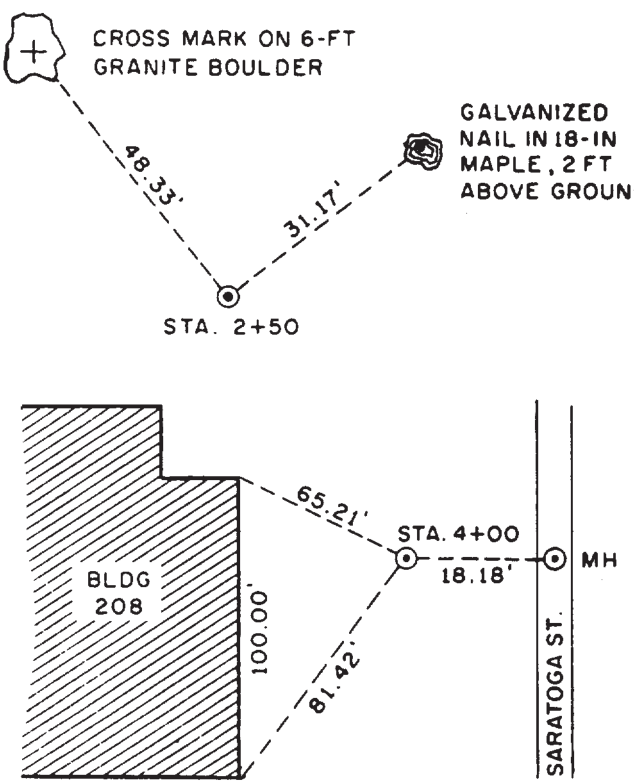


Figure 12-8.-Natural objects or man-made structures used as reference points.

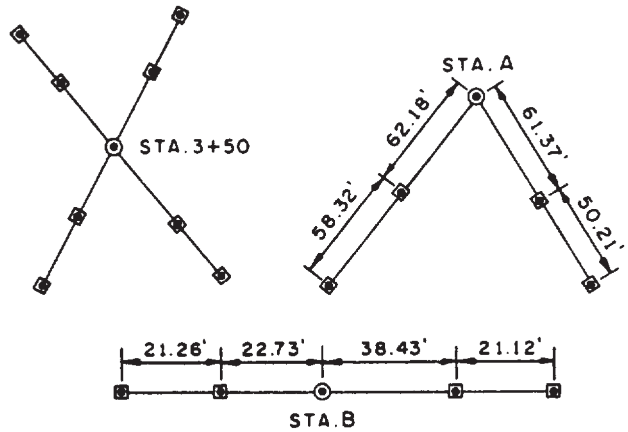


Figure 12-9.-Accurate methods for tying points.

points are plotted, and these station descriptions are used in conjunction with this map. The Navy's public works offices also maintain descriptions of stations within their naval reservation and its vicinity for immediate reference.

The methods of referencing points shown in figure 12-8 are ideal for recovering points that have been covered or otherwise hidden, and those shown in figure 12-9 are for reestablishment of these points accurately. The methods shown in figure 12-9 are generally used in construction surveys.

As you gain more experience, you may be assigned the task of writing a station description. In doing this, be sure to describe the location in detail, and make a sketch showing the location, ties, and magnetic or true meridian. Make your description concise and clear; and be sure to test its effectiveness by letting another EA (preferably not a member of the survey party that established the point) interpret your description. From the feedback of the interpretation, you can determine the accuracy of your written description. Your description, for example, should be written as follows (refer to figure 12-8): "Point A—plugged G.I. pipe 65.21 ft SE of NE corner of PWC Admin. Bldg. (Bldg. 208) and 81.42 ft from the SE corner of same building. It is 18.18 ft W of the center of a circular manhole cover located in Saratoga Street."

Protecting Markers

Markers are to be protected against physical disturbance by the erection of a temporary fence (or barricade) around them. Sometimes guard stakes embellished with colored flaggings are simply driven near the hub or similar marker to serve as deterrence against machinery or heavy equipment traffic. On the other hand, permanent markers are protected by fixed barricades, such as steel or concrete casing.

METHODS OF DIRECT LINEAR MEASUREMENTS

One of the most fundamental surveying operations is the measurement of horizontal distance between two points on the surface of the earth. Generally, there are two basic methods used: direct and indirect. Direct linear measurements, as explained earlier in this chapter, are methods used for determining horizontal distances with a tape (or chain) and/or with an electronic distance-measuring instrument. In indirect methods, the transit and stadia or theodolite and stadia are used. This section will discuss the common methods used in direct linear measurements.

CHAINING (OR TAPING)

The most common method used in determining or laying off linear measurements for construction surveys, triangulation base lines, and traverse distances is often referred to as CHAINING. The name is carried over from the early days when the Gunter's chain and the engineer's chain were in use. Today, it is more appropriate to call this operation TAPING because the steel tape has replaced the chain as the surveyor's measuring device. In this manual, however, chaining and taping are used interchangeably.

Identifying Duties of Chaining Party Members

Obviously, the smallest chaining party could consist of only two people—one at each end of the tape. To lay off a line to a desired distance, one person holds the zero end of the tape and advances in the direction of the distant point, while the other holds a whole number of the tape at the starting point. The person ahead, holding the zero end, is called the HEAD CHAINMAN; the other person is known as the REAR CHAINMAN.

In ordinary chaining operations, if the distance being measured is greater than a tape length, it is necessary to mark the terminal point with a range pole. In this way, the rear chainman can keep the head chainman aligned at all times whenever a full tape length or a portion of it is transferred to the ground.

The head chainman also acts as the recorder, and the rear chainman is responsible for keeping the tape in alignment. If more speed or precision in taping is required, additional personnel are assigned to the party. This relieves the chainmen of some of their duties and permits them to concentrate primarily on the measurement.

For more precise chaining, a three-man party is essential. In addition to the head and rear chainmen, a stretcherman is added. The duties of the stretcherman are to apply and to maintain the correct tension on the tape while the chainmen do the measuring. The head chainman still acts as the recorder and also reads and records the temperature of the tape.

Either of the two chaining parties described may have additional personnel assigned as follows:

- A recorder keeps a complete record of all measurements made by the taping party, makes any sketches necessary, writes descriptions of stations and reference points, and records any other data required. The head chainman or the chief of the chaining party may perform these duties.

- A rodman sets a range pole at the forward station to define the line to be taped, drives stakes to mark stations and reference points, carries the taping stool (discussed later) to the forward point, and performs other duties as directed.

- One or more axmen clear lines of sight between stations, cut and drive stakes, and perform other duties as directed.

- The chief of the chaining party directs the work of making the tape measurements, the establishment of stations, and other activities of the party in the field. The head chainman performs these duties when there is no separate party chief.

Coiling and Throwing a Steel Tape

Tapes generally come equipped with a reel; however, it is not always necessary to replace a steel tape on the reel at the end of each work period. A tape can be easily coiled and thrown into a circular roll.

Grasp the 100-ft graduation on the tape faceup with your left hand. Using your right hand, you take in 5 ft of tape at a time. Place the 95-ft mark over the 100-ft mark, next the 90-ft mark over the 95-ft mark—holding these 5-ft marks firmly with the left hand so that the tape will not turn over. Continue this operation for the entire length of the tape, placing each 5-ft division over the preceding one until the zero graduation is reached, (Actually, you can start at either end of the tape, whichever is convenient.) As you are taking in the tape, you will notice that the coils fall into the shape of the figure "8." (See fig. 12-10.)

When you have completed this coiling, square up the tape ribbons. The leather thong at the 100-ft end should be on the underneath side of the coil next to your hand. Wrap the thong around the complete coil. Continue wrapping until there is just enough of the thong left to conveniently insert it through the coil at about the 50-ft graduation. Draw the thong firmly back against the completed windings of the thong.

You can throw the tape into a more compact circular roll by giving the "8" a twist, as shown in figure 12-11. Now, tie the tape with the remaining thong.

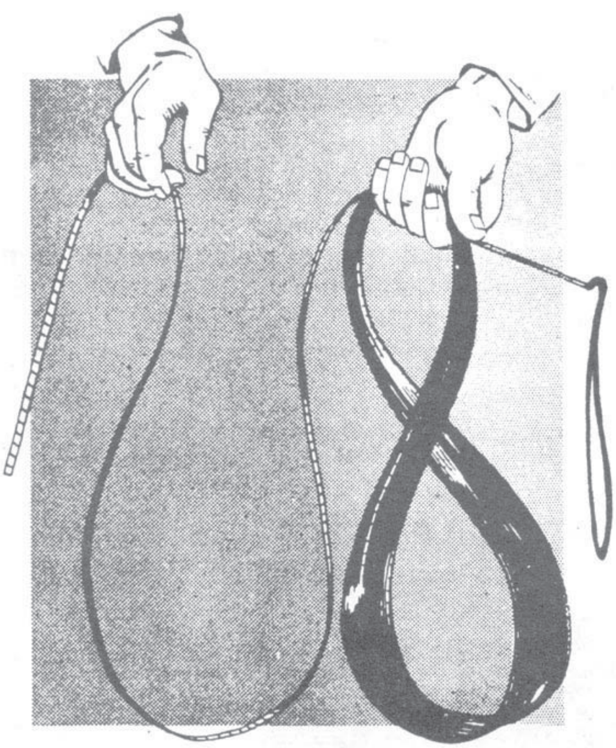


Figure 12-10.-Coiling a tape into a figure "8" form.

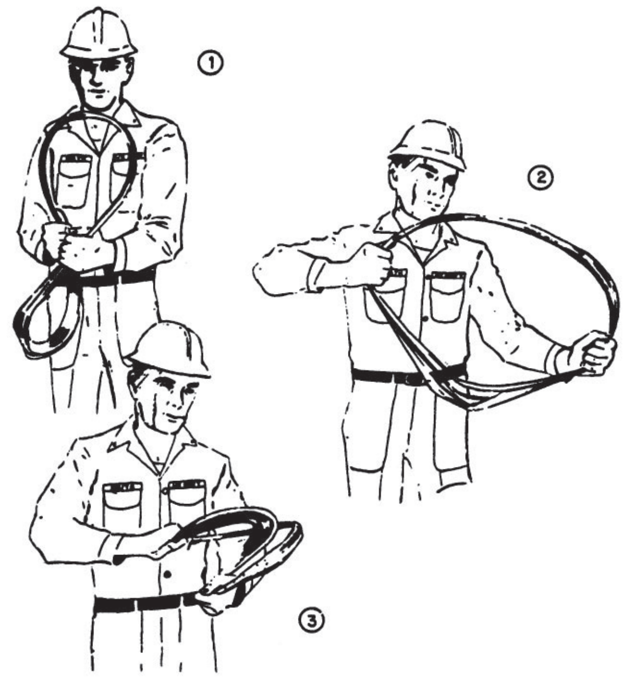


Figure 12-11.-Throwing the tape into a circular roll.

When you wish to use the tape again, reverse the process. Be sure you let the tape out from the zero end in the same way that it was wound. Walk away from the end of the tape as you unwind it to prevent kinks.

Chaining on Level Ground

When taping distances on a relatively level surface and of the third or lower order accuracy, you may lay the tape on smooth ground or on a paved road or support its ends by taping stools or stakes. In horizontal chaining, the tape is held horizontally, and the positions of the pertinent graduations are projected to the ground by a plumb bob and cord. For ordinary chaining on level ground, the following procedures are generally used:

1. A range pole is set on line slightly behind the point toward which the taping will proceed. The rear chainman, with one chaining pin, stations himself at the starting point of the line to be measured.

2. The head chainman, holding the zero end of the tape and with 10 pins in his hand, then moves forward toward the distant point while guiding himself with the range pole. Assuming that the tape was already off the reel when they

started, the rear chainman watches the tai1 end (100-ft mark) of the tape as the head chainman moves forward.

3. When the rear chainman sees that the tail end is about to reach his position, he calls "Chain!" At that time, the head chainman stops and looks back. The rear chainman holds the 100-ft mark at the starting point and checks the alignment; then signals the way the head chainman should move the chaining pin to be in line. While doing this, they are both in a kneeling position, the rear chainman facing the distant point, and the head chainman to one side facing the line so that the rear chainman has a clear view of the range pole. The head chainman, while stretching the tape with one hand, sets the pin vertically on line a short distance past the zero mark with the other hand. Then by pulling the tape taut and making sure that the tape is straight, the head chainman brings it in contact with the pin, The rear chainman, watching carefully for the 100-ft mark to be exactly on the point, calls "All right!" The head chainman relocates the pin to exactly the zero mark of the tape and places it sloping away from the line. He then pulls on the tape again to make sure that the zero mark really matches the point where the pin is stuck in the ground. Then, he calls "All right!" or "Stuck!" This is a signal to the rear chainman to release the tape so he can continue forward for the next measurement. The process is repeated until the entire distance is measured.

4. As the rear chainman moves forward, he pulls the pin from his point. Thus, there is always one pin stuck in the ground; therefore, the number of pins in his possession at any time indicates the number of 100-ft (stations) tape lengths they have measured from the starting point to the pin in the ground.

Every time the head chainman runs out of pins, he signals the rear chainman to come forward, and both of them count the pins in the rear chainman's possession. There should be 10 pins.

SUPPORTING THE TAPE.— When a full tape length is being measured, the two chainmen support the ends of the tape. The tape maybe laid on a level ground surface, such as a paved road or railroad rail, or suspended between stools or bucks set under the ends of the tape. For precise measurement, such as base line measurement, the tape is supported at midpoint or even at quarter points by bucks or stakes.

In horizontal taping over sloping or irregular terrain, one end of the tape is held on the point at ground level, while the other end is supported high enough to make the tape horizontal. As shown in figure 12-12, the rear chainman is holding a full graduation of the tape at the point near the ground, and the head chainman, holding the zero end, projects the desired distance to the point on the ground by using the plumb bob.

ALIGNING THE TAPE.— Any misalignment of the tape, either horizontally or vertically, will result in an error in the measurement. Misalignment always results in a recorded distance that is too great, or a laid offline that is too short. This is obvious, since the shortest distance between two points is a straight line. Keep the tape straight and level at all times.

APPLYING TENSION.— A tape supported or held only at the ends will hang in the shape of a curve, called a catenary, because of its own weight. Depending on the tension or pull applied at the ends, this catenary will become shallower or deeper; and the distance between the supported ends will vary considerably. To standardize this distance, you should apply a recommended "standard" tension when you are measuring. You should attach a spring balance or tension handle to one end of the tape and measure the correct standard tension. The amount of standard tension is discussed later under "Making Tape Corrections."

Maintaining a constant tension for any length of time by a hand pull is uncomfortable and can be erratic. For easier chaining, each chainman uses a pole or rod about 1/2 to 2 in. in diameter and about 6 ft long. The leather thong attached to the tension handle is wrapped around the pole at the proper height. The chainman braces the bottom end of the pole against the outside of his foot and applies tension by bracing his shoulder against the

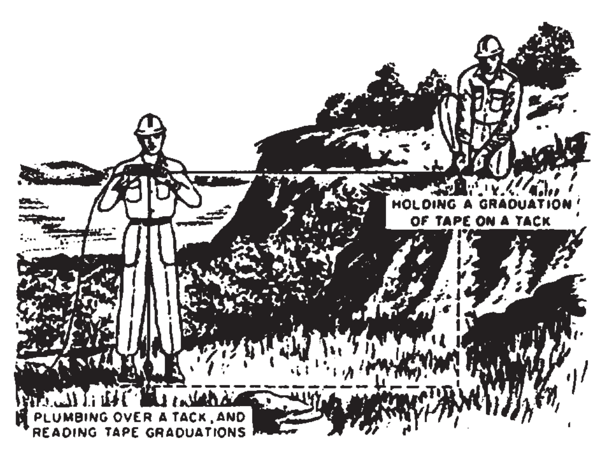


Figure 12-12.-Horizontal taping on a slope.

pole and shifting his body weight until the correct tension is read on the scale. This position can be held steadily and comfortably for a comparatively long time.

Measuring distances less than a full tape length requires the use of the clamp handle (or “scissors clamp”), which is attached to the tape at some convenient point along its length. The handle permits a firm hold on the tape and furnishes a convenient attachment for a spring balance. When properly used, the handle will prevent kinking of the tape.

READING THE TAPE.— A chain tape may be either a PLUS (or ADD) tape or a MINUS (or SUBTRACT) tape. On a plus tape, the end foot, graduated in subdivisions, is an extra foot, lying outside the 0-ft mark on the tape and graduated AWAY FROM the 0-ft mark. On a minus tape, the end foot, graduated in subdivisions, is the foot lying between the 0-ft mark and 1-ft mark and graduated AWAY FROM the 0-ft mark and TOWARD the 1-ft mark. As will be seen, this difference is significant when a distance of less than a full tape length is being measured.

Suppose that you are measuring the distance between point A and point B with a 100-ft tape, and the distance is less than 100 ft. Suppose that you are the head chainman. To start off, you and the rear chainman are both at point A. You walk away from point A with the zero-foot end of the tape. Because this is a plus tape, the tape has an extra foot beyond the zero-foot end, and this foot is subdivided in hundredths of a foot, reading from the zero.

You set the zero on point B, or plumb it over point B; then call out, “Take a foot!” When the rear chainman hears this, he pulls back the first even-foot graduation between A and B to point A, or plumbs it over point A. Let’s say this is the 34-ft graduation, The rear chainman calls out, “Thirty-four!”

You now read the subdivided end-foot graduation that is on or over point B. Let’s say it is the 0.82-ft graduation. You call out, “Point eight two!“ The rear chainman rechecks the even-foot graduation on point A and calls out, “Thirty-four point eight two!” As you can see, your subdivided-foot reading is added to his even-foot reading; hence, the expression “plus” tape.

Suppose now that you are measuring the same distance between the same points, but using a “minus” tape; that is, a tape on which the subdivided end-foot lies between the zero-foot and 1-ft graduations. This time when you walk away with the zero-foot end, you set the 1-ft graduation on point B and call out, “Take a foot!” When he hears this, the rear chainman again hauls back the first even-foot graduation between A and B to point A—but this time this will be the 35-ft graduation. So the rear chainman sings out, “Thirty-five!” When you hear this, you read the subdivided-foot graduation on point B. This time this will be 0.18-ft graduation, so you call out, “Minus point one eight!” The rear chainman mentally subtracts 0.18-ft from 35.00 ft and calls out, “Thirty-four point eight two!” When you are also acting as the recorder, recheck the subtraction before you record the distance in the field notebook.

GIVING A LINE.— The range pole is set on line slightly behind the point toward which the taping will proceed. Line may be given (that is, the person with the range pole may be guided or signaled onto the line) by “eyeball” (that is, by eye-observation alignment by the rear chainman or someone else at the point from which chaining is proceeding) or by instrument.

Slope Chaining

The methods used in slope chaining are basically the same as in chaining on level ground. There are some differences, however, as follows: In slope chaining, the tape is held along the slope of the ground, the slope distance is measured, and the slope distance is converted, by computation, to horizontal distance. The slope angle is usually measured with an Abney hand level and clinometer; however, for precise measurement, it is measured with a transit.

In using the clinometer, you take the slope angle along a line parallel to the slope of the ground or along the tape that is held taut and parallel to the slope of the ground. To use the clinometer, you sight on an object that is usually a point on a pole approximately equal to your height of instrument (HI); that is, the vertical distance from the ground to the center (horizontal axis) of the sight tube. While sighting the object, you rotate the level tube about the axis of vertical arc until the cross hairs bisect the bubble as you look through the eyepiece. Then, you read either the slope angle or percentage on the vertical arc and record it along with the slope distance measurement. The horizontal distance is computed, or in other words, the tape correction is applied.

If the station points are being marked, the corrections to the slope distances are applied as the chaining progresses. These correct ions are computed either mentally, by calculator, or by using a table.

If the ground slope is fairly uniform, and if the tape corrections do not exceed 1 ft, a plus 100-ft tape is very useful to establish these station points. The head chainman determines the slope correction first, then lays off the true slope distance that gives a horizontal distance of 100 ft. If the slope is less than 2 percent, no slope correction is required. Slope corrections will be discussed later in this chapter.

Horizontal Chaining

In horizontal chaining, the tape is supported only at its ends and held in a horizontal position. Plumb bobs are used to project the end graduations of the tape (or, for a less-than-tape-length measurement, an end and an intermediate graduation) to the ground. Be very careful when you use the plumb bob both in exerting a steady pull on the tape and in determining when the tape is horizontal.

PLUMBING.— Plumbing is complete when the tape is in horizontal alignment and under the proper tension.

The rear chainman holds a plumb bob cord at the proper graduation of the tape, and the point of the plumb bob about one-eighth of an inch above the marker from which the measurement is being made. When the plumb bob is directly over the marker, he calls, "Mark!"

The head chainman holds a plumb bob cord at the correct graduation of the tape with the point of the plumb bob about 1 in. above the ground. He allows his plumb bob to come to rest; sees that the tape is horizontal; checks its alignment and tension; and when the rear chainman calls, "Mark!" allows the plumb bob to fall and stick in the ground. This spot is then marked with a chaining pin.

At times, in rough country, a small area around the point may require clearing for dropping the plumb bob. Because the clearing is usually done by kicking away small growth, this type of clearing is commonly called a KICKOUT. To determine the approximate location of the kickout, the head chainman may call, "Line for kickout!" and then "Distance for kickout!" At "Line for kickout!" the rear chainman or instrumentman gives the approximate line by eyeball. At "Distance for kickout!" the rear chainman holds approximately over the starting point without being too particular about plumbing.

LEVELING THE TAPE.— Figure 12-13 shows a pair of chainmen making a horizontal measurement on a slope. You can see that, to make the tape level, the person at the lower level is holding the end at chest level while the person at the higher level is holding it at knee level.

To maintain the tape in a horizontal position, the chainman at the lower level held the hand level. By studying the position of the other chainman, he decided that it would be possible to hold the tape at chest level. He then held the hand level at about the height of his own chest level and trained it on the other chainman. It indicated that a level line from his own chest level intersected the person of the other chainman at that person's knee level. So he called out, "At

Figure 12-13.-Horiziontal chaining using plumb bobs.

your knee!" thus informing the other chainman where to hold the end of the tape.

BREAKING TAPE.— The term *breaking tape* is used to describe the procedure for measuring directly horizontal distance on sloping ground, or through obstacles that do not permit the use of a full tape length. The procedure used in breaking tape is the same as ordinary chaining on level ground, except that the distances are measured by using portions of a tape, as shown in figure 12-14.

Generally, you will start breaking tape when the slope of the existing ground exceeds 5 percent (this depends also on the height of the chainmen). The reason for breaking tape is that the chainman on the lower ground will have difficulty in holding the tape steady and horizontal when his point of support exceeds his height. You also break tape to avoid hazardous measurements, such as crossing power lines and making measurements across a heavily traveled highway.

Now, to measure the distance AB shown in figure 12-14, the chainmen may proceed as follows: The rear chainman stations himself at point A. The head chainman pulls the tape forward a full tape length uphill toward point B and drops it approximately on line with the two range poles. He then comes back along the tape until he reaches a point at which a partial tape length, held level, is below the armpits of the rear chainman at point A. At this point, the head chainman selects a convenient whole-foot graduation, and the chainmen measure off the partial tape length (distance Aa) from starting point. As shown in the figure, the head chainman must be holding at the 60-ft mark to measure Aa. Then, he calls out, "Holding sixty!" so that the rear chainman knows what graduation he is holding when the measurement is made. As in other chaining methods, the rear chainman always checks the alignment.

After the pin is placed, the rear chainman (leaving the tape lying in position) moves forward to point a and gives a pin to the head chainman who, in turn, moves to point b; to make sure that the rear chainman takes the right graduation, he calls out, "Hold Sixty!" This procedure is repeated until a full station is measured or until a full-tape length measurement can be resumed. You see that to measure distance bc, both chainmen will probably use plumb bobs to transfer the distance to the ground.

Remember that the rear chainman gives the head chainman a pin only at each INTERMEDIATE point of a tape length. He keeps the pin at full tape lengths to keep track of the number of stations laid out as in ordinary horizontal chaining.

LAYING OFF A GIVEN DISTANCE.— Frequently, a chaining party is required to lay off a given distance and establish a new point on the ground. This is measuring by using a known distance on the tape and transferring it to the ground. If the distance is greater than a tape length, then the procedure described for measuring a full tape length is followed for the

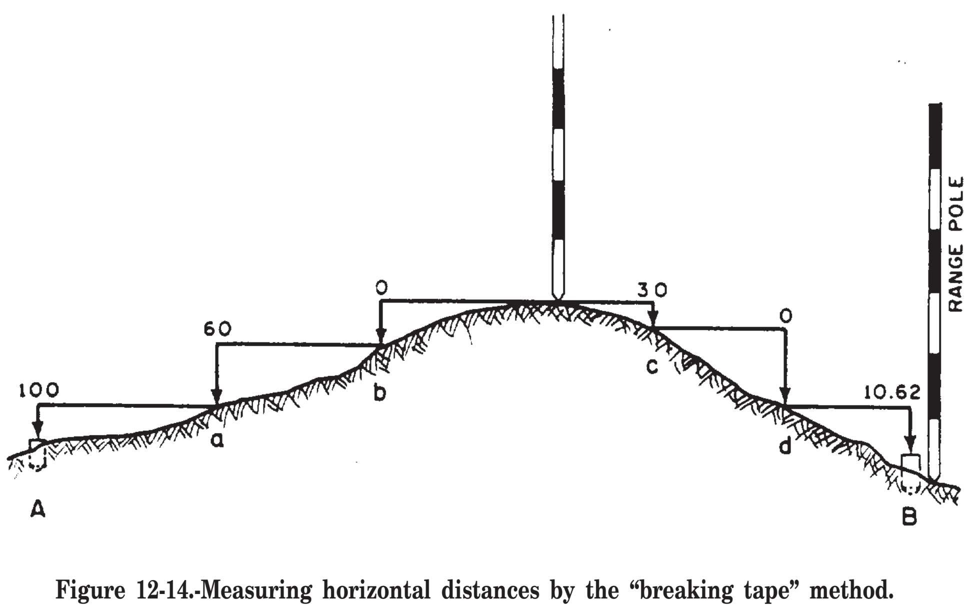


Figure 12-14.-Measuring horizontal distances by the "breaking tape" method.

required number of full tape lengths. The remaining partial tape length is then laid off by setting the rear chainman's plumb bob at the appropriate tape graduation.

Making Tape Corrections

A 100-ft tape should, in theory, indicate exactly 100.00 ft when it is in fact measuring 100.00 ft. However, a tape supported only at the ends has a sag in it, so when it indicates 100.00 ft, actually the distance measured is less. Even a tape supported throughout on a flat surface can be slightly longer under tension than it is without tension. Also, a tape will be longer when it is warm than when it is cold.

CALIBRATING A TAPE.— All tapes are graduated under controlled conditions of temperature and tension. When they are taken to the field, these conditions change. The tape, regardless of the material used to make it, will be either too short or too long. For low accuracy surveys, the amount of error is too small to be considered. As accuracy requirements increase, variations caused by the temperature and sag must be computed and used to correct the measured distance. In the higher orders of accuracy, the original graduation is checked for accuracy or calibrated at intervals against a standard distance. This standard is usually two points, a tape length apart, that have been set and marked using a more precise tape or a tape already checked. The standard may be just the precise or checked tape (known as the king or master tape). This tape is kept in a safe location and is not used for making field measurements, but only to check the accuracy of the field tapes. For the highest orders of accuracy, the tapes are sent to the National Bureau of Standards, U.S. Department of Commerce, Washington, DC, 20234, for standardization under exact conditions of tension, temperature, and points of support. A tape standardization certificate is issued for each tape, showing the amount of error under the different support conditions and the coefficient of expansion. The certificate (or a copy) is kept with each tape. For field operations, the tapes are combined in sets; one is selected as the king tape, while the others are used as field tapes.

The standard tension for a tape supported throughout is 10 lb, and the standard temperature is 68°F. Standard length is, simply, the nominal length of the tape. A 100-ft tape, for example, at a temperature of 68°F, supported throughout, and subject to a tension of 10 lb, should indicate 100 ft when it is measuring exactly 100 ft.

To CALIBRATE a 100-ft tape means to determine the exact distance it is actually measuring when it indicates 100 ft, while being supported throughout, at a temperature of 68°F and under a tension of 10 lb.

In addition to the National Bureau of Standards, many state and municipal authorities provide standardizing service.

RECOGNIZING TAPE OR STANDARD ERROR.— Suppose now that you send a 100-ft tape to the Bureau of Standards to be calibrated; the bureau will return a certificate with the tape. Assume that the certificate states that when the tape, supported throughout at a temperature of 68°F, and under a tension of 10 lb, indicates 100 ft, it actually measures 100.003 ft on the standard tape. The tape, then, has a STANDARD ERROR (also called TAPE ERROR) of 0.003 ft for every 100 ft it measures. This tape "reads short." Depending on the order of precision of the survey, you may have to apply this as a correction to measurements made with this particular tape.

CORRECTING FOR STANDARD ERROR.– Whether you add or subtract the standard error depends upon the direction of the error. The tape in the above example indicates a distance that is shorter than it actually measures; in other words, when you use this tape to lay off a distance of 100 ft, the line is actually 100.003 ft.

The decision to add or subtract the error depends upon whether you are measuring to determine the distance between two points or to set a point at a given distance from another.

Assume first that you're measuring the distance between two given points, and the distance as indicated by the tape is 362.73 ft. First, what is the total tape error? Obviously, it is 0.003 times the number of tape lengths. In this case, it is

$$0.003 \times 3.6273 = 0.0108819 \text{ ft},$$

which rounds off to 0.01 ft.

The next question is: Do you add this total correction to, or subtract it from, the recorded distance of 362.73 ft? Well, if you remember that the tape reads short, you will realize the reasonable thing to do is ADD the total standard error to the recorded distance. The correct distance between the two points, then, is 362.74 ft.

Suppose now that with the same tape, you are to set a point 362.73 ft away from another point.

Your correction here will be applied in the opposite direction. Since the tape reads short, the laid tape distance of 362.73 ft is LONGER than 362.73 ft by the amount of the total correction for standard error (0.01 ft). Therefore, you must SUBTRACT the total tape error. To lay off a distance of 362.73 ft with this tape, you would actually measure off a distance of 362.72 ft.

Suppose now that the Bureau of Standards calibration certificate states that when a tape indicates 100.00 ft under standard conditions, it is actually measuring only 99.997 ft. Again, the standard error is 0.003 ft per 100 ft, but this tape "reads long"; that is, the interval it indicates is LONGER than the interval it is actually measuring. Suppose you measure the distance between two given points with the tape and find that the tape indicates 362.73 ft. The total standard error is again 0.01 ft. Because the tape reads long, however, the distance it indicated was longer than the distance it actually measured. Therefore, the total standard error should be subtracted, and the distance between the given points should be finally recorded as 362.72 ft.

Suppose you are using this same tape to set a point 362.73 ft away from another point. Again, the total standard error is 0.01 ft. Because the tape reads long, however, a measurement of 362.73 ft by the tape will actually be LESS than 362.73 ft. Therefore, the total correction for standard error should be added, and you should measure off 362.74 ft by the tape.

CORRECTING FOR TEMPERATURE VARIATION.— Take again a 100-ft steel tape that has been calibrated at a standard temperature of 68°F. The coefficient of thermal expansion of steel is about 0.0000065 unit per 1°F. The steel tape becomes longer when its temperature is higher than the standard and shortens the same amount when it's colder. The general formula for variation in temperature correction is as follows:

$$C_t = 0.0000065L\,(T - To)$$

Where

C_t = Correction for expansion or contraction caused by variation in temperature

L = Tape calibrated length

To = Standard temperature (usually 68 °F)

T = Temperature during measurement.

From the above formula, you can deduce that the correction for a 100-ft tape is about 0.00065 ft per 1°F, which is about 0.01 ft for every 15°F change in temperature above or below the standard temperature of 68°F.

The temperature correction is applied in the same manner and direction as the standard tape error. If the tape measurement is taken at a higher temperature than standard, the tape will expand and will read short; naturally the correction should be added.

The error caused by variation in temperature is greatly reduced when an Invar tape is used.

CORRECTING FOR SAG.— Even under standard tension, a tape supported or held only at the ends will sag in the center, based on its weight per unit length. This sag will cause the recorded distance to be greater than the length being measured. When the tape is supported at its midpoint, the effect of sag in the two sections is considerably less than when the tape is supported only at its ends. As the number of equally spaced intermediate supports is increased, the distance between the end graduations will approach the length of the tape when supported throughout its length. The correction for the error caused by the sag between the two supports for any section can be determined by the following equation:

$$C_s = \frac{w^2 l^3}{24t^2}.$$

Where

C_s = correction for sag (in feet)

w = weight per unit length of the tape (in pounds per foot)

l = the length of the suspended section of tape (in feet)

t = tension applied to the tape (in pounds)

For full tape-length measurements, the correction for sag is usually taken care of by having the tape calibrated. The tape must be calibrated regardless of how it is supported and under standard temperatures and tension. To reduce the value of the horizontal correction for sag, the Bureau of Standards suggests standard tensions for tapes supported at only the ends as follows:

For 100-ft tapes, from 20 to 30 lb

For 150-ft tapes, from 25 to 30 lb

For 200-ft tapes, from 30 to 40 lb

Generally, for a heavy 100-ft tape weighing about 3 lb that was standardized, whether supported throughout or at the ends only, the systematic error per tape length caused by sag is as follows:

10-lb tension = 0.37 ft

20-lb tension = 0.09 ft

30-lb tension = 0.04 ft

For the Engineering Aid's survey work, measurements are normally in the lower order of precision. The correction for sag varies with the cube of the unsupported length; for short spans, it is often negligible.

CORRECTING FOR SLOPE.— When you take a measurement with a tape along an inclined plane (along the natural slope of the ground), obviously, the taped distance is greater than the horizontal distance. This taped distance is represented by s in figure 12-15.

The difference between the slope distance and the horizontal distance (s – d) is called the slope correction. This correction is always subtracted from the slope distance. To compute for the slope correction, you should know either the vertical angle, A, or the difference in elevation h between the taped stations.

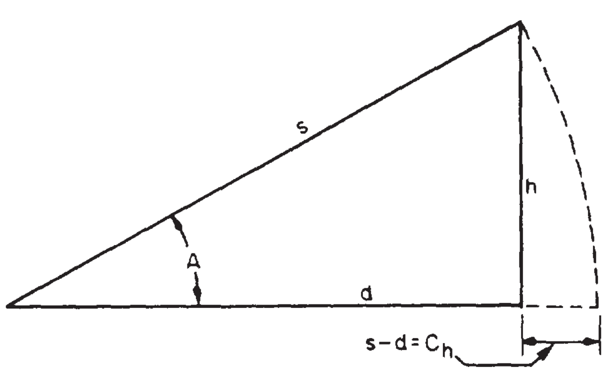


Figure 12-15.-Correction for slope distance.

When the vertical angle is used, the formula for slope correction is as follows:

$$C_h = s \text{ Vers } A.$$

Since

$$\text{Vers } A = (1 - \cos A),$$

then

$$C_h = s(1 - \cos A).$$

Where

C_h = the slope distance correction

s = the taped slope distance (usually a tape length)

A = the vertical angle

When the difference in elevation is used, the approximate formula derived by Pythagorean theorem of a right triangle (fig. 12-15) for the slope correction is as follows:

$$h^2 = s^2 - d^2$$

$$h^2 = (s + d)(s - d)$$

$$s - d = \frac{h^2}{s + d}.$$

But for a small slope, d is approximately equal to s; therefore,

$$s + d = 2s.$$

And since $C_h = s - d$ (from fig. 12-15), therefore,

$$C_h = \frac{h^2}{2s}.$$

For slopes greater than 5 percent, a closer approximation of C_h can be determined by expanding the above formula to this form.

$$C_h = \frac{h^2}{2s} + \frac{h^4}{8s^3}.$$

Preparing Chaining Notes

Before discussing the subject of chaining notes, we will mention a few general principles applicable to all types of field notes. It goes without saying that it is essential that measurements and other data be accurately recorded and that any additional information required to identify and clarify the data be included.

Field notes are required to be legible as well as accurate. If you don't write or print legibly, you will have to improve your script. All notes should be recorded in pencil; a 3H or 4H pencil is best for the job. A pencil that is too soft blunts too quickly; one that is too hard makes a faint mark and scores the paper. In the field, you need to carry a pocketknife or pocket pencil sharpener to keep your pencil sharpened or pointed.

There is a general rule to the effect that erasures are not permitted in field notes. Suppose that in the course of chaining several intervals you make a 10-ft "bust" in one of the intervals by misreading 10 ft as 20 ft. After you total up the distance, some circumstance leads you to suspect that the total is off. You recheck the work and discover where you made the bust. The notebook record for that interval must be changed. You make the change by crossing out the wrong entries and entering the correct ones above them—not by erasing the wrong entries.

RECORDING NOTES FOR HORIZONTAL CHAINING.— A typical example of a horizontal chaining conducted for a closed traverse is shown in figure 12-16. The chaining party started at station A and chained around by way of B, C, and so on. Arriving back at A, the party reversed its direction and chained back around by way of E, D, C, and so on, as a check. The distance finally recorded for each traverse line was the mean (average) between the forward measurement and the backward measurement.

Note on the bottom left-hand side the fact that the tape had a standard error of 0.013 ft per 100 ft of tape. The error is marked " + ," meaning that the amount of error should be added to the measurement as indicated by the tape. Obviously, the tape was reading short.

The corrections in the "Correction" column indicate that only correction for standard error

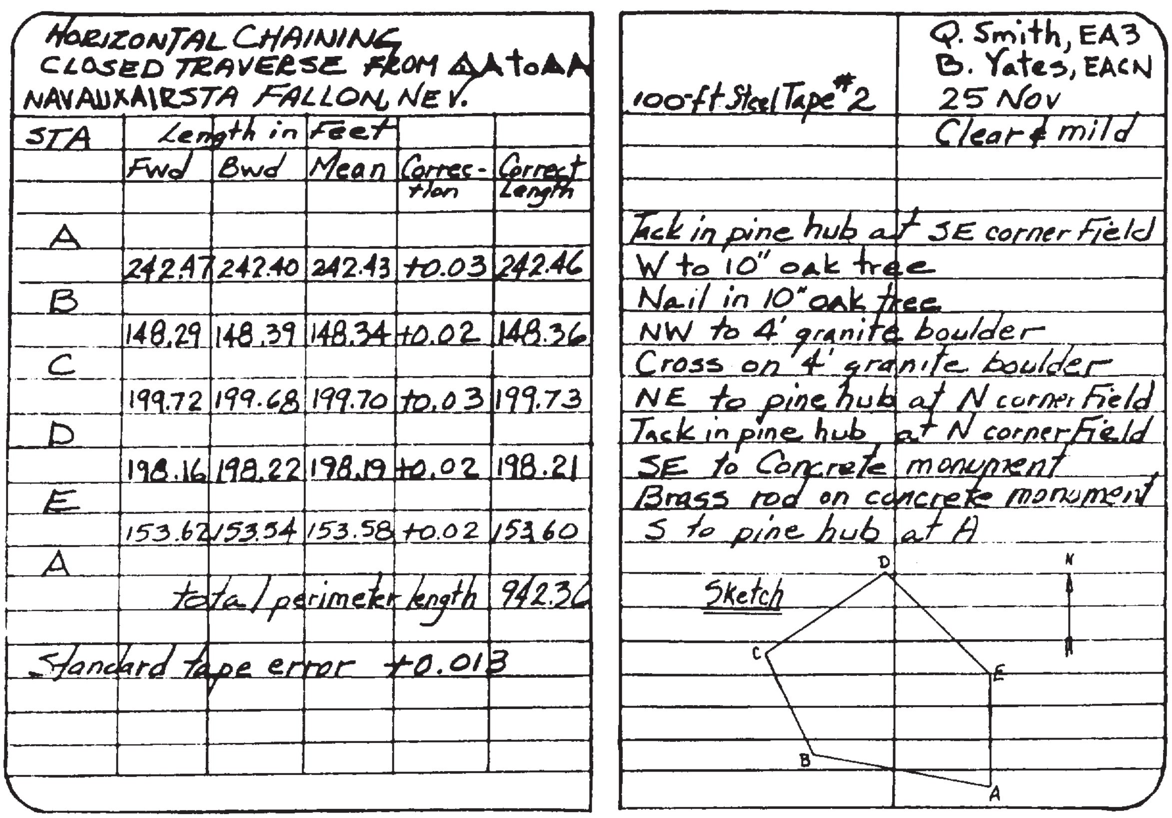


Figure 12-16.-Notes for horizontal chaining.

was made. If corrections for temperature and sag had been made as well, the algebraic sum of all three would have been entered in the correction column, or additional columns for temperature and sag correction would appear.

The symbol for each station is listed in the first column on the data page. Opposite, on the remarks page, a description of the station is recorded.

In the second and third columns on the data page, the measured forward and backward distances between adjacent stations are recorded. The average distance is recorded in the fourth column. In the fifth column, the standard error of 0.013 ft per 100 ft of tape is computed for each mean measurement. In the sixth column, the result of this error, added to the mean measurement, appears as the "Corrected Length." The sum of the corrected lengths appears below as "total length perimeter."

RECORDING NOTES FOR SLOPE CHAINING.— Figure 12-17 shows an example of slope chaining notes. Notice that on the data page, extra columns have been assigned for the temperature of the tape at each interval, the difference in elevation between supports, and the slope distance.

Under "Tape Corr." in the fifth column, the standard error for each interval is entered. Again, the tape had a standard error of 0.013 ft per 100 ft; therefore, the standard error for each interval except the last is 0.013 ft. For the last interval of 73.18 ft, the error works out as 0.009 ft.

If you will look to the right of the "Tape Corr." column, you will see the "Temp. Corr." column. For the first two intervals measured, the temperature of the tape was 78°F, or 10°F above standard. The correction amounts to 0.01 ft for each 15°F above standard; therefore, the total temperature correction for each of these intervals equals the value of x in the equation

$$\frac{0.01}{15} = \frac{x}{10}.$$

The total temperature correction is 0.007 ft. Because the temperature was above standard, the tape lengthened and was reading short. So the

SLOPE CHAINING
FROM △K to △L
NAVAUXAIR STA FALLON, NEV.

STA	°F	Elv.	Slope Dist.	Tape Corr.	Temp Corr.	Slope Corr.	Total Corr.	Horiz. Dist.
K								
	78	6.0	100.00	+.013	+.007	-.180	-.160	99.84
	78	6.7	100.00	+.013	+.007	-.224	-.204	99.80
	79	7.1	100.00	+.013	+.007	-.252	-.232	99.77
	79	6.9	100.00	+.013	+.007	-.238	-.218	99.78
	79	6.8	100.00	+.013	+.007	-.231	-.211	99.79
	79	7.0	100.00	+.013	+.007	-.245	-.225	99.77
	80	6.9	100.00	+.013	+.008	-.235	-.217	99.78
	80	6.8	100.00	+.013	+.008	-.231	-.210	99.79
	80	4.7	73.18	+.009	+.006	-.151	-.136	73.04
L		Total △K to △L					=	871.35
Standard Tape error				±0.013				

	Q. Smith, EA3
	B. Yates, EACN
100' Steel Tape #2	2 APR
	Clear & Warm
Tack in pine hub	at NW corner field
Tack in pine hub	30' SE of Tower

Figure 12-17.-Notes for slope chaining.

corrections should be added as indicated by the plus signs.

To the right of the "Temp. Corr." column is the "Slope Corr." column. Its entries are to be subtracted as indicated. Use the following equation to compute the slope correction.

$$C_h = \frac{h^2}{2s}.$$

For the first taped interval, we have an h of 6.0 ft and an s of 100 ft.

Therefore

$$h^2 = 6.0^2 = 36.0 \text{ ft and}$$

$$2s = 2 \times 100 = 200 \text{ ft}.$$

The slope correction is computed as follows:

$$\frac{36.00}{200.00} = 0.180 \text{ ft}.$$

Next to the column for slope correction comes the "Total Corr." column, containing the algebraic sum of the three corrections for each taped interval. Finally, in the "Horiz. Dist." column, each value is determined by subtracting the total correction for each interval from the measured slope distance for that interval. (This example used in figure 12-17 happens to be all negative.) At the bottom of this column, the sum of the horizontal distances appears. This is the horizontal distance from station K to station L.

Solving Surveying Problems by Tape

Before the modern instruments used to measure angles directly in the field were devised, the tape (or rather, its equivalent, the Gunter's chain) was often used. This tape was used not only for measuring linear distances but also for measuring angles more accurately than was possible with a compass.

LAYING OUT A RIGHT ANGLE.— In laying out a right angle (or erecting a perpendicular) by tape, you apply the basic trigonometric theory that a triangle with sides in the ratio of 3:4:5 is always a right triangle.

Assume that on the line AB shown in figure 12-18, you want to use a 100-ft tape to run a line from C perpendicular to AB. If a triangle with sides in the ratio of 3:4:5 is a right triangle, then one with sides in the ratio of 30:40:50 is also a right triangle. From C, measure off DC, 30 ft

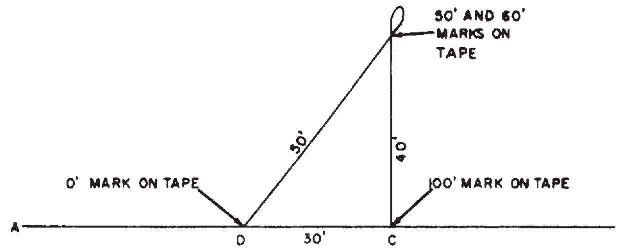


Figure 12-18.-Laying out a right angle using a 100-foot tape.

long. Set the zero-foot end of the tape on D and the 100-ft end on C. Have a person hold the 50-ft and 60-ft marks on the tape together and run out the bight. When the tape becomes taut, the 40-ft length from C will be perpendicular to AB.

MEASURING AN ANGLE BY TAPE.— There are two methods commonly used to determine the size of an angle by tape: the CHORD method and the TANGENT method.

The chord method can be applied, using the example shown in figure 12-19. Suppose you want to determine the size of angle A. Measure off equal distances from A (80.0 ft), and establish points B and C. Measure BC; assume that it measures 39.5 ft, as shown. You can now determine the size of angle A by applying the following equation:

$$1 - \cos A = \frac{2(s - b)(s - c)}{bc}$$

in which

$$s = 1/2(a + b + c) = 99.7 \text{ ft}.$$

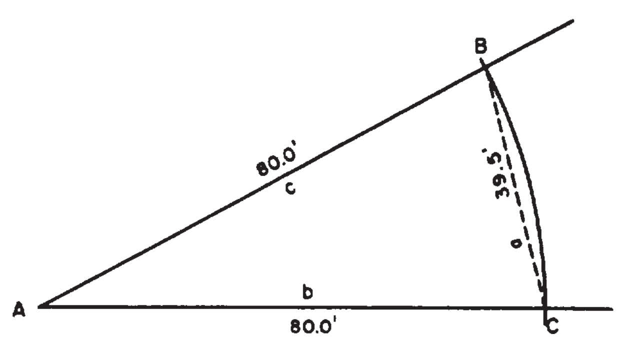


Figure 12-19.-Determining the size of an angle by the chord method.

First, solving for

$$1 - \cos A$$

we have

$$1 - \cos A = \frac{2(19.7)(19.7)}{6400} = \frac{776.2}{6400} = 0.12128.$$

Since

$$1 - \cos A = 0.12128$$

$$\cos A = 1.00000 - 0.12128 = 0.87872.$$

Reference to a table of natural functions shows that the angle with cos equal to 0.87872 measures, to the nearest 1 min., 28°29´.

The intervals measured off from A were made equal for mere convenience. The solution will work just as well for unequal intervals.

In determining the size of an angle by the tangent method, you simply lay off a right triangle and solve for angle A by the common tangent solution.

Suppose that in figure 12-20, you want to determine the size of angle A. Measure off AC a convenient length (say, 80.0 ft). Lay off CB perpendicular to AC and measure it; say it measures 54.5 ft, as shown. The angle is computed by using the following formula:

$$\tan A = \frac{54.5}{80.0} = 0.68125.$$

The angle with tangent 0.68125 measures 34°18´.

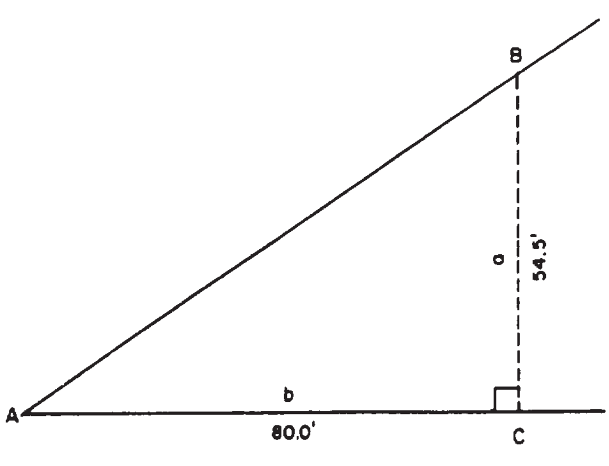


Figure 12-20.-Determining the size of an angle by the tangent method.

LAYING OFF AN ANGLE OF A GIVEN SIZE.— An angle of a given size can be laid off by tape by applying the tangent right triangle solution. Suppose that in figure 12-21, you want to lay off a line AC from A, 25° from line AB,

Again measure off a convenient 80.0 ft from A to establish point B. Erect a perpendicular from B as shown by the dotted line. You want to measure off along this perpendicular side a (opposite side), the distance that, when divided by the adjacent side, will give the value of the natural tangent of 25°. Use the following formula:

$$\tan 25° = \frac{a}{80.0}$$

$$a = 80.0 \tan 25°.$$

The tangent of 25° is 0.46631, so

$$a = 80.0 \times 0.46631 = 37.3 \text{ ft}.$$

Measure off 37.3 ft from B to establish point C. A line from A through C will form an angle of 25° from AB.

Identifying Chaining Mistakes and Errors

In surveying, distinctions are made between ERRORS and MISTAKES. Errors are caused by factors such as the effects of nature, the physical condition of the personnel performing the survey, and the condition of your instruments. Mistakes, however, are simply human blunders. While errors may be compensated for, mistakes can be detected, correct, and better yet, prevented only by the exercise of care.

COMMON MISTAKES.— Mistakes may result from poor work habits, lack of judgment, or confusion. They are often costly, time consuming, and difficult to detect. The easiest way to avoid them is to establish a definite procedure and follow it, being constantly alert during the

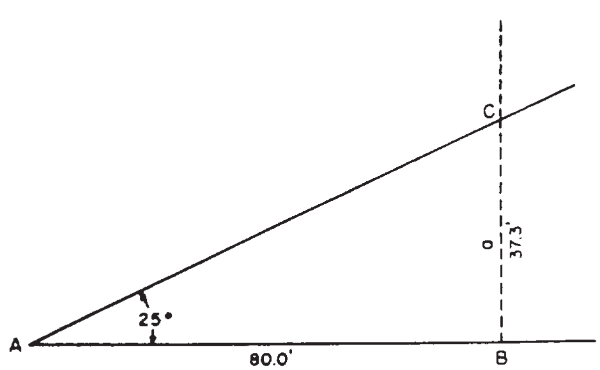


Figure 12-21.-Laying off an angle of a given size.

operations in which mistakes are possible. Some of the more common mistakes are as follows:

- Failing to hold graduations plumb over points

- Involuntarily transposing figures, such as recording 48.26 for 48.62

- Misreading figures that are viewed upside down, such as recording an upside-down 9 as a 6

- Reading a subdivided end-foot from the wrong end, as, for example, 0.28 ft instead of 0.22 ft

- Associating subdivided end-foot reading with wrong whole-foot mark, as 38.21 ft instead of 37.21 ft

- Subtracting incorrectly when using a minus tape

- Omitting an entire tape length

RECOGNIZING COMMON ERRORS.— There are two types of errors: accidental and systematic.

An accidental error is, generally speaking, one that may have a varying value. Examples are as follows: variation of the tension applied to the tape, inaccurate sticking of pins or other markings, and inaccurate determination of slope. Accidental errors can be minimized by carefulness, but not entirely eliminated.

A systematic error has a constant value. The standard error in a tape, for example, is a systematic error. Temperature and sag corrections are applied to correct systematic errors. Systematic errors can be compensated for or otherwise eliminated by the application of corrections.

Caring for and Maintaining a Survey Tape

If a steel or metallic tape gets a kink in it, it is then subjected to strain. The tape at best will be distorted at the point where the kink lies. At worst, if the strain is strong enough, the tape will break at the point where the kink lies. Kinks, therefore, are to be avoided at all costs; it is especially important to avoid putting a strain on a tape with a kink in it.

Under favorable circumstances, when a tape is shifted ahead, the head chainman may simply drag it over the ground. It is not a good idea for the rear chainman to assist by dragging that end because this develops a curve in the tape. This curve may snag on an obstruction and also may be the cause of a kink. When a tape is being dragged, the rear chainman should simply allow the end to trail along. The cardinal rule is "keep, the tape straight."

When taping in traffic, you plan your moves in advance and make the measurement as fast as possible. If possible, do not let vehicles run over the tape; however, if this is absolutely unavoidable, be sure the tape is laid flat and taut on the road. NEVER let a vehicle run over a tape laid on a soft or rugged ground surface.

Tapes are made as corrosion-resistant as possible, but no steel tape is entirely immune to corrosion, especially when used around salty water. Therefore, a tape should always be wiped dry before it is put away, and it should be oiled periodically with a light, rust-resistant oil. If a tape does rust, rubbing it with light steel wool dipped in a rust-removing compound is the best and safest way to remove the rust. Tapes, especially those in reels, though not used during the week, should be removed from the reel and inspected each week for signs of corrosion. A damp climate in your area of operations could easily start corrosion in tapes.

Splicing a Tape

In spite of being carefully handled, tapes sometimes break. A broken tape is rejoined by splicing. A relatively light tape can be repaired with a punch-and-rivet tape splicer and repair stock (fig. 12-22). A repair stock consists of a

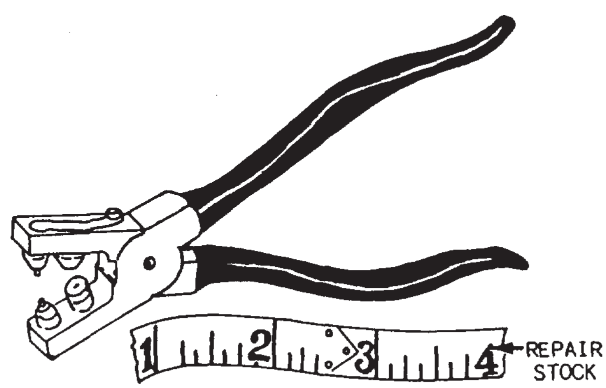


Figure 12-22.-A punch-and-rivet tape splicer with repair stock.

length of tape of the same thickness and width as that of the broken tape. When a tape is repaired, it is best to use a good section of the tape for calibration (matching a whole-foot mark). Place the section used for calibrating beside the broken section to make sure that you will maintain the original length of the tape after rejoining it.

In splicing a broken tape, first align and rivet the repair stock at one end of the break. Next, place the repair stock on the face of the other section of the tape by using the calibrating section as a measure for the break splice. Insert one rivet at a time and arrange rivets in a triangular pattern. Do not place rivets closer together than one-fourth in. from center to center. Now use a three-edge file. File partially through the surplus stock diagonally across the tape. The segment of the surplus will readily break off, leaving a clean splice.

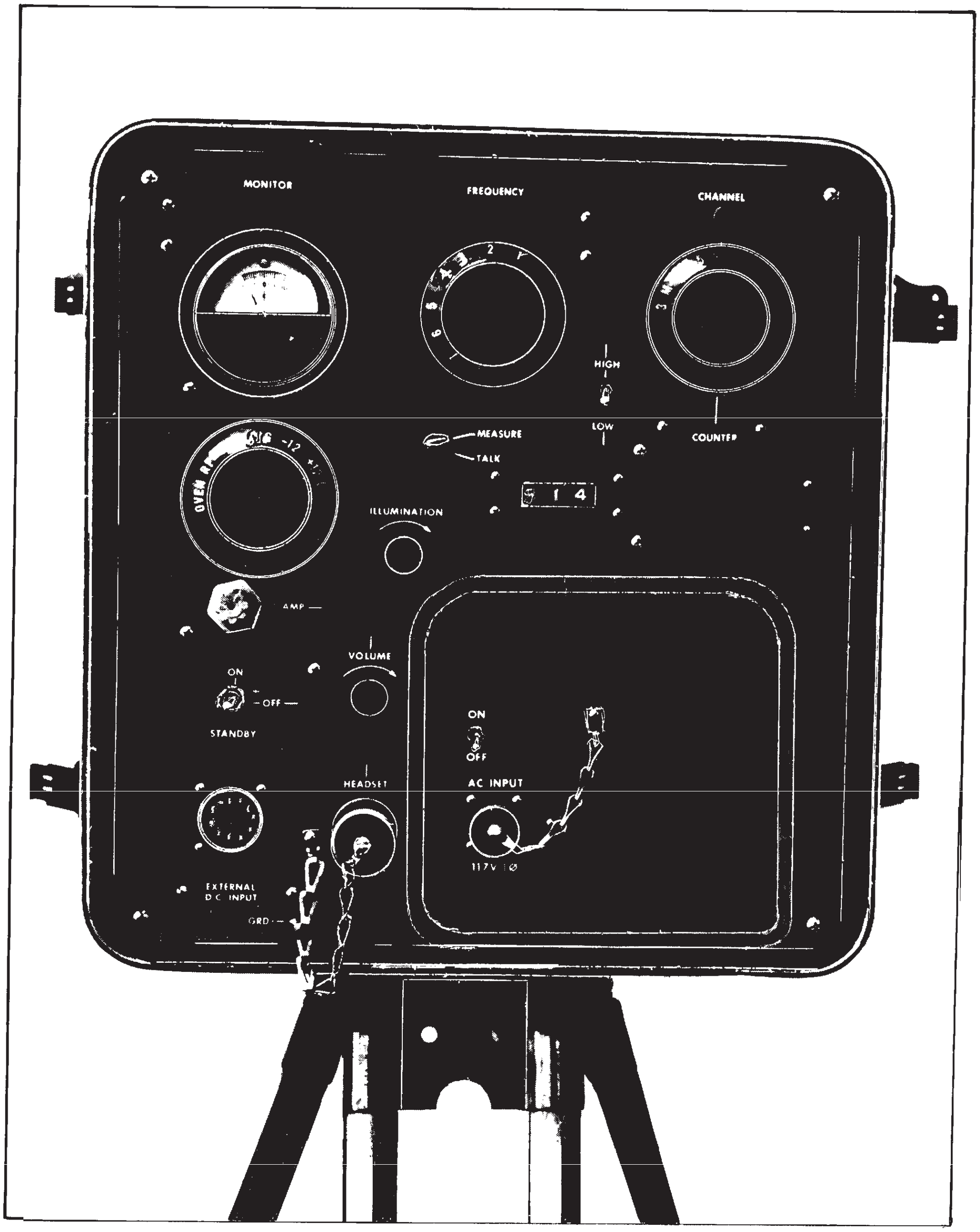


Figure 12-23.—A microwave distance-measuring device (Model 99).

Heavy steel tapes are repaired in a similar manner, using the tape repair kit shown in chapter 11, figure 11-55.

MEASURING BY THE ELECTRONIC DISTANCE-MEASURING SYSTEM

The electronic distance-measuring system is now incorporated in various present-day surveying practices, including traverse and triangulation network. In traverse measurements, accurate distances are directly measured in a straight line and with minimum instrument setups. In triangulation, the system is used to conduct base line measurements that are precise enough to maintain the accuracy of the survey.

In the electronic distance-measuring system, the length of a linear interval is determined by the use of equipment that (1) sends out an electronic impulse of some sort, such as a radar microwave or a modulated light wave, and (2) measures the time required for the impulse to travel the length of the interval. The velocity or rate of travel of the impulse is known. Therefore, once the time is also known, the length of the linear interval can be determined by applying the well-known equation "distance = rate x time."

Two types of electronic distance-measuring devices (also called EDMs) commonly used today are the MICROWAVE DEVICES and the LIGHT WAVE DEVICES.

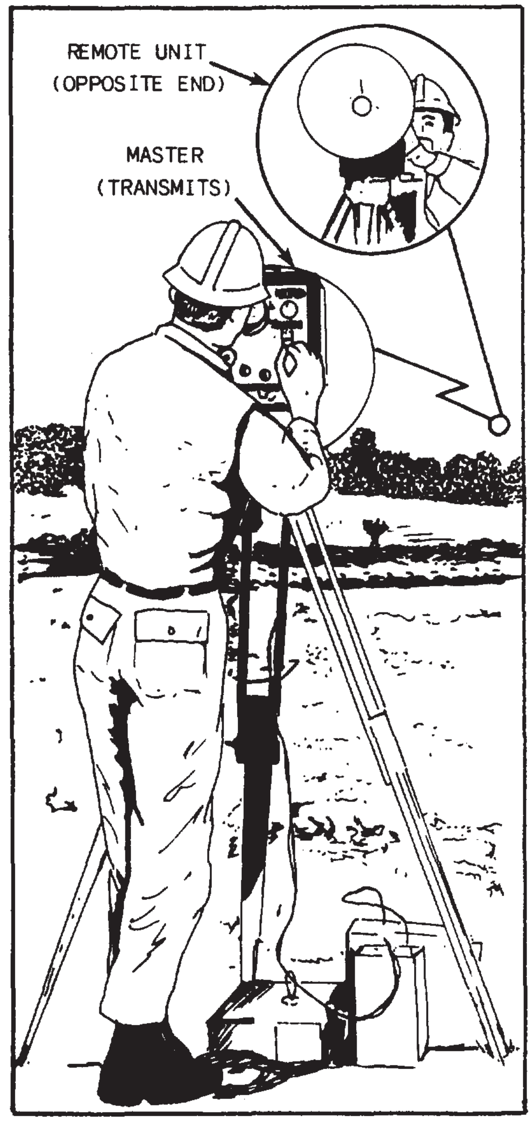


Figure 12-24.-Setting a microwave distance-measuring unit.

Measuring by Microwave Devices

The microwave distance-measuring device (fig. 12-23) is an electronic instrument that transmits precisely controlled RADIO WAVES between two units. The waves are compared and electronically changed into a visually readable form from which the distance between the units can be computed.

As shown in figure 12-24, the unit that originates and transmits the modulated radio waves is called the master. The unit at the opposite end of the line from the master is known as the remote. The two are identical instruments, each being adaptable to use as either master or remote. At the remote unit, the original transmission is received, interpreted, and put on a new carrier. This new modulation is amplified and retransmitted to the master. The master analyzes the new transmission and translates it into a trace on a cathode ray tube that can be read visually. The trace information is converted into a distance based on the velocity of the radio waves. Because this velocity is affected by atmospheric conditions, corrections for temperature and barometric pressure are applied according to instructions.

Each instrument is equipped with a shortwave telephone set. By this means, the person at each instrument can maintain communication with the other. Details of the method of operating the system must be learned from the manufacturer's instructions.

Measuring by Light Wave Devices

The light wave measuring device (fig. 12-25) uses electro-optical instruments to measure distances accurately. The device consists basically of two units: the measuring unit (transmitter/ receiver) and the reflector unit (fig. 12-26). The distance is measured by precise electronic timing of a modulated LIGHT WAVE after it travels to, and when it returns from, a reflector at the other end of a course (fig. 12-27). When the instrument receives the reflected light flash, it registers readings that can be converted into the linear distance between the instrument and the reflector (with corrections made for atmospheric conditions).

Like their microwave counterparts, the light wave distance-measuring devices are capable of first order base lines in triangulation and all orders of traverse distance measurements. Most of these instruments have a rated range of 200 to 50,000 meters.

These instruments, as all delicate scientific equipment, are to be treated with proper care and operator maintenance so that they may continue to be available for use. Refer to the instrument manufacturer's manual for instructions on basic operation, care, adjustments, calibrations, and other details of the system.

FIELD PARTY SAFETY

A surveying field party is frequently working its way through rugged terrain a long distance away from any professional medical assistance. Working through brush, felling trees, scaling bluffs, and crossing streams are all hazardous. Also, the use of such sharp-edged tools as machetes, brush hooks, axes, and hatchets is equally hazardous. Besides those dangers that are inherent in the work itself, a party may be exposed to a variety of natural dangers, such as those created by weather conditions, by reptiles, by insects, and by poisonous plants. Occasionally, in some areas, there may be dangerous wild animals or even dangerous domestic animals, such as vicious dogs or angry bulls. When a party is working along a thoroughfare on which vehicular

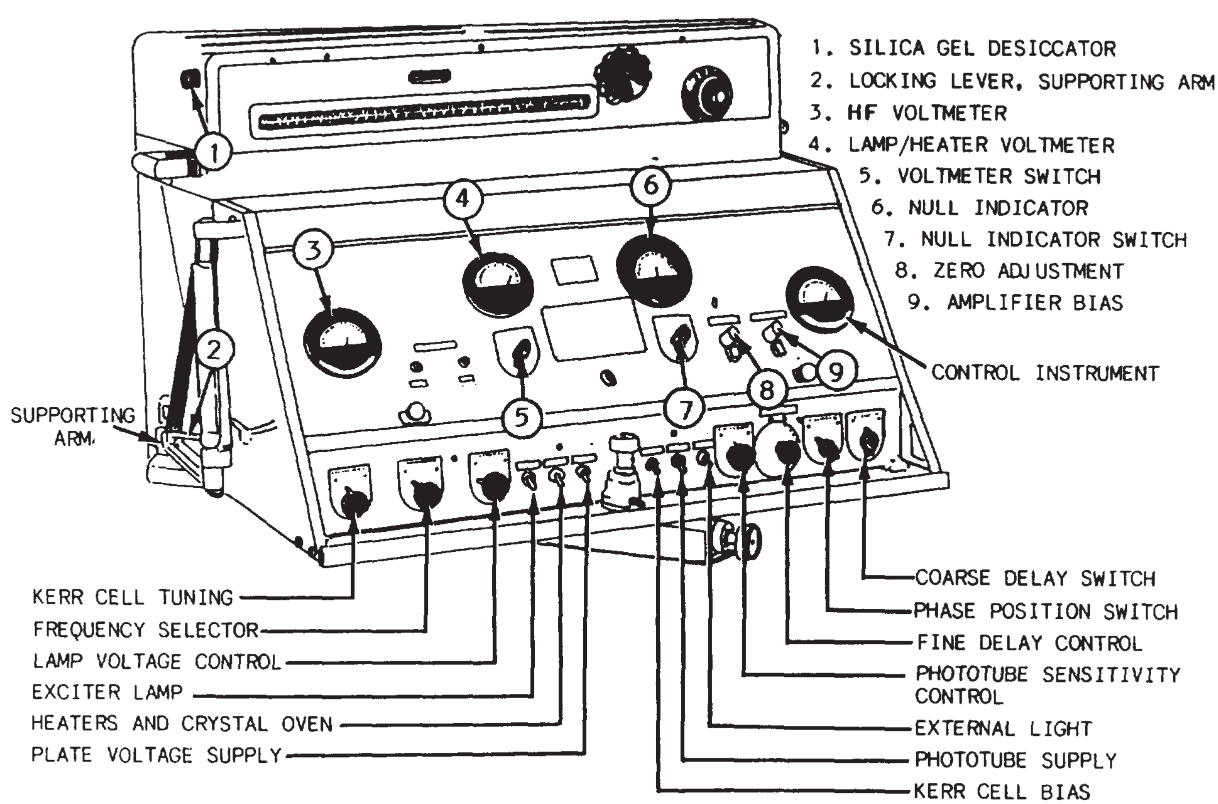


Figure 12-25.-A light wave distance-measuring device (Geodimeter, Model 2A).

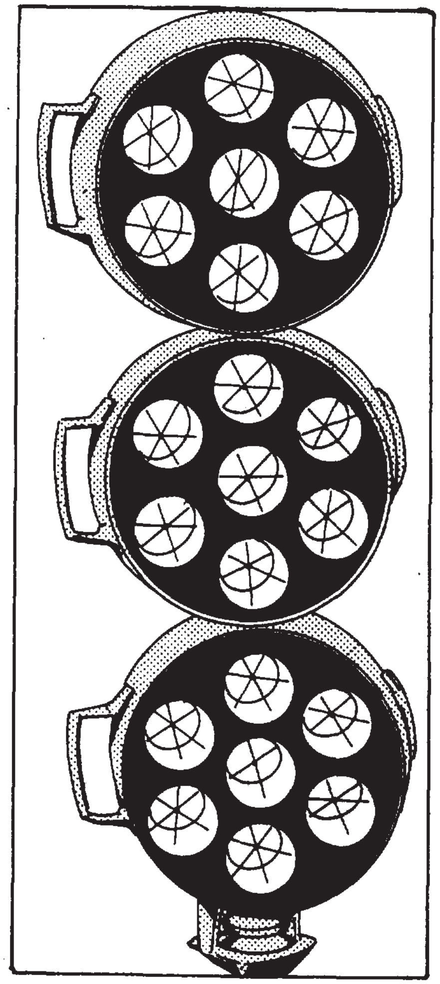


Figure 12-26.-Light wave reflector units, stacked.

traffic is proceeding as usual, there is the ever-present idanger of being hit by a vehicle.

In the midst of such a variety of constant dangers, the only way to prevent injury is by the exercise of continual care and vigilance. Every person in a party must be aware of all existing hazards, be able to recognize a hazardous situation, and be trained to take the correct preventive measures.

Indeed, it is common practice for surveying field crews to prepare a CHECKLIST of essential items, personal protective equipment, communication gear, and other miscellaneous items relative to their line of work.

ADMINISTERING FIRST AID

If personal injuries do occur, it is essential that the injuries be taken care of to the extent possible by the application of first aid. The *Standard First Aid Training Course,* NAVEDTRA 10081 (latest revision), defines first aid as "the emergency care given sick or injured persons until regular medical or surgical aid can be obtained." Your principal source of information on first aid is the *Standard First Aid Training Course.*

Every person in a field party should be able to administer first aid, regardless of how junior in rate and experience each person may be. A chaining party may consist of only two persons, one of whom may be very junior in rate and time in service. Since the party chief may be the one injured, the junior member of the party would be responsible for administering first aid.

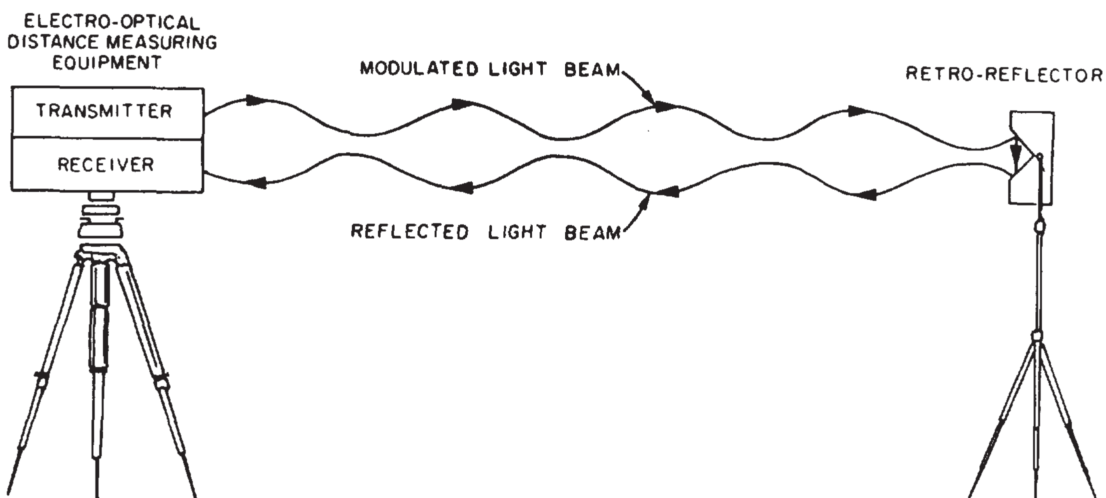


Figure 12-27.-Typical configuration of a light wave distance-measuring device.

As a rule, field crew members should be familiar with the telephone number and location of the nearest hospital or dispensary their party will be operating, should have a transport vehicle available and ready, and should have valid government vehicle operator's licenses. In addition, a first-aid kit should be kept handy at all times.

PROTECTING AGAINST WEATHER HAZARDS

For all weather hazards, the best preventive measure is the wearing of adequate protective clothing. When the weather is cold enough to cause frostbite, wear a hat that covers your ears, gloves or mittens for your hands, and cold-weather footgear for your feet. These are the primary areas most subject to frostbite. Wear a hat also when there is danger of heatstroke. Unless or until you are immune to sunburn (by tanning), keep your skin covered against the sun. Fair-haired or sandy-haired individuals, even when they tan, may be susceptible to a form of skin cancer caused by exposure to sunlight. If you are in this category, you should keep the skin covered whether you "tan" or not.

Two very common weather hazards, frostbite and heatstroke (commonly called sunstroke), are fully covered in the *Standard First Aid Training Course.* Lesser weather hazards, such as the exposure caused by wearing insufficient clothing in cold or wet weather and the possibility of a bad sunburn in hot weather, are not mentioned.

In general, when you set forth with a field party, wear or carry with you clothing that will provide adequate protection against the weather—not just as it is at the time you set forth, but as it may possibly develop before you get back.

RECOGNIZING AND AVOIDING POISONOUS REPTILES AND INSECTS

As a general rule, it is best to assume that all reptiles of the snake family found in the United States and overseas and that all insects you can't recognize as poisonous MAY BE poisonous.

The poisonous snakes of the North American continent belong to the viper family. The distinguishing characteristics of a viper area flat head and a thick body. The most common North American viper is the RATTLESNAKE. All rattlesnakes are distinguishable by a row of hard rings, called rattles, on the tail. The snake makes a hissing sound with them when it is angry or alarmed. The banded, or timber, rattler of the northeastern United States is smooth, silver gray in color. The diamondback rattler of the United States Deep South is silver gray with a diamond-shaped pattern on the skin. The western diamond-back rattler has the same diamond pattern, but is a copper color. The red rattler of southern California is a deeper copper color.

Besides the rattlesnake, the most common North American poisonous snake is the WATER MOCCASIN, sometimes called the cottonmouth because of a white mouth lining that the snake exposes when preparing to strike. The skin of the water moccasin is dark brown with black bars on the upper side and black blotched with yellowish white on the under side.

The reddish brown COPPERHEAD has no rattles. This viper is found especially in uplands of the eastern Unites States.

The most common poisonous insects encountered in North America are the BLACK WIDOW SPIDER, the TARANTULA, and the SCORPION. The black widow (which may be encountered anywhere in the United States) is recognizable by its small, shiny black body. The tarantula is a long-legged, hairy member of the spider family, found chiefly in and close to Texas. The scorpion, found mainly in the semitropical parts of the United States, resembles a lobster or crawfish in shape.

The symptoms that develop from the bite of each of the reptiles and insects mentioned, together with the appropriate first aid, are thoroughly described in the *Standard First Aid Training Course,* NAVEDTRA 10081 (latest edition).

AVOIDING OR TREATING POISONING FROM POISONOUS PLANTS

The *Standard First Aid Training Course* contains an extensive section on a variety of poisons. However, it does not mention a type of poisoning to which survey parties are particularly exposed—poisoning resulting from contact with poisonous plants. Poisoning of this kind is not likely to be fatal (although it can be, under certain circumstances), but it can cause you a lot of misery and considerable reduction in on-the-job efficiency.

The most common poisonous plants in the United States are POISON IVY (including a variety called poison oak) and POISON SUMAC, both of which occur everywhere in North America. These plants contain and exude a resinous juice that produces a severe reaction when it comes into contact with the skin of the average person. The first symptom of itching or a burning sensation may develop in a few hours or even after 5 days or more. The delay in the development of symptoms is often confusing when an attempt is made to determine the time or location where the contact with the plant occurred. The itching sensation and subsequent inflammation that usually develops into watery blisters under the skin may continue for several days from a single contamination. Persistence of symptoms over a long period is most likely caused by new contacts with plants or by contact with previously contaminated clothing or animals.

Severe infection may produce more serious symptoms that result in much pain through abscesses, enlarged glands, fever, or other complications. Secondary infections are always a possibility in any break in the skin that occurs when the watery blisters break.

With poison ivy, the next development is usually the appearance of a scabrous, deep red rash over large skin areas. With poison, sumac, it is usually the appearance of large blisters, filled with a thick yellowish white liquid strongly resembling pus. When the blisters break, this liquid runs over adjacent skin areas and, thus, enlarges the area of infection.

The resinous juice exuded by these poisonous plants is almost entirely nonvolatile; that is, nonevaporating or will not dry up. Consequently, the juice may be carried on clothing, shoes, tools, or soil for long periods. In this way, it may infect persons who have actually not come into contact with the plants themselves. Individuals have, in fact, been severely infected by juice carried through air by smoke from burning plants. Other persons have been infected by resinous juice being carried on the fur of animals.

Figure 12-29.-Poison oak (leaves and fruit).

To avoid contact with the plants themselves, you must have an idea of what they look like. Poison ivy has a trefoil (three leaflet) leaf, as shown in figure 12-28. The upper surface of the leaflet has a shiny, varnished appearance. The variety called poison oak has a leaflet with a serrated, or lobed, edge like that of an oak leaf, as shown in figure 12-29. Ordinary poison ivy is

Figure 12-28.-Different varieties of poison ivy leaves.

usually a vine; poison oak, usually a bush. In the flowering season, both types produce clusters of small white berries.

Different varieties of poisonous sumac leaves are shown in figure 12-30. There are poisonous sumacs and harmless sumacs, and it is difficult to distinguish the leaf of one from the leaf of the other. The only way to tell the poisonous plant from the harmless one is by the fruit. Both plants produce a drooping fruit cluster. The difference lies in the color of their fruits—that of the harmless sumac is RED; that of the poison sumac is WHITE. In other than the fruit season, it would be better to avoid contact with all sumacs.

There are no "do-it-yourself" remedies for plant poisoning; treatment must be by, or as directed by, professional medical personnel. However, if you have reason to believe that you have been infected, you should wash thoroughly with water and an alkaline laundry soap. Do not use an oily soap (most facial soaps are oily) because this will tend to spread the juice. Lather profusely, and do not rinse the lather off, but allow it to dry on the skin. Repeat this procedure every 3 to 4 hours, allowing the lather to dry each time.

If job conditions make contact with plants unavoidable, wear gloves and long sleeve shirts and keep all other skin areas covered. When you remove your clothing, take care not to allow any skin area to come into contact with exposed clothing. Launder all clothing at once.

USING FIELD EQUIPMENT SAFELY

The standard source of information on the safe use of dangerous field equipment and other safety precautions is *Safety Precautions for Shore Activities,* NAVMAT P-5100. A copy of this publication should be available in your technical library.

Since tools are a potential source of danger in all occupations, they should be inspected periodically to find out whether any repairs or replacements are needed. Only tools in good condition should be used. There should be no loose heads on any hand tools. Sharp-edged tools should be kept sharp. All tools should be stored safely when not being used.

If tools with sharp blades or points are laid down on the job temporarily, they should be placed in such a way that no injury can result to anyone. Sheaths or guards are desirable when sharp-edged or pointed tools are being carried from one place to another. If sheaths are not available, carry a tool with the sharp edge or point

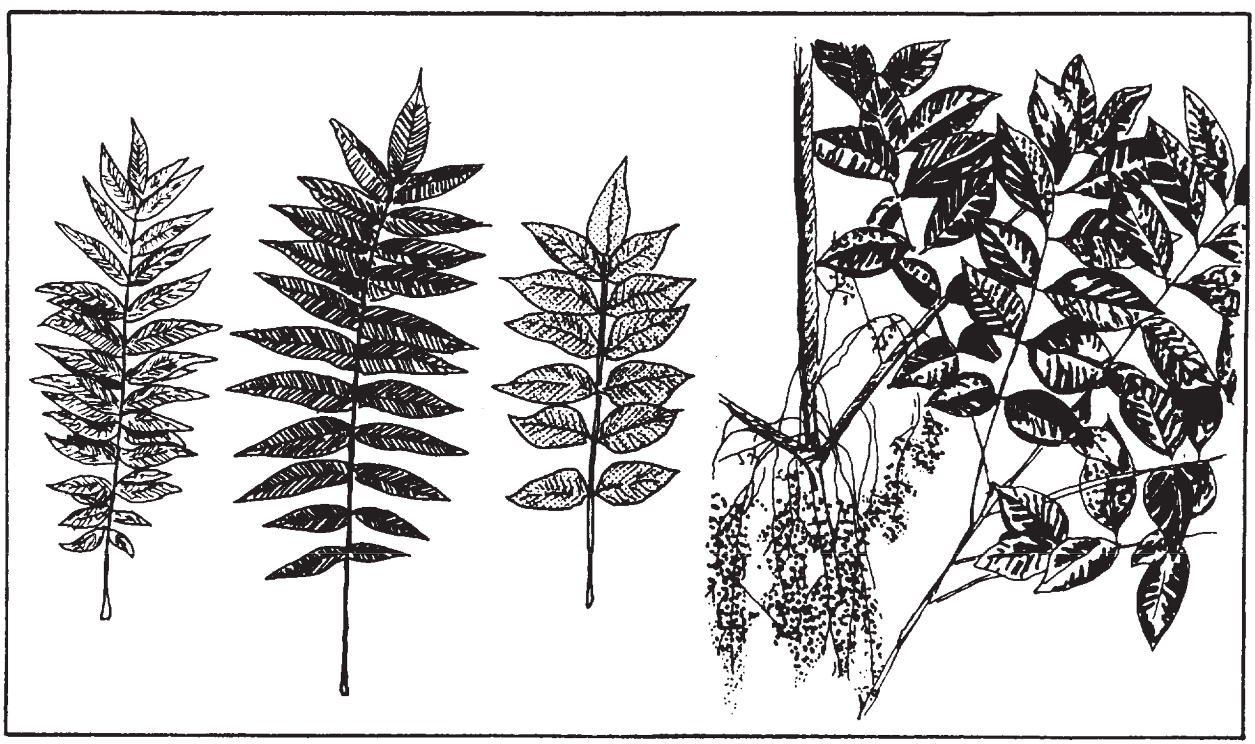


Figure 12-30.-Varieties of sumac leaves.

away from your body and take care that you do not injure others with it.

When working near other people, carry your range poles or level rods vertically against your body so that another person's head or eyes will not be injured if you turn suddenly. Do not hold a stake or bull-point with your hand around the shank while another person is driving it with a sledgehammer. Do not let a tape or plumb bob cord slide fast through your hands.

Always use tools correctly and for the purpose for which they are intended. For example, when cutting brush near the ground with a machete, swing it away from your legs and feet. Never cut at short range from your body. Be sure that the radius of your swing is clear of obstructions, such as vines or twigs, that might deflect the intended direction of the swing. Use your full arm's length to get a safe-swing radius. Always work at least 10 ft away from the nearest person. If it is necessary to use an ax to clear an area, you can prevent painful blisters by wearing a pair of thin gloves. Above all, use common sense and consider the possible results of your actions.

To climb poles and trees safely, it is best to use authorized climbing equipment. A lineman's pole climbers are made of steel and have a strap loop and short spur. Tree climbers have straps, pads for protection against friction, and a longer spur for penetrating bark. To avoid falling, use both belt and straps. Except in an emergency, never work in or on trees during a high wind. Watch out for power lines that may be in contact with the tree you are climbing.

Burning operations should always be conducted in the clear, where the fire will not ignite tree leaves or limbs, dry wooded areas, or nearby buildings. Remember that it is imperative that all burning or smoldering material be completely extinguished before it is left unattended.

When practicable, use only nonflammable solvents for cleaning instruments. Do not leave the caps off or the stoppers out of flammable liquid containers. Use solvents only in a well-ventilated location.

All of the above could be boiled down to this: **ALWAYS USE GOOD JUDGMENT AND COMMON SENSE.**

FOLLOWING SAFETY PROCEDURES IN TRAFFIC

A party working on a highway where vehicular traffic is proceeding is in great danger of being struck. Every motion made by a member of such a party must be made with a continuing, full awareness that vehicular traffic is, in fact, proceeding as usual. The dangers of the situation should be minimized as much as possible by the following measures as well as by others that some situations may require.

Work should be scheduled as much as possible to take place during those hours when traffic is slack. Work during "rush hour" on a metropolitan highway, for instance, could be so dangerous as not to be a practical endeavor.

Adequate traffic warning signs, such as "Men Working," "Drive Slowly," "Single Lane Ahead," and the like, should be placed where they will be most effective in warning drivers and, if possible, in detouring traffic away from the field party. If detouring requires two-way traffic on a single lane, a flagman has to be posted at each end of the lane.

Signs, barriers, and equipment in use, such as instruments, targets, and the like, should be made as conspicuous as possible by the attachment of bright-colored bunting. Personnel should also make themselves as conspicuous as possible by wearing orange-colored shirts, vests, or jackets.

One last word of advice may seem inconsistent with your standards about what constitutes proper performance of duty. Suppose you are functioning as an instrumentman with a party on a highway, and you suddenly observe that a car out of control is bearing down on the instrument at high speed. You will have a strong impulse to attempt to rescue the instrument. Do NOT do this if it could result in death or injury to yourself.

ADDITIONAL DUTIES OF A SURVEY CREW

Other tasks that you might perform as a survey crew member include the maintenance of various surveying equipment and accessories, preparation of the field party's essential needs, field sanitation, and the conducting of prestart checks and operator's maintenance of government survey vehicles.

MAINTAINING SURVEYING EQUIPMENT

Generally, the maintenance of surveying equipment and accessories involves proper cleaning and stowage. For example, steel tapes, brush hooks, axes, chain saws, and so forth, must be cleaned and dried and, if necessary, a thin coat of oil applied after each day's work before they are stored for the night. Never stow any surveying gear (especially if made of ferrous material) without checking it thoroughly to make sure it is clean and dry—particularly steel tapes. The reason for this is that, in the SEABEEs, we have a multitude of jobs done under variable conditions. Suppose that today you are sent to a job that does not require the same equipment you used yesterday and failed to clean. You are kept on this job for a few days. There is a good chance that the equipment you used the first day will be rusty when you return to use it again.

Remember that you are liable for payment for any loss of government property caused by your own negligence.

You will be required to sharpen surveying clearing tools, replace any broken handles, especially those on sledgehammers, and do many other things. For delicate equipment, consult the manufacturer's handbook or other applicable publications before you attempt any servicing or cleaning, and, if necessary, ask your senior EA to explain the correct procedure to follow.

PREPARING FOR FIELD PARTY'S ESSENTIAL NEEDS

You need to know how to prepare or gather your various needs for the day; for example, stakes, hubs, markers, safety gear, drinking water, and food. The preparation of the list of these things is the responsibility of your party chief; however, everyone in the survey party should review the list to make sure that everything needed for that particular job is there. Remember that you are concerned with the necessary equipment not only for the job, but also for your personal needs, especially if the job is quite a distance from your base camp.

In a triangulation survey, for example, your stations are generally situated in remote places. You may be ferried to your station point by helicopter or by some other means, depending on the location and the mode of transportation available. Be sure to take extra drinking water to jobs like this, and DO NOT discard your excess water until you are safely back to your base camp.

MAINTAINING FIELD SANITATION

In the field, devices necessary for maintaining personal hygiene and field sanitation must be improvised. If you are surveying at a remote location, it is unlikely that you will find a waterborne sewage system available for your use. The usual alternative is digging a "cat hole" about 1 ft deep and covering the feces completely with dirt.

Proper disposal of garbage should also be undertaken during field surveys. Whenever possible, avoid burning dry garbage on site. Disposal bags offer a good means of preventing litter and should be used whenever available.

In extremely hot climates, your supply of potable water is expected to run low at a faster rate. To avoid dehydration, you will be required to treat your own water or face infections or diseases, such as dysentery, cholera, diarrhea, and typhoid fever. It is imperative that water taken from any source (such as lakes, rivers, streams, and ponds) be properly treated before being used, as all these sources are presumed to be contaminated. To treat water for drinking, you can use either a plastic or aluminum canteen with the water purification compounds available in tablet form (iodine) or in ampule form (calcium hypochlorite). When disinfecting compounds are not available, boiling the water is another method for killing disease-producing organisms. The standard source of information for SEABEEs on field sanitation and personal hygiene is *Seabee Combat Handbook,* NAVEDTRA 10479-C2, chapter 8.

GIVING VEHICLE PRESTART CHECKS AND MAINTAINING VEHICLE OPERATIONS

It is likely that the field survey crew will be assigned a vehicle to transport people and equipment to and from the jobsite. Before operating the vehicle, the operator is to give it a prestart check to make sure that it is ready to run.

When a vehicle is assigned to you, an operator's daily preservice maintenance report is issued at the dispatch office. Use this form to record or log items in the vehicle requiring attention as observed during the prestart check and during the working day. Other information, such as mileage readings, operating hours, and fuel consumption may also be required.

A complete checklist of the vehicle prestart and operator's maintenance procedures are described in *Equipment Operator 3 & 2,* NAVEDTRA 10640-J1, chapters 2 and 4.

CHAPTER 13

HORIZONTAL CONTROL

A system of control stations, local or universal, must be established to locate the positions of various points, objects, or details on the surface of the earth. The relative positions of detail points can be easily determined if these points are TIED IN to a local control station; or, if the control station is tied in to a geodetic control, the positions of other detail points can also be located relative to a worldwide control system.

The main control system is formed by a triangulation network supplemented by traverse. A traverse that has been established and is used to locate detail points and objects is often spoken of as a CONTROL TRAVERSE. Any line from which points and objects are located is a CONTROL LINE. A survey is controlled horizontally by measuring horizontal distances and horizontal angles. This type of survey is often referred to as HORIZONTAL CONTROL.

Horizontal control surveys are also conducted to establish supplementary control stations for use in construction surveys. Supplementary control stations usually consist of one or more short traverses run close to or across a construction area to afford easy tie-ins for various projects. These stations are established to the degree of accuracy needed for the purpose of the survey.

In this chapter, we will identify common procedures used in converting angular measurements taken from a compass or transit survey, recognize the methods used in establishing horizontal control, and identify various field procedures used in running a traverse survey.

DIRECTIONS AND DISTANCES

There are various ways of describing the horizontal locations of a point, as mentioned in chapter 12. In the final analysis, these ways are all reducible to the basic method of description; that is, by stating the length (distance) and direction of a straight line between the point whose location is being described and a reference point.

Direction, like horizontal location itself, is also relative; that is, the direction of a line can only be stated relative to a REFERENCE LINE of known (or sometimes of assumed) direction. In true geographical direction, the reference line is the meridian passing through the point where the observer is located; and the direction of a line passing through that point is described in terms of the horizontal angle between that line and the meridian. In magnetic geographical direction, the reference line is the magnetic meridian instead of the true meridian.

CONVERTING DIRECTIONS

The direction of a traverse line is commonly given by bearing. In field traversing, however, turning deflection angles with a transit is more convenient than orienting each traverse line to a meridian. The method of converting bearings to deflection angles is explained in the following paragraphs.

Converting Bearings to Deflection Angles

Converting bearings to deflection angles is based on the well-known geometrical proposition shown in figure 13-1.

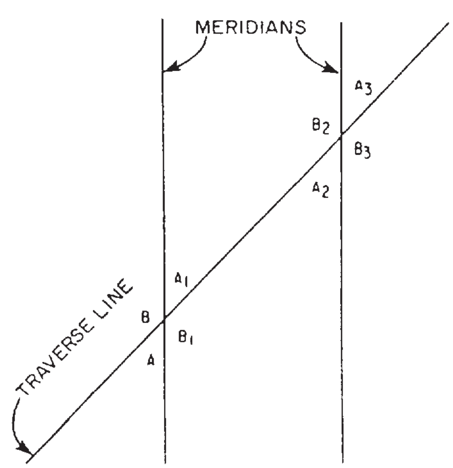


Figure 13-1.-Parallel lines (meridians) intersected by a traverse line, showing relationship of corresponding angles.

This figure shows two meridians or parallel lines that are intersected by another line called a traverse. It can be proved geometrically that the angles A and A_1, B and B_1, A_2 and A_3, and B_2 and B_3 are equal (vertically opposite angles). It can also be shown that angles $A = A_2$, and $B = B_2$ (corresponding angles). Therefore,

$$A = A_1 = A_2 = A_3 \text{ and}$$

$$B = B_1 = B_2 = B_3.$$

It can also be shown that the sum of the angles that form a straight line is 180°; the sum of all the angles around the point is 360°.

Figure 13-2 shows a traverse containing traverse lines AB, BC, and CD. The meridians through the traverse stations are indicated by the lines NS, N´S´, and N´´S´´. Although meridians are not, in fact, exactly parallel, they are assumed to be, for conversion purposes. Consequently, we have here three parallel lines intersected by traverses, and the angles created will therefore be equal, as shown in figure 13-1.

The bearing of AB is given as N20°E, which means that angle NAB measures 20°. To determine the deflection angle between AB and BC, you proceed as follows: If angle NAB measures 20°, then angle N'BB' must also measure 20° because the two corresponding angles are equal. The bearing of BC is given as S50°E, which means angle S´BC measures 50°E. The sum of angle N´BB´ plus S´BC plus the deflection angle between AB and BC (angle B´BC) is 180°. Therefore, the size of the deflection angle is

$$180° - (N'BB' + S'BC) \text{ or}$$

$$180° - (50° + 20°) = 110°.$$

The figure indicates that the angle should be turned to the right; therefore, the complete deflection angle description is 11°R.

The bearing of CD is given as N70°E; therefore, angle N´´CD measures70°. Angle S´´CC´ is equal to angle S´BC and therefore measures 50°. The deflection angle between BC and CD equals

$$180° - (S''CC + N''CD) \text{ or}$$

$$180° - (50° + 70°) = 60°.$$

The figure indicates that the angle should be turned to the left.

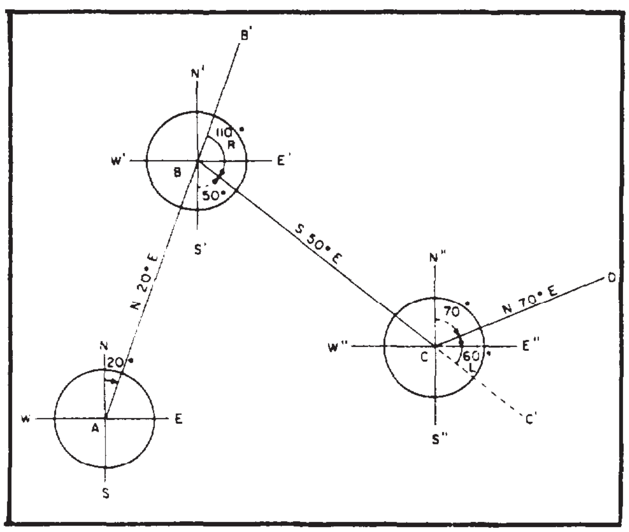


Figure 13-2.-Converting bearings to deflection angles from given traverse data.

Converting Deflection Angles to Bearings

Converting deflection angles to bearings is simply the same process used for a different end result. Suppose that in figure 13-2, you know the deflection angles and want to determine the corresponding bearings. To do this, you must know the bearing of at least one of the traverse lines. Let's assume that you know the bearing of AB and want to determine the bearing of BC. You know the size of the deflection angle B´BC is 110°. The size of angle N´BB´ is the same as the size of NAB, which is 20°. The size of the angle of bearing of BC is

$$180° - (B'BC + NAB) \text{ or}$$

$$180° - (110° + 20°) = 50°.$$

The figure shows you that BC lies in the second or SE quadrant; therefore, the full description of the bearing is S50°E.

Converting Bearings to Interior and Exterior Angles

Converting a bearing to an interior or exterior angle is, once again, the same procedure applied for a different end result. Suppose that in figure 13-2, angle ABC is an interior angle and you want to determine the size. You know that angle ABS´ equals angle NAB, and therefore measures 20°.

You know from the bearing of BC that, angle S′BC measures 50°. The interior angle ABC is

$$ABS' + S'BC \text{ or}$$

$$20° + 50° = 70°.$$

The sum of the interior and exterior angles at any traverse station or point equals the sum of all the angles around that point, or 360°. Therefore, the exterior angle at station B equals 360° minus the interior angle or

$$360° - 70° = 290°.$$

The process of measuring angles around a point to obtain a check on their sum, which should equal 360°00’, is sometimes referred to as CLOSING THE HORIZON.

Converting Azimuths to Bearings or Vice Versa

Suppose you want to convert an azimuth of 135° to the corresponding bearing. This azimuth is greater than 90° but less than 180°; therefore, the line lies in the southeast quadrant. As shown in figure 13-3, the bearing angles are always measured from the north and south ends of thereference meridian. (When solving any bearing problem, draw a sketch to get a clear picture.) For the azimuth, the horizontal direction is reckoned clockwise from the meridian plane. It is measured between either the north or the south end of the reference meridian and the line in question. When we talk about azimuth in this training manual, however, you must understand that the azimuth is referenced clockwise from the NORTH point of the meridian. The numerical value of this 135° azimuth angle is measured from the north. Therefore, in this figure, the value of the bearing is

$$180° - 135 = 45°.$$

The complete description of the bearing then is S45°E.

For example, if you want to convert a bearing of N30°W into an azimuth angle, you know that the angle location must be in the northwest quadrant. Then, draw an angle of 30° from the north end of the reference meridian because you measure azimuth angles clockwise from the north end of the reference meridian. To compute this azimuth angle, subtract 30° from 360°; the result is 330°. Therefore, the bearing of N30°W is equal to 330° azimuth angle.

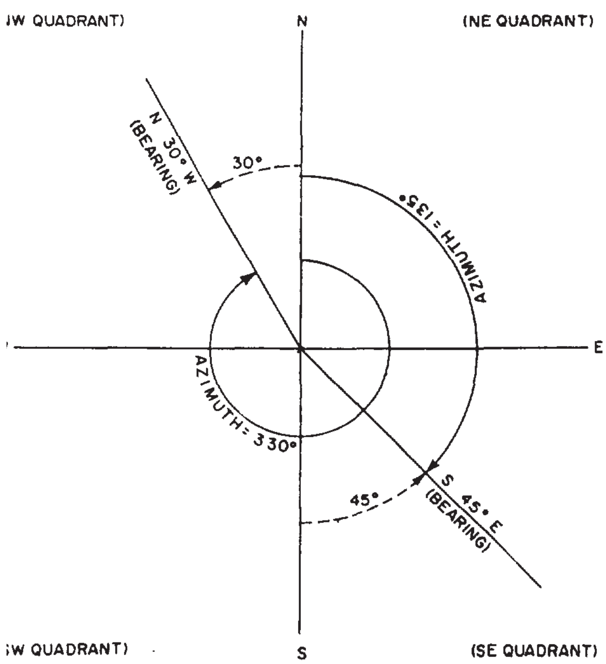


Figure 13-3.-Converting azimuths to corresponding bearings or vice versa.

ESTABLISHING DIRECTION BY SURVEYOR’S COMPASS

The basic method of establishing direction of a survey line or a point is with a surveyor’s compass. (Notice that on most surveyor’s compasses, the east and west indicators are in the opposite positions from those of the east and west indicators on a map or chart.) In figure 13-4, an

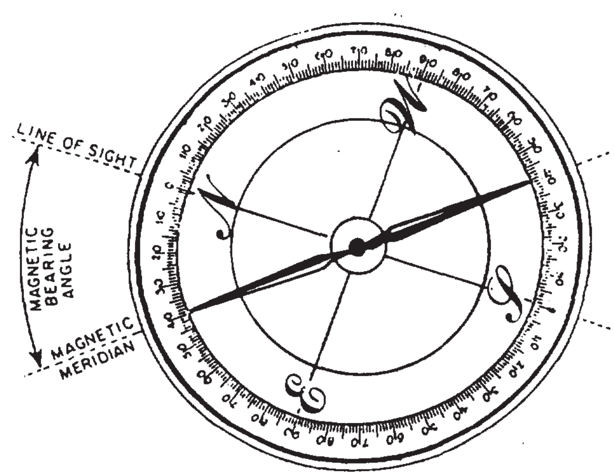


Figure 13-4.-A magnetic compass reading corrected for local attraction.

observer is determining the magnetic bearing of the dotted line labeled Line of Sight. First, the observer mounts the compass on a steady support, levels it, and waits for the needle to stop oscillating. Then, the observer carefully rotates the compass until the north-south line on the card lies exactly along the line whose bearing is being taken.

The bearing is now indicated by the needlepoint. The needlepoint indicates a numerical value of 40°. The card indicates the northeast quadrant. The magnetic bearing is, therefore, N40°E.

Correcting for Local Magnetic Attraction

Figure 13-4 shows the compass needle lying along the magnetic meridian. This means either that the compass is in an area free of "local magnetic attraction" or that the effect of local attraction has been eliminated by adjusting the compass card as described later. "Local magnetic attraction" means the deflection of the compass needle by a local magnetic force, such as that created by nearby electrical equipment or by a mass of metal, such as a bulldozer. When local attraction exists and is not compensated for, the bearing you get is a COMPASS bearing. A compass bearing does not become a magnetic bearing until it has been corrected for local attraction. Suppose, for example, you read a compass bearing of N37°E. Suppose the effect of the magnetic attraction of a nearby pole transformer is enough to deflect the compass needle 4° to the west of the magnetic meridian. In the absence of this local attraction, the compass would read N33°E, not N37°E. Therefore, the correct magnetic bearing is N33°E.

To correct a compass bearing for local attraction, you determine the amount and direction (east or west) of the local attraction. First, set up the compass where you propose to take the bearing. Then, select a distant object that you may presume to be outside the range of any local attraction. Take the bearing of this object. If you read a bearing of S60°W, shift the compass to the immediate vicinity of the object you sighted on; and take, from there, the bearing of the original setup point. In the absence of any local attraction at the original setup point, you would read the back bearing of the original bearing or N60°E. Suppose instead you read N48°E. The back bearing of this is S48°W. Therefore, the bearing as indicated by the compass under local attraction is S60°W; but as indicated by the compass not under local attraction, it is S48°W. The amount and direction of local attraction are, therefore, 12°W.

The question of whether you add the local attraction to, or subtract it from, the compass bearing to get the magnetic bearing depends on (1) the direction of the local attraction and (2) the quadrant the bearing is in.

As a rule, for a bearing in the northeast quadrant, you add an easterly attraction to the compass bearing to get the magnetic bearing and subtract a westerly attraction from the compass bearing to get the magnetic bearing.

Now, consider the compass shown in figure 13-5. This compass indicates a bearing of S40°W. Suppose the local attraction is 12°W. The needle, then, is 12°W of where it would be without local attraction. You can see that, in the southwest quadrant, you would subtract westerly attraction and add easterly attraction.

From a study of the paragraphs above, it becomes obvious that the procedure is the opposite for bearings in the northwest or southeast

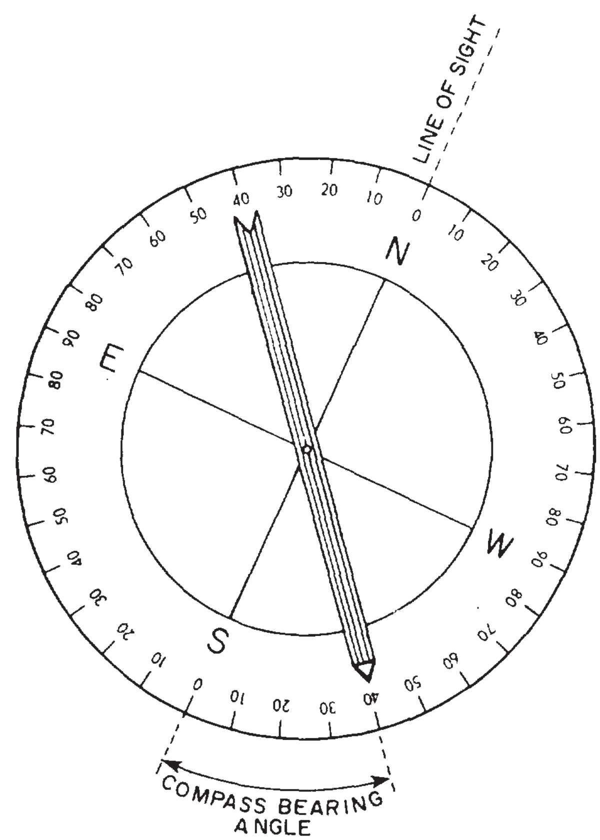


Figure 13-5.-Compass bearing affected by local magnetic attraction.

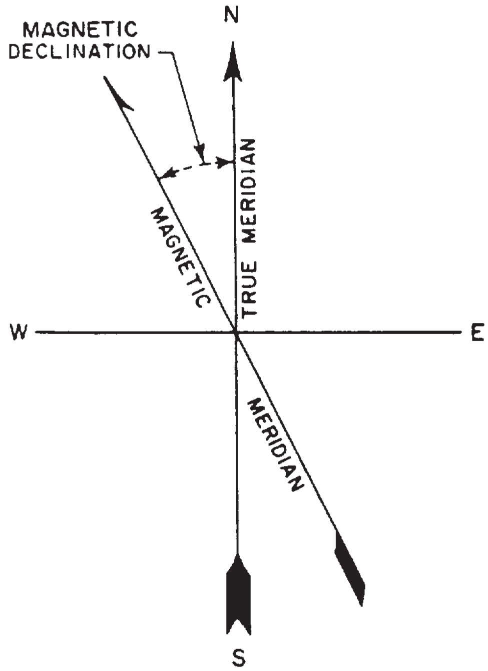


Figure 13-6.-Magnetic declination (west).

quadrants. In these quadrants, you add westerly attraction and subtract easterly attraction to the compass bearing to get the magnetic bearing.

Determining Magnetic Declination and Dip

The angle between the true meridian and the magnetic meridian is MAGNETIC DECLINATION. If the north end of the compass needle is pointing to the east of the true meridian, the declination is said to be east. If the north end of the compass needle is pointing to the west of the true meridian, the declination is said to be west. (See fig. 13-6.)

The magnetic needle aligns itself with the earth's magnetic field and points toward the earth's magnetic pole. In horizontal projections, these lines incline downward toward the north in the Northern Hemisphere and downward toward the south in the Southern Hemisphere. Since the bar takes the position parallel with the lines of force, it inclines with the horizontal. This phenomenon is the MAGNETIC DIP.

Converting Magnetic Bearings to True Bearings

When you have corrected a compass bearing for local attraction, you have a MAGNETIC BEARING. As explained previously, in most areas of the earth, a magnetic bearing differs from a true bearing by the amount of the local magnetic declination (called magnetic variation by navigators). The amount and direction of local declination are shown on maps or charts of the area in a format similar to the following: "Magnetic Declination 26°45°W (1968), Annual Increase 11´. " This means, if you are working in 1988 (20 years later), the local declination is

$$26°45' + (11' \times 20) \text{ or}$$

$$26°45' + 220' = 26°45' + 3°40' = 30°25'.$$

To convert a magnetic bearing to a TRUE BEARING, you apply the declination to the magnetic bearing in precisely the same way that you apply local attraction to a compass bearing. If the declination is east, it is added to northeast and southwest magnetic bearings, and it is subtracted from southeast and northwest magnetic bearings. If the declination is west, it is added to southeast and northwest magnetic bearings and subtracted from northeast and southwest magnetic bearings.

When you have a compass bearing and know both the local attraction and the local declination, you can go from compass bearing to true bearing in a single process by applying the ALGEBRAIC SUM of local attraction and local declination, Suppose that local attraction is 6°W and declination, 15°E. You could correct for local attraction and convert from magnetic to true in the same operation by applying a correction of 9°E to the compass bearing.

Uncorrecting and Unconverting

You correct a compass bearing to a magnetic bearing by applying the local attraction. You convert a magnetic bearing to a true bearing by applying the local declination.

At some time, you may be given a magnetic bearing and have to figure the corresponding compass bearing by using both local attraction and local declination.

The terms used to describe these calculations are, for the want of any better expressions, UNCORRECTING and UNCONVERTING. All YOU need to remember is that, when you are uncorrecting or unconverting, you apply local attraction and local declination in the REVERSE of the directions in which you apply them if you were correcting or converting.

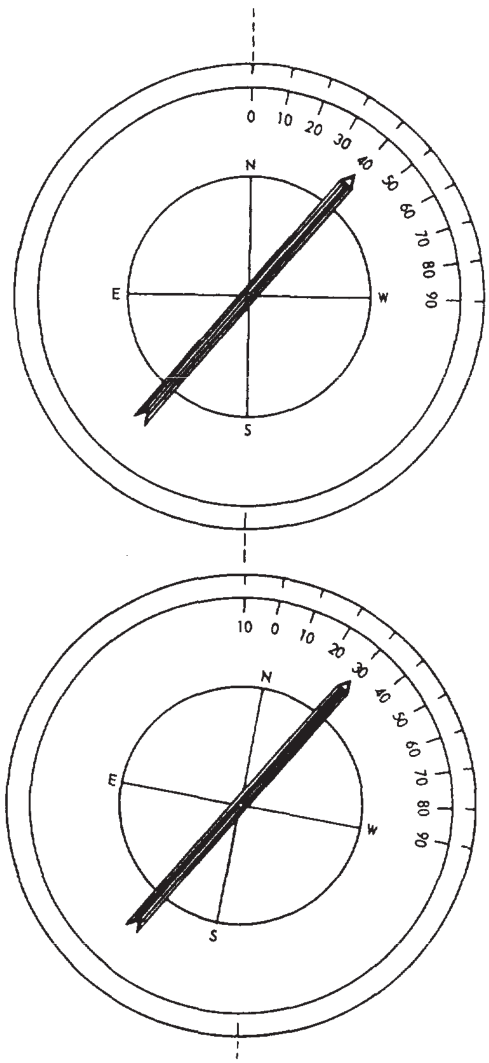


Figure 13-7.-Orienting a compass for a 10° easterly attraction.

For example, with a compass affected by a 10°W local attraction, you want to lay off a line bearing S28°W magnetic by compass. If you were correcting, you would subtract a westerly attraction in the southwest quadrant. However, for uncorrecting you ADD a westerly attraction in that quadrant. Therefore, to lay off a line bearing S28°W, you would lay off S38°W by the compass.

The same rule applies to azimuths. Suppose you have an azimuth-reading (measured from north) compass set up where local attraction is 10°W and declination is 25°E, and you want to lay off a line with true azimuth 256°. The algebraic sum of these is 15°E. For correcting or converting azimuths, you ADD easterly and SUBTRACT westerly corrections; therefore, if you were correcting or converting, you would add the 15° to 256°. Because you are uncorrecting or unconverting, however, you subtract; and, to lay off a line with true azimuth 256°, you read 241° by the compass.

Orienting a Compass

Some transit compasses and most surveyor's and forester's field compasses are equipped for offsetting local attraction, local declination, and/or the algebraic sum of the two. In figure 13-7, the upper view shows a compass bearing of N40°W on a compass presumed to be affected by a local attraction of 10°E. In this quadrant, you subtract easterly attraction; therefore, the magnetic bearing should read N30°W.

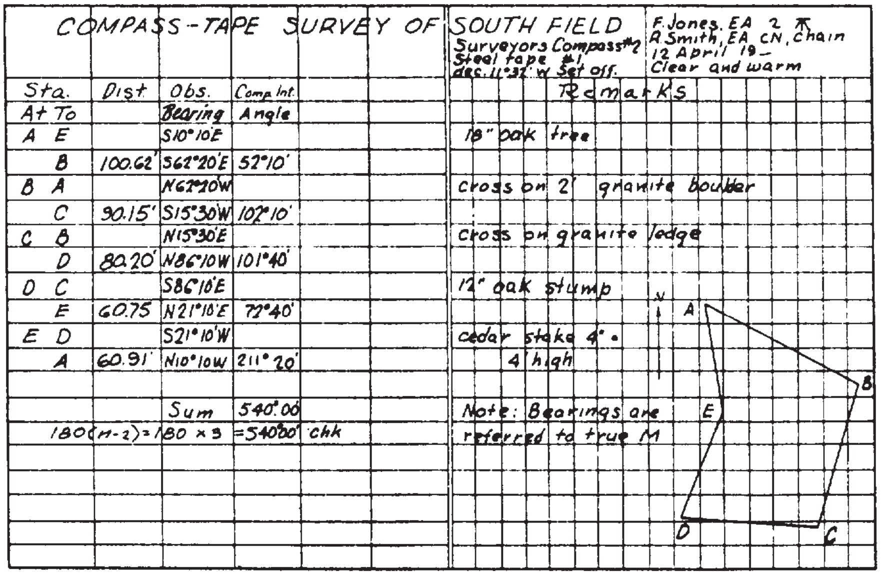
In the lower view, the same compass has been oriented for an error of 10°E by simply rotating the compass card 10°E clockwise. On most orienting compasses, the card can be released for rotating by backing off a small screw on the face of the card. Note that you now read the correct magnetic bearing of N30°W.

Conducting a Compass-Tape Survey

Figure 13-8 shows field notes from a compass-tape survey of a small field. The instrument used was a surveyor's compass. The compass was first set up at station A, shown in the sketch drawn on the remarks page. The first bearing taken was that of the line AE. This was actually the back bearing of EA, taken for the purpose of later checking against the forward bearing of EA.

Next, the bearing of AB was taken, and the distance from A to B was chained. The observed bearing (S62°20´E) was entered beside B in the column headed "Obs. Bearing." The chained distance was entered beside B in the column headed "Dist."

The compass was shifted to station B, and the back bearing of AB (that is, the bearing of BA) was taken as a check on the previously taken bearing of AB. The back bearing turned out to have, as it should have, the same numerical value (62°20´) as the forward bearing. A difference in the two would indicate either an inaccuracy in reading one bearing or the other or a difference in the strength of local attraction.



COMPASS-TAPE SURVEY OF SOUTH FIELD

Surveyors Compass #2, Steel tape #1, dec. 11°32' W Set off.

F. Jones, EA 2 ∧ ; R. Smith, EA CN, Chain; 12 April 19—; Clear and warm

Sta. At	To	Dist.	Obs. Bearing	Comp. Int. Angle	Remarks
A	E		S10°10'E		18" oak tree
	B	100.62'	S62°20'E	52°10'	
B	A		N62°20'W		cross on 2' granite boulder
	C	90.15'	S15°30'W	102°10'	
C	B		N15°30'E		cross on granite ledge
	D	80.20'	N86°10'W	101°40'	
D	C		S86°10'E		12" oak stump
	E	60.75	N21°10'E	72°40'	
E	D		S21°10'W		cedar stake 4" •
	A	60.91'	N10°10'W	211°20'	4' high
			Sum	540°00'	Note: Bearings are
180(n-2)=	180 × 3			=540°00' chk	referred to true N

Figure 13-8.-Sample field notes from a compass-tape survey.

Proceeding in this fashion, the party took bearings and back bearings, and chained distances all the way around to the starting point at station A. The last forward bearing taken, that of EA, has the same numerical value as the back bearing of EA (bearing of AE) taken at the start.

Checking Accuracy of Observed Bearings

As a check on the accuracy of the whole bearing-reading process, the size of the interior angle at each station was computed from the observed bearings by the method previously described for converting bearings to interior angles. The sizes of these angles were entered in the column headed "Comp. Int. Angle," and the sum was entered below.

The sum of the interior angles in a closed traverse should equal the product of 180° (n – 2), n being the number of traverse lines in the traverse. In this case, the traverse has five lines; therefore, the sum of the interior angles should be

$$180°(5 - 2) = 180° \times 3 = 540°.$$

The computed sum is, therefore, the same as the added sum of the angles converted from observed bearings.

Recognizing, Reducing, and Correcting Compass Errors

If a magnetic compass has a bent needle, there will be a constant instrumental error in all observed bearings and azimuths. To check for this condition, set up and level the compass, wait for the needle to cease oscillating, and read the graduation indicated at each end of the needle. If the compass is graduated for bearings, the numerical value at each end of the needle should be the same. If the compass is graduated for azimuths, the readings should be 180° apart.

Similarly, if the pivot supporting the needle on a magnetic compass is bent, there will be an instrumental error in the compass. However, this error, instead of being the same for all readings, will be variable.

You, can eliminate either of these instrumental errors by reading both ends of the needle and using the average between them. Suppose, for example, that with a compass graduated for bearings you read a bearing of N45°E and a back bearing of S44°W. You would use the average, or

$$1/2\ (45° + 44°) = N44°30'E.$$

The error in the compass should, of course, be corrected as soon as possible. Normally, this is a job for an expert. Remember the cause of a discrepancy in the reading at both ends when there is one. It is more probable that the needle, rather than the pivot, is bent. After a bent needle has been straightened, if a discrepancy still exists, then probably the pivot is bent too.

If a compass needle is sluggish—that is, if it moves unusually slowly in seeking magnetic north—it will probably come to rest a little off the magnetic meridian. The most common cause of sluggishness is weakening of the magnetism of the needle. A needle may be demagnetized by drawing it over a bar magnet. The needle should be drawn from the center of the bar magnet toward the end, with the south end of the needle drawn over the north end of the magnet and vice versa. On each return stroke, lift the needle well clear of the magnet.

Sometimes the cause of a sluggish needle is a blunt point on the pivot. This may be corrected by sharpening the pivot with a fine file.

If the compass is not level when a bearing or azimuth is being read, the reading will be incorrect. A similar error will exist if the compass is equipped with sighting vanes and one or more of them are bent. To check for bent compass vanes, you set up and level the compass, and then sight with the vanes on a plumb bob cord.

The most common personal error the observer can make in compass work is MISREADING. This is caused by the observer's eye not being vertically above the compass at the time of the reading. Other common mistakes are reading a needle at the wrong end and setting off local attraction or declination in the wrong direction when the compass is being oriented.

ESTABLISHING DIRECTIONS BY TRANSIT

Directions are similarly determined by the use of a transit. This can be done by measuring the size of the horizontal angle between the line whose direction is sought and a reference line. With a transit, however, you are expected to do this with considerably more accuracy and precision than with a surveyor's compass. Some of the basic procedures associated with the proper operation of the instrument will be discussed in the following paragraphs.

Setting Up the Transit

The point at which the line of sight, the horizontal axis, and the vertical axis of a transit meet is called the INSTRUMENT CENTER. The point on the ground over which the center of the instrument is placed is the INSTRUMENT POINT, TRANSIT POINT, or STATION. A wooden stake or hub is usually marked with a tack when used as a transit station or point. To prevent jarring or displacement of the transit, avoid those stations having loose planking, those having soft or marshy ground, and those having other conditions that would cause the legs of the tripod to move. The following steps are recommended when you are setting up a transit over a station point:

1. Center the instrument as closely as possible over the definite point by suspending a plumb line from a hook and chain beneath the instrument. The plumb string is tied with a slipknot, so that you can adjust the height of the plumb.
2. Move the tripod legs as necessary until the plumb bob is about 1/4 in. short of being over the tack, meanwhile maintaining a fairly level foot plate. Spread the tripod legs, and apply sufficient pressure to the legs to make sure of their firmness in the ground. Make sure to loosen the wing nuts to rid the static pressure in them before retightening.
3. Turn the plates so that each plate level is parallel to a pair of opposite leveling screws. (It is common practice to have a pair of opposite leveling screws in line with the approximate line of sight.) The leveling screws are then tightened to firmness, but not tight. Rotate opposing pairs of leveling screws either toward each other or away from each other until the plate bubbles are centered.

If the plumb bob is not directly over the center of the tack, you may loosen two adjacent leveling screws enough to free the shifting plate. Relevel the instrument if the bubbles become off-center. During breezy conditions, you may shield the plumb line with your body when setting up an instrument. Sometimes in windy locations, it may be necessary to construct a wind shield.

Setting and leveling the transit rapidly requires a skill on your part that you will learn and develop through consistent practice. You should take advantage of any opportunity that you can to train yourself and increase your skills in handling surveying instruments. Again, when setting up or operating a transit, you should remember the following points:

1. The plate bubble follows the direction of the left thumb when you are manipulating the leveling screws.
2. You should always check to see if the plumb bob is still over the point after leveling it. If the plumb bob has shifted, you should recenter the instrument.
3. While loosening the two adjacent leveling screws, you can shift the transit head laterally.

4. You should always maintain contact between the leveling screw shoes and the foot plate.

5. You should not disturb the setup of the instrument until you are certain that all observations at that point are completed and roughly checked. You should move the instrument from that setup only after checking with the party chief.

6. Before the transit is moved or taken up, you should center the instrument on the foot plate, roughly equalize the height of the leveling screws, clamp the upper motion (the lower motion may be tightened lightly), and point the telescope vertically upward and also lightly tighten the vertical motion clamp.

Measuring Horizontal Angles

The transit contains a graduated horizontal circle, referred to as the horizontal limb. The horizontal limb may be graduated clockwise from 0° through 360°, as shown in figure 13-9, view A, or clockwise from 0° through 360° and also in quadrants, as shown in figure 13-9, view B; or both clockwise and counterclockwise from 0° through 360°, as shown in figure 13-9, view C.

The horizontal limb can be clamped to stay fast when the telescope is rotated (called clamping the lower motion), or it can be released for rotating by hand (called releasing the lower motion).

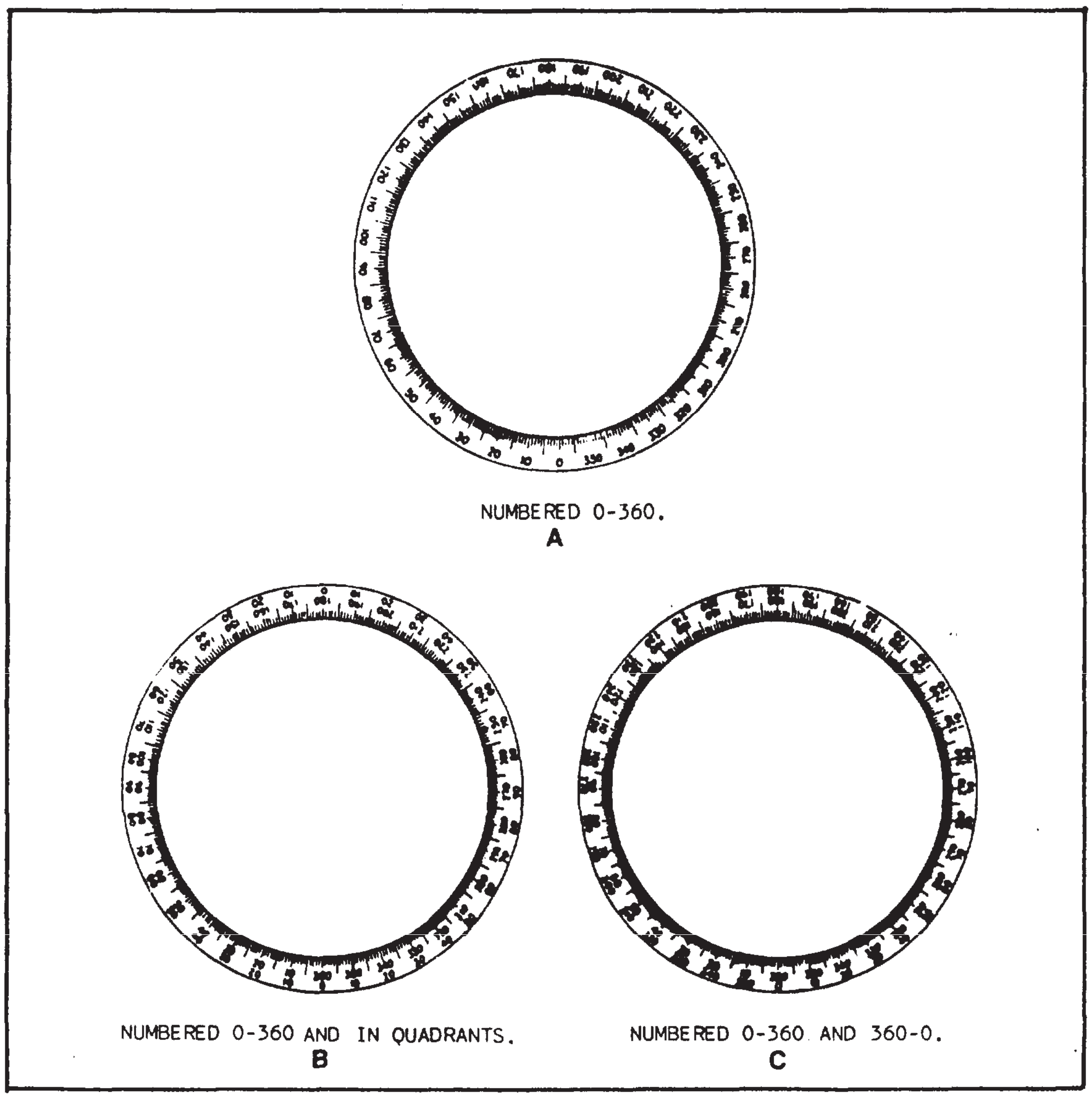


Figure 13-9.-Three types of horizontal limb graduations.

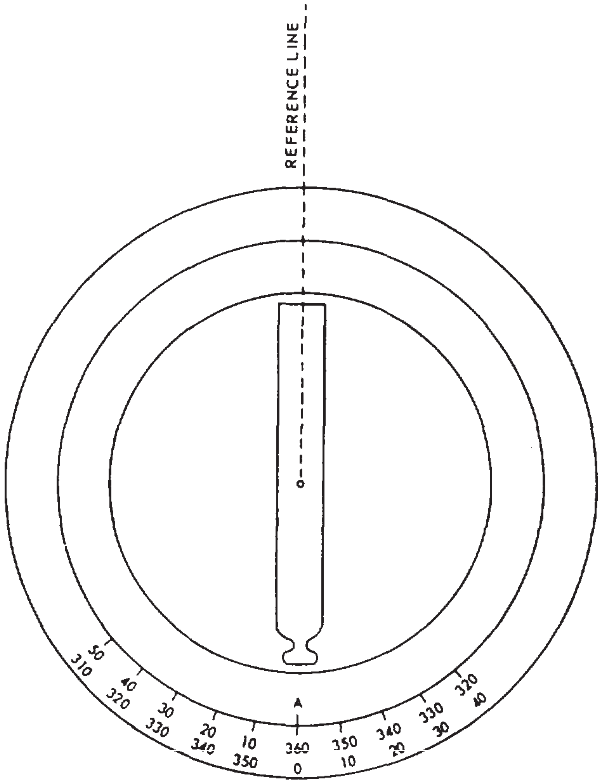


Figure 13-10.-Setting the vernier at zero-zero.

The horizontal limb is paired with another circle (the vernier plate), which is partially graduated on either side of zero graduations located 180° apart on the plate. When the telescope is in the normal (upright) position, the A vernier is located vertically below the eyepiece, and the B vernier, below the objective end of the telescope. The zero on each vernier is the indicator for reading the sizes of horizontal angles turned on the horizontal limb.

Figures 13-10 and 13-11 illustrate the method of turning an angle of 30° from a reference line with a transit.

1. With the transit properly set over the point or station, bring one of the horizontal verniers near zero by hand; clamp the upper motion; and, by turning the upper tangent screw, set one vernier at 0°, usually starting with the A vernier (fig. 13-10). Train the telescope to sight the marker (range pole, chaining pin, or the like) held on the reference line; clamp the lower motion; and, by using the lower tangent screw, set the line of sight on the marker.

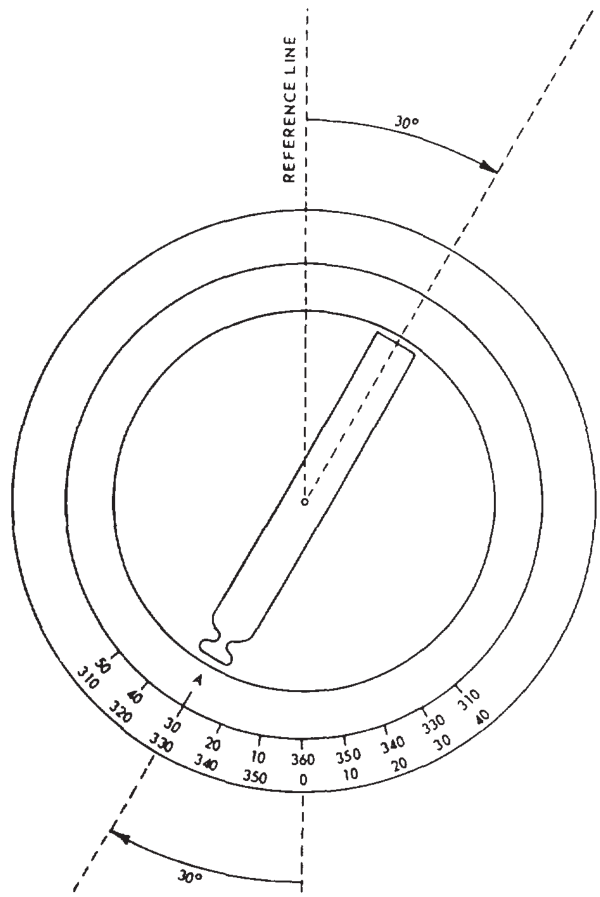


Figure 13-11.-Setting an angle exactly on the vernier zero.

2. Release the upper motion and rotate the telescope to bring the zero on the A vernier in line with th3 30° graduation on the horizontal limb, as shown in figure 13-11. To set the vernier exactly at 30°, use the upper tangent screw. You may use a magnifying glass to set the vernier easily and accurately.

3. Mark the next point with a marker, and follow the procedures for establishing a point or station.

Similarly, you may use the procedures above to measure a horizontal angle by sighting on two existing points and reading their interior angle. In addition, the following hints may help you when you are taking horizontal measurements:

1. Make the centering of the line of sight as close as possible by hand so that you will not turn the tangent screw more than one or two turns. Make the last turn of the tangent screw clockwise to compress the opposing springs.

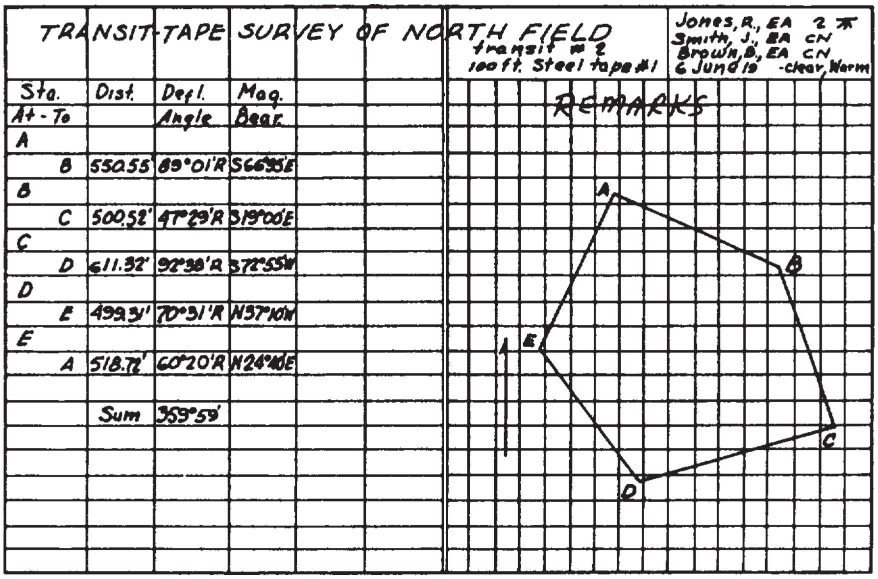


Figure 13-12.-Sample field notes from a deflection angle transit-tape survey.

2. Read the vernier with the eye directly over the top of the coinciding graduations to eliminate the effects of parallax.

3. Take the reading of the other vernier as a check. The readings should be 180° apart.

4. Check the plate bubbles before measuring an angle to see if they are centered, but do not disturb the leveling screws between the initial and final settings of the line of sight. If an angle is measured again, the plate may be releveled after each reading before sighting again on the starting point.

5. Make sure that the rodman is holding the range pole truly vertical when you sight at it. When the bottom of the range pole is not visible, let the rodman use a plumb bob.

6. Avoid accidental movement of the horizontal circle; for instance, moving the wrong clamp or tangent screw. If a number of angles will be observed from one setup without moving the horizontal circle, you should sight at some clearly defined distant object that will serve as a reference mark and take note of the angle. Occasionally, you should recheck the reading to this point during measurement to see if there is any accidental movement.

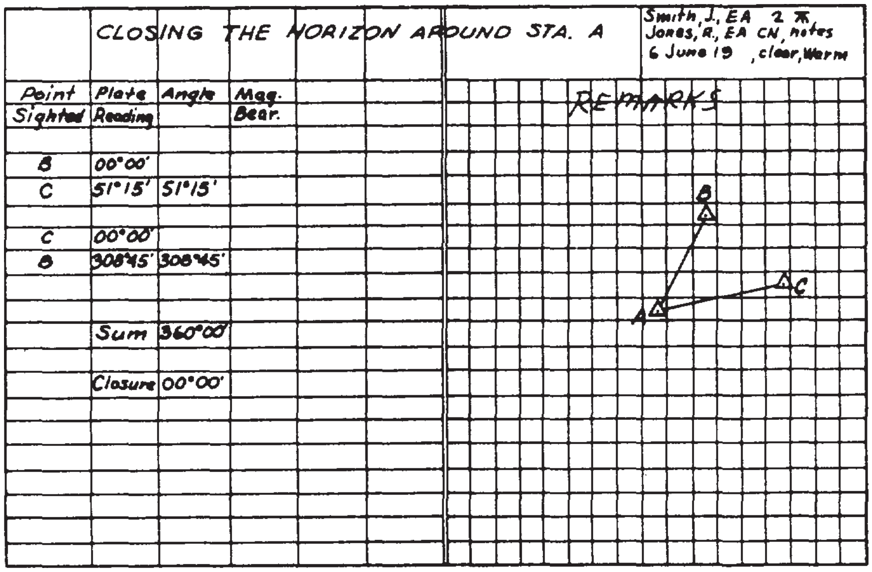
An example of a horizontal deflection angle measurement is shown in figure 13-12. The field notes contain data taken from a loop traverse shown in the sketch. The transit was first set up at station A, and the magnetic bearing of AB was read on the compass. Then the deflection angle between the extension of EA and AB was turned in the following manner:

1. The instrumentman released both clamps, matched the vernier to zero by hand, tightened the upper motion clamp, and set the zero exactly with the upper tangent screw.

2. With the telescope plunged (inverted position), the instrumentman sighted the range pole held on station E. Then he tightened the lower motion clamp and manipulated the lower motion tangent screw to bring the vertical cross hair to exact alignment with the range pole.

3. The instrumentman replunged the telescope and trained on the extension of EA. (Notice that the telescope is in its normal position now.) He then released the upper motion and rotated the telescope to the right until the vertical cross hair came into line with the range pole held on station B. He further set the upper motion clamp screw and brought the vertical cross hair into exact alignment with the range pole by manipulating the upper motion tangent screw.

4. The instrumentman then read the size of the deflection angle on the A vernier (89°01´). Since the angle was turned to the right, he recorded 89°01´R in the column headed "Defl. Angle." Likewise, he recorded the chained distance between stations A and B and the magnetic bearing of traverse line AB under their appropriate headings.



CLOSING THE HORIZON AROUND STA. A

Smith, J., EA 2 ⊼,
Jones, R., EA CN, notes
6 June 19 , clear, Warm

Point Sighted	Plate Reading	Angle	Mag. Bear.
B	00°00'		
C	51°15'	51°15'	
C	00°00'		
B	308°45'	308°45'	
	Sum	360°00'	
	Closure	00°00'	

Figure 13-13.-Sample field notes for closing the horizon.

The instrumentman used the same method at each traverse station, working clockwise around the traverse to station E. Note that the algebraic sum of the measured deflection angle (angles to the right considered as plus, to the left as minus) is 350°59´. For a closed traverse, the algebraic sum of the deflection angles from the standpoint of pure geometry is 360°00´. Therefore, there is an ANGULAR ERROR OF CLOSURE here of 0°01´. This small error would probably be considered a normal error. A large variance would indicate a larger mistake made in the measurements.

In the example just presented, the general accuracy of all the angular measurements was checked by comparing the sum of the deflection angles with the theoretical sum. The accuracy of single angular measurement can be checked by the, procedure CLOSING THE HORIZON. The method is based on the fact that the theoretical sum of all the angles around a point is 360°00´.

The field notes in figure 13-13 show the procedure for closing the horizon. The transit was set up at station A, and angle BAC was turned, measuring 51°15´. Then the angle from AC clockwise around to AB was turned, measuring 308°45´. The sum of the two angles is 360°00´. The angular error of closure is therefore 0°00´, meaning that perfect closure is obtained.

Measuring Vertical Angles

The vertical circle and the vertical vernier of a transit were discussed in chapter 11 of this training manual. They are used for measuring vertical angles.

A vertical angle is the angle measured vertically from a horizontal plane of reference. (See fig. 13-14, view A.) When the telescope is pointed in the horizontal plane (level), the value of the vertical angle is zero. When the telescope is pointed up at a higher feature (elevated), the vertical angle increases from zero and is a PLUS VERTICAL ANGLE or ANGLE OF ELEVATION. These values increase from 0° to +90° when the telescope is pointed straight up.

As the telescope is depressed (pointed down), the angle also increases in numerical value, A depressed telescope reading, showing that it is below the horizontal plane, is a MINUS VERTICAL ANGLE or ANGLE OF DEPRESSION. These numerical values increase from 00 to –90° when the telescope is pointed straight down.

To measure vertical angles, you must set the transit upon a definite point and level it. The plate bubbles must be centered carefully, especially for transits that have a fixed vertical vernier. The line of sight is turned approximately at the point; the horizontal axis is clamped. Then, the horizontal cross hair is brought exactly to the point by means of the telescope tangent screw. The angle is read

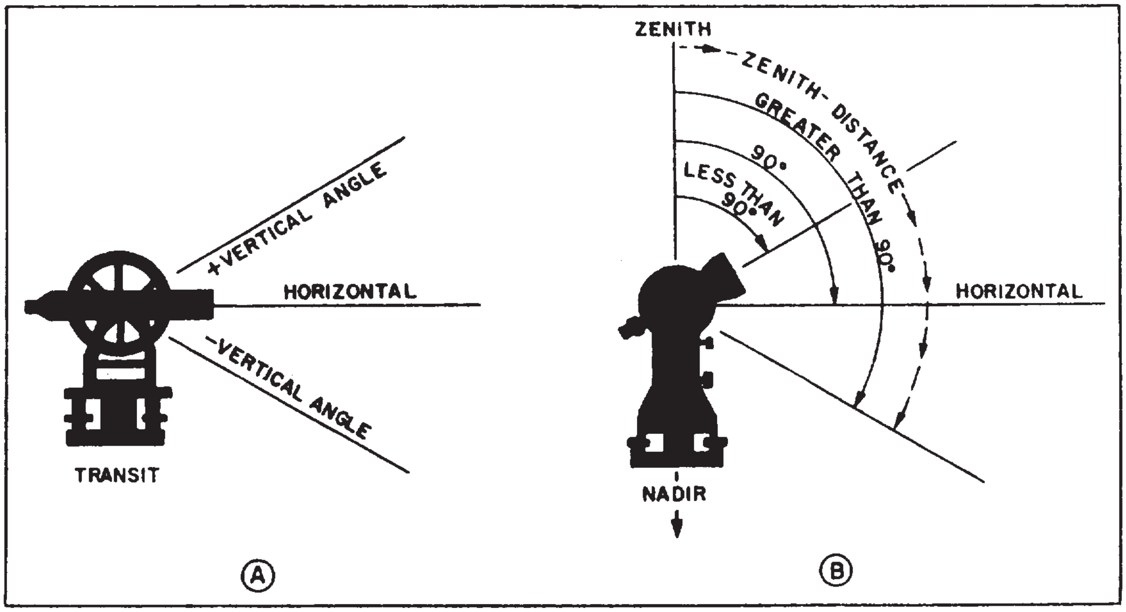


Figure 13-14.-Vertical angles and zenith distances.

on the vertical limb by means of the vertical vernier.

On a transit with a movable vertical vernier, the vernier is equipped with a control level. The telescope is centered on the point as described above, but the vernier bubble is centered before the angle is read.

The ZENITH is an imaginary point overhead where the extension of the plumb line will intersect an assumed sphere on which the stars appear projected. The equivalent point, directly below the zenith, is the NADIR. Use of the zenith permits reading angles in a vertical plane without using a plus or a minus. Theodolites have a vertical scale reading zero when the telescope is pointed at the zenith instead of in a horizontal plane. With the telescope in a direct position and pointed straight up, the reading is 0°; on a horizontal line, the reading is 90°; and straight down, 180°. When measuring vertical angles with the theodolites (fig. 13-14, view B), you should read the angle of elevation with values less than 90°and the angle of depression with values greater than 90°. These angle measurements with the zenith as the zero value are called the ZENITH DISTANCES. DOUBLE ZENITH DISTANCES are observations made with the telescope direct and reversed to eliminate errors caused by the inclination of the vertical axis and the collimation of the vertical circle.

Zenith distance is used in measuring vertical angles involving trigonometric leveling (discussed in the next chapter) and in astronomical observations. (See Engineering Aid 1 & C, NAVEDTRA 10635-C.)

Measuring Angles by Repetition

You may recall, from a previous discussion, the distinction between precision and accuracy. A transit on which angles can be measured to the nearest 20 sec is more precise than one that can measure only to the nearest 1 min. However, this transit is not necessarily more accurate.

The inherent angular precision of a transit can be increased by the process of REPETITION. To illustrate this principle, suppose that with a 1-min transit you turn the angle between two lines in the field and read 45°00´. The inherent error in the transit is 1´; therefore, the true size of this angle is somewhere between 44°59´30´´ and 45°00´30´´.

For example, when using repetition, you leave the upper motion locked but release the lower motion. The horizontal limb will now rotate with the telescope, holding the reading of 45°00´. You plunge the telescope, train again on the initial line of the angle, and again turn the angle. You have now doubled the angle. The A vernier should read approximately 90°00´.

For this second reading, the inherent error in the transit is still 1 min, but the angle indicated

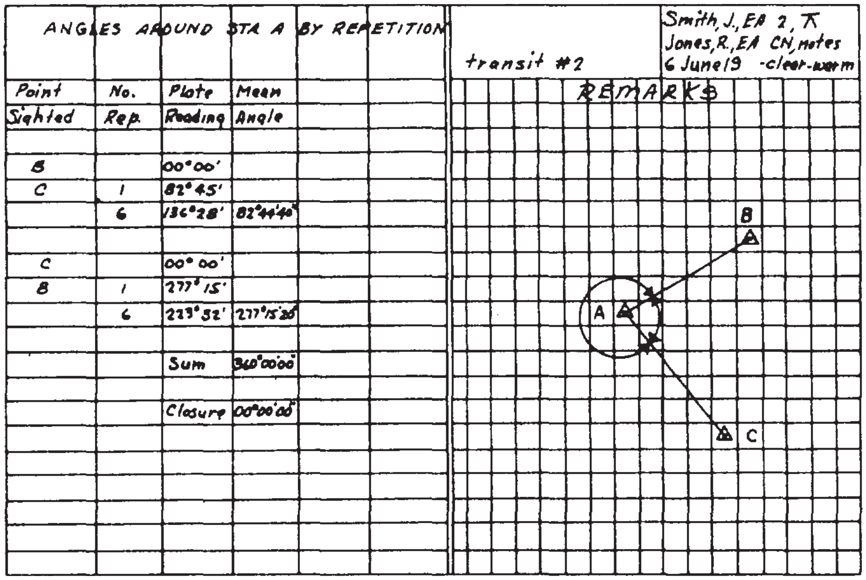


Figure 13-15.-Notes for the angle around a station, repeated six times.

on the A vernier is about twice the size of the actual angle measured. The effect of this is to halve the total possible error. This error was originally plus or minus 30 sec. Now, the error is plus or minus only 15 sec.

If you measure this angle a total of six times, the total possible error will be reduced to one-sixth of 30 see, or plus or minus 5 sec. In theory, you could go on repeating the angle and increasing the precision indefinitely. In actual practice, because of lost motion in the instrument and accidental errors, it is not necessary to repeat the angle more than six times.

The observation may be taken alternately with the telescope plunged before each subsequent observation. But a much simpler way is to take the first half of the observations with the telescope in the normal position, the other half, in an inverted position. In the example given above, the first three readings may be taken when the telescope is in its normal position; the last three when it is in its reversed position. To avoid the effect of tripod twist, after each repetition, rotate the instrument on its lower motion in the same direction that it was turned during the measurement; that is, the direction of movement should always be either clockwise or counterclockwise.

Measuring angles by repetition eliminates certain possible instrumental errors, such as those caused by eccentricity and by nonadjustment of the horizontal axis.

Figure 13-15 shows field notes for the angle around a station, repeated six times. The angle BAC was measured six times, and the angle closing the horizon around station A was also measured six times. The first measurement is not a true repeat, but it is counted as one in the column headed “No. Rep.” (number of repetitions).

With the transit first trained on B and the zeros matched, the plate reading was 00°00´. This is recorded beside B in the column headed “Plate Reading.” The upper motion clamp was then released, the telescope was trained on C, and a plate reading of 82°45´ was obtained. This reading is recorded next to the figure “1” (for “1st repetition”) in the column headed “No. Rep.” The measurement of angle BAC was then repeated five more times. After the final measurement, the plate reading was 136°28´. This plate reading is recorded as the sixth repetition.

Now to get the mean angle, it is obvious that you need to divide some number, or figure, by the total number of repetitions. The question is, what figure? To determine this, you first multiply the initial measurement by the total number of repetitions. In this case, this would be as follows:

$$82°45' \times 6 = 496°30'.$$

Next, you determine the largest multiple of 360° that can be subtracted from the above product. Obviously, the only multiple of 360° that can be subtracted from 496°30´ is 360°. This multiple is then added to the final measurement to obtain the figure that is to be divided by the total number of repetitions. In this example,

$$136°28' + 360° = 496°28'.$$

The mean angle then is

$$496°28' \div 6 = 82°44'40''.$$

Enter this in the column headed "Mean Angle."

The following computation shows that you should use the same method to obtain the mean closing angle.

$$277°15' \times 6 = 1663°30'$$

$$360° \times 4 = 1440° \text{ (largest multiple of } 360°)$$

$$223°32' + 1440° = 1663°32'$$

$$1663°32' \div 6 = 277°15'20''$$

In the example shown above, the sum of the mean angle (82°44´40´´) and the mean closing angle (277°15´20´´) equals 360°00´00´´. This reflects perfect closure. In actual practice, perfect angle closure would be unlikely.

RUNNING A DISTANCE (LINE)

It is often necessary to extend a straight line marked by two points on the ground. One of the methods discussed below may be used depending on whether or not there are obstacles in the line ahead, and, if so, whether the obstacles are small or large.

Double Centering or Double Reversing

This method is used to prolong or extend a line. Suppose you are extending line AB, shown in figure 13-16. You set up the transit at B, backsight on A, plunge the telescope to sight ahead, and set the marker at C´. With the telescope still inverted, you again sight back on A; but this time do it by rotating the telescope through 180°. You then replunge the telescope and mark the point C´´. Mark the point C halfway between C´ and C´´. This is the point on the line

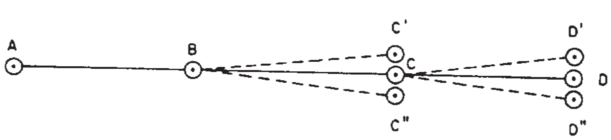


Figure 13-16.-Double centering.

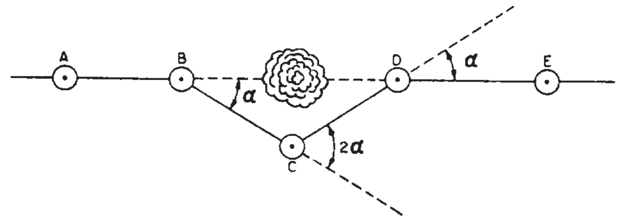


Figure 13-17.-Bypassing a small obstacle by the angle offset method.

AB you need to extend. If the instrument is in perfect adjustment (which seldom happens), points C´ and C´´ will coincide with point C. For further extension, the instrument is moved to C and the procedure repeated to obtain D.

Bypassing an Object by Angle Offset

This method is applied when a tree or other small obstacle is in the line of sight between two points. The transit or theodolite is set up at point B (fig. 13-17) as far from the obstacle as practical. Point C is set off the line near the obstacle and where the line BC will clear the obstacle. At B, measure the deflection angle a. Move the instrument to C, and lay off the deflection angle 2a. Measure the distance BC, and lay off the distance CD equal to BC. Move the instrument to D, and lay off the deflection angle α. Mark the point E. Then, line DE is the prolongation of the line AB.

Bypassing an Object by Perpendicular Offset

This method is used when a large obstruction, such as a building, is in the line of sight between two points. The solution establishes a line parallel to the original line at a distance clear from the obstacle, as shown in figure 13-18. The instrument

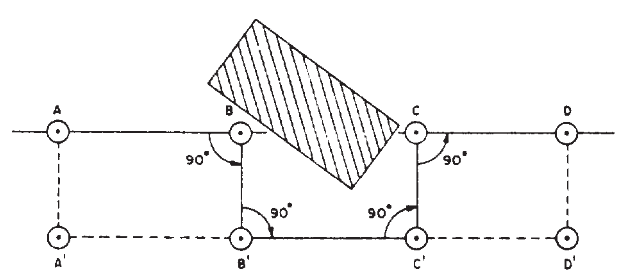


Figure 13-18.-Bypassing a large obstacle by the perpendicular offset method.

is set up at B, and a 90° angle is turned from line AB. The distance BB´ is carefully measured and recorded. The instrument is moved to B´, and another 90° angle is turned. B´C´ is laid off to clear the obstacle. The instrument is moved to C, and a third 90° angle is turned. Distance CC´, equal to BB´, is measured and marked. This establishes a point C on the original line. The instrument is moved to C, and a fourth 90° angle is turned to establish the alignment CD that is the extension of AB beyond the obstacle.

When the distance to clear the obstacle, BB´ or CC´, is less than a tape length, you can avoid turning four 90° angles as follows: Erect perpendicular offsets from points A and B in figure 13-18 so that AA´ equals BB´. Set up the instrument at B', and measure angle A´B´B to be sure that it's 90°. Extend line A´B´ to C´ and then to D´, making sure that point C clears the obstacle. Then, lay off perpendicular offset C´C equal to AA´ or BB´ and perpendicular offset D´D equal to C´C. Then, line CD is the extension of line AB. The total distance of the line AD is the sum of the distances AB, B´C´, and CD.

You also compute the diagonals formed by the end rectangles and compare the result to the actual measurement, if you can, as a further check.

Line Between Nonintervisible Points

Sometimes you need to run a straight line between nonintervisible points when events make the use of the above methods of bypassing an obstacle impractical. If there is an intermediate point on the straight line from which both of the end points can be observed, the method called BALANCING IN (also called BUCKING IN, JIGGLING IN, WIGGLING IN, or RANGING IN) may be used.

A problem often encountered in surveying is to find a point exactly on the line between two other points when neither can be occupied or when an obstruction, such as a hill lies between the two points. The point to be occupied must be located so that both of the other points are visible from it. The process of establishing the intermediate point is known as wiggling in or ranging in.

The approximate position of the line between the two points at the instrument station is first estimated by using two range poles. The range poles are lined in alternately in the following manner. In figure 13-19, view A, set range pole 1 and move range pole 2 until it is exactly on line between pole 1 and point A. You do this by sighting along the edge of pole 1 at the station *A* until pole 2 seems to be on line. Set range pole 2 and move pole 1 until it is on line between pole 2 and point C. Now, move pole 2 into line again, then pole 1, alternately, until both are on line AC. The line will appear to pass through both poles and both stations from either viewing position.

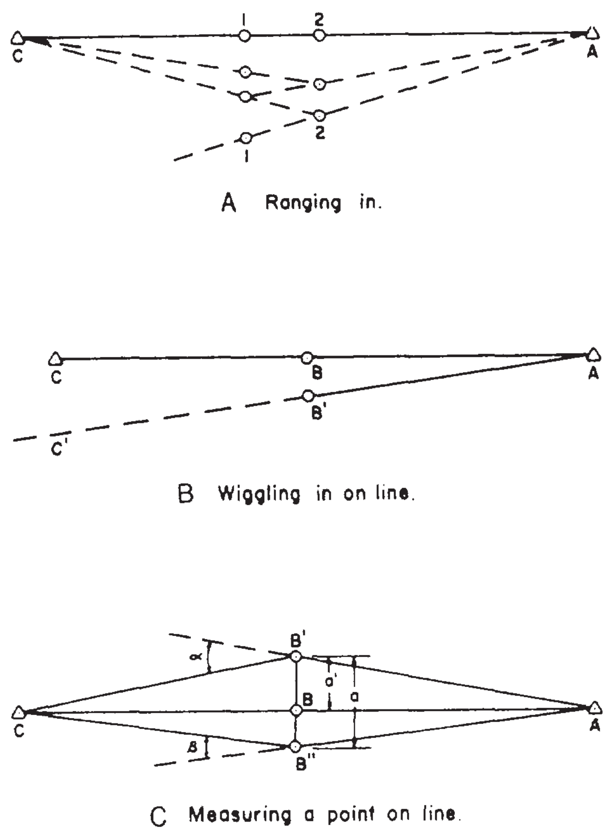


Figure 13-19.-Setting up on a line between two points.

After finding the approximate position of the line between the two points, you set up the instrument on this line. The instrument probably will not be exactly on line, but will be over a point, such as *B´,* (see fig. 13-19, view B). With the instrument at *B´*, you backsight on A and plunge the telescope and notice where the line of sight *C* passes the point C. Estimate this distance CC´ and also the distance that *B´* would be away from C and A. Estimate the amount to move the instrument to place it on the line you need. Thus, if *B´* is midway between *A* and C, and C´ misses *C* by 3 feet to the left, *B´* must be moved about 1.5 feet to the right to reach *B*. Continue the sequence of backlighting, plunging the telescope, and moving the instrument until the line of sight

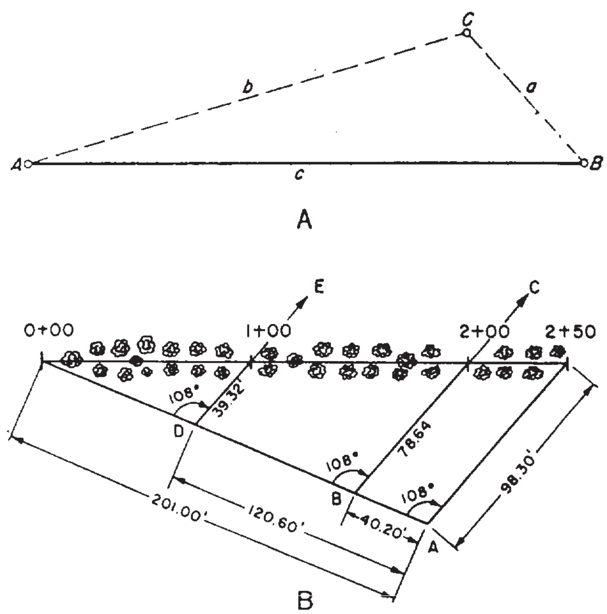


Figure 13-20.-Random line method of locating intermediate stations.

passes through both *A* and *C*. When you do this, the telescope is reversed, but the instrument is not rotated. This means that if the telescope is reversed for backlighting on *A,* all sightings on *A* are made with the telescope reversed. Mark a point on the ground directly under the instrument. Then, you continue to use this method with the telescope direct for each backsight on *A*. Mark a second point on the ground. The point you need on the line *AC* is then the midpoint between the two marked points.

The method outlined above is usually time consuming. Even though the shifting head of the instrument is used in the final instrument movements, you may have to pick up and move the instrument several times. The following method often saves time. After finding the approximate position of the line between the two points, you mark two points *B´* and *B´´*, (fig. 13-19, view C), 1 or 2 feet apart where you know they straddle the line *AC*. Set up over each of these two points in turn and measure the deflection angles α and β. Also measure the horizontal distance a, between points *B´* and B´´. Then you can find the position *B* on the line *AC* by using the following equation:

$$a' = a \frac{\alpha}{\alpha + \beta}$$

in which a' is the proportionate offset distance from *B´* toward B´´ for the required point *B,* and α and β are both expressed in minutes or in seconds.

RANDOM LINE

It is sometimes necessary to run a straight line from one point to another point that is not visible from the first point. If there is an intermediate point on the line from which both end-points are visible, this can be done by the balancing-in method described previously. If no such intermediate point exists, the RANDOM LINE method illustrated in figure 13-20, view A may be used.

The problem here is to run a line from A to B, B being a point not visible from A. It happens, however, that there is a clear area to the left of the line AB, through which a random line can be run to C; C being a point visible from A and B.

To train a transit set up at A on B, you must know the size of the angle at A, You can measure side b and side a, and you can measure the angle at C. Therefore, you have a triangle in which you know two sides and the included angle. You can solve this triangle for angle A by (1) determining the size of side c by the law of cosines, then determining the size of angle A by the law of sines, (2) solving for angle A by reducing to two right triangles.

Suppose you find that angle A measures 16°35´. To train a transit at A on B, you would simply train on C and then turn 16°35´ to the right.

You may also use the random line method to locate intermediate stations on a survey line, In figure 13-20, view B, stations 0 + 00 and 2 + 50, now separated by a grove of trees, were placed at some time in the past. You need to locate stations 1 + 00 and 2 + 00, which lie among the trees.

Run a line at random from station 0 + 00 until you can see station 2 + 50 from some point, A, on the line. The transitman measures the angle at A and finds it to be 108°00´. The distances from A to stations 0 + 00 and 2 + 50 are chained and found to be 201.00 ft and 98.30 ft. With this information, it is now possible to locate the intermediate stations between stations

0 + 00 and 2 + 50. The distances AB and AD can be computed by ratio and proportion, as follows:

$$AB = \frac{50}{250} \times 201.0 = 40.20 \text{ ft}$$

$$\text{and } AB = \frac{150}{250} \times 201.0 = 120.60 \text{ ft.}$$

These distances are laid off on the random line from point A toward station 0 + 00. The instrumentman then occupies points B and D; turns the same angle, 108°00´, that he measured at point A; and establishes points C and E on lines from points B and D through the stations being sought. The dist antes are computed by similar triangles as follows:

$$\text{B to station } 2 + 00(\text{BC}) = \frac{200}{250} \times 98.3 \text{ ft} = 78.64 \text{ ft}$$

$$\text{D to station } 1 + 00(\text{DE}) = \frac{100}{250} \times 98.3 \text{ ft} = 39.32 \text{ ft}$$

TYING IN A POINT

Determining the horizontal location of a point or points with reference to a station, or two stations, on a traverse line is commonly termed *TYING IN THE POINT*. Various methods used in the process are presented in the next several paragraphs.

Locating Points by Swing Offsets

The SWING OFFSET is used for locating points close to the control lines (fig. 13-21). Measurement of a swing offset distance provides an accurate determination of the perpendicular

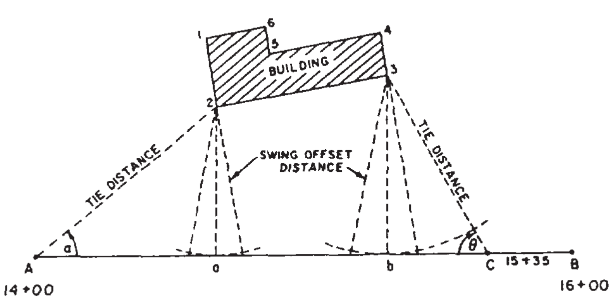


Figure 13-21.-Swing offset method of locating points.

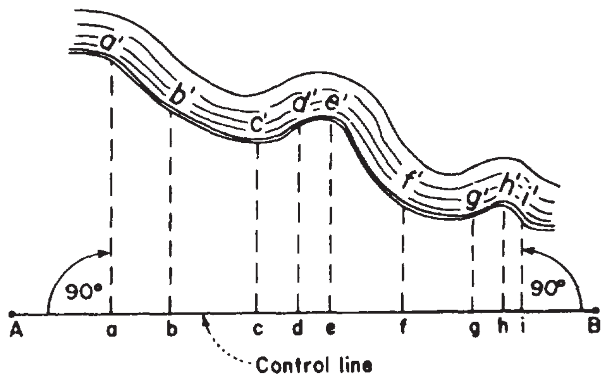


Figure 13-22.-Perpendicular offsets.

distance from the control line to the point being located. The swing offset is somewhat similar to the range tie (explained later), but as a rule, requires no angle measurement. To determine the swing offset distance, a chainman holds the zero mark of the tape at a corner of the structure while another chainman swings an arc with the graduated end of the tape at the transit line AB. When the shortest reading on the graduated end of the tape is observed, the swing offset or perpendicular distance to the control line is obtained at points a or b. In addition, the horizontal distances between the instrument stations (A and B) and the swing offset points (a and b) maybe measured and marked. A tie distance and angle α or Φ may be measured from either instrument station to the corner of the structure to serve as a check.

Locating Points by Perpendicular Offsets

The method of PERPENDICULAR OFFSETS from a control line (fig. 13-22) is similar to swing offsets. This method is more suitable than the swing offset method for locating details of irregular objects, such as stream banks and winding roads. The control line is established close to the irregular line to be located, and perpendicular offsets, aa´, bb´, cc´, and so on, are measured to define the irregular shape. When the offset distances are short, the 90° angles are usually estimated; but when the distances are several hundred feet long, the angles should be laid off with an instrument. The distances to the offset points from a to i are measured along the control line.

Locating Points by Range Ties

A point's location can also be determined by means of a RANGE TIE, using an angle and a

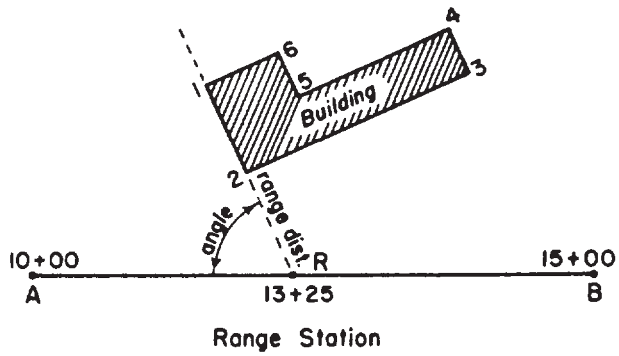


Figure 13-23.-Range ties.

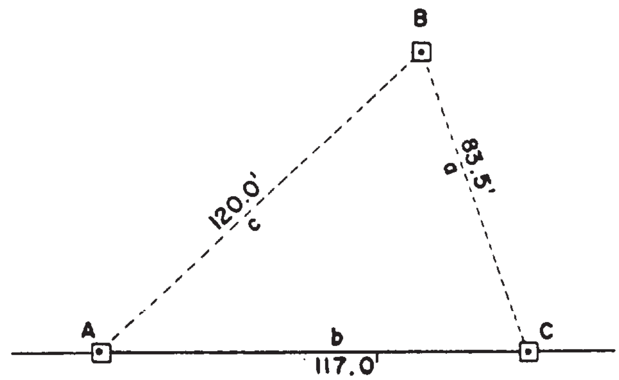


Figure 13-24.-Locating a point by distances from two stations.

distance. The method requires extra instrument manipulation and should be used only when none of the previous methods are satisfactory for use. Actually, range ties establish not only the corner of a structure but also the alignment of one of the sides. In figure 13-23, assume that the building is not visible from either A or B or that either or both of the distances from A to B to a corner of the building cannot be measured easily. With the instrument set up at either A or B and the line AB established, one member of the party moves along AB until he reaches point R, which is the intersection of line 1-2 extended. The instrument is moved and set up on R, and the distance along the line AB to R is measured. An angle measurement to the building is made by using either A or B as the backsight. The range distance, R-2, is measured as well as the building dimensions.

SETTING ADJACENT POINTS

"To set a point adjacent to a traverse line" means to establish the location of a point by following given tie data. This tie data may be (1) a perpendicular offset distance from a single specified station, (2) angles from two stations, or (3) an angle from one station and the distance from another station.

Setting Points When Given a Perpendicular Offset Distance

To set a point when given an angle and its distance from a single station, you simply setup the instrument at the station, turn the designated angle, and chain the distance along the line of sight. For perpendicular offset, the angle is 90°.

To set a point when given a distance from each of two stations, you can manage by using two tapes if each of the distances is less than a full tape length. To do so, you set the zero end of the tapes on both stations, run out the tapes, and match the distance mark on each tape to correspond with the required distance from the stations. When the tape is drawn taut, the point of contact between the tapes will be over the location of the desired point.

If one or both of the distances is greater than a full tape length, you can determine direction of one of the tie lines by correct triangle solution. For example, in figure 13-24, you want to set Point B 120.0 ft from station A and 83.5 ft from station C. A and C are 117.0 ft apart. You can determine the size of the angle at A by triangle solution as follows:

$$1 - \cos A = \frac{2(s - b)(s - c)}{bc}$$

$$s = 1/2(120.0 + 117.0 + 83.5) = 160.25$$

$$1 - \cos A = \frac{2(43.25)(40.25)}{(117.0)(120.0)} = 0.24797$$

$$\cos A = 1.00000 - 0.24797 - 0.75203$$

$$A = 41°14'$$

To set point B, you can set up a transit at A, sight on C, turn 41°14´ to the left, and measure off 120.0 ft on that line of sight. As a check, you can measure BC to be sure it measures 83.5 ft.

Setting Points When Given Angles from Two Stations

To set a point when given the angle from each of two traverse stations, you should ordinarily

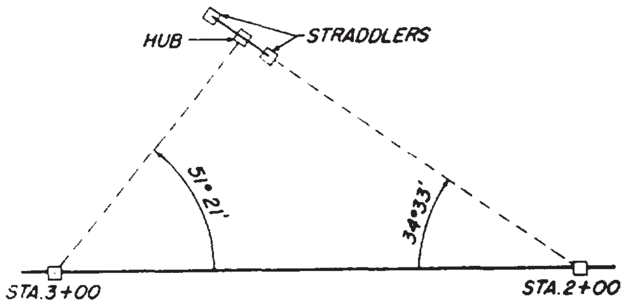


Figure 13-25.-Setting a point by the use of straddlers.

use a pair of straddle hubs (commonly called STRADDLERS), as shown in figure 13-25. Here the point was to be located at an angle of 34°33´ from station 2 + 00 and at an angle of 51°21´ from station 3 + 00. The transit was set up at station 2 + 00, sighted on station 3 + 00, and an angle of 34°33´ was turned to the right. On this line of sight, a pair of straddle hubs was driven, one on either side of the estimated point of intersection of the tie lines. A cord was stretched between the straddlers.

The transit was then shifted to station 3 + 00, sighted on station 2 + 00, and an angle of 51°21´ was turned to the left. A hub was driven at the point where this line of sight intercepted the cord between the straddlers.

Setting Points When Given an Angle from One Station and the Distance from Another

To set a point with a given angle from one station and the distance from another, you would find it best to determine the direction of the distance line by triangle solution. In figure 13-26,

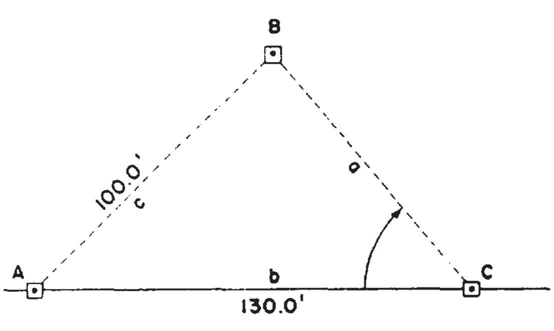


Figure 13-26.-Locating a point by angle and distance from two stations.

point B is to be located 100.0 ft from station A and at an angle of 50°00´ from station C.

In this example, you can determine the size of the angle at A by first determining the size of angle B, then subtracting the sum of angles B and C from 180°. The solution for angle B is as follows:

$$\sin B = \frac{130.0 \sin 50°00'}{100.0}$$

$$\sin B = \frac{130.0(0.76604)}{100.0} = 0.99585.$$

Angle B then measures, to the nearest minute, 84°47´. Therefore, angle A measures

$$180°00' - (84°47' + 50°00') = 45°13'.$$

Set up a transit at A, sight on C, and turn 45°13´ to the left. Then, you set B by measuring off 100.0 ft on this line of sight. As a check, you set up the transit at C, sight on A, turn 50°00´ to the right, and make sure this line of sight intercepts the marker at B.

TRANSIT-TAPE SURVEY

The exact method used in transit-tape survey may vary slightly, depending upon the nature of the survey, the intended purpose, the command or unit policy, and the preferences of the survey party chief. The procedures presented in this section are customary methods described in general terms.

SELECTING POINTS FOR MARKING

All points where a traverse changes direction are marked, usually with a hub that locates the station exactly, plus a guard stake on which the station of the change-of-direction point is inscribed, such as 12 + 35. In the expression "station 12 + 35," the 12 is called the full station and the 35 is called the plus.

The points that are to be tied to the traverse or set in the vicinity of the traverse are usually selected and marked or set as the traverse is run. The corresponding tie stations on the traverse are selected and marked at the same time. The first consideration in selecting tie stations is VISIBILITY, meaning that tie stations and the point to be tied or set must be intervisible. The next is PERMANENCY (not easily disturbed). Last is the STRENGTH OF INTERSECTION, which generally means that the angle between two tie lines should be as close to 90° as possible. The more acute or obtuse the angle is between tie lines, the less accurate the location of the point defined by their intersection.

IDENTIFYING PARTY PERSONNEL

A typical transit-tape survey party contains two chainmen, a transitman, a recorder (sometimes the transitman or party chief doubles as recorder), a party chief (who may serve as either instrumentman or recorder, or both), and axmen, if needed. The transitman carries, sets up, and operates the transit; the chainmen do the same with the tapes and the marking equipment.

When the transitman turns an angle, he calls out the identity and size of the angle to the recorder, as "Deflection angle AB to BC, 75°16´, right." The recorder repeats this, then makes the entry. Similarly, the head chainman calls out the identity and size of a linear distance, as "B to C, 265.72 ft," then the recorder repeats this back and makes the entry at that time. If the transitman closes the horizon around a point, he calls out, "Closing angle, such and such." The recorder repeats this and then adds the closing angle to the original angle. If the sum of the angles doesn't come close to 360°, the recorder notifies the party chief.

The party chief is in complete charge of the party and makes all the significant decisions, such as the stations to be marked on the traverse.

ATTAINING THE PRESCRIBED ORDER OF PRECISION

The important distinction between accuracy and precision in surveying is explained as follows:

- Accuracy denotes the degree of conformity with a standard. It relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

The accuracy attained by field surveys is the product of the instructions or specifications to be followed in doing the work and the precision in following those instructions.

For example, the "accuracy of a surveyor's tape" means the degree to which an interval of 100 ft, as measured on the tape, actually agrees with the exact interval of a standard 100-ft tape. If a tape indicates 100 ft when the interval it measures is only 99.97 ft, the tape contains an inaccuracy of 0.03 ft for every 100 ft measured. The accuracy of this particular tape, expressed as a fraction, is 0.03/100, or approximately 1/3,300.

- Precision denotes degree of refinement in the performance of an operation or in the statement of a result. It relates to the quality of execution and is distinguished from accuracy that relates to the quality of the result. The term *precision* not only applies to the fidelity of performing the necessary operations but, by custom, has been applied to methods and instruments used in obtaining results of a high order of accuracy. Precision is exemplified by the number of decimal places to which a computation is carried and a result stated. In a general way, the accuracy of a result should determine the precision of its expression. Precision will not have significance unless accuracy is also obtained.

If you measure a linear distance with a tape graduated in feet that are subdivided into tenths, you can read (without estimation) only to the nearest tenth (0.1) of a foot. But with a tape graduated to hundredths of a foot, you can directly read distances measured to the nearest hundredth (0.01) of a foot. The apparent nearness of the second tape will be greater; that is, the second tape will have a higher precision.

Completely precise measurement is impossible in the nature of things. There is always a built-in or inherent error, amounting to the size of the smallest graduation. Precision for the first tape above, expressed as a fraction, is 0.1/100 or 1/1,000 and for the second tape, 1/10,000.

Precision in measurements is usually expressed in a fractional form with unity as the numerator, indicating the allowable error within a certain limit as indicated by the denominator, such as 1/500. In this case, you are allowed a maximum error of 1 unit per 500 units measured. If your unit of measure is in feet, you are allowed 1 ft for every 500 ft.

In general, any survey has to be carried out accurately, meaning that errors and mistakes have to be avoided. The precision of a survey, however, depends upon the order of precision that is either specified or is implied from the nature of the survey.

The various orders of precision are absolute, not relative, in meaning. Federal agencies control surveys. They are generally classified into four orders of precision; namely, FIRST ORDER, SECOND ORDER, THIRD ORDER, and

Table 13-1.-Control Traverse Order of Precision

ORDER OF PRECISION	MAXIMUM NUMBER OF AZIMUTH COURSES BETWEEN AZIMUTH CHECKS	DISTANCE MEASUREMENT ACCURATE WITHIN	MAXIMUM LINEAR ERROR OF CLOSURE	MAXIMUM ERRORS OF ANGLES
FIRST ORDER	15	$\frac{1}{35,000}$	$\frac{1}{25,000}$	* 2 sec $\sqrt{N}$ or 1.0 sec per station.
SECOND ORDER	25	$\frac{1}{15,000}$	$\frac{1}{10,000}$	* 10 sec $\sqrt{N}$ or 3.0 sec per station
THIRD ORDER	50	$\frac{1}{7,500}$	$\frac{1}{5,000}$	* 30 sec $\sqrt{N}$ or 8.0 sec per station
FOURTH ORDER	--	$\frac{1}{3,000}$	$\frac{1}{1,000}$	2 min or compass

N = the number of stations carrying azimuth.
* Use whichever is smaller in value.

FOURTH ORDER control surveys. The FIRST ORDER is the highest and the FOURTH ORDER, the lowest standard of accuracy.

Because of the type of instruments available in the SEABEEs, most of your surveys may not require a precision higher than a third order survey. When the order of precision is not specified, you may use table 13-1 in this training manual (TM) as a standard for a horizontal control survey when using the traverse control method. For surveys that call for a higher order of precision, you will have to use theodolites to obtain the required precision.

The triangulation control method is discussed fully in *Engineering Aid 1 & C,* NAVEDTRA 10635-C. At present, however, you may have survey problems that require the use of the triangulation method. In such a case, you may use table 13-2 in this TM as a guide for the order of precision if it is not specified in the survey.

The practical significance of a prescribed or implied order of precision lies in the fact that the instruments and methods used must be capable of attaining the required precision. The precision of an instrument is indicated by a fraction in which the numerator is the inherent error. (In a 1-min transit, the inherent error is 1 min.)

The denominator is the total number of units in which the error occurs. For a transit, this last is 90°, or 5,400´. The precision of a 1-min transit. then, is 1/5,400, adequate for a third order survey.

Precision of a tape is given in terms of the inherent error per 100 ft. A tape that can be read to the nearest 0.01 ft has a precision of 0.01/100, or 1/10,000—adequate for second order work.

Attaining Precision with a Linear Error of Closure

For a closed traverse, you should attain a RATIO OF LINEAR ERROR OF CLOSURE that corresponds to the order of precision prescribed or implied for the traverse. The ratio of linear error of closure is a fraction in which the numerator is the linear error of closure and the denominator is the total length of the traverse.

To understand the concept of linear error of closure, you should study the closed traverse shown in figure 13-27. Beginning at station C, this traverse runs N30°E300 ft, thence S30°E300 ft; thence S90°W 300 ft. The end of the closing traverse, BC, lies exactly on the point of beginning, C. This indicates that all angles were turned and all distances chained with perfect accuracy, resulting in perfect closure, or an error of closure of zero feet.

However, in reality, perfect accuracy in measurement seldom occurs. In actual practice,

Table 13-2.-Triangulation Order of Precision

PRECISION	APPLICATION	BASE LINE MEASUREMENT MAX. PROBABLE ERROR	TRIANGLE CLOSURE: MAX. AVERAGE ERROR	LENGTH CLOSURE: MAX. DISCREPANCY BET. MEASURED AND COMPUTED LENGTH BASE LINE
FIRST ORDER	CASE I For city and scientific study survey.	$\frac{1}{1,000,000}$	1.0 sec	$\frac{1}{100,000}$
	CASE II Basic network of U.S.	$\frac{1}{1,000,000}$	1.0 sec	$\frac{1}{50,000}$
	CASE III All other purposes.	$\frac{1}{1,000,000}$	1.0 sec	$\frac{1}{25,000}$
SECOND ORDER	CASE I Area networks and supplemental cross arcs in national net.	$\frac{1}{1,000,000}$	1.5 sec	$\frac{1}{20,000}$
	CASE II Coastal areas, inland waterways, and engineering surveys.	$\frac{1}{500,000}$	3.0 sec	$\frac{1}{10,000}$
THIRD ORDER	Topographic Mapping	$\frac{1}{250,000}$	5.0 sec	$\frac{1}{5,000}$

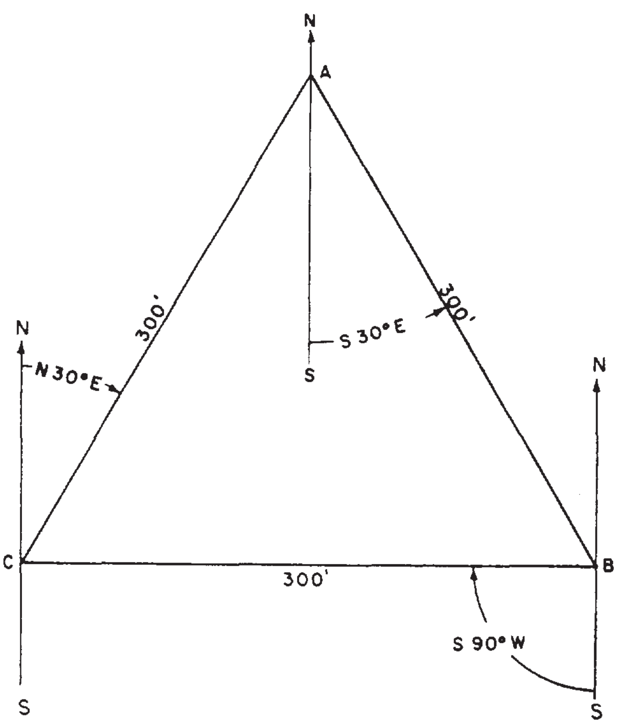


Figure 13-27.-An example of a closed traverse with a perfect (zero-error) closure.

the closing traverse line, BC, shown in figure 13-27, is likely to be some distance from the starting point, C. If this should happen, and, say, the total accumulated linear distance measured along the traverse lines is 900.09 ft, the ratio of error of closure then is .09/900 or 1/10,000. This resulting ratio is equivalent to the precision prescribed for second order work.

Attaining Precision with a Maximum Angular Error of Closure

You know that the sum of the interior angles of a closed traverse should theoretically equal the product of 180° (n – 2), n being the number of sides in the polygon described by the traverse. A prescribed MAXIMUM ANGULAR ERROR OF CLOSURE is stated in terms of the product of a given angular value times the square root of the number of interior angles in the traverse.

Again, if we use the traverse shown in figure 13-27 as an example, the prescribed maximum angular error of closure in minutes is 01 $\sqrt{3}$ because the figure has three interior angles. The sum of the interior angles should be 180°. If the sum of the angles as actually measured and recorded is 179°57′, the angular error of closure is 03′. The maximum permissible error of closure is the product of 01´ times the square root of 3, or about 1.73´. The prescribed maximum angular error of closure has therefore been exceeded.

Meeting Precision Specifications

The following specifications are intended to give you only a general idea of the typical precision requirements for various types of transit-tape surveys. When linear and angular errors of closure are specified, it is understood that a closed traverse is involved.

For many types of preliminary surveys and for land surveys, typical precision specifications may read as follows:

- Transit angles to nearest minute, measured once. Sights on range poles plumbed by eye. Tape leveled by eye, and standard tension estimated. No temperature or sag corrections. Slopes under 3 percent disregarded. Slopes over 3 percent measured by breaking chain or by chaining slope distance and applying calculated correction. Maximum angular error of closure in minutes is $1.5\sqrt{n}$. Maximum ratio linear error of closure, 1/1000. Pins or stakes set to nearest 0.1 ft.

For most land surveys and highway location surveys, typical precision specifications may read as follows:

- Transit angles to nearest minute, measured once. Sights on range poles, plumbed carefully. Tape leveled by hand level, with standard tension by tensionometer or sag correction applied. Temperature correction applied if air temperature more than 15° different from standard (68°F). Slopes under 2 percent disregarded. Slopes over 2 percent measured by breaking chain or by applying approximate slope correction to slope distance. Pins or stakes set to nearest 0.05 ft. Maximum angular error of closure in minutes is $1\sqrt{n}$. Maximum ratio linear error of closure, 1/3,000.

For important boundary surveys and extensive topographical surveys, typical precision specifications may read as follows:

- Transit angles by 1-rein transit, repeated four times. Sights taken on plumb lines or on range poles carefully plumbed. Temperature and slope corrections applied; tape leveled by level. Pins set to nearest 0.05 ft. Maximum angular error of closure in minutes is $0.5\sqrt{n}$. Maximum ratio linear error of closure is 1/5,000.

Note that in the first two specifications, one-time angular measurement is considered sufficiently precise. Many surveyors, however, use two-line angular measurement customarily to maintain a constant check on mistakes.

Measuring Angles vs. Measuring Distances

It is usually the case on a transit-tape survey that the equipment for measuring angles is considerably more precise than the equipment for measuring linear distances. This fact leads many surveyors into a tendency to measure angles with great precision, while overlooking important errors in linear distance measurements.

Making the precision of angular measurement greater than that of linear measurement is useless because your angles are only as good as your linear distances. Suppose that you are running traverse line BC at a right deflection angle of 63°45´ from AB, 180.00 ft to station C. You set up at B, orient the telescope to AB extended, and turn exactly 63°45´00´´ to the right. But instead of measuring off 180.00 ft, you measure off 179.96 ft. Regardless of how precisely you turn all of the other angles in the traverse, every station will be dislocated because of the error in the linear measurement of BC.

Remember that angles and linear distances must be measured with the same precision.

IDENTIFYING ERRORS AND MISTAKES IN TRANSIT WORK

In transit work, errors are grouped into three general categories; namely, INSTRUMENTAL, NATURAL, and PERSONAL errors. First, we will discuss these errors, and then, later, we will explain the common mistakes in transit work.

Identifying Instrumental Errors

A transit will not measure angles accurately unless the instrument is in the following condition:

1. The vertical cross hair must be perpendicular to the horizontal axis. If the vertical cross hair is not perpendicular, the measurement of horizontal angles will be inaccurate.
2. The axis of each of the plate levels must be perpendicular to the vertical axis. If they are not, the instrument cannot be accurately leveled.

If the instrument is not level, the measurement of both horizontal and vertical angles will be inaccurate.

3. The line of sight through the telescope must be perpendicular to the horizontal axis. If it is not, the line of sight through the telescope inverted will not be 1800 opposite the line of sight through the telescope erect.

4. The horizontal axis of the telescope must be perpendicular to the vertical axis. If it is not, the measurement of both horizontal and vertical angles will be inaccurate.

5. The axis of the telescope level must be parallel to the line of sight through the telescope. If it is not, the telescope cannot be accurately leveled. If the telescope cannot be accurately leveled, vertical angles cannot be accurately measured.

6. The point of intersection of the vertical and horizontal cross hairs must coincide with the true optical axis of the telescope. If it doesn't, measurement of both horizontal and vertical angles will be inaccurate.

NOTE: Any or all of the above conditions may be absent in an instrument that is defective or damaged, or one that needs adjustment or calibration.

Identifying Natural Errors

Common causes of natural errors in transit work are as follows:

1. Settlement of the tripod in yielding soil. If the tripod settled evenly—that is, if the tip of each leg settled precisely the same amount—there would be little error in the results of measuring horizontal angles. Settlement is usually uneven, however, which results in the instrument not being level.

2. Refraction—but the effect of this is usually negligible in ordinary precision surveying.

3. Unequal expansion or contraction of instrument parts caused by excessively high or low temperature. For ordinary precision surveying, the effect of this is also usually negligible.

4. High wind may cause plumbing errors when you are plumbing with a plumb bob and cord and may also cause reading errors because of vibration of the instrument.

Identifying Personal Errors

Personal errors are the combined results of carelessness and of the limitations of the human eye in setting up and leveling the instrument and in making observations.

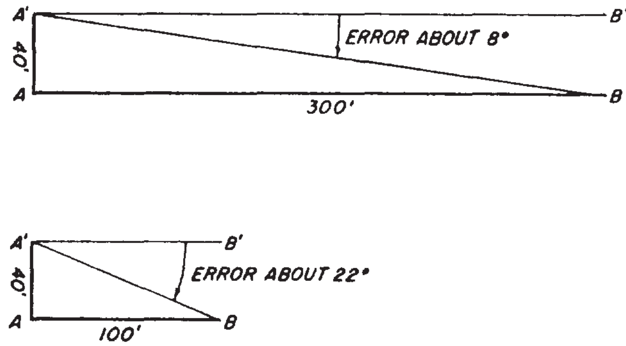


Figure 13-28.-Exaggerated illustration of error caused when the transit is not centered exactly over the occupied station.

Common causes of personal errors in transit work are as follows:

1. Failure to plumb the vertical axis exactly over the station. Figure 13-28 shows how the result of inaccuracy increases drastically as the sight distance decreases. In that figure, an instrument supposed to be set up at A was actually set up at A´, 40 ft away from A. (For demonstration purposes the figure was exaggerated to magnify the error; in actual practice the eccentricity amounts only to a fraction of an inch. Remember that mathematically, 1 in. is the arc of 1 min when the radius is 300 ft.)

In the upper view, you can see that with B located 300 ft from A, the angular error caused by the displacement is about 8°. In the lower view, however, with B located only 100 ft from A, the angular error caused by the displacement is about 22°.

The practical lesson to be learned from this is that you must plumb the instrument much more carefully for a short sight than for a long one.

2. Failure to center plate level bubbles exactly. The result of this is that the instrument is not leveled exactly. The consequent error is at a minimum for a horizontal sight and increases as a sight becomes inclined.

The practical lesson is that you should level the instrument much more carefully for an incline sight than for a horizontal one.

3. Inexact setting or reading of a vernier. The use of a small, powerful pocket magnifying glass is helpful here. Also, when you have determined the vernier graduation that most nearly coincides with a limb graduation, it is a good idea to check your selection by examining the graduations on either side of the one selected. These should fall in coincidence with the limb counterparts by about the same amount.

4. Failure to line up the vertical cross hair with the true vertical axis of the object sighted. The effect is similar to that of not plumbing exactly over the station, which means that the error increases drastically as the length of the sight decreases.

5. Failure to bring the image of the cross hair or that of the object sighted into clear focus (parallax). A fuzzy outline makes exact alignment difficult.

Common mistakes in transit work are the following:

1. Turning the wrong tangent screw. For example, by turning the lower tangent screw AFTER taking a backsight, you will introduce an error in the backsight reading.

2. Forgetting to tighten the clamp(s), or a clamp slipping when it is supposed to be tight.

3. Reading in the wrong direction from the index (zero mark) on a double vernier.

4. Reading the wrong vernier; for example, reading the vernier opposite the one that was set.

5. Reading angles in the wrong direction; that is, reading from the outer row rather than the inner row, or vice versa, on the horizontal scale.

6. Failure to take a full-scale reading before reading the vernier. For example, you may drop 20 to 30 min from the reading, erroneously recording only the number of minutes indicated on the vernier, such as 15°18´ instead of 15°48´. Do not be so intent on reading the vernier that you lose track of the full-scale reading of the circle.

CARING FOR AND MAINTAINING SURVEYING INSTRUMENTS

The accuracy and quality of a survey depend upon the condition of the surveying instrument and the experience of the surveyor. The life expectancy and usefulness of an instrument can be extended considerably by proper and careful handling, stowing, and maintenance. Undoubtedly, by simply working in your rating conscientiously, you will become experienced in the proper use of the instrument.

As stated earlier, every instrument is accompanied by an instruction manual that tells you not only the proper operation and components of the instrument but also procedures for its proper care and maintenance. Study this instruction manual thoroughly before you even attempt to use the instrument.

Carrying and Stowing

Every transit, theodolite, or level comes equipped with a carrying box or case. The instrument and its accessories can be stowed in the case in a manner that ensures a minimum of motion during transportation. The instrument should ALWAYS be stowed in the carrying case when it is not in use.

Cleaning and Lubricating

In general, all surveying instruments, equipment, or tools must be cleaned thoroughly immediately after you have used them. For example, you dust off the transit or theodolite and wipe it dry before placing it back in its case after each use. Remove all dust with a clean cloth. This applies particularly to the optical parts. Chamois leather is suitable for this purpose, but it is better to use a clean handkerchief than a soiled chamois leather. Use no liquid for cleaning — neither water, petrol, nor oil. If necessary, you can breathe on the lenses before polishing them. When the instrument becomes wet, you should remove its case and dry it thoroughly at room temperature as soon as you get home. If you leave the instrument in the closed case, the air inside the hood will take up humidity by increasing temperature and will in time diffuse inside the instrument. While cooling off, the water will condense and form a coating or tarnish that may make any sighting with the telescope and reading of the circles difficult.

Remove any mud or dirt that may adhere to the tripod, range pole, level rod, and so forth, after each use. Clean each instrument, equipment, or tool after each use to eliminate the chance of forgetting it. This is important, especially when the surveying gear is made of a material that is susceptible to rust action or decay.

When lubricating the instruments, you must use the recommended lubricant for each part in conjunction with the climatic condition in your area. For instance, it is recommended that graphite be used to lubricate transit moving parts when the transit is to be used in sub-zero temperatures instead of the light film of oil (preferably watch oil) when its use is confined to an area with normal weather conditions. The lubricant should be applied thinly to avoid making the lubricated parts an easy repository for dust or catcher of dust.

Consult the manufacturer's manual or your senior EA whenever you are in doubt before doing anything to an instrument.

NOTE: Information on tests, adjustments, and minor repairs of surveying instruments will be presented at the EA2 level.

TRAVERSE OPERATIONS (FIELD PROCEDURES)

A survey traverse is a sequence of lengths and directions of lines between points on the earth, obtained by or from field measurements and used in determining positions of the points. A survey traverse may determine the relative positions of the points that it connects in series; and, if tied to control stations based on some coordinate system, the positions may be referred to that system. From these computed relative positions, additional data can be measured for layout of new features, such as buildings and roads.

Traverse operations (actions commonly called TRAVERSING) are conducted for basic area control; mapping; large construction projects, such as military installation or air bases; road, railroad, and pipeline alignment; control of hydrographic surveys; and for many other projects. In general, a traverse is always classified as either a CLOSED TRAVERSE or an OPEN TRAVERSE.

A closed loop traverse (fig. 13-29, view A), as the name implies, forms a continuous loop, enclosing an area. This type of closed traverse starts and ends at the same point, whose relative horizontal position is known. A closed connecting traverse (fig. 13-29, view B) starts and ends at separate points, whose relative positions have been determined by a survey of an equal or higher order accuracy. An open traverse (fig. 13-29, view C) ends at a station whose relative position is not previously known, and unlike a closed traverse, provides no check against mistakes and large errors. Open traverses are often used for preliminary survey for a road or railroad.

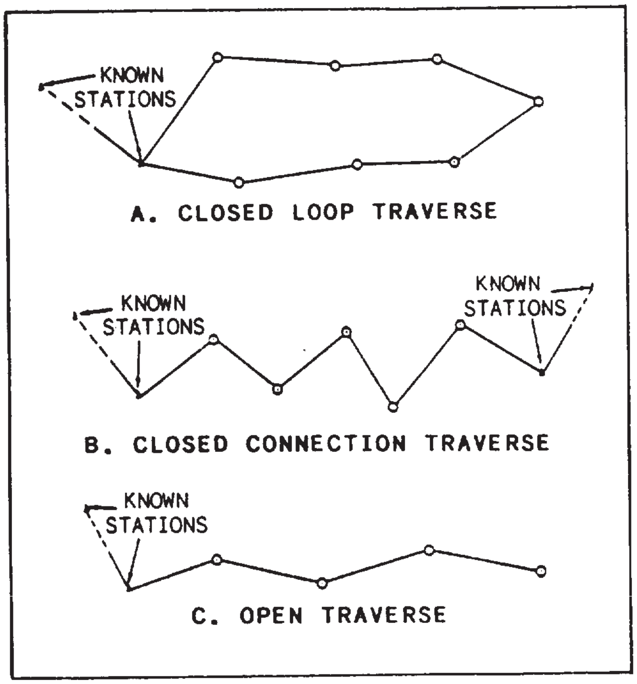


Figure 13-29.-Types of traverses.

The order of ACCURACY for any traverse is determined by the equipment and methods used in the traverse measurements, by the accuracy attained, and by the accuracy of the starting and terminating stations. Hence, the order of accuracy must be specified before the measurements are started. For engineering and mapping projects, the distance measurement accuracy for both electronic and taped traverses for first, second, and third order are 1/35,000, 1/15,000, and 1/7,500, respectively.

For military use such as field artillery, lower order accuracies of fourth, fifth, and sixth are 1/3,000, 1/1,000, and 1/500, respectively. The order referred to as lower order is applied to all traverses of less than third order.

To accomplish a successful operation, the traverse party chief must ensure that initial preparations and careful planning are done before the actual traversing begins. In the remainder of this chapter, we will discuss some of the basic procedures normally undertaken by a transit-tape traverse party.

ORGANIZING THE PARTY

A traverse party may vary from 2 to about 12 personnel, all under the supervision of a traverse party chief. It usually consists of a distance-measuring crew, an angle crew, sometimes a level crew, and other support personnel. This breakdown of personnel is ideal; but, on many occasions, the same personnel will have to perform a variety of tasks or functions. Therefore, each party member is trained to assume various duties and functions in several phases of the work survey.

CONDUCTING A RECONNAISSANCE

Whenever possible, a reconnaissance must be made to determine the starting point, the route to be followed, the points to be controlled, and the closing station. When selecting the starting and closing points, you must select an existing control station that was determined by a survey whose order of accuracy was equal to or greater than the traverse to be run. When running a traverse in which the direction of the traverse lines are not fixed before the start, select a route that offers minimum clearing of traverse lines. The best available maps and aerial photographs should be used during the office and field reconnaissance. By selecting a route properly, you can lay out the traverse to pass relatively close to points that have to be located or staked out.

On other surveys, such as road center line layout, the directions of the traverse lines are predetermined, and all obstructions, including large trees, have to be cleared from the line. Often the assistance of the equipment and construction crews is needed at this point. For the lower order surveys and where taping is used, the exact route and station locations normally are selected as the traverse progresses. These stations have to be selected so that at any one station, both the rear and forward stations are visible, and only a minimum number of instrument setups is kept, reducing the possibility of instrument error and the amount of computing required.

Furthermore, the electronic distance-measuring devices (EDMs) have made traverse reconnaissance even more important. The possibility y of using an EDM should be considered after the general alignment in direction and the planned positioning of stations. A tower or platform installed to clear surface obstruction will permit comparatively long optical sights and distance measurements, hence avoiding the necessity of taping it in short increments.

PLACING STATION MARKS

Some station marks are permanent markers, and some are temporary markers, depending upon the purpose of the traverse. A traverse station that will be reused over a period of several years is usually marked in a permanent manner. Permanent traverse station markers are of various forms, including such forms as an iron pipe filled with concrete; a crosscut in concrete or rock; or a hole drilled in concrete or rock and filled with lead, with a tack to mark the exact reference point. Temporary markers, on the other hand, are used on traverse stations that may never be reused, or perhaps will be reused only a few times within a period of 1 or 2 mo. Temporary traverse station markers are usually 2-in. by 2-in. wooden hubs, 12 in. or more in length. They are driven flush with the ground and have a tack or small nail on top to mark the exact point of reference for angular and linear measurements. To assist in recovering the hub, a 1-in. by 2-in. wooden guard stake, 16 in. or more in length is driven at an angle so that its top is about 1 ft over the hub. Keel (lumber crayon) or a large marking pen is used to mark letters and/or numbers on the guard stake to identify the hub. The marked face of the guard stake is toward the hub. Since many of the hubs marking the location of road center lines, landing strips, and other projects will require replacement during construction, reference marks are placed several hundred feet or meters away from the station they reference. Reference marks, usually similar in construction to that of the station hub, are used to reestablish a station if its marker has been disturbed or destroyed.

NOTE: Procedures for marking hub and guard stakes for traverse stations, road center line layout, and other surveys are presented in the next chapter.

TYING IN TO EXISTING CONTROL

As we discussed earlier in this chapter, the starting point of a closed traverse must be a known position or control point; and, for a closed loop traverse, this point is both the starting and closing point. Closed connecting traverses start at one control point and tie into another control point.

A traverse starting point should be an existing station with another station visible for orienting the new traverse. The adjacent station must be intervisible with the starting point to make the tie easy. If you do not find the adjacent station easily, you should observe an astronomic azimuth to orient the starting line, and then continue the traverse. Any existing control near the traverse line should be tied in to the new work.

PERFORMING LINEAR MEASUREMENTS

As traversing progresses, linear measurements are conducted to determine the distance between stations or points. Generally, the required traverse accuracy will determine the type of equipment and the method of measuring the distance. For the lower orders, a single taped distance is sufficient. However, as the order of accuracy gets higher, DOUBLE TAPING (once each way) is required. Ordinary steel tapes must be compared to an Invar or Lovar tape at specified intervals. For the highest accuracy, electronic distance-measuring devices (EDM) are used to measure linear distances. Linear measurements may also be made by indirect methods, using an angle measuring instrument, like the transit or theodolite with stadia. When the distances are determined by stadia readings, the vertical angles are read and used to convert slope distances to horizontal distances.

If double taping or chaining is required, follow these procedures:

1. Follow a direct line between stations, using a guide, such as a transit and a range pole, for alignment. Start measuring from the occupied station, keeping the front end of the tape aligned with the forward station.

2. Start back from the forward station, using the same alignment but not the same taping points. The second measurement must be independent of the first.

3. Compare the two distances, and if within accuracy requirements, the distance is accepted. If the two measurements disagree by more than the allowable amount, retape the distance.

4. Proceed to the next line measurement, and continue double taping until the tie-in control point is reached.

PERFORMING ANGULAR MEASUREMENT

Horizontal angles formed by the lines of each traverse station determine the relative directions of the traverse lines. These angles are measured using a transit or a theodolite, or determined graphically with a plane table and alidade. In a traverse, three traverse stations are significant: the REAR STATION, the OCCUPIED STATION, and the FORWARD STATION (fig. 13-30). The rear station is that station from which the crew performing the traverse has just moved, or it is a point, the azimuth to which is known. The occupied station is the station at which the crew is now located and over which the surveying instrument is set. The forward station is the next station in succession and constitutes the immediate destination of the crew. The stations are numbered consecutively starting at Number 1 and continuing throughout the traverse. In addition to the number of station, an abbreviation indicating the type of traverse is oftentimes

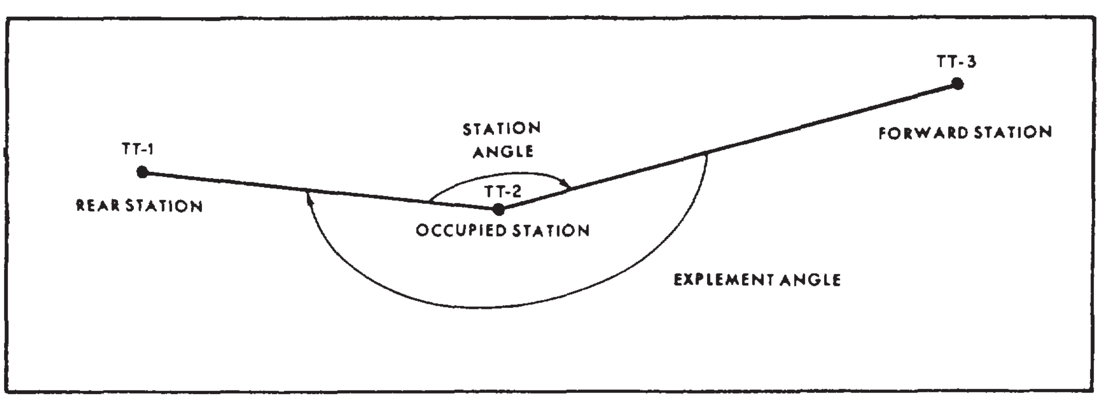


Figure 13-30.-Traverse stations and angles.

included; for example, ET for electronic traverse or TT for theodolite- or transit-tape traverse.

Horizontal angles are always measured at the occupied station by pointing the instrument toward the rear station and turning the angle clockwise to the forward station for the direct angle, and clockwise from the forward to the rear station for the explement (fig. 13-31). If a deflection angle is to be used, plunge the instrument telescope, after sighting the rear station, and read the angle left or right of the forward station.

NOTE: Office procedures for traverse computations and adjustments, methods of computing traverse area, and plotting horizontal control are discussed at the EA2 level.

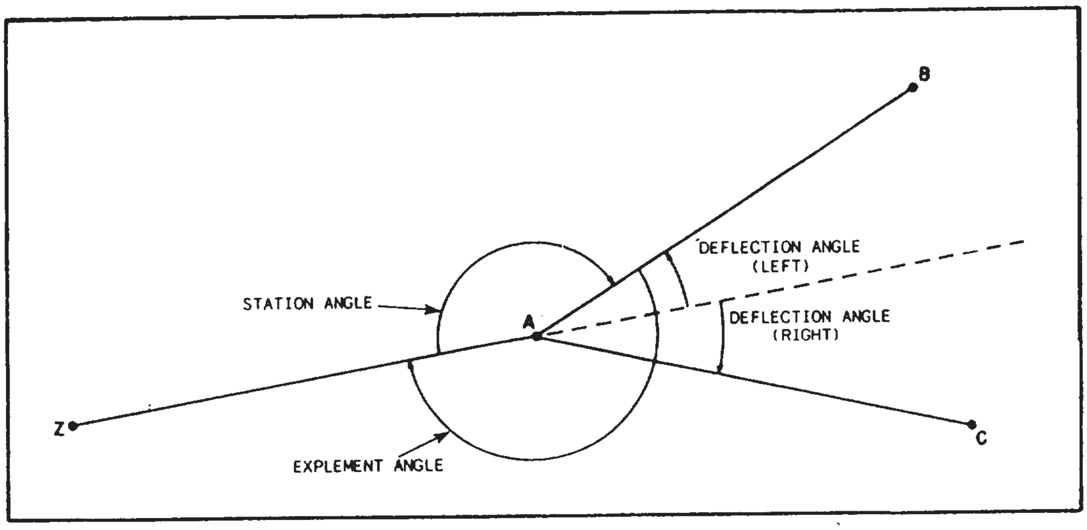


Figure 13-31.-Kinds of angles measured at the occupied station.

CHAPTER 14

DIRECT LEVELING AND BASIC ENGINEERING SURVEYS

Leveling is an operation that is used for determining the elevations of points or the differences in elevation between points on the earth's surface. This operation is extremely vital for deriving necessary data required for various engineering designs, mapping, and construction. Data from a finished level survey are used to (1) design roads, highways, and airfields; (2) develop maps, showing the general configuration of the ground; (3) calculate volume of earthwork; and (4) lay out construction projects.

In this chapter, we discuss the basic principles of DIRECT LEVELING and the types of methods used; the duties and responsibilities of the leveling crew; field procedures used in differential leveling; precision in leveling; and proper ways of handling leveling instruments and equipment. INDIRECT LEVELING, such as barometric and trigonometric leveling, adjustment of level network, and end areas and volume of earth's computations, is not covered in this book.

In this chapter, you will find a general description of basic engineering surveys and various construction-site safety hazards commonly associated with the EA survey party. Other types of engineering and construction surveys—particularly those for curves and earthwork—will be presented at the EA2 level.

BASIC TERMS USED IN LEVELING OPERATIONS

Generally, the basic vertical control for topographic survey and mapping is derived from first- and second-order leveling. For many construction projects and for filling gaps between second-order bench marks (BMs), less precise third-order leveling is acceptable.

In leveling, a level reference surface, or datum, is established, and an elevation is assigned to it. This datum may be assigned an assumed elevation, but true elevation is required for the establishment of a BM. A series of properly established BMs is therefore the framework of any vertical control.

Although further discussion will follow, fundamentally, direct leveling describes the method of measuring vertical distances (differences in elevation) between the plane of known or assumed elevation (datum) and the plane of a point whose elevation you are seeking. Once these distances are known, they may be added to, or subtracted from, the known or assumed elevation to get the elevation of the desired point. These vertical distances are obtained by use of a leveling rod and, usually, an engineer's level.

Some of the basic terms commonly used in leveling operations are defined in the following paragraphs.

BENCH MARK

ABM is a relatively permanent object, natural or artificial, bearing a marked point whose elevation is known. BMs are established over an area to serve as (1) starting points for leveling operations so the topographic parties can determine other unknown elevation points and (2) reference marks during later construction work. BMs are classified as PERMANENT or TEMPORARY. Generally, BM is used to indicate a permanent bench mark and TBM, to signify a temporary bench mark. TBMs are established to use for a particular job and are retained for the duration of that job. Throughout the United States, a series of BMs have been established by various government agencies. These identification markers are set in stone, iron pipe, or concrete

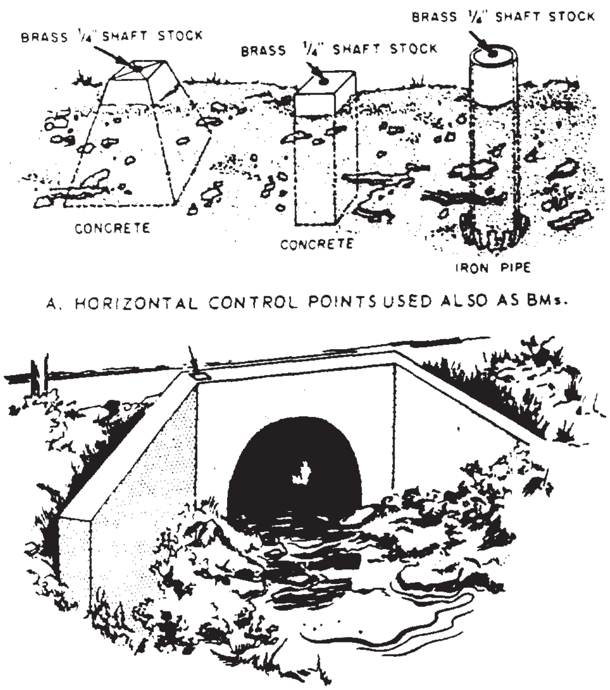


Figure 14-1.-Common types of bench mark construction and application.

and are generally marked to show the elevation above sea level. When the elevation is not marked, you can find out what it is by contacting the government agency that originally set the BM. Just be sure you give them the same identification number as the one on the marker. The type of standard bronze markers used was discussed in chapter 11 of this training manual.

BMs may be constructed in several ways. Figure 14-1, view A, shows brass shaft stocks in the tops of permanent horizontal control points (monuments). Sometimes, monuments of this type are also used for vertical control BMs. Original BMs may be constructed in the same manner. When regular BM disks are not available, brass, not steel, 50-caliber empty shell casings may be used. The shank of the empty shell casings should be drilled crosswise and a nail inserted to prevent its being pulled out or forced out by either expansion or contraction.

For short lines and a level circuit of a limited area, any substantial object may be used for vertical control BMs. The remark in the field notes should bear the proper identification of the BMs used.

Figure 14-1, view B, shows a mark like those commonly used on tops of concrete walls, foundations, and the like. Lines are chiseled out with a cold chisel or small star drill and then marked with paint or keel. The chiseled figures should be about the same size as the base area of the rod. Preferably, they should be placed on some high spot on the surface of the concrete structure.

A spike may be driven into the root of a tree or placed higher up on the trunk of the tree when the limb clearance allows higher rod readings. Figure 14-2, view A, shows the recommended way to do this. The rod should be held on the highest edge of the spike, and the elevation should be marked on the blazed portion of the tree. Figure 14-2, view B, shows a spike driven on a pole or post that also represents a BM. Drive the spike in horizontally on the face of the post in line with the direction of the level line. For the reading, hold the rod on the uppermost edge of the spike. After the elevation has been figured, mark it on the pole or post for future reference.

Stakes driven into the ground can also be used as TBMs, especially if no frost is expected before they are needed. A detailed description of these points is just as important as one for a monument station.

In most permanent military installations, monument BMs are established in a grid system approximately one-half mile apart throughout the base to have a ready reference for elevations of later construction in the station. Generally, these BMs are fenced to mark their locations. The fence also serves to protect them from being accidentally disturbed.

BM systems or level nets consist of a series of BMs that are established within a prescribed order of accuracy along closed circuits and are tied to a datum. These nets are adjusted by computations that minimize the effects of accidental errors and are identified as being of a specific order of accuracy.

In certain areas, TIDAL BENCH MARKS must be established to obtain the starting datum plane or to check previously established elevations. Tidal bench marks are permanent BMs set on high ground and are tied to the tide station near the water surface.

Tide stations are classified as primary and secondary. Primary stations require observations for periods of 19 yr or more to derive basic tidal data for a locality. Secondary stations are operated over a limited period (usually less than 1 yr) and for a specific purpose, such as checking elevations. The secondary station observations are always compared to, and computed from, data obtained by primary stations.

A tide station is set up, and observations are made for a period that is determined by a desired accuracy. These observations are compared with a primary tide station in the area and, then, are furnished with a mean value of sea level in the area.

A closed loop of spirit levels is run from the tide station over the tidal BMs and is tied back to the tide station. The accuracy of this level line must be the same as or higher than the accuracy required for the BMs.

For permanency, tidal BMs usually are set in sets of three and away from the shoreline where natural activity or future construction probably will not disturb or destroy them.

DATUM

Tidal datums are specific tide levels that are used as surfaces of reference for depth measurements in the sea and as a base for determining elevations on land. In leveling operations, the tidal datum most commonly used is the MEAN SEA LEVEL. Other datums, such as mean low water, mean lower low water, mean high water, and mean higher high water, are sometimes used, depending upon the purpose of the survey. Still other datums have been used in foreign countries. When conducting leveling operations overseas, you should check into this matter carefully to avoid mistakes.

Mean Sea Level

Mean sea level (MSL) is defined as the average height of the sea for all stages of the tide after long periods of observations. It is obtained by averaging the hourly heights as they are tabulated on a form similar to that

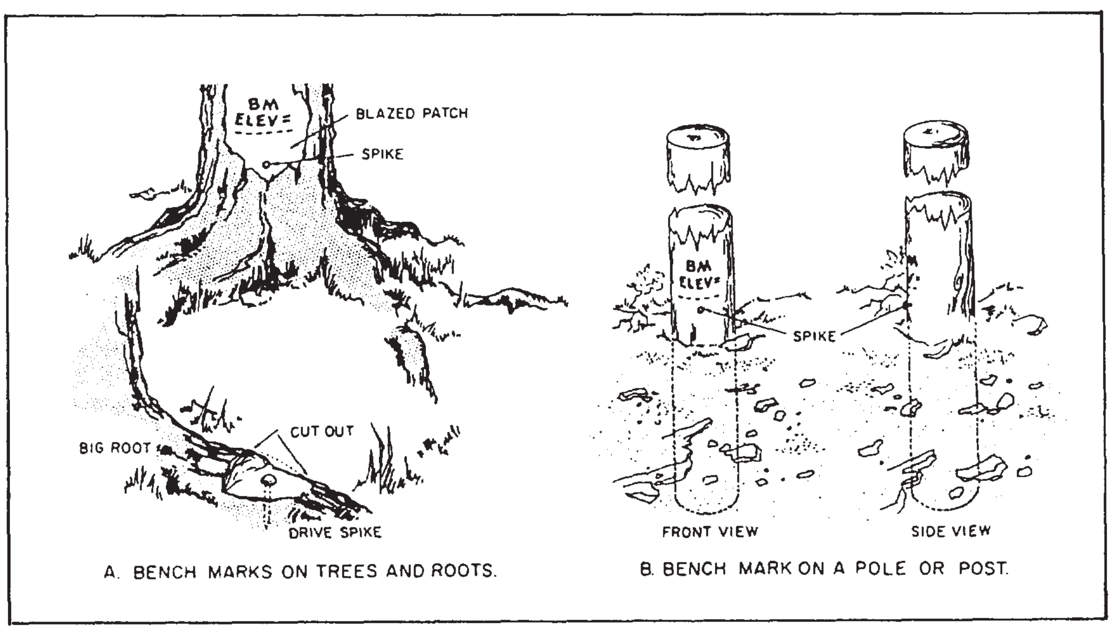


Figure 14-2.-Ways of using spikes as bench marks.

Day & Mo Hour 0	1 Mar. 15.1 Ft.	2 15.5 Ft	3 15.4 Ft	4 13.9 Ft.	5 12.0 Ft.	6 9.0 Ft.	7 6.6 Ft.	Sum 87.5 Ft.	Tides:	Remarks: Hourly Heights	
1	14.4	15.7	16.6	15.9	14.8	12.1	9.5	99.0	Station: Portsmouth		
2	13.5	15.4	17.0	17.3	17.1	15.1	12.8	108.2	Lat. 44° 50'N		
3	12.5	14.8	16.9	17.9	18.6	17.5	15.8	114.0	Long. 68° 10'W		
4	11.7	14.0	16.5	17.8	19.2	19.0	18.0	116.2	Party Chief EA2 Long		
5	11.6	13.3	15.7	17.3	19.1	19.6	19.4	116.0	Tide Gage No. 85		
6	12.3	13.2	14.9	16.4	18.5	19.5	19.8	114.6	Scale 1:24		
7	13.7	13.7	14.6	15.5	17.4	18.7	19.5	113.1	Tabulated by EA3 Smith		
8	15.4	15.0	15.0	15.0	16.3	17.6	18.6	112.9			
9	17.6	16.5	15.9	15.2	15.6	16.3	17.1	114.2			
10	19.2	18.2	17.2	16.0	15.8	15.6	15.9	117.9			
11	20.1	19.4	18.5	17.2	16.6	15.6	15.1	122.5			
12	19.9	19.8	19.4	18.4	17.7	16.3	15.4	126.9			
13	19.0	19.3	19.7	19.2	18.7	17.5	16.2	129.6			
14	17.3	18.0	18.9	19.2	19.5	18.4	17.3	128.6			
15	15.0	15.9	17.3	18.2	19.4	19.0	18.3	123.3			
16	12.2	13.1	14.8	16.3	18.1	18.6	18.9	112.0			
17	10.3	10.5	11.8	13.6	15.9	17.1	18.4	97.7			
18	9.5	8.5	9.2	10.5	13.0	14.7	16.8	82.2			
19	9.7	7.8	7.4	7.8	9.8	11.5	14.1	68.1			
20	10.5	8.3	6.7	6.1	7.0	8.1	10.9	57.6			
21	11.8	9.5	7.5	5.8	5.3	5.6	7.8	53.3			
22	13.4	11.4	9.1	7.0	5.1	4.2	5.4	55.6			
23	14.8	13.6	11.4	9.1	6.6	4.6	4.2	64.3			
Sum	340.5	340.4	347.5	346.6	357.1	351.2	352.0	2435.3			

Figure 14-3.–Sample format showing hourly heights of tide required for computing average mean sea level (MSL).

shown in figure 14-3. The heights on this form are added both horizontally and vertically. The total sum covering 7 days of record is entered in the lower right-hand corner of the page. The mean for each calendar month is found by combining all daily sums for the month and dividing by the total number of hours in the month. The monthly mean, to two decimal places, is entered on the sheet that includes the record for the last day of the month. Yearly means are determined from the monthly means, and a mean is taken of all yearly means for the period of record. Three or more years of record should be used for a good determination of sea level. The actual value varies somewhat from place to place, but this variation is small. The station used for MSL determinations should be on the open coast or on the shore of bays or harbors having free access to the sea. Stations on tidal rivers at some distance from the open sea will have a MEAN RIVER LEVEL that is higher than mean sea level because of the river slope. It should be noted that mean sea level is NOT identical with mean tide level (MTL). The latter is derived from the mean of all high and low points on the tidal curve. But MSL is derived from the mean of a much larger number of points taken at hourly intervals along the tidal curve.

The datum universally used in leveling is mean sea level (MSL), and it is considered to be the zero unit. The vertical distance of a given point above or below this datum then becomes the elevation of that point.

Other Datums

Along the Atlantic coast of the United States, the mean low water (MLW) datum has been generally adopted as the datum used for hydrographic surveys. It is the mean of all low water tides observed over a long period (usually a 19-yr period). Mean lower low water (MLLW) has been generally adopted for hydrographic surveys along the Pacific coast of the United States, Hawaii, Alaska, and the Philippine Islands. It is the mean of the lower of the two low water tides for each day observed over a long period. Mean low water spring (MLWS) is used on the Pacific coast of the Panama Canal Zone. It is defined as the mean of the low waters of the spring tides occurring a day or two after a full moon and is obtained by subtracting one-half of the range of the spring tides from the mean sea tide level.

LEVEL PARTY ORGANIZATION, EQUIPMENT, AND FIELD PROCEDURES

Certain basic preparations relative to the magnitude and complexity of the job must be performed before any leveling survey is undertaken. Proper planning and thorough identification of the procedures to be followed in all phases of the work are essential to the success of the leveling operation. Participating in this preparatory work will also enhance the experience and increase the capabilities of the crew members. Some of the preparations you must be familiar wit h are discussed in the next several paragraphs.

LEVEL PARTY ORGANIZATION

The size of your leveling party will depend upon such variables as the order of accuracy required and the number of experienced personnel available. Ordinarily, the smallest crew may consist of two individuals: an instrumentman and a rodman. To improve the efficiency of the leveling operations, additional personnel are required. The addition of a second rodman to alternate on backlights (BSs) and foresights (FSs) will speed up leveling. If you add a recorder, the instrumentman will be able to take readings as soon as the rodmen are in position. In surveys requiring a shaded instrument, an umbrellaman is required.

Duties of the Instrumentman

An instrumentman, or levelman, runs the level and makes adjustments required for proper operation. He makes certain that no stations are omitted, that turning points (TPs) are properly selected, and that BMs are properly established and identified. The levelman is usually designated by the EA1 or EAC to act as the chief of the party. When a two-man leveling party uses a self-reading rod, the levelman is also the recorder. However, if a target rod is used, the rodman usually acts as the recorder. A good levelman keeps within the required limits of error.

As chief of the party, you must be alert to recognize common problems encountered in the field and be able and ready to solve them using the best solution. Your sound judgment and proper course of action in handling these field problems will influence the quality of your survey and the meeting of your survey schedules.

Handling Leveling Instruments and Equipments

Leveling instruments, as well as all surveying instruments and equipments, have to be accorded the care and proper handling that any delicate instrument merits. Give special attention to prevent sudden shocks, jolts, and bumps, which will cause retesting of the instrument to be required. A damaged or disturbed scientific instrument, however minor, will adversely affect correct and accurate results. As a rule, a visual inspection for signs of physical damage of the instrument is to be conducted before each use.

An engineer's level is a precision instrument containing many delicate and fragile parts. Movable parts should, when not locked in place, work easily and smoothly. When a part resists movement, there is something wrong; if you force the part to move, you are quite likely to damage the instrument. You will also cause damage by wear if you use excessive force in tightening clamps and the like.

To ensure easy movement, keep threads and bearing surfaces on movable parts lubricated. For the same reasons, these parts have to be kept clean. Always clean the parts before oiling them. When oiling the parts, use only fine instrument oil; and do not use too much of it. An excess of oil gathers dust and also thickens, which will interfere with free movement of the parts. This is especially true in cold weather because low temperatures cause oil to congeal. In cold weather, graphite powder is a more suitable lubricant than oil.

Keep the level in its case when it is not in use and when you are transporting it to and from the jobsite. The level screws and the clamp screws should be tightened just enough to prevent motion of the parts inside the case. The instrument case is designed to reduce the effect of jarring and is strongly made and well padded to protect the level from damage. When transporting the level by vehicle, you should place the carrying case about midway between the front and rear wheels. This is the point at which the bouncing of the wheels has the minimum effect.

Never lift the instrument out of the carrying case by grasping the telescope; wrenching the telescope in this manner could damage a number of delicate parts. Always lift the instrument out of the case by grasping the footplate or the level bar.

When the instrument and the tripod are to be carried from one setup point to another, loosen

Figure 14-4.-Recommended carrying position of instrument when obstacles may be encountered.

the level and clamp screws slightly. They should be tight enough to prevent the telescope from swinging and the instrument from sliding on the footplate, but loose enough to allow a "give" in case of an accidental bump against an obstacle.

When you are carrying the instrument over terrain that is free of possible contacts (for example, across an open field), you may carry it over your shoulder like a rifle. But when obstacles may be encountered, carry the instrument under your arm, as shown in figure 14-4.

To avoid the effects of sunlight, you should use a surveyor's umbrella or the like. If there is any great difference between the working and storage temperature, the instrument should be allowed to adjust itself to the actual working conditions for about 15 min before observations are started.

Duties of the Rodman

The rodman must hold the leveling rod properly in order to sight on it or read it accurately. This is the rodman's responsibility. The actions of a rodman in positioning and holding the rod will affect the speed and accuracy of the leveling operation, so if you are the rodman, use extreme care. It is also the rodman's responsibility to take care of the rod during and after the leveling operation. Your duties as a rodman are as follows:

1. Clean the base (or shoe) of the rod before setting the rod on any point. Also, clean the top of the point to ensure good contact between the rod and the point.

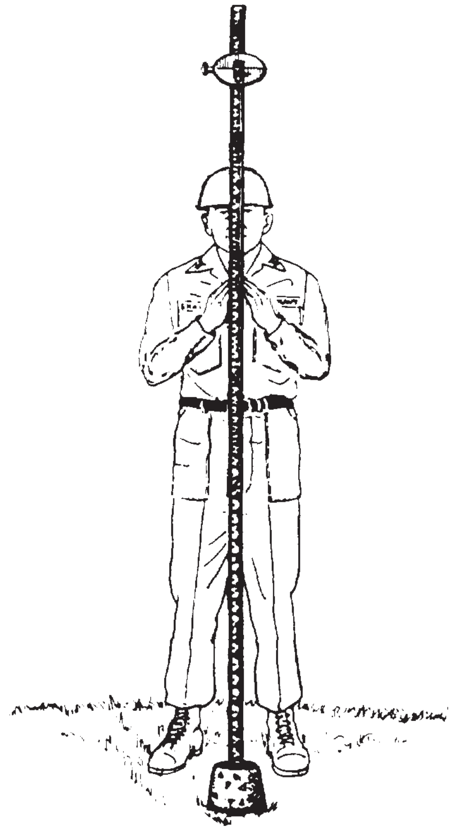


Figure 14-5.-Proper stance for holding a level rod on a bench mark while facing the instrument.

2. Place the rod firmly on the point; then stand facing the instrument and slightly behind the rod; hold the rod in front of you with both hands (fig. 14-5). Space your feet about 1 ft apart for a comfortable stance. Also, make sure that the graduations of the rod are right side up and are turned towards the instrumentman.

3. Hold the rod as nearly vertical as possible, then place a rod level against the rod, and move the top end of the rod until the bubbles are centered. If you do not use a rod level, balance the rod by using your fingertips to prevent it from falling. A properly balanced rod will stand for several seconds before starting to fall. This process of balancing the rod vertically is known as PLUMBING THE ROD.

4. Plumb the rod and hold it as steady as possible during strong winds. When this condition exists, the instrumentman may call for you, as the rodman, to WAVE THE ROD. Wave the rod by pivoting it on its base and swinging it in a slow arc toward the instrument and away. Keep the shoe firmly seated during this operation. The

motion of the rod permits the instrumentman to read the rod when it reaches a vertical position at the top of the arc and when the lowest reading appears on the rod. Before or after the rod is in this vertical position, the rod reading is greater.

5. Set the turning pin or pedestal firmly in contact with the ground when setting a TP. Any unfirm footing can sag under the weight of the rod and result in incorrect readings between the FS and BS. During freezing and thawing weather conditions, the ground surface can heave in a comparatively short time. Pins and pedestals can be affected by the heave between the FS and the following BS. For higher order of accuracy surveys, you should be aware of this possibility and select firm locations.

6. Extend the leveling rod to its maximum length when the instrumentman calls for extending the rod. The standard Philadelphia leveling rod can be read to 7.100 ft or 2.164 meters when collapsed and 13.000 ft or 3.962 meters when extended. An extended leveling rod is called a LONG ROD.

A leveling rod is a precision instrument and has to be treated with care. Most rods are made of carefully selected, kiln-dried, well-seasoned hardwood and have metal scale faces on which the scale graduations are painted. Unless a rod is always handled with great care, the painted face will become scratched, dented, or damaged in other ways. Accurate readings on a rod that is damaged are difficult.

Letting an extended rod close "on the run" by allowing the extended upper section to drop tends to damage both sections of the rod and to displace the vernier. Always close an extended rod by easing down the upper section.

A rod will read accurately only if it is perfectly straight, so you must avoid anything that might bend or warp the rod. Do not lay a rod down flat unless it is supported throughout on a flat surface. Do not use a rod as a support or as a lever. Store the rod in a dry place to avoid any possible warping and swelling from dampness, and always wipe a wet rod dry before stowing it away.

If there is mud on the rod, rinse it off, but do not scrub it. If you have to use a soap solution to remove grease, use a mild solution. Repeated washings with strong soap solutions will eventually cause the painted graduations to fade.

FIELD PROCEDURES FOR DIFFERENTIAL LEVELING

Leveling operations require the teamwork of both the instrumentman and the rodman to achieve consistent results. The accuracy of the survey depends upon the refinement with which the line of sight can be made horizontal by the instrumentman, the ability of the rodman to hold the rod vertically, and the precision with which the rod reading is made. Some of the basic procedures and preparations applicable to direct leveling are presented below.

Selecting Setup Points

Terrain and atmospheric conditions are the main considerations affecting the selection of setup points. It is essential that you select a point from which you can best observe a rod reading on the BS and FS points. In the interest of balanced shots, a setup point should be about equidistant from both BS and FS. In addition, shorter setup distances will result in smaller instrument errors caused by the atmospheric refraction and curvature of the earth.

The average instrument height at any setup is about 5 ft (1.5 m). On even downhill slopes, the ground where the instrument is set up may not be more than 3 to 5 ft below the TP for a level BS. On the FS, the extended rod can be held on the ground about 8 ft (2.5 m) below the instrument ground level and still permit a reading to be taken. This means that the tendency will be to make FS distances longer going downhill and to make BSs longer going uphill.

Therefore, it is necessary to conduct a reconnaissance of the terrain before you start leveling. You should note probable locations of instrument setup and TPs. During the reconnaissance, you should estimate the line of sight by sighting through a hand level.

Setting Up a Level

In setting up the tripod, you first hold two tripod legs with both hands and spread the tips of these legs a convenient distance apart. Then bring the third leg to a position that approximately levels the top of the protector cap when the tripod stands on all three legs. Then unscrew the protector cap.

Next, you lift the instrument out of the carrying case by the footplate or level bar, NOT by the telescope, and set it gently and squarely on the tripod head threads. Rotate the footplate counterclockwise one-fourth turn or until the instrument seats itself; then rotate it clockwise to engage the head nut threads to the tripod head threads. If the threads do not engage smoothly, they are cross-threaded. Do not force the head if you encounter resistance, but back it off, square up the instrument, and try again gently to engage the threads. When they engage, screw the head nut up firmly but not too tightly. Setting up the instrument too tightly causes eventual wearing of the threads, making unthreading difficult.

After you have attached the instrument, if you are set up on stable soil, thrust the tripod legs' tips into the ground far enough to be sure of a stable support, taking care to keep the footplate approximately level. Some tripods have legs equipped with short metal stirrups. These stirrups allow you to force the legs' tips into the ground by foot pressure.

If you are set upon a hardened surface, such as concrete, make sure the tripod legs do not accidentally spread, causing the tripod to collapse. In figure 14-6, view A, the legs' tips are inserted in cracks in a concrete pavement. In figure 14-6, view B, they are held by an equilateral wooden triangle called a floor triangle.

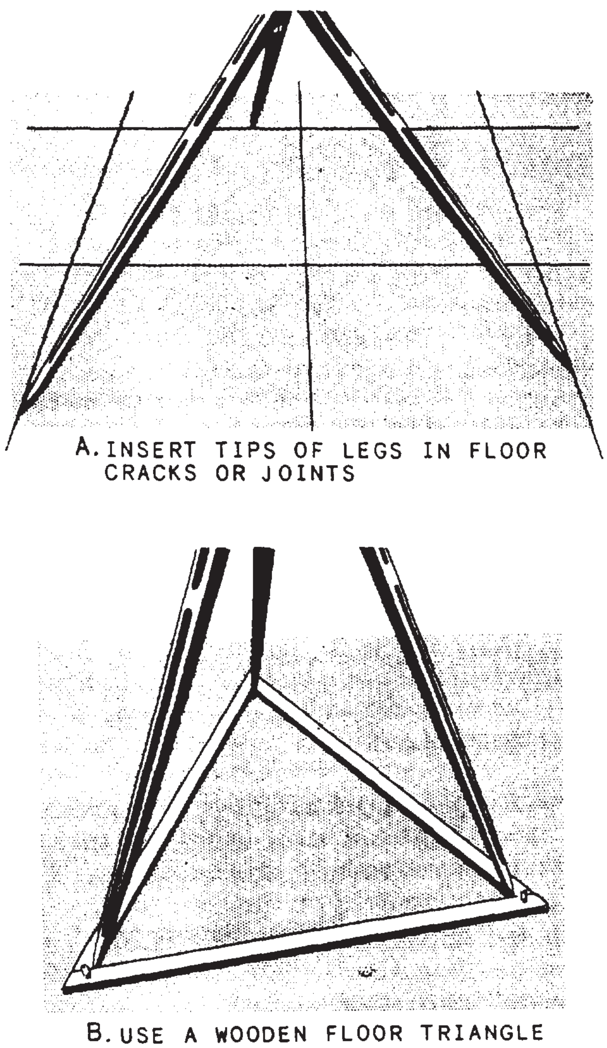


Figure 14-6.-Two ways of preventing tripod legs from spreading on hardened surface.

Leveling the Engineer's Level

As a rodman, you must concentrate on keeping your rod perfectly plumb. Readings on a rod that is out of plumb are inaccurate. Similarly, as a levelman, you must constantly bear in mind that the line of sight through the telescope must be perfectly level in every direction or every reading you make with the instrument will be inaccurate. After you initially place the instrument, level it carefully as follows:

Train the telescope in line with a pair of level screws and manipulate the level screws by turning them in opposite directions, as shown in figure 14-7, until the bubble in the level vial is in the exact center. It is helpful to know that the bubble in the level vial will move in the direction that your left thumb moves. To put this another way: When you turn the left-hand screw clockwise, the bubble moves to your left; when you turn the left-hand screw counterclockwise, it moves to your right.

When the bubble is centered with the telescope over one pair of screws, train the telescope over the other pair and repeat the process. As a check, swing the telescope over each pair of screws in all four possible positions to make sure the bubble is centered in each position.

Making Direct Readings

The instrumentman makes a direct rod reading as viewed directly on the graduation of the rod (self-reading) that is in line with the horizontal

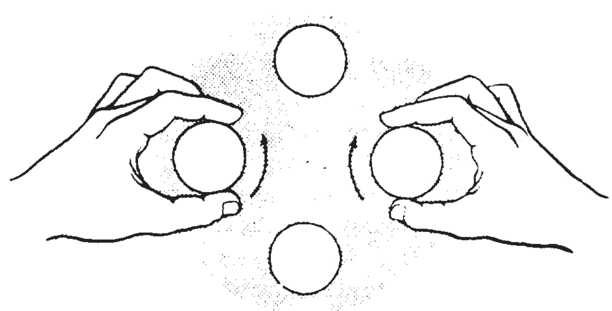


Figure 14-7.-Manipulating level screws.

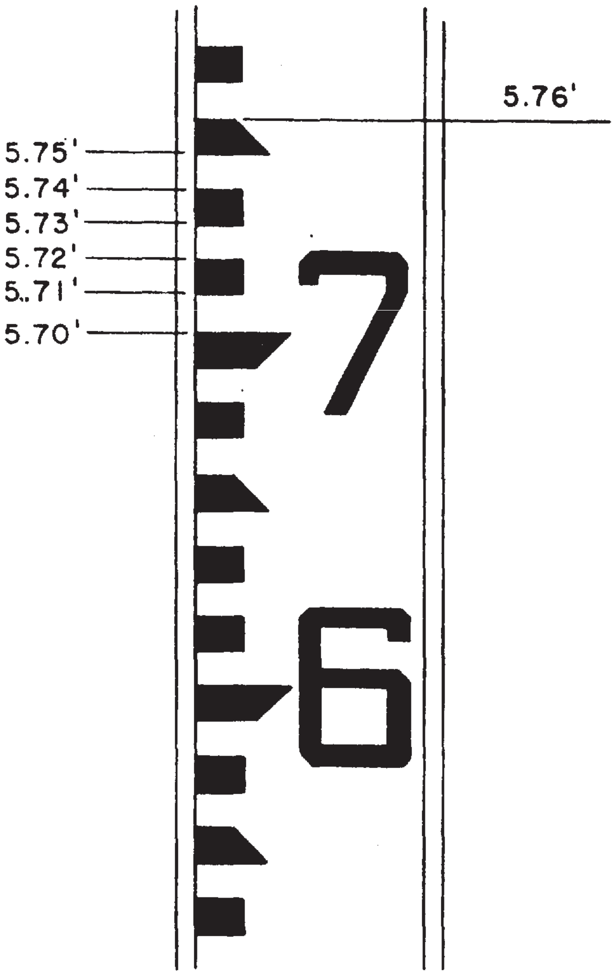


Figure 14-8.-Showing a direct reading of 5.76 ft on a Philadelphia rod.

cross hair. A rod other than an architect's rod is usually graduated in feet subdivided to the nearest 0.01 ft; therefore, direct readings are possible only to the nearest 0.01 ft.

Figure 14-8 shows a direct reading of 5.76 ft on a Philadelphia rod. You can see that each black graduation and each white, interval represents 0.01 ft.

You can see also that the black figure 7 is the only numeral of the reading 5.76 ft that appears in the view. The red numeral 5 would not be visible through the telescope unless the sight distance was quite far away. For this reason, you would signal the rodman to "raise for red," as described in the previous chapter.

To make sure you relate the reading for tenths and hundredths to the correct whole-foot red numeral, it is best to make a direct reading as follows: When the horizontal cross hair and the rod are brought into clear focus, first determine the number of hundredths. Then, read the next lower black figure for the tenths. Finally, signal for a "raise for red," and note the number of whole feet.

Making Target Readings

The three most common situations in which target readings rather than direct readings are made are as follows: (1) when the rod is too far from the instrument to be read directly; (2) when you desire a reading to the nearest 0.001 ft, which requires the use of the vernier by the rodman; and (3) when the instrumentman thinks a reading by the rodman instead of by himself more likely will be accurate.

For target readings up to 7.000 ft, the Philadelphia rod is used fully closed and read on the face by the rodman. The rodman sets the target on the face by the signals from the instrumentman, who determines when the horizontal axis of the target intercepts the horizontal cross hair.

When the instrumentman signals "all right," the rodman clamps the target in place with the target screw clamp, as shown in figure 14-9; then

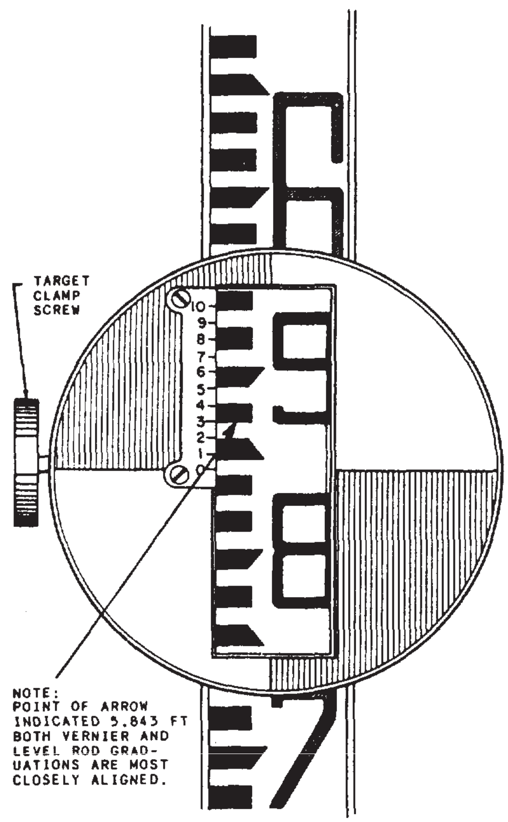


Figure 14-9.-Target reading of 5.843 ft on a Philadelphia rod.

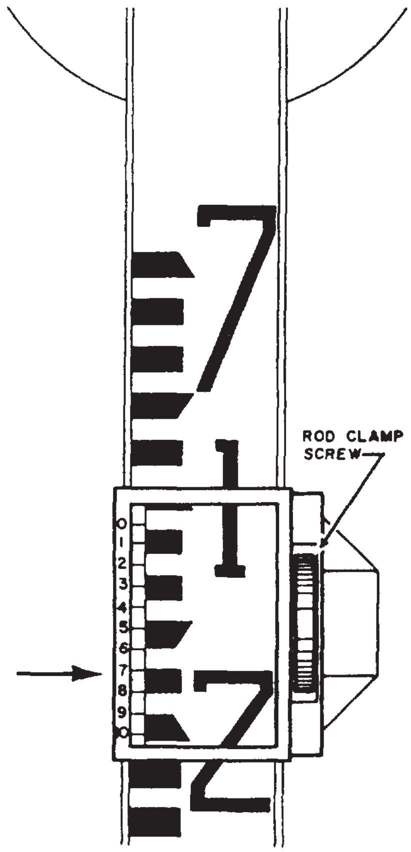


Figure 14-10.-Reading of 7.107 ft on back of Philadelphia rod as indicated by arrow.

the rodman reads the target vernier, shown in the same figure.

The reading to the nearest 0.01 ft is indicated by the zero on the vernier. In figure 14-9, the vernier zero indicates a reading of a few thousandths of a foot more than 5.84 ft. To determine how many thousandths over 5.84 ft, you examine the graduations on the vernier to determine the one most exactly in line with a graduation on the rod. In figure 14-9, this is the 0.003-ft graduation; therefore, the reading to the nearest 0.001 ft is 5.843 ft.

For target readings of more than 7.000 ft, the Philadelphia rod is used extended; the rodman makes the reading on the back of the rod. In figure 14-10, the back of the upper section of the rod is shown, graduated FROM THE TOP DOWN, from 7.000 ft through 13.000 ft. You can also see a rod vernier on the back, fixed to the top of the lower section of the rod, also reading from the top down.

For a target reading of more than 7.000 ft, the rodman, on receiving the signal to "extend the rod," fixes the target on the face of the upper section all the way to the top of the upper section. While doing this, the rodman makes sure the target vernier is set at exactly the same reading indicated by the rod vernier on the back of the rod, He then releases the rod screw clamp and slides the upper section of the rod slowly upwards until the instrumentman gives the signal "all right." When the horizontal axis of the target reaches the level where it is intersected by the horizontal cross hair, the instrumentman gives this signal.

FUNDAMENTAL LEVELING PROCEDURE

Now that you have learned how to setup and level the engineer's level and how to read the leveling rod, let us take a look at an example that will explain the basic procedure of determining elevations during a leveling operation.

In figure 14-11, there is a BM at Point A with a known elevation of 365.01 ft. You wish to determine the elevation of a point on the ground at Point B. To do so, you first set up and level your engineer's level approximately half-way between Points A and B. When the instrument is leveled properly, you will have a perfectly level line of sight that can be rotated all around the horizon.

The next thing to do is to determine the elevation of this line of sight. This elevation is called the HEIGHT OF INSTRUMENT, familiarly known as the HI. To obtain this elevation, the instrumentman takes a backsight (BS) on a leveling rod held on the BM and, in this example, obtains a rod reading of 11.65 ft. The HI, then, is the BM elevation PLUS the rod reading, or 365.01 + 11.56, which equals 376.57 ft. This means that no matter to which direction the telescope is trained, any point around the horizon that is intercepted by the horizontal cross hair has an elevation of 376.57 ft.

To determine the ground elevation at Point B, the instrumentman now takes a foresight (FS) on a rod held at Point B. This time, a rod reading of 1.42 ft is read. Since the elevation of the line of sight (HI) is 376.57 ft, obviously the ground elevation at Point B is the HI MINUS the rod reading, or 376.57 – 1.42, which equals 375.15 ft.

Balancing Shots

The balancing of the FS and BS distances is important in leveling. The effeet of curvature and refraction may be eliminated by a balanced BS and FS distance; however, instrumental error is a far more important reason for careful balancing.

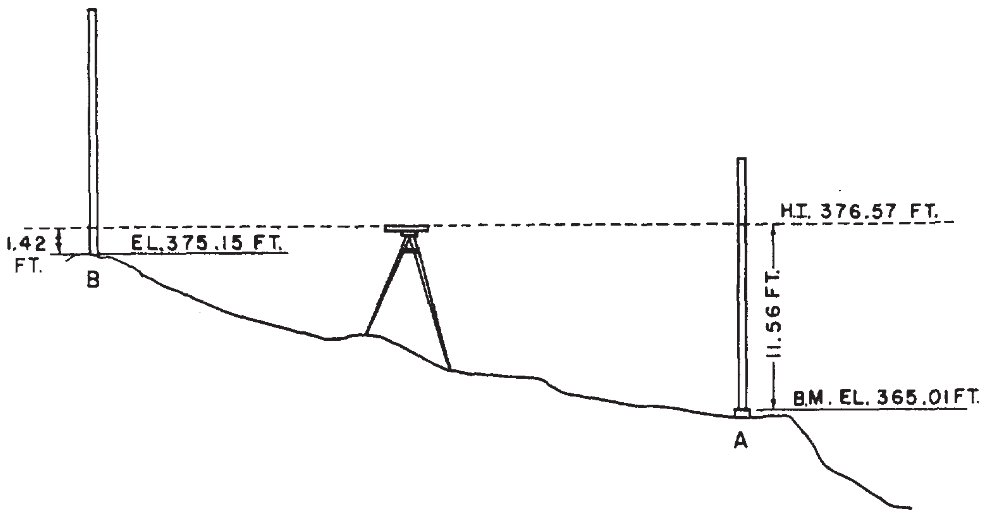


Figure 14-11.-Procedure for direct leveling.

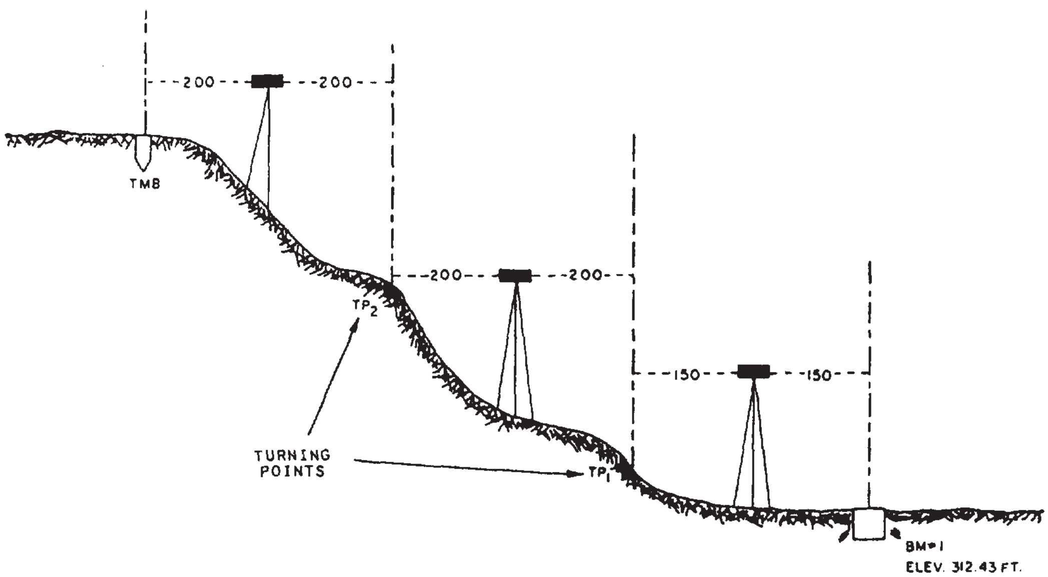


Figure 14-12.-Turning points.

"Balancing shots" means equalizing as much as possible BS and FS distances by selecting turning points that are approximately an equal distance from both the BS and FS points.

No matter how carefully you level a level telescope, it is likely to be still slightly out of the horizontal. The error this causes increases with the length of the sight taken. If the BS distance differs from the FS distance, the BS and FS errors will also differ. If the distances are the same, the errors will be the same. Balancing shots therefore eliminates the effect of instrumental error and also of curvature and refraction, other errors that increase with distance.

To balance distances for a setup, you will find that using the same number of paces for BS as for FS is helpful. In general, BS and FS distances should be kept under 300 ft except when necessary to pass or cross an obstacle.

Establishing Turning Points

Suppose you want to determine the elevation of a point at the summit of a long slope, and the nearest BM is at the foot of the slope some 30 ft or so below the summit. Obviously, you cannot sight a rod held on the BM and another held on the summit from the same instrument setup point. You must work up the slope in a series of steps, as shown in figure 14-12, by establishing as many intermediate TPs as you need to solve the problem. A "turning point" is defined as a point on which both a minus sight (FS) and a plus sight (BS) are taken on a line of direct levels.

As shown in figure 14-12, if we assume that the elevation of the BM is correct, the accuracy of the elevation you determine for the summit depends upon how accurately you determine the elevation of each intermediate TP. This accuracy depends upon a number of things, the most important of which are the following:

1. If you are doing leveling of ordinary precision, FS and BS distances should not exceed 300 ft. Therefore, the first setup point for the instrument should be not more than 300 ft from the BM, and the first TP should be not more than 300 ft from the instrument. To balance shots, you should place the instrument about the same distance from the BM as the distance to the TP.

2. Obviously, the first setup point must be one you can observe with a rod held on the BM and also a rod held on the first TP.

3. Generally, setup points should be used that make rod readings as small as possible. The reason small rod readings are desirable is that, for a rod held out of plumb, each reading on the rod will be in error. The larger the rod reading, the greater the error. Suppose, for example, a rod is so far out of plumb that it indicates 12.01 ft for a reading that should be 12.00 ft if the rod were plumb. For a 12.00-ft reading on the rod, the error is 0.01 ft. For a 2.00-ft reading on the same rod held in the same manner, however, the error would be only about 0.002 ft.

4. A TP must have not only visibility and accessibility, but also stability; that is, it must furnish a firm, nonsettling support for the base of the rod. Suppose you select a point in soft, yielding ground as your first TP. Assume the elevation of the BM is 312.42 ft. You take a BS on the BM and read 3.42 ft. Then, HI is

$$312.42 + 3.42 = 315.84 \text{ ft.}$$

The rodman shifts the rod to the TP. You take an FS and read 5.61 ft. The elevation of the TP is, therefore,

$$315.84 - 5.61 = 310.23 \text{ ft.}$$

Now, you shift the instrument ahead and take a BS to carry on the line of levels to a new TP.

But suppose that before you take the BS on the rod, the TP has settled 0.02 ft in the ground. Then you take a BS and read 4.74 ft. There is now an error of 0.02 ft in the new HI, and every subsequent HI and elevation of TP will be off by the same amount.

So BE SURE that each TP is stable. When the use of a point in yielding ground is unavoidable, you need to base the rod on a turning point pin or turning point plate. A pin is driven in the ground; if you don't have a regular pin, a marlinspike or a railroad spike makes a good substitute. You should use a plate on soil too soft to support a driven pin.

METHODS OF LEVELING

Leveling methods are subdivided into two major categories: DIRECT and INDIRECT. Direct leveling describes the method of measuring vertical distance (difference in elevation) directly with the use of precise or semi-precise leveling instruments. Indirect leveling methods, on the other hand, apply to measuring vertical distances indirectly or by computation. Unlike direct leveling operations, indirect leveling operations do not depend on lines of sight or intervisibility of points or stations. Some of the surveying instruments commonly used for indirect leveling methods are the transit and theodolite.

DIRECT LEVELING

This method of leveling uses the measured vertical distance to carry elevation from a known point to an unknown point. Direct leveling is the most precise method of determining elevation and yields accuracies of third or higher orders. When this method is specified for lower accuracy surveys, direct leveling is sometimes referred to as "spirit" or "fly" levels. Fly levels are leveling operations used to rerun original levels to make sure that no mistake has been made. Fly levels use a shorter route and smaller number of turning points than the original survey. Let's take a look at some of the processes involving direct leveling.

Differential Leveling

Differential leveling (also called direct leveling) is generally used in determining elevations of points to establish a chain or network of BMs for future use. It requires a series of instrument setups along the survey route; and for setup, a horizontal line of sight is established, using a sensitive level. The SEABEEs commonly use this type of leveling in determining elevation during construction surveys.

As shown in figure 14-13, the basic procedure used to determine elevations in a differential leveling operation is the same as previously discussed. First, you take a BS on a rod held on a point of known elevation (KE). Then add the BS reading to the known elevation to determine the HI. Next, take an FS on a rod held at the point of unknown elevation (UKE). Finally, subtract the FS reading from the HI to establish the elevation of the new point.

After you complete the FS, leave the rod on that point and move the instrument forward. Set up the instrument approximately MIDWAY between the old and new rod positions. The new sighting on the back rod becomes a BS, and you can now establish a new HI. The points other than the BMs or TBMs on which you hold the rods for the BSs and FSs are called TURNING POINTS (TPs). Other FSs made to points not along the main route are known as SIDESHOTS. You can use this procedure as many times as necessary to transfer a point of known elevation to another distant point of unknown elevation.

Figure 14-14 shows a sample differential leveling run. The rod is held on BM 35 (Elev. = 133.163). The level is set up midway between BM 35 and

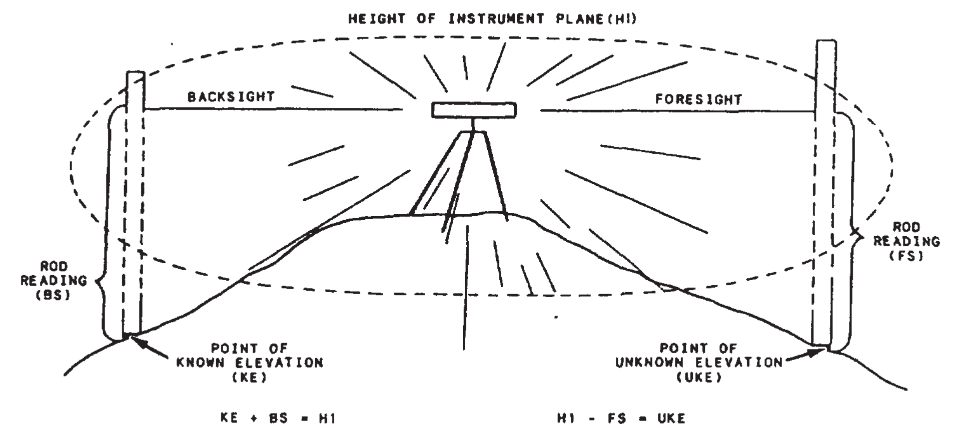


Figure 14-13.-Differersthd leveling.

	LEVEL	CIRCUIT					Leveler EA2 M T Todd / Rodman EA3 C L Miller / B & B Dumpy Level 31057 — FROM B.M. 35 TO B.M. 19
Sta	BS +	HI	FS −	Elev	Sights BS	Sights FS	Remarks
							April 3, 1984 (3 hours) Cloudy, moderate
BM 35	6 659	139 822		133 163	220		Concrete monument
⊙ 16	4.968	139 819	4.971	134 851	250	220	Peg
⊙ 17	4 508	136 875	7.452	132 367	310	250	"
⊙ 18	1.412	132 430	5.857	131.018	100	310	"
TP 1	7073	138 242	1.261	131 169	190	100	Turning Point
BM 19			1.785	136 457		190	Concrete monument
	24.620		21 326	133 163	1070	1070	Actual elevation of □ 19 = 136.442 ft
			24 620	3 294		1070	Permissible error = 0 05 √2140/3280 = 0 032 ft
			3 294	Check		2140	Actual error of closure = 0 015 ft

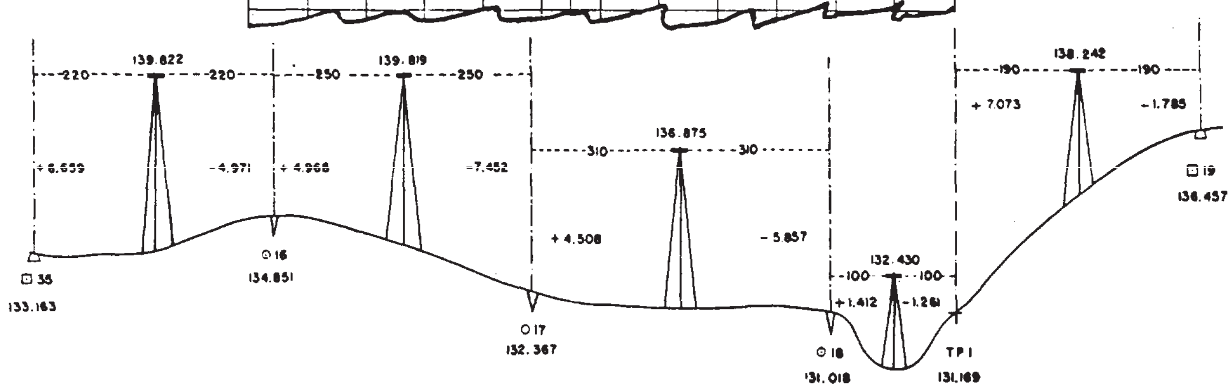


Figure 14-14—Sample field notes and profile of a differential-level circuit.

TBM 16. The BS reading of +6.659 is added to the elevation of BM 35 and gives the resulting HI (139.822). The rod is moved to Peg 16 (which later becomes TBM 16). The FS reading of –4.971 is subtracted from the HI to get the elevation of Peg 16. Note that the distance (220 ft each way) is also recorded for balancing. The process continues until BM 19 is reached.

LEVEL COMPUTATIONS.— ln making level computations, you should be sure to check on the notes for a level run by verifying the beginning BM; that is, by determining that you used the correct BM and recorded its correct elevation, as required.

Then, you should check on the arithmetical accuracy with which you added BSs and subtracted FSs. The difference between the sum of the BSs taken on BMs or TPs and the sum of the FSs taken on BMs or TPs should equal the difference in elevation between the initial BM or TP and the final BM or TP.

Balanced BS and FS distances are shown in figure 14-14. The distance used for the first instrument setup was 220 ft. The first BS (rod reading on ⊡ 35) was 6,659 ft. The first FS (rod reading on ⊙ 16) was 4.971. Notice that the plus sign (+) appears at the top of the BS column and that the minus sign (–) appears at the top of the FS column in the field notebook. This helps you to remember that BSs are added and FSs are subtracted as you compute the new elevations.

The BS taken on a point added to the elevation of the point gives the HI. This establishes the elevation of the line of sight so that an FS can then be taken on any point (BM, TBM, or TP). The level line is extended as far as desired with as many instrument setups as may be necessary by a repetition of the process used in the first setup.

The elevation of ⊡ 35 is 133.163 ft. The first HI is

133.163 + 6,659 = 139.822 ft.

The FS subtracted from the HI,

139.822 – 4.971 = 134.851 ft,

gives the elevation of ⊙ 16, the first established. Following through with a similar computation for each setup, notice that the elevation of ⊡ 19 was found to be 136.457 ft.

Look now at the notes in figure 14-14. The sum of all the BSs is 24.620 ft. The sum of all the FSs is 21.326 ft. The difference between the sum of the BSs and the sum of the FSs is

24.620 – 21.326 = 3.294 ft.

This difference should agree with the difference between the actual elevation of BM 35 and the elevation already found for BM 19; that is,

136.457 – 133.163 = 3.294 ft.

This provides a check on the step-by-step computation of elevations.

ADJUSTMENT OF INTERMEDIATE BENCH MARK ELEVATIONS.— Level lines that begin and end on points that have fixed elevations, such as BMs, are often called level circuits. When leveling is accomplished between two previously established BMs or over a loop that closes back on the starting point, the elevation determined for the final BM will seldom be equal to its previously established elevation. The difference between these two elevations for the same BM is known as the ERROR OF CLOSURE. The Remarks column of figure 14-14 indicates that the actual elevation of BM 19 is known to be 136.442 ft. The elevation found through differential leveling was 136.457 ft. The error of closure of the level circuit is

136.457 – 136.442 = 0.015 ft.

It is assumed that errors have occurred progressively along the line over which the leveling was done so that adjustments for these errors are distributed proportionally along the line as shown by the following example: Referring to figure 14-14, you will notice that the total distance between BM 35 and BM 19, over which the line of levels was run, was 2,140 ft. The elevation on the closing BM 19 was found to be 0.015 ft greater than its known elevation. You must therefore adjust the elevations found for the intermediate TBMs 16, 17, and 18.

The amount of correction is calculated as follows:

$$\text{Correction} = \text{Error of closure}\left[\frac{\text{distance between the starting BM and the intermediate BM}}{\text{distance between the starting and closing BM}}\right]$$

TBM 16 is 440 ft from the starting BM. The total length distance between the starting and closing BMs is 2,140 ft. The error of closure is 0.015 ft.

$$\text{Correction} = -0.015 \times \frac{440}{2140} = -0.003 \text{ ft}$$

The adjusted elevation of TBM 16 is

134.851-0.003 = 134.848 ft.

The adjustments for intermediate TBMs 17 and 18 are made in a similar manner.

Reciprocal Leveling

This procedure is used for either differential or trigonometric leveling when along sight across a wide river, ravine, or similar obstacle must be made. This long sight will be affected by curvature and refraction and by any small error in aligning the line of sight with the bubble axis. The alignment error can be minimized by balancing the long sight and computing the curvature. The atmospheric conditions will vary so much over an open expanse that the refraction correction will be quite erratic. Reciprocal leveling is desired to minimize the effect of the atmosphere as well as the line of sight and curvature corrections. To do this, take the following actions:

1. In reciprocal leveling, balance the BSs and FSs as carefully as possible before you reach the obstacle. In figure 14-15, a TP, N, is selected close to the edge of the obstruction so that it is visible from a proposed instrument location, B, on the other side. A second rod is held on the other side of the obstruction at F. Point F should be selected so that the equivalent distances, AN and FB, and AF and NB, are almost equal. The instrument is setup at point A and leveled carefully. A BS reading is taken on the N rod and an FS on the F rod. These readings are repeated several times. The instrument is moved to point B, set up, and carefully leveled. The rods remain at their stations. Again, a BS is taken on the N rod and an FS on the F rod, and repeated several times. Since instrument leveling is especially critical on reciprocal leveling, you need to check the bubble before each reading and center it carefully. If it is off-center a slight amount, the procedure must be repeated. The difference in elevation between N and F is computed from the readings at A setup and from the readings at B setup separately. Because of the errors in the long sight, the two results will have slightly different values. Note, however, that the long sight is an FS from A and a BS from B. The true difference in elevation is the average of both values, since the errors have opposite signs and will cancel each other.

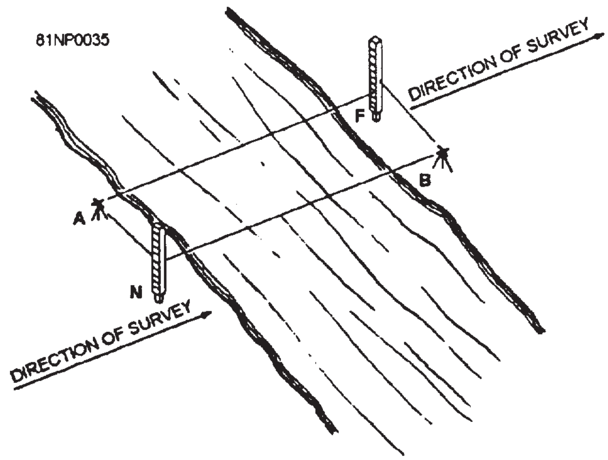


Figure 14-15.-Reciprocal leveling.

2. For more accuracy, make several long sight readings for each short sight and average them. You should use a target on the rod and reset it for each reading. Average each series of long sights and combine this average with corresponding short sights for the computations.

3. Changes in atmospheric density and temperature affect the refraction of a line of sight. The longer the time interval is between reciprocal long sights, the greater the chance of an atmospheric change and a variation in the refraction value. For this reason, you should keep the time lapse between the long sights as short as possible.

4. An excellent method of avoiding the time lapse problem is simultaneous-reciprocal observation. The object is to read both long sight values at the same time. This requires two instruments and two observers and two rods and two rodmen. Some method of communication or sequence of operations must be agreed upon.

5. The note keeping for reciprocal leveling is identical to differential leveling. Take a series of either BS or FS readings on the far rod from one setup and take only one sighting on the rear rod. Average the series of readings, and use a single value to make the elevation computations.

Profile Leveling

In surveying, a PROFILE is a vertical section of the earth measured along a predetermined or fixed line. In practice, profiles are a series of ground elevations determined by differential leveling or other methods that, when plotted along

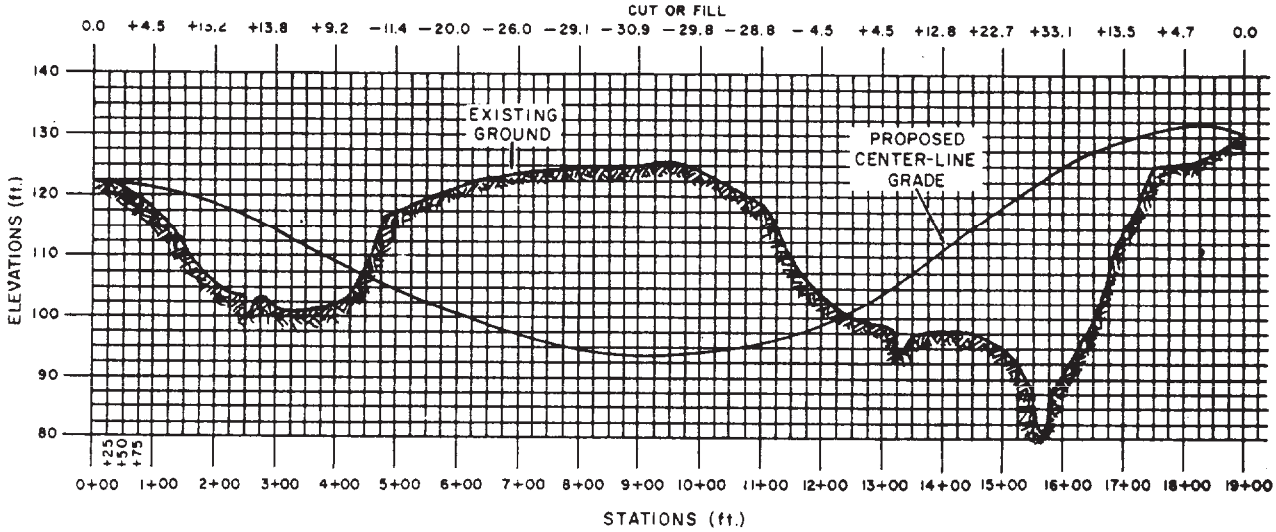
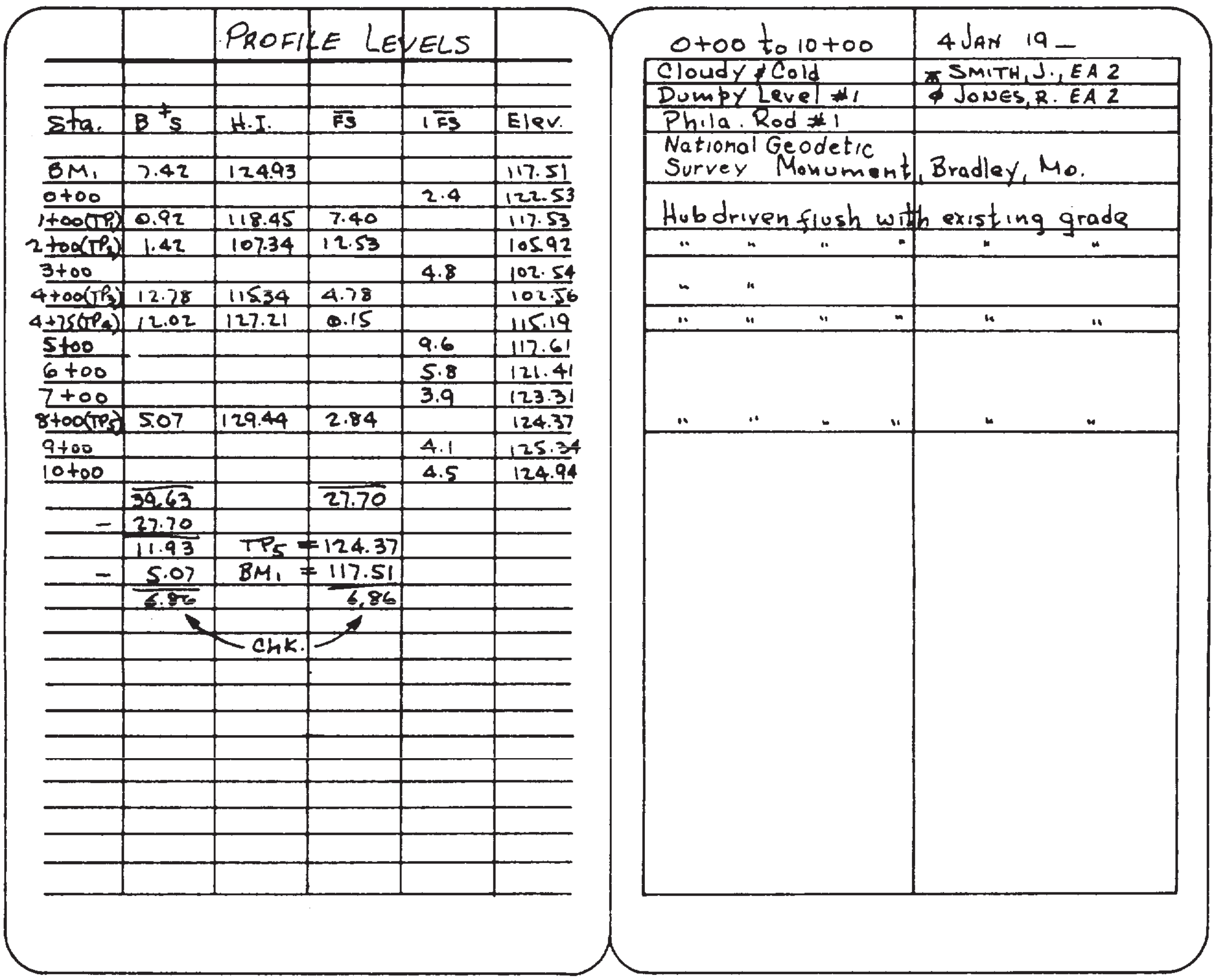


Figure 14-16.-Plotted profile and grade lines along a proposed road center line.



PROFILE LEVELS

Sta.	B+S	H.I.	FS	IFS	Elev.
BM1	7.42	124.93			117.51
0+00				2.4	122.53
1+00(TP1)	0.92	118.45	7.40		117.53
2+00(TP2)	1.42	107.34	12.53		105.92
3+00				4.8	102.54
4+00(TP3)	12.78	115.34	4.78		102.56
4+75(TP4)	12.02	127.21	0.15		115.19
5+00				9.6	117.61
6+00				5.8	121.41
7+00				3.9	123.31
8+00(TP5)	5.07	129.44	2.84		124.37
9+00				4.1	125.34
10+00				4.5	124.94
	34.63		27.70		
−	27.70				
	11.93	TP5 =	124.37		
−	5.07	BM1 =	117.51		
	6.86		6.86		
	Chk.				

0+00 to 10+00	4 JAN 19__
Cloudy & Cold	⊼ SMITH, J., EA 2
Dumpy Level #1	⌀ JONES, R. EA 2
Phila. Rod #1	
National Geodetic Survey Monument,	Bradley, Mo.
Hub driven flush with	existing grade
" " " "	" "
" "	
" " " "	" "
" " " "	" "

Figure 14-17.-Field notes for profile levels shown in figure 14-7.

some line, such as the center line of a road, can be used to determine the final grade or alignment of that road, railroad, or sewer line. Profiles are also used to compute volumes of earthwork.

Figure 14-16 shows a plotted profile of the existing ground surface along a proposed highway center line. Horizontally on the graph, you read a succession of 100-ft stations, from 0 + 00 to 19 + 00. Vertically, you read elevations. Note that, horizontally, the interval between adjacent vertical grid lines represents 25 ft; but vertically the interval between adjacent horizontal grid lines represents 2.5 ft.

The profile was plotted through a succession of points, each of which was obtained from a profile elevation taken on the ground. Figure 14-17 shows field notes for the levels taken from 0 + 00 through 10 + 00. The level was first set up at a point about equidistant from station 0 + 00 and from a BM identified as National Geodetic Survey Monument, Bradley, Missouri. The elevation of the BM was 117.51 ft. The first backsight reading on a rod held on the BM was 7.42 ft. The height of instrument (HI) was therefore

117.51 + 7.42 = 124.93 ft.

You can see this entered in the “HI” column.

From the first instrument setup, FSs were taken on station 0 + 00 and 1 + 00. The elevation of the station in each case was determined by subtracting the FS reading from the HI. Note that the FS taken on station 1 + 00 is entered in a column headed “FS, ” while the one taken on station 0 + 00 is entered in a different column, headed “IFS.” “IFS” means intermediate FS, or an FS taken on a point that is neither a BM nor a TP, You can see that station 1 + 00 was used as a TP in shifting the instrument ahead. Only FSS taken on BMs or TPs are entered in the column headed “FS.”

After an FS was taken on station 1 + 00, it became necessary to shift the instrument ahead. Station 1 + 00 was used as the TP. From the new instrument setup, a BS was taken on a rod held on 1 + 00. The new HI was found by adding the BS reading to the previously determined elevation of 1 + 00.

From the new setup, an FS was taken on station 2 + 00; again, the elevation was found by subtracting the FS reading from the HI. After this sight was taken, the instrument was again shifted ahead, probably because of the steepness of the slope. This time, station 2 + 00 was used as the TP_2. From the new setup, a BS was taken on station 2 + 00 and a new HI established. From this setup, it was possible to take FSs on both station 3 + 00 and station 4 + 00. Because station 3 + 00 was not used as a TP, the FS on it was entered under IFS.

Apparently, the slope between station 4 + 00 and station 5 + 00 was so steep that sighting both stations from the same setup with the rod being used was impossible. Consequently, an intermediate TP (TP_4) was established at station 4 + 75 by determining the elevation of this station. The instrument was shifted to a setup from which a BS could be obtained on a rod held on this station and from which FSs on stations 5 + 00, 6 + 00, 7 + 00, and 8 + 00 could be taken, Station 8 + 00 was then used as a TP for the last shift ahead. From this last setup, it was possible to take FSs on stations 9 + 00 and 10 + 00.

As a check on the arithmetic, you customarily check each page of level notes to check the difference between the sum of the FSs and the sum of the BSs against the difference in elevation between the initial BM or TP and final BM or TP. Obviously, only the BSs and FSs taken on BMs and TPs are relevant to this check, This is the reason why intermediate FSS not taken on BMs or TPs are entered in a separate column.

If the arithmetic is correct, the two differences will be the same. As you can see, the sum of the relevant BSs in figure 14-17 is 39.63; the sum of the FSs is 27.70; and the difference between the two is 11.93. Note that from this difference, the BS taken on TP_5 is deducted. The reason is the fact that this BS is not offset by a corresponding FS on a BM or TP. With the BS taken on TP_5 deducted, the difference between the sum of the FSs and the sum of the BSs is 6.86. The difference between the elevation of TP_5 and the elevation of the initial BM is 6.86, so the arithmetic checks.

Remember that this procedure provides a check on the arithmetic only. If you have recorded any incorrect values, the arithmetic will check out just as well as when you have recorded the correct values. The procedure is valuable, however, for detecting two mistakes commonly made by beginners. These are subtracting a BS from, instead of adding it to, a BM elevation to get the HI; and adding an FS to, instead of subtracting it from, the HI to get an elevation.

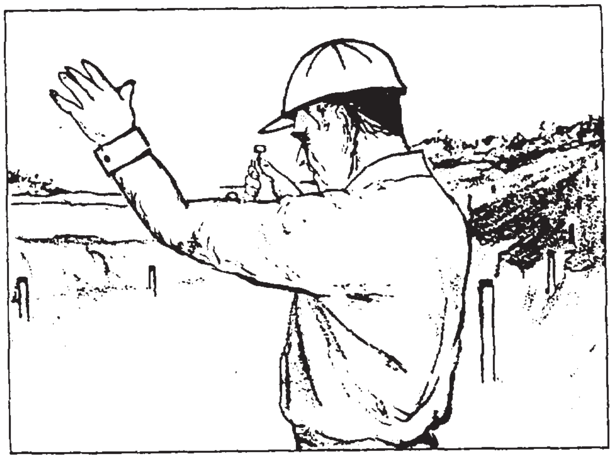


Figure 14-18.—Using angle prism for sighting 90° from the center-line stakes.

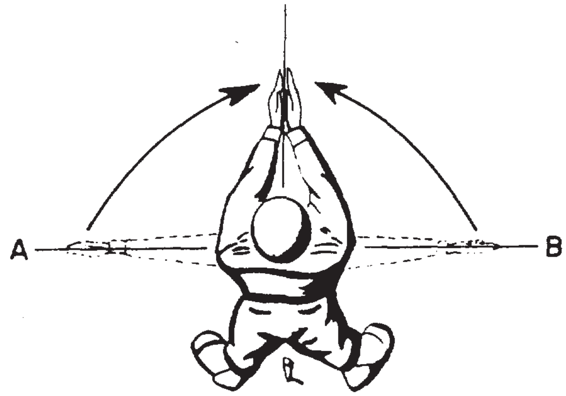


Figure 14-19.-Laying off a 90°angle from the center-line stakes.

Cross-Section Leveling

In profile leveling, you determine the elevations of a series of points lengthwise along a highway. In cross-section leveling, you determine the elevations of points on a succession of lines running at right angles to the lengthwise line of the highway. The principal purpose of profile leveling is to provide data from which the depth of fill or cut required to bring the existing surface up to, or down to, the grade elevation required for the highway can be determined.

Note that profile leveling provides this data relative to the center line. In figure 14-16, you can see along the top the depth of cut or fill required at each station to bring the existing surface to grade—the prescribed grade line for the highway is indicated by the smoothly curved grade line shown. At each station, you can determine the cut or fill by counting the squares between the profile and the grade line.

The cross-section lines are established at regular stations, at any plus stations, and at intermediate breaks in the ground. Short crosslines are laid out by eye, but long crosslines are laid out at a 90° angle to the center line with the transit. For short crosslines, most surveyors prefer to use an angle prism for sighting 90°angles from the center line. Figure 14-18 shows a surveyor using an angle prism for sighting a 90°angle from the center line of the highway.

For cross-section leveling, strip topography, and some other purposes, it is necessary to lay off a 90°angle at numerous points along a line. This 90°angle can often be established by estimation with sufficient accuracy for the particular job. The surveyor straddles the point on the line, arms extended sideward along the marked line (fig. 14- 19). By looking alternately right then left, he adjusts the position of his feet until his body is in line with AB. He then brings his hands together in front of him, thus pointing along an approximate 90°line from the marked line. An experienced surveyor can lay off a 90° angle by this method so that a point 100 ft away will be within 1 ft of the true perpendicular.

You should measure all elevations at abrupt changes or breaks in the ground with a rod and level. Measure all distances from the center line with a metallic tape. In rough country, the hand level can be used to advantage for obtaining cross sections if the center-line elevations have been determined by use of the engineer's level.

Cross-section leveling is usually done with a hand level after the profile run has been made. The method is as follows:

From the profile run, you know the center-line elevation at each station. Suppose you want to take cross-section elevations at 10 ft intervals for 40 ft on either side of the center line. The first thing you do is to determine the vertical distance from the ground to your line of sight through the hand level when you stand erect with the level at your eye. The best way to do this is to sight on a level rod held plumb in front of you. Suppose you find that the vertical distance is 5.5 ft. Then your HI at any center-line station is the center-line elevation (obtained in the profile level run) plus 5.5 ft.

Suppose that you are standing at station 0 + 00, figure 14-16. The elevation of this station is 122.53 ft. Your HI is therefore

.122.53 + 5.5 = 128.03 ft.

You round off cross-section elevations to the nearest 0.1 ft. If a rodman holds a rod 40 ft to the left of the center line at station 0 + 00 and you read 1.9 ft on the rod, then the elevation of the point plumbed by the rod is

128.0 − 1.9 = 126.1 ft.

The rodman now moves on to a point 30 ft from the center line. If you read 3.3 ft on the rod, the elevation of this point is

128.0 − 3.3 = 124.7 ft.

Going on in this manner, you determine the elevations at all the required points on the cross section. You then move to the next station and repeat the process.

Cross section notes are recorded in the field book by using one of two basic methods. In the first, and often preferred, method, begin at the bottom of the page and read upward, as shown in figure 14-20. This method helps to keep you oriented in the direction in which the line runs and helps to prevent confusion as to which is the right or left side of the line. It therefore reduces the possibility of recording your readings on the wrong side of the center line.

In the second method, the notes are recorded in the conventional manner of reading from top to bottom of the page. Whichever method you use, you must remember that as you stand facing the direction in which the line runs, left

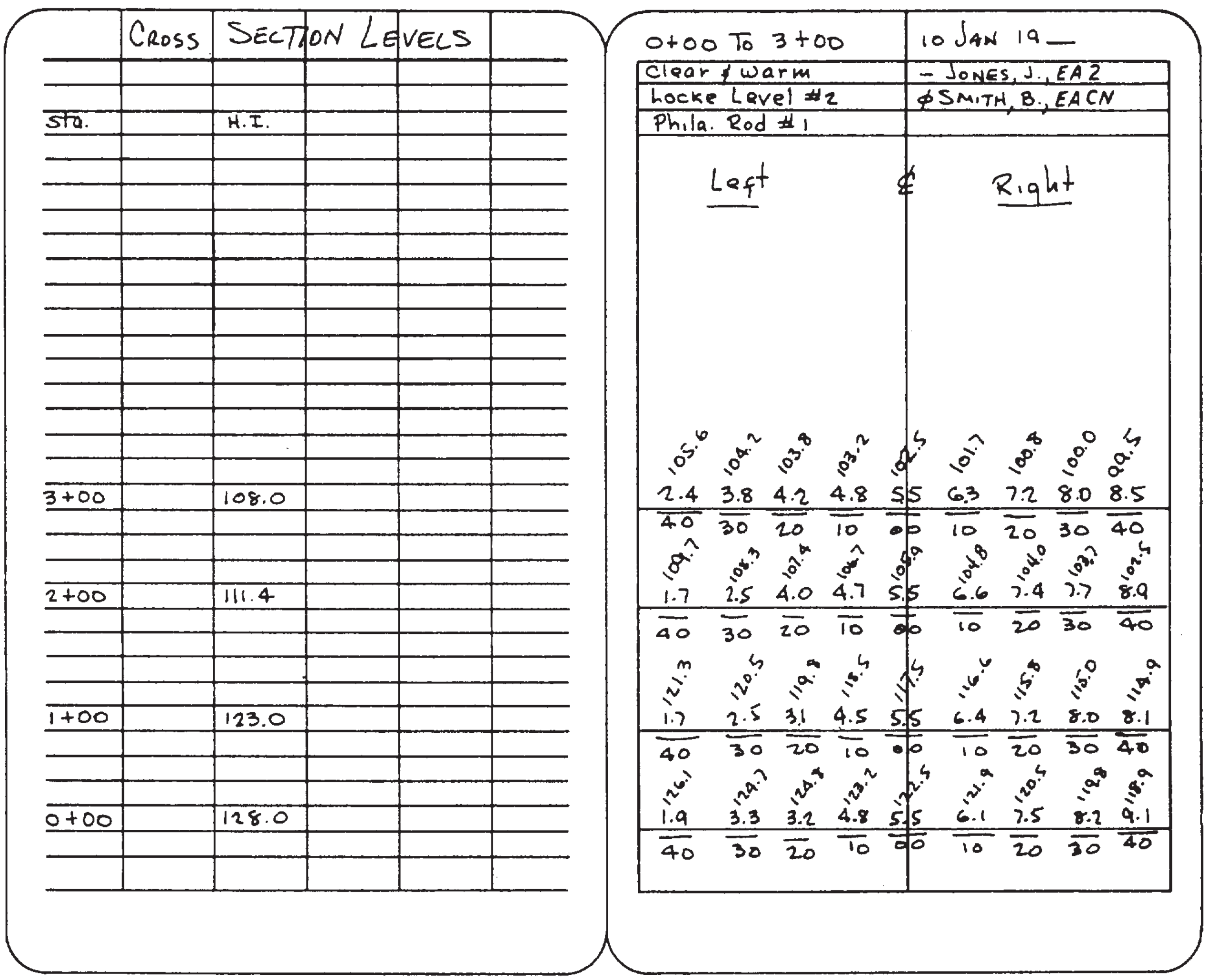


Figure 14-20.-Sample field notes from cross-section leveling at first three stations shown in figure 14-7.

and right in the notebook must correspond to left and right in the field.

Figure 14-20 shows field notes for cross-section levels taken on the first three stations shown in figures 14-16 and 14-17. On the data side, only the station and the HI need to be listed. On the remarks side, each entry consists of a point elevation, written over the distance of the point from the center line. The computed elevation, determined by subtracting the rod reading from the HI, is written in above as shown. Note that the rod reading at the center line is the 5.5-ft vertical distance from your line of sight to the ground. Also, notice that the center-line elevation written in at each station. is the one obtained in the profile level run. You obtain the HI for each station by simply adding together these two figures.

Double Rodding

Double rodding is a form of differential leveling in which a continuous check is maintained on the accuracy of the leveling procedure. It is called double rodding because it can be done most conveniently by two rodmen. However, it is possible to carry out the procedure using only one rodman.

In double rodding, you determine the HI at each setup point by backlights taken on two different TPs. If no mistake or large error has been made, the result will be two HIs that differ slightly from each other. Elevations computed this way will also differ slightly. In each case, the average is taken as the elevation.

Figure 14-21 shows double-rodded level notes for a run from one BM to another by way of three

DOUBLE RODDED LEVELS

Sta	Bts	H.I.	F.S.	Elev.	Mean
BM1				852.76	
	3.74	856.50			
	3.74	856.50			
TP1	5.17	855.53	6.14	850.36	
TP1L	6.31	855.54	7.27	849.23	
TP2	3.15	854.43	4.25	851.28	
TP2L	4.06	854.44	5.16	850.38	
TP3	6.18	857.49	3.12	851.31	
TP3L	7.18	857.47	4.15	850.29	
BM2			5.51	851.98	851.99
BM2			5.47	852.00	
TP	18.24		19.02		
TPL	21.29		22.05		

19.02 BM1 852.76
− 18.24 BM2 851.98
0.78 0.78
CHK

22.05 BM1 852.76
− 21.29 BM2 852.00
0.76 0.76
CHK

BM1 To BM2	10 JAN. 19__
Clear, Cold	T Johnson, EA 2
Dumpy Level #2	ϕ#1 SMITH, F., EACN
Phila. Rods #1 & #2	ϕ#2, JONES, A, EACN
National Geodetic Survey B.M. Fairoaks Sta.	
Concrete monument N.E. Corner park	

Figure 14-21.-Sample field notes from double-rodded levels.

intermediate TPs. In each case, a "higher" TP (as TP_1) and a "lower" TP (as TP was used, resulting in two different HIs for each. Computed by way of the higher HIs, the elevation of BM_2 came to 851.98 ft. Computed by way of the lower HIs, it came to 852.00 ft. The mean (average) of 851.99 ft was taken as the correct elevation.

INDIRECT LEVELING

Indirect methods of leveling encompass both trigonometric and barometric leveling. TRIGONOMETRIC LEVELING uses vertical angles and a horizontal distance to compute the difference in elevation, BAROMETRIC LEVELING uses the difference in atmospheric pressures that are observed by a barometer or an altimeter to determine the elevation differences. Indirect methods of leveling will be discussed at the EA2 level.

PRECISION IN LEVELING; MISTAKES AND ERRORS IN LEVELING

Leveling, like any other surveying operation, is carried out by following a prescribed ORDER OF PRECISION—meaning that the instruments you use and the methods you follow have to be those that can give you the specified standard of accuracy.

PRECISION IN LEVELING

FIRST-ORDER leveling is used to establish the main level network for an area and to provide basic vertical control for the extension of level networks of the same, or lower, accuracy in support of mapping projects, cadastral (recording property boundaries, subdivision lines, buildings, etc.), and local surveys. Level lines must start and end on proven, existing BMs of the same order. New levels must be run between the starting BM being used and at least one other existing BM and must show there is no change in their relative elevations.

SECOND-ORDER leveling is used to subdivide nets of first-order leveling and to provide basic control for the extension of levels of the same, or lower, accuracy in support of mapping projects and local surveys. Second-order levels are divided into two classes: Class I and Class II. CLASS I is used in remote areas where the line must be longer than 25 mi because routes are unavailable for the development of additional or higher order networks and for spur lines. CLASS II levels are used for the development of nets in the more accessible areas. In Class I leveling, it is required that all lines start and close on previously established BMs of first or second order. New levels have to be run between the existing BM being used and at least one other existing BM to prove that they have not changed their relative elevations. The criteria for Class II are the same as for Class 1, except that Class II lines are run in one direction only.

THIRD-ORDER leveling is used to subdivide an area surrounded by first- and second-order leveling and to provide elevations for the immediate control of cadastral, topographic, and construction surveys for permanent structures. The following criteria should be observed in third-order leveling:

1. All lines have to start from, and close on, two previously established BMs of third, or higher, order of accuracy if the new leveling indicates they have not changed in their relative elevations.
2. In the United States, third-order lines should not be extended more than 30 mi from BMs of first or second order. In foreign or remote areas, the distance may be extended according to the evaluation of the existing control and the situation. They may be single-run (one direction) lines but should always be loops or circuits that close upon BMs of an equal or a higher order.
3. When a line from previously established third-order marks is extended, the maximum length of the new line is greatly reduced. The distance and allowable error are to be carried back through the existing line to the nearest tie BM of the second or higher order.
4. Balanced sights should not be greater than 300 ft. BS and FS distances maybe measured by pacing and approximately balanced between BMs, Rod readings are read to thousandths and the rod waved for extended rod readings. The bubble is checked to make sure it is exactly centered before each sighting and reading. Turning point pins or plates or well-defined points on solid objects are used for TPs.

FOURTH-ORDER leveling is used to subdivide an area within a third-order network. This is the method of leveling used in connection "with the location and construction of highways, railroads, and most other engineering works that concern the SEABEEs in advanced base projects.

But, in practice, trying to shoot for a higher degree of accuracy is advantageous if it does not affect the proper progress of the work. The following criteria should be observed in fourth-order leveling:

1. All lines are to start from, and close on, previously established BMs of the third or fourth order of accuracy.

2. Maximum sight distance is about 500 ft. Rod readings are read to hundredths of a foot. BS and FS distances are roughly balanced only when lines of great lengths are run, either uphill or downhill. TPs are taken on solid or any well-defined, firm objects.

The instrument commonly used in third- and fourth-order leveling is the engineer's level and the Philadelphia rod. Always check the proper adjustments of the instrument before using it.

Order of Precision

The precision of a level run is usually prescribed in terms of a maximum error of closure. This is obtained by multiplying a constant factor by the square root of the length of the run in miles or in kilometers, depending upon the system of measurement being used. The Federal Bureau of Surveying and Mapping specifies certain requirements and the maximum closing errors, such as those shown in table 14-1. You may refer to this standard if the order of precision is not specified for a particular survey project.

Calculating Error of Closure

A level run that begins at a particular BM and is carried back again to the same BM is called a level loop. A run that does not close on the initial BM is called a level line. A level line closes on another BM; but when a level line is carried back to its origin, it becomes a level loop. Usually, a level line is carried back to the initial BM to determine the error of closure.

Error of closure is simply the difference between the known elevation of the initial BM and the elevation of the same (BM) as computed in the level run.

The error of closure that can be allowed depends on the precision required (first, second, or third order). The permissible (or allowable) error of closure in accuracy leveling is expressed in terms of a coefficient and the square root of the horizontal length of the actual route over which the leveling was done.

Most differential leveling (plane surveying) is third-order work. In third-order leveling, the closure is usually made on surveys of higher accuracy without doubling back to the old BM at the original starting point of the level circuit. The length of the level circuit, therefore, is the actual distance leveled. For third-order leveling, the allowable error is as follows:

$$0.050 \text{ ft}\sqrt{\text{length of the level circuit in miles}}$$

By adding the sight distances in the sixth and seventh columns of the differential level circuit shown in figure 14-14, you will find that the length of the level circuit is 2,140 ft. The length in miles is

$$2140 \div 5280 = 0.405.$$

The allowable error of closure is

$$0.050\sqrt{0.405} = 0.050(0.64) = 0.032 \text{ ft}.$$

Since the actual error is only 0.015 ft, the results are sufficiently accurate.

First- and second-order levels usually close on themselves. The leveling party runs a line of levels from an old BM or station to the new BM or station, and then doubles back to the old BM for closure. The actual distance leveled is twice the length of the level circuit.

For second-order leveling, the allowable error is

$$0.035 \text{ ft}\sqrt{\text{length of the level circuit in miles}}$$

First-order leveling is still more precise. The allowable error cannot be greater than

$$0.017 \text{ ft}\sqrt{\text{length of the level circuit in miles}}$$

MISTAKES AND ERRORS IN LEVELING

As explained in an earlier chapter, the terms *mistakes* and *errors* are NOT synonymous in surveying.

Leveling operations, like other survey measurements, are susceptible to both. Mistakes can be avoided by a well-arranged system of operation and by constant alertness by the survey party members. Checking, as described in some of the operations, will eliminate many possible

Table 14-1.—Leveling Order of Precision

REQUIREMENTS	FIRST ORDER	SECOND ORDER		THIRD ORDER	FOURTH ORDER
		Class 1	Class II		
*Spacing of lines and crosslines ----------------	72 km or 40 miles	40-56 km or 25-35 miles	10 km or 6 miles	Not specified	None
Average spacing of permanently marked BMs along lines, not to exceed ----------------	2 km or 1 mile	2 km or 1 mile	2 km or 1 mile	5 km or 3 mile	None
Length of sections -----	1-2 km or 1/2-1 mile	1-2 km or 1/2-1 mile	1-2 km or 1/2-1 mile	Not specified	None
Check between forward and backward running between fixed elevations or loop closure not to exceed -------------------	$4mm\sqrt{k}$ or $0.017\ ft\sqrt{M}$	$8.4mm\sqrt{k}$ or $0.035\ ft\sqrt{M}$	$8.4mm\sqrt{k}$ or $0.035\ ft\sqrt{M}$	$12mm\sqrt{k}$ or $0.05\ ft\sqrt{M}$	0.6 m for lines up to 20 km or $0.1\ ft\sqrt{M}$

k = the distance in kilometers.
M = the distance in miles.
*In areas outside the U.S. this criteria may be changed to conform with the situation.

areas of mistakes. Errors cannot be completely eliminated, but they can be minimized so that their effect on the survey accuracy will be small and within the tolerances permitted.

Identifying Leveling Mistakes

The leveling mistakes discussed here are not intended to include all possibilities but will give an idea of the more common ones. The survey party personnel should be aware of these possibilities and should be careful to avoid these mistakes. Some of the common mistakes are as follows:

1. Not setting the rod on the same point for an FS and the following BS. Using a turning pin, pedestal, stake, or marking the location with chalk on hard surfaces will help you to recover the identical point.

2. Neglecting to clamp the target or the rod when extended. Any slippage can pass unnoticed and result in a wrong reading that may require an entire rerun of the line to discover the mistake. The rodman should watch the rod or target for any movement as the clamp is tightened. The rod extension or target should be read again after the clamp has been set.

3. Reading the wrong mark. This is a common mistake. The figures on a rod may be obscured by brush or may fall in a position in the field of view so that the instrumentman cannot see two consecutive numbers. Under these conditions, he may read the wrong mark or even read in the wrong direction. This is a great possibility when an inverting eyepiece is being used. For example, if the figure 2 is the only number visible, the instrumentman might read "up" the rod—2.1, 2.2, 2.3 when actually he should be reading 1.9, 1.8, 1.7. Another possibility is miscounting the number of divisions. There is no way to check or discover these mistakes except to be aware of their possibility and to read carefully.

4. Recording a reading in the wrong column. In leveling, readings are not entered into the notebook in a normal sequence, such as left to right across the page. There is always a chance that one or more values may be recorded in the wrong column. The recorder must be alert to avoid making this mistake.

5. Reading the wrong angle sign in trigonometric leveling. The instrumentman can accidentally call out a wrong sign in reading the angle. This type of mistake can be eliminated by the recorder watching the telescope as a pointing is made on the rod. If the wrong one is called out, both the recorder and the instrumentman can resolve it immediately.

6. Recording the wrong sign. The sign varies depending on whether the rod reading is a BS or an FS, and whether the angle is a depression or an elevation. Also, the difference in elevation computation requires a sign reversal if the angle is read for the BS, but not for the FS. These variations can be confusing; the recorder has to be careful to avoid mistakes. This can be done by recording the angle and rod reading signs as read. The sign conversion, if needed, shows up when you compute the DE. Examining the computations to see if all BS DEs have a sign opposite to the angle sign is simple.

7. Subtracting the BS or adding the FS in differential leveling. If the BS or FS is recorded properly (see Number 4 above), you can discover the mistake when you add the BS column and the FS column for a computation check.

8. Using the wrong horizontal cross hairs. This occurs on an instrument provided with stadia hairs.

Identifying Leveling Errors

Generally, errors cannot be totally eliminated, but they can be contained within acceptable tolerances. This requires you to use the prescribed methods and instruments and apply corrections established either mathematically or by experience. Some of the conditions that produce errors are listed below.

1. Instrument not properly adjusted. A small amount of residual error will always exist in any adjustment. For the more accurate surveys, the residual error can be minimized by using BS and FS balancing and, in trigonometric leveling, by taking direct and reverse (circle left and circle right) readings for the angles.

2. Instrument not leveled properly. Unlike the residual adjustment error that will affect the readings one way consistently, this is a random or accidental error. It may affect the line of sight differently at each setup. This error can be minimized only by careful leveling each time the instrument is set up and by recentering the bubble before each reading.

3. Telescope not focused properly. Misfocusing and parallax in the eyepiece create accidental errors that cannot be corrected. The only way to avoid or minimize this error is to take care to focus properly at each setup. The instrumentman

should check and clear parallax before the first sighting and should not readjust it until all sightings from the setup are complete.

4. Rod improperly plumbed. This error is caused by a rodman who does not pay attention to his work. The instrumentman can call attention to plumbing if it is at a right angle to his line of sight, but he cannot see it in the direction of line of sight. The use of a rod level or waving the rod will avoid this error.

5. Unstable object used for a TP. The rodman causes this error by selecting a poor point of support, such as loose rocks or soft ground. As the rod is turned between sights, the weight of the rod can shift a loose rock or sink into soft ground. The elevation of the TP as used for the next BS can change appreciably from the value that had been computed from the previous FS. This error can be avoided by using the turning pin or pedestal when the ground does not present solid points.

6. Rod length erroneous. This error results in either too long or too short rod readings at each point. In a survey predominately over slopes, this error will accumulate. The rod length should be checked with a steel tape at intervals to locate this error.

7. Unbalanced BS and FS distances. The unbalanced distances do not cause the error. It is caused by the effect on the line of sight from residual adjustment and leveling errors and the effect of curvature and refraction errors. Readings you take at a long distance will have a greater error than those at a short distance. This unbalance may not be critical on one setup but can be compounded into a considerable error if the unbalance continues over several setups. By balancing the sight distances at each instrument setup, if possible, and the sums of the BS and FS distances at every opportunity, you will keep these errors to a minimum.

8. Earth's curvature. This produces an error only on unbalanced sights in leveling. When the BS distances are constantly greater than FS distances, or vice versa, a greater systematic error results, especially when the sights are long. To eliminate this error, you must maintain a balanced sight distance in every BS and FS reading, not just their sum total between BMs (the error varies directly as the square of the distance from the instrument to the rod).

9. Atmospheric refraction. This error also varies as the square of the distance but opposite in sign (+ or –) to that caused by the earth's curvature. The effect of atmospheric refraction is only one-seventh of that caused by the earth's curvature. In first- and second-order leveling, the effect of refraction is minimized by taking the BS and FS readings in quick succession and avoiding readings near the ground. (They should be taken at least 2 ft from the ground.)

10. Variation in temperature. If a portion of the telescope is shaded and some parts are exposed to the sun's rays, it produces some warping effect on the instrument that may affect its line of sight. This effect is negligible in ordinary leveling; but in leveling of higher precision, this effect may produce appreciable error. This is one of the reasons why surveyors use an umbrella to shield the instrument when doing more refined work.

BASIC ENGINEERING SURVEYS AND CONSTRUCTION SITE SAFETY

An engineering survey forms the first of a chain of activities that will ultimately lead to a completed structure of some kind, such as a building, a bridge, or a highway. An engineering survey is usually subdivided into a DESIGN-DATA SURVEY and a CONSTRUCTION SURVEY.

This section discusses the basic engineering surveys commonly performed by an EA survey party in support of military construction activities. In addition, various types of occupational hazards relating to specific surveying operation are also presented in this section together with the precautions or applicable abatement procedures that must be carried out to deter injury to the survey crew and/or damage to surveying equipment or material.

HIGHWAY SURVEYS

Surveys for roads and streets involve both field work and office work. The extent of each type of work depends on the magnitude and complexity of the job. Some phases of the work may be done either in the field or in the office, and the decision as to the exact procedures to be followed will be influenced by the number of personnel available and by the experience and capabilities of the individuals involved.

Design-Data Survey

This type of survey is conducted for the purpose of obtaining information that is essential for planning an engineering project or development and estimating its cost. A typical design-data survey, for example, is a route survey required in the design and construction of a particular road or highway. The initial activities included in a route survey are as follows: reconnaissance survey, preliminary-location survey, and final-location survey.

On the other hand, a long established Navy base might already have well-marked horizontal and vertical control networks and up-to-date topographic maps available. Then perhaps neither a reconnaissance nor a preliminary survey would be required. The road could probably be designed by using the existing design data, and the fieldwork would begin with making the final location survey. In summary, the extent to which data is already available is an important factor in determining what field operations have to be performed.

RECONNAISSANCE SURVEY.— A reconnaissance survey provides data that enables design engineers to study the advantages and disadvantages of a variety of routes and then to determine which routes are feasible. You begin by finding all existing maps that show the area to be reconnoitered. In reconnaissance, studying existing maps is as important as the actual fieldwork. Studying these maps and aerial photographs, if any exist, will often eliminate an unfavorable route from further consideration, thus saving your reconnaissance field party much time and effort.

Contour maps give essential information about the relief of an area. Aerial photographs provide a quick means for preparing valuable sketches and overlays for your field party. Direct aerial observation gives you an overview of an area that speeds up later ground reconnaissance if the region has already been mapped.

Begin the study of a map by marking the limits of the area to be reconnoitered and the specified terminals to be connected by the highway. Note whether or not there are any existing routes. Note ridgelines, water courses, mountain gaps, and similar control features. Look for terrain that will permit moderate grades without too much excavating. Use simplicity in alignment and have a good balance of cuts and fills; or use a profile arrangement that makes it possible to fill depressions with the cut taken from nearby high places.

Mark the routes that seem to fit the needs and that should be reconnoitered in the field. From the map study, determine grades, estimate the amount of clearing required, and locate routes that will keep excavation to a minimum by taking advantage of terrain conditions. Mark stream crossings and marshy areas as possible locations for fords, bridges, or culverts.

Have the reconnaissance field party follow the route or routes marked earlier during the map study. Field reconnaissance provides you with an opportunity for checking the actual conditions on the ground and for noting any discrepancies in the maps or aerial photographs. Make notes of soil conditions, availability of construction materials, such as sand or gravel, unusual grade or alignment problems, and requirements for clearing and grubbing. Take photographs or make sketches of reference points, control points, structure sites, terrain obstacles, landslides, washouts, or any other unusual circumstances.

Your reconnaissance survey party will usually carry lightweight instruments that are not precise. Determine by compass the direction and angles. Determine the approximate elevations by an aneroid barometer or altimeter. Use an Abney hand level (clinometer) to estimate elevations and to project level lines. Other useful items to carry are pocket tapes, binoculars, pedometer and pace tallies, cameras, watches, maps, and field notebooks.

Keep design considerations in mind while running a reconnaissance survey. Remember that future operations may require further expansion of the route system presently being designed. Locate portions of the new route, whenever possible, along roads or trails that already exist. Locate them on stable, easily drained, high-bearing-strength soils. Avoid swamps, marshes, low-bearing-strength soils, sharp curves, and routes requiring large amounts of earthmoving.

Keep the need for bridges and drainage structures to a minimum. When the tactical situation permits, locate roads in forward combat zones where they can be concealed and protected from enemy fire.

The report you turn in for the reconnaissance field party must be as complete as possible; it provides the major data that makes the selection of the most feasible route or routes possible.

PRELIMINARY SURVEY.— A preliminary survey is a more detailed study of one or more routes tentatively selected on the basis of a reconnaissance survey report. It consists essentially of surveying and mapping a strip of land along the center line of a tentatively selected route.

Some of the activities associated with a preliminary survey are as follows: running a traverse (sometimes called a P-line or survey base line), establishing BMs, running profiles, and taking cross sections. For many projects, the preliminary survey may be conducted by a transit-tape party alone. Other projects may require a level party and a topographic party.

Normally, the data gathered from a preliminary survey are plotted while the party is in the field, This practice gives a more accurate representation of the terrain, reduces the possibility of error, and helps to resolve any doubtful situations while you are actually observing the terrain.

FINAL-LOCATION SURVEY.— The final-location survey, usually called the location, constitutes a continuous operation; or, in other words, the survey operation goes on from the start of the project through to the end of the actual construction. The location survey consists of establishing the approved layout in the field, such as providing the alignment, grades, and locations that will guide the construction crew.

The EAs tasked with final-location survey normally start (time and distance) ahead of the construction crew. This is often done to save construction time and to avoid delay of scheduled activities. Some of these activities are setting stakes to mark the limits of final earthmoving operations to locate structures and establishing final grades and alignment.

Before making the final-location survey, you should make office studies consisting of the preparation of a map from preliminary survey data, projection of a tentative alignment and profile, and preliminary estimates of quantities and costs. Use this information as a guide for the final location phase. The final location in the field is carefully established by your transit party, using the paper location prepared from the preliminary survey. The center line may vary from the paper location because of objects or conditions that were not previously considered; but these changes should not be made by you, the surveyor, without the authority of the engineering officer.

Office Work

After the type and general location of a highway are decided and the necessary design data is obtained in the field, a number of office tasks must be performed. These tasks include the following:

1. Plotting the plan view
2. Plotting the profile
3. Plotting the alignment
4. Designing the gradients
5. Plotting the cross sections
6. Determining end areas
7. Computing the volumes of cut and fill

Repeat these operations one or more times as trial designs are developed and then revised or discarded. For a highway plan and profile, plot on the same sheet. Figure 14-22 shows a plotted highway plan and profile view. Plotting cross sections is discussed later in this chapter.

PLOTTING THE PLAN VIEW.— Plotting the plan view of a highway is similar to a traverse except for the introduction of topographic details, curves, and curve data. As a study of highway curves and curve data is beyond the scope of this TRAMAN (but will be studied at the EA2 level), suffice it to say that the important elements of the curve are shown in the form of notes at each curve point. (See the plan view, figure 14-22.)

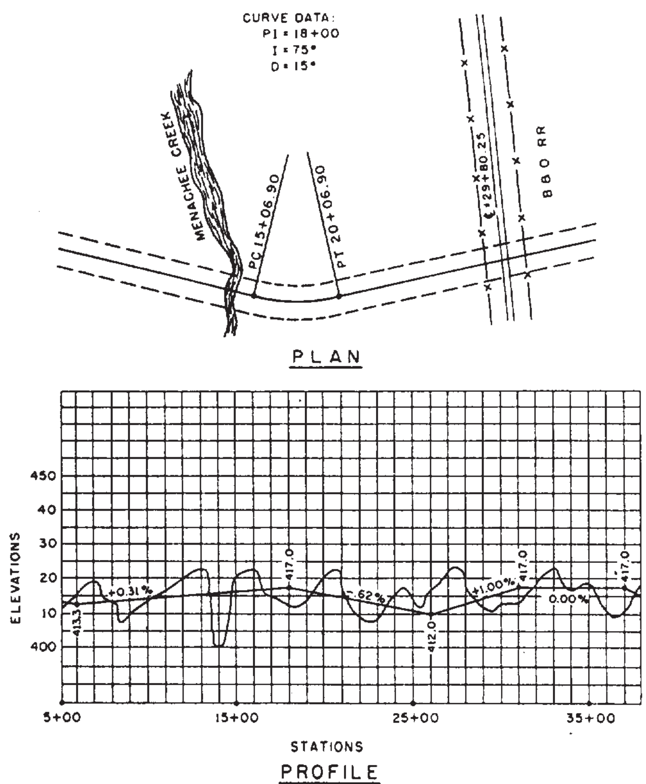


Figure 14-22.-Plan and profile for a highway.

PROFILE PLOTTING.— Make profile plotting on regular profile paper that has ruled horizontal and vertical parallel lines, as shown in figure 14-22. Vertical lines are spaced 1/4 or 1/2 in. apart; horizontal lines are spaced 1/20 or 1/10 in. apart. In figure 14-22, the vertical lines on the original paper (reduced in size for reproduction in this book) were 1/4 in. apart. On the original paper, there was a horizontal line at every 1/20-in. interval; for the sake of clarity, only those at every 1/4-in. interval have been reproduced.

For the first consideration in profile plotting, select suitable horizontal and vertical scales for the profile paper. The suitability of scales varies with the character of the ground and other factors. In figure 14-22, the horizontal scale used was 1 in. = 400 ft, and the vertical scale used was 1 in. = 20 ft (reduced in size for reproduction in this book). Normally, to facilitate the plan plotting, choose scales that are proportional numbers in multiples of ten, such as those given above (H, 1 in. = 400 ft, and V, 1 in. = 20 ft). Write the stations and elevations, as shown in figure 14-22.

Plot the profile, usually from profile level notes, though you may plot it from the elevations obtained from the contour lines. Assume that profile level notes indicate the following centerline elevations at the following stations from 5 + 00 through 15 + 00.

Station	Elevation (feet)
5 + 00	411.9
6 + 00	415.0
7 + 00	417.8
8 + 00	412.0
8 + 75	406.9
9 + 00	411.0
10 + 00	413.2
10 + 50	413.5
11 + 00	415.9
12 + 00	417.3
13 + 00	423.0
13 + 80	412.0
14 + 00	402.0
15 + 00	418.2

As you can see, an elevation was taken at every full station and also at every plus where there was a significant change in elevation. Can you see now how important it is to follow this last procedure? If an elevation had not been taken at 8 + 75, the drop that exists between 8 + 00 and 9 + 00 would not show on the profile.

Check through the listed elevations, and see how each of them was plotted as a point located where a vertical line indicating the station intersected a horizontal line indicating the elevation of that station. Note, too, that usually stations are labeled where the line crosses highways, streams, and railroads.

Besides the profile of the existing terrain, the vertical tangents of the proposed highway center line have been plotted. The end elevation for each of these (that is, the elevations of points of vertical intersection [PVI]) were determined by the design engineers. Various circumstances were considered. One of the important ones was facilitating, as much as possible, the filling of each depression with an approximately equal volume of cut taken from a nearby hump or from two nearby humps.

The gradient, in terms of percentage of slope (total rise or fall in feet per 100 horizontal feet), is marked on each of the vertical tangents. This percentage is computed for a tangent as follows. For the tangent running from station 6 + 00 to station 18 + 00, the total rise is the difference in elevation, or

$$417.0 - 413.3, \text{ or } + 3.7 \text{ ft.}$$

The horizontal distance between the stations is 1,200 ft. The percentage of slope, then, is the value of x in the equation

$$\frac{1200.00}{3.7} = \frac{100}{x} = \text{ or } 0.31 \text{ or } 31\%$$

For a tangent running from station 18 + 00 to station 26 + 00, the total slope downward is the difference in elevation, or

$$412.0 - 417.0, \text{ or } -5.0 \text{ ft.}$$

The distance between the stations is 800 ft. The percentage of slope then is the value of x in the equation

$$\frac{800}{-5.0} = \frac{100}{x} = -0.62 \text{ or } -62\%.$$

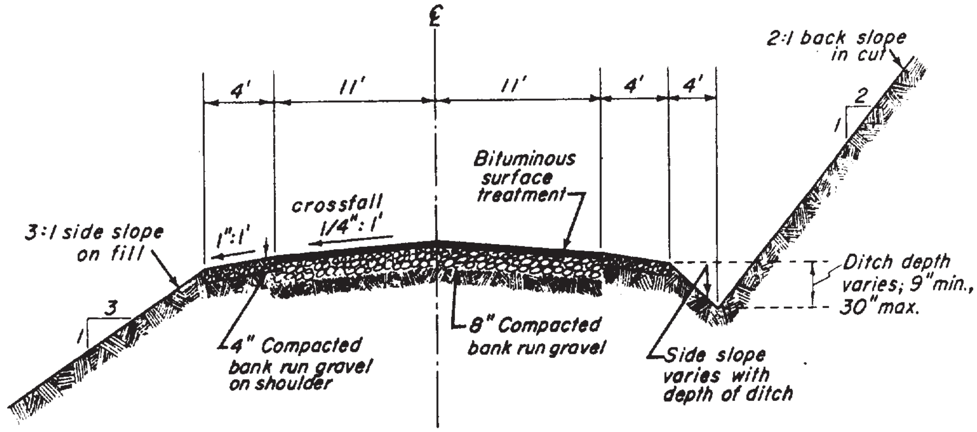


Figure 14-23.-Typical design cross section.

TYPES OF CROSS SECTIONS.— Figure 14-23 shows a typical design cross section, Just about everything you need to know to construct the highway, including the materials to be used and their thicknesses, is given here.

However, this design section is a section of the completed highway. For the purpose of staking out and for earthmoving calculations, the cross-section line of the existing ground at each successive station must be plotted; the design data cross section (typical section of the highway) is then superimposed.

The cross section of the road, with design data available from a previous design-data survey, is staked out by an EA survey party, preferably the leveling crew. Figure 14-24 shows a designed cross section of a 40-ft-wide road taken from a station or point along the road center line. The elevation of the existing surface is 237.4 ft all the way across; therefore, this is called a level section. Finished grade for the highway at this station—that is, the proposed center-line elevation for the finished highway surface—is 220.4 ft. The prescribed side-slope ratio is 1.5:1; that is; a horizontal unit of 1.5 for every unit of vertical rise.

Because the ground line across the cross section is level and the side-slope ratio is the same on both sides, the horizontal distance from the center line to the point where the side slope will meet the natural surface will be the same on both sides. A slope stake is driven at this point to guide the earthmovers. The horizontal distance from the center line to a slope stake can be computed by methods that will be explained later.

In the case of this designed cross section, the data available to you are

1. the width of the highway,

2. the side-slope ratio, and

3. the proposed finished grade.

Besides this, all you need to know to set slope stakes is the ground elevation of the slope-stake point on each side. Because the elevation of the level section in figure 14-24 is the same on both sides, only a single-level shot for elevation is needed. For this reason, a section of this kind is called either a one-level section, or just a level section. Because the entire sectional area consists of material to be excavated or CUT, it is called a section in cut.

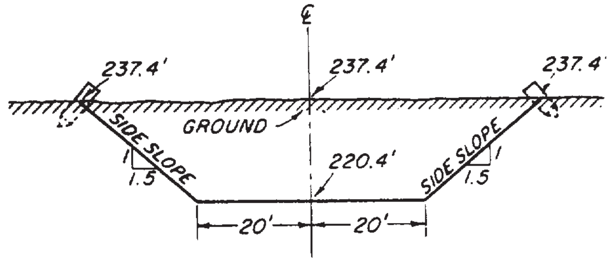


Figure 14-24.-Level section in cut.

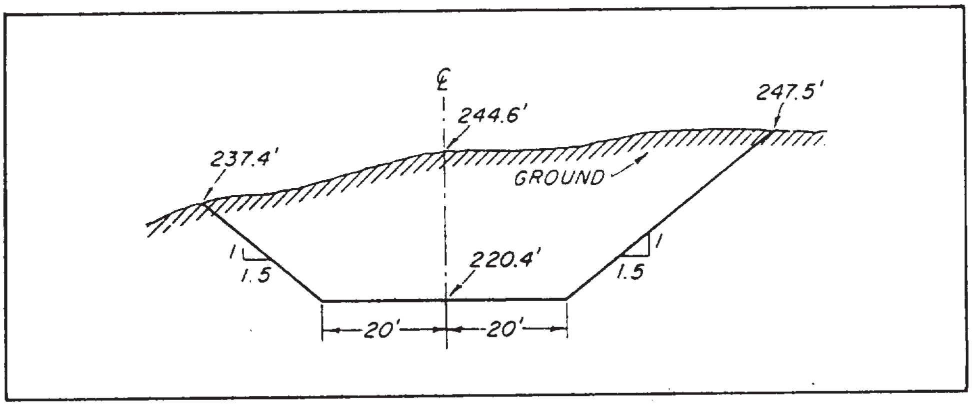


Figure 14-25.-Three-level section in cut.

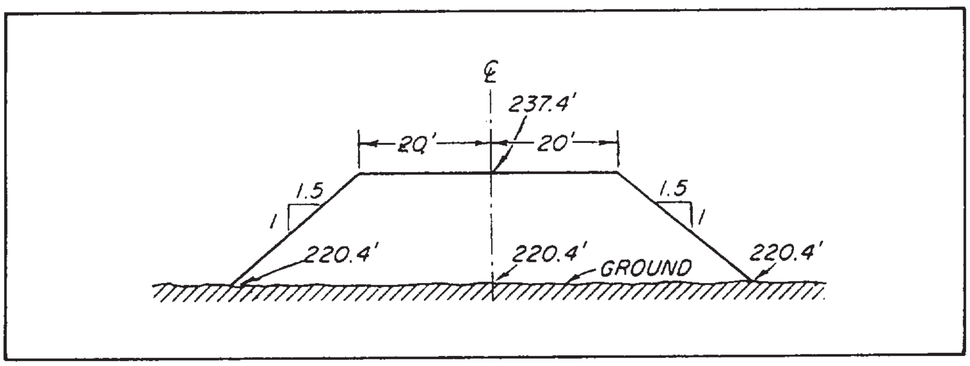


Figure 14-26.-Level section in fill.

In the section shown in figure 14-25, the ground line across the section is sloping rather than level. Therefore, to plot this section, you would need three different elevations: one for the left slope stake, one for the center-line grade stake, and one for the right slope stake. If these three levels are taken, the section is called a three-level section in cut. If additional levels are taken midway between the center line and the slope stake on either side, it is called a five-level section in cut. Therefore, it is a section in cut because the entire cross-sectional area consists of cut.

Level, three-level, and five-level sections are called regular sections.

Figure 14-26 shows a level section in fill; figure 14-27 shows a three-level section in fill. The section shown in figure 14-28 consists of both cut and fill and is called a sidehill section.

When a more accurate picture of cross sections than can be obtained from regular sections is desired, irregular sections are taken and plotted. For an irregular section you take, besides the regular levels, additional levels on either side of the center line. You take these at set intervals and at major breaks in the ground line.

Cross sections may be preliminary or final. Preliminary cross sections, from the P-line or survey base line, are irregular sections that are plotted before the finished grade has been determined. They may be obtained by levels run in the field or by elevations found on the contour lines of a topographic map.

Final cross sections are sections of the final road design. They may be prepared in the same manner as preliminary sections, or they may be regular sections plotted from field data obtained after the finished grade has been set. The term *final cross section* is also applied to as-built sections taken after construction is completed.

PLOTTING CROSS SECTIC)NS.— Cross sections are usually plotted on cross-section paper, which comes either in rolls or sheets. It is ruled into 1-in. squares with heavy, orange or green

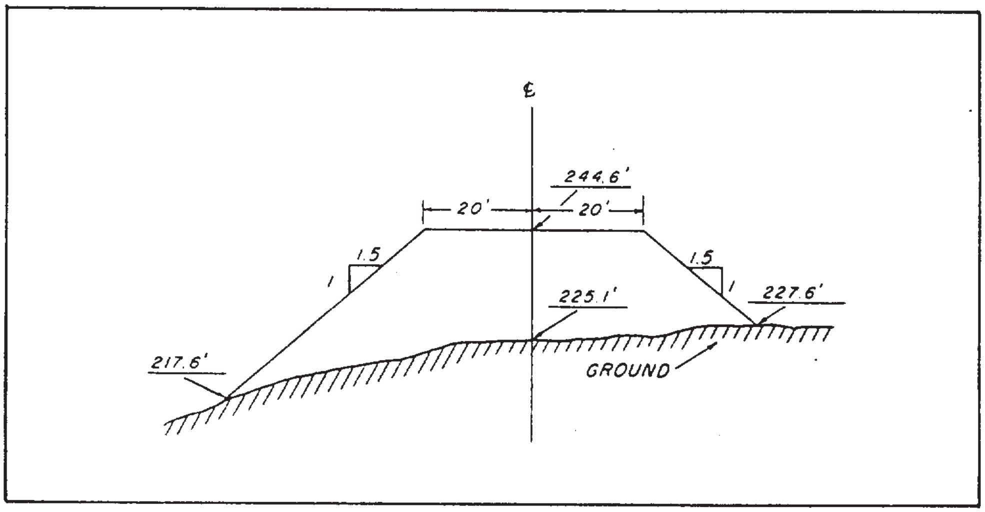


Figure 14-27.-Three-level section in fill.

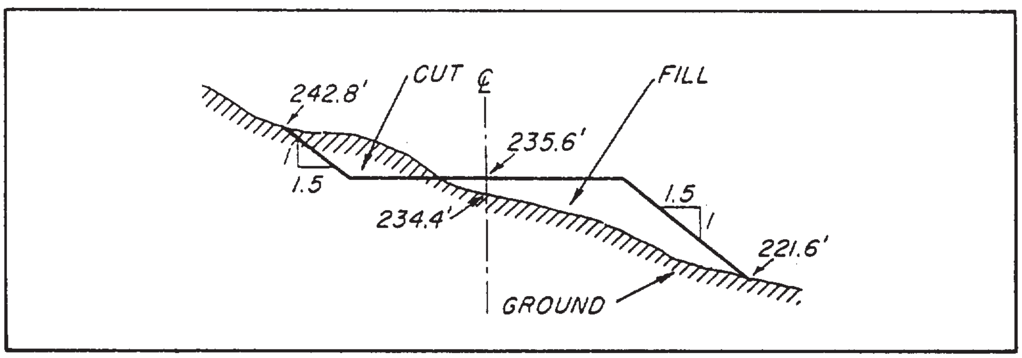


Figure 14-28.-Sidehlll section.

lines and with lighter lines into 1/10-in. squares, Cross-section paper is commonly called 10- x 10-in, paper.

Plot each cross section separately; and below each plot, show the station number. Place the first cross section at the top of a sheet and continue downward until you plot all the sections. Two or more sections may be plotted on the same sheet. In a major highway project, plot cross sections on a continuous roll of cross-section paper. Some surveyors prefer to plot the cross sections from the bottom to the top of the paper. They may also prefer to record cross-section notes in the same manner. If you follow these methods of plotting and recording, you are properly oriented with the actual direction of the highway; that is, your left is also towards the left of the highway; it is also to the left of the cross-section notes and the plotted cross section. Really, it doesn't matter which method you follow as long as you are properly oriented to the direction of the highway at all times.

Unlike profile plotting, in cross-section plotting, the same scale is often used for both the vertical and the horizontal distance. Common scales are 1 in. = 5 ft and 1 in. = 10 ft. When sections are shallow, it is best to exaggerate the vertical scale, making it from two to ten times the horizontal scale.

For the center line for a row of sections, use one of the heavier vertical lines on the paper far enough away from the margin so that no points plotted will run outside the limits of the paper. Note the depths indicated for the first section to be plotted, and select a horizontal line for the base

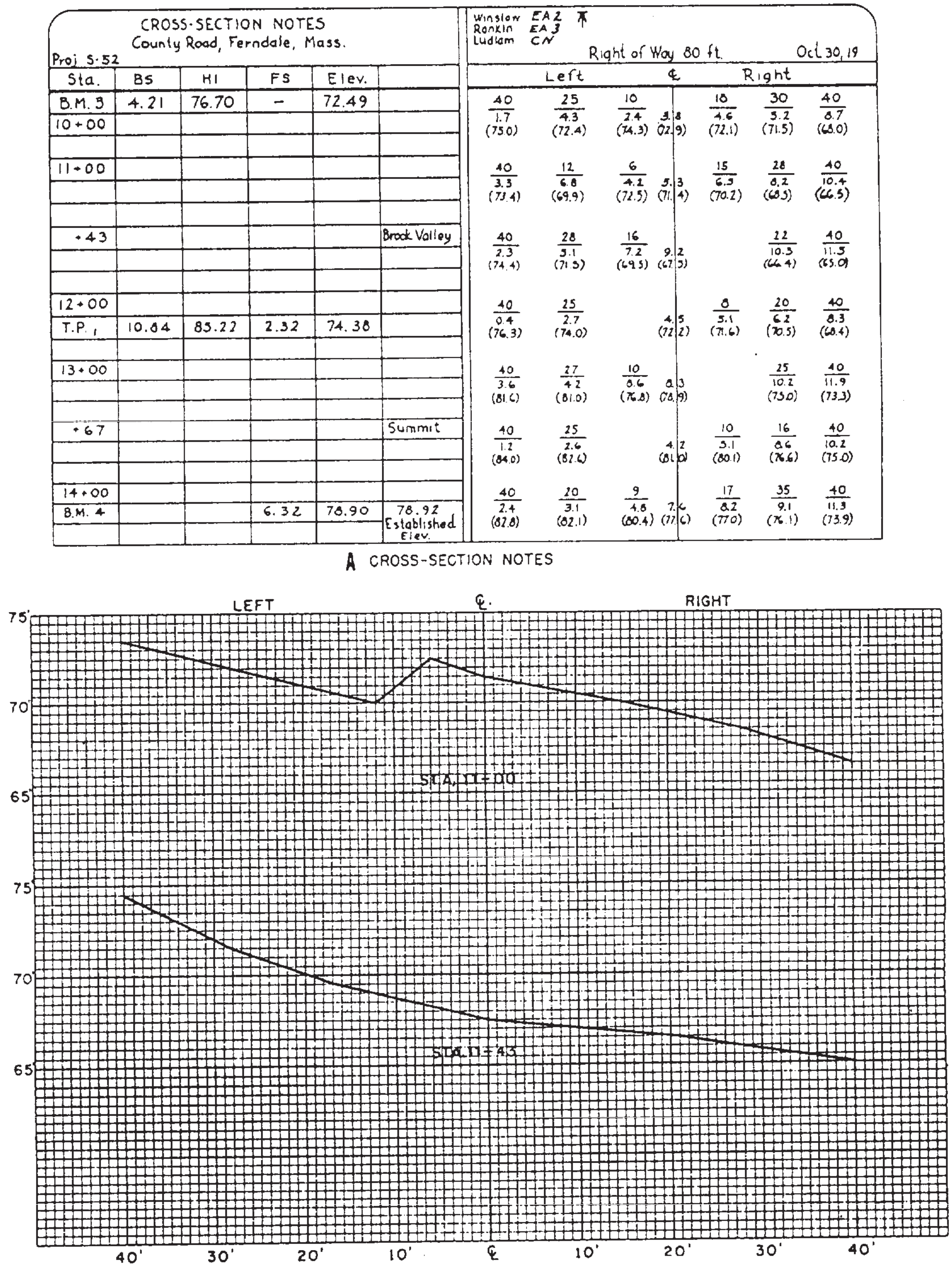


Figure 14-29.-A. Cross section notes. B. Cross sections plotted.

that is about centered between the top and bottom margins. Mark this with the base elevation. Then lay off the horizontal distances of the section surface elevations on either side of the center line, and plot the elevations by using the level data. Finally, connect these plotted points by using a straightedge or by drawing freehand lines.

In figure 14-29, view A, cross-section notes are shown for the existing ground along a proposed road. In figure 14-29, view B, the sections at stations 11 + 00 and 11 + 43 have been plotted. The field party took, for each station, the ground elevation 40 ft to both the right and to the left of the center line. For each station, however, the center-line distance of the intermediate elevations varies. Therefore, these are irregular sections.

For both of the stations plotted, the HI was 76.70 ft. For the point 6 ft left of the center line at station 11 + 00, note the 4.2 written below the 6. This reading was obtained from a rod held on this point. The number 72.5 shown in the parentheses right below the number 4.2 is the elevation of this point. You obtain the elevation by subtracting from the HI, the rod reading FS:

76.70 – 4.20, or 72.50

You can see this point is plotted 6 ft to the left of the center line and at an elevation of 72.5 ft in figure 14-29, view B. Now if the notes are reduced in the office, the general practice is to print the elevations in RED; then the elevation just computed (72.5) will appear in red in the cross-section notes (fig. 14-29, view A).

After the road gradients, either preliminary or final, have been designed, plot the design data cross section on the existing ground line section plot at each station to complete the picture of the end-area as it will be in the finished highway. Obtain the finished grade elevation for each station from the profile. Plot the finished grade point usually located on the center at each cross section. Then draw in the outline of the pavement surface, ditches, and cut or fill slopes as they show on the typical design section. Plotting may be done with triangles, but a faster method is to use templates made of plastic, thin wood, sturdy cardboard, or other suitable material. Prepare templates for a cut section, a fill section, and a sidehill section that may be flipped over to accommodate the direction of hillside slope.

The procedures just described are the most common and pertain to irregular sections. However, if regular sections have been taken in the field after the gradients have been designed, then both the existing and the finished surfaces will be plotted. Field notes for simplified three-level sections on a highway are shown in figure 14-30. On the data side, the profile elevation and the grade elevation at each station are listed. In the columns headed Left and Right on the

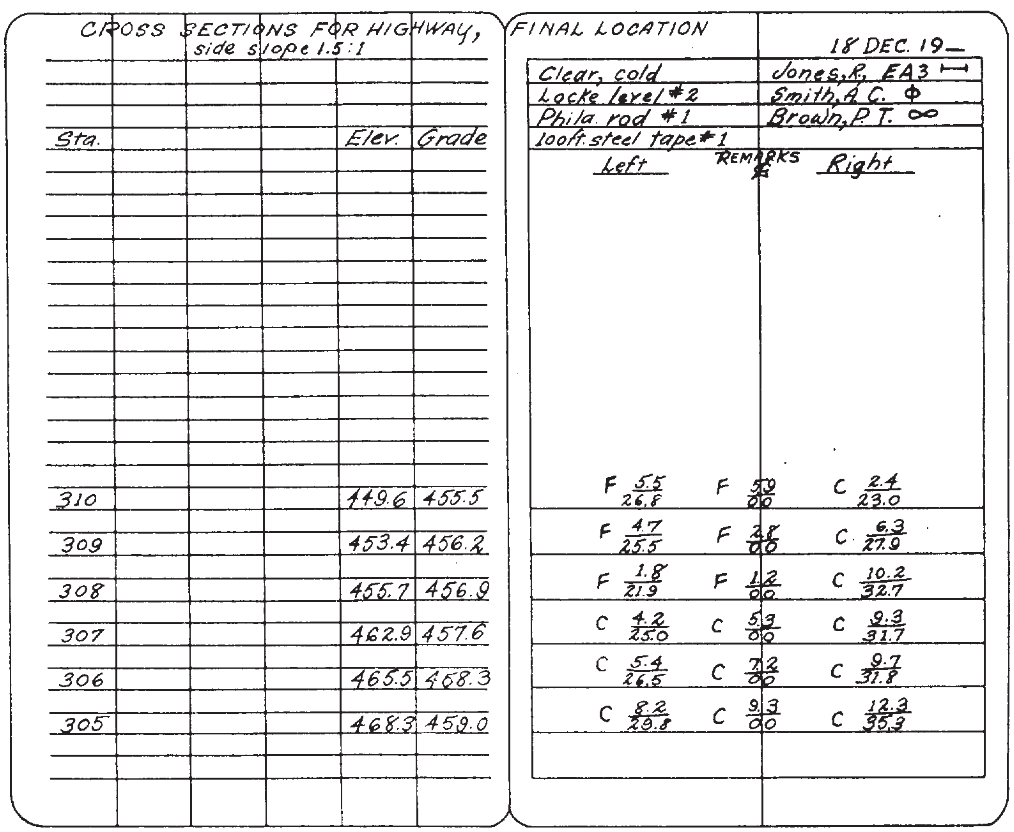


Figure 14-30.-Field notes for three-level cross sections.

remarks side, the upper numbers with the appropriate letter symbols (C for cut, F for fill) are the cuts or fills; the lower numbers are the distances out from the center. These values indicate points at which the slope stakes are driven. If a five-level or irregular section is being recorded, the other points must be written between those for the center and for the slope stakes.

These field notes given you the coordinates that you can use to plot sections, as shown in figure 14-30. In that figure for purposes of clarity, only the lines at every 1/4-in. interval are shown. The scale, both horizontal and vertical, is 1 in. = 10 ft; therefore, the interval between each pair of lines represents 2.5 ft.

The highway is to be 40 ft wide; therefore, the edge of the pavement for each plotted section will be 8 squares (8 x 2.5 = 20) on either side of the center line. Figure 14-30 shows that, for station 305, the left-hand slope stake is located 29.8 ft from the center line and 8.2 ft above grade. The right-hand slope stake is located 35.3 ft from the center line and 12.3 ft above grade. Note how the locations of these stakes can be plotted after you have selected an appropriate horizontal line for the grade line and how the side slopes can then be drawn.

The ground line at the center line is 9.3 feet above grade. Plot a point here, and then finish the plot of the section by drawing lines from the center-line point to the two slope stake points.

Plot a five-level section in exactly the same way, except that you plot in additional ground points between the center line and the slope stakes.

Layout/Stakeout Procedures

The design-data survey is followed by the construction survey that consists broadly of the LAYOUT or STAKEOUT survey and the AS-BUILT survey, which will be discussed later in this chapter. In a layout survey, both horizontal and vertical control points are located and marked (that is, staked out) to guide the construction crews. Figure 14-31 identifies various stakes and hubs used in highway or road construction and their typical arrangement. The functions of the various stakes and hubs are described briefly as follows:

1. CENTER-LINE STAKES indicate the exact center of the roadway construction.
2. SHOULDER STAKES are used to indicate the inside edge of the roadway shoulders. These stakes are set opposite each center-line stake.
3. REFERENCE HUBS, as the name implies, are used to reference other stakes or to aid in establishing or reestablishing other stakes.
4. SLOPE STAKES mark the intersection of side slopes with the natural ground surface. They indicate the earthwork limits on each side of the center line.
5. RIGHT-OF-WAY STAKES indicate the legal right of passage and outmost bounds of construction.
6. GRADE STAKES indicate required grade elevations to the construction crews. During the final grading stage of construction, hubs called "blue tops" are used in lieu of stakes. The blue

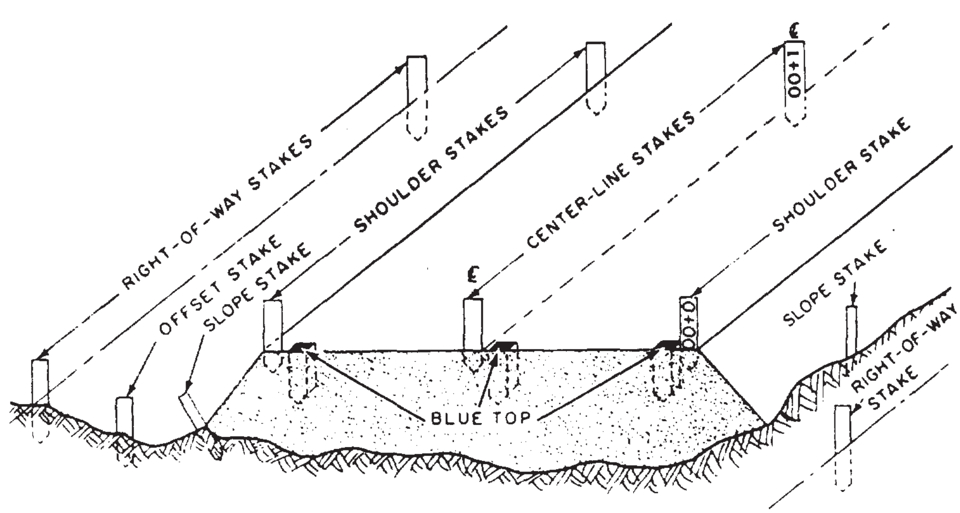


Figure 14-31.-Typical arrangement of various hubs and stakes on a road section (final grading).

tops are driven so that the top of the hub is set at the required grade elevation.

7. GUARD STAKES are used to identify and protect hubs. The face of the stake is marked with station identification and is placed so that the stake faces the hub it identifies. Sometimes more than one guard stake will be used to protect a hub.

8. OFFSET STAKES may be additional stakes that are offset a known distance from other stakes that will likely be disturbed during construction. The offset stake is marked with the same information as the stake it offsets, and it is also marked to show the offset distance. Often, stakes will themselves be offset a known distance from their true location. This eliminates the requirement for additional stakes.

CENTER-LINE LAYOUT.— The first major step in highway construction is usually the rough grading; that is, the earthmoving that is required to bring the surface up to, or down to, the approximate elevation prescribed for the subgrade. The SUBGRADE is the surface of natural soil, or the place where the pavement will be laid. The subgrade elevation, therefore, equals grade (finished surface) elevation minus the thickness of the pavement.

In rough grading, the equipment operators are usually guided by grade stakes that are set along the center line by the transit-tape survey party at center-line stations. The center-line stations (stakes) are usually set at intervals of 100 ft or more on straight-line stretches and intervals of 50 ft or less on roads with horizontal and vertical curvatures. On a small-radius, street-corner curve, a center-line hub or stake might be set at the center of the circle of which the curve is a part. This is done so the construction crew may outline the curve by swinging the radius with the tape. Reference stakes or hubs are also set on one or both sides of the center line to permit reestablishment of the center line at any time.

Each center-line stake is marked with the vertical depth of cut or fill required to bring the surface to grade elevation. The surveyor must indicate the station markings and the cut and fill directions on stakes. Let's look at the stakes on the center line of the road-building job. The starting point is the first station in the survey;

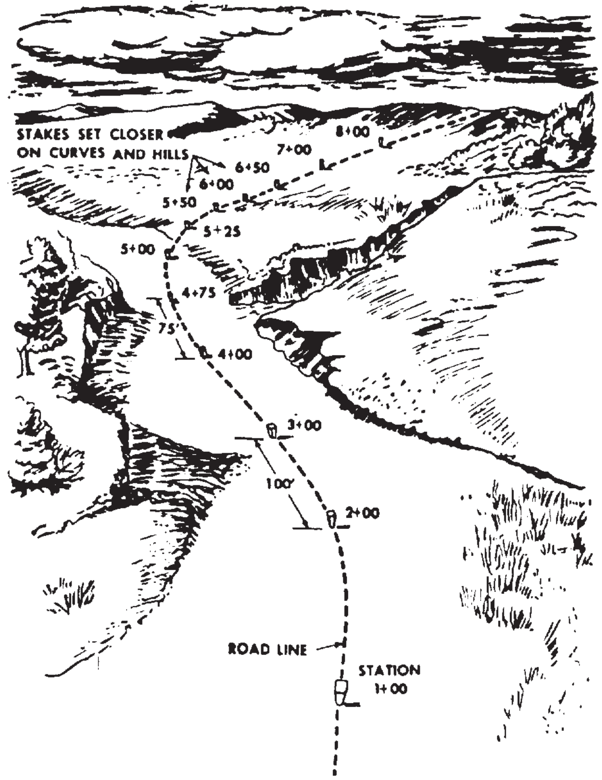


Figure 14-32.-Station markings.

this station is numbered 0 + 00. The next station is normally 100 ft farther and is marked 1 + 00; the third station is another 100 ft farther and is marked 2 + 00; and so on. On sharp curves on rough ground, the stakes may be closer together. (See fig. 14-32.) Generally, the station markings face the starting point. The mark ℄, which is also on the side facing the starting point, is used to indicate that the stake is a center-line stake.

A cut is designated by the letter C, and the fill is indicated by the letter *F*. Numerals follow the letters to indicate the amount that the ground should be cut or filled. The symbol C– $1^{\underline{5}}$ indicates that the existing ground should be cut 1.5 ft, as measured from the reference mark. During rough grading, the cut and fill are generally carried just up to the nearest half foot; exact grade elevations are later marked with hubs (blue tops). The mark ⊻ is called a crowfoot. The apex of the V indicates the direction of the required change in elevation; so a cut is indicated by ⊻, and a fill is indicated by ⊼. In some cases, surveyors mark the grade stake only with a negative or a positive number and the crowfoot, indicating the cut or fill.

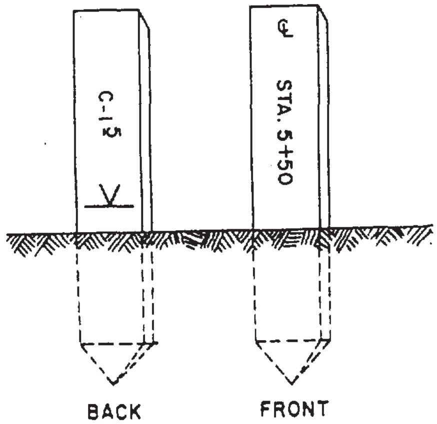


Figure 14-33.—Cut stake.

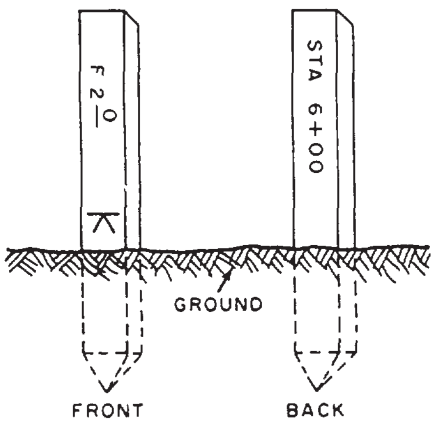


Figure 14-34.-Fillstake (not on centerline).

Figure 14-33 shows a cut stake that also happens to be a center-line marker. Note that station mark is written on the front of the stake and the construction information on the back. On grade stakes other than the center-line stakes, the construction information should be written on the front and the station marked on the back.

The stake shown in figure 14-34 indicates that fill operations are to be performed. The letter *F* at the top of the stake stands for fill. The numerals $2^{\underline{0}}$ indicate that 2 ft of fill are required to bring the construction up to grade.

Some stakes indicate that no cutting or filling is required. Figure 14-35, for example, shows a grade stake that is on the proper grade and also is a center-line stake. The word *GRADE* (or *GRD)* is on the back of the stake, and the crowfoot mark may not be indicated; some surveyors prefer to use a crowfoot mark on all grade stakes. If this

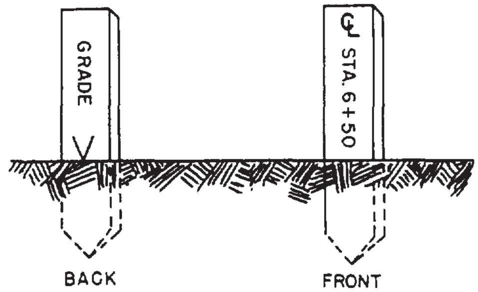


Figure 14-35.-Stake on proper grade.

grade stake is not a center-line stake, the GRD mark will be written on the front of the stake.

SETTING GRADE STAKES.— GRADE STAKES are set at points having the same ground and grade elevation. They are usually set after the center line has been laid out and marked with hubs and guard stakes. They can be reestablished if the markers are disturbed. Elevations are usually determined by an engineer's level and level rod. One procedure you can use for setting grade stakes is as follows:

1. From BMs, turn levels on the center-line hubs or on the ground next to a grade stake at each station.
2. Reduce the notes to obtain hub-top or ground elevation.
3. Obtain the finished grade elevation for each station from the construction plans.
4. Compute the difference between finished grade and the hub or ground elevation to determine the cut or fill at each station.
5. Go back down the line and mark the cut or fill on each grade stake or guard stake.

The elevations and the cuts or fills may be recorded in the level notes, or they may be set down on a construction sheet, as explained later in this chapter.

Another procedure may be used that combines the method listed above so that the computations may be completed while at each station; then the cut or fill can be marked on the stake immediately.

As before, levels are run from BMs; the procedure at each station is as follows:

1. Determine the ground elevation of the station from the level notes to obtain HI.
2. Obtain the finished grade for the station from the plans.

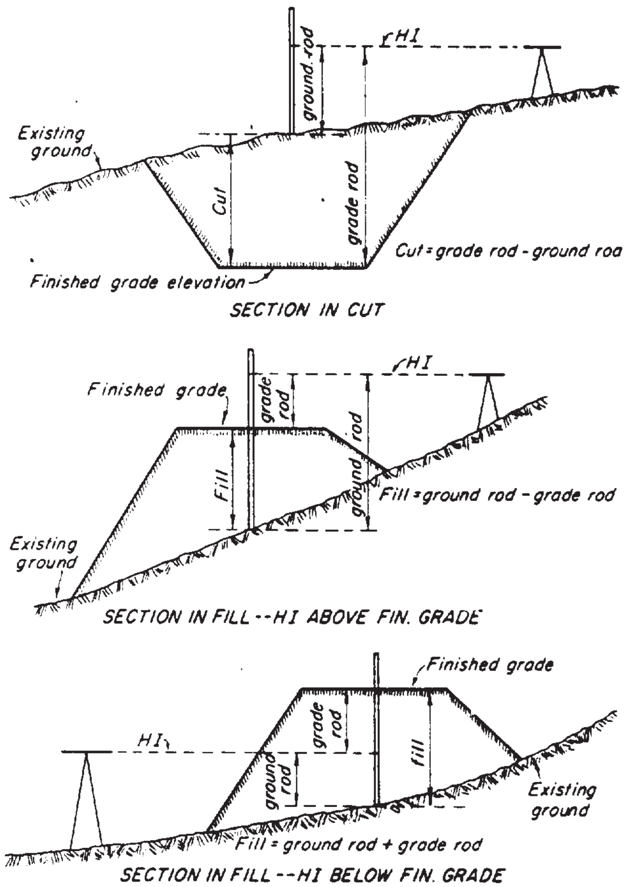


Figure 14-36.-Determining cut or fill from grade rod and ground rod.

3. Compute the difference between the HI and finished grade; this vertical distance is called grade rod.
4. Read a rod held on the hub top or ground point for which the cut or fill is desired. This rod reading is called ground rod.
5. Determine the cut or fill by adding or subtracting the grade rod and the ground rod, according to the circumstances, as shown in figure 14-36.
6. Mark the cut or fill on the stake.

During the final grading, you will most likely be working with hubs called BLUE TOPS (fig. 14-31). These hubs are driven into the ground until the top is at the exact elevation of the finished grade as determined by the surveying crew. When the top of the stake is at the desired finish grade elevation, it is colored with blue lumber crayon (keel) to identify it as a finished grade stake. Other colors may be used, but be consistent and use the same color keel throughout the project so as not to confuse the Equipment Operators. Blue tops are normally provided with a guard stake to avoid displacement during construction work. The guard stake usually shows the station and the elevation of the top of the hub. The elevation and station markings may be required only at station points; otherwise, all that is needed is the blue top and the guard stake with flagging.

The procedure for setting blue tops lends itself primarily to final grading operations. It is carried out as follows:

1. Study construction plans and center-line profiles for each station to determine (1) the exact profile elevation and (2) the horizontal distance from center line to the edge of the shoulder.
2. Measure the horizontal distance from the center line to the shoulder edge at each station, and drive a grade stake at this point on each side. Sometimes it is advisable to offset these stakes a few feet to avoid displacement during construction.
3. Set the top of the stake even with the grade elevation, using both the level and the rod. This is accomplished by measuring down from the HI a distance equal to the grade rod (determined by subtracting grade elevation from the HI). The target on the rod is set at the grade-rod reading; the rod is held on the top of the stake; and after a few trials, the stake is driven into the ground until the horizontal hair of the level intersects the rod level indicated by the target. Color the top of a stake with blue crayon (keel).
4. Where the tops of stakes cannot be set to grade because grade elevation is too far below or above the ground line, set in ordinary grade stakes marked with the cut or fill as in rough grading. However, for final grading, it is usually possible to set mostly blue tops.

Where grade stakes cannot be driven, for example, in hard coral or rock areas, use your ingenuity to set and preserve grade markings in a variety of conditions. Markings may often be made on the rock itself with a chisel or with a keel.

SETTING SLOPE STAKES.– SLOPE STAKES are driven at the intersection of the ground and each side slope or offset a short distance; they indicate the earthwork limits on each side of the center line. The minimum areas to be cleared and grubbed extend outward about 6 ft from the slope stakes.

Refer back to figure 14-31 and take a close look at the position of the slope stakes. The horizontal distance of a slope stake from the center line varies, and to determine what it is, you must know three things.

1. The width of the roadbed, including widths of shoulders and ditches, if any
2. The side-slope ratio (expressed in units of horizontal run in feet per foot of vertical rise or fall)
3. The difference in elevation between the grade for the road and the point on the natural ground line where the slope stake will be set

In figure 14-37, view A, d is the horizontal distance from the center line to the slope stake, W/2 is the horizontal distance from the center line to the top of the slope, h is the difference in elevation between the finished grade and the ground at the slope stake, ands is the slope ratio. The product of h x s gives the run of the slope; that is, the horizontal distance the slope covers. The horizontal distance (d) of the slope stake from the center line, then, equals the sum of W/2 plus hs. For example, suppose that W/2 is 20 ft, h is 10 ft, and the bank is a 4:1 slope. Then

$$hs = 10 \times 4, \text{ or } 40$$

and

$$d = 20 \text{ ft} + 40 \text{ ft, or } 60 \text{ ft.}$$

In practice, you may have to take other factors into account, such as transverse slope or the crossfall of the pavement (sometimes called the crown), ditches, and so on. In figure 14-37, view B, for example, there is a crossfall (h=) across W/2 so that the run (horizontal distance covered) of the bank $(h_b s)$ is the product of s x h_b instead of hs, as in figure 14-31, view A. The crossfall is usually constant and may be obtained from the typical design sect ion shown on the plans.

Figure 14-37, view C, shows a cut section in which W/2 varies with crossfall, side slope, ditch depth, and back slope. For example, assume that the distance from the center line to the beginning of the side slope is 20 ft, that the cross fall totals 1 ft, that ditch depth is 1.5 ft, and that both the side slope and back slope ratios are 2:1. The distance W/2, then, comprises horizontal segments as follows:

1. From the center line to the top of the slope which is 20 ft

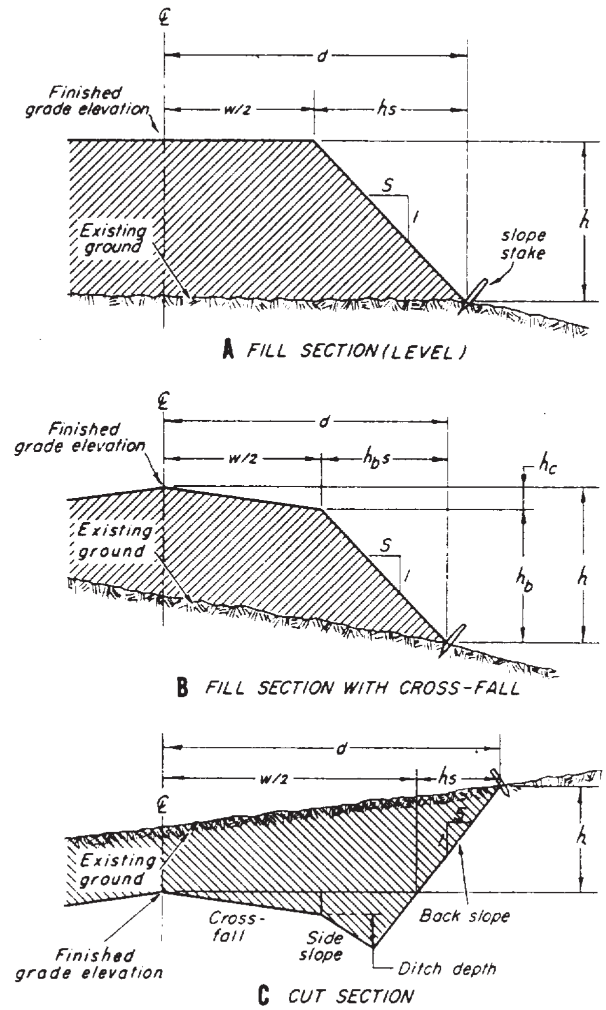


Figure 14-37.-Determining slope stake location (distance from center line) for a proposed roadway.

2. Then to the ditch flow line, which equals the product of slope ratio (2) times ditch depth (1.5), or 3 ft
3. Then to the point on the back slope that is level with the finished center line, which equals slope ratio (2) times difference in elevation; that is, crossfall plus ditch depth,

$$2(1 + 1.5), \text{ or } 5 \text{ ft.}$$

The total distance, W/2, then, is the sum of

$$20 + 3 + 5, \text{ or } 28 \text{ ft.}$$

SLOPE-STAKE PARTY PROCEDURE.— Slope stakes are usually set with an engineer's or automatic level, a level rod, and a metallic or nonmetallic tape. In rough terrain, a hand level is generally used instead of an engineer's level.

If the engineer's level is used, three crew members are generally employed for fieldwork; they are the instrumentman, the rodman, and one person to hold the zero end of the tape at the center line. When a hand level is used, two persons can take care of the job—the instrumentman also holds the zero end of the tape and is positioned at the center-line station as the rod reading is taken. The procedure followed is a trial and error process. Under field conditions, the rodman is at times as much as 200 or 300 ft away from the instrumentman. If power equipment is operating nearby or a wind is blowing, oral instructions cannot be given to the rodman about where to take trials shots; in fact, often there. is not a clear view of the ground slope at the station being worked.

Consequently, the rodman must know as much as the instrumentman does about the theory and practice of setting slope stakes. The speed and efficiency of the party depend on the rodman more than on any other member. The rodman must be constantly mentally alert.

The most practical field procedure requires that the rodman know the value of W/2 and of s (the slope ratio). This is not difficult, since these values are usually constant for several stations, and the rodman can be informed when they change. A typical procedure for setting slope stakes is as follows:

1. The instrumentman computes the center-line cut or fill, using the HI, finished grade, and the existing ground elevation. Refer back to figure 14-36.
2. The instrumentman calls or signals the center-line cut or fill to the rodman.
3. The rodman mentally computes the approximate value of d by multiplying h x s and adding W/2. He pulls the tape taut while holding the tape at the computed distances.
4. Noting the approximate rise or fall of the ground, the rodman adjusts the approximate value of d, moves to the d point, and sets up the rod for a trial shot.
5. The instrumentman quickly calculates the cut or fill at this point and calls the value to the rodman.
6. The rodman compares this with the estimated cut or fill. He should be fairly close and should know at once whether to move toward, or away from, the center line. Having a much shorter distance over which to estimate ground slope, he again estimates new cut or fill and hs + W/2, and moves the rod to the new d value.

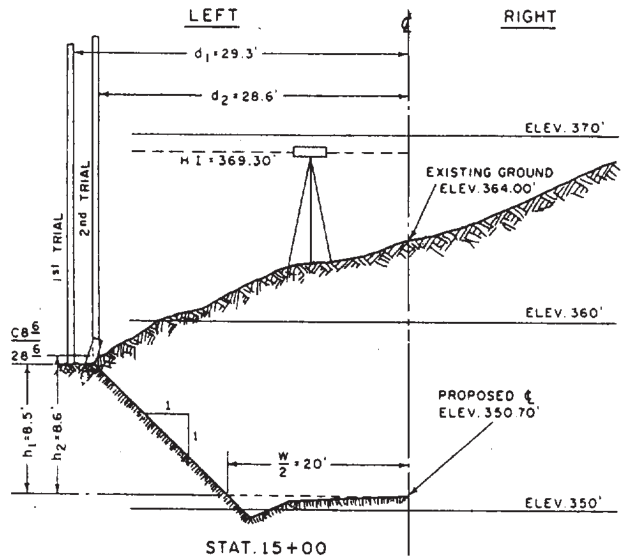


Figure 14-38.-Setting slope stakes.

7. The instrumentman again gives the cut or fill; if the value checks, the rodman calls or signals back the cut or fill and the distance.

8. The instrumentman quickly checks the two values mentally, and if the values are correct, records the values in the field book, signaling "Good" to the rodman.

9. The rodman marks and drives the stake.

With practice and on fairly smooth ground, a good rodman will seldom miss the first trial by more than 0.2 ft vertically and will, quite often, hit the correct value on the first trial.

Figure 14-38 shows the application of these procedures to an actual situation. The following data are known for this slope-stake stakeout:

1. The station is 15 + 00.

2. The W/2 (from the typical design section) is 20 ft.

3. The slope ratio is 1:1; therefore, s = 1.

4. The existing ground elevation at the center line (from the previously run profile) is 364.00 ft.

5. The HI is determined to be 369.30 ft at that setup.

The steps taken by the instrumentman and the rodman are as follows:

1. The instrumentman determines the center-line cut by subtracting 350.7 ft from 364.0 ft to get the cut, or 13.3 ft.

2. The rodman holds at the center line for a check. The rod should-read 369.3 (the HI) minus 364.0, or 5.3 ft.

3. The instrumentman calls to the rodman, "Cut 13.3 feet."

4. The rodman computes

$$d = 20 + (1 \times 13.3) = 33.3$$

as he walks to the left.

5. As he approaches about 30.0 ft from the center line, he estimates that the ground has a fall of 4 ft. Therefore, he computes the new cut as

$$13.3 - 4.0, \text{ or } 9.3 \text{ ft.}$$

This means a new d of

$$20 + (1 \times 9.3) = 29.3 \text{ ft.}$$

6. The rodman sets up the rod 29.3 ft from the center line, as measured by metallic tape.

7. The instrumentman reads 10.1 on the rod and computes the new cut as

$$369.3 - (350.7 + 10.1), \text{ or } 8.5 \text{ ft.}$$

NOTE: Here you can also use the grade rod and ground rod values as explained earlier; the new cut then will be

$$18.6 - 10.1 = 8.5 \text{ ft.}$$

Refer back to figure 14-36.

8. The instrumentman calls, "Cut 8.5," to the rodman.

9. The rodman computes

$$d = 20 + (1 \times 8.5) = 28.5 \text{ ft.}$$

He knows, therefore, that 29.3 ft from the center line is too far out.

10. Figuring that the ground rises about 0.1 ft between 29.3 left and 28.5 left, the rodman calculates that the more nearly correct cut will be

$$8.5 + 0.1, \text{ or } 8.6 \text{ ft.}$$

11. By using this cut, the rodman calculates the new d as

$$20 + (1 \times 8.6),$$

and sets the rod at 28.6 ft left.

12. The instrumentman reads 10.0 on the rod and computes the new cut as

$$369.3 - (350.7 + 10.0) = 8.6 \text{ ft.}$$

13. The instrumentman calls, "Cut 8.6," to the rodman.

14. The rodman sees that the actual cut of 8.6 ft agrees with his estimated cut of the same, and calls, "Cut 8.6 at 28.6," to the instrumentman.

15. The instrumentman checks

$$d = 20 + (1 \times 8.6) = 28.6,$$

signals the rodman, "Good," and makes the following entry into the field book:

$$\frac{C8^6}{28}$$

16. The rodman marks a stake with 15 + 00 and $C8^6$ and drives it in the ground at 28.6 ft left.

More often, slope stakes may be set by using a hand level. Their distances out are generally measured to the nearest half or tenth of a foot. If a slope stake is placed in an offset position, the offset distance is also marked on the stake so the equipment operator is not confused about its actual location. Slope stakes are seldom used in areas requiring less than 2 ft of cut or fill.

Curb and Gutter Stakeout

For a thoroughfare that will have a curb and gutter, these items are usually constructed before the finish grading is done. The curb constructors obtain their line and grade from offset hubs like those described previously. Guided by these, the earthmovers make the excavation for the curb, the formsetters set the forms, and the concrete crew members pour, finish, and cure the curb.

Once the curb has been constructed, shaping the subgrade to correct subgrade elevation and laying the pavement to correct finished grade is simply a matter of measuring down the correct distance from a cord stretched from the top of one curb to the top of the curb opposite.

Pavement Stakeout

Pavement stakeout will depend on the type of paving equipment used. Steps in the method commonly used for paving concrete highways are as follows:

1. Set a double line of steel side forms, equipped with flanges that serve as tracts for traveling paving equipment.
2. Fill the space between the forms with concrete poured from a concrete paving machine (commonly called just a paver).
3. Spread the' concrete with a mechanical spreader that travels on the flanges of the side forms.
4. Finish the surface with a finisher, a machine that also travels on the side forms.

The line-and-grade problem—that is, the layout or stakeout problem—consists principally of setting the side forms to correct line with the upper edges of the flanges at the grade prescribed for the highway. If the finished grade shown on the plans is the center-line grade, then the forms are set with tops at the center-line grade less the crossfall. If the design elevations are shown for points other than those on the center line, the form elevation is related to the design points as indicated by the typical section.

Stakeout maybe done by setting a line or lines of offset hubs, as previously described. Sometimes, however, a line of hubs is driven along the line the forms will occupy and driven to grade elevation less the depth of a side form. The forms are then set to the line and the grade by simply placing them on the hubs.

Concrete paving is also done by the slip form method in which, instead of a complete double line of forms, a sliding or traveling section of formwork is an integral part of the spreading and finishing machinery. The machinery is kept on line and the pavement finished at grade by a control device or devices. The line control device usually follows a wire stretched between rods that are offset from the pavement edge.

Forms are not usually used in asphalt paving. Asphalt paving equipment, in general, is designed to lay the pavement at a given thickness, following the fine-graded subgrade surface. The manner in which a given piece of equipment is kept on line varies, and the stakeout for equipment varies accordingly.

STRUCTURAL SURVEYS

A STRUCTURAL survey is one that is part of the chain of human activities that will bring a structure, such as a building, a bridge, or a pier into existence.

Earthwork

As when a highway is built, the first major step in the construction of a structure is usually the rough grading—that is, the earthmoving needed to bring the surface of the site up to, or down to, the approximate specified rough grade.

The stakeout for rough grading is commonly done by the GRID method. The area to be graded, which is shown, along with the prescribed finish grade elevation on the site or plot plan is laid off in 25-, 50-, or 100-ft grid squares. The elevation at each corner point is determined; the difference between that and the prescribed grade elevation is computed; and a grade stake is marked with the depth of cut or fill; then the stake is driven into the ground at the point.

Building Stakeout

If the structure is a building, the next major step after the rough grading is the building stakeout; that is, the locating and staking of the main horizontal control points of the building. These are usually the principal corner points plus any other points of intersection between building lines.

The procedure followed varies with circumstances. Figure 14-39 shows a simple building

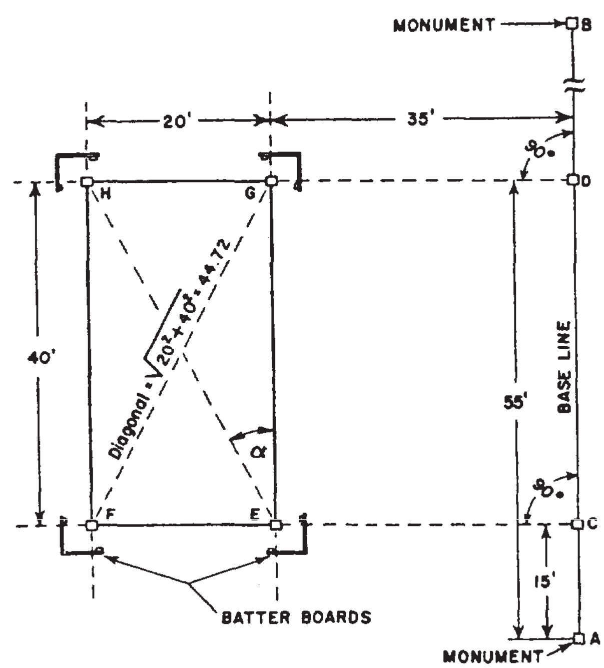


Figure 14-39.-Building stakeout.

stakeout. This site plan shows that the building is to be a 40- by 20-ft rectangular structure, located with one of the long sides parallel to, and 35 ft away from, a base line. The base line is indicated at the site and on the plans by Monuments A and B.

One of the short sides of the building will lie on a line running from C, a point on AB 15 ft from A, perpendicular to AB, The other short side will lie on a similar line running from D, a point on AB 40 ft from C and, therefore, 40 + 15, or 55 ft from A, perpendicular to AB.

The steps in the stakeout procedure would probably be as follows:

1. Set up the transit at Monument A; train the telescope on a marker held on a Monument B; then have the hubs driven on the line of sight, one at C 15 ft from A, the other at D 55 ft from A and 40 ft from C.

2. Shift the transit to C, train on B, match the zeros, and turn 900 left. Measure off 35 ft from C on the line of sight and drive a stake to locate E. Measure off 55 ft from C (or 20 ft from E) and drive another stake to locate F.

3. Shift the transit to D and repeat the procedure described in Step 2 to locate and stake points G and H.

THE ACCURACY OF A RECTANGULAR STAKEOUT CAN BE CHECKED BY MEASURING THE DIAGONALS OF THE RECTANGLE. The diagonals should, of course, be equal. You can determine what the correct length of each diagonal should be by applying the Pythagorean theorem, as shown in figure 14-39.

For a large rectangle, checking the accuracy of the stakeout by angular measurement with the transit may be more convenient. For example: You can determine the correct size of angle GEH, (let's call it a) in figure 14-39 by a convenient right-triangle solution, such as

$$\tan \alpha = 20/40 = 0.50000.$$

The angle with tangent 0.50000 measures (to the nearest minute) 26°34´. Therefore, angle FEH should measure

$$90°00' - 26°34', \text{ or } 63°26'.$$

The corresponding angles at the other three corners should have the same dimensions. If the sizes as actually measured vary at any corner, the stakeout is inaccurate.

Remembering the angles may be necessary to obtain the correct angular precision for the lengths of the lines being checked.

BATTER BOARDS are suitable marks placed for use as references or guides during the initial excavation and rough grading of a building construction and/or a sewer line stakeout. They are more or less temporary devices that support the stretched cords that mark the outline and grade of the structure.

Batter boards consist of 2- by 4-in. stakes driven into the ground. Each stake has a crosspiece of 1- by 6-in. lumber nailed to it. The

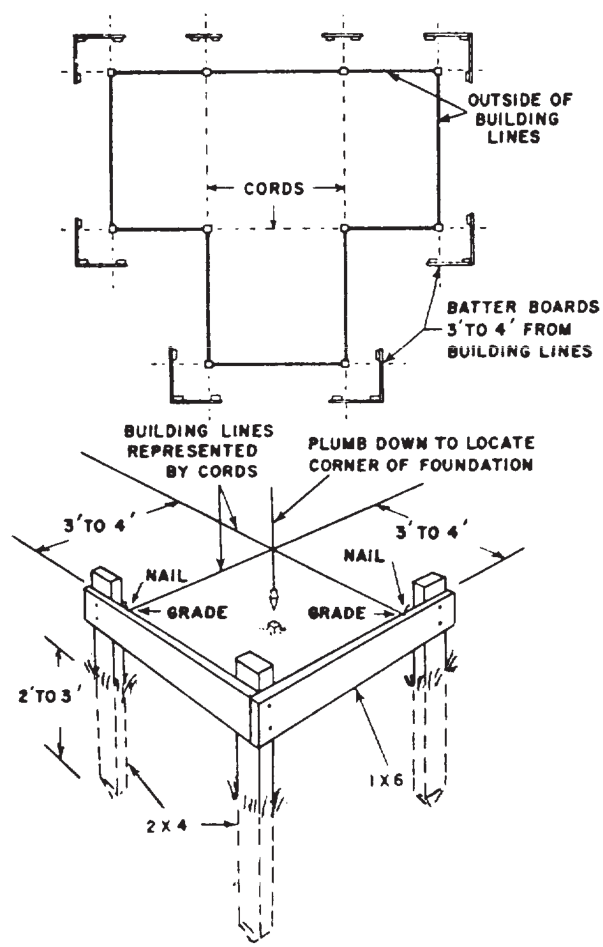


Figure 14-40.-Batter boards.

stakes are driven about 3 to 4 ft away from the building line where they will not be disturbed by the construction. They are driven far enough apart to straddle the line to be marked. Note in figure 14-40, only three stakes are driven on outside corners because one of them is a common post for two directions. The length of the stakes is determined by the required grade line. They must be long enough to accept the 1- by 6-in, crosspiece to mark the grade. The 1- by 6-in, crosspiece is cut long enough to join both stakes and is nailed firmly to them after the grade has been established. The top of the crosspiece becomes the mark from which the grade will be measured. All batter boards for one structure are set to the same grade or level line. A transit is used to locate the building lines and to mark them on the top edge of the crosspiece. A nail is driven at each of these marked points, or a V notch is carved at the top outer edge of the crosspiece towards the marked point and the nail is driven on the outer face of the board.

When a string is stretched over the top edge of the two batter boards and is held against the nails or against the bottom of the notch, the string will define the outside building line and grade elevation.

Sometimes a transit is not available for marking the building line on the batter boards, but the corner stakes have not been disturbed. A cord is stretched over two opposite batter boards, and plumb bobs are held over the corner stakes; then the building line can be transferred to the batter boards. The cord is moved on each batter board until it just touches both plumb bob strings. This position of the cords is marked, and nails are driven into the top of the batter boards.

Batter boards are set and marked as follows:

1. After the corner stakes are laid out, 2-by 4-in. stakes are driven 3 to 4 ft outside of each corner. These are selected to bring all crosspieces to the same elevation.

2. These stakes are marked at the grade of the top of the foundation or at some whole number of inches or feet above or below the top of the foundation. A level is used to mark the same grade or elevation on all stakes.

3. One- by six-in. boards are nailed to the stakes so the edge of the boards is flush with the grade marks.

4. The prolongation of the building lines on the batter boards is located by using a transit or by using a line and plumb bob.

5. Either nails are driven into the top edges of the batter boards or the boards are notched to mark the building line.

UTILITIES STAKEOUT

UTILITIES is a general term applied to pipelines, such as sewer, water, gas, and oil pipelines; communications lines, such as telephone or telegraph lines; and electric power lines.

Aboveground Utilities

For an aboveground utility, such as a pole-mounted telephone, telegraph, or power line, the survey problem consists simply of locating the line horizontally as required and marking the stations where poles or towers are to be erected. Often, the directions of guys and anchors maybe staked as well, and sometimes pole height for vertical clearance of obstructions is determined.

Underground Utilities

For an underground utility, you will often need to determine both line and grade. For pressure lines, such as water lines, it is usually necessary to stake out only the line, since the only grade requirement is that the prescribed depth of soil cover be maintained. However, staking elevations may be necessary for any pressure lines being installed in an area that (1) is to be graded downward or (2) is to have other, conflicting underground utilities.

Gravity flow lines, such as storm sewer lines, require staking for grade to be sure the pipe is installed at the design elevation and at the gradient (slope) the design requires for gravity flow through the pipe.

Grade for an underground sewer pipe is given in terms of the elevation of the invert. The INVERT of the pipe is the elevation of the lowest

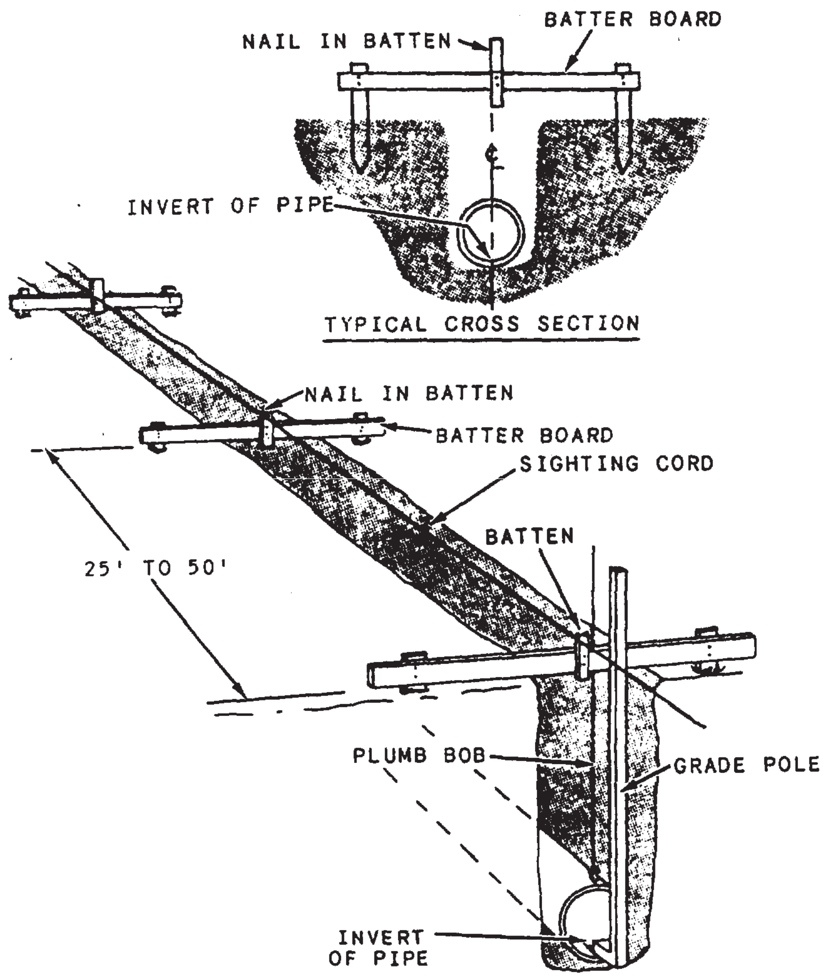


Figure 14-41.-Use of batter boards (with battens) for utility shakeout.

part of the inner surface of the pipe. Figure 14-41 shows a common method of staking out an underground pipe. Notice that both alignment and elevation are facilitated by a line of batter boards and battens (small pieces of wood) set at about 25- to 50-ft intervals. The battens, nailed to the batter boards, determine the horizontal alignment of the pipe when placed vertically on the same side of the batter boards and with the same edges directly over the center line of the pipe. As the work progresses, you should check the alignment of these battens frequently. A sighting cord, stretched parallel to the center line of the pipe at a uniform distance above the invert grade, is used to transfer line and grade into the trench. The center line of the pipe, therefore, will be directly below the cord, and the sewer invert grade will be at the selected distance below the cord. A MEASURING stick, also called a grade pole, is normally used to transfer the grade from the sighting cord to the pipe (fig. 14-41). The grade pole, with markings of feet and inches, is placed on the invert of the pipe and held plumbed. The pipe is then lowered into the trench until the mark on the grade pole is on a horizontal line with the cord.

Figure 14-42 shows another method of staking out an underground sewer pipe without the use of battens. Nails are driven directly into the tops of the batter boards so that a string stretched tightly between them will define the pipe center line. The string or cord can be kept taut by wrapping it around the nails and hanging a weight

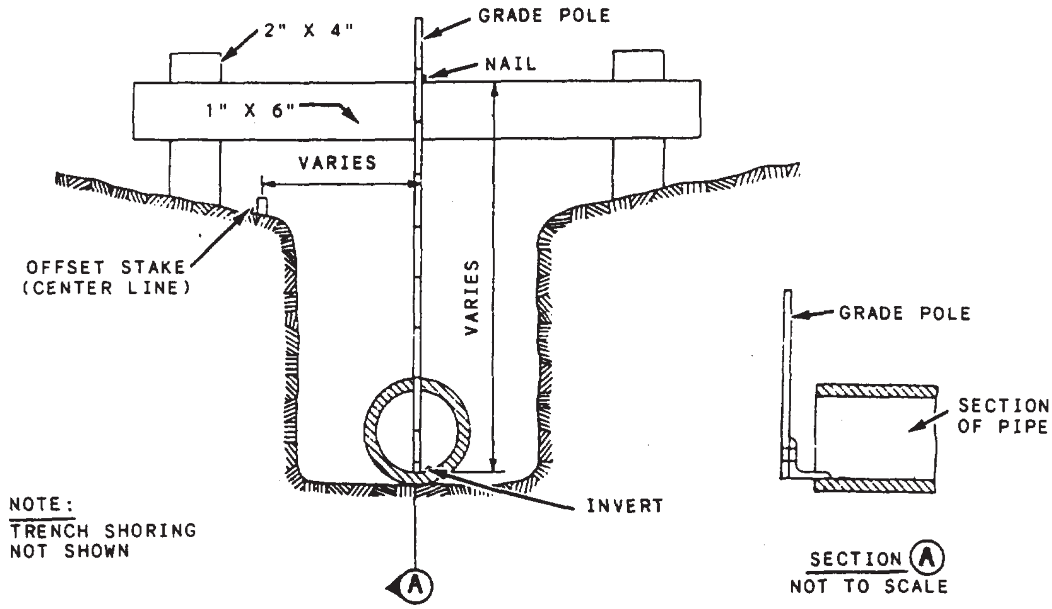


Figure 14-42.-Batter boards (without battens) for utility stakeout.

on each end. Similarly, the string (or cord) gives both line and grade.

AS-BUILT SURVEY

A finished structure seldom corresponds exactly to the original plans in every detail. Unexpected, usually unforeseeable difficulties often make variations from the plans necessary—or, occasionally, variations may occur accidentally that are economically unfeasible to correct.

The purpose of an AS-BUILT SURVEY is to record these variations. The as-built survey should begin as soon as it becomes feasible—meaning that the actual horizontal and vertical locations of features in the completed structure should be determined as soon as the features are erected.

At times, variations from the original plans are recorded on new tracings of the working drawings, on which as-built data are recorded in the place of the original design data when the two happen to differ. Sometimes, reproductions of the original drawings are used with variations recorded by crossing out the original design data and writing in the as-built data.

In either case, the term *as-built survey,* together with the date of revision, is written in, or near, the title block.

CONSTRUCTION-SITE SAFETY

WARNING

A survey party working at a construction site is always in a dangerous situation.

Where blasting or logging is going on, inform the powder crew or logging crew of the location of the area in which surveyors are working. Also, instruct the individual crew members of the survey party to be on the alert at all times—particularly to listen for the warning signal given by a crew using powder to set off a charge or a logger felling a tree.

When surveying near highways, railroads, or airstrips, use red flagging generously unless you are working in a combat area. Place flagging on the legs of your surveying equipment and at a few places along the tape. Put flags on rods and range poles. Attach some flagging to your hat and also to the back of your shirt or jacket.

Think constantly of personal safety when working near heavy construction equipment. Let the equipment operators know when surveyors are in the vicinity. Also, alert all members of the surveying crew because an equipment operator's vision is often obscured by dust or by the equipment itself.

When ascending steep, rocky slopes, do not climb directly behind another crew member. If the crew member were to accidentally fall, loosen a rock, or drop something, it could mean serious injury to anyone directly below the crew member.

EXCAVATIONS

WARNING

When your work involves excavation, you should observe definite precautions to prevent accidents.

To avoid slides or cave-ins, support the sides of the excavations 5 ft or more deep by substantial bracing, shoring, or sheet piling if the sides are steeper than the angle of repose. The ANGLE OF REPOSE is the maximum angle at which material will repose without sliding. Trenches in partly saturated or otherwise highly unstable soil should be stabilized with vertical sheet piling or suitable braces. Foundations of structures adjacent to excavations should be shored, braced, or underpinned as long as the excavation remains open. Excavated or other material should not be allowed to accumulate closer than 2 ft from the edge of an excavation. In a traffic area use barricades, safety signs, danger signals, red lights, or red flagging on at least two sides.

Do not enter a manhole until you are certain that it is free from dangerous gases. Do not guess. If there is any question at all as to whether a sewer is free of gas, wait for clearance from a competent authority. If necessary, provide first for thorough ventilation. Do not smoke in manholes; and if illumination is required, use only a safety flashlight or lantern.

Avoid contact with ALL ELECTRIC wiring. Never throw a metal tape across electric wires; if you must chain across wiring, do it by breaking chain. Avoid placing yourself so that you might fall across wiring in the event of an accident.

When walking, stay at least 2 feet away from the edge of a vertical excavation. Near thoroughfares or walkways, excavations should have temporary guardrails or barricades; and if permissible, depending on combat conditions, red lights or torches should be kept alongside from sunset to sunrise.

TREE CLIMBING

Before climbing a tree, be sure it is safe to climb, and carefully cheek the condition of the branches on which you are likely to stand. Different kinds of wood vary greatly in strength. Oak, hickory, and elm trees that have strong, flexible wood are safer for climbing than trees such as poplar, catalpa, chestnut, or willow, which have soft or brittle wood. Limbs of all trees become brittle at low temperature—meaning that they break more easily in cold weather than they do in warm. Dead branches or those containing many knots or fungus growths are usually weak.

When standing on a limb, have your feet as close to the parent trunk as possible. Climb with special care when limbs are wet or icy. Wear goggles when working in bushy trees; they may prevent an eye injury.

WARNING

Before climbing a tree, be sure there are no overhead wires passing through its foliage. If you MUST take a position in a tree within reach of live wire, place some sort of insulating safety equipment between yourself and the wire. DO NOT allow tree limbs to contact live wires because moisture in a limb may cause a short circuit.

If you require cutting tools to clear a working space in a tree, haul them up with a handline, and lower them by the same device. Tools should never be thrown up into a tree or down onto the ground.

UNDERGROUND AND OVERHEAD LINES

If a structure has an access opening and is below the street, such as a manhole or a transformer vault, it should be protected by a barrier or other suitable guard when the cover to the access opening is removed.

CROSSING ICE

Do not cross ice unless, and until, you are certain it will support your weight.

Both the thickness and the nature of ice are important in determining its carrying capacity.

Because part of the supporting power of ice is derived from the water below it, a layer of ice that is in contact with the water surface is safer than one that has no contact with the water surface.

An ice layer usually becomes thinner over current, near banks of streams or lakes, over warm springs, and over swampy ground. Rotten ice that can be identified by its dull color and honeycomb texture has little supporting power.

WORK SAFELY—STRESS SAFETY

CHAPTER 15

MATERIALS TESTING: SOIL AND CONCRETE

In previous chapters of this TRAMAN, you studied the importance of many and various construction materials. However, one material that was not discussed was SOIL which, as you will learn in this chapter, is perhaps the most important material of all. Just as a poorly constructed and weak concrete foundation will not support a building, neither will a poorly "constructed" and weak soil, since the ultimate foundation for any road, airfield, building, or other structure is the natural earth upon which it is built.

During this chapter you will learn what soil is. You will learn the different types of soil you might encounter. You will also learn the basic properties and characteristics of soil and the importance those characteristics play in determining the adequacy of a soil for use as a construction material. In addition, you will learn how to collect (sample) soil for testing purposes and how to perform certain tests that you, as an EA3, will be responsible for performing. Most importantly, you will learn why those tests are performed and their importance in properly and correctly identifying and classifying the many types of soil that exist in nature.

Finally, this chapter begins your studies of concrete testing. In this chapter you will learn what the various tests are and the purpose and importance of those tests. You will learn how to perform certain tests and how to prepare concrete samples for other tests that will be performed by more senior EAs.

SOIL ORIGIN

As defined by Webster's New World Dictionary, *soil* is the surface layer of the Earth that supports plant life. While that is certainly a correct definition and one that is perfectly satisfactory to many groups of people, it lacks the precision required by the civil engineer and soil technician. A more precise definition is that soil is a mixture of uncemented or loosely cemented mineral grains enclosing various sizes of voids that contain air (or other gases), water, organic matter, or different combinations of these materials in varying amounts. The importance of understanding this definition will become obvious as you progress through this chapter; but, first, let us consider where soil comes from.

SOIL FORMATION

The formation of soil is a continuous process that is still in action today. Basically, the Earth's crust consists of rock, which geologists classify into three groups: igneous, which is formed by cooling from a molten state; sedimentary, formed by the accumulation and cementing of existing particles and remains of plants and animals; and metamorphic, formed from existing rocks that have been subjected to heat and pressure. When exposed to the atmosphere, this rock undergoes a physical and chemical process called WEATHERING, which, over a sufficient length of time, disintegrates and decomposes the rock into a loose, incoherent mixture of gravel, sand, and finer material. It is this process that produces soils of various designations.

RESIDUAL SOIL

Any soil that results from weathering in place, and that is not moved during the weathering process, is called a RESIDUAL soil. A mantle of residual soil reflects the characteristics of the underlying parent rock from which it was derived.

TRANSPORTED SOIL

When the forces of nature cause the mantle of soil to be moved to a place other than that of its origin, the soil becomes a TRANSPORTED soil. One of these soils often bears properties induced by its mode of transportation. The chief agents of transportation are water, wind, ice, and the force of gravity.

Alluvial Soil

ALLUVIAL soil is formed when a soil-carrying stream gradually loses its carrying capacity with decreasing velocity. In slowing down, a river does not have sufficient power to keep the large particles of soil suspended; these particles settle to the riverbed. Further decrease in velocity causes smaller particles to settle. As the river becomes slow and sluggish (as in the lowlands where its gradient becomes small), it holds only the extremely fine particles in suspension. These particles are deposited, finally, at the mouth of the river, where they form DELTAS of fine-grained soil.

Marine Soil

MARINE soil is formed from materials carried into the seas by streams and by material eroded from the beaches by the tidal action of the waves. Part of the material is carried out and deposited in deep water; part is heaped upon the beaches along the coast.

Lacustrine Soil

Freshwater lake deposits are called LACUSTRINE soils. Generally speaking, they are fine-grained soils resulting from material brought into freshwater lakes by streams or rivers.

Aeolian Soil

Wind-transported grains make up AEOLIAN soils. Sand deposits from wind are called "dunes," and the finer particles (which are generally carried further) are deposited to form a material called LOESS. Dune deposits seldom contain material larger than sand size.

Glacial Soil

GLACIAL soil is often called DRIFT. It consists of material carried along with or upon an advancing ice sheet or of material pushed ahead of it. As glaciers melt, deposits of various forms occur, such as MORAINES, KAME TERRACES, ESKERS, and OUTWASH PLANES. Moraines consist of mixtures of unstratified boulders, gravels, sands, and clays. The other forms (kame terraces, eskers, and outwash planes) mentioned consist of somewhat stratified and partly sorted stream gravels, sand, and fines transported outward from the glacier by streams during the melting period.

Colluvial Soil

COLLUVIAL soil consists of mixed deposits of rock fragments and soil materials accumulated at the bases of steep slopes through the influence of gravity.

Table 15-1.-Size Groups as Used in the Unified Soil Classification System

Size Groups	Sieve Size	
	Passing	Retained on
Cobbles ------------	No maximum size* --------------------	3 in.
Gravels -------------	3 in. --------------------------------------	No. 4
Sands ---------------	No. 4--------------------------------------	No. 200
Fines ----------------	No. 200-----------------------------------	No minimum size

*In military engineering, maximum size of cobbles is accepted as 40 inches, based upon maximum jaw opening of the crushing unit.

PHYSICAL CHARACTERISTICS OF SOILS

The physical characteristics of soils aid in determining their engineering characteristics and are the basis of the system of soil classification used in the SEABEEs and by the military in general for the identification of soil types. A knowledge of these physical characteristics aids in determining the degree to which local soils can be used in engineering projects to support traffic loads or to serve as a subgrade or foundation material. Those characteristics of concern to the EA are discussed below.

PARTICLE SIZE

Soils are divided into groups based on the size of the particle grains in the soil mass. The EA identifies the sizes through the use of sieves. A sieve is a screen attached across the end of a shallow cylindrical frame. The screen permits particles smaller than the openings to fall through and larger ones to be retained on the sieve. When sieves of different sizes are stacked so that the largest screen openings are at the top and the smallest at the bottom, soil can be separated into particle groups based on size. The amount remaining on each sieve is measured and described as a percentage by weight of the entire sample. Table 15-1 shows size groups as used in the Unified Soil Classification System. Particles passing the No. 200 sieve but larger than 0.002 mm to 0.005 mm are called silt, and those finer are clays.

PARTICLE SHAPE

The shape of the particles influences the strength and stability of a soil. Two general shapes are normally recognized: BULKY (fig. 15- 1) and PLATY.

Bulky

Cobbles, gravel, sand, and silt particles cover a large range of sizes; however, they are all bulky in shape. The term bulky is confined to particles that are relatively large in all three dimensions, as contrasted to platy particles, in which one dimension is small as compared to the other two. The bulky shape has the following four subdivisions listed in descending order of desirability for construction:

ANGULAR particles are those that have been recently broken up and are characterized by jagged projections, sharp ridges, and flat surfaces. Angular gravels and sands are generally the best materials for construction because of their interlocking characteristics. Such particles are seldom found in nature, however, because the weathering process does not generally produce them. Angular material must usually be produced artificially, by crushing.

SUBANGULAR particles are those that have been weathered to the extent that the sharper points and ridges have been worn off.

SUBROUNDED particles are those that have been weathered to a further degree than subangular particles. They are still somewhat irregular in shape but have no sharp corners and few flat areas. Materials with this shape are frequently found in stream beds. If composed of hard, durable particles, subrounded material is adequate for most construction needs.

ROUNDED particles are those on which all projections have been removed, with few irregularities in shape remaining. The particles resemble spheres and are of varying sizes. Rounded particles are usually found in or near stream beds or beaches.

Platy

Platy (or flaky) particles are those that have flat, platelike grains. Clay is a common example. Because of their shape, these flaky particles have a greater contact area for moisture and are undesirable for construction purposes.

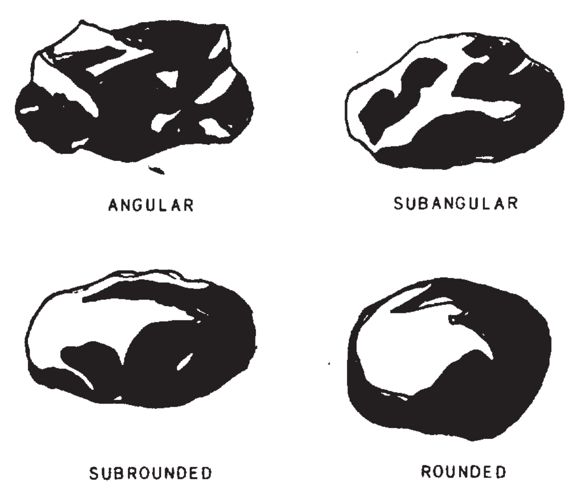


Figure 15-1.-Types of bulky-shaped soil particles (grains).

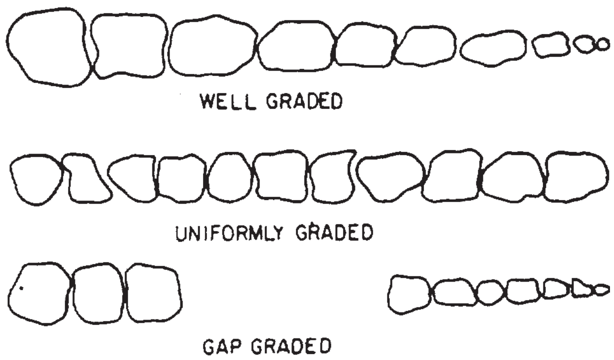


Figure 15-2.-Types of soil gradation.

GRADATION

The size and shape of the soil particles discussed above deal with properties of the individual grains in a soil mass. Gradation describes the distribution of the different size groups within a soil sample. The soil may be well or poorly graded.

To be classified as WELL GRADED, a soil must have a good range of all representative particle sizes between the largest and the smallest. All sizes must be represented, and no one size should be either overabundant or missing (fig. 15-2).

Poorly graded soils are either those containing a narrow range of particle sizes or those with some intermediate sizes lacking (fig. 15-2). Soils with a limited range of particle sizes are called UNIFORMLY GRADED. Soils that have some intermediate size or sizes not well represented or missing are called GAP GRADED, STEP GRADED, or SKIP GRADED.

COMPACTNESS

Compactness refers to how closely a mass of soil particles are packed together; the closer the packing, the greater the compactness and the larger the weight of soil per unit volume.

The structure of a total mass of soil particles may be dense. In this case, the particles are closely packed and have a high degree of compactness. A dense structure provides interlocking of particles with smaller grains filling the voids between the larger particles. When each particle is closely surrounded by other particles, the grain-to-grain contacts are increased. This lessens the tendency for displacement of the individual grains under load, and the soil is then capable of supporting heavier loads. Well-graded coarse materials usually are dense and have strength and stability under load.

On the other hand, the structure may be loose, in which case the particles are not packed as closely together as possible, thereby lacking compactness. Loose, open structures have large voids, which will lead to settlement or disintegration when foundation or traffic loads are applied.

SPECIFIC GRAVITY

Specific gravity is designated by the symbol G_s. It is defined as the ratio between the weight per unit volume of the material and the weight per unit volume of water at a stated temperature—usually 20°C. If you use the system international (SI) (metric) system, you can determine specific gravity by the following formula:

$$\text{Specific gravity} = \frac{\text{weight of sample in air (g)}}{\text{weight of sample in air (g)} - \text{weight of sample submerged (g)}}$$

Test procedures will be discussed in detail later in this chapter. The specific gravity of the solid substance of most inorganic soils varies between 2.60 and 2.80. Tropical iron-rich laterite, as well as some lateritic soils, generally has a specific gravity of 3.0 or more. Sand particles composed of quartz have a specific gravity of about 2.65. Clays can have values as high as 3.50. The solids of soil particles are composed of minerals. Generally, these minerals have a specific gravity greater than 2.60. Values of specific gravity smaller than that are an indication of the possible presence of organic matter.

SOIL MOISTURE

The moisture content of a soil mass is often the most important factor affecting the engineering characteristics of the soil. The water may enter from the surface or may move through the subsurface layers by either gravitational pull, capillary action, or absorption. This moisture is present in most cases. It influences various soils differently; it probably has the greatest effect upon the behavior of the soil when the soil is subjected to loading.

Sources of Water in Soils

Surface water results from precipitation or runoff and enters the soil through the openings between the particles. This moisture may adhere to the different particles, or it may penetrate the soil to some lower layer.

Subsurface water is collected or held in pools or layers beneath the surface by a restricting layer of soil or rock. This water is constantly acted upon by one or more external forces.

Water controlled by gravity (free or gravitational water) seeks a lower layer and moves through the voids or spaces until it reaches some restriction. This restriction may be a bedrock or an impervious layer of soil whose openings or voids are so small as to prevent water passage.

The voids or spaces in a soil may form continuous tunnels or tubes and cause the water to rise in the tubes by capillary action (capillary moisture). The smaller the tube, the stronger the capillary action; therefore, the water rises higher in the finer soils, which have smaller interconnected voids. This area of moisture above the free water layer or pool is called the capillary fringe.

Another force acting on soil water is absorption by the atmosphere. As the moisture evaporates from the soil surface, more moisture is drawn from the soil below and is, in turn, also evaporated. This process continues until the soil is in an airdry condition in which the moisture in the soil is in equilibrium with the moisture vapor in the air. In this airdry state, the moisture remaining in the soil is in the form of thin films of water surrounding the individual soil particles and is called the hydroscopic moisture. These moisture films are due to naturally occurring electrical forces, which bind the water molecules to the soil particles. Hydroscopic moisture films may be driven off from airdried soil by heating the material in an oven at a controlled temperature for 24 hr or until constant weight is attained.

To define the amount of water present in a soil sample, the term *moisture content* (symbol w) is used. It is the proportion of the weight of water to the weight of the solid mineral grains (weight of dry soil) expressed as a percentage or

$$w = \frac{\text{weight of water}}{\text{weight of dry soil}} \times 100$$

When wet soil is dried in air in the laboratory, the amount of hydroscopic moisture remaining in the airdried soil, expressed as a percentage of the weight of the dry soil, is called the hydroscopic moisture content.

Plasticity

Plasticity is a property of the fine-grained portion of a soil that allows it to be deformed beyond the point of recovery without cracking or changing volume appreciably. Some minerals, such as quartz powder, cannot be made plastic no matter how fine the particles or how much water is added. All clay minerals, on the other hand, are plastic and can be rolled into thin threads at a certain moisture content without crumbling. Since practically all fine-grained soils contain some clay, most of them are plastic. The degree of plasticity is a general index to the clay content of a soil.

The term *fat* and *lean* are sometimes used to distinguish between highly plastic and slightly plastic soils. For example, lean clay is only slightly plastic, whereas fat clay is highly plastic. In engineering practice, soil plasticity is determined by observing the different physical states that a plastic soil passes through as the moisture conditions change. The boundaries between the different states, as described by the moisture content at the time of change, are called consistency limits or Atterberg limits.

The liquid limit (LL) is the moisture content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil. Above this value, the soil is presumed to be a liquid and behaves as such by flowing freely under its own weight. Below this value, it deforms under pressure without crumbling, provided the soil exhibits a plastic state.

The plastic limit (PL) is the moisture content at an arbitrary limit between the plastic and semisolid state. It is reached when the soil is no longer pliable and crumbles under pressure. Between the liquid and plastic limits is the plastic range. The numerical difference in moisture content between the two limits is called the plasticity index (PI). The equation is $PI = LL - PL$. It defines the range of moisture content within which the soil is in a plastic state.

The shrinkage limit is the boundary in moisture content between the solid and the semisolid states. The solid state is reached when the soil sample, upon being dried, finally reaches a limiting or minimum volume. Beyond this point, further drying does not reduce the volume but may cause cracking. The limit tests are described later in this chapter.

Effects of Soil Moisture

Moisture affects coarse-grained soils much less than fine-grained soils. One reason for this is that coarser soils have larger void openings, and, as a rule, drain more rapidly. Capillarity is practically nonexistent in gravels and in sands containing little fines. These soils, if they are above the groundwater table, will not usually retain large amounts of water. A second reason is that since the particles in gravelly and sandy soils are relatively large (in comparison to clay and silt particles), they are, by weight, heavy in comparison to the films of moisture that might surround them.

On the other hand, the small (sometimes microscopic) particles of fine-grained soil weigh so little that water in the voids has considerable effect. It is not unusual, for example, for clays to undergo large volume changes with variations in moisture content, as witness the shrinkage cracks in a dry lake bed. Consequently, unpaved clay roads, though hard enough when sun-baked, often lose stability and turn into mud in rainy weather.

Not only do clays swell and lose stability when they become wet, but they also, because of their flat, platelike grain shapes and small size, retard the drainage of water. Since drainage is of the greatest importance in (for example) the construction of airfield pavement, design engineers must know whether or not subsurface clay exists. Plasticity is, as you know, the characteristic by which clay is primarily identified.

ORGANIC SOILS

Soils of organic origin are formed either by the growth and subsequent decay of plant life or by the accumulation of inorganic particles of skeletons or shells of organisms. The term *organic soil,* though, refers to soils containing mineral grains and a more or less conspicuous admixture of vegetable matter. An organic soil may be an organic silt or clay, or it may be a HIGHLY ORGANIC soil, such as peat or meadow mat.

Organic soils are most often black in color, and usually have a characteristic musty odor. These soils are usually compressible and have poor load-maintaining properties.

EFFECTS OF SOIL CHARACTERISTICS

In summary, soil characteristics area measure of the suitability of the soil to serve some intended purpose. Generally, a dense, solid soil withstands greater applied loads (has greater bearing capacity) than a loose soil. Particle size has a definite relation to this capacity. From empirical tests, it has been found that well-graded, coarse-grained soils generally can be compacted to a greater density than fine-grained soils. This is because the smaller particles tend to fill the spaces between the larger ones. The shape of the grains also affects the bearing capacity. Angular particles tend to interlock, forma denser mass, and become more stable than the rounded particles, which can roll or slide past one another. Poorly graded soils, with their lack of one or more sizes, leave more or greater voids and comprise a less dense mass. Moisture content and the consistency limits aid in describing the suitability of the soil. A coarse-grained sandy or gravelly soil generally has good drainage characteristics and may be used in its natural state. A fine-grained clayey soil with a high plasticity index may require considerable treatment, especially if used in a moist location.

SOIL CLASSIFICATION

As can be inferred from the previous discussions in this chapter, soil types are important factors to consider when selecting the proper location on which to construct any structure or facility. With the soil accurately identified and described, its suitability for supporting traffic as a subgrade, base, or foundation material or as an aggregate, a filler, or a binder for a mixture can be evaluated.

CLASSIFYING SOILS

The UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) is a common soil classification reference or system that has a universal interpretation. In this system, all soils are divided into three major divisions as follows:

COARSE-GRAINED SOILS are those in which at least half of the material, by weight, is larger than (retained on) a No. 200 sieve. This division is further divided in GRAVELS and SANDS. If more than half of the coarse fraction, by weight, is retained on a No. 4 sieve, it is classified as a gravel. If less than half is retained on a No. 4 sieve, then it is a sand. Gravels and sands are further subdivided into additional categories dependent upon the amount and characteristics of any plastic fines the soil sample contains.

FINE-GRAINED SOILS are those in which more than half of the material, by weight, is smaller than (passes) a No. 200 sieve. The fine-grained soils are not classified on the basis of grain size distribution but according to plasticity and compressibility.

HIGHLY ORGANIC SOILS are those organic soils, such as peat, that have too many undesirable characteristics from the standpoint of their behavior as foundations and their use as construction materials. A special classification is reserved for these soils, and no laboratory criteria are established for them. Highly organic soils can generally be readily identified in the field by their distinctive color and odor, spongy feel, and frequently fibrous textures. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils.

CLASSIFICATION TESTS

The above is by no means a thorough description of the USCS and the methods used to classify soils; nor is it intended to be. However, the results of certain tests (sieve analysis and Atterberg limits) that you will be performing as an EA3 will be used for the purpose of soil classification. The preceding discussion is presented so that you have an understanding of why you perform the tests, what the results are used for, and the importance of ensuring that your test results are correct and reliable. A full discussion of the test procedures will be presented later in this chapter, Should you desire to learn more about the USCS and soils classification, you may refer to the EA1 TRAMAN, to NAVFAC MO-330, *Materials Testing,* or to one of numerous commercial publications on soil mechanics.

SOIL SAMPLING

In the planning and execution of construction operations, it is vital to know as much information of engineering significance as possible about the subsurface conditions in the construction area. That information includes not only the location, extent, and condition of the soil layers but also the elevation of the groundwater table and bedrock; the drainage characteristics of the surface and subsurface soils; and the location of possible borrow areas from which soil and other mineral-product materials may be "borrowed" for a construction operation. Soil surveys are conducted to gather (explore) this information. These are multifaceted surveys that consist of the following: gathering soil samples; soil testing by either laboratory or field procedures, or both; soil classification; and the development of soil profiles. In the full scope of soil surveying, your primary concern, as an EA3, is gathering soil samples and conducting certain of the laboratory soils tests. Should you desire to learn more about soil surveying, an excellent source is NAVFAC MO-330, *Materials Testing*.

SAMPLING METHODS

The gathering, or collecting, of soil samples in the field for testing is called SOIL SAMPLING. The three principal methods of sampling are the taking of samples from the surface, from already existing excavations, and from test pits and test holes. The extent and methods used will be dependent upon the time available.

The method that provides the most satisfactory results for both studying the natural soil conditions and for collecting undisturbed soil samples is the taking of samples from test pits. A test pit is an open excavation that is large enough for a person to enter. Usually, these pits are dug by hand; however, when power equipment is available, power excavation by clamshell, dragline, bulldozer, backhoe, or a power-driven earth auger can expedite the digging. Excavations below the groundwater table require the use of pneumatic caissons or the lowering of the water table. Additionally, excavations that extend to 5 ft or more in depth may require adequate shoring and bracing to prevent cave-ins, as discussed in the previous chapter. Load-bearing tests can also be performed on the soil in the bottom of the pit.

Test hole exploration, with the use of the hand auger, is the most common method of digging test holes. It is best suited to cohesive soils but can be used on cohesionless soils above the water table, provided the diameter of the individual aggregate particles is smaller than the bit clearance of the auger. Auger borings are usually used for work at shallow depths, but if pipe extensions are added, the earth auger may be used to a depth of about 30 ft in relatively soft soils. Samples obtained by this method are completely disturbed but are satisfactory for determining the soil profile, classification, moisture content, compaction capabilities, and similar soil properties.

In a hasty soil survey, which is made under expedient conditions or when time is limited, the number of test pits and test holes is kept to a minimum by the use of existing excavations for soil sampling. In a deliberate survey, where time and conditions allow a more thorough sampling operation, test holes are used extensively and are augmented by test pits, governed by the judgment of the engineering officer.

Table 15-2.-Methods of Underground Exploration and Sampling

Common name of method	Materials in which used	Method of advancing the hole	Method of sampling	Value for foundation purposes
Auger boring	Cohesive soils and cohesionless soils above groundwater elevation	Augers rotated until filled with soil and then removed to surface	Samples recovered from material brought up on augers	Satisfactory for highway exploration at shallow depths
Well drilling	All soils, rock, and boulders	Churn drilling with power machine	Bailed sample of churned material or clay socket	Clay socket samples are dry samples Bailed samples are valueless
Rotary drilling	All soils, rock, and boulders	Rotating bits operating in a heavy circulating liquid	Samples recovered from circulating liquid	Samples are of no value
Test pits	All soils. Lowering of groundwater may be necessary	Hand digging or power excavation	Samples taken by hand from original position in ground	Materials can be inspected in natural condition and place

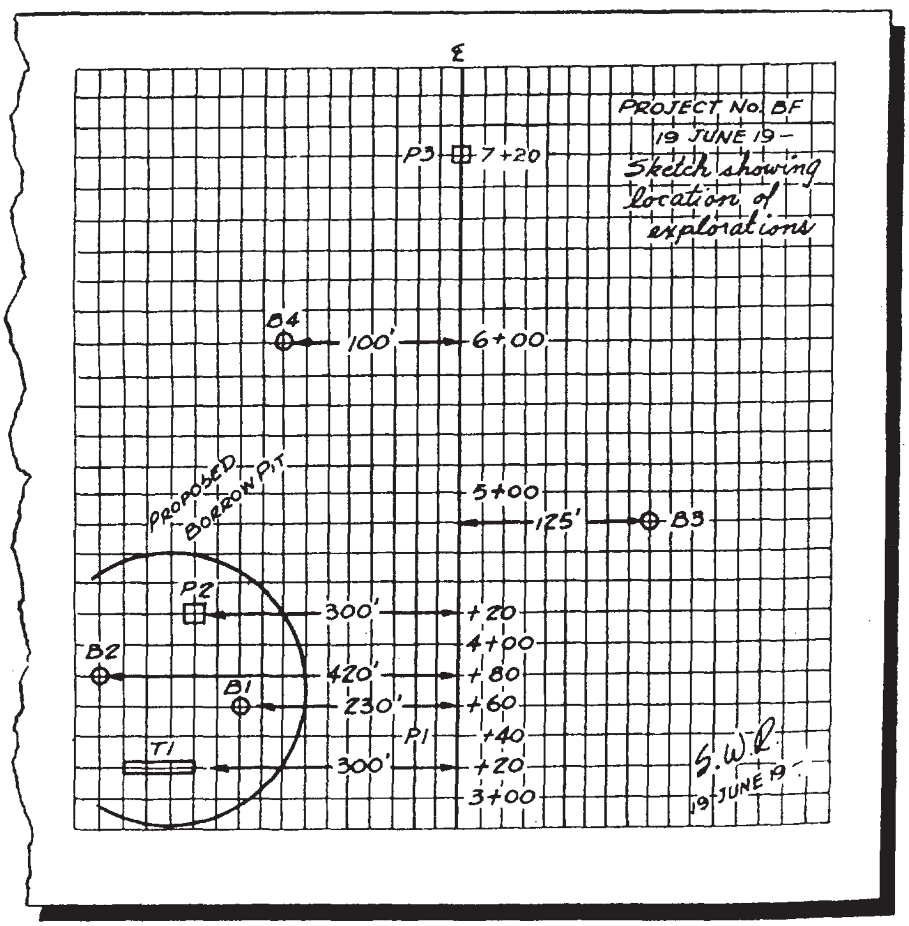


Figure 15-3.-Sketch showing locations of soil exploration points.

Table 15-2 shows methods of underground exploration and sampling in a condensed form.

TAGGING SAMPLES

Let us suppose that soil in a given area is to be tested (such as the area on which a structure is to be erected). The officer in charge of soil exploration decides how many points are needed and where they must be located to produce a representative test of the soil in the area. This information is recorded in a sketch like the one shown in figure 15-3.

This figure shows the locations of exploratory points along a highway, the point locations referenced by the center-line station and the distance from the center line. To the left of the center line, between stations 2 + 80 and 4 + 60, there is a borrow pit, from which soil for fill is taken. The soil here is tested by samples taken from a 60-ft trench (T1), located at station 3 + 20, 300 ft from the highway center line; from two borings (B1 and B2) at stations 3 + 60 and 3 + 80, 230 ft and 420 ft from the center line, respectively; and from a 20-ft- square pit (P2) at station 4 + 20, 300 ft from the center line.

Besides the borrow pit exploration, there is a boring (B3) at station 4 + 80, 125 ft to the right of the center line; another boring (B4) at station 6 + 00, 100 ft to the left of the center line; and a 20-ft-square pit (P3) on the center line at station 7 + 20.

Each sample taken is tagged according to the location from which it was taken. Locations are given in consecutive numbers; for those shown in figure 15-3, the numbers might run from the bottom up, with T1 being No. 1; B 1, No. 2; and so on. A sample is tagged with the project symbol (the symbol for the project shown in fig. 15-3 is BF) and the location symbol (such as T1 or B1). If more than one sample is taken from the same location, you need to use additional numbers. For example, a sample taken from B2 in figure 15-3 maybe tagged “BF-B2-4, bag 1 of 6.” This means “boring No. 2, location No. 4, the first of 6 bags taken from that location.”

The sample identification is printed with a marking pencil or pen on two tags, one of which is placed inside the bag, and the other of which is tied on the outside. Gummed labels may be similarly used to identify samples that are placed in moisture content boxes, cylinders, or jars.

DISTURBED SAMPLES

Samples taken by hand scoops, auger borings, shovels, or any other convenient hand tool with no attempt to obtain the material in its natural state of structure or density is known as a DISTURBED sample. These samples are used for mechanical analysis, plasticity, specific gravity, frost susceptibility, compaction, and laboratory compacted CBR tests. The size of the sample taken will depend upon the tests to be performed.

Individual Samples

When taking individual samples from a pit, trench, or exposed face (fig. 15-4), first shave off loose and dried soil to obtain a fresh surface and to expose any soil variations clearly. Then take a typical sample of each type of soil or of those requiring additional investigation. When sampling in auger holes, place typical portions of the soil obtained

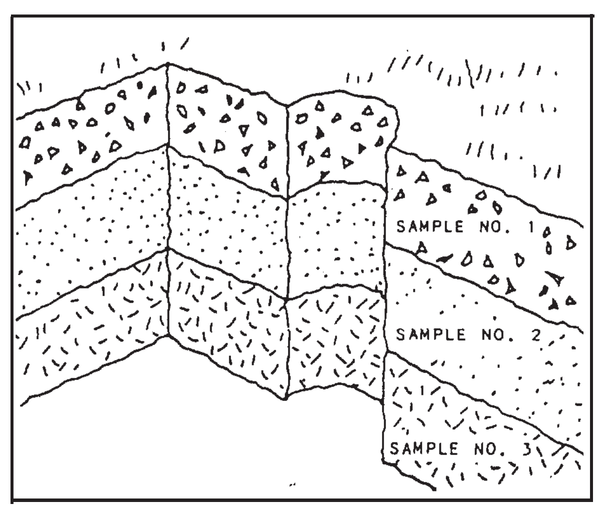


Figure 15-4.-Obtaining individual bag samples from an exposed face.

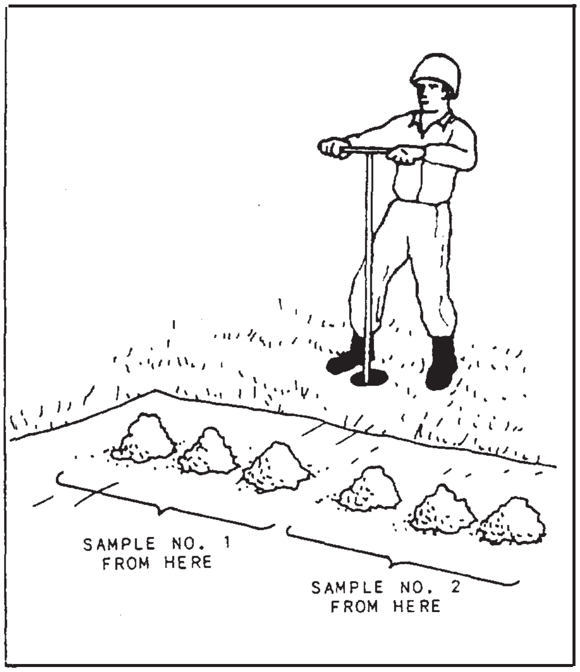


Figure 15-5.-Obtaining individual bag samples.

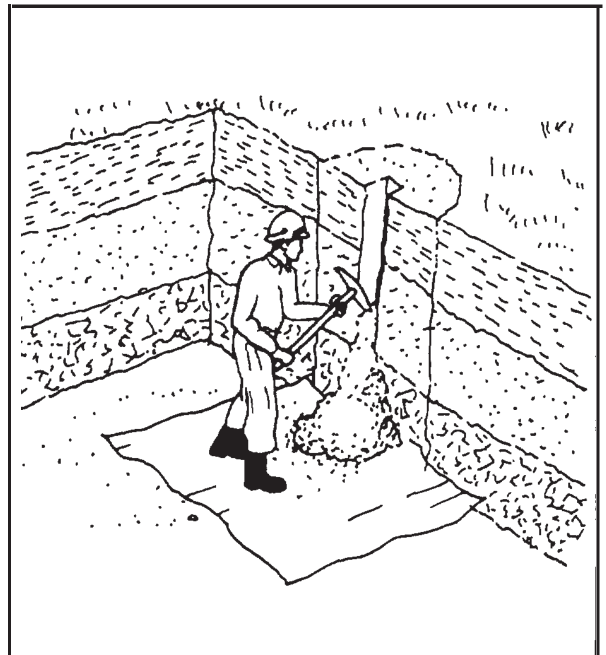


Figure 15-6.-Taking a composite sample with an exposed face.

along a row in correct order, as shown in figure 15-5.

Composite Samples

A composite sample is a representative mixture of all soil within a soil mass to be investigated or of the material contained in a stockpile or windrow of soil excavated from a trench. A test sample is obtained from a composite sample by quartering (to be explained later) in the laboratory.

To take composite samples from test pits, trenches, or power shovel cuts, take the following steps:

1. Remove any overburden or surface soil that is to be wasted.

2. Shave off loose and dried soil to obtain a fresh surface for taking the sample.

3. Excavate a channel of uniform cross section from top to bottom, and deposit the soil onto a quartering cloth, canvas, or tarpaulin, as shown in figure 15-6.

Collect and bag all material removed to ensure that the sample contains the correct proportions. To take composite samples from auger holes, collect all material excavated from the hole after first removing the overburden. When taking representative composite samples from stockpiles or large windrows, take particular care. When material is dumped on large piles, the coarse material tends to roll to the bottom, leaving the finer material on the top. To compensate for this, take the sample from a full height strip after clearing the surface. To sample from a small windrow, excavate and bag material from a short section, as shown in figure 15-7.

Moisture Content Samples

The natural moisture content of soil is determined from samples taken in the field and placed in a container, which is then sealed to prevent loss of moisture by evaporation. Natural moisture content determinations are valuable in interpreting information obtained from test borings or pits,

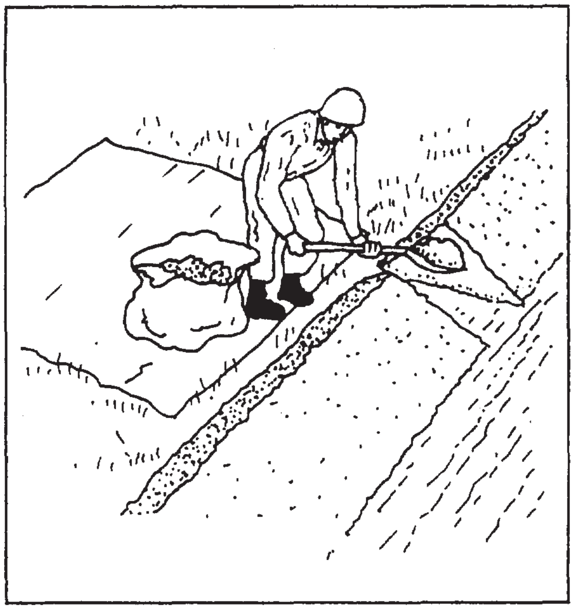


Figure 15-7.-Taking a composite sample from a small windrow.

in drawing the soil profile, and in estimating the physical properties of soils encountered in the field.

Generally, 100 g of soil is enough to determine the moisture content of fine-grained soils. Larger samples are required for soils that contain gravel. Normally, moisture content samples are placed in metal dishes (canisters) that have tight-fitting covers; however, any other clean container that can be adequately sealed may be used. When the moisture content test is to be performed within 1 day after the sample is obtained, sealing of the container is not required. If a longer time interval will elapse between sampling and testing, the containers may be sealed, as shown in figure 15-8.

Figure 15-8.-Sealing a container to retain moisture content of a sample.

UNDISTURBED SAMPLES

UNDISTURBED soil samples are those that are cut, removed, and packed with the least possible disturbance. They are samples in which the natural structures, void ratio, and moisture content are preserved as carefully as possible. Samples of this type are used for determining the density (unit weight) of soil in the laboratory and investigating the strength of undisturbed soils in the laboratory by the CBR or unconfined compression tests. These samples may be shipped to more completely equipped laboratories for shear, consolidation, or other strength tests.

Types of undisturbed samples are chunk samples, cut by hand with a shovel and knife, and cylinder samples, obtained by use of a cylindrical sampler or the CBR mold equipped with a sampling cutter. Expedient methods of obtaining cylinder samples are also used.

The method of sampling chosen depends upon the equipment available, the tests required, and the type of soil. All undisturbed samples must be handled with care. Cohesionless soil samples must be kept in the container until ready for testing, and the container should be handled without jarring or vibration. Some soils are too hard or contain too many stones to permit sampling with the cylindrical samplers and can be sampled only by cutting out chunks by hand. Taking of undisturbed samples frequently requires a great deal of ingenuity in adapting the sampling devices to job conditions and in devising schemes for their use. Whatever method is used, the sample must be taken and packed in the container for shipment without allowing its structure to change. Protection against change in moisture content during sampling and shipment is also required.

Chunk Samples

The simplest type of undisturbed sample is the chunk sample. It should be noted, however, that these can be obtained only from soils that will not deform, break, or crumble while being removed.

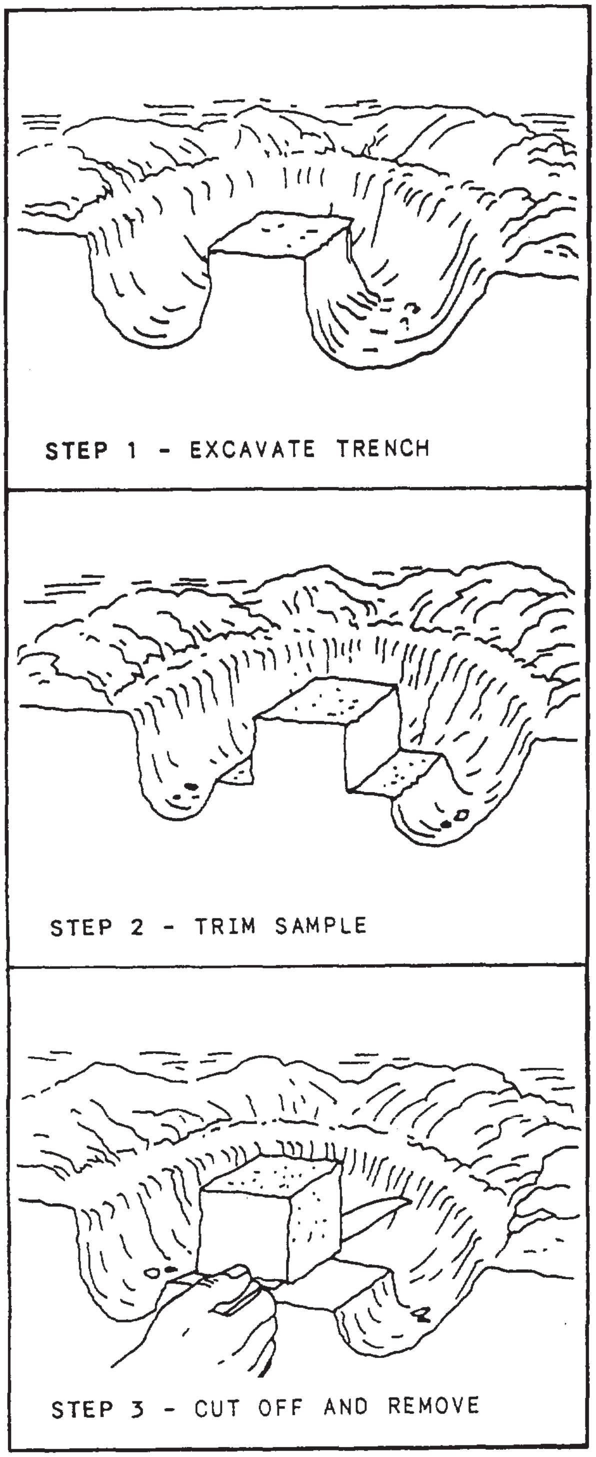


Figure 15-9.-Taking a chunk sample from a level surface.

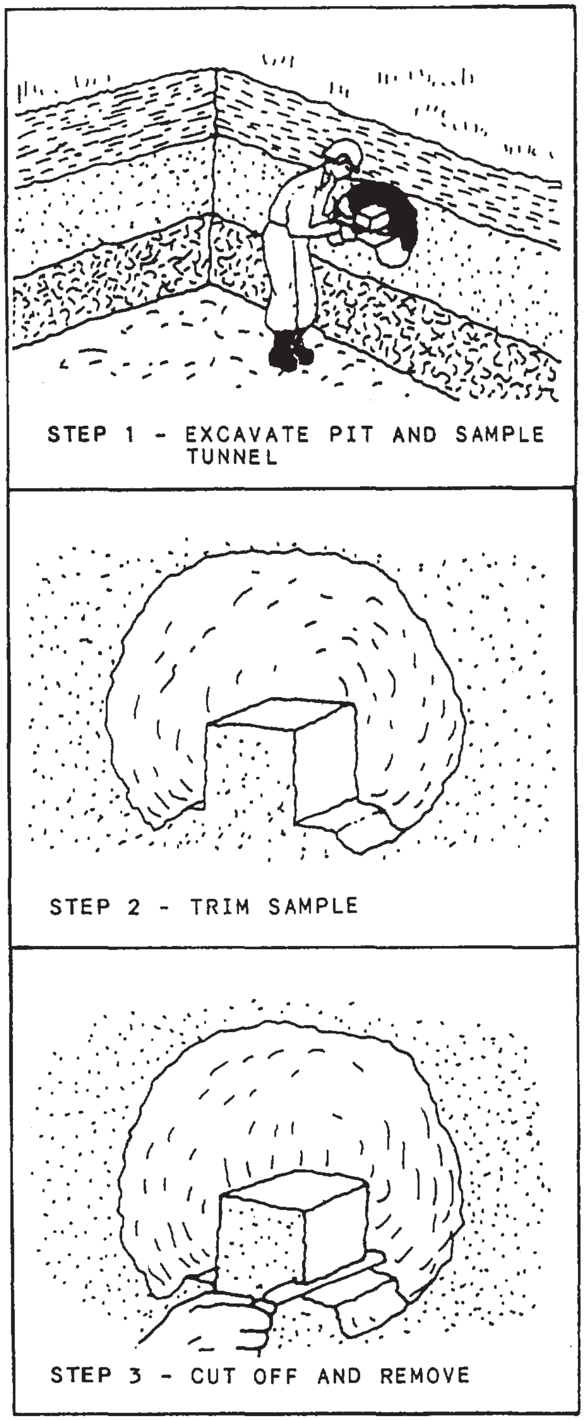
Figure 15-9 shows the process of taking a chunk sample from a level surface, such as a subgrade or the bottom of a test pit. After smoothing the ground surface and marking the outline of the chunk, the first step is to excavate a trench around the chunk. Then deepen the excavation and trim the sides of the chunk with a knife. Finally, using a knife, trowel, or hacksaw blade, cut off the chunk at the bottom and carefully remove it from the hole.

To take a chunk. from the vertical face of a test pit or trench, as shown in figure 15-10, smooth the surface of the face and mark the chunk outline. Then excavate the soil from the top, sides, and back of the chunk. After shaping the chunk with a knife, cut it off and carefully remove it.

After removing the chunk sample from the hole, you need to seal it. One method is to apply three coats of melted paraffin, as shown in figure 15-11. Each coat is allowed to cool and become firm before the next coat is applied. This gives adequate protection for strong samples that will be used within a few days. When the samples are weak or may not be used within a few days, wrap them with cheesecloth or other soft cloth and seal them with paraffin (fig. 15-12). If cloth is not available, you can reinforce the sample with several loops of friction tape or twine. Then apply three coats of paraffin. Take extra precaution in these operations so that the sample is not damaged.

Another method is to dip the entire sample in melted paraffin after the first brush coat is applied and the sample is wrapped (fig. 15-13). This requires a larger container and more paraffin. However; this method provides a more uniform coating that, by repeated dippings, can be built up to 1/8 in. or more in thickness.

When samples are to shipped, as from a construction battalion's remote detail site to the battalion's main body site, additional protection is required. This can be accomplished by applying many coats of paraffin or by placing the chunk in a small



NOTE: EXCAVATION SHOWN WITHOUT VERTICAL SHORING FOR CLARITY.

Figure 15-10.-Taking a chunk sample from a vertical face.

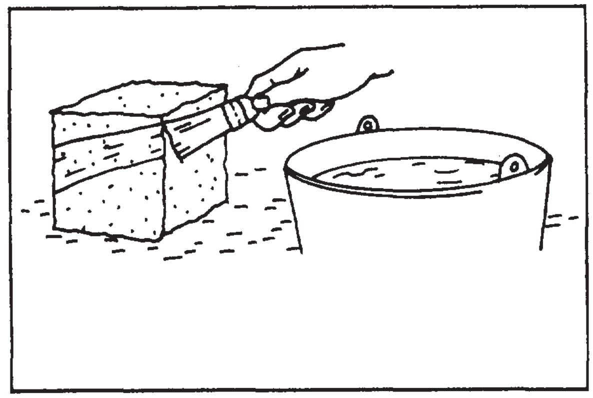


Figure 15-11.-Applying paraffin to seal a chunk sample.

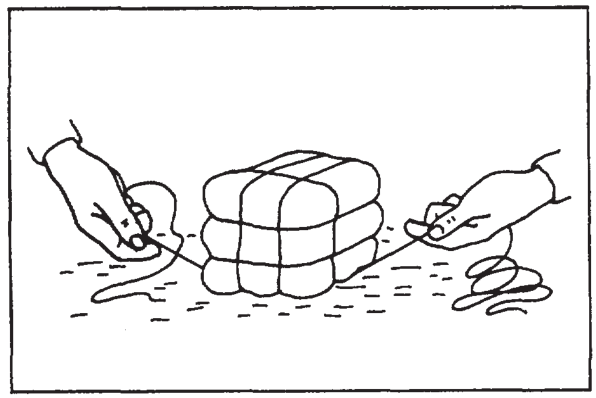


Figure 15-12.-Wrapping a weak chunk sample before final sealing.

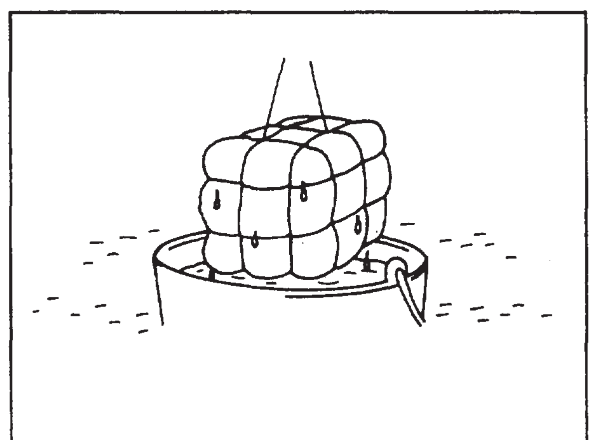


Figure 15-13.-Dipping a chunk sample into melted paraffin.

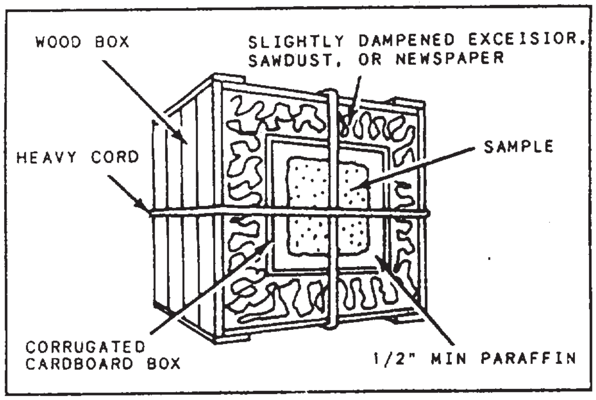


Figure 15-14.-Packing a chunk sample for transportation or shipment to laboratory.

box and packing it, as shown in figure 15-14.

Cylinder Samples by CBR Mold

Figures 15-15 through 15-19 show a CBR compaction mold, fitted with a sampling collar (or cutter), and how to obtain a cylinder sample by using the CBR mold. This method may be used in taking an undisturbed sample from soft, fine-grained soils for undisturbed CBR or density tests.

When using this method, first smooth the ground surface and then press the sampling collar and mold into the soil with moderate

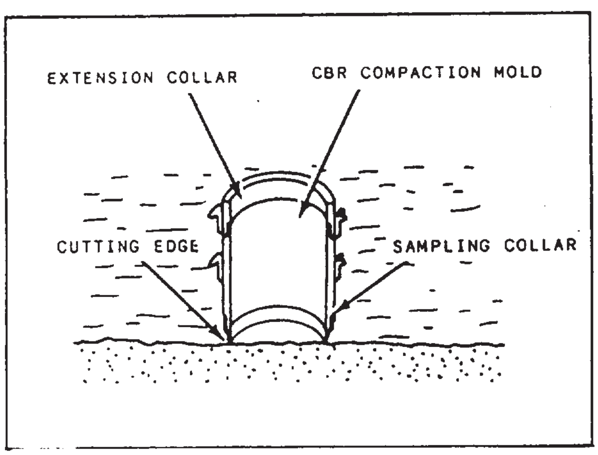


Figure 15-15.-Section through a CBR mold.

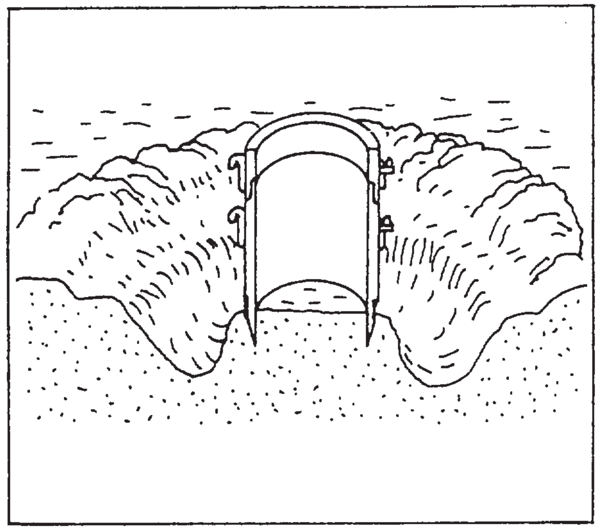


Figure 15-16.-Trench cut around a cylinder.

pressure. Then excavate a trench around the cylinder and again press the mold down over the soil, using the hand driver or loading bar if necessary. You can improvise a loading bar from any suitably sized piece of timber. Trim the soil away from the sampling collar carefully with a knife, cutting downward and outward to avoid cutting into the

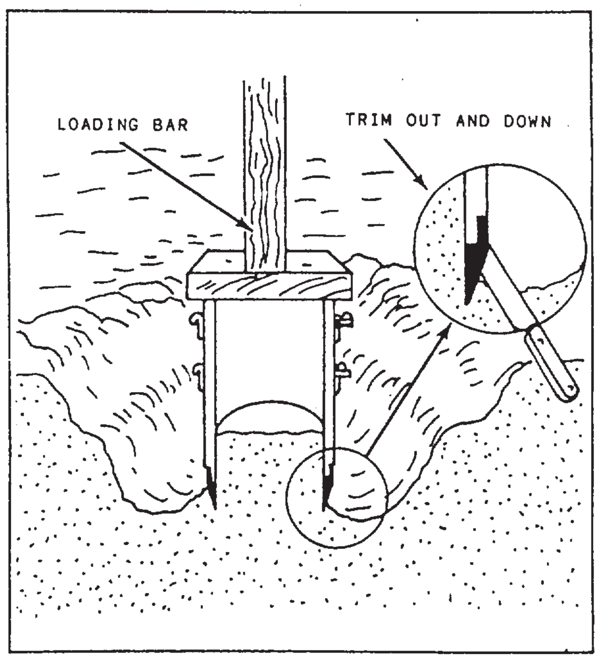


Figure 15-17.-Using a loading bar to drive a cylinder.

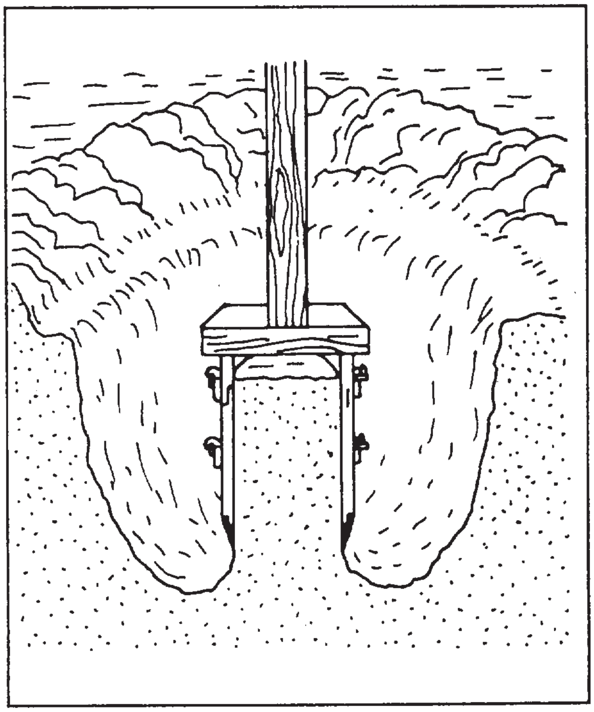


Figure 15-18.-Cylinder in position before cutting a sample.

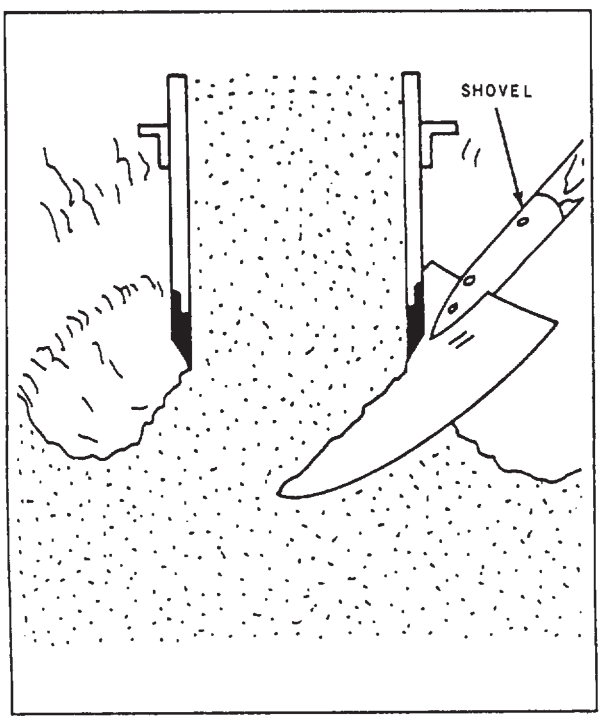


Figure 15-19.-Cutting off a cylindrical sample.

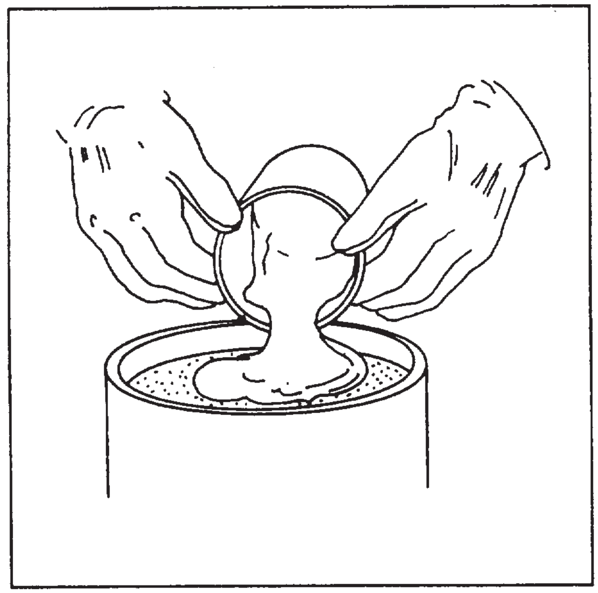


Figure 15-20.-Sealing a sample in a CBR mold.

sample. You actually do the cutting to size with the sampling collar. You can force the sampler down with the field CBR jack; however, since this jack has only about 2 in. of travel, you would do better to use a truck jack, if available. In either case, you should not force the sampler down ahead of the trimming on the outside of the cylinder. Then excavate the trench deeper and repeat the process until the soil penetrates well into the extension collar. Finally, as shown in figure 15-19, cut off the sample at the bottom of the mold with a shovel, knife, or wire, and remove the mold and sample from the hole.

After removing the mold and sample from the hole, remove the upper collar of the mold, and trim the top surface of the sample down to approximately 1/2 in. from the top of the mold. Then fill this recess with paraffin, as shown in figure 15-20, to seal the end of the sample. Then, after you turn the mold over and remove the cutting edge, a similar recess is formed in the bottom of the sample. Fill this recess with paraffin also. If the sample is to be handled a great deal, you should overfill the ends with paraffin and then trim them exactly flush, using a straightedge. Place boards over both ends and clamp them in place, using bolts, string, or wire, as

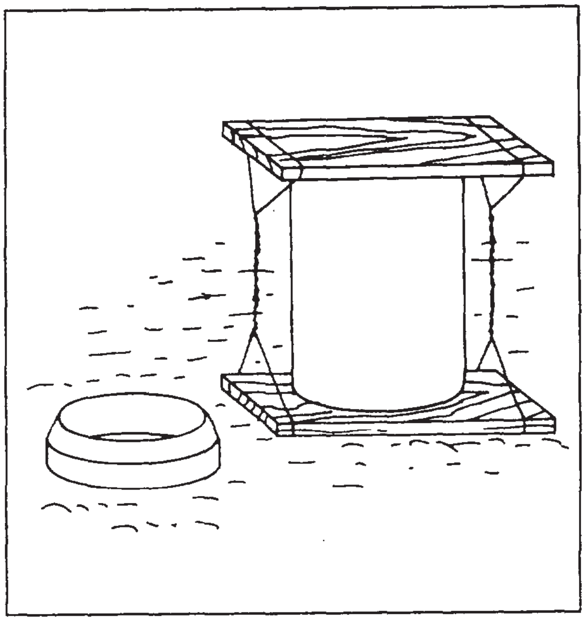


Figure 15-21.-Potecting a sample in a CBR mold.

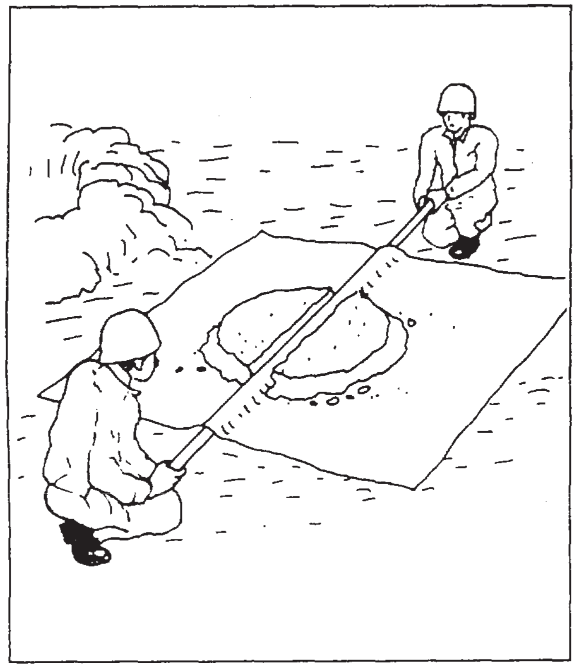


Figure 15-22.-Halving the sample.

shown in figure 15-21. If the samples are to be transported some distance or will be handled quite a bit before testing, you should wrap them in cloth and soak them in paraffin layers.

QUARTERING SAMPLES

The process of reducing a representative soil sample to a convenient size or of dividing a sample into two or more smaller samples for testing is called QUARTERING. The procedures vary somewhat, depending upon the size of the sample.

Samples Weighing Over 100 Pounds

To quarter a sample of this size, first mix and pile the sample on a canvas, using a shovel. Place each new shovelful on the top-center of the preceding one so that the soil will be distributed evenly in all directions. Then flatten the sample to a circular layer of approximately uniform thickness. Next, insert a stick or length of pipe under the canvas and then lift it at both ends to divide the sample into two equal parts, as shown in figure 15-22. Remove the stick, leaving a fold in the canvas, and then reinsert it under the sample, but this time, at right angles to the first division. Again, lift the stick. This divides the sample into four parts, as shown in figure 15-23. Discard two diagonally opposite quarters, taking care to clean the fines from the canvas. Then remix the remaining material, taking alternate shovelful from each quarter. Repeat the quartering process as necessary to reduce the sample to the desired size.

Samples Weighing Between 25 and 100 Pounds

In quartering a sample of this size, pile the soil on the canvas and mix it by alternately lifting the

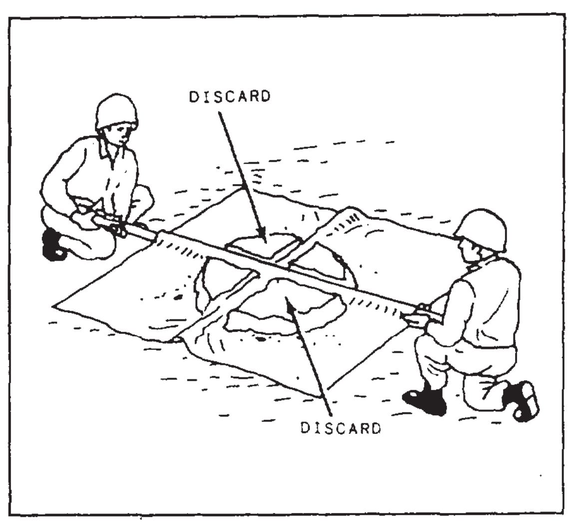


Figure 15-23.-Quartering the sample.

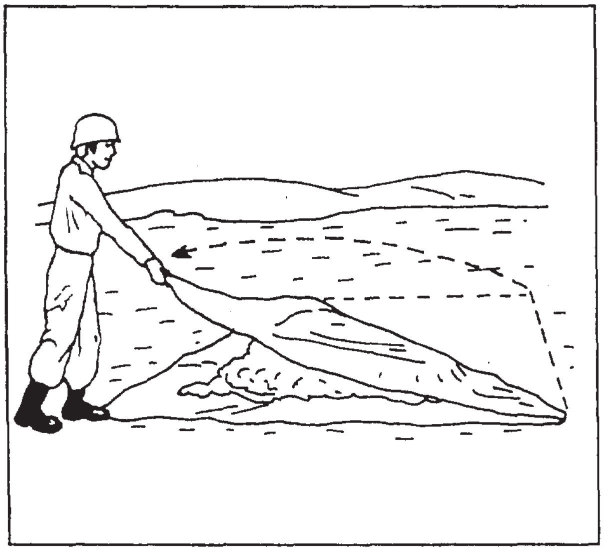


Figure 15-24.-Mixing a sample weighing 25 to 100 pounds.

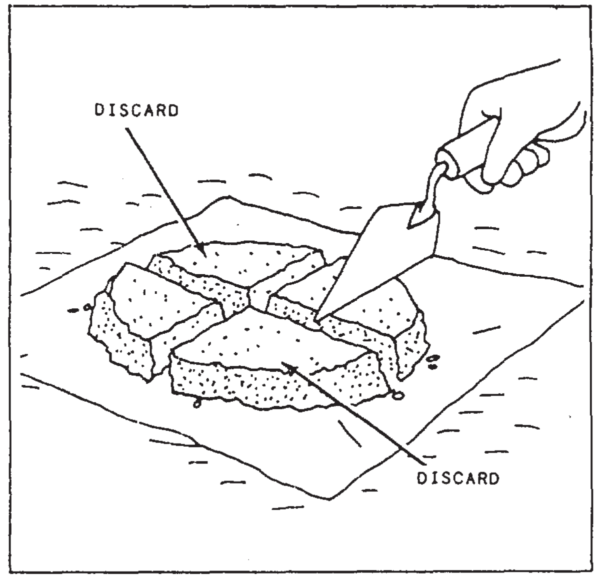


Figure 15-25.-Quartering a small sample.

corners of the canvas and pulling over the samples as if preparing to fold the canvas diagonally, as shown in figure 15-24. Then flatten and quarter the sample.

Samples Weighing Less Than 25 Pounds

For samples of this size, place the sample on the canvas or a clean sheet of paper. Mix it thoroughly with a trowel, form it into a conical shape, and then flatten it with the trowel. Using the trowel, divide the sample into quarters, and discard two diagonally opposite quarters, as shown in figure 15-25. Remix the remaining material, and repeat the process until the sample is the size needed for the test.

SOIL TESTING

In soil testing, the Navy follows procedures laid down by the American Society for Testing Materials (ASTM). Generally speaking, a complete soil test proceeds according to the following steps:

1. Determine the moisture content of representative samples. (This is preceded, of course, by the extraction of representative samples.)
2. Perform a mechanical analysis of the sample to determine the sizes of soil particles (or grains) and the distribution of sizes; this means the percentage of each size contained in the whole mass.
3. Determine the specific gravity of representative samples. The specific gravity of a substance is expressed in terms of the ratio of the weight of a given volume of the substance to the weight of an equal volume of water. A cubic foot of water weighs 62.43 lb.

For soil, determine the absolute specific gravity; by this we mean determine the ratio of the weight of a dense volume (volume exclusive of air spaces) to the weight of an equal volume of water. A cubic foot of dry sand, for example, weighs about 100 lb. With air exhausted, however, a cubic foot of sand weighs about 165.44 lb. Therefore, the specific gravity of sand equals 165.44 divided by 62.43, or about 2.65.

4. If the soil is clay or a similar fine-grained soil, determine the Atterberg limits. Over a certain range of moisture content, a fine-grained soil remains plastic. A reduction below the bottom of the range causes the soil to become semisolid; an increase above the range causes it to become fluid. The upper moisture content is called the liquid limit; the lower is called the plastic limit.
5. Compaction testing is used to determine the moisture-density relationships; or, in other words, to determine what moisture content results in maximum compaction for a given compactive

effort. Compaction testing is not included in this TRAMAN but will be discussed at the EA2 level.

6. Field control testing is used to determine (1) the field moisture content (with an eye to reducing or increasing it to the optimum, if feasible) and (2) the point at which the specified density has been obtained by compaction. Field control testing is not included in this TRAMAN but will be discussed at the EA2 level.

DETERMINING MOISTURE CONTENT

Several methods of determining moisture content of soil are in existence. The most accurate is the ovendrying method, in which an electric or portable gasoline oven is used to dry the samples. A more expedient method is the calcium carbide gas pressure method. This method, however, is less accurate and should always be approved by your supervisor. A third method uses the NUCLEAR MOISTURE-DENSITY METER. Since specialized training and operator certification are required, use of the nuclear moisture-density meter will not be discussed in this training manual.

Ovendrying Method

As noted above, this is the most accurate method used to determine moisture content. The apparatus and procedures used are discussed below.

APPARATUS.— Laboratory apparatus for moisture content determination includes the following items:

- A balance (fig. 15-26) for weighing material in grams. There are 453.6 g in a pound.
- Several small circular moisture boxes (called cans) (fig. 15-26) for placing samples in to weigh and dry.
- An electric oven or a portable gasoline oven to dry samples.
- Crucible tongs.

In the absence of an electric oven or gasoline oven, you may dry the materials in a frying pan held over an ordinary stove or hot plate. The

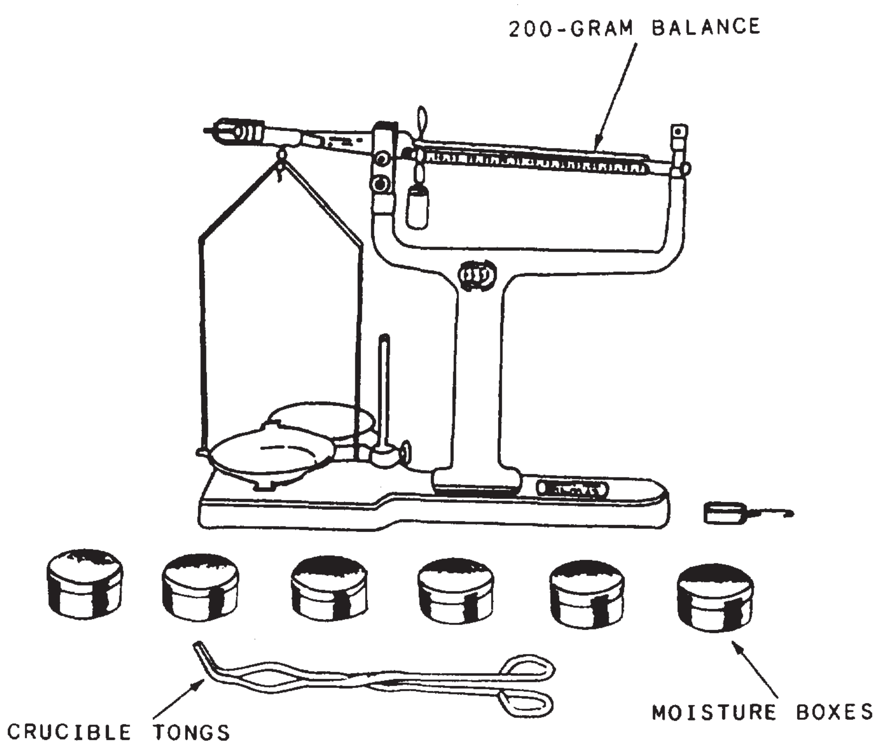


Figure 15-26.-Apparatus for determining moisture content.

disadvantage here is that the temperature is hard to control and the organic material in the sample may be burned; this would cause a slight to moderate inaccuracy in the result. The thermostat on an electric oven can be set to the desired temperature.

PROCEDURE.— Before beginning the tests, weigh each of the moisture boxes and record the weight by can number. Record this weight as tare weight (weight that allows for a deduction of the can). Then fill each can with a sample and weigh the can (with lid on) and contents.

Remove the lid and place the can, contents, and lid in the oven or pan to dry. In an electric oven, maintain the temperature between 212°F and 230°F (105°C ± 10°C); dry the sample for at least 8 hr—even longer for clay or silt. Then weigh the dry can, contents, and lid.

Record the results on a form like the one shown in figure 15-27. In the example shown in

SOIL MOISTURE CONTENT						DATE 16 June 19 –
PROJECT Faulkner Airbase						
EXCAVATION NUMBER 3	SAMPLE NUMBER FA-P2-1		FORMULA Water Content, $w = \frac{W_w}{W_s} \times 100$			
TEST Natural Soil Moisture Content						UNIT
RUN NUMBER	1	2	3			
TARE NUMBER	5	10	1			
A. WEIGHT OF TARE + WET SOIL	189.3	175.0	223.0			g
B. WEIGHT OF TARE + DRY SOIL	170.0	162.1	204.0			g
C. WEIGHT OF WATER, W_w (A.-B.)	19.3	12.9	19.0			g
D. WEIGHT OF TARE	44.0	42.9	45.2			g
E. WEIGHT OF DRY SOIL, W_s (B.-D.)	126.0	119.2	158.8			g
WATER CONTENT, w	15.3 %	10.8 %	12.0 %	%	%	
TEST						UNIT
RUN NUMBER						
TARE NUMBER						
A. WEIGHT OF TARE + WET SOIL						
B. WEIGHT OF TARE + DRY SOIL						
C. WEIGHT OF WATER, W_w (A.-B.)						
D. WEIGHT OF TARE						
E. WEIGHT OF DRY SOIL, W_s (B.-D.)						
WATER CONTENT, w	%	%	%	%	%	
TEST						UNIT
RUN NUMBER						
TARE NUMBER						
A. WEIGHT OF TARE + WET SOIL						
B. WEIGHT OF TARE + DRY SOIL						
C. WEIGHT OF WATER, W_w (A.-B.)						
D. WEIGHT OF TARE						
E. WEIGHT OF DRY SOIL, W_s (B.-D.)						
WATER CONTENT, w	%	%	%	%	%	
REMARKS						
TECHNICIAN (Signature) James Perry		COMPUTED BY (Signature) James Perry		CHECKED BY (Signature) Thomas Connors		

Figure 15-27.-Data sheet for moisture content tests.

figure 15-27, three tests (called runs) were made, using cans numbered 5, 10, and 1. Online D (weight of tare), record the weight of each can. Note that although the cans are identical in appearance, they vary slightly in weight. Online A (weight of tare and wet soil), record the weight of each can with wet contents. On line B (weight of tare and dry soil), record the weight of each can with contents after drying.

Online C, Ww (weight of water in the soil sample) was obtained by subtracting (B) from (A). On line E, Ws (weight of dry soil) was obtained by subtracting (D) from (B).

The line labeled "water content, w," shows the results obtained by substituting the known values in the following formula:

$$w = \frac{Ww}{Ws} \times 100$$

The average of these three values, or 12.7 percent, is the value of w (percentage of moisture content) for the sample.

Calcium Carbide Gas Pressure Method

This method uses a 26-g SPEEDY MOISTURE TESTER to determine the moisture content of soils, fine aggregates, sand, and clay. By using the SPEEDY tester, the moisture content can be determined in the laboratory or field in from 45 sec to 3 rein, depending upon the material being tested. The tester operates on the principle of a calcium carbide reagent (reactive agent) being introduced into the free moisture of the soil sample. The resulting chemical reaction creates a gas that is contained in a sealed chamber, the pressure of which can be measured with the built-in gas pressure gauge.

APPARATUS.— The SPEEDY moisture test set (fig. 15-28) includes the SPEEDY tester, a balance, half-weight reagent, measuring scoop, brushes, cleaning cloth, and two 1 1/4-in. steel balls.

PROCEDURE.— The procedure for determining moisture content using the SPEEDY MOISTURE TESTER is as follows:

1. Weigh a 26-g sample of soil.

2. Place the soil sample and two 1 1/4-in. steel balls in the large chamber.

FIGURE REMOVED
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for electronic media.

Figure 15-28.—SPEEDY moisture test set.

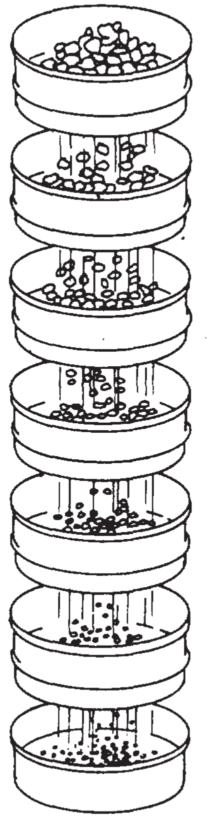


Figure 15-29.-Varying sieve sizes.

3. Place three scoops (24 g) of reagent in the cap. Then, with the pressure vessel in a horizontal position, insert the cap into the pressure vessel and tighten the clamp to seal the cap to the unit.

4. Raise the moisture tester to a vertical position so that the reagent falls into the vessel.

5. Hold the moisture tester horizontally; vigorously shake the device with a rotating motion for 10 sec to put the steel balls into orbit around the inside circumference; then rest for 20 sec. Repeat the shake-rest cycle for a total of 3 min. Do not allow the steel balls to fall against either the cap or orifice leading to the dial; this may cause damage.

6. Holding the tester horizontally at eye level, read and record the dial reading as the percent of moisture by wet mass.

7. When the sample is dumped, examine it for lumps. If the soil sample is not completely broken down, increase the time limit (shaking unit) by 1 min on the next test.

8. To determine the percentage of moisture by dry mass (ovendry moisture percentage), read the direct reading obtained in No. 6 above into a calibration curve that is also supplied with the test set.

MECHANICAL ANALYSIS

Mechanical analysis is the determination of grain sizes and the percentage distribution of each size. A complete mechanical analysis is accomplished in two parts: sieve analysis and hydrometer analysis.

Sieve Analysis

A sieve analysis is applicable to soils that are larger than the No. 200 sieve or that contain small amounts of material passing the No. 200 sieve. You can conduct the sieve analysis either on the entire sample or on the sample after the fines are removed by prewashing. The apparatus and procedures used to conduct a sieve analysis are described below.

APPARATUS.— Typical sieve analysis apparatus includes a gram weighing balance and a number of sieves with apertures of varying sizes used to determine grain sizes (fig. 15-29). Sieves may be of the ordinary circular SIFTER type (usually about 8 in. in diameter) or the ROCKER type, which consists of a rocker frame in which screens with apertures of various sizes can be placed.

The sieve used for analysis is the so-called standard sieve. A standard sieve has a square aperture. Screen sizes are designated as follows: A sieve with fewer than four apertures to the linear inch is designated by the size of an aperture; for example, a 1/4-in., 1/2-in., 3/4-in., or 1-in. sieve.

A sieve with four or more apertures to the linear inch is designated by a number that represents the number of apertures to the linear inch. A No, 4 sieve, for example, has four apertures to the linear inch, a No. 6 has six apertures, and so on. The finest sieve used is a No. 200, with 200 apertures to the linear inch and an aperture size slightly smaller than one two-hundredth of an inch square.

To conduct a sieve analysis, you need an electric or hand-operated sieve shaker.

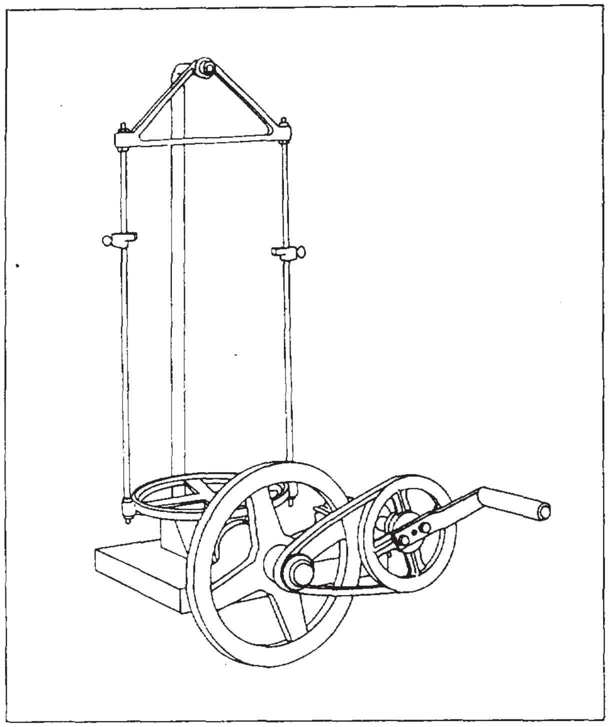


Figure 15-30.-Hand-operated sieve shaker.

The hand-operated shaker is shown in figure 15-30.

SIEVE ANALYSIS, DRY.— The minimum sample weight required for a sieve analysis is dependent upon the maximum particle size in the sample as follows:

Maximum particle size (sieve opening)	Minimum dry weight of test specimen
3 in.	6,000 g
1 1/2 in.	3,000 g
3/4 in.	1,500 g
3/8 in.	600 g
No. 4	200 g

Samples that contain cohesive soil, which forms hard lumps, must be prewashed. This procedure is described later. Other samples are analyzed DRY by the following procedure:

1. Oven-dry the sample.
2. Break up lumps. For coarse material, use a rolling pin on a clean, hard, smooth surface. For fine material, use a mortar and pestle (usually a part of the laboratory apparatus). Take care not to crush individual grains. The object is to separate aggregations of clustering grains.
3. Weigh the sample.
4. Select and weigh the sieves and pan to be used in the test. The sieve selection varies according to the type of soil being tested. The following is a selection commonly used:

3 in. (76.2 mm)	No. 10 (2.00 mm)
1 1/2 in. (38.1 mm)	No. 20 (1.21 mm)
1/2 in. (12.7 mm)	No. 40 (0.42) mm
3/8 in. (9.52 mm)	No. 100 (0.149 mm)
No. 4 (4.76 mm)	No. 200 (0.074 mm)

Stack (nest) the sieves one on top of the other such that the largest sieve is on top. The coarsest sieve actually recorded is the next above the first one that retains any material. The weight recorded as retained on this sieve is 0 g; the weight recorded as passing it is the total weight of the sample.

5. Place the sieve pan under the stack of sieves; place the total sample in the top sieve and shake. The shaking interval depends on the amount of fine material. Five minutes is usually enough for most coarse-grained soils, and 15 min is enough for most fine-grained soils.
6. Remove the sieves from the shaker. Starting with the first to retain any material, carefully weigh each sieve with the retained material. Subtract the weight of the sieve from the combined weight of the sieve and material to determine the weight of the material retained on each sieve. Finally, determine the weight of the material that reached the pan; that is, that passed the No. 200, or finest, sieve.

Enter the results on a data sheet like the one shown in figure 15-31. In this analysis, all the material (359. 1 g) passed the 3/8-in. sieve; none was retained on this one. The No. 4 retained 51.0 g. This means that 308.1 g (359.1 – 51.0) passed this sieve. You can see how the weight passing was determined from the weight retained in each subsequent case. In column d, the percent passing is computed for each sieve by multiplying the weight passing by 100 and dividing the result by the total weight of the sample.

SIEVE ANALYSIS DATA

DATE: 11 July 19—

PROJECT: Fraunce Theater

EXCAVATION NUMBER: 2

SAMPLE NUMBER: FT-P1-1

DESCRIPTION OF SAMPLE: 25 lb. bag sample

PREWASHED: ☐ YES ☒ NO

WEIGHT ORIGINAL SAMPLE (g): 359.1

WEIGHT AFTER PREWASHING[1] (g):

WASHING LOSS[1] (g):

SIEVE OR SCREEN a	WEIGHT RETAINED ON SIEVE (g) b	PASSING SIEVE WEIGHT (g) c	PASSING SIEVE PERCENT d
*	0		100
3/4			
1/2			
3/8		359.1	100.0
No. 4	51.0	308.1	85.8
10	40.9	267.2	74.4
20	83.3	183.9	51.2
40	75.4	108.5	30.2
100	49.9	58.6	16.3
NUMBER 200	47.4	11.2	3.1

A. WEIGHT SIEVED THROUGH NO. 200 (g): 11.1

B. WASHING LOSS[1] (g):

TOTAL PASSING NO. 200 (g) (A + B.) C.: 11.1

TOTAL WEIGHT OF FRACTIONS (Total of all entries in Col. b + c): 359.0

ERROR (Original weight - total weight of fractions)(g): 359.1 - 359.0 = 0.1

PERCENT ERROR: $(\frac{\text{Error (g)}}{\text{Original weight (g)}} \times 100) = .028\%$

REMARKS

TECHNICIAN (Signature): Paul Massin

COMPUTED BY (Signature): Paul Massin

CHECKED BY (Signature): John Stark

[1] For prewashed samples only. *Maximum particle size.

Figure 15-31.-Data sheet for dry sieve analysis.

The total weight of fractions plus the weight of the material that reached the pan comes to 359.0 g. The weight of the sample originally was 359.1 g; there is an error here of 0.1 g. At the lower right, you can see how the percentage of error is computed. The maximum permissible percentage of error is normally (±) 1 percent. If the percentage exceeds the maximum, the test must be rerun. For an error smaller than the maximum permissible, correction is made by adding the value of the error to the largest amount listed as retained. The value of the error in this case is 0.1 g. The largest amount retained is 83.3 g for the No. 20 sieve. This amount would be changed to 83.4 g.

SIEVE ANALYSIS WITH PREWASHING.— When inspection indicates that a sample contains an excessively high portion of superfine material (material that passes the No. 200 sieve), analysis with prewashing is done as follows:

1. Oven-dry the sample.
2. Weigh and record the total weight after cooling.
3. Place the sample in a clean pan and add clean water until it is completely covered. Allow it to soak until it is completely disintegrated—from 2 to 12 hr. Stir to break up lumps and hasten the action.
4. Wash the material thoroughly on a No. 200 sieve under running water and discard the material that passes.
5. Oven-dry and reweigh. Record the difference between this weight and the original weight as washing loss.
6. Continue as for sieve analysis, dry.

Figure 15-32 shows a data sheet for sieve analysis with prewashing. The ovendry weight of the original sample was 75.0 g; the ovendry weight after prewashing was 55.0 g; therefore, the washing loss was 75.0 -55.0 or 20.0 g. The sum of the weights retained (53.0 g, the total of column b) plus the 2.0 g that, in spite of prewashing, was still left in the sample to pass the No. 200 sieve, equals 55.0 g. This was the original weight after prewashing. Therefore, no error was made.

Hydrometer Analysis

As you learned in the preceding discussion, the determination of grain size distribution by sieve analysis is limited to those materials larger than the No. 200 (0.074-mm) sieve. For uses such as soil classification, this is sufficient since grain size distribution is not used to classify fine-grained soils. For determination of frost susceptibility, however, the distribution of particles smaller than the No. 200 sieve is necessary. A soil is considered frost susceptible if it contains 3 percent or more by weight of particles smaller than 0.020 mm in diameter. Frost susceptibility should always be considered in areas subject to substantially freezing temperatures, since repeated freezing, and subsequent thawing, of water in the soil can seriously affect the ability of the soil to support a structure. Hydrometer analysis is the test used to determine the grain size distribution of the soils passing the No. 200 sieve.

Hydrometer analysis is based on Stokes' law, which relates the terminal velocity of a free-falling sphere in a liquid to its diameter. The relation is expressed by the following equation.

$$V = \frac{G_s - G_w}{18n} D^2$$

Where:

V = terminal velocity
G_s = specific gravity of solids
G_w = specific gravity of the liquid in which the sphere is falling
n = viscosity of the liquid
D = diameter of the sphere

It is assumed that Stokes' law can be applied to a mass of dispersed soil particles of various shapes and sizes. Larger particles settle more rapidly than the smaller ones. The hydrometer analysis is an application of Stokes' law that permits the calculation of the grain size distribution in silts and clays, where the soil particles are given the sizes of equivalent spherical particles.

The density of a soil-water suspension depends upon the concentration and specific gravity of the soil particles. If the suspension is allowed to stand, the particles will gradually settle out of the suspension, and the density will be decreased. The hydrometer is the instrument used to measure the density of the suspension at a known depth below the surface. The density measurement, together with knowledge of specific gravity of the soil particles, determines the percentage of dispersed soil particles in suspension at the time and depth of measurement. Stokes' law is used to calculate the maximum equivalent particle diameter for the material in suspension at this depth and for the elapsed time of settlement. A series of density measurements at known depth of suspension and at known times of settlement gives the percentages of particles finer than the diameters given by Stokes' law. Thus the series of readings will reflect the amount of different sizes of particles in the fine-grained soils. The particle diameter (D) is

SIEVE ANALYSIS DATA			DATE 11 July 19—
PROJECT Fraunce Theater		EXCAVATION NUMBER 2	SAMPLE NUMBER FT-P2-1
DESCRIPTION OF SAMPLE 25 lb bag sample			PREWASHED ☒ YES ☐ NO
WEIGHT ORIGINAL SAMPLE (g) 75.0	WEIGHT AFTER PREWASHING[1] (g) 55.0	WASHING LOSS[1] (g) 20.0	

SIEVE OR SCREEN a	WEIGHT RETAINED ON SIEVE (g) b	PASSING SIEVE WEIGHT (g) c	PASSING SIEVE PERCENT d
*	0		100
No. 10		75.0	100.0
20	8.7	66.3	88.4
40	29.0	37.3	49.8
100	13.3	24.0	31.1
NUMBER 200	2.0	22.0	29.4

A. WEIGHT SIEVED THROUGH NO. 200 (g) 2.0	ERROR (Original weight - total weight of fractions)(g) none
B. WASHING LOSS[1] (g) 20.0	
TOTAL PASSING NO. 200 (g.) (A. + B.) c 22.0	PERCENT ERROR ($\frac{\text{Error (g)}}{\text{Original weight (g)}} \times 100$) none
TOTAL WEIGHT OF FRACTIONS (Total of all entries in Col. b + c) 75.0	

REMARKS

TECHNICIAN (Signature)	COMPUTED BY (Signature)	CHECKED BY (Signature)
Paul Masin	Paul Masin	John Stark

[1]For prewashed samples only. *Maximum particle size.

Figure 15-32.-Data sheet for sieve analysis with prewashing.

calculated from Stoke's equation using corrected hydrometer reading and a nomographic chart.

The procedures used to perform the hydrometer analysis are not discussed in this TRAMAN but are contained in ASTM D 422.

SPECIFIC GRAVITY TESTING

The specific gravity of a solid substance is the ratio of the weight of the solid to the weight of an equal volume of water. In dealing with soils, the specific gravity is necessary for certain tests, such as hydrometer analysis. It is also necessary for computations involving volume and weight relationships. The specific gravity of a soil mass can be expressed in one of three different forms as follows:

SPECIFIC GRAVITY OF SOLIDS (G_s) is the ratio of the weight in air of a given volume of soil particles to the weight of an equal volume of distilled water, both at a stated temperature. The specific gravity of solids is only applied to that fraction of a soil that passes a No. 4 sieve.

APPARENT SPECIFIC GRAVITY (G_a) is the ratio of the weight in air of a given volume of the impermeable portion of soil particles to the weight in air of an equal volume of distilled water, both at a stated temperature. The impermeable portion of a porous material, such as most large soil grains, includes the solid material plus impermeable pores or voids within the particles.

BULK SPECIFIC GRAVITY (G_m) is the ratio of the weight in air of a given volume of permeable material (including permeable and impermeable voids) to the weight of an equal volume of distilled water at a stated temperature.

Sample Selection

For specific gravity tests, the soil samples may be either disturbed or undisturbed. Care must be taken, however, to ensure that representative samples are obtained. When the sample contains both large and small particles, the sample should be separated on a No. 4 sieve. Then the specific gravity of the fine fraction is determined separately from the coarse fraction. A composite specific gravity for the entire soil sample is then calculated in the manner to be described later.

For samples smaller than the No. 4 sieve, it is easier to begin the test with an ovendried sample. However, some soils, particularly those with high organic content, should be tested at their natural water content; the ovendried weight determined at the end of the test.

Specific Gravity of Solids

As discussed earlier, the specific gravity of solids is applied to soil that passes a No. 4 sieve. However, when the specific gravity is to be used in conjunction with hydrometer analysis, it is determined only on the fraction that passes a No. 200 sieve. In either case, the specific gravity may be determined for soil at natural water content or ovendried.

APPARATUS.— A 500-milliliter (ml) volumetric flask is required for this test. For the discussion in this TRAMAN, it is assumed that the flask has been calibrated. This means that the weight of the flask and water has been calibrated over a range of temperatures that would likely be encountered in the laboratory. As a matter of interest, calibration procedures are located in ASTM D 854. Some other apparatus used to perform test are as follows:

Balance, 2,000-g capacity
Balance, 200-g capacity
Cans, moisture content
Dishes, evaporating
Funnel
Mortar and pestle
Pump, vacuum (optional)
Stirrer, soil dispersion (optional)
Thermometer, general laboratory

PROCEDURE.— AS mentioned previously, you can perform the specific gravity test on soils at natural water content. When possible, however, you should first oven-dry the sample, as this makes it easier to perform the test. The procedure for performing the specific gravity test is as follows:

1. Record all identifying information regarding the sample on a data sheet similar to figure 15-33. Also, record identifying information for the flask and dish (or moisture can) that will be used for the test.
2. Air-or oven-dry the sample and breakup all lumps with a mortar and pestle. About 50 g of clay and about 100 g of coarser samples are the usual quantities.
3. Weigh and record the tare weight of a moisture can. Then fill the can with the dry sample; oven-dry and determine the weight to the nearest 0.01 g. This weight minus the tare weight is the weight of the dry soil (W_s) entered in block 6g of figure 15-33. This weight is critical to the accuracy of the test. **YOU MUST TAKE GREAT CARE NOT TO LOSE ANY OF THE MATERIAL DURING THE REMAINDER OF THE TEST.**
4. Transfer the material to the volumetric flask, using a funnel. Use a battery filler, or syringe, to CAREFULLY wash ALL material from the can and funnel into the flask.
5. Fill the flask two-thirds full of clean water (for exact analysis use distilled or demineralized water). Allow the material to soak from 4 to 6 hr, except for clean, sandy soil, which does not require soaking.

SPECIFIC GRAVITY TESTS

SPECIFIC GRAVITY TESTS			1. DATE 10 JAN 1991	
2. PROJECT PARKING APRON EXPANSION		3. BORING NUMBER TEST PIT	4. JOB NUMBER	5. EXCAVATION NUMBER

6.	SPECIFIC GRAVITY OF SOLIDS (G_s)				
a.	SAMPLE OR SPECIMEN NUMBER		TP-1		
b.	FLASK NUMBER		1		
c.	TEMPERATURE OF WATER AND SOIL (T, °C)		28.5		
d.	DISH NUMBER		3		
WEIGHT IN GRAMS e.	DISH + DRY SOIL		123.0		
f.	DISH		41.0		
g.	DRY SOIL	W_s	82.0		
h.	FLASK + WATER AT T, °C)	W_{bw}	637.85		
i.	$W_s + W_{bw}$		719.85		
j.	FLASK + WATER + IMMERSED SOIL	W_{bws}	690.5		
k.	DISPLACED WATER, $W_s + W_{bw} - W_{bws}$		29.35		
l.	CORRECTION FACTOR	K	0.9979		
m.	$(W_sK) \div (W_s + W_{bw} - W_{bws})$	G_s	2.79		

7.	APPARENT (G_a) AND BULK (G_m) SPECIFIC GRAVITY				
a.	SAMPLE OR SPECIMEN NUMBER		TP-1		
b.	TEMPERATURE OF WATER AND SOIL (T, °C)		25.0		
c.	TARE + SATURATED SURFACE-DRY SOIL		1200.0		
WEIGHT IN GRAMS d.	TARE		225.0		
e.	SATURATED SURFACE-DRY SOIL	B	945.0		
f.	(WIRE BASKET + SOIL) IN WATER		1994.0		
g.	WIRE BASKET IN WATER		1420.0		
h.	SATURATED SOIL IN WATER	C	574.0		
i.	TARE AND DRY SOIL		1149.0		
j.	TARE		230.0		
k.	DRY SOIL	A	919.0		
l.	CORRECTION FACTOR	K	0.9988		
m.	(AK) ÷ (A - C) (APPARENT)	G_a	2.66		
n.	(AK) ÷ (B - C) (BULK)	G_m	2.47		

8. REMARKS

RETAINED No. 4 - 60%
PASSED No. 4 - 40%

COMPOSITE G = 2.71

9 TECHNICIAN (Signature)	10. COMPUTED BY (Signature)	11. CHECKED BY (Signature)
[signature]	ED SHERMAN	[signature]

DD Form 1208, DEC 86 *Previous editions are obsolete.*

Figure 15-33.-Data sheet for specific gravity test.

6. Attach a vacuum pump to the flask and exhaust all air. The exhausted air is indicated by rising bubbles. For most soils, 30 min of pumping is enough. A heavy clay, however, may require as much as 2 hr of pumping. As an alternative to the vacuum pump, the air may be exhausted by gently boiling the suspension for at least 10 min. To aid in the removal of entrapped air, occasionally roll the flask. A slow boil should be used, as fast

Table 15-3.-Relative Density of Water and Correction Factor (K) at Various Temperatures

TEMP °C	RELATIVE DENSITY	CORRECTION FACTOR, K	TEMP °C	RELATIVE DENSITY	CORRECTION FACTOR, K	TEMP °C	RELATIVE DENSITY	CORRECTION FACTOR, K
18.0	0.99862	1.0004	23.0	0.99756	0.9993	28.0	0.99626	0.9980
18.5	0.99852	1.0003	23.5	0.99744	0.9992	28.5	0.99611	0.9979
19.0	0.99843	1.0002	24.0	0.99732	0.9991	29.0	0.99597	0.9977
19.5	0.99833	1.0001	24.5	0.99720	0.9990	29.5	0.99582	0.9976
20.0	0.99823	1.0000	25.0	0.99707	0.9988	30.0	0.99567	0.9974
20.5	0.99813	0.9999	25.5	0.99694	0.9987	30.5	0.99552	0.9973
21.0	0.99802	0.9998	26.0	0.99681	0.9986	31.0	0.99537	0.9971
21.5	0.99791	0.9997	26.5	0.99668	0.9984	31.5	0.99521	0.9970
22.0	0.99780	0.9996	27.0	0.99654	0.9983	32.0	0.99505	0.9968
22.5	0.99768	0.9995	27.5	0.99640	0.9982	32.5	0.99490	0.9967

boiling may cause material to be boiled out of the flask.

7. After all air has been exhausted, and the flask and contents have cooled, add more de-aired, distilled water until the flask is filled to the ring marked on the neck. To ensure all air is exhausted, a second boiling may be necessary.

8. Next, dry the outside of the flask and any moisture above the water surface inside the flask.

9. Weigh the flask and contents to the nearest 0.01 g, and record the information in block 6j (fig. 15-33). This is W_{bws}.

10. Immediately after weighing, stir the suspension to assure even temperature distribution. Immerse a thermometer to mid-depth of the flask, and read the temperature of the soil-water suspension. Record this temperature in block 6c (fig. 15-33).

11. Finally, with the data entered on the data sheet, compute the specific gravity using the following formula:

$$G = \frac{W_s K}{W_s + W_{bw} - W_{bws}}$$

where:

W_s = Dry weight of the sample

K = Correction factor based on the density of water at 20°C. You can get this factor from table 15-3 by selecting the correction factor that corresponds to the temperature obtained in Step 10, above.

W_{bw} = Weight of the flask filled with water only, at test temperature. You can get this value from a calibration curve, or table, previously prepared for the flask used in the test.

W_{bws} = Weight of the flask, water, and sample at test temperature

Bulk and Apparent Specific Gravity

The following discussion applies to determination of bulk and apparent specific gravity. Bulk specific gravity is usually determined for the coarser materials that are retained on a No. 4 sieve. Large stones may be determined individually.

SAMPLE PREPARATION.— Separate the sample on a No. 4 sieve, and use the material retained on that sieve for the test. Approximately 2 kg is required. Ensure the sample is a representative sample.

In preparing the sample, first wash the material to remove dust and coatings. Then immerse and soak the sample in water for 24 hr. Just before making the test, dry the sample to-a saturated-surface-dry condition. Do this by rolling the sample in art absorbent cloth to remove excess surface water. You may wipe large particles individually. When saturated-surface-dry, the surface may still appear damp. Take care to avoid excessive evaporation during the surface drying.

APPARATUS.— Apparatus for the test is as follows:

Balance, 5 kg or larger, sensitive to 0.1 g

Wire mesh basket, approximately 8 in. in diameter and 8 in. high; 2-mm (No. 6) or finer mesh

Container, large enough to permit immersing the wire basket

Suitable equipment for suspending the wire basket from the center of balance scale pan

Thermometer, general laboratory

PROCEDURE.— Perform the test in the following steps. You must complete the first step as quickly as possible after surface-drying the sample.

1. Determine the weight of the saturated-surface-dry sample and container. This weight minus the tare weight of the container is the weight of the saturated-surface-dry soil that you should enter in block 7e (fig. 15-33).
2. Determine the weight of the wire basket suspended in water. Record this weight in block 7g (fig. 15-33).
3. Place the sample in the basket and immerse the basket and sample in water. (Hang the basket from the balance and support the container so that the basket hangs freely in the water.) Read the weight and record it in block 7f (fig. 15-33). Subtract the weight of the empty basket suspended in water, Step 2 above, to determine the weight of the saturated soil in water. Record this weight in block 7h (fig. 15-33).
4. Measure and record the temperature of the water and soil. Enter this temperature in block 7b (fig. 15-33).
5. Determine the ovendry weight of the sample and enter the results in block 7k (fig.15-33).
6. From the recorded information, you may now calculate both the bulk specific gravity (G_m) and the apparent specific gravity (G_a) using the following formulas:

$$G_m = \frac{\text{weight of dry soil in air x K}}{\text{weight of satured sample in air} - \text{weight of sample in water}} = \frac{AK}{B-C}$$

and

$$G_a = \frac{\text{weight of dry soil in air x K}}{\text{weight of dry soil in air} - \text{weight of sample in water}} = \frac{AK}{A-C}$$

Specific Gravity of Composite Sample

After determining the specific gravity of solids (G_s) and the apparent specific gravity (G_a), you can calculate the specific gravity of an entire soil sample (both larger and smaller than a No. 4 sieve). To do so, use the following formula:

$$G = \frac{100}{\frac{\text{\% Passing No. 4 Sieve}}{G_s} + \frac{\text{\% Retained No. 4 Sieve}}{G_a}}$$

Enter this composite specific gravity in the remarks block of the data sheet. Note, too, that you should also enter in the remarks block the percent of materials that is retained on, or passes, the No. 4 sieve.

Comment Regarding Correction Factor (K)

Refer again to figure 15-33. In this figure, you see the values of G_s, G_a, and G_m that were obtained using the correction factor (K). Now, if you were to disregard K and recalculate, you would obtain values of the following: G_s = 2.7939, G_a = 2.6638, and G_m = 2.4471. As you can see, these values, obtained without the correction factor, are hardly different than the values obtained with the correction factor. Therefore, unless unusually accurate precision is required, the correction factor may be disregarded.

ATTERBERG LIMITS

As you previously learned, fine-grained soils are not classified under the Unified Soils Classification System on the basis of grain size distribution. They are, instead, classified on the basis of plasticity and compressibility. The Atterberg limits are laboratory classification criteria used for classifying fine-grained soils. As an EA3, you will be responsible for the performance of the Atterberg limits test.

A clay or related fine-grained soil, when dry or nearly dry, has a semisolid consistency. As moisture content increases, a point is reached where the material has a plastic (putty like) consistency. This point is called the PLASTIC LIMIT (PL). As moisture content continues to increase, the material remains plastic over a certain range. However, at a point called the LIQUID LIMIT (LL), the consistency of the material finally changes to semiliquid.

The upper and lower limits of the plastic range (that is, the liquid and plastic limits) are called ATTERBERG LIMITS. These limits were named after a Swedish scientist who developed the concept of the limits. The liquid limit (LL) is simply the moisture content (W_L) at the upper limit of the plastic range, expressed as a percentage. The plastic limit (PL) is the moisture content at the lower limit of the plastic range.

Test Equipment

Figure 15-34 shows equipment for determining the Atterberg limits of a soil sample. The LIQUID LIMIT TESTING DEVICE consists of a brass bowl mounted on a box type of apparatus. When you turn the crank, the apparatus elevates the bowl containing the sample and then drops it downward a specific distance onto the hard-rubber anvil of the testing device. Each of these drops is called a BLOW. We will explain the purpose of the procedure as we describe the test.

TeBst **Procedure**

The liquid and plastic limit tests normally are conducted only on the portion of the soil that passes the No. 40 sieve. A few particles that are large enough to be retained on the No. 40 sieve do not cause serious difficulty. However, it is generally faster to remove these larger particles by hand by kneading the soil between the fingers. If the percentage of particles retained on the No. 40 sieve is higher, these particles must be removed by passing the soil through the No. 40 sieve. Do not oven-dry or subject the sample to any artificial drying before you process or test it.

Soak the sample in water for 24 hr before washing. Then wash it through the No. 40 sieve and collect it in a large evaporating dish or collecting can. Oven-dry the material retained on the sieve, then dry-sieve it through the No. 40 sieve. Combine the portion dry sieved through the No. 40 sieve with the material washed through the sieve; the combined material is used for the tests. Break up soil particles that are lumping together or adhering to aggregate particles and separate them by rubbing them with your hands.

Next, dry the sample to approximately the liquid limit by decanting or blotting the water off, by evaporating it off (taking care to stir the soil frequently during evaporation), or by a combination of both procedures.

After this, place the soil mass in the liquid limit testing device cup, and divide it into sections by a central groove made with the grooving tool (fig. 15-34). The water content at the liquid limit is the water content at which the soil mass makes contact for a distance of 1/2 in. when the cup is dropped 25 times (25 blows) for a distance of 1 cm (0.3937 in.) at a rate of two drops per second. First, adjust the machine for this drop distance as follows:

A metric gauge is located on the handle of the grooving tool. The machine has an ADJUSTMENT PLATE and a pair of ADJUSTMENT

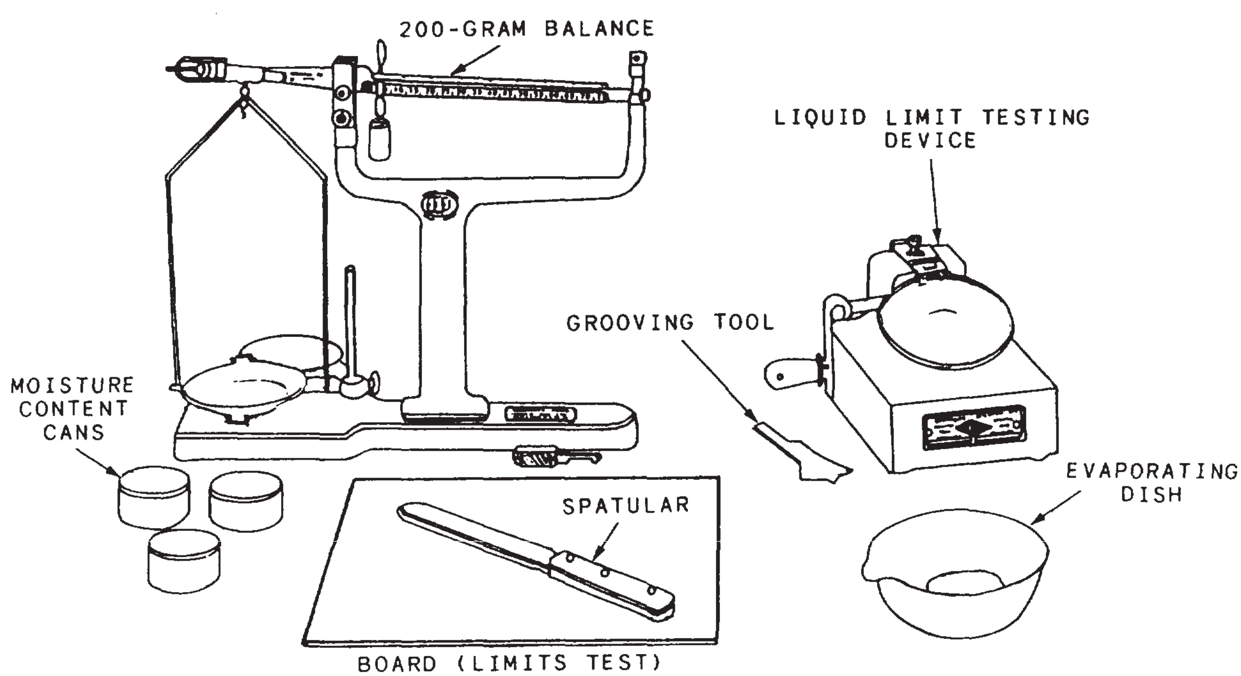


Figure 15-34.-Apparatus for determining Atterberg limits.

SCREWS. Manipulate the screws to adjust the height to which the cup is lifted. The point on the cup that comes into contact with the anvil of the machine should be exactly 1 cm above the anvil (the upper surface of the hard-rubber base of the machine). Check the adjustment by turning the crank at a rate of two drops per second. You should hear a slight click when the adjustment is correct.

Steps in the test procedure are as follows:

1. From the prepared test material, take a sample that weighs about 100 g and place a portion in the cup above the spot where the cup rests on the base. Squeeze the sample and spread it with as few strokes of the spatula as possible, taking care to prevent the air bubbles from getting trapped within the mass. With the spatula, level the soil as you trim it to a depth of 1 cm at the point of maximum depth. Divide the soil in the cup by making a groove with the grooving tool along the center line of the cam follower or hook that holds the cup. When you make the groove, hold the cup in your left hand with the hook upward, and draw the grooving tool, beveled edge forward, through the material downward away from the hook. With some soils (especially sandy soils and soils containing organic matter), it is not possible to draw the grooving tool through the specimen without tearing the sides of the groove. In such cases, make the groove with a spatula, using the tool only for final shaping. When made correctly, the groove is wedge-shaped in section; it is open at the bottom for a distance equal to the width of the tip of the grooving tool.

2. Attach the cup to the carriage and turn the crank at a rate of two revolutions per second. Count the blows as you continue to turn the crank until the two halves of the soil cake come into contact at the bottom of the groove along a distance of about 1/2 in. (fig. 15-35). Record the number of blows required to close the groove in this manner.

After you record the number of blows, remove the cup from the testing device. Remix and regroove the sample. Place the cup again in the testing device and repeat the test. If the number of blows on the second test differs from the number on the first by one or less, record both numbers on the data sheet and consider the test finished. If the number of blows on the second test differs by more than one, repeat the test until three successive tests give a reasonably consistent sequence. The average of the three is taken as the number required for the closure.

3. Remove a slice of soil approximately the width of the spatula (say about 10 g), extending from the edge of the soil cake at right angles to

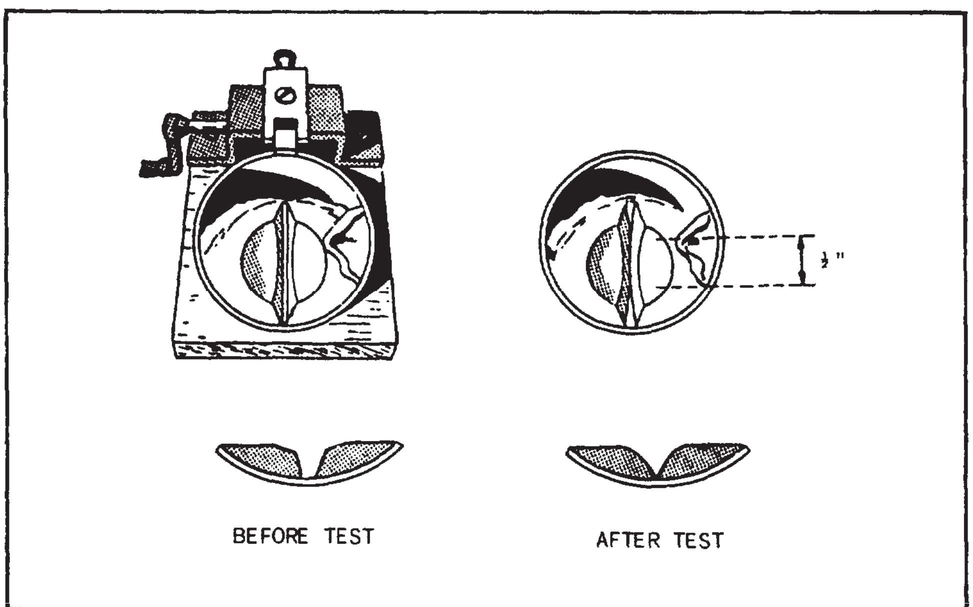


Figure 15-35.-Liquid limit test.

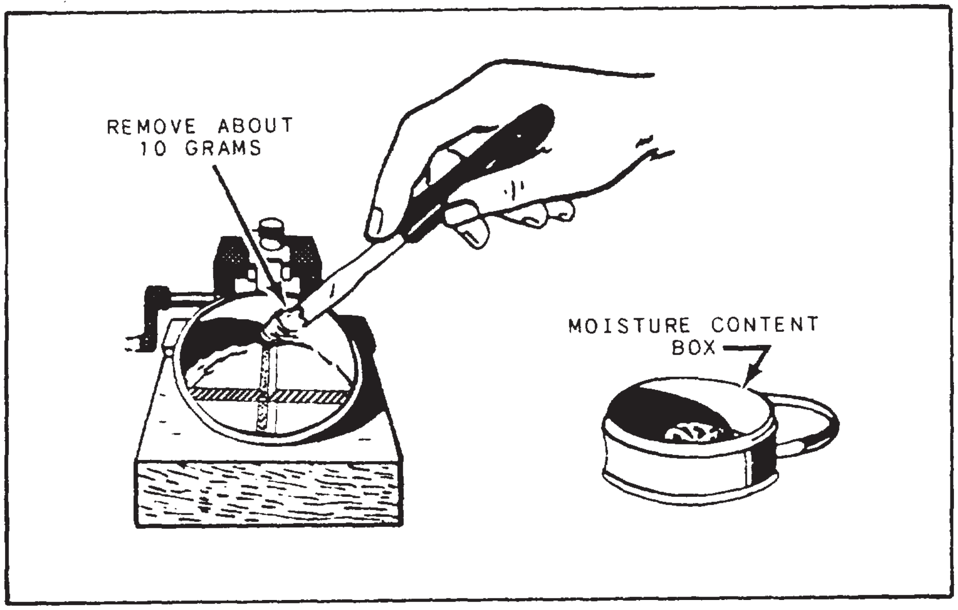


Figure 15-36.-Removing sample portion for moisture content.

the groove (fig. 15-36). Place this in a moisture content can, weigh it, and record the weight. Oven-dry and record the difference in weights. This is the weight of the water content.

4. Transfer the remaining soil in the cup to the evaporation dish. Wash and dry the cup and grooving tool. Reattach the cup in preparation for the next run.

5. Run at least five tests on each soil, with two closures above, two closures below, and one closure at or near the 25-blow line. An ideal spread is closures at 16, 23.5, 29, and 33 blows. If each testis perfect, the plotted line through all points is shown as a straight line. If some tests are imperfect, the operator can usually get good results by using the three plotted points lying most nearly in a straight line.

To determine the liquid limit, plot a FLOW CURVE on a graph like the one shown in figure 15-37. It is a semilogarithmic graph, in which the vertical coordinates are water content and the horizontal coordinates are number of blows. The flow curve is a straight line plotted as nearly as possible through three or more of the plotted points.

In figure 15-37, the first-run sample was tested three times for an average number of 16 hammer blows. The water content was 47.3 percent. On the graph, 16 and 47.3 are the coordinates of one of the three Xs shown plotted. The second-run sample indicated 24 hammer blows and 46.6 percent water content; these are the coordinates of another of the Xs plotted to the right. Coordinates for the third X are the hammer blows and water content for the third-run sample. The coordinates of the rest of the plotted points are as indicated by the hammer blows and water content for the succeeding runs. The plotted points in the graph may not form a straight line; however, the liquid limit line (or flow curve) is a straight line, passing nearly through the mean of the plotted points (fig. 15-37). The usual recommendation is that five or six trials be made so that the results are more representative.

The liquid limit (LL) is the water content for 25 blows; it is therefore indicated by the point of intersection between the flow curve and the vertical line representing 25 blows. The water content indicated is about 46.4 percent. This, when rounded off to 46, is the liquid limit.

The plastic limit of soil is the lowest water content at which the soil just begins to crumble when rolled into threads 1/8 in. in diameter, at slowly decreasing water content. First, prepare the sample as follows:

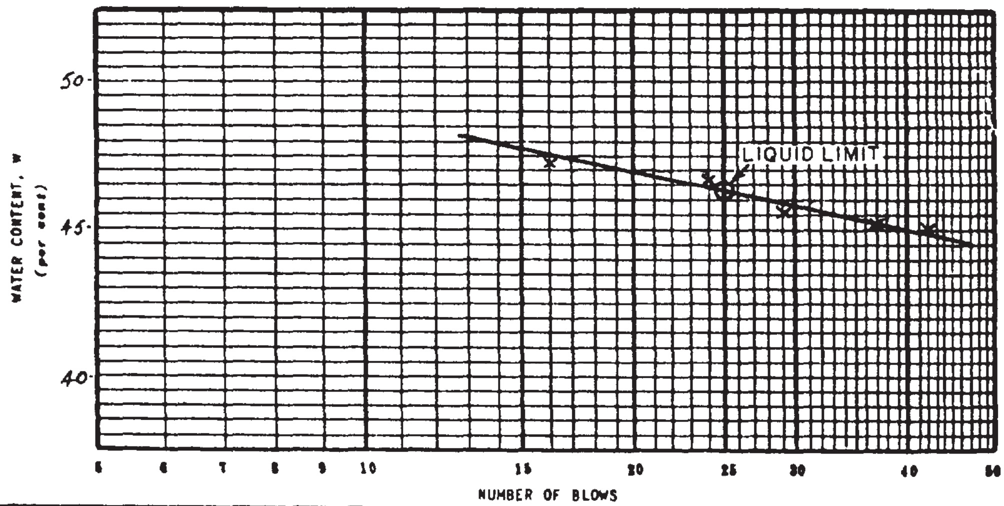
If you need only the plastic limit, take a quantity of soil weighing about 15 g from the prepared material in the evaporating dish. Place this air-dried soil in an evaporating

ATTERBERG LIMITS DETERMINATION		DATE: 1 June 19—
PROJECT: Britt Airfield	EXCAVATION NUMBER:	SAMPLE NUMBER: B-P3-1

LIQUID LIMIT, w_L

RUN NUMBER	1	2	3	4	5	6
TARE NUMBER	41	42	43	44	45	46
A. WEIGHT OF WET SOIL + TARE	44.41	44.89	41.07	41.27	41.17	40.91
B. WEIGHT OF DRY SOIL + TARE	41.08	41.52	38.16	38.39	38.32	38.08
C. WEIGHT OF WATER, W_w (A.-B.)	3.33	3.37	2.91	2.88	2.85	2.83
D. WEIGHT OF TARE	34.04	34.29	31.88	32.06	32.01	31.80
E. WEIGHT OF DRY SOIL, W_s (B.-D.)	7.04	7.23	6.28	6.33	6.31	6.28
WATER CONTENT, $w = (\frac{W_w}{W_s} \times 100)$ %	47.3	46.6	46.3	45.5	45.2	45.0
NUMBER OF BLOWS	15-17-16	23-24	29-28-30	33-33	37-38	41-42

LL	PL	PI=LL-PL
46	18	28



PLASTIC LIMIT, w_P

					NATURAL WATER CONTENT
RUN NUMBER	1	2	3		
TARE NUMBER	45	46	47		48
F. WEIGHT OF WET SOIL + TARE	56.21	55.15	60.60		58.72
G. WEIGHT OF DRY SOIL + TARE	55.90	54.89	60.10		57.82
H. WEIGHT OF WATER, W_w (F.-G.)	0.31	0.26	0.50		0.90
I. WEIGHT OF TARE	54.10	53.40	57.43		55.02
J. WEIGHT OF DRY SOIL, W_s (G.-I.)	1.80	1.49	2.67		2.80
WATER CONTENT, $w = (\frac{W_w}{W_s} \times 100)$	17.2	17.4	18.7		32.1
PLASTIC LIMIT, w_p (Average w)			18		

REMARKS

TECHNICIAN (Signature)	COMPUTED BY (Signature)	CHECKED BY (Signature)
William Denis	William Denis	Joseph Stephen

Figure 15-37.-Data sheet, Atterberg limits determination.

dish and thoroughly mix it with distilled water, adding water until the soil mass becomes plastic enough to be shaped into a ball easily. Take a portion of the ball weighing about 8 g for the sample.

Steps in the test procedure are as follows:

1. Squeeze and form the 8-g test sample into an oval-shaped mass. Roll this mass between the

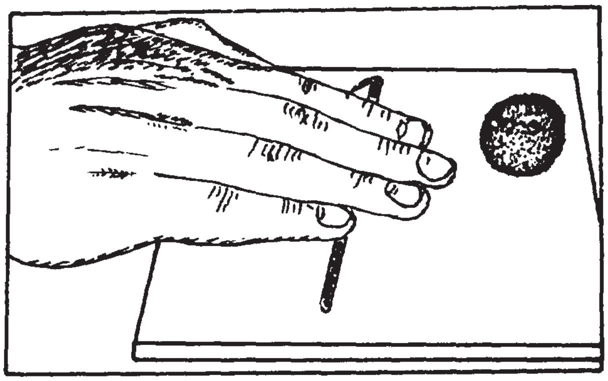


Figure 15-38.-Roll or thread test.

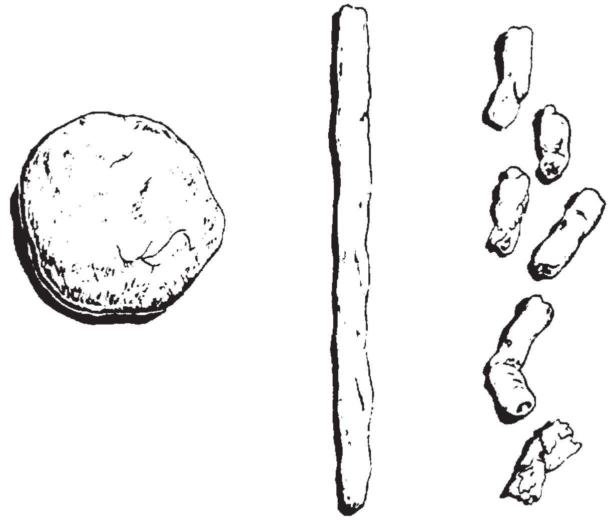


Figure 15-39.-Roll or thread test sample, before and after crumbling.

fingers and the test board (fig. 15-38) with just enough pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling should be between 80 and 90 strokes a minute, considering a stroke to be one complete motion of the hand forward from and back to the starting point.

2. When the diameter of the thread has been reduced to 1/8 in., break the thread into six or eight pieces (fig. 15-39). Squeeze the pieces together between the thumbs and fingers of both hands into a uniform mass roughly oval in shape, and again roll out into a thread. Continue this alternate rolling to a thread 1/8 in. in diameter, breaking, combining together, and rerolling. Do this until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the diameter of the thread is still greater than 1/8 in. This is considered a satisfactory end point, provided the soil has previously been rolled into a 1/8-in. thread at least once.

3. Gather the portions of the crumbled soil together, place it in the moisture content can, and determine the water content from the difference in weight before and after you oven-dry it.

4. Repeat the process on at least two additional specimens. All three tests should agree within 1 percent.

The plastic limit is simply the determined water content.

Plasticity Index

The PLASTICITY INDEX (PI) of a soil is the numerical difference between its liquid limit and its plastic limit; that is, PI = LL – PL. The PI that appears in figure 15-37 means plasticity index.

CONCRETE TESTING

Before delving into the remainder of this chapter, you may find it helpful to return to chapter 7 and review the topics concerning concrete. As you recall, in that chapter you studied concrete in terms of its use as a construction material, and you learned of the properties and requirements that comprise a good concrete. You also know that when concrete is placed in the field on a construction project, the concrete used must satisfy certain specified requirements. It is towards those properties and various requirements that concrete testing is directed.

CONCRETE TESTS

In concrete testing, as in soils testing, no single test will provide all of the information required. Rather, there is an array of tests that must be performed. The following describes those tests with which an EA is most commonly concerned.

Aggregate Tests

In order to provide the strongest and most durable concrete, the aggregate contained in the mixture must be the best possible in terms of gradation, shape, strength, and cleanliness. During the design of a concrete mixture, the aggregate selected for use must adequately meet those requirements. To determine this, various tests are performed. These include tests for

Table 15-4.-Recommended Slumps for Various Types of Construction

Types of construction	Slump, inches*	
	Maximum	Minimum
Reinforced foundation walls and footings	5	2
Plain footings, caissons, and substructure walls	4	1
Reinforced slabs, beams, and walls	6	3
Building columns	6	3
Pavements	3	2
Heavy mass construction	3	2
Bridge decks	4	3
Sidewalks, driveways, and slabs on ground	6	3

*When high-frequency vibrators are used, the values may be decreased approximately one-third; in no case should the slump exceed 6 inches.

gradation; specific gravity, absorption, and surface moisture; impurities, such as organic material, clay, or other water-absorbing particles; and soundness, which is the property of an aggregate to resist disintegration due to freezing and thawing. Although these tests are not included in this TRAMAN, you may refer to NAVFAC MO-330, *Materials Testing,* should you desire to learn more about them.

Slump Tests

As you are aware from your study of chapter 7, WORKABILITY is the relative ease or difficult y of placing and consolidating concrete. When placed, all concrete should be as stiff as possible, yet maintain a homogeneous, voidless mass. Too much stiffness, however, makes it too difficult or impossible to work the concrete into the forms and around reinforcing steel. On the other hand, too fluid a mixture is also detrimental. The measure of the workability or consistency of concrete is its slump, which is a design consideration that is inversely proportional to the stiffness of the mix. As shown in table 15-4, the recommended values for slump vary for different types of construction. To measure slump, either during the preparation of concrete trial batches or as a quality control check during construction, testers perform slump tests. The procedures for performing slump tests will be explained later in this chapter.

Strength Tests

In the design of concrete structures, the design engineer specifies given strengths that the final concrete products must be capable of attaining. When trial batches are prepared during mix design or as a quality control measure to ensure that concrete mixed or delivered in the field satisfies those specified strengths, the following tests are performed.

COMPRESSION TEST.— Compression tests are conducted to determine the compressive strength of concrete (or its ability to resist a crushing force). In this test, a standard test load is applied parallel to the longitudinal axis of a premolded and properly cured concrete cylinder of a standard size. When the testis properly conducted, a maximum load is obtained at the point at which the cylinder ruptures. With this maximum load, the compressive strength, measured in pounds per square inch (psi), can be easily calculated. Although the test procedures will be covered at the EA2 level, the procedures used to prepare the cylinders for testing will be discussed later in this chapter.

FLEXURAL STRENGTH TEST.— The flexural strength (modulus of rupture) test determines the flexural strength of concrete (or its ability to resist a breaking force). In this test, a standard

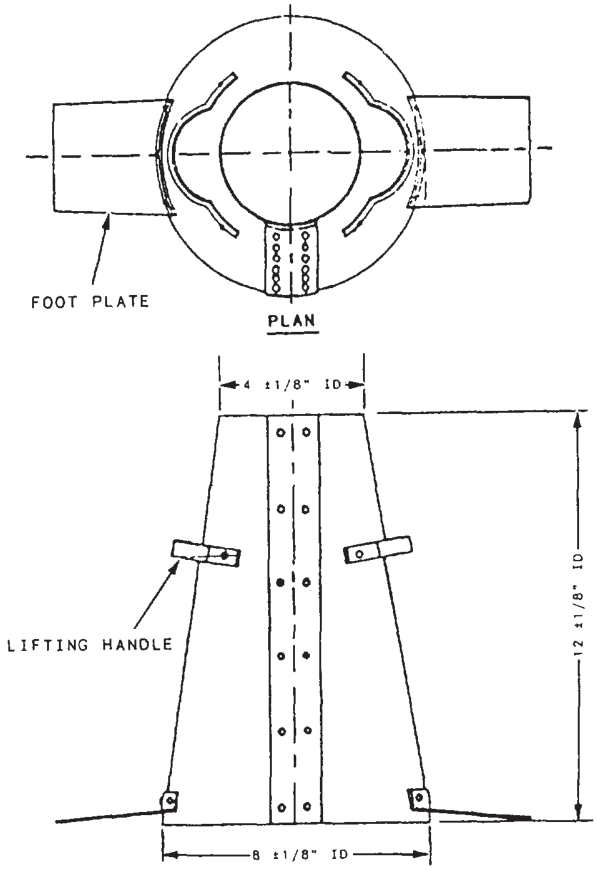


Figure 15-40.-Slump cone.

test load is applied perpendicular to the longitudinal axis of a standard size, premolded, and-properly cured concrete beam. From this test, the flexural strength, expressed in terms of modulus of rupture and given in psi, can be readily calculated. As with the compression test, only the procedures to prepare the test beams correctly will be discussed in this TRAMAN.

SLUMP TESTS

The slump test is performed on newly mixed concrete. To perform the test, you need a slump cone and a tamping rod. The slump cone (fig. 15-40) should be made of galvanized steel, 12 in. in height, with a base opening 8 in. in diameter and the top opening 4 in. in diameter. Both the top and bottom openings are perpendicular to the vertical axis of the cone. The tamping rod is a straight, steel rod that is 5/8 in. in diameter and approximately 24 in. in length. One end of the rod is rounded to a diameter of 5/8 in. (Do not substitute a piece of rebar.)

Sampling Procedures

Sampling (or obtaining) concrete for the slump test should be accomplished according to ASTM C 172. In this TRAMAN, only the procedure of sampling from a revolving drum truck mixer (TM) or agitator is discussed. If you should ever need to sample from a paving mixer, open-top truck mixer, or other type of equipment, be sure to refer to the most recent ASTM C 172.

Samples taken for the test specimens must be representative of the entire batch. This is accomplished by taking the samples at two or more regularly spaced intervals during discharge of the middle portion of the batch. Sample by repeatedly passing a scoop or pail through the entire discharge stream. Composite these samples into one sample for testing purposes. Be sure that the first and last portions of the composite sample are taken as quickly as possible, but never exceeding 15 min. If it is necessary to transport the samples away from the mixer to the place where the slump test is to be performed, combine the samples and remix them with a shovel to ensure uniformity.

Testing Procedures

Perform the slump test according to ASTM C 143. Be sure to start the test within 5 min after obtaining the final portion of the composite sample. In performing the test, first dampen the slump cone and place it on a flat, moist, nonabsorbent, rigid surface. From the composite sample obtained and while standing on the two foot pieces of the cone, fill the cone in three layers, each approximately one third of the volume of the cone. In placing each scoopful of concrete, rotate the scoop around the top edge of the cone as the concrete slides from it to ensure even distribution of concrete within the mold.

Rod each layer with 25 strokes of the tamping rod (using the rounded end), and uniformly distribute the strokes over the entire cross section of each layer. Rod the bottom layer throughout its depth. Rod the second layer and the top layer each throughout its depth so that the strokes just penetrate into the underlying layer. In filling and rodding the top layer, heap the concrete above the mold before the rodding is started. If the rodding results

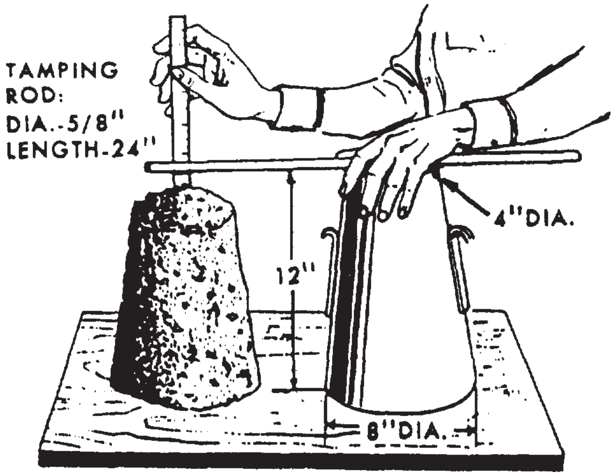


Figure 15-41.-Measurement of slump.

in subsidence of the concrete below the top edge of the cone, add additional concrete to keep an excess of concrete above the top of the cone at all times. After the top layer has been rodded, strike the surface of the concrete off flush by means of a screeding and rolling motion of the tamping rod. Immediately remove the slump cone from the sample by carefully and steadily lifting it straight up at the rate of 5 ± 2 sec for the height of the cone. Place the cone next to the test specimen. At this point, the entire test from the start of filling the cone to completing the removal of the cone should not exceed 2 1/2 min.

In measuring the slump, first place the tamping rod across the top of the cone so that it extends over the test specimen as shown in figure 15-41. Next, measure the vertical distance from the bottom of the rod to the average height of the subsided concrete specimen. This measurement is known as the SLUMP. If a decided falling away or shearing off of concrete from one side or portion of the specimen mass has occurred, disregard the slump measurement and make a new test on another portion of the sample. If two consecutive tests show a falling away or shearing off, the concrete probably lacks the necessary plasticity and cohesiveness for the slump test to be applicable.

After measuring and recording the slump, you have completed the slump test. As a supplementary procedure, however, tap the sides of the specimen gently with the tamping rod. The reaction of the concrete indicates its cohesiveness and workability. A well proportioned, workable mix gradually slumps to lower elevations and retains its original identity. A poor mix crumbles, segregates, and falls apart.

If the slump testis performed for a trial batch during concrete mix design, then too little, or too much, slump indicates the need for a new trial batch with revised ingredient proportions. When the test is performed as a quality control measure for a construction project, the slump obtained by testing will be compared to the specified slump for the concrete used for that particular project. If too little, or too much, slump has been determined by the test, then the quality control inspector, or other appropriate authority, will determine whether to accept or reject the concrete.

PREPARATION OF CONCRETE SPECIMENS

Concrete specimens that are representative of a distinct batch of concrete must be sampled and analyzed for the purpose of quality control.

Cylinder Specimens

Tests are performed on concrete cylinder specimens to evaluate the compressive strength of the concrete. The standard cylindrical specimen is 6 in. in diameter by 12 in. long.

STANDARDS FOR CYLINDER MOLDS.— Cylinder molds should be made of steel, cast iron, or other nonabsorbent material that does not react with concrete containing portland cement or other hydraulic cements. Molds should hold their dimensions and shapes under conditions of severe use. They should be able to hold, without leakage, the water poured into them. Before using the molds, coat them lightly with mineral oil or a suitable nonreactive form of release material.

FILLING CYLINDER MOLDS.— Place the molds on a level, rigid surface, free of vibration or other disturbances, at a place as near as possible to the location where they are to be stored for the first 24 hr.

Fill the molds with concrete specimens (taken as previously described for the slump test). The number of layers is determined by the mold size

Table 15-5.-Numbers of Layers Required for Specimens

Specimen Type and Size, as Depth, in. (mm)	Mode of Compaction	Number of Layers	Approximate Depth of Layer, in (mm)
Cylinders:			
12 (305)	rodding	3 equal	4 (100)
Over 12 (305)	rodding	as required	4 (100)
Beams:			
6 (125) to 8 (200)	rodding	2 equal	half depth of specimen
Over 8 (200)	rodding	3 or more	4 (100)

(table 15-5). As you fill a mold, rotate each scoopful of the concrete around the top edge of the mold as the concrete slides from it. This ensures a symmetrical concrete distribution within the mold.

Tamp each layer with the tamping rod, distributing the strokes uniformly over the cross section of the mold and penetrating the underlying layer. Tamp the bottom layer throughout its depth. The number of roddings is determined by the diameter of the cylinder. (See table 15-6.)

After tamping the top layer, strike off the surface with a trowel or rod so that the concrete fills the mold exactly. Do not add unrepresentative concrete to an underfilled mold. If voids are left by the tamping rod, tap the sides of the mold lightly with your open hand to close the voids. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff portland cement paste, which you should then permit to harden and cure with the specimens. When finished, move the specimens to the storage place and leave them undisturbed for the initial curing period.

CURING AND STORING CYLINDERS.– During the initial curing period of test specimens, be sure to take precautions to prevent the evaporation and loss of water in the specimens. Cover the specimens with a sheet of plastic. You may place wet burlap on top of the plastic to help retard evaporation, but be sure that it does not come in contact with the concrete surface. The exterior of cardboard molds must be protected against the absorption of water or molds may expand, allowing the specimens to be damaged. The test specimens now begin the initial curing period of 24 hr ± 8 hr. Test specimens maybe transported after the initial curing period, providing they remain in the mold. Upon completion of the initial curing period, remove the specimens from the molds and place them immediately in a moist environment with water maintained on their surface at a temperature of 73.4°F ± 3° (23°C ± 1.7°). You can also obtain the required condition by immersing the specimens in saturated limewater or by storing them in a moist room or cabinet. Do not expose test specimens to a flow of running or dripping water.

CAPPING CYLINDERS.— The ends of compression-test specimens must be planed within 0.002 in. and within 0.5 degrees of being perpendicular to the axis of the cylinder.

Specimens formed in strong metal molds having accurately flat baseplates can be capped with neat cement at 2 to 4 hr after molding. A stiff paste of portland cement and water is made at the time the cylinder is molded so that the capping mixture will have shrunk before application. Any free water or laitance (layer of fine particles on the surface) is removed from the end of the specimen. The paste is applied to the top of the concrete and worked with a flat plate until it is smooth and level with the top of the mold.

Hardened concrete specimens may be ground to place ends or capped with a material having greater compressive strength than the concrete. Prepared mixtures of sulfur and granular materials, special high-strength gypsum plasters, and neat high-early strength cement are satisfactory capping materials (ordinary low-strength plaster of paris, compressible rubber, or fibrous materials are not suitable for caps). You should apply these materials in a plastic state and finish them to the desired plane surface by applying glass or metal

Table 15-6.-Number of Roddings to be Used in Molding Cylinder Specimens

Diameter of Cylinder, in. (mm)	Number of Strokes/Layer
6 (152)	25
8 (200)	50
10 (250)	75

plates and squeezing out excess material to provide a cap that is as thin as possible. Sulfur caps may be applied in time to harden for at least 2 hr before testing. Plaster caps cannot be stored over 4 hr in a moist room. Neat cement caps must be aged 6 days or more in a moist room (2 days when Type II cement is used). During capping, protect moist, cured specimens against drying by covering them with wet burlap.

Beam Specimens

Tests are performed on concrete beam specimens to evaluate the flexural strength of the concrete. The standard beam specimen is 6 in. by 6 in. by 21 in. (152 mm by 152 mm by 532 mm) for concrete in which the maximum size of the coarse aggregate is 2 in. (50 mm). When the maximum size of the coarse aggregate exceeds 2 in. (50 mm), the smaller cross-sectional dimension is to be increased to at least three times the nominal maximum size of the coarse aggregate. All beam specimens prepared in the field are to be at least 6 in. wide and 6 in. deep unless required otherwise by project specifications.

STANDARDS FOR BEAM MOLDS.— The beam molds are to be smooth on all interior surfaces and free from warpage. The molds are to produce specimens that do not exceed the required cross-sectional dimensions by 1/8 in. The length of the specimens is not to be more than 1/16 in. shorter than the specified length, but it may exceed that length.

RODDING.— Place the concrete in the mold in the required number of layers. (See table 15-5.) Rod the bottom layer throughout, distributing the strokes uniformly over the cross section of the mold. When rodding the upper layers, allow the rod to penetrate the previous layer 1/2 in., providing the previous layer is 4 in. or less and 1 in. if the previous layer is greater than 4 in. The number of strokes' per layer is one for each 2 $in.^2$ (13 cm^2) of the top surface area of the specimen. After each layer is rodded, spade the concrete with a trowel along the sides of the mold to help in the removal of surface voids. Strike off the top surface with a straightedge, and finish it with a wooden float.

CURING.— YOU should cure the beam specimens in the same manner as the cylinder specimens with the following exceptions: (1) extend the initial curing period to 48 hr ± 4 hr and (2) do not allow the surface of the beam specimen to become dry between the time of removal from curing and the completion of testing.

When transporting specimens from the field to the laboratory, be sure they are sufficiently cushioned to protect them from damage by jarring. Additional measures are required to prevent damage by freezing temperatures and moisture loss. You can prevent moisture loss by covering the specimens with plastic or surrounding them by wet sand or wet sawdust.

CHAPTER 16

ADMINISTRATION

This chapter is provided to help you prepare for the "job ahead" and to acquaint you with your duties and responsibilities as an EA3 in a typical SEABEE billet. This chapter also discusses the training requirements and methods of preparing for in-rate advancement and discusses your role, in general, in the overall organization of the Naval Construction Force (NCF).

THE ENGINEERING AID RATING

The Engineering Aid rating is a general rating, as are all others in the Occupational Field 13 ratings. The scope of duties and responsibilities follows.

SCOPE OF DUTIES AND RESPONSIBILITIES

Engineering Aids plan, supervise, and perform tasks required in construction surveying, construction drafting, planning and estimating, and quality control; prepare progress reports, time records, construction schedules, and material and labor estimates; establish and operate a basic quality control system for testing soils, concrete, and other construction materials; prepare, edit, and reproduce construction drawings; and make and control surveys, performing such tasks as running and closing traverses, running level circuits, staking out construction projects, and obtaining other field data necessary for engineering studies or for actual construction of any type of structure that may come under the cognizance of the NCF.

IMPORTANCE OF THE EA RATING

The necessity for naval construction need not be emphasized, and each of the Occupational Field 13 ratings performs a vital and indispensable function in naval construction. In one sense, however, the function of the EA is of special significance. By merely studying the scope of the EA's duties and responsibilities, one can deduce that the EA's functions relate to the WHOLE construction project, rather than to one particular phase of it. From the project's conception until its final completion report, the EA contributes directly or indirectly towards its completion.

Some of your efforts might not be measurable in terms of work-in-place; however, they may be the deciding factor as to the accuracy and quality of the finished project. Your alertness in compiling man-hour expenditures and progress reports may have alerted the operations officer to see lagging work schedules. This enables the operations officer to readjust timetables and priorities to meet standing completion requirements.

The foregoing are just a few examples of your support to the mission of the NCF. You will encounter and learn a majority of your tasks through on-the-job training (or informal schools). The specific tasks you perform will depend upon your particular duty assignments and the prevailing contingency—operational, logistical, or both. Some of the various support assignments that you, as an EA, might encounter are discussed in later sections.

TYPICAL EA BILLETS

Generally, most of the billets for an EA3 on sea duty are in the Naval Mobile Construction Battalion, commonly called the "green machine. " This is where most of your skills as an EA will be put to use, honed, and tested. The experience you will gather from this type of duty is vast, provided you take on the challenges of your rate. For shore duty, assignment to public works activities is common to an EA3. However, other types of independent sea, shore, or oversea billets are available to you. Ask your leading petty officer (LPO) or your unit career counselor for additional information.

Assignment to an NMCB Operations Department

Normally, EAs reporting to a SEABEE unit for duty will be assigned to the operations department (S-3). The organization of a SEABEE operations department—be it in a staff, in a battalion, or in any detached unit—is similar in basic composition, with minor variations to suit the type of unit, its mission, and the prevailing conditions. In support of the construction organization, the specific functions of the operations department include planning and estimating, engineering, monitoring/reporting, quality control, disaster preparedness, minicomputer operations, and resources control. Figure 16-1 shows a standard organizational chart of a Naval Mobile Construction Battalion operations department. Using this chart as a guide, the operations officer may expand or modify the organization to suit the mission of the battalion and the availability of personnel to fill the billets.

In the following sections you will learn where you fit into the organization and how your duties and responsibilities relate to the functions of the operations department. The information is taken mainly from the *Naval Construction Force Manual,* NAVFAC P-315, and some actual observations currently prevailing in the NMCBs.

ENGINEERING DIVISION.— Most EAs are assigned to the engineering division of the operations department. Therefore, it is important that you become familiar with the overall organization breakdown of the division and the duties and responsibilities of personnel within the division. As you study the following sections, try to visualize how your contributions to the division will assist in accomplishing the overall mission of the division and the mission of the operations department. In other words, see where you fit into the "big picture."

The engineering division is under the direction of the engineering officer (fig. 16-1), who is normally a Civil Engineer Corps (CEC) officer. The engineering officer and his staff are

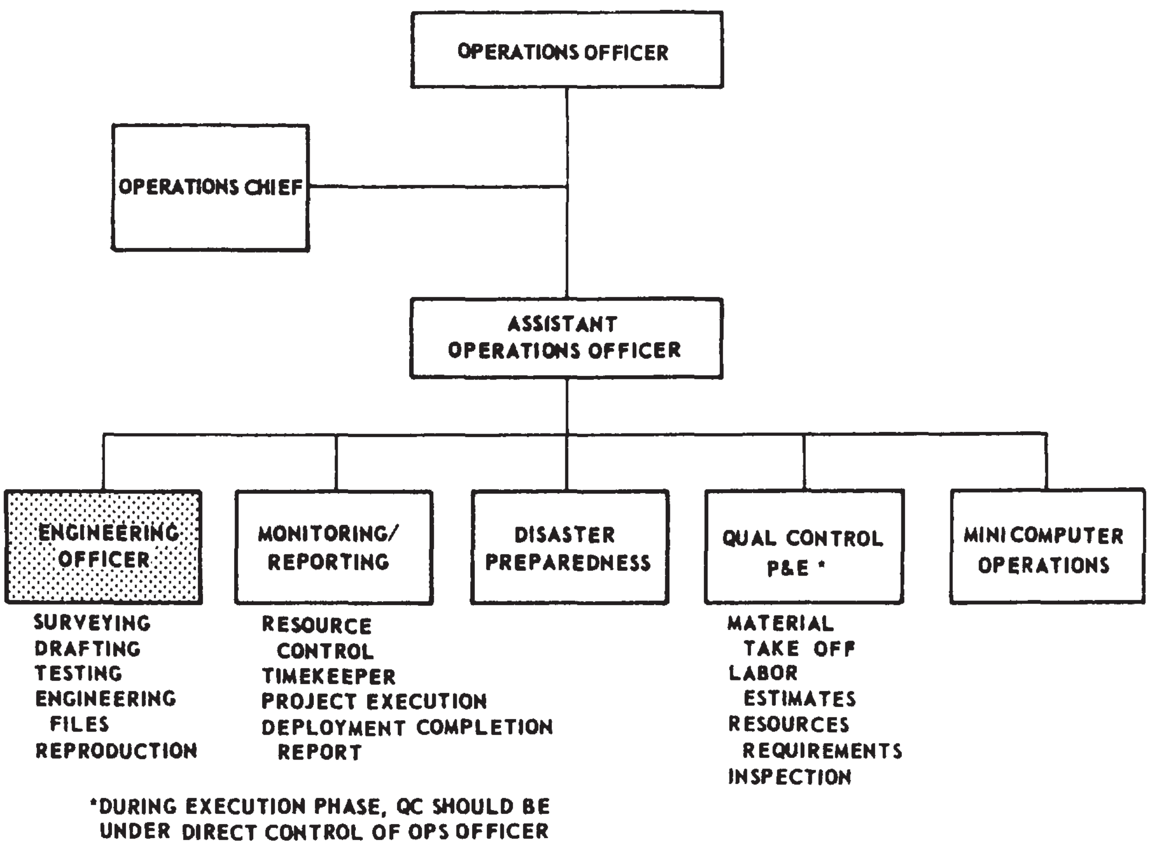


Figure 16-1.-Standard operations department organization.

responsible for providing all engineering services and design necessary for the successful conduct of the construction program. Their specific responsibilities are as follows:

1. Providing guidance and support to the company deployment planning team
2. Reviewing all plans for sound engineering practices and practicability of planning and construction
3. Resolving field problems relative to errors or revisions in design
4. Briefing company commanders on engineering aspects of new projects
5. Providing liaison with customers concerning engineering and design
6. Providing liaison with other divisions in the operations department in the interest of the successful conduct of the construction program

The engineering division is also responsible for, and renders technical support in, the following areas:

1. Providing technical engineering construction inspection by the engineering officer on behalf of the operations officer to ensure that projects are built according to the plans and specification and that quality workmanship prevails at all times
2. Providing survey services for the construction companies, as required
3. Providing up-to-date drawings and specifications for projects in progress
4. Providing soils and materials testing and evaluation services
5. Maintaining as-built drawings and providing copies, as appropriate, to customer commands

MONITORING/REPORTING DIVISION.— The monitoring/reporting division of the operations department is headed by the assistant operations officer. This division is sometimes referred to as the management division of the operations department. The division is normally staffed by the operations Yeomen and the battalion timekeeper. Sometimes the position of timekeeper/computer is assigned to capable EAs.

The monitoring/reporting division collects, compiles, and analyzes all information related to the construction operations. This information is used in the preparation of construction operations reports, including the Deployment Completion Report, the Project Execution Report, the Monthly Situation Reports, and any other special reports that may be required by higher authority. The engineering division will be required to assist in the preparation of these reports by supplying technical information concerning construction projects. Some reports may be compiled from existing records, and others may require special investigation and research.

For example, let us take the preparation of a Monthly Situation Report. Each battalion submits a monthly report of operations to either COMCBLANT or COMCBPAC (depending on what theater of operation it is in). Copies are sent to the commander, NAVFAC, and to administrative, military, and operational commanders concerned. This report is a concise review of the activities of the battalion during the month, regarding accomplishments, problems, and capabilities. It includes such information as planning, construction, welfare, morale, discipline, safety, training, and equipment. The numbers of officers and enlisted men are shown for the battalion and for all detachments, specifying the method of movement.

Enclosures to the Monthly Situation Report are specified by the commander, NCF. The following are generally included:

1. Progress and performance reports
2. Progress photographs
3. Labor distribution reports
4. Financial reports
5. Equipment status reports
6. Training reports
7. Summary of important events that occurred in the battalion during the reporting period

There are detailed instructions covering the preparation of the Monthly Situation Report and other reports, so your only problem is the compilation of the data that will go with them.

Besides the aforementioned reports, the monitoring/reporting division is responsible for the following:

1. Maintaining a complete status folder on each project
2. Maintaining complete and accurate timekeeping records and labor analysis reports
3. Maintaining and updating visual status boards required for effective construction management including the following: (1) company personnel strength, (2) project status, 3) labor analysis, and (4) project schedules

4. Preparing project completion letters according to applicable instructions from higher authority

5. Maintaining constant liaison with the material liaison officer

The monitoring/reporting division maintains constant coordination and works closely with the quality control or planning and estimating division and the company deployment planning team on the technical aspects of the project, progress reports, and master scheduling.

Assignment to a Typical Public Works Department

SEABEEs receiving orders to a shore or overseas shore activity other than a SEABEE staff or school command are normally assigned to the public works department (PWD) of the activity. EAs assigned to PWDs may fill several different types of billets, depending on the organization of the department and the capabilities of the EAs assigned. Although most PWD jobs are filled by civilians, military billets do exist to implement rotation of Occupational Field 13 personnel from sea to shore duty. Most of the EA public works billets are in the engineering division, where the EA works hand in hand with civil service personnel in performing drafting and/or surveying tasks. Senior EAs with planning and estimating or inspecting experience may be assigned to the facilities management engineering division to work as planners and estimators or maintenance inspectors. Sometimes when there is a shortage of senior military personnel in the facilities management engineering division, EAs and other Occupational Field 13 petty officers are trained for planning and estimating or maintenance inspecting.

A unique situation exists at most public works departments. Your military duties and responsibilities will fall under military supervision, whereas your professional work will be directly supervised by a civilian engineer. Adjusting to this situation may be difficult at first, but as an alert EA, you will benefit from the vast experience of the professional civilian engineer. A good working relationship between you and your civilian co-worker is of the utmost importance. Once this relationship is established, duty at a public works department becomes interesting and rewarding.

The basic organization for a public works department is shown in figure 16-2.

ENGINEERING DIVISION.— The public works engineering division (fig. 16-2) is responsible for all matters pertaining to engineering studies and reports, including preliminary designs and estimates for special repair and improvement projects; for engineering design, including development of plans and specifications; and for the maintenance of technical plan files and records. This division is responsible for preparation of shore facilities development reports and for the submission of basic data required by the NAVFAC engineering field division director for preliminary engineering studies.

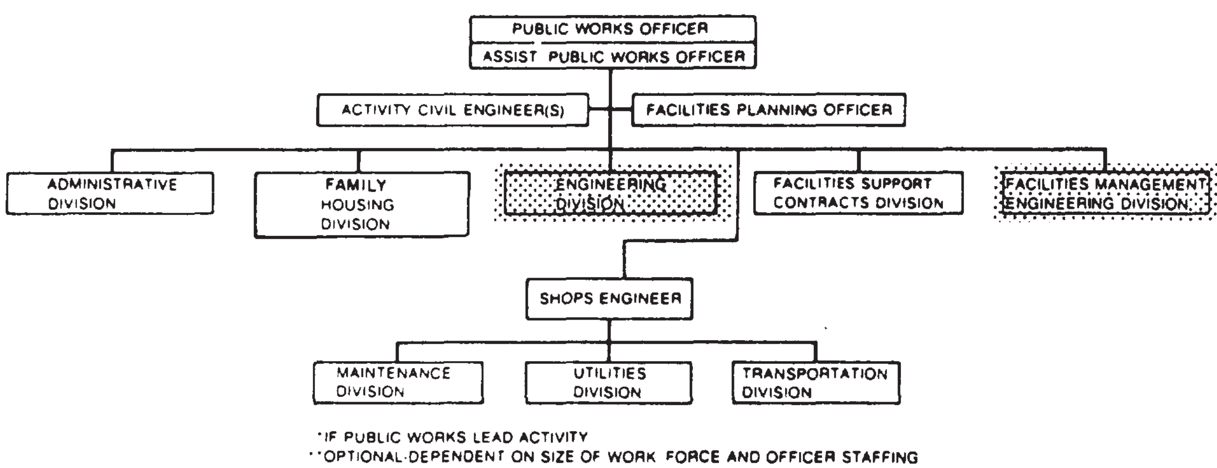


Figure 16-2.-Standard organization for a public works department.

Whenever the work load justifies or requires such action, the engineering division may be subdivided into the following branches:

1. Electrical branch
2. Mechanical branch
3. Architectural and structural branch
4. Civil branch
5. Plans and specifications branch

In some PW departments, it will be desirable to combine the mechanical and electrical branches or to merge the civil branch into the architectural and structural branch. In all cases, surveying work is performed as part of the civil component.

The PW officer establishes an engineering division to handle only routine work. He relies upon the engineering field division of NAVFAC for the design of major public works and public utilities, for the preparation of specifications in connection with them, and for the engineering investigations in specialized fields.

PW departments with limited work load and staffing may combine the engineering and maintenance control components into a single engineering division.

As mentioned previously, the majority of the EAs assigned to public works activities will work in the engineering division. With the exception of supervision, your tasks, such as design, reproduction, surveying, and so forth, will be similar to those performed in the engineering division of the NMCB. Often you will be the only EA assigned to a particular public works activity; therefore, your supervisory duties, if any, will be limited.

MANAGEMENT ENGINEERING FACILITIES DIVISION.— This is the division in the public works department whose entire effort is directed toward maintenance management. It is responsible for the integration of a maintenance work load program; the screening and classifying of all work requests, including emergency-service-type work, before submission to shops for accomplishment; the continuous inspection of public works and public utilities to reveal the need for maintenance work; the preparation of manpower and material estimates for job orders; the determination of the need for engineering advice and assistance; and the initiation of requests to the public works officer for approval to perform work by contract. The facilities management engineering division may be composed of the following branches:

1. Inspection branch
2. Planning and estimating branch
3. Work reception and control branch

At some PWDs, the inspection branch is supplemented with experienced BUs, CEs, UTs, SWs, and a few EAs with broad construction experience. Public works departments that are primarily staffed with SEABEEs may have senior or master chief petty officers for the inspection branch and planning and estimating branch supervisors.

Other EA Billets

As mentioned earlier, you, as an EA, maybe offered a variety of available billets or be given orders to a particular unit as the needs arise. Other types of billets for EAs include assignment to Construction Battalion Units (CBUs), Naval Oceanographic Units, Naval Support Force Antarctica (NSFA), Underwater Construction Teams (UCTs), SEABEE teams, and various other commands. Senior EAs are commonly assigned to SEABEE headquarters or regimental staff; as instructors at one of the Naval Construction Training Centers (NCTCs); as personnel detailers at Naval Manpower Procurement Center (NMPC); and as writers of advancement examinations and training manuals at the Naval Education and Training Program Management Support Activity (NETPMSA).

ADMINISTRATIVE DUTIES

As an EA3, you have a great deal to learn about your profession, including the development of skills related to drafting, surveying, materials testing, quality control, and eventually planning and estimating. However, from time to time, you will be called upon to demonstrate your supervisory abilities. Your duties and responsibilities as a supervisor will probably be limited, but they will gradually increase as you advance in your career development.

Becoming an EA3 is a big step in your naval career. The Navy imposes special trust and confidence in you. In return, the Navy expects you to be professionally competent and capable of instructing and supervising your subordinates. Your example of leadership and responsibility will influence others, so you must always exhibit a strong sense of personal integrity and dedication to your work and to the Navy.

The most challenging task you will have is adjusting to your role as a supervisor. Now is the time to start preparing yourself for the job ahead. Prior knowledge of both professional and administrative duties will put you ahead. Proper training and diligent study will prove itself beneficial when you are called upon to lead others.

To help you prepare for the job ahead, we will acquaint you with some of the common administrative and professional duties and responsibilities of an EA3. We will not attempt, however, to discuss the basic techniques of leadership; they are adequately covered in *Military Requirements for Petty Officer Third Class,* NAVEDTRA 10044, and *Military Requirements for Petty Officer Second Class,* NAVEDTRA 10045 (latest revisions). You need to carefully review those basic leadership techniques and apply them, where applicable, in all phases of your job. Also, in this section, you will learn to recognize the scope of other general duties and responsibilities associated with an EA3 in a typical SEABEE billet or assignment.

Several other administrative duties and responsibilities that you, as an EA3, may be exposed to or tasked with in your current assignment may be that of an EA2 or higher. You will notice that this section, for the most part, will discuss only your duties as outlined in the current EA3 occupational standards.

ASSIGNMENT AS TEAM LEADER

Normally, assignment as team, party, or crew leader is awarded to you at the EA2 level. However, in some cases in which you hold seniority in years over the rest of the junior personnel assigned to your team or section, you will be called upon to perform EA2 duties and occupy a position of higher responsibility. EA3 supervisory roles have been, at most times, assignments as party chief of a survey crew or a drafting room supervisor.

In general, your duties as a crew leader or party chief will involve planning work assignments, supervising, coordinating your work with the work of other teams, initiating requisitions, and keeping time cards. Information that will aid you in carrying out these duties is given below.

Planning Work Assignments

Proper planning saves time, effort, and money for the Navy and makes the job easier for all concerned parties. The following pointers will help you in planning day-to-day work assignments.

UNDERSTAND THE TASK CLEARLY.— When you are assigned a task, whether in writing or orally, the first thing you should do is make sure you fully understand just what is to be accomplished. Don't be afraid to ask questions. Find out the answers from those in a position to supply the information you need. Make sure you know the priority of the project, required time of completion, and any special instructions that must be followed. When the task is assigned orally, take detailed notes. Don't leave anything to memory; you might forget important information or instructions. A good supervisor carries a notebook at all times.

KNOW THE CAPABILITY OF YOUR CREW.— You should always consider the capability of your crew when planning for the accomplishment of each assigned task. With this in mind, you can determine who is to do what and how long it should take to finish the job. Realizing that idleness tends to breed boredom and discontent, plan to have another job ready to start as soon as the first one is finished.

ESTABLISH DAILY GOALS.— Each workday, encourage your crew to work together as a team to accomplish these goals. You want your goals to be such that your crew will be kept busy, but make sure they are "realistic" goals. During a contingency, people will make a tremendous effort to meet the deadline. But these people are not machines. When there is no anticipated urgency, they cannot be expected to continuously achieve an excessively high rate of production. In your planning, you should allow for those things that do not contribute directly to the accomplishment of the assigned task, such as in-house technical training, safety stand-down and other administrative matters.

SELECT PROPER METHODS, EQUIPMENT, AND SUPPLIES.— When you are planning an assigned task, you should consider every possible method that could be used to accomplish the task. If there is more than one way of doing a particular job, make sure the method you select is the best way. After selecting a method, analyze it to see if it can be simplified with a resultant saving in time and effort.

When you are planning for surveying operations, a vital step is the selection of proper required equipment and supplies. Proper selection of surveying equipment may greatly affect the end result of a survey. Forgetting to bring certain equipment or supplies to the jobsite is one of the most common mistakes made by supervisors. Nothing is more frustrating than to arrive at the jobsite only to discover that "someone" forgot to bring a tripod for the transit. The best way to minimize this embarrassing situation is to prepare an equipment and supply checklist for each job assignment and double-check the list after gathering all the items to make sure nothing was omitted. If more than one job is planned, include sufficient equipment and supplies to accomplish all jobs.

The same planning steps apply to drafting assignments. Certain drafting assignments are difficult to accomplish without proper equipment and supplies. As you gain experience, you will devise methods that will enable you to improvise with the equipment and supplies you have on hand.

Supervision

After a task has been properly planned, it is necessary to supervise the job carefully to ensure that it is completed properly, safely, and on time. Some pointers that will aid you in supervising work teams are outlined below.

KEEP THE CREW WELL INFORMED.— Before starting a job, make sure your crew knows what is to be done. Give instructions clearly and urge your people to ask questions about any points that are not clear to them. Explain how the job is related to other jobs and to the overall mission. Make sure that each crew member knows exactly what is expected of him and what his responsibilities are.

A crew performs much more efficiently when it is well informed. Be sure each crew member knows all pertinent safety precautions and wears safety apparel where required. Check all equipment and tools before use to ensure they are in safe condition. Do not permit the use of dangerously defective tools and equipment; see that they are turned in for repair immediately.

While the job is under way, check from time to time to ensure that the work is progressing satisfactorily. Determine if the proper methods and equipment are being used. If a member is doing a job incorrectly, stop him and point out his mistakes. Then explain the correct procedure and check to see that he follows it. In checking the work of your crew, try to do it in such a way that your men will feel that the purpose of your checking is to teach, guide, and direct, rather than to criticize and find fault.

When time permits, rotate your crew members to various jobs. Rotation gives them varied experience and will help ensure your having somebody who can do the work if a member is hospitalized, transferred, or on leave.

SEEK TEAMWORK.— A good supervisor should be able to get others to work together in getting the job accomplished. You should maintain an approachable attitude towards your men, making them feel free to come to you and seek your advice when in doubt at any time during the project. Emotional balance is especially important; a supervisor cannot become panicky before his men, unsure of himself in the face of conflicting forces, or pliable with influence. You should use tact and courtesy in dealing with your men and not show partiality to certain members of the work team. You should keep your men informed on matters that affect them personally or concern their work. You should also seek to maintain a high level of morale, keeping in mind that low morale can have a definite effect upon the quantity and quality of work turned out by your men.

The above is only a brief treatment on the subject of supervision. As you advance in rate, you will be spending more and more of your time in supervising others, so let us urge that you make a continuing effort to learn more about the subject. Study books on supervision as well as leadership. Also, read articles on topics of concern to supervisors, such as safety, training, job planning, and so forth, that appear from time to time in trade journals and other publications. There is a big need in the Navy for petty officers who are skilled supervisors. So, consider the role of supervisor a challenge and endeavor to become proficient in all areas of the supervisor's job.

Cooperation

If a project is to run smoothly and be completed on time, all crew leaders or supervisors must coordinate their work efforts and cooperate with one another as one big team. Most surveying operations are performed to guide the work done by other construction crews. You must therefore work closely with other crew leaders to ensure that your surveys are timely and do not delay the overall project. Cooperation with other supervisors will eliminate many problems that would otherwise arise when you are coordinating work efforts. In effect, you are merging your ideas and efforts to make the project run smoothly.

Cooperation is also essential to your success as a drafting supervisor. Consult the Builder crew supervisor on design problems and construction methods. Spending too much time on unnecessary details could delay the job if the Builders are awaiting the drawings to start the job. So right from the start, get into the habit of cooperating with other supervisors, and you will soon gain their respect as well as the respect of your superiors and your crew members.

MAINTAINING FILES

Maintaining file records, or simply "filing," is one job an EA needs to learn fast and well. When you are transferred to a new unit or command, chances are good that you will be involved in organizing and keeping track of a variety of engineering drawings normally found in the drafting and reproduction section. Your biggest challenge in filing is to make it possible for any single drawing (sheet), as well as the record pertaining to that particular drawing, to be readily located. Since most filing cabinets or protected stowage receptacles are limited in space, you may develop an ingenious approach to a highly organized filing system.

You must keep in mind that each engineering drawing is commonly identifiable by a drawing number assigned by the agency (such as NAVFACENGCOM) that made the drawing. The first major file breakdown for drawings, then, is a breakdown into separate files for the different agencies that have supplied the drawings. Within each agency file, the most convenient way to file drawings and prints is by the numerical sequence of drawing numbers.

Filing Original Copies

Original drawings and sepia copies are filed flat-NEVER folded. For large size originals, use shallow-drawer file cabinets of the type shown in figure 16-3. Smaller size drawings are generally stowed on edge in the standard deep-drawer-type cabinet, as shown in figure 16-4. Each drawer is divided into compartments by stationary partitions, and in each compartment there is a "compressor spring" to keep the drawings on edge and in a compressed stack.

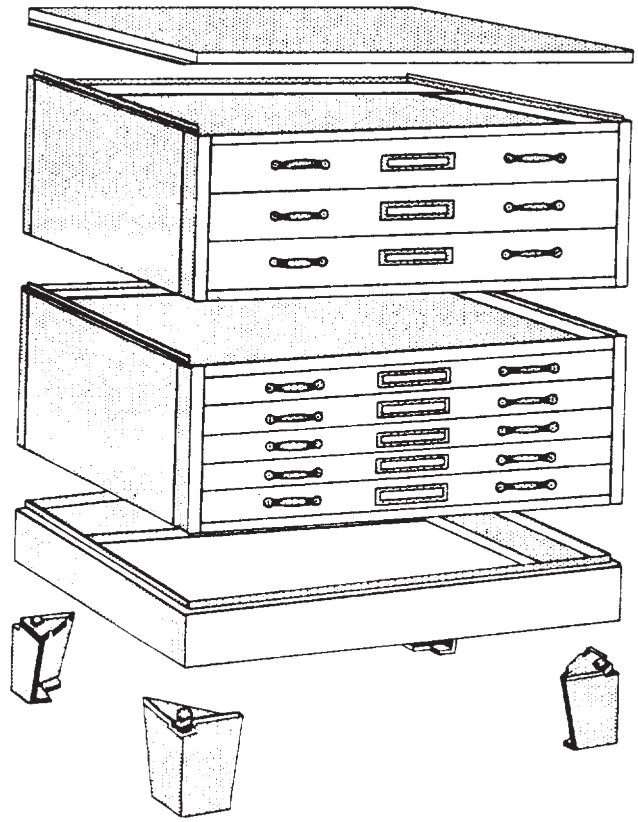


Figure 16-3.-Shallow-drawer cabinet for filing large original drawings, tracings, and negatives.

Filing Prints and Data

Prints are handled in a manner appropriate for their current status. Prints of drawings for active projects are generally placed on STICK FILES for easy reference. Stick files are either manufactured metal components or locally prepared strips of wood. Inactive prints, such as those from completed projects and some as-built drawings, are either stowed flat in shallow-drawer file cabinets (fig. 16-3) or folded and stowed in the standard deep-drawer-type cabinet (fig. 16-4). Extra sets of project drawings are sometimes rolled and stowed in some type of cylindrical plastic or cardboard tube.

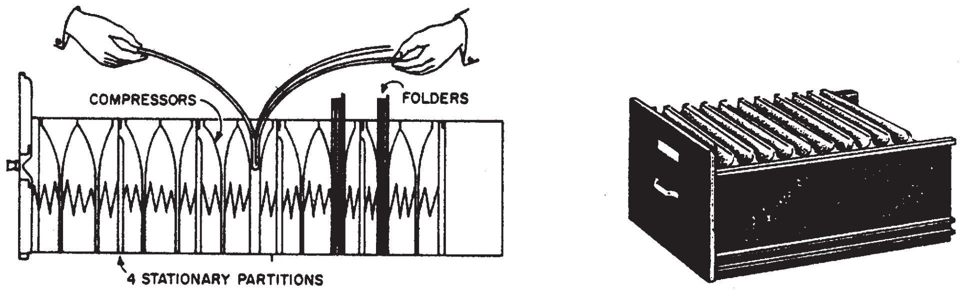


Figure 16-4.—Drawer of cabinet used for filing small original drawings, tracings, and negatives.

A print larger than size B is folded in accordion-pleat type folds in such a manner as to ensure that the drawing number is outside after the print has been folded. Final folded size should be 8 1/2 by 11 in. You should make yourself a plastic or plywood 8 3/8- by 10 7/8-in. "folding guide" or procure a ready-made one. The steps in folding a large print are as follows:

1. First, fold the print into 10 7/8-in. lengthwise accordion-pleat folds. Lay the print face-down, and start by turning the edge containing the drawing number, using the folding guide, as shown in figure 16-5. Use a small block of wood, like the one shown in the figure, to compress the crease.
2. Turn the print over and make the next lengthwise fold, as shown in figure 16-6. Continue turning over and folding until the width of the drawing is used up.
3. Place the lengthwise-folded drawing so that the side on which the drawing number appears is down. Begin at the end that contains the drawing number, and make the first 8 1/2-in. crosswise accordion-pleat fold, using the folding guide, as shown in figure 16-7.

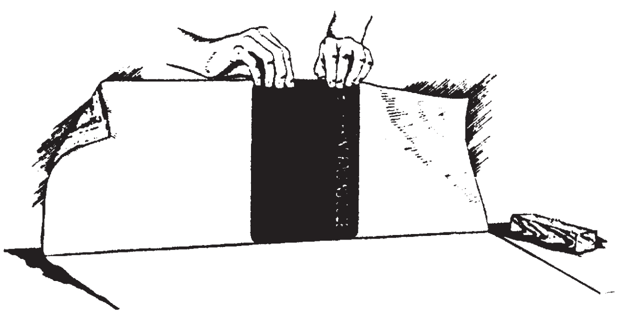


Figure 16-5.—Making first lengthwise fold in a large print.

4. Turn the print over and make the next fold. Continue until the length of the drawing is used up.

Data related to drawings discussed above, such as correspondence, should be filed according to SECNAVINST 5210.11 (series), or if a limited number of drawings are affected, they can be filed by drawing numbers in a separate drawer or cabinet. If a separate folder for each project is

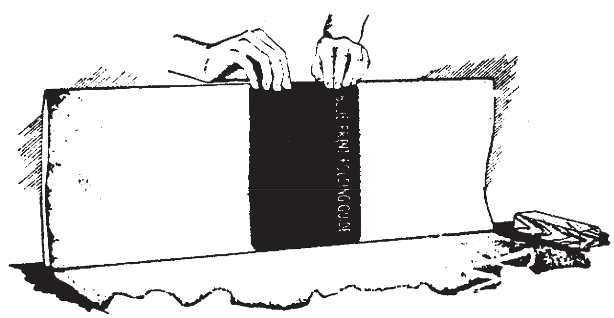


Figure 16-6.-Making second lengthwise fold in a large print.

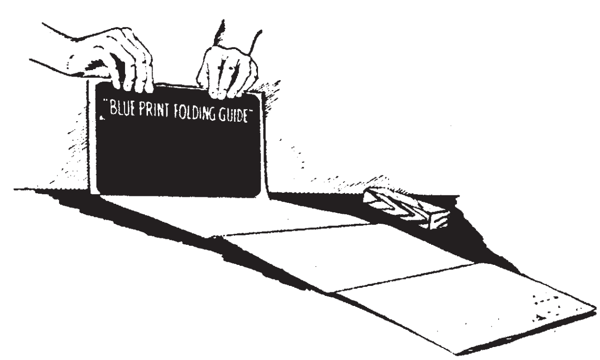


Figure 16-7.—Making first crosswise fold in a large print.

maintained, such data must be filed in the related projects folder.

Recording Files

A record of each drawing should be kept on an INDEX CARD in a suitable file drawer. A card similar to that shown in figure 16-8 may be used. A brief description of the information to be entered in each of the numbered spaces shown on this card is as follows:

① The standard subject identification code (numerical and/or name title). These classification codes are prescribed in the Department of the Navy *Standard Subject Identification Codes Manual,* SECNAVINST 5210.11 series. A copy of this instruction is available in your personnel office and in your technical library. The classification systems in this manual are designed to meet the needs of the entire Department of the Navy for a single, standard subject scheme to be used in numbering, arranging, filing, and referencing various types of Navy and Marine Corps documents by subject.

The Subject Identification Codes System is generally used by large shore activities, such as public works departments, Naval Construction Battalion Centers, or regimental headquarters. For smaller mobile units, such as an NMCB, the drafting room supervisor, the quality control (QC) staff, and EAs assigned to various detachments may devise their own indexing systems for field drawings according to the volume of records handled by the unit.

② The agency drawing number (NAVFACENGCOM DWG No.).

③ The title of the drawing, taken from the title block.

④ Cross-index references to any correspondence or data that may be on file relating to the drawing.

⑤ Number of the agency letter, if any, that was forwarded with the drawing.

⑥ and ⑦ The number and name of the A & E firm, contractor, naval shipyard, or other agency that actually made the drawings.

⑧ Applicable unit or vessel.

Again, if a separate folder or drawer file is maintained for each project, a notation must be

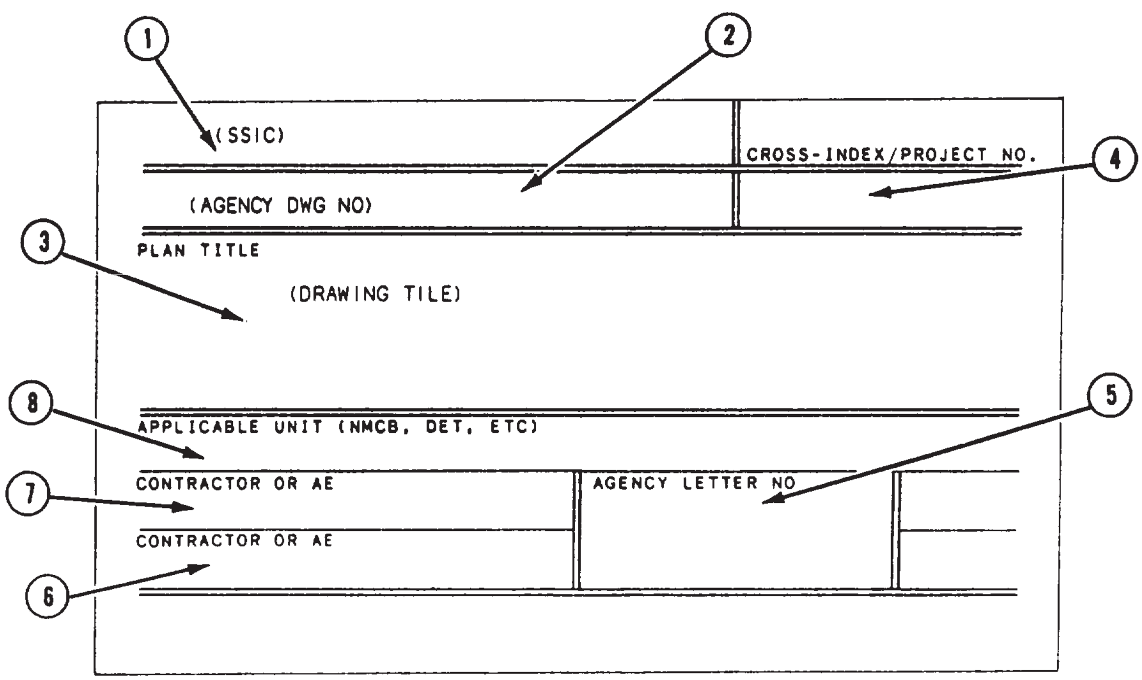


Figure 16-8.-Sample of a drawing file index card.

placed in the folder as to where to find the drawings related to that project. The project number will appear in the cross-index block ④ of the index card. You may, however, modify your index card to accommodate additional information or to suit the requirements in your unit.

PROFESSIONAL DUTIES

On the technical side, you, as an EA3, assigned to a typical SEABEE battalion, have a variety of jobs to choose from or to be assigned to. The sections within the engineering division to which you may be assigned are the drafting/print-reproduction section, the surveying section, and the materials testing section. Some of your duties and responsibilities while assigned to these sections are presented in the following paragraphs.

ASSIGNMENT TO DRAFTING/ REPRODUCTION SECTION

When you are first assigned to the drafting section, you are usually tasked with the simplest drafting or reproduction tasks so that the experienced drafting crew may be freed for more complicated work. These tasks also serve as training for the inexperienced draftsman. Your drafting assignments should include, in general, a variety of engineering services requests, such as reproduction of prints, preparation of charts, revising working drawings, preparing simple construction and fabrication drawings from sketches, and performing other EA3-related office jobs. Other EA-related tasks may include preparing overlay maps for operational, logistics, and/or contingency needs; performing operator's maintenance of reproduction machines; lettering, using the Kroy machine; plastic and metal engraving; maintaining a complete up-to-date technical library; and assisting other divisions and sections within the operations department as directed by the drafting supervisor.

Reproducing Blueprints

Quite often, the bulk of your job in the drafting section during home port is to reproduce several project drawings needed for planning and material estimates by the different construction crews and details. Failure to produce required quantities on time could have an adverse effect on the whole construction project planning and execution. To achieve maximum production, it is essential that every draftsman be properly trained to perform this assigned task. An experienced EA3 must be able to plan ahead to make sure that sufficient quantities of basic reproduction material requirements, such as print paper, are on hand and that the reproduction machine is in good working condition. Along with other preparations, you, as an EA3, need to learn to properly store blueprint paper and ammonia. Procedures related to the care and use of reproduction machines and supplies were discussed earlier in chapter 3.

Maintaining a Technical Library

Another important responsibility of the drafting section is that of establishing and maintaining an engineering technical library of current reference publications. The library is used by all personnel of the operations department as well as by anyone else in the battalion who requires technical information. To render service to others, the library must be maintained in an orderly manner.

Normally, the collateral duty of a librarian will be assigned to an EA3 working in the drafting room. He is responsible for arranging the publications, indexing, checking in and checking out publications. He is also tasked with packing the entire library for embarkation during overseas deployment.

Minimum requirements for a technical library are contained in a current COMCBPAC 5070 series instruction. The instruction includes all administrative, military, and technical library requirements that have to be met by each construction battalion. Publications not listed in the COMCBPAC instruction are included in appendix 11 of this training manual. Additional publications may be required depending on the particular mission of the battalion at each deployment.

It is essential that the librarian constantly monitor the technical library and know where each publication is at all times. Loss of important reference publications could cause delays in solving engineering problems. Security of frequently borrowed publications and a good checkout system will help prevent the loss of important publications.

ASSIGNMENT TO SURVEYING SECTION

One of the main units of the engineering division is the surveying or field engineering section. This section, like the drafting reproduction section, falls under the direct supervision of an EA1, depending on the number of senior EAs on board and their surveying experience. The size and organization of the entire surveying section will vary with the anticipated work load.

Your job, as an EA3, along with the other crew members in this section, is to carry out the scope of the tasks and responsibilities required of the surveying section. Depending on the overall mission of the battalion, typical surveying tasks may include the following: collecting field data and sketches for design purposes; conducting surveys for horizontal construction (roads, airfields, aboveground and belowground utilities); conducting layout surveys for vertical construction (buildings, retaining walls, waterfront structures, and so forth); developing level nets and level loops to establish vertical control; developing triangulation networks to establish horizontal control; and measuring structures in place for the purpose of preparing as-built drawings.

Versatility of the surveying section is essential to the accomplishment of all the assigned tasks. Sometimes all crews are used on one phase of the surveying task; at other times, crews are shuttled from one phase to another. Basically, for most surveying tasks, personnel are organized into two types of surveying parties: the TRANSIT PARTY and the LEVEL PARTY. They are named after the type of surveying instrument used.

ASSIGNMENT TO MATERIALS TESTING SECTION

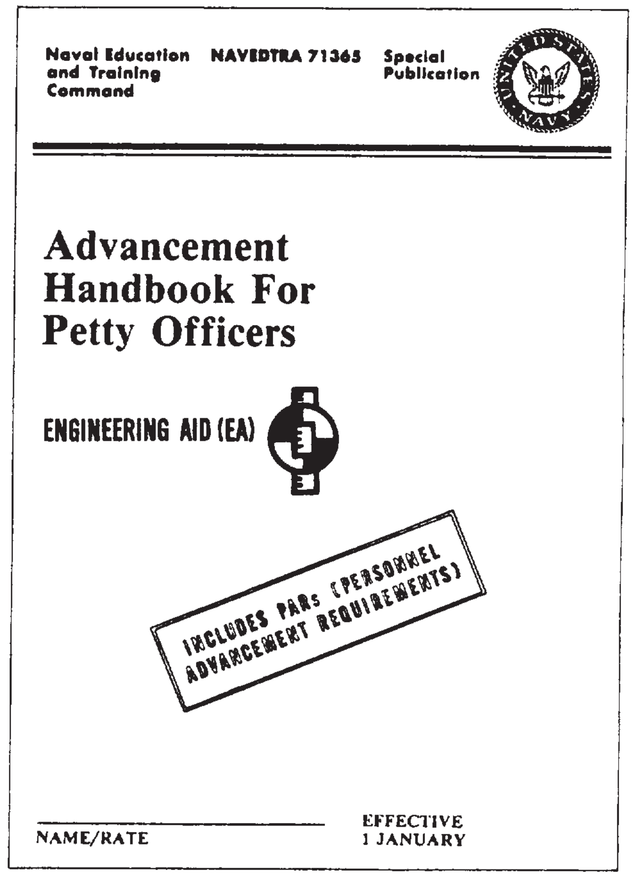
EAs assigned to the soils laboratory are tasked with performing tests on such items as subbase materials, aggregates, and concrete and bituminous mixes to determine if these materials meet specified quality requirements. You, as an EA3, may be tasked to perform some of these tests together with a more experienced EA. Chapter 15 of this book can serve as a guide for a review of some of the tests commonly performed by an EA3.

As you gain experience in testing different types of materials used in construction, you may be tasked to work with the quality control section of the operations department. EAs assigned to the material testing section work closely with the QC staff in several areas, such as in testing materials to ensure that their inherent character meets minimum requirements; interpreting results of tests conducted on soil, concrete, and asphalt; and preparing reports of the tests performed by the testing section.

CAREER DEVELOPMENT

To get ahead, you, as an EA3, must meet certain requirements that have been prescribed for your paygrade and rating. These requirements are referred to as standards. Since these standards deal with the technical or occupational subject matter of each rating, they are called occupational standards. Occupational standards may be found in the *Advancement Handbook for Petty Officers,* NAVEDTRA 71365 (fig. 16-9).

In addition to the occupational standards prescribed for each rating, there are certain military requirements to be met. The military requirements for advancement are discussed briefly later in this chapter and are discussed in detail in special training manuals prepared to cover the military requirements for advancement.


Naval Education and Training Command NAVEDTRA 71365 Special Publication

Advancement Handbook For Petty Officers

ENGINEERING AID (EA)

INCLUDES PARs (PERSONNEL ADVANCEMENT REQUIREMENTS)

NAME/RATE

EFFECTIVE 1 JANUARY

Figure 16-9.-Cover page of Advancement Handbook for Petty Officers (EA), NAVEDTRA 71365.

These military requirements are called naval standards.

The advantages of developing your career and getting ahead are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating. And second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

Many of the rewards of the Navy life are earned through the advancement system. The basic ideas behind the system have remained stable for years, but specific portions may change rather rapidly. It is important that you know the system and follow the changes carefully. One handbook that will normally keep you up to date regarding the basic advancement requirements is the *Advancement Handbook for Petty Officers,* NAVEDTRA 71365. The handbook outlines the Navy Advancement System in general and provides you with information about advancement paths, eligibility requirements for advancement, professional development, exams, and exam scoring. It contains naval and occupational standards with their supporting bibliographies and also personnel advancement requirements (PARS) certification.

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties and responsibilities of the EA rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the naval and occupational standards of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time and may even be seriously misleading.

PERSONNEL READINESS CAPABILITY PROGRAM

The Personnel Readiness Capability Program (PRCP) provides a standard means of identifying, collecting, processing, and utilizing information on all members of the Naval Construction Force, both active and reserve. This information can be used by all levels of management and supervision to determine a unit's readiness capability by comparing it to actual or planned requirements.

The majority of PRCP information consists of an inventory of individual skills acquired through formal or on-the-job training. A record of these skills, combined with other data from the service record, such as expiration of enlistment, rotation data, and so forth, provides a ready means of predicting future capabilities and requirements. Some of these may be the following:

a. Construction and military capabilities

b. Personnel, logistics, and training requirements

c. Berthing, messing, and housing requirements

d. Contingency requirements

Your initial PRCP skill inventory will be based upon an interview with your crew/squad leader or another senior petty officer of your rating. Special PRCP Interviewer's Standards and Guides have been prepared to assist persons conducting interviews. Each "Guide" contains a detailed explanation of every skill identified in the PRCP. These definitions are standard throughout the entire Naval Construction Force, and any person, regardless of duty assignment, can turn to these standards and know what is expected in a given skill area.

During an interview, it is imperative that you discuss your capabilities openly and honestly. Remember, if you exaggerate, you may be depriving yourself of valuable and needed training. Then too, you may be the one selected to do that special job all on your own. Will you be ready?

A more detailed discussion of the Personnel Readiness Capability Program may be found in chapter 2 of *Engineering Aid 1 & C,* NAVEDTRA 10635-C.

SOURCES OF INFORMATION—GOVERNMENT

There are various government publications that you may find useful as sources of reference. A number of publications issued by the Naval Facilities Engineering Command (NAVFACENGCOM) that will be of interest to you are listed in the *Documentation Index,* NAVFAC P-349 (updated semiannually). The publications are generally classified as follows: Design Manuals (DMs); Technical Publications (TPs); Maintenance and Operations (MOs); and Administrative Information (P).

NAVFAC publications should be available in your battalion technical library or in the engineering division of the public works activity. Their titles are self-explanatory and you can consult the publications that contain the subject matter in which you are interested. Suggested publications that should be in the engineering section of the battalion technical library are listed in appendix II.

Some Air Force Manuals (AFMs) and Army Technical Manuals (TMs) have subjects that are related to the Engineering Aid rating. They may be available in the technical library of the battalion; if not, they are easily ordered through the normal naval supply procurement system. TMs and AFMs of particular importance to you are included in the engineering section of the battalion technical library listing in appendix II of this manual.

To improve your ability in preparing any type of construction drawing, you should also refer to training manuals of other Occupational Field 13 ratings, especially those for the E-4 level.

Detailed standards for armed forces drawings are set forth in *Military Standards,* published by the Assistant Secretary of Defense (Supply and Logistics), Office of Standardization. Any Navy activity can obtain copies of these standards by writing to the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120. A complete and up-to-date copy of each of these standards is a must to have in any drafting room library of the SEABEES.

SOURCES OF INFORMATION—COMMERCIAL

To keep up to date on the current progress of new equipment and on the new materials related to your rating, you will find that the best source of information is commercial publications. These publications may be in the form of a textbook or an operation manual for a particular instrument. The instrument operation manual can be obtained from instrument manufacturers or dealers. On the other hand, textbooks are to be purchased. Your technical library may, however, have some of them on hand.

Every EA should strive to acquire at least a few textbooks for his personal use by purchasing them himself, if feasible. The knowledge and skill you learned through formal studies and on-the-job training in the SEABEEs must be supplemented continuously with off-hours studies on your own initiative. This will not only broaden your knowledge but will also enhance your chances of getting a high score in Navy-wide professional examinations.

APPENDIX I

GLOSSARY

Many terms have different meanings when used in relation to different subjects. The definitions in this glossary of terms are meant to be used in conjunction with the subject matter within this text.

ACCIDENTAL ERROR—Any small error accidentally incurred in a measurement. Unlike systematic errors, accidental errors are not governed by fixed laws. They are as likely to be positive as negative, and the theory of probability is based on the occurrence of these errors.

ACCURACY—The degree of conformity with a standard or the degree of perfection attained in a measurement. Accuracy relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

ACTUAL ERROR—The difference between the accepted value and the measured value of a physical quantity.

ACUTE ANGLE—An angle of less than 90°.

ADJUSTED POSITION—An adjusted value for the horizontal or vertical position of a survey station, in which discrepancies due to errors in the observed data are removed. This adjustment forms a coordinated and correlated system of stations.

ADMIXTURE—A material other than water, aggregates, and portland cement (including air-entraining portland cement and portland blast-furnace slag cement) that is used as an ingredient of concrete and is added to the batch immediately before or during its mixing.

ADSORBED MOISTURE—In soil mechanics, the thin films of moisture that may surround and cling to the individual particles in a soil mass because of naturally occurring electrical attraction of water molecules to the soil particles.

AGGREGATE—Any hard, inert, mineral material used for mixing in graduated fragments. It includes sand, gravel, crushed stone, and slag.

AGGREGATE, COARSE—Aggregate that is retained on the No. 8 sieve.

AGGREGATE, FINE-Aggregate that passes the No. 8 sieve.

AGONIC LINE—The line along which the magnetic declination is zero.

ALGEBRA—That branch of mathematics that pertains to the relations and properties of numbers by means of letters, signs of operation, and other symbols. Algebra includes solution of equations, polynomials, verbal problems, graphs, and so on.

ALIDADE—The part of a surveying instrument that consists of a sighting device with index and reading or recording accessories. 1. The alidade of a theodolite or engineer transit is the part of the instrument that includes the telescope, micrometer microscopes or verniers, and accessories. These are mounted on what is called the "upper motion" of the instrument, and they are used in observing direction or angle on the graduated circle, which is mounted on the "lower motion." 2. The alidade used in topographic surveying consists of a straightedge ruler carrying a telescope or other sighting device, and it is used in plotting a direction on the plane-table sheet. If a telescope is used, the instrument is often called a "telescopic alidade. "

ALTITUDE—1. The vertical angle between a horizontal plane and the line to the observed or defined object. In surveying, a positive altitude (measured upward from the horizon) is termed an angle of elevation, and a negative altitude (measured downward from the horizontal) is termed an angle of depression. 2. Altitude is sometimes used to apply to elevation above a datum; for example, the altitude of an airplane.

ANGLE—A figure formed by two lines or planes extending from or diverging at the same point.

ANGLE OF DEPRESSION—A negative altitude.

ANGLE OF ELEVATION—A positive altitude.

ANGLE OF INCLINATION—A vertical angle of elevation or depression.

ANNUAL VARIATION—The annual change in the magnetic declination.

ANTILOG—The result when a logarithm is converted to a number.

ARC—A portion of the circumference of a circle.

ARCHITECT'S SCALE—Scale used when dimensions or measurements are to be expressed in feet and inches.

ARITHMETIC—The art of computation by the use of positive real numbers.

ASPHALT—A dark brown to black cementitious material in which the predominating constituents are bitumens that occur in nature or are obtained in petroleum processing. Asphalt is a constituent in varying proportions of most crude petroleums.

AUXILIARY PLANE—A plane (NOT one of the normal planes) from which the auxiliary view is projected.

AUXILIARY VIEW—A view that is not on one of the normal planes of projection. It is used to show features of objects that do not appear in their true size and shape in the normal views.

AXONOMETRIC—A single view of an object depicting all three dimensions. The projection lines are parallel to each other and perpendicular to the plane of projection. The object is inclined to the plane of projection, thereby allowing the viewer to see three dimensions.

AZIMUTH (Surveying)—The horizontal direction of a line measured clockwise from a reference plane, usually the meridian; often called FORWARD AZIMUTH to differentiate from BACK AZIMUTH. In the basic control surveys of the United States, azimuths are measured clockwise from south following the continental European geodetic practice. However, this practice is not followed in all countries.

AZIMUTH MARK—A marked point visible from a survey station, the azimuth to which is determined for use in dependent surveys.

BACK AZIMUTH—As the azimuth of the line from A to B is known as the forward azimuth, the azimuth of the same line from B to A is known as the back azimuth.

BACKSIGHT—1. In traversing, a backsight (BS) is a sight on a previously established traverse or triangulation station, that is not the closing sight of the traverse. 2. In leveling, a backsight is a reading on a rod held on a point whose elevation has been previously determined and not the closing sight of a level line.

BALANCING A SURVEY—Distributing corrections through a closed traverse to eliminate the error of closure and to obtain an adjusted position for each traverse station.

BASE COURSE—The layer of material immediately beneath the surface or intermediate course. It may be composed of crushed stone, crushed slag, crushed or uncrushed gravel and sand, or combinations of these materials. It also may be bound with asphalt.

BASE LINE—A surveyed line established with more than usual care as the known length of a triangle side for computing other triangle sides.

BASE CONTROL—Horizontal or vertical control, the positions of whose stations have been accurately coordinated and correlated, forming a framework to which other surveys are adjusted.

BEARING—The direction of a line within a quadrant, with respect to the meridian. Bearings are measured clockwise or counterclockwise from north or south, depending on the quadrant.

BENCH MARK-A relatively permanent object, natural or artificial, bearing a marked point whose elevation above or below an adopted datum is known. Usually designated as a BM, such a mark is sometimes further qualified as a PBM (permanent bench mark) or as a TBM (temporary bench mark).

BILL OF MATERIALS—List of materials needed for a given project placed directly above the title block; not normally found on construction drawings.

BISECT—To divide into two equal parts.

BITUMEN—A mixture of hydrocarbons of natural or pyrogenous origin, or a combination of both; frequently accompanied by nonmetallic derivatives, which may be gaseous, liquid, semisolid, or solid, and which are completely soluble in carbon disulfide.

BLAST-FURNACE SLAG—The nonmetallic product, consisting essentially of silicates and aluminosilicates of lime and of other bases, which is developed simultaneously with iron in a blast furnace.

BLAZE—A mark made on the trunk of a standing tree by chipping off a spot of bark with an axe. It is used to indicate a trail, a boundary, location for a road, a tree to be cut, and so on.

BORDER LINES—Dark lines defining the inside edge of the margin on a drawing.

BREAK LINES—Lines used to reduce the graphic size of an object generally to conserve paper space. There are two types.

Long—Thin ruled line with freehand zigzag.

Short—Thick, wavy freehand line.

BROKEN SECTION—See partial section.

BUBBLE AXIS (LEVEL VIAL)—The horizontal line tangent to the upper surface of the centered bubble, which lies in the vertical plane through the longitudinal axis of the bubble tube.

CABINET PROJECTION—A single view of an object having one face in orthographic projection and depicting all three dimensions (length, width, and height). The projection lines are parallel and at an oblique angle with the plane of projection (generally 45°). The lengths of the receding lines are foreshortened to make the object appear optically correct.

CALIBRATION—The determination in terms of an adopted unit and by mechanical interpolation based on the values obtained by standardization of the supplementary marks on a measuring instrument or device. Also, the determination of the values of the divisions of a circle as proportional parts of a circumference.

CAVALIER PROJECTION—A single view of an object having one face in orthographic projection and showing all three dimensions. The projection lines are parallel and at an oblique angle with the plane of projection (generally 45°). The lengths of all object lines are drawn to scale and do not appear optically correct.

CENTER LINES—Lines that indicate the center of a circle, arc, or any symmetrical object; consist of alternately long and short dashes evenly spaced.

CHAIN (Gunter's)—A unit of distance formerly much used in land measurement and a term frequently found in deed descriptions. A chain equals 66 ft, 4 rods, 1/80 mi.

CIRCLE—A plane closed figure having every point on its circumference (perimeter) equidistant from its center.

CIRCUIT CLOSURE—In leveling, the amount by which the algebraic sum of the measured differences of elevation around a circuit fails to equal the theoretical closure, zero.

CIRCUMFERENCE—The length of a line that forms a circle.

CIRCUMSCRIBED FIGURE—A figure that completely encloses another figure.

CLOCKWISE ANGLE—A horizontal angle measured from left to right. A clockwise angle may have between 0° and 360°. Azimuths are clockwise angles measured from either north or south.

CLOSED TRAVERSE—A traverse that starts and ends at the same point or at stations whose positions have been determined by other surveys. (See CONNECTING TRAVERSE and LOOP TRAVERSE.)

CLOSING THE HORIZON—Measuring the last of a series of horizontal angles at a station required to make the series complete around the horizon. At any station, the sum of the horizontal angles between adjacent lines should equal 360°. The amount by which the sum of the measured angles fails to equal 360° is the angular error of closure. This error is distributed as a correction among the measured angles to make their sum exactly 360°. The error and the correction have opposite algebraic signs.

COLLIMATE—Adjust the line of sight of a telescopic surveying instrument to its proper position relative to the other parts of the instrument.

COLLIMATION LINE—The line through the second nodal point of the objective (object glass) of a telescope and the center of the reticle. It is variously termed the line of sight, sight line, pointing line, and the aiming line of the instrument. The center of the reticle of the telescope of a transit can be defined by the intersection of cross hairs or by the middle point of a fixed vertical wire or of a micrometer wire in its mean position. In a leveling instrument, the center of the reticle may be the middle point of a fixed horizontal wire.

COMMON LOGARITHMS—Logarithms with 10 as a base.

COMPASS-PIVOT JOINT, BOW, DROP BOW, BEAM—Instrument used to draw circles or arcs of circles.

COMPOUND CURVE—A curve composed of a series of successive tangent circular arcs.

CONE—A solid figure that tapers uniformly from a circular base to a point.

CONNECTING TRAVERSE-A closed traverse that starts and ends at different stations whose relative positions have been determined by other surveys.

CONSTRUCTION LINES—Lightly drawn lines used in the preliminary layout of a drawing.

CONTOUR—An imaginary level line (constant elevation) on the ground surface; it is called a CONTOUR LINE on a corresponding map.

CONTOUR INTERVAL—A predetermined difference in elevation (vertical distance) at which contour lines are drawn. The contour interval is usually the same for maps of the same scale.

CONTOUR LINE—An imaginary line on the ground, all points of which are at the same elevation above or below a specified datum.

CONTOUR MAP—A map that portrays relief by means of contour lines.

CONTROL—A system of points whose relative positions have been determined from survey data. (See BASIC CONTROL, HORIZONTAL CONTROL, and VERTICAL CONTROL.)

CONTROL STATION—A station whose position (horizontal or vertical) has been determined from survey data and is used as a base for a dependent survey.

CONTROL SURVEY—A survey that provides positions (horizontal or vertical) of points to which supplementary surveys are adjusted.

COORDINATES—Linear or angular quantities, or both, that designate the position of a point in relation to a given reference frame. There are two general divisions of coordinates used in surveying: polar coordinates and rectangular coordinates. These may be subdivided into three classes: plane coordinates, spherical coordinates, and space coordinates.

COUNTERCLOCKWISE ANGLE—A horizontal angle measured in a counterclockwise direction. The counterclockwise angle is used primarily for the measurement of deflection angles.

COURSE—The direction of a line with reference to a meridian, usually given as a true or as a magnetic bearing.

CRUSHED GRAVEL-The product resulting from the artificial crushing of gravel with substantially all fragments having at least one face resulting from fracture.

CRUSHED STONE—The product resulting from the artificial crushing of rocks, boulders, or large cobblestones, substantially all faces of which have resulted from the crushing operation.

CUBE—Rectangular solid figure in which all six faces are square.

CUTTING PLANE LINES—Thick, heavy lines used to indicate a plane or planes in which a sectional view is taken.

CYLINDER—A solid figure with two equal circular bases.

DATUM—Any numerical or geometrical quantity that serves as a reference or base for other quantities. It is described by such names as geodetic, leveling, North American, or tidal datum, depending upon its purpose when established.

DATUM LINES—Dark medium lines consisting of one long and two short dashes evenly spaced; used to define a line or plane of reference.

DECIMAL—The result of dividing the numerator (top number) of a fraction by the denominator (bottom number); for example, 1/2 = .5, 3/8 = .375, 17/100 = .17.

DECLINATION—The angle between true north and either grid or magnetic north.

DEFLECTION ANGLE—A horizontal angle measured from the prolongation of the preceding line, clockwise or counterclockwise as necessary, to the following line.

DEGREE—A 360th part of the circumference of a circle; also, a 360th part of a revolution about a point; used to define the size of an angle.

DEPARTURE—In a plane survey, the amount that one end of a line is east or west of the other end. The plane coordinates of a point are known as the casting and northing of the point, and the departure is the difference between the castings of the two ends of the line, which may be either plus or minus.

DESIGN MANUALS (DMs)—Publications containing guidelines set forth by the Naval Facilities Engineering Command.

DETAIL PAPER—Heavy opaque, buff, or neutral green drawing paper that takes pencil well.

DIAGONAL—A line that connects any two nonadjacent corners of a plane figure.

DIAMETER—A straight line passing through the center of a circle or sphere whose ends terminate at the circumference or surface.

DIMENSION LINE—A thin, unbroken line (except in the case of structural drafting) with each end terminating with an arrowhead; used to define the dimensions of an object. Dimensions are placed above the line except in structural drafting where the line is broken and the dimension placed in the break.

DIRECT LEVELING—The determination of differences of elevation by means of a continuous series of short horizontal lines. Vertical distances from these lines to adjacent ground marks are determined by direct observations on graduated rods with a leveling instrument equipped with a spirit level.

DIRECT READING—The reading of the horizontal or vertical circle of a theodolite or engineer transit with the telescope direct.

DISCREPANCY—1. The difference between duplicate or comparable measures of a quantity. 2. The difference between computed values of a quantity obtained by different processes in the same survey.

DISPLAY CHART—Chart used to convey data to nontechnical audiences.

DIVIDERS—Instrument used to transfer distances.

DRAFTING MEDIA—Materials used to draw on. Basically, three types are used: paper, cloth, and film.

EASTING—One of the two values indicating the position of a point on a grid system. The casting coordinate is abbreviated E.

ELEVATION—The vertical distance of a point above or below a reference surface, or level datum; often abbreviated ELEV.

ELLIPSE—A plane closed curve having the sum of the distances from any point on the curve to two fixed points a constant.

ENGINEER'S SCALE—A scale used whenever dimensions are in feet and decimal parts of a foot, or when the scale ratio is a multiple of 10.

EQUILATERAL—A polygon with sides of equal length.

ERROR—The difference between an observed or computed value of a quantity and the true value of the quantity. Errors are of two classifications: accidental errors and systematic errors.

ERROR OF CLOSURE—The amount by which the value of a quantity obtained by surveying operations fails to agree with another value of the same quantity held fixed from earlier determinations or with a theoretical value of the quantity.

EXPONENT—A small number or symbol placed above and to the right of a mathematical quantity to indicate the number of times the quantity is to be multiplied by itself; for example, $3^3 = 3 \cdot 3 \cdot 3 = 27$.

EXTENSION LINES—Thin, unbroken lines used to extend dimensions beyond the outline of a view so they can be more easily read.

FINITE DISTANCE—A defining measurable distance.

FIRST ANGLE PROJECTION—Multiview projection commonly used in Europe in which the top view is below the front view and the right side of the object, as shown in the front view, is toward the left side view of the object.

FORESHORTENING—The reduction in length of receding lines in an oblique projection that allows the object to appear to be optically correct.

FORESIGHT— 1. A sight on a new survey point, made in connection with its position determination; or a sight on a previously established point to close a circuit. 2. In leveling, a foresight (FS) is the rod reading on a rod held on a point whose elevation is being determined. (See BACKSIGHT.)

FORMAT—The systematic arrangement of drawing sheet space to standardize the location of required information.

FRACTION—A division indicated by placing the dividend (numerator) over the divisor (denominator) wit h a line between them.

Proper Fraction: 3/4

Improper Fraction: 3/2 = 1 1/2

Mixed Fraction: 1 7/8

FRENCH CURVE—Instrument used to draw smooth irregular curves.

FREEHAND DRAFTING—Any drawing in which the pen or pencil is guided solely by hand.

FRUSTUM OF A CONE—The portion of a cone-shaped solid next to the base that is formed by cutting off the upper part by a plane parallel to the base.

FRUSTUM OF A PYRAMID—The portion of a pyramid-shaped solid next to the base that is formed by cutting off the top by a plane parallel to the base.

FULL SECTION—A sectional view that passes entirely through the object.

GEODETIC DATUM—Datum that forms the basis for the computation of horizontal-control surveys in geodetic surveying. It consists of five quantities: the latitude and the longitude of an initial point, the azimuth of a line from this point, and two constants necessary to define the terrestrial spheroid.

GEOMETRY—That branch of mathematics that investigates the relations, properties, and measurement of solids, surfaces, lines, and angles; it also deals with the theory of space and of figures in space.

GRADE (GRADIENT)—The rate of rise and fall or slope of a line; generally expressed in percent or as a ratio.

GRAPH PAPER—Gridded paper in a variety of scales and patterns used for plotting, sketching, and drawing.

GRID—A network composed of two sets of equidistant parallel lines intersecting at right angles.

GRID COORDINATES—The numbers and letters of a coordinate system that designate a point on a grid.

GUARD STAKE—A stake driven near a hub, usually sloped with the top of the guard stake over the hub. The guard stake protects, and its markings identify, the hub.

HACHURES—A method of portraying relief by short, wedge-shaped marks radiating from high elevations and following the direction of slope to the lowland.

HALF SECTION—A sectional view that passes halfway through the object; used when the shape of one half is identical to the other half.

HATCHING—Sections lines that are drawn on the internal surface of sectional views; may be used to define the kind or type of material of which the sectioned surface consists.

HEIGHT OF INSTRUMENT—1. (Spirit leveling) The height of the line of sight of a leveling instrument above the adopted datum. 2. (Stadia surveying) The height of the center of the telescope (horizontal axis) of transit or telescopic alidade above the ground or station mark. 3. (Trigonometrical leveling) The height of the center of the theodolite (horizontal axis) above the ground or station mark.

HELIOTROPE—An instrument composed of one or more plane mirrors so mounted at the station being sighted upon that the sun's rays can be reflected to any one observing the station.

HEPTAGON—A polygon of seven sides.

HEXAGON—A polygon of six sides.

HIDDEN LINES—Thick, short, dashed lines indicating the hidden features of an object being drawn.

HORIZONTAL ANGLE—The angle formed by two intersecting lines on a horizontal plane.

HORIZONTAL CONTROL—Control that determines horizontal positions only, with respect to parallels and meridians or to other lines of reference.

HORIZONTAL DATUM—In plane surveying, the grid system of reference used for the horizontal control of an area; defined by the casting and northing of one station in the area, and the azimuth from this selected station to an adjacent station.

HORIZONTAL DIRECTION—A direction in a horizontal plane.

HORIZONTAL DISTANCE—A distance measured along a level line. It is commonly thought of as the distance between two plumb lines. The distance may be measured either horizontally or inclined, but the inclined distance is always reduced to its horizontal length.

HORIZONTAL LINE—A line tangent to a level surface, or a line lying on a horizontal plane.

HORIZONTAL PLANE—A plane perpendicular to the direction of gravity.

HORIZONTAL POSITION—The grid position of a horizontal control point.

HORIZONTAL REFRACTION—A natural error in surveying that is the result of the horizontal bending of light rays between a target and an observing instrument. This refraction is usually caused by the differences in density of the air along the path of the light rays, resulting from temperature variations.

HORN CENTER—Device used to prevent the compass needle from making holes in a drawing.

HUB—A wooden stake or pipe set in the ground with a tack or other marker to indicate the exact position. A guard stake protects and identifies the hub.

HYDROSCOPIC MOISTURE—The films of adsorbed moisture that may be present in airdried soil. Hydroscopic moisture may be driven off by oven-drying. (See also adsorbed moisture.)

ILLUSTRATION BOARD—Smooth white paper with a cardboard backing, used for signs or charts or mounting of maps, photos, or drawings that require a strong backing.

IMAGE PLANE—See PLANE OF PROJECTION.

INDIA INK—Drawing ink consisting of a pigment (usually powdered carbon) suspended in an ammonia-water solution.

INFINITE DISTANCE—An indefinite unmeasurable distance; for example, parallel lines are said to converge at infinity.

INSCRIBED FIGURE—A figure that is completely enclosed by another figure.

INTERSECTION—A method of locating the horizontal position of a point by observations from two or more points of known position, thus measuring directions that intersect at the station being located. A station whose horizontal position is located by an intersection is known as an intersection station.

IRRATIONAL NUMBER—Real number that cannot be expressed in the ratio of two integers; for example, 3, π.

IRREGULAR POLYGON—A nonequilateral polygon.

ISOMETRIC AXIS—Axis used in isometric projections and drawings. Each line in the axis forms an angle of 120° with the adjacent line, easily constructed with a straightedge and a 30°/60° triangle.

ISOMETRIC DRAWING—Same as an isometric projection except that the dimensions of the object drawn are scaled and not projected.

ISOMETRIC PROJECTION—A single view projection of an object showing three dimensions. The object is inclined so all faces make the same angle with the plane of projection, making all lines and surfaces foreshortened in the same ratio. This allows one scale to be used throughout.

ISOSCELES TRIANGLE—A triangle having two equal sides.

LATERAL FACES—Faces or surfaces forming the sides of a solid figure; also known as lateral surfaces.

LATERAL SURFACES—See LATERAL FACES.

LATITUDE—In plane surveying, the amount that one end of a line is north or south of the other end. As the plane coordinates of a point are known as the casting and northing of the point, the latitude is the difference between the northings of the two ends of the line, which may be either plus or minus. (See DEPARTURE.)

LAW OF COSINES—A law of mathematics that states that, in any triangle, the square of one side is equal to the sum of the squares of the other two sides minus twice the product of these two sides multiplied by the cosine of the angle between them. This statement may be expressed in formula form as follows:

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$b^2 = a^2 + c^2 - 2ac \cos B$$

$$c^2 = a^2 + b^2 - 2ab \cos C$$

LAW OF SINES—A law of mathematics that states that the lengths of the sides of any triangle are proportional to the sines of their opposite angles. It is expressed in formula form as follows:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

LAW OF TANGENTS—A law of mathematics that states that, in any triangle, the difference between two sides is to their sum as the tangent of half the difference of the opposite angles is to the tangent of half their sum. For any pair of sides—as, side a and side b—the law may be expressed as follows:

$$\frac{a - b}{a + b} = \frac{\tan 1/2(A-B)}{\tan 1/2(A+B)}$$

LEADER LINES—Thin unbroken lines used to connect numbers, references, or notes to appropriate surfaces or lines.

LEGEND—A description, explanation, table of symbols, and so on, printed on a map or chart for a better understanding and interpretation of it.

LEVEL—1. Pertaining to a level surface; 2. To make horizontal at the point of observation; 3. An instrument for leveling.

LEVEL DATUM—A level surface to which elevations are referred. The generally adopted level datum for leveling in the United States is mean sea level. For local surveys, an arbitrary level datum is often adopted and defined in terms of an assumed elevation for some physical mark (bench mark).

LEVEL LINE—1. A line in a horizontal plane; 2. A line over which leveling operations are accomplished.

LEVEL NET—Lines of spirit leveling connected together to form a system of loops or circuits extending over an area. This is also called a vertical control net.

LEVEL SURFACE—A surface that is parallel with the spheroidal surface of the earth, such as a body of still water.

LEVELING—The operations of measuring vertical distances, directly or indirectly, to determine elevations.

LINE OF SIGHT—1. The straight line between two points. This line is in the direction of a great circle, but it does not follow the curvature of the earth. 2. The line extending from an instrument along which distant objects are seen when viewed with a telescope or other sighting device.

LINE OF SYMMETRY—A line that divides an object into two equal identical parts; used only when the two halves of an object are identical.

LIQUID LIMIT—The upper limit of the plastic state, expressed as the moisture content at which the flow curve intersects the "25 blows" ordinate.

LOGARITHM—The exponent or the power to which a fixed number, called the base, must be raised to produce a given number; for example, common log $.3979 = 10^{.3979} = 2.5$

LOOP TRAVERSE—A closed traverse that starts and ends at the same station.

MAGNETIC AZIMUTH—An azimuth measured with reference to the direction indicated by a magnetic compass needle. Magnetic azimuth is measured from magnetic north, which is east or west of true north, as shown by the magnetic declination.

MAGNETIC DECLINATION—The angular amount that a magnetic compass needle points eastward or westward from true north.

MAP MEASURE—Instrument used when lengths of irregular outlines are measured.

MATCH LINES—Lines used when an object is too large to fit on a single drawing sheet and must be continued on another sheet. The points where the object stops on one sheet and continues on the next sheet must be identified with corresponding match lines. They are medium weight lines indicated with the words *match line* and referenced to the sheet that has the corresponding match line.

MATHEMATICS—The science that deals with the relationships that exist between quantities and operations, and with methods by which these relationships can be applied to determine unknown quantities from given or measured data.

MEAN SEA LEVEL—The average height of the sea for all stages of the tide. Mean sea level at numerous tide-gaging stations usually forms the basis of a level datum for large areas.

MEASURED ANGLES—Angles that are either vertical or horizontal.

MECHANICAL DRAFTING—Any drawing in which the pen or pencil is guided by a mechanical device.

MERIDIAN—A north-south line from which longitudes (or departures) and azimuths are reckoned.

MIDPOINT—That point on the arc of a circular curve that is the same distance from both ends of the arc.

MILITARY STANDARDS (MIL-STDs)—Instructions set forth by the Department of Defense that members of all armed services are required to follow. Only a few of these standards refer directly to drafting.

MINUTE—A 60th part of a degree used to define the size of an angle.

MOISTURE CONTENT (w.)—The ratio, expressed as a percentage, of the weight of water in a given soil mass to the weight of solid particles.

MONUMENT—Any object or collection of objects that indicates the position on the ground of a survey station. In military surveys, the term *monument* usually refers to a stone or concrete station marker containing a special bronze plate on which the exact station point is marked.

NONCIRCULAR CURVE—A curve composed of a series of extremely small circular arcs of varying radii.

NON-NORMAL LINE—A line that is oblique to one or more of the planes of projection.

NORMAL LINE—A line that is parallel to two planes of projection and perpendicular to the third. A line or plane that forms a 90° angle with another line or plane is normal to that line or plane.

NORTHING—One of the two values indicating the position of a point on a grid system. The northing coordinate is abbreviated N. (See GRID COORDINATES.)

OBLIQUE PROJECTION—A single view of an object showing three dimensions (length, width, and height).

OBLONG—A nonequilateral rectangle.

OBTUSE ANGLE—An angle greater than 90°.

OCCUPIED STATION—A traverse or triangulation station over which a theodolite or an engineer transit is set up for the measurement of angles at this station. Also, a station at which angles have been so measured.

OCTAGON—A polygon of eight sides.

OFFSET LINE—A supplementary line close to, and usually parallel to, a main survey line to which it is referenced by measured offsets. When the line for which data are desired is in such a position that it is difficult to measure over it, the required data are obtained by running an offset line in a convenient location and measuring offsets from it to salient points on the other line.

OGEE CURVE—Any curve composed of two consecutive tangent circular arcs that curve in opposite directions; also known as reverse curve.

OPEN TRAVERSE—A traverse that starts at a point of known or assumed position and ends at a point whose relative position is unknown with respect to the starting point.

ORDER OF ACCURACY—A mathematical ratio defining the general accuracy of the measurements made in a survey. The orders of accuracy for surveys are divided into four classes named first-order, second-order, third-order, and fourth-order.

ORGANIC SOIL—Soil that contains mineral grains and a more or less conspicuous admixture of vegetable matter.

ORIENT—To establish the correct relationship in direction with reference to the points of the compass; to bring into correct relationship in direction with reference to the points of the compass.

ORTHOGRAPHIC PROJECTION—The projection of height, width, and depth of an object into various single planes so as to depict the true size and shape of the object as seen from each individual plane, each plane showing only two dimensions, thereby necessitating a minimum of two planes to show all three dimensions.

PARALLAX—The apparent displacement or the difference in apparent direction of an object as seen from two different points not on a straight line with the object. In testing the focus of a telescope, the head of the observer must move from side to side or up and down while sighting through the eyepiece. Any apparent movement of the cross hairs in relation to the object image means that parallax is present. Parallax can be practically eliminated by careful focusing.

PARALLEL OF LATITUDE—A line on the surface of the earth having the same latitude at every point.

PARALLELEPIPED—A solid figure whose base is a parallelogram.

PARALLELOGRAM—A quadrilateral with each pair of opposite sides parallel.

PARTIAL AUXILIARY VIEW—An auxiliary view in which only the features of an object that are specifically desired are shown.

PARTIAL SECTION—A sectional view consisting of less than a half section; used to show the internal structure of a small portion of an object; also known as a broken section.

PAVEMENT STRUCTURE—All courses of selected material placed on the foundation or subgrade soil, other than any layers or courses constructed in grading operations.

PENTAGON—A polygon of five sides.

PERCENT—Portion in one hundred parts.

PERIMETER—The sum of the sides of a polygon.

PERMANENT BENCH MARK—A bench mark of as nearly permanent character as it is practicable to establish; usually designated bench mark.

PERSPECTIVE—A single-view drawing of an object showing three dimensions. Lines and surfaces are foreshortened to make it appear optically correct. Perspective drawing is used when the end product is to be of an illustrative nature.

PHANTOM LINE—Thin broken line consisting of one long and two short evenly spaced dashes; used to indicate the alternate position of **a** moving part.

PICTORIAL PROJECTION—Any projection that shows three dimensions in a single view as it would be seen by the eye.

PLAN/PROFILE PAPER—Upper half (plan) is plain white paper used to draw the plan view; lower half is gridded and used to draw profiles.

PLANE COORDINATES—See GRID COORDINATES.

PLANE OF PROJECTION—The theoretical, transparent plane placed between the point of sight and the object in any type of projection. The observer sees the features of an object as they lie on the plane of projection; also known as image plane.

PLANE SURVEY—A survey in which the effect of the curvature of the earth is almost entirely neglected, and computations of the relative positions of the stations are made using the principles of plane geometry and plane trigonometry.

PLASTIC LIMIT (PL)—The lower limit of the plastic state, expressed as the minimum moisture content, at which a soil can be rolled into a thread one-eighth in, in diameter without crumbling.

PLASTICITY—The property of a fine-grained soil that allows it to be deformed beyond the point of recovery without cracking or changing volume appreciably.

PLASTICITY INDEX (PI)—The numerical difference between the moisture content at the liquid limit and the moisture content at the plastic limit.

PLUMB LINE—The line indicated by a plumb bob cord. The direction in which gravity acts.

PLUNGE THE INSTRUMENT—Turn the instrument telescope end-for-end about its horizontal axis.

POINT OF SIGHT—The position of the observer in relation to the object and the plane of projection in any type of projection; also known as station point.

POLYGON—A plane figure that is bounded by straight-line sides.

POROSITY—The ratio, expressed as a percentage, of the intergranular space in a given soil mass to the total volume of the soil mass.

POSITION— 1. Data that define the location of a point with respect to a reference system. The coordinates that define the location of a point on a grid. 2. A circle position.

POWER—The number of times, as indicated by an exponent, a number occurs as a factor; for example, $2^4 = 2 \cdot 2 \cdot 2 \cdot 2 =$ to the 4th power=16.

POZZOLAN—A siliceous or aluminous material that in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

PRECISION—The degree of refinement in the performance of an operation or the degree of perfection in the instruments and methods used when making measurements. Precision relates to the quality of the operation by which a result is obtained and is distinguished from accuracy that relates to the quality of the result.

PROJECTION CHART—Chart showing the comparison of scheduled progress and actual progress.

PROJECTION LINES—The imaginary lines from the eye of the viewer to the points on the object in any type of projection; also known as lines of sight.

PROPORTION—An equation in which two ratios are set equal to each other; for example, $3/4 = 9/12$, $3:4::9:12$.

PROTRACTOR—Instrument used for measuring and laying off angles.

PYRAMID—A figure having a plane polygon for its base and triangles meeting at a common vertex for its sides.

PYTHAGOREAN THEOREM—A law of mathematics that states that the square of the hypotenuse of a right triangle equals the sum of the squares of the other two sides.

QUADRILATERAL—A polygon bounded by four sides.

QUALITATIVE CHART OR GRAPH—Any chart that emphasizes the relationships of facts.

QUANTITATIVE CHART OR GRAPH—A chart or graph that emphasizes numerical values.

RADIAN—A system for measuring angles where 2π radians equals 360°; 1 radian = 57.3°.

RADICAL—A symbol placed on a mathematical quantity to indicate the root of the quantity; for example.

$\sqrt{4}$ = square root = 2 (that is, $2 \cdot 2 = 4$)

$\sqrt[3]{8}$ = cube root = 2 (that is, $2 \cdot 2 \cdot 2 = 8$)

$\sqrt[4]{16}$ = 4th root = 2 (that is, $2 \cdot 2 \cdot 2 \cdot 2 = 16$)

RADIUS-A straight line from the center of a circle or sphere to its circumference or surface.

RATIO-A comparison of two like quantities; for example, 2/3, 2:3.

RATIONAL NUMBER—A number that can be expressed as the quotient or ratio of two whole numbers: Fractions 2/7, Integers 3/1 = 3. A radical is a rational number if the radical is removable; for example, $\sqrt{4} = 2$, $\sqrt[3]{27} = 3$.

REAL NUMBERS—All positive and negative numbers.

RECIPROCAL—The reciprocal of a number equals 1 divided by the number.

RECTANGLE—A parallelogram in which adjacent sides join at right angles.

RECTANGULAR PRISM—A solid figure whose base is a rectangle.

REFERENCE PLANE—The normal plane from which all information is referenced.

REGULAR POLYGON—An equilateral polygon.

RESIDUAL SOIL—Any soil that results from weathering in place and that is not moved from its place of origin.

RETICLE—A system of wires, hairs, threads, etched lines, or the like, placed normal to the axis of a telescope at its principal focus by means of which the telescope is sighted on a star, or target, or by means of which appropriate readings are made on some scale, such as a leveling or stadia rod.

REVERSE CURVE—See OGEE CURVE.

REVISION BLOCK—Block drawn in the upper right corner of construction drawings; contains chronological list of all changes or revisions to the drawing.

REVOLUTION—Object is projected on one or more of the planes of projection but rather than being in the normal position, it is revolved on an axis perpendicular to one of the regular planes; used when it can show the features of an object more clearly than a normal orthographic projection.

REVOLVED SECTION—A sectional view used to show the internal structure of an item within the normal orthographic view.

RHOMBOID—A nonequilateral parallelogram in which adjacent sides join at oblique angles.

RHOMBUS—An equilateral parallelogram in which adjacent sides join at oblique (other than right) angles.

RIGHT ANGLE—An angle of 90°.

ROOT—The number of times a quantity is found as an equal factor within another quantity; for example.

$\sqrt[4]{16}$ = 4th root of 16 = 2

$2 \cdot 2 \cdot 2 \cdot 2 = 16$

2 is the 4th root of 16

SATURATION, DEGREE OF (S.)—The ratio, expressed as a percentage, of the volume of water in a given soil mass to the total volume of intergranular space (voids).

SCALE—The ratio between the dimensions of the graphic representation of an object and the corresponding dimensions of the object itself.

SCALENE TRIANGLE—A triangle in which no sides or angles are equal.

SECANT—The ratio between the hypotenuse and the side adjacent an angle in a right triangle: sec = hyp/ad.

SECONDARY AUXILIARY VIEW—An auxiliary view that is used when neither the normal views nor the primary auxiliary view shows the features of an object in its true size and shape.

SECTION LINES—Thin diagonal lines used to indicate the surface of an imaginary cut in an object.

SECTION VIEW—A view used to show the internal structure of an object; used when hidden lines in the normal orthographic views do not amply describe the object.

SECTOR OF A CIRCLE—The part of a circle bounded by two radii and their intercepted arc.

SEGMENT OF A CIRCLE—The part of a circle bounded by a chord and its arc.

SHRINKAGE LIMIT—The maximum water content at which a reduction in water content will not cause a decrease in volume of the soil mass.

SHRINKAGE RATIO-The ratio between a given volume change, expressed as a percentage of the dry volume, and the corresponding change in water content above the shrinkage limit, expressed as a percent of the weight of the oven-dried soil.

SINE—The ratio between the side opposite an angle and the hypotenuse of a triangle: sin = opp/hy.

SKETCH—A quick freehand drawing, usually pictorial, used to convey information or an idea.

SOIL—A mixture of uncemented or loosely cemented mineral grains enclosing various sizes of voids containing air (or other gases), water, and organic matter, or varying combinations of these materials.

SOIL, COARSE-GRAINED-Soil in which more than half of the material, by weight, is retained on a No. 200 sieve.

SOIL, FINE-GRAINED—Soil in which more than half of the material, by weight, passes a No. 200 sieve.

SPACE BLOCKS—Strips placed under the edges of triangles, french curves, and like instruments to prevent ink from running under the edge.

SPECIFIC GRAVITY, APPARENT **(G_A)—The** The ratio of the weight in air of a given volume of the impermeable portion of soil particles to the weight in air of an equal volume of distilled water, both at a stated temperature.

SPECIFIC GRAVITY, BULK **(G_M)—The** The ratio of the weight in air of a given volume of permeable material (including permeable and impermeable voids) to the weight of an equal volume of distilled water at a stated temperature.

SPECIFIC GRAVITY OF SOLIDS **(G_S)—The** The ratio of the weight in air of a given volume of soil particles to the weight of an equal volume of distilled water, both at a stated temperature.

SPHERE—A solid figure having every point on its surface equidistant from its center.

SQUARE—An equilateral rectangle.

STATION—A definite point on the earth's surface whose location has been determined by surveying methods. It maybe a point on a traverse over which an instrument is set up or a length of 100 ft measured on a given line-broken, straight, or curved.

STATION POINT—See POINT OF SIGHT.

STITCH LINE—Dark medium line consisting of very short dashes closely spaced; used to indicate stitching or sewing lines on an article.

SUBBASE—The course in the asphalt pavement structure immediately below the base course is called the subbase course. If the subgrade soil is of adequate quality, it may serve as the subbase.

SUBGRADE—The soil prepared to support a structure or a pavement system. It is the foundation for the pavement structure. The subgrade soil is sometimes called "basement soil" or "foundation soil."

SYSTEMATIC ERRORS—Errors that, as long as conditions are unchanged, will always have the same magnitude and the same algebraic sign.

TANGENT—The ratio between the side opposite and the side adjacent an angle in a right triangle: tan = opp/ad.

TANGENT LINE—A line that touches the circumference of a circle at one point and is perpendicular to the radius at the point of tangency.

TARGET—Any object to which the instrument is pointed. A target may be a plumb bob or plumb bob cord, a nail in the top of a stake, a taping arrow, a ranging pole, a pencil, or any other object that will provide a sharply defined, stationary point or line. A target is usually placed vertically over an unoccupied transit station.

TECHNICAL ENGINEERING CHARTS—Charts based on a series of measurements of laboratory experiments or work activities.

TEMPLATES—Timesaving devices used to draw various shapes and symbols. Templates are available for all types of drawings.

THIRD-ANGLE PROJECTION—Multiview projection commonly used in the United States. The top view projects above the front view, and the sides and bottom automatically project into their proper positions.

TITLE BLOCK—Block drawn in the lower right corner of a drawing; it should contain all the information necessary to identify the drawing.

TRACING PAPER—High-grade, white, transparent paper that takes pencil well; used when reproductions are to be made of drawings; also known as tracing vellum.

TRACING VELLUM—See TRACING PAPER.

TRANSIT STATION—A marked point over which the instrument is, has been, or will be, accurately positioned for use.

TRANSPORTED SOIL—A soil that has been moved by natural forces to a location other than its origin.

TRAVERSE THE INSTRUMENT—Rotate the instrument about its vertical axis; that is, turn the instrument in azimuth.

TRIANGLE—A polygon of three sides.

TRIANGULAR PRISM—A solid figure whose base is a triangle.

TRIGONOMETRY—That branch of mathematics that deals with certain constant relationships that exist in triangles and with methods of applying these relationships to compute unknown values from known values.

TRAPEZOID—A quadrilateral with only one pair of opposite sides parallel, the other pair being not parallel.

TRAPEZIUM—A quadrilateral with no sides parallel.

TRIM LINES—Lightly drawn lines used as guides to trim a drawing to standard size.

VERTICAL ANGLE—An angle between two intersecting lines in a vertical plane. It should be understood that one line lies on the horizontal plane, and the angle originates from the intersection of the two planes.

VERTICAL CONTROL—Established bench marks.

VERTICAL LINE—A line that lies in the vertical plane and is perpendicular to the plane of the horizon, such as the direction of a plumb line.

VERTICAL PLANE—A plane that is perpendicular to the horizontal plane.

VIEWING PLANE LINES—Thick, heavy lines used to indicate the plane or planes from which a surface or several surfaces are viewed.

VISIBLE LINES—Solid, thick lines indicating the edges of the object being drawn.

WATER-CEMENT RATIO—The ratio of the amount of water, exclusive only of that absorbed by the aggregates, to the amount of cement in a concrete mixture. This ratio is variously stated as follows: (1) by bulk volume of cement (assuming cement to weigh 94 lb per cu ft); (2) by absolute volume of cement; (3) by weight; and (4) in terms of gallons of water per 94-lb sack of cement.

APPENDIX II

ENGINEERING TECHNICAL LIBRARY

The technical library is setup and maintained according to guidelines set forth in the COMCBPAC/LANT 5070 series instructions. These instructions contain a list of both civilian and military publications that are pertinent to most normal construction. It is the responsibility of the Engineering Aid to ensure that the library contains up-to-date publications. This is done by checking the contents of the library against the latest instructions. As the instructions give only the title and not the year of the publication, they must be compared with (1) the NAVFAC *Documentation Index,* P-349, a list of current publications available through the Navy, and (2) the Department of the Army Pamphlet 310-4, *Military Publications,* a list of current Army Technical Manuals (TMs). If special construction is anticipated, it may be necessary to add publications not included in the COMCBPAC/LANT 5070 instructions.

The following is a suggested list of civilian publications that could be added to the technical library:

AASHTO *Standard Method of Tests,* American Association of State Highway and Transportation Officials

Annual Book of ASTM Standards, American Society of Testing Materials

Architectural and Building Trades Dictionary, American Technical Society

Architectural Drawing and Light Construction, Muller

Architectural Graphic Standards, Ramsey and Sleeper

Concrete Topics, Kaiser Cement and Gypsum Corporation

Construction Form work, Design and Erection, Boley

Design and Construction of Aspha[t Pavements, Rogers and Wallace

Design and Control of Concrete Mixtures, Koswatka and Panarese

Handbook of Standard Structural Details for Buildings, Ketchum

Mechanical and Electrical Systems in Construction and Architecture, Dagostino

Placing Reinforcing Steel, Concrete Reinforcing Steel Institute

Principles and Practices of Heavy Construction, Smith

Reinforcing Bar Detailing, Concrete Reinforcing Steel Institute

Route Surveys and Design, Hickerson

Surveying, Legault, McMaster, and Marlette

Surveying: Theory and Practice, Davis, Foote, and Kelley

Elementary Surveying, Brinker and Wolf

APPENDIX III

USEFUL MATHEMATICAL SYMBOLS, FORMULAS, AND CONSTANTS

A. MATHEMATICAL SYMBOLS

SYMBOL	NAME OR MEANING	SYMBOL	NAME OR MEANING
+	Addition or positive value	√	Square root symbol
-	Subtraction or negative value	$\sqrt{\quad}$	Square root symbol with vinculum. Vinculum is made long enough to cover all factors of the number whose square root is to be taken.
±	Positive or negative value	$\sqrt[n]{\ }$	Radical symbol. Letter n represents a number indicating which root is to be taken.
·	Multiplication dot (Centered; not to be mistaken for decimal point.)	i or j	Imaginary unit; operator j for electronics; represents $\sqrt{-1}$.
x	Multiplication symbol	∞	Infinity symbol
( )	Parentheses (Grouping symbols)	. . .	Ellipsis. Used in series of numbers in which successive numbers are predictable by their conformance to a pattern; meaning is approximated by "etc."
[ ]	Brackets (Grouping symbols)	$\log_a N$	Logarithm of N to the base a.
{ }	Braces (Grouping symbols)	log N	Logarithm of N to the base 10. (understood)
——	Vinculum (overscore) (Grouping symbols)	ln N	Natural or Napierian logarithm of N.
%	Percent	e	Base of the natural or Napierian logarithm system=2.71828 (Approx.)
÷	Division symbol	|X|	Absolute value of X.
:	Ratio symbol	π	Pi. The ratio of the circumference of any circle to its diameter. Approximate numerical value is 22/7.
: :	Proportion symbol	∴	Therefore
=	Equality symbol	∟ or ∢	Angle
≠	"Not equal" symbol		
<	Less than		
≤	Less than or equal to		
>	Greater than		
≥	Greater than or equal to		
∝	"Varies directly as" or "is proportional to" (Not to be mistaken for Greek alpha (α).)		

B. WEIGHTS AND MEASURES

Dry Measure

2 cups = 1 pint (pt)

2 pints = 1 quart (qt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Liquid Measure

3 teapoons (tsp) = 1 tablespoon (tbsp)

16 tablespoons = 1 cup

2 cups = 1 pint

16 fluid ounces (OZ) = 1 pint

2 pints = 1 quart

4 quarts = 1 gallon

31.5 gallons = 1 barrel (bbl)

231 cubic inches = 1 gallon

7.48 gallons = 1 cubic foot (CU ft)

Weight

16 ounces = 1 pound (lb)

2,000 pounds = 1 short ton (T)

2,240 pounds = 1 long ton

Distance

12 inches = 1 foot (ft)

3 feet = 1 yard (yd)

5-1/2 yards = 1 rod (rd)

16-1/2 feet = 1 rod

1,760 yards = 1 statute mile (mi)

5,280 feet = 1 statute mile

Area

144 square inches = 1 square foot (sq ft)

9 square feet = 1 square yd (sq yd)

30- 1/4 square yards = 1 square rod

160 square rods = 1 acre (A)

640 acres = 1 square mile (sq mi)

Volume

1,728 cubic inches = 1 cubic foot

27 cubic feet = 1 cubic yard (CU yd)

Counting Units

12 units = 1 dozen (doz)

12 dozens = 1 gross

144 units = 1 gross

24 sheets = 1 quire

480 sheets = 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces

1 gallon of water weighs 8-1/3 pounds (approx)

1 cubic foot = 7.48 gallons

1 inch = 2.54 centimeters

1 foot = 30.4801 centimeters

1 meter = 39.37 inches

1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)

1 nautical mile = 6,080 feet (approx)

1 fathom = 6 feet

1 shot of chain = 15 fathoms

Feet	× .00019	= miles
Feet	× 1.5	= links
Yards	× .9144	= meters
Yards	× .0006	= miles
Links	× .22	= yards
Links	× .66	= feet
Rods	× 25	= links
Rods	× 16.5	= feet
Square inches	× .007	= square feet
Square inches	× 6.451	= square centimeters
Square centimeters	× 0.1550	= square inches
Square feet	× .111	= square yards
Square feet	× .0929	= centares (square meters)
Square feet	× 929	= square centimeters
Square feet	× 144	= square inches
Square yards	× .0002067	= acres
Acres	× 4840.0	= square yards
Square yards	× 1,296	= square inches
Square yards	× 9	= square feet
Square yards	× 0.8362	= centares
Square miles, statute	× 640	= acres
Square miles, statute	× 25,900	= ares
Square miles, statute	× 259	= hectares
Square miles, statute	× 2.590	= square kilometers
Cubic inches	× .00058	= cubic feet

Cubic feet	× .03704	= cubic yards
Tons (metric)	× 2,204.6	= pounds (avoirdupois)
Tons (metric)	× 1,000	= kilograms
Tons (short)	× 2,000	= pounds (avoirdupois)
Tons (short)	× 0.9072	= metric tons
Tons (long)	× 2,240	= pounds (avoirdupois)
Tons (long)	× 1.016	= metric tons
π	= 3.141592654	
1 radian	= $180°/\pi$ = 57.2957790° = approx. 57°17′44.8″	
1 radian	= 1018.6 miles	
1 degree	= 0.0174533 radian	
1 minute	= 0.0002909 radian	
1 mil	= 0.0009817 radian	
π radians	= 180°	
$\pi/2$ radians	= 90°	
Radius	= arc of 57.2957790°	

Arc of 1° (radius = 1) = .017453292

Arc of 1′ (radius = 1) = .000290888

Arc of 1″ (radius = 1) = .000004848

Area of sector of circle = 1/2 Lr (L = length of arc; r = radius)

Area of segment of parabola = 2/3 cm (c = chord; m = mid. ord.)

Area of segment of circle = approx. 2/3 cm

Arc − chord length = 0.02 foot per 11 1/2 miles

Curvature of earth's surface = approx. 0.667 foot per mile

C. GEOMETRIC FORMULAS

(Area, Perimeter, Volume, Surface Area)

In the geometric formulas listed in this appendix the following letter designations are used except as noted otherwise:

a, b, c, d and e denote lengths of sides

h denotes perpendicular height

s denotes slant height

A denotes area (plane figures)

C denotes circumference

D denotes diameter

I denotes interior angles

L denotes lateral area (lateral area)

P denotes perimeter

R denotes radius

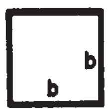
S denotes surface area (solid figures)

V denotes volume

C. GEOMETRIC FORMULAS—CONTINUED

TRIANGLES

$$A = \frac{bh}{2}$$



SQUARE

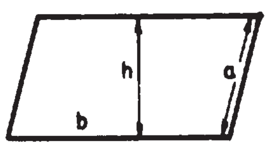
$$A = b^2$$

$$P = 4b$$

RECTANGLE

$$A = bh$$

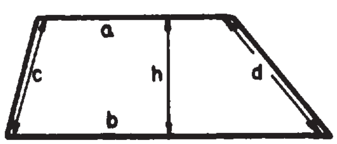
$$P = 2b + 2h$$



PARALLELOGRAM

$$A = bh$$

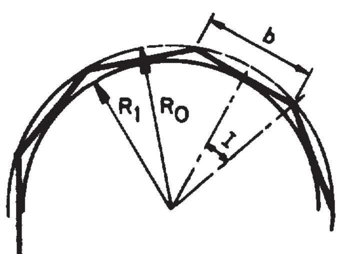
$$P = 2a + 2b$$



TRAPEZOID

$$A = \frac{h\,(a+b)}{2}$$

$$P = a + b + c + d$$

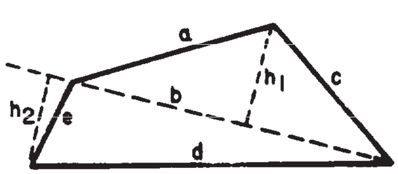


REGULAR POLYGON

$$A = \frac{nb\ R_1}{2}$$ WHERE n DENOTES THE NUMBER OF SIDES

$$b = 2\sqrt{R_O^2 - R_1^2}$$

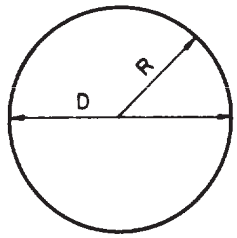
$$R_O = \frac{b}{2\ \text{TAN}\ I}, \quad R_1 = \frac{b}{2\ \text{SIN}\ I}$$



TRAPEZIUM

$$A = \frac{b\ (h_1 + h_2)}{2}$$ WHERE b IS A COMMON BASE

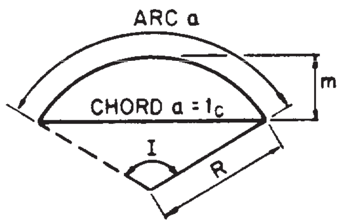
$$P = a + c + d + e$$



CIRCLE

$A = \pi R^2$, $A = \frac{1}{4}\pi D^2$

$C = 2\pi R$, $C = \pi D$



CIRCULAR SEGMENT

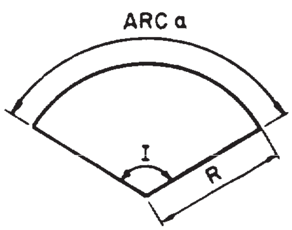
$A = \dfrac{a(R - l_c)(R - m)}{2}$

$l_c = 2\sqrt{2mR - m^2}$

$l_c = 2R \sin \dfrac{I}{2}$

$a = \dfrac{\pi R I}{180^\circ}$, $a = 0.0175RI$ (APPROX.)

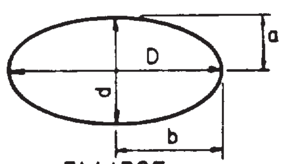
WHERE a DENOTES LENGTH OF ARC
l_c DENOTES CHORD LENGTH
m DENOTES MIDDLE ORDINATE



CIRCULAR SECTOR

$A = \dfrac{aR}{2}$, $A = \dfrac{\pi R^2 I}{360}$, $A = 0.0087R^2 I$ (APPROX.)

a = (SEE FORMULAS FOR CIRCULAR SEGMENT)



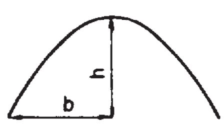
ELLIPSE

$A = \dfrac{\pi D d}{4}$

WHERE D = THE MAJOR AXIS
d = THE MINOR AXIS

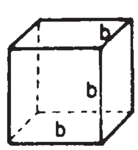
$P = \pi\sqrt{2(a^2 + b^2)}$ (APPROX.)

WHERE
$a = \frac{1}{2}$ THE MINOR AXIS
$b = \frac{1}{2}$ THE MAJOR AXIS



PARABOLA

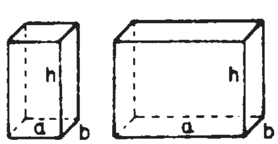
$A = \dfrac{4hb}{3}$



CUBE

$V = b^3$

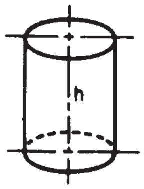
$S = 6b^2$



RIGHT RECTANGULAR PRISMS

$V = abh$

$S = 2ab + 2ah + 2bh$



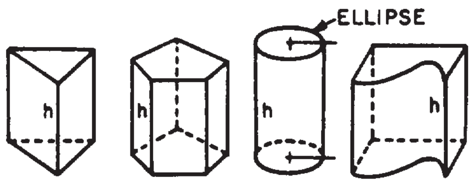
RIGHT CIRCULAR

$V = \pi R^2 h$

$L = 2\pi R h$

$S = 2\pi R^2 + 2\pi R h$

S = 2 (AREA OF BASE) + (CIRCUMFERENCE X HEIGHT)

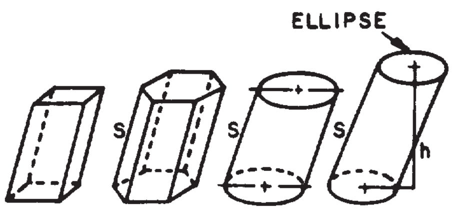


ANY RIGHT PRISM OR CYLINDER
REGULAR OR IRREGULAR

V = AREA OF THE BASE X THE HEIGHT

L = PERIMETER OF BASE X HEIGHT

S = 2 (AREA OF BASE) + (PERIMETER OF BASE X HEIGHT)



ANY OBLIQUE PRISM OR CYLINDER
REGULAR OR IRREGULAR

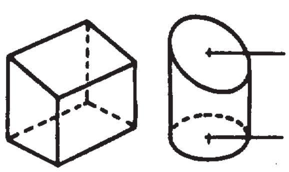
V = AREA OF BASE X HEIGHT

L = PERIMETER X SLANT HEIGHT

S = 2 (AREA OF BASE) + (PERIMETER OF BASE X SLANT HEIGHT)

WHERE HEIGHT = PERPENDICULAR DISTANCE BETWEEN BASES

SLANT HEIGHT = DISTANCE ALONG SLANTED SURFACE BETWEEN BASES



ANY REGULAR RIGHT PRISM OR
CYLINDER WITH NONPARALLEL
BASES

V = COMPUTE VOLUME THE SAME AS IF BASES ARE PARALLEL BUT LET THE HEIGHT EQUAL THE AVERAGE PERPENDICULAR DISTANCES BETWEEN BASES

NOTE: PRISMS MUST HAVE AN EVEN NUMBER OF SIDES (2,4,6,...) THERE IS NO SIMPLE METHOD OF COMPUTING THE VOLUME OF PRISMS WITH AN ODD NUMBER OF SIDES OR FACES.

AREAS – (CYLINDERS AND EVEN-SIDED PRISMS)

L = PERIMETER OF BASE X AVERAGE HEIGHT

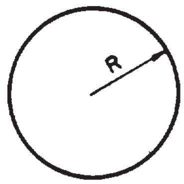
(ODD-SIDED PRISMS)

L = DIVIDE EACH SIDE INTO SIMPLE GEOMETRIC FIGURES COMPUTE AREA AND TOTAL

S = LATERAL AREA + AREA OF BASES

NOTE: THE AREA OF THE OBLIQUE BASE MAY NOT BE COMPUTABLE BY A SIMPLE METHOD.

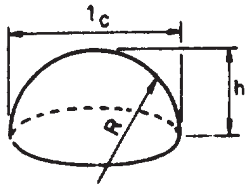
C. GEOMETRIC FORMULAS—CONTINUED



SPHERE

$V = \frac{4\pi R^3}{3}$, $V = 0.5236D^3$ (APPROX.)

$S = 4\pi R^2$, $S = \pi D^2$

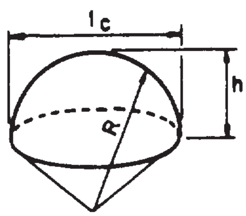


SEGMENT OF SPHERE

$V = \frac{\pi h^2(3R-h)}{3}$

$S = 2\pi Rh$ (NOT INCLUDING CIRCULAR BASE)

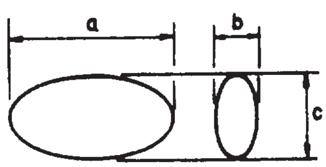
$S = 2\pi Rh + \frac{l_c^2}{4}$ (TOTAL) WHERE l_c = CHORD LENGTH



SECTOR OF SPHERE

$V = \frac{2\pi R^2 h}{}$

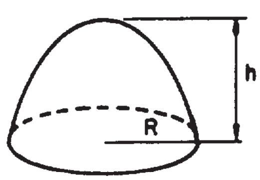
$S = \frac{\pi R\,(4h + l_c)}{2}$ WHERE l_c = CHORD LENGTH



ELLIPSOID

$V = \frac{\pi abc}{6}$

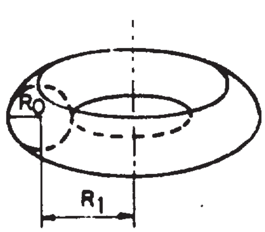
SURFACE AREA - NO SIMPLE METHOD OF COMPUTATION



PARABOLOID OF REVOLUTION

$V = \frac{\pi R^2 h}{2}$

SURFACE AREA - NO SIMPLE METHOD OF COMPUTATION

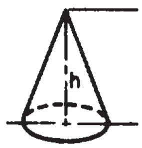


CIRCULAR RING (TORUS)

$V = 2\pi^2 R_0^2 R_1$

$S = 4\pi^2 R_0 R_1$

C. GEOMETRIC FORMULAS–CONTINUED

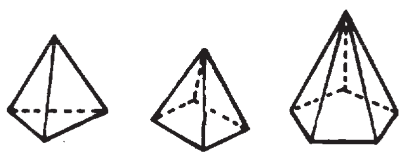


RIGHT CIRCULAR CONE

$$V = \frac{\pi R^2 h}{3}$$

$$L = s\pi R$$

$$S = s\pi R + \pi R^2 \quad \text{(TOTAL)}$$

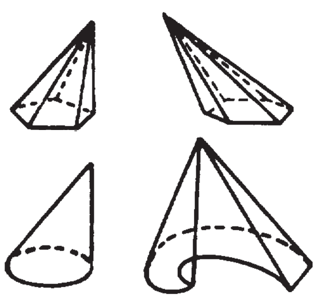


ANY REGULAR RIGHT PYRAMID

$V = \frac{1}{3}$ HEIGHT X AREA OF THE BASE

$L = \frac{1}{2}$ SLANT HEIGHT X PERIMETER OF THE BASE

NOTE: TO OBTAIN TOTAL SURFACE, ADD AREA OF BASE TO GIVEN SURFACE FORMULA.

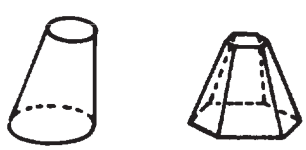


ANY OBLIQUE PYRAMID OR CONE
(REGULAR OR IRREGULAR)

$V = \frac{1}{3}$ HEIGHT X AREA OF THE BASE

WHERE THE HEIGHT IS THE PERPENDICULAR DISTANCE FROM THE BASE TO THE VERTEX

L, S, – NO SIMPLE METHOD OF COMPUTATION

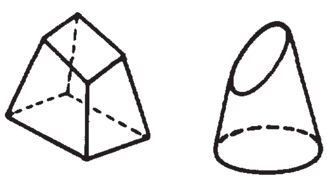


FRUSTUM OF ANY PYRAMID OR CONE

IN ANY FRUSTUM THE BASES ARE PARALLEL:

1. TOTAL HEIGHT OF FIGURE MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
2. HEIGHT OF FRUSTUM MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
3. COMPUTE VOLUME OR SURFACE AREA OF TOTAL FIGURE
4. COMPUTE VOLUME OR SURFACE AREA OF PORTION REMOVED
5. SUBTRACT REMOVED PORTION FROM TOTAL
6. ADD AREA OF BOTH BASES TO OBTAIN TOTAL SURFACE AREA

C. GEOMETRIC FORMULAS—CONTINUED



TRUNCATED PORTION OF ANY PYRAMID OR CONE

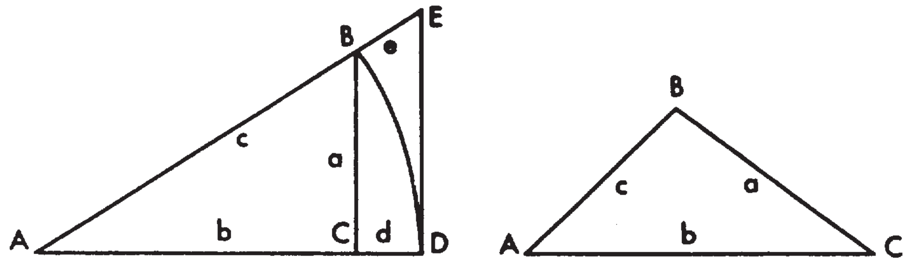
IN ANY TRUNCATED FIGURE THE BASES ARE NOT PARALLEL:

1. TOTAL HEIGHT OF FIGURE MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
2. AVERAGE HEIGHT OF TRUNCATED FIGURE MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
3. COMPUTE VOLUME OR SURFACE AREA OF TOTAL FIGURE
4. COMPUTE VOLUME OR SURFACE AREA OF PORTION REMOVED (HEIGHT = HEIGHT OF TOTAL FIGURE MINUS THE AVERAGE HEIGHT OF THE TRUNCATED FIGURE)
5. SUBTRACT REMOVED PORTION FROM TOTAL
6. ADD AREA OF BOTH BASES (IF THEY ARE OBTAINABLE) TO OBTAIN TOTAL AREA

NOTE: TRUNCATED PYRAMIDS MUST HAVE AN EVEN NUMBER OF SIDES (2, 4, 6, ... etc.) TO BE COMPUTED.
OBLIQUE TRUNCATED PYRAMIDS AND CONES ARE TREATED IN THE SAME MANNER AS FULL OBLIQUE PYRAMIDS AND CONES

D. RIGHT AND OBLIQUE TRIANGLE FORMULAS

1. Solution of triangles



SOLUTION OF RIGHT TRIANGLES

1. $\sin A = \frac{a}{c} = \cos B$

2. $\cos A = \frac{b}{c} = \sin B$

3. $\tan A = \frac{a}{b} = \cot B$

4. $\cot A = \frac{b}{a} = \tan B$

5. $\sec A = \frac{c}{b} = \text{cosec } B$

6. $\text{cosec } A = \frac{c}{a} = \sec B$

7. $\text{vers } A = \frac{c-b}{c} = \frac{d}{c}$

8. $\text{exsec } A = \frac{e}{c}$

9. $a = c \sin A = b \tan A = c \cos B = b \cot B = \sqrt{(c+b)(c-b)}$

10. $b = c \cos A = a \cot A = c \sin B = a \tan B = \sqrt{(c+a)(c-a)}$

11. $d = c \text{ vers } A$

12. $e = c \text{ exsec } A$

13. $c = \frac{a}{\cos B} = \frac{b}{\sin B} = \frac{a}{\sin A} = \frac{b}{\cos A} = \frac{d}{\text{vers } A} = \frac{e}{\text{exsec } A}$

SOLUTION OF OBLIQUE TRIANGLES

Given	Sought	Formulas
14. A, B, a	b, c	$b = \frac{a}{\sin A} \cdot \sin B.$ $\quad c = \frac{a}{\sin A} \sin (A + B)$
15. A, a, b	B, c	$\sin B = \frac{\sin A}{a}\ b.$ $\quad c = \frac{a}{\sin a} \cdot \sin C.$
16. C, a, b	A − B	$\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$
17. a, b, c	A	Let $s = \frac{1}{2}(a + b + c)$; $\sin \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}}$
18.		$\cos \frac{1}{2} A = \sqrt{\frac{s(s-a)}{bc}}$; $\tan \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$
19.		$\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)};}{bc}$
20.		$\text{vers } A = \frac{2(s-b)(s-c)}{bc}$
21.	area	$\text{area} = \sqrt{s(s-a)(s-b)(s-c)}$
22. A, B, C, a	area	$\text{area} = \frac{a^2 \sin B \cdot \sin C}{2 \sin A}$
23. C, a, b	area	$\text{area} = \frac{1}{2} a b \sin C.$

D. RIGHT AND OBLIQUE TRIANGLE FORMULAS—CONTINUED

	0°	30°	45°	60°	90°	120°	135°	150°	180°	270°
Sine	0	$\frac{1}{2}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}\sqrt{3}$	1	$\frac{1}{2}\sqrt{3}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}$	0	-1
Cosine	1	$\frac{1}{2}\sqrt{3}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}$	0	$-\frac{1}{2}$	$-\frac{1}{2}\sqrt{2}$	$-\frac{1}{2}\sqrt{3}$	-1	0
Tangent	0	$\frac{1}{3}\sqrt{3}$	1	$\sqrt{3}$	$\pm\infty$	$-\sqrt{3}$	-1	$-\frac{1}{3}\sqrt{3}$	0	$\pm\infty$
Cotangent	$\pm\infty$	$\sqrt{3}$	1	$\frac{1}{3}\sqrt{3}$	0	$-\frac{1}{3}\sqrt{3}$	-1	$-\sqrt{3}$	$\pm\infty$	0
Secant	1	$\frac{2}{3}\sqrt{3}$	$\sqrt{2}$	2	$\pm\infty$	-2	$-\sqrt{2}$	$-\frac{2}{3}\sqrt{3}$	-1	$\pm\infty$
Cosecant	$\pm\infty$	2	$\sqrt{2}$	$\frac{2}{3}\sqrt{3}$	1	$\frac{2}{3}\sqrt{3}$	$\sqrt{2}$	2	$\pm\infty$	-1

a. Trigonometrical formulas.—The six most usual trigonometrical functions are the ratios defined for a right-angled triangle, as follows:

$$\text{sine} = \frac{\text{opposite side}}{\text{hypotenuse}}$$

$$\text{cosine} = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

$$\text{tangent} = \frac{\text{opposite side}}{\text{adjacent side}}$$

$$\text{cotangent} = \frac{\text{adjacent side}}{\text{opposite side}}$$

$$\text{secant} = \frac{\text{hypotenuse}}{\text{adjacent side}}$$

$$\text{cosecant} = \frac{\text{hypotenuse}}{\text{opposite side}}$$

Right-angled triangles can be solved by the above and oblique triangles may be solved by the use of the additional relations for any triangle

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$\frac{a - b}{a + b} = \frac{\tan \frac{1}{2}(A - B)}{\tan \frac{1}{2}(A + B)}$$

and the group

$$a^2 = b^2 + c^2 - 2bc \cos A$$
$$b^2 = a^2 + c^2 - 2ac \cos B$$
$$c^2 = a^2 + b^2 - 2ab \cos C$$

Where A, B, and C are the angles and a, b, and c are the sides opposite to these angles, respectively.

b. Fundamental relations.

$$\sin A = \frac{1}{\csc A};\ \cos A = \frac{1}{\sec A};\ \tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A}$$

$$\csc A = \frac{1}{\sin A};\ \sec A = \frac{1}{\cos A};\ \cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A}$$

$$\sin^2 A + \cos^2 A = 1;\ \sec^2 A - \tan^2 A = 1;\ \csc^2 A - \cot^2 A = 1$$

c. Functions of multiple angles.

$$\sin 2A = 2 \sin A \cos A$$
$$\cos 2A = 2 \cos^2 A - 1 = 1 - 2 \sin^2 A = \cos^2 A - \sin^2 A$$
$$\sin 3A = 3 \sin A - 4 \sin^3 A;$$
$$\cos 3A = 4 \cos^3 A - 3 \cos A$$

d. Functions of half angles.

$$\sin\frac{A}{2} = \pm\sqrt{\frac{1-\cos A}{2}} \qquad \cos\frac{A}{2} = \pm\sqrt{\frac{1+\cos A}{2}}$$

$$\tan\frac{A}{2} = \pm\frac{1-\cos A}{\sin A} = \frac{\sin A}{1+\cos A} = \pm\sqrt{\frac{1-\cos A}{1+\cos A}}$$

Powers of functions.

$\sin^2 A = \frac{1}{2}(1 - \cos 2A)$; $\qquad \cos^2 A = \frac{1}{2}(1 + \cos 2A)$

$\sin^3 A = \frac{1}{4}(3 \sin A - \sin 3A)$; $A = \frac{1}{4}(\cos 3A + 3 \cos A)$

e. Sum and difference of angles.

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

f. Sums, differences, and products of functions.

$$\sin A \pm \sin B = 2 \sin \tfrac{1}{2}(A \pm B) \cos \tfrac{1}{2}(A \mp B)$$

$$\cos A + \cos B = 2 \cos \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$$

$$\cos A - \cos B = -2 \sin \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$$

$$\tan A \pm \tan B = \frac{\sin(A \pm B)}{\cos A \cos B}$$

$$\sin^2 A - \sin^2 B = \sin(A + B) \sin(A - B)$$

$$\cos^2 A - \cos^2 B = -\sin(A + B) \sin(A - B)$$

$$\cos^2 A - \sin^2 B = \cos(A + B) \cos(A - B)$$

$$\sin A \sin B = \tfrac{1}{2}\cos(A - B) - \tfrac{1}{2}\cos(A + B)$$

$$\cos A \cos B = \tfrac{1}{2}\cos(A - B) + \tfrac{1}{2}\cos(A + B)$$

$$\sin A \cos B = \tfrac{1}{2}\sin(A + B) + \tfrac{1}{2}\sin(A - B)$$

The relations for angles greater than 90° are shown in the following tabulation where x represents an angle in the first quadrant where all the functions are positive.

angle	sine	cosine	tangent	cotangent
x	+ sin x	+ cos x	+ tan x	+ cot x
90° + x	+ cos x	− sin x	− cot x	− tan x
180° + x	− sin x	− cos x	+ tan x	+ cot x
270° + x	− cos x	+ sin x	− cot x	− tan x

D. RIGHT AND OBLIQUE TRIANGLE FiORMULAS—CONTINUED

2. General formulas

24. $\sin A = 2 \sin \frac{1}{2} A \cos \frac{1}{2} A = \sqrt{1 - \cos^2 A} = \tan A \cos A$
25. $\cos A = 2 \cos^2 \frac{1}{2} A - 1 = 1 - 2 \sin^2 \frac{1}{2} A = \cos^2 \frac{1}{2} A - \sin^2 \frac{1}{2} A$
26. $\tan A = \dfrac{\sin A}{\cos A} = \dfrac{\sin 2A}{1 + \cos 2A}$
27. $\cot A = \dfrac{\cos A}{\sin A} = \dfrac{\sin 2A}{1 - \cos 2A} = \dfrac{\sin 2A}{\text{vers } 2A}$
28. $\text{vers } A = 1 - \cos A = \sin A \tan \frac{1}{2} A = 2 \sin^2 \frac{1}{2} A$
29. $\text{exsec } A = \sec A - 1 = \tan A \tan \frac{1}{2} A = \dfrac{\text{vers } A}{\cos A}$
30. $\sin 2A = 2 \sin A \cos A$
31. $\cos 2A = 2 \cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2 \sin^2 A$
32. $\tan 2A = \dfrac{2 \tan A}{1 - \tan^2 A}$
33. $\cot 2A = \dfrac{\cot^2 A - 1}{2 \cot A}$
34. $\text{vers } 2A = 2 \sin^2 A = 2 \sin A \cos A \tan A$
35. $\text{exsec } 2A = \dfrac{2 \tan^2 A}{1 - \tan^2 A}$
36. $\sin^2 A + \cos^2 A = 1$
37. $\sin (A \pm B) = \sin A \,.\, \cos B \pm \sin B \,.\, \cos A$
38. $\cos (A \pm B) = \cos A \,.\, \cos B \pm \sin A \,.\, \sin B$
39. $\sin A + \sin B = 2 \sin \frac{1}{2} (A + B) \cos \frac{1}{2} (A - B)$
40. $\sin A - \sin B = 2 \cos \frac{1}{2} (A + B) \sin \frac{1}{2} (A - B)$
41. $\cos A + \cos B = 2 \cos \frac{1}{2} (A + B) \cos \frac{1}{2} (A - B)$
42. $\cos B - \cos A = 2 \sin \frac{1}{2} (A + B) \sin \frac{1}{2} (A - B)$
43. $\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin (A + B) \sin (A - B)$
44. $\cos^2 A - \sin^2 B = \cos (A + B) \cos (A - B)$
45. $\tan A + \tan B = \dfrac{\sin (A + B)}{\cos A \,.\, \cos B}$
46. $\tan A - \tan B = \dfrac{\sin (A - B)}{\cos A \,.\, \cos B}$
47. $\sin 3A = 3 \sin A - 4 \sin^3 A$
48. $\cos 3A = 4 \cos^3 A - 3 \cos A$
49. $\sin \dfrac{A}{2} = \pm \sqrt{\dfrac{1 - \cos A}{2}}$
50. $\cos \dfrac{A}{2} = \pm \sqrt{\dfrac{1 + \cos A}{2}}$
51. $\tan \dfrac{A}{2} = \pm \dfrac{1 - \cos A}{\sin A} = \dfrac{\sin A}{1 + \cos A} = \pm \sqrt{\dfrac{1 - \cos A}{1 + \cos A}}$
52. $\sin^2 A = \frac{1}{2} (1 - \cos 2A)$
53. $\cos^2 A = \frac{1}{2} (1 + \cos 2A)$
54. $\sin^3 A = \frac{1}{4} (3 \sin A - \sin 3A)$
55. $\cos^3 A = \frac{1}{4} (\cos 3A + 3 \cos A)$
56. $\sin A \sin B = \frac{1}{2} \cos (A - B) - \frac{1}{2} \cos (A + B)$
57. $\cos A \cos B = \frac{1}{2} \cos (A - B) + \frac{1}{2} \cos (A + B)$
58. $\sin A \cos B = \frac{1}{2} \sin (A + B) + \frac{1}{2} \sin A - B$

E. NATURAL SINES AND COSINES

MIN	0°		1°		2°		3°		4°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0000000	1.00000	0.01745	0.99985	0.03490	0.99939	0.05234	0.99863	0.06976	0.99756	60
1	0.00029	1.00000	0.01774	0.99984	0.03519	0.99938	0.05263	0.99861	0.07005	0.99754	59
2	0.00058	1.00000	0.01803	0.99984	0.03548	0.99937	0.05292	0.99860	0.07034	0.99752	58
3	0.00087	1.00000	0.01832	0.99983	0.03577	0.99936	0.05321	0.99858	0.07063	0.99750	57
4	0.00116	1.00000	0.01862	0.99983	0.03606	0.99935	0.05350	0.99857	0.07092	0.99748	56
5	0.00145	1.00000	0.01891	0.99982	0.03635	0.99934	0.05379	0.99855	0.07121	0.99746	55
6	0.00175	1.00000	0.01920	0.99982	0.03664	0.99933	0.05408	0.99854	0.07150	0.99744	54
7	0.00204	1.00000	0.01949	0.99981	0.03693	0.99932	0.05437	0.99852	0.07179	0.99742	53
8	0.00233	1.00000	0.01978	0.99980	0.03723	0.99931	0.05466	0.99851	0.07208	0.99740	52
9	0.00262	1.00000	0.02007	0.99980	0.03752	0.99930	0.05495	0.99849	0.07237	0.99738	51
10	0.00291	1.00000	0.02036	0.99979	0.03781	0.99929	0.05524	0.99847	0.07266	0.99736	50
11	0.00320	0.99999	0.02065	0.99979	0.03810	0.99927	0.05553	0.99846	0.07295	0.99734	49
12	0.00349	0.99999	0.02094	0.99978	0.03839	0.99926	0.05582	0.99844	0.07324	0.99731	48
13	0.00378	0.99999	0.02123	0.99977	0.03868	0.99925	0.05611	0.99842	0.07353	0.99729	47
14	0.00407	0.99999	0.02152	0.99977	0.03897	0.99924	0.05640	0.99841	0.07382	0.99727	46
15	0.00436	0.99999	0.02181	0.99976	0.03926	0.99923	0.05669	0.99839	0.07411	0.99725	45
16	0.00465	0.99999	0.02211	0.99976	0.03955	0.99922	0.05698	0.99838	0.07440	0.99723	44
17	0.00495	0.99999	0.02240	0.99975	0.03984	0.99921	0.05727	0.99836	0.07469	0.99721	43
18	0.00524	0.99999	0.02269	0.99974	0.04013	0.99919	0.05756	0.99834	0.07498	0.99719	42
19	0.00553	0.99998	0.02298	0.99974	0.04042	0.99918	0.05785	0.99833	0.07527	0.99716	41
20	0.00582	0.99998	0.02327	0.99973	0.04071	0.99917	0.05814	0.99831	0.07556	0.99714	40
21	0.00611	0.99998	0.02356	0.99972	0.04100	0.99916	0.05844	0.99829	0.07585	0.99712	39
22	0.00640	0.99998	0.02385	0.99972	0.04129	0.99915	0.05873	0.99827	0.07614	0.99710	38
23	0.00669	0.99998	0.02414	0.99971	0.04159	0.99913	0.05902	0.99826	0.07643	0.99708	37
24	0.00698	0.99998	0.02443	0.99970	0.04188	0.99912	0.05931	0.99824	0.07672	0.99705	36
25	0.00727	0.99997	0.02472	0.99969	0.04217	0.99911	0.05960	0.99822	0.07701	0.99703	35
26	0.00756	0.99997	0.02501	0.99969	0.04246	0.99910	0.05989	0.99821	0.07730	0.99701	34
27	0.00785	0.99997	0.02530	0.99968	0.04275	0.99909	0.06018	0.99819	0.07759	0.99699	33
28	0.00814	0.99997	0.02560	0.99967	0.04304	0.99907	0.06047	0.99817	0.07788	0.99696	32
29	0.00844	0.99996	0.02589	0.99966	0.04333	0.99906	0.06076	0.99815	0.07817	0.99694	31
30	0.00873	0.99996	0.02618	0.99966	0.04362	0.99905	0.06105	0.99813	0.07846	0.99692	30
31	0.00902	0.99996	0.02647	0.99965	0.04391	0.99904	0.06134	0.99812	0.07875	0.99689	29
32	0.00931	0.99996	0.02676	0.99964	0.04420	0.99902	0.06163	0.99810	0.07904	0.99687	28
33	0.00960	0.99995	0.02705	0.99963	0.04449	0.99901	0.06192	0.99808	0.07933	0.99685	27
34	0.00989	0.99995	0.02734	0.99963	0.04478	0.99900	0.06221	0.99806	0.07962	0.99683	26
35	0.01018	0.99995	0.02763	0.99962	0.04507	0.99898	0.06250	0.99804	0.07991	0.99680	25
36	0.01047	0.99995	0.02792	0.99961	0.04536	0.99897	0.06279	0.99803	0.08020	0.99678	24
37	0.01076	0.99994	0.02821	0.99960	0.04565	0.99896	0.06308	0.99801	0.08049	0.99676	23
38	0.01105	0.99994	0.02850	0.99959	0.04594	0.99894	0.06337	0.99799	0.08078	0.99673	22
39	0.01134	0.99994	0.02879	0.99959	0.04623	0.99893	0.06366	0.99797	0.08107	0.99671	21
40	0.01164	0.99993	0.02908	0.99958	0.04653	0.99892	0.06395	0.99795	0.08136	0.99668	20
41	0.01193	0.99993	0.02938	0.99957	0.04682	0.99890	0.06424	0.99793	0.08165	0.99666	19
42	0.01222	0.99993	0.02967	0.99956	0.04711	0.99889	0.06453	0.99792	0.08194	0.99664	18
43	0.01251	0.99992	0.02996	0.99955	0.04740	0.99888	0.06482	0.99790	0.08223	0.99661	17
44	0.01280	0.99992	0.03025	0.99954	0.04769	0.99886	0.06511	0.99788	0.08252	0.99659	16
45	0.01309	0.99991	0.03054	0.99953	0.04798	0.99885	0.06540	0.99786	0.08281	0.99657	15
46	0.01338	0.99991	0.03083	0.99952	0.04827	0.99883	0.06569	0.99784	0.08310	0.99654	14
47	0.01367	0.99991	0.03112	0.99952	0.04856	0.99882	0.06598	0.99782	0.08339	0.99652	13
48	0.01396	0.99990	0.03141	0.99951	0.04885	0.99881	0.06627	0.99780	0.08368	0.99649	12
49	0.01425	0.99990	0.03170	0.99950	0.04914	0.99879	0.06656	0.99778	0.08397	0.99647	11
50	0.01454	0.99989	0.03199	0.99949	0.04943	0.99878	0.06685	0.99776	0.08426	0.99644	10
51	0.01483	0.99989	0.03228	0.99948	0.04972	0.99876	0.06714	0.99774	0.08455	0.99642	9
52	0.01513	0.99989	0.03257	0.99947	0.05001	0.99875	0.06743	0.99772	0.08484	0.99639	8
53	0.01542	0.99988	0.03286	0.99946	0.05030	0.99873	0.06773	0.99770	0.08513	0.99637	7
54	0.01571	0.99988	0.03316	0.99945	0.05059	0.99872	0.06802	0.99768	0.08542	0.99635	6
55	0.01600	0.99987	0.03345	0.99944	0.05088	0.99870	0.06831	0.99766	0.08571	0.99632	5
56	0.01629	0.99987	0.03374	0.99943	0.05117	0.99869	0.06860	0.99764	0.08600	0.99630	4
57	0.01658	0.99986	0.03403	0.99942	0.05146	0.99867	0.06889	0.99762	0.08629	0.99627	3
58	0.01687	0.99986	0.03432	0.99941	0.05175	0.99866	0.06918	0.99760	0.08658	0.99625	2
59	0.01716	0.99985	0.03461	0.99940	0.05205	0.99864	0.06947	0.99758	0.08687	0.99622	1
60	0.01745	0.99985	0.03490	0.99939	0.05234	0.99863	0.06976	0.99756	0.08716	0.99619	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	89°		88°		87°		86°		85°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	5° SIN	5° COS	6° SIN	6° COS	7° SIN	7° COS	8° SIN	8° COS	9° SIN	9° COS	
0	0.08716	0.99619	0.10453	0.99452	0.12187	0.99255	0.13917	0.99027	0.15643	0.98769	60
1	0.08745	0.99617	0.10482	0.99449	0.12216	0.99251	0.13946	0.99023	0.15672	0.98764	59
2	0.08774	0.99614	0.10511	0.99446	0.12245	0.99248	0.13975	0.99019	0.15701	0.98760	58
3	0.08803	0.99612	0.10540	0.99443	0.12274	0.99244	0.14004	0.99015	0.15730	0.98755	57
4	0.08831	0.99609	0.10569	0.99440	0.12302	0.99240	0.14033	0.99011	0.15758	0.98751	56
5	0.08860	0.99607	0.10597	0.99437	0.12331	0.99237	0.14061	0.99006	0.15787	0.98746	55
6	0.08889	0.99604	0.10626	0.99434	0.12360	0.99233	0.14090	0.99002	0.15816	0.98741	54
7	0.08918	0.99602	0.10655	0.99431	0.12389	0.99230	0.14119	0.98998	0.15845	0.98737	53
8	0.08947	0.99599	0.10684	0.99428	0.12418	0.99226	0.14148	0.98994	0.15873	0.98732	52
9	0.08976	0.99596	0.10713	0.99424	0.12447	0.99222	0.14177	0.98990	0.15902	0.98728	51
10	0.09005	0.99594	0.10742	0.99421	0.12476	0.99219	0.14205	0.98986	0.15931	0.98723	50
11	0.09034	0.99591	0.10771	0.99418	0.12504	0.99215	0.14234	0.98982	0.15959	0.98718	49
12	0.09063	0.99588	0.10800	0.99415	0.12533	0.99211	0.14263	0.98978	0.15988	0.98714	48
13	0.09092	0.99586	0.10829	0.99412	0.12562	0.99208	0.14292	0.98973	0.16017	0.98709	47
14	0.09121	0.99583	0.10858	0.99409	0.12591	0.99204	0.14320	0.98969	0.16046	0.98704	46
15	0.09150	0.99580	0.10887	0.99406	0.12620	0.99200	0.14349	0.98965	0.16074	0.98700	45
16	0.09179	0.99578	0.10916	0.99402	0.12649	0.99197	0.14378	0.98961	0.16103	0.98695	44
17	0.09208	0.99575	0.10945	0.99399	0.12678	0.99193	0.14407	0.98957	0.16132	0.98690	43
18	0.09237	0.99572	0.10973	0.99396	0.12706	0.99189	0.14436	0.98953	0.16160	0.98686	42
19	0.09266	0.99570	0.11002	0.99393	0.12735	0.99186	0.14464	0.98948	0.16189	0.98681	41
20	0.09295	0.99567	0.11031	0.99390	0.12764	0.99182	0.14493	0.98944	0.16218	0.98676	40
21	0.09324	0.99564	0.11060	0.99386	0.12793	0.99178	0.14522	0.98940	0.16246	0.98671	39
22	0.09353	0.99562	0.11089	0.99383	0.12822	0.99175	0.14551	0.98936	0.16275	0.98667	38
23	0.09382	0.99559	0.11118	0.99380	0.12851	0.99171	0.14580	0.98931	0.16304	0.98662	37
24	0.09411	0.99556	0.11147	0.99377	0.12880	0.99167	0.14608	0.98927	0.16333	0.98657	36
25	0.09440	0.99553	0.11176	0.99374	0.12908	0.99163	0.14637	0.98923	0.16361	0.98652	35
26	0.09469	0.99551	0.11205	0.99370	0.12937	0.99160	0.14666	0.98919	0.16390	0.98648	34
27	0.09498	0.99548	0.11234	0.99367	0.12966	0.99156	0.14695	0.98914	0.16419	0.98643	33
28	0.09527	0.99545	0.11263	0.99364	0.12995	0.99152	0.14723	0.98910	0.16447	0.98638	32
29	0.09556	0.99542	0.11291	0.99360	0.13024	0.99148	0.14752	0.98906	0.16476	0.98633	31
30	0.09585	0.99540	0.11320	0.99357	0.13053	0.99144	0.14781	0.98902	0.16505	0.98629	30
31	0.09614	0.99537	0.11349	0.99354	0.13081	0.99141	0.14810	0.98897	0.16533	0.98624	29
32	0.09642	0.99534	0.11378	0.99351	0.13110	0.99137	0.14838	0.98893	0.16562	0.98619	28
33	0.09671	0.99531	0.11407	0.99347	0.13139	0.99133	0.14867	0.98889	0.16591	0.98614	27
34	0.09700	0.99528	0.11436	0.99344	0.13168	0.99129	0.14896	0.98884	0.16620	0.98609	26
35	0.09729	0.99526	0.11465	0.99341	0.13197	0.99125	0.14925	0.98880	0.16648	0.98604	25
36	0.09758	0.99523	0.11494	0.99337	0.13226	0.99122	0.14954	0.98876	0.16677	0.98600	24
37	0.09787	0.99520	0.11523	0.99334	0.13254	0.99118	0.14982	0.98871	0.16706	0.98595	23
38	0.09816	0.99517	0.11552	0.99331	0.13283	0.99114	0.15011	0.98867	0.16734	0.98590	22
39	0.09845	0.99514	0.11580	0.99327	0.13312	0.99110	0.15040	0.98863	0.16763	0.98585	21
40	0.09874	0.99511	0.11609	0.99324	0.13341	0.99106	0.15069	0.98858	0.16792	0.98580	20
41	0.09903	0.99508	0.11638	0.99320	0.13370	0.99102	0.15097	0.98854	0.16820	0.98575	19
42	0.09932	0.99506	0.11667	0.99317	0.13399	0.99098	0.15126	0.98849	0.16849	0.98570	18
43	0.09961	0.99503	0.11696	0.99314	0.13427	0.99094	0.15155	0.98845	0.16878	0.98565	17
44	0.09990	0.99500	0.11725	0.99310	0.13456	0.99091	0.15184	0.98841	0.16906	0.98561	16
45	0.10019	0.99497	0.11754	0.99307	0.13485	0.99087	0.15212	0.98836	0.16935	0.98556	15
46	0.10048	0.99494	0.11783	0.99303	0.13514	0.99083	0.15241	0.98832	0.16964	0.98551	14
47	0.10077	0.99491	0.11812	0.99300	0.13543	0.99079	0.15270	0.98827	0.16992	0.98546	13
48	0.10106	0.99488	0.11840	0.99297	0.13572	0.99075	0.15299	0.98823	0.17021	0.98541	12
49	0.10135	0.99485	0.11869	0.99293	0.13600	0.99071	0.15327	0.98818	0.17050	0.98536	11
50	0.10164	0.99482	0.11898	0.99290	0.13629	0.99067	0.15356	0.98814	0.17078	0.98531	10
51	0.10192	0.99479	0.11927	0.99286	0.13658	0.99063	0.15385	0.98809	0.17107	0.98526	9
52	0.10221	0.99476	0.11956	0.99283	0.13687	0.99059	0.15414	0.98805	0.17136	0.98521	8
53	0.10250	0.99473	0.11985	0.99279	0.13716	0.99055	0.15442	0.98800	0.17164	0.98516	7
54	0.10279	0.99470	0.12014	0.99276	0.13744	0.99051	0.15471	0.98796	0.17193	0.98511	6
55	0.10308	0.99467	0.12043	0.99272	0.13773	0.99047	0.15500	0.98791	0.17222	0.98506	5
56	0.10337	0.99464	0.12071	0.99269	0.13802	0.99043	0.15529	0.98787	0.17250	0.98501	4
57	0.10366	0.99461	0.12100	0.99265	0.13831	0.99039	0.15557	0.98782	0.17279	0.98496	3
58	0.10395	0.99458	0.12129	0.99262	0.13860	0.99035	0.15586	0.98778	0.17308	0.98491	2
59	0.10424	0.99455	0.12158	0.99258	0.13889	0.99031	0.15615	0.98773	0.17336	0.98486	1
60	0.10453	0.99452	0.12187	0.99255	0.13917	0.99027	0.15643	0.98769	0.17365	0.98481	0
	84° COS	84° SIN	83° COS	83° SIN	82° COS	82° SIN	81° COS	81° SIN	80° COS	80° SIN	MIN

E. NATURAL SINES AND COSINES—CONTINUED

MIN	10° SIN	10° COS	11° SIN	11° COS	12° SIN	12° COS	13° SIN	13° COS	14° SIN	14° COS	
0	0.17365	0.98481	0.19081	0.98163	0.20791	0.97815	0.22495	0.97437	0.24192	0.97030	60
1	0.17393	0.98476	0.19109	0.98157	0.20820	0.97809	0.22523	0.97430	0.24220	0.97023	59
2	0.17422	0.98471	0.19138	0.98152	0.20848	0.97803	0.22552	0.97424	0.24249	0.97015	58
3	0.17451	0.98466	0.19167	0.98146	0.20877	0.97797	0.22580	0.97417	0.24277	0.97008	57
4	0.17479	0.98461	0.19195	0.98140	0.20905	0.97791	0.22608	0.97411	0.24305	0.97001	56
5	0.17508	0.98455	0.19224	0.98135	0.20933	0.97784	0.22637	0.97404	0.24333	0.96994	55
6	0.17537	0.98450	0.19252	0.98129	0.20962	0.97778	0.22665	0.97398	0.24362	0.96987	54
7	0.17565	0.98445	0.19281	0.98124	0.20990	0.97772	0.22693	0.97391	0.24390	0.96980	53
8	0.17594	0.98440	0.19309	0.98118	0.21019	0.97766	0.22722	0.97384	0.24418	0.96973	52
9	0.17623	0.98435	0.19338	0.98112	0.21047	0.97760	0.22750	0.97378	0.24446	0.96966	51
10	0.17651	0.98430	0.19366	0.98107	0.21076	0.97754	0.22778	0.97371	0.24474	0.96959	50
11	0.17680	0.98425	0.19395	0.98101	0.21104	0.97748	0.22807	0.97365	0.24503	0.96952	49
12	0.17708	0.98420	0.19423	0.98096	0.21132	0.97742	0.22835	0.97358	0.24531	0.96945	48
13	0.17737	0.98414	0.19452	0.98090	0.21161	0.97735	0.22863	0.97351	0.24559	0.96937	47
14	0.17766	0.98409	0.19481	0.98084	0.21189	0.97729	0.22892	0.97345	0.24587	0.96930	46
15	0.17794	0.98404	0.19509	0.98079	0.21218	0.97723	0.22920	0.97338	0.24615	0.96923	45
16	0.17823	0.98399	0.19538	0.98073	0.21246	0.97717	0.22948	0.97331	0.24644	0.96916	44
17	0.17852	0.98394	0.19566	0.98067	0.21275	0.97711	0.22977	0.97325	0.24672	0.96909	43
18	0.17880	0.98389	0.19595	0.98061	0.21303	0.97705	0.23005	0.97318	0.24700	0.96902	42
19	0.17909	0.98383	0.19623	0.98056	0.21331	0.97698	0.23033	0.97311	0.24728	0.96894	41
20	0.17937	0.98378	0.19652	0.98050	0.21360	0.97692	0.23062	0.97304	0.24756	0.96887	40
21	0.17966	0.98373	0.19680	0.98044	0.21388	0.97686	0.23090	0.97298	0.24784	0.96880	39
22	0.17995	0.98368	0.19709	0.98039	0.21417	0.97680	0.23118	0.97291	0.24813	0.96873	38
23	0.18023	0.98362	0.19737	0.98033	0.21445	0.97673	0.23146	0.97284	0.24841	0.96866	37
24	0.18052	0.98357	0.19766	0.98027	0.21474	0.97667	0.23175	0.97278	0.24869	0.96858	36
25	0.18081	0.98352	0.19794	0.98021	0.21502	0.97661	0.23203	0.97271	0.24897	0.96851	35
26	0.18109	0.98347	0.19823	0.98016	0.21530	0.97655	0.23231	0.97264	0.24925	0.96844	34
27	0.18138	0.98341	0.19851	0.98010	0.21559	0.97648	0.23260	0.97257	0.24954	0.96837	33
28	0.18166	0.98336	0.19880	0.98004	0.21587	0.97642	0.23288	0.97251	0.24982	0.96829	32
29	0.18195	0.98331	0.19908	0.97998	0.21616	0.97636	0.23316	0.97244	0.25010	0.96822	31
30	0.18224	0.98325	0.19937	0.97992	0.21644	0.97630	0.23345	0.97237	0.25038	0.96815	30
31	0.18252	0.98320	0.19965	0.97987	0.21672	0.97623	0.23373	0.97230	0.25066	0.96807	29
32	0.18281	0.98315	0.19994	0.97981	0.21701	0.97617	0.23401	0.97223	0.25094	0.96800	28
33	0.18309	0.98310	0.20022	0.97975	0.21729	0.97611	0.23429	0.97217	0.25122	0.96793	27
34	0.18338	0.98304	0.20051	0.97969	0.21758	0.97604	0.23458	0.97210	0.25151	0.96786	26
35	0.18367	0.98299	0.20079	0.97963	0.21786	0.97598	0.23486	0.97203	0.25179	0.96778	25
36	0.18395	0.98294	0.20108	0.97958	0.21814	0.97592	0.23514	0.97196	0.25207	0.96771	24
37	0.18424	0.98288	0.20136	0.97952	0.21843	0.97585	0.23542	0.97189	0.25235	0.96764	23
38	0.18452	0.98283	0.20165	0.97946	0.21871	0.97579	0.23571	0.97182	0.25263	0.96756	22
39	0.18481	0.98277	0.20193	0.97940	0.21899	0.97573	0.23599	0.97176	0.25291	0.96749	21
40	0.18509	0.98272	0.20222	0.97934	0.21928	0.97566	0.23627	0.97169	0.25320	0.96742	20
41	0.18538	0.98267	0.20250	0.97928	0.21956	0.97560	0.23656	0.97162	0.25348	0.96734	19
42	0.18567	0.98261	0.20279	0.97922	0.21985	0.97553	0.23684	0.97155	0.25376	0.96727	18
43	0.18595	0.98256	0.20307	0.97916	0.22013	0.97547	0.23712	0.97148	0.25404	0.96719	17
44	0.18624	0.98250	0.20336	0.97910	0.22041	0.97541	0.23740	0.97141	0.25432	0.96712	16
45	0.18652	0.98245	0.20364	0.97905	0.22070	0.97534	0.23769	0.97134	0.25460	0.96705	15
46	0.18681	0.98240	0.20393	0.97899	0.22098	0.97528	0.23797	0.97127	0.25488	0.96697	14
47	0.18710	0.98234	0.20421	0.97893	0.22126	0.97521	0.23825	0.97120	0.25516	0.96690	13
48	0.18738	0.98229	0.20450	0.97887	0.22155	0.97515	0.23853	0.97113	0.25545	0.96682	12
49	0.18767	0.98223	0.20478	0.97881	0.22183	0.97508	0.23882	0.97106	0.25573	0.96675	11
50	0.18795	0.98218	0.20507	0.97875	0.22212	0.97502	0.23910	0.97100	0.25601	0.96667	10
51	0.18824	0.98212	0.20535	0.97869	0.22240	0.97496	0.23938	0.97093	0.25629	0.96660	9
52	0.18852	0.98207	0.20563	0.97863	0.22268	0.97489	0.23966	0.97086	0.25657	0.96653	8
53	0.18881	0.98201	0.20592	0.97857	0.22297	0.97483	0.23995	0.97079	0.25685	0.96645	7
54	0.18910	0.98196	0.20620	0.97851	0.22325	0.97476	0.24023	0.97072	0.25713	0.96638	6
55	0.18938	0.98190	0.20649	0.97845	0.22353	0.97470	0.24051	0.97065	0.25741	0.96630	5
56	0.18967	0.98185	0.20677	0.97839	0.22382	0.97463	0.24079	0.97058	0.25769	0.96623	4
57	0.18995	0.98179	0.20706	0.97833	0.22410	0.97457	0.24108	0.97051	0.25798	0.96615	3
58	0.19024	0.98174	0.20734	0.97827	0.22438	0.97450	0.24136	0.97044	0.25826	0.96608	2
59	0.19052	0.98168	0.20763	0.97821	0.22467	0.97444	0.24164	0.97037	0.25854	0.96600	1
60	0.19081	0.98163	0.20791	0.97815	0.22495	0.97437	0.24192	0.97030	0.25882	0.96593	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	79°		78°		77°		76°		75°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	15°		16°		17°		18°		19°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.25882	0.96593	0.27564	0.96126	0.29237	0.95630	0.30902	0.95106	0.32557	0.94552	60
1	0.25910	0.96585	0.27592	0.96118	0.29265	0.95622	0.30929	0.95097	0.32584	0.94542	59
2	0.25938	0.96578	0.27620	0.96110	0.29293	0.95613	0.30957	0.95088	0.32612	0.94533	58
3	0.25966	0.96570	0.27648	0.96102	0.29321	0.95605	0.30985	0.95079	0.32639	0.94523	57
4	0.25994	0.96562	0.27676	0.96094	0.29348	0.95596	0.31012	0.95070	0.32667	0.94514	56
5	0.26022	0.96555	0.27704	0.96086	0.29376	0.95588	0.31040	0.95061	0.32694	0.94504	55
6	0.26050	0.96547	0.27731	0.96078	0.29404	0.95579	0.31068	0.95052	0.32722	0.94495	54
7	0.26079	0.96540	0.27759	0.96070	0.29432	0.95571	0.31095	0.95043	0.32749	0.94485	53
8	0.26107	0.96532	0.27787	0.96062	0.29460	0.95562	0.31123	0.95033	0.32777	0.94476	52
9	0.26135	0.96524	0.27815	0.96054	0.29487	0.95554	0.31151	0.95024	0.32804	0.94466	51
10	0.26163	0.96517	0.27843	0.96046	0.29515	0.95545	0.31178	0.95015	0.32832	0.94457	50
11	0.26191	0.96509	0.27871	0.96037	0.29543	0.95536	0.31206	0.95006	0.32859	0.94447	49
12	0.26219	0.96502	0.27899	0.96029	0.29571	0.95528	0.31233	0.94997	0.32887	0.94438	48
13	0.26247	0.96494	0.27927	0.96021	0.29599	0.95519	0.31261	0.94988	0.32914	0.94428	47
14	0.26275	0.96486	0.27955	0.96013	0.29626	0.95511	0.31289	0.94979	0.32942	0.94418	46
15	0.26303	0.96479	0.27983	0.96005	0.29654	0.95502	0.31316	0.94970	0.32969	0.94409	45
16	0.26331	0.96471	0.28011	0.95997	0.29682	0.95493	0.31344	0.94961	0.32997	0.94399	44
17	0.26359	0.96463	0.28039	0.95989	0.29710	0.95485	0.31372	0.94952	0.33024	0.94390	43
18	0.26387	0.96456	0.28067	0.95981	0.29737	0.95476	0.31399	0.94943	0.33051	0.94380	42
19	0.26415	0.96448	0.28095	0.95972	0.29765	0.95467	0.31427	0.94933	0.33079	0.94370	41
20	0.26443	0.96440	0.28123	0.95964	0.29793	0.95459	0.31454	0.94924	0.33106	0.94361	40
21	0.26471	0.96433	0.28150	0.95956	0.29821	0.95450	0.31482	0.94915	0.33134	0.94351	39
22	0.26500	0.96425	0.28178	0.95948	0.29849	0.95441	0.31510	0.94906	0.33161	0.94342	38
23	0.26528	0.96417	0.28206	0.95940	0.29876	0.95433	0.31537	0.94897	0.33189	0.94332	37
24	0.26556	0.96410	0.28234	0.95931	0.29904	0.95424	0.31565	0.94888	0.33216	0.94322	36
25	0.26584	0.96402	0.28262	0.95923	0.29932	0.95415	0.31593	0.94878	0.33244	0.94313	35
26	0.26612	0.96394	0.28290	0.95915	0.29960	0.95407	0.31620	0.94869	0.33271	0.94303	34
27	0.26640	0.96386	0.28318	0.95907	0.29987	0.95398	0.31648	0.94860	0.33298	0.94293	33
28	0.26668	0.96379	0.28346	0.95898	0.30015	0.95389	0.31675	0.94851	0.33326	0.94284	32
29	0.26696	0.96371	0.28374	0.95890	0.30043	0.95380	0.31703	0.94842	0.33353	0.94274	31
30	0.26724	0.96363	0.28402	0.95882	0.30071	0.95372	0.31730	0.94832	0.33381	0.94264	30
31	0.26752	0.96355	0.28429	0.95874	0.30098	0.95363	0.31758	0.94823	0.33408	0.94254	29
32	0.26780	0.96347	0.28457	0.95865	0.30126	0.95354	0.31786	0.94814	0.33436	0.94245	28
33	0.26808	0.96340	0.28485	0.95857	0.30154	0.95345	0.31813	0.94805	0.33463	0.94235	27
34	0.26836	0.96332	0.28513	0.95849	0.30182	0.95337	0.31841	0.94795	0.33490	0.94225	26
35	0.26864	0.96324	0.28541	0.95841	0.30209	0.95328	0.31868	0.94786	0.33518	0.94215	25
36	0.26892	0.96316	0.28569	0.95832	0.30237	0.95319	0.31896	0.94777	0.33545	0.94206	24
37	0.26920	0.96308	0.28597	0.95824	0.30265	0.95310	0.31923	0.94768	0.33573	0.94196	23
38	0.26948	0.96301	0.28625	0.95816	0.30292	0.95301	0.31951	0.94758	0.33600	0.94186	22
39	0.26976	0.96293	0.28652	0.95807	0.30320	0.95293	0.31979	0.94749	0.33627	0.94176	21
40	0.27004	0.96285	0.28680	0.95799	0.30348	0.95284	0.32006	0.94740	0.33655	0.94167	20
41	0.27032	0.96277	0.28708	0.95791	0.30376	0.95275	0.32034	0.94730	0.33682	0.94157	19
42	0.27060	0.96269	0.28736	0.95782	0.30403	0.95266	0.32061	0.94721	0.33710	0.94147	18
43	0.27088	0.96261	0.28764	0.95774	0.30431	0.95257	0.32089	0.94712	0.33737	0.94137	17
44	0.27116	0.96253	0.28792	0.95766	0.30459	0.95248	0.32116	0.94702	0.33764	0.94127	16
45	0.27144	0.96246	0.28820	0.95757	0.30486	0.95240	0.32144	0.94693	0.33792	0.94118	15
46	0.27172	0.96238	0.28847	0.95749	0.30514	0.95231	0.32171	0.94684	0.33819	0.94108	14
47	0.27200	0.96230	0.28875	0.95740	0.30542	0.95222	0.32199	0.94674	0.33846	0.94098	13
48	0.27228	0.96222	0.28903	0.95732	0.30570	0.95213	0.32227	0.94665	0.33874	0.94088	12
49	0.27256	0.96214	0.28931	0.95724	0.30597	0.95204	0.32254	0.94656	0.33901	0.94078	11
50	0.27284	0.96206	0.28959	0.95715	0.30625	0.95195	0.32282	0.94646	0.33929	0.94068	10
51	0.27312	0.96198	0.28987	0.95707	0.30653	0.95186	0.32309	0.94637	0.33956	0.94058	9
52	0.27340	0.96190	0.29015	0.95698	0.30680	0.95177	0.32337	0.94627	0.33983	0.94049	8
53	0.27368	0.96182	0.29042	0.95690	0.30708	0.95168	0.32364	0.94618	0.34011	0.94039	7
54	0.27396	0.96174	0.29070	0.95681	0.30736	0.95159	0.32392	0.94609	0.34038	0.94029	6
55	0.27424	0.96166	0.29098	0.95673	0.30763	0.95150	0.32419	0.94599	0.34065	0.94019	5
56	0.27452	0.96158	0.29126	0.95664	0.30791	0.95142	0.32447	0.94590	0.34093	0.94009	4
57	0.27480	0.96150	0.29154	0.95656	0.30819	0.95133	0.32474	0.94580	0.34120	0.93999	3
58	0.27508	0.96142	0.29182	0.95647	0.30846	0.95124	0.32502	0.94571	0.34147	0.93989	2
59	0.27536	0.96134	0.29209	0.95639	0.30874	0.95115	0.32529	0.94561	0.34175	0.93979	1
60	0.27564	0.96126	0.29237	0.95630	0.30902	0.95106	0.32557	0.94552	0.34202	0.93969	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	74°		73°		72°		71°		70°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	20°		21°		22°		23°		24°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.34202	0.93969	0.35837	0.93358	0.37461	0.92718	0.39073	0.92050	0.40674	0.91355	60
1	0.34229	0.93959	0.35864	0.93348	0.37488	0.92707	0.39100	0.92039	0.40700	0.91343	59
2	0.34257	0.93949	0.35891	0.93337	0.37515	0.92697	0.39127	0.92028	0.40727	0.91331	58
3	0.34284	0.93939	0.35918	0.93327	0.37542	0.92686	0.39153	0.92016	0.40753	0.91319	57
4	0.34311	0.93929	0.35945	0.93316	0.37569	0.92675	0.39180	0.92005	0.40780	0.91307	56
5	0.34339	0.93919	0.35973	0.93306	0.37595	0.92664	0.39207	0.91994	0.40806	0.91295	55
6	0.34366	0.93909	0.36000	0.93295	0.37622	0.92653	0.39234	0.91982	0.40833	0.91283	54
7	0.34393	0.93899	0.36027	0.93285	0.37649	0.92642	0.39260	0.91971	0.40860	0.91272	53
8	0.34421	0.93889	0.36054	0.93274	0.37676	0.92631	0.39287	0.91959	0.40886	0.91260	52
9	0.34448	0.93879	0.36081	0.93264	0.37703	0.92620	0.39314	0.91948	0.40913	0.91248	51
10	0.34475	0.93869	0.36108	0.93253	0.37730	0.92609	0.39341	0.91936	0.40939	0.91236	50
11	0.34503	0.93859	0.36135	0.93243	0.37757	0.92598	0.39367	0.91925	0.40966	0.91224	49
12	0.34530	0.93849	0.36162	0.93232	0.37784	0.92587	0.39394	0.91914	0.40992	0.91212	48
13	0.34557	0.93839	0.36190	0.93222	0.37811	0.92576	0.39421	0.91902	0.41019	0.91200	47
14	0.34584	0.93829	0.36217	0.93211	0.37838	0.92565	0.39448	0.91891	0.41045	0.91188	46
15	0.34612	0.93819	0.36244	0.93201	0.37865	0.92554	0.39474	0.91879	0.41072	0.91176	45
16	0.34639	0.93809	0.36271	0.93190	0.37892	0.92543	0.39501	0.91868	0.41098	0.91164	44
17	0.34666	0.93799	0.36298	0.93180	0.37919	0.92532	0.39528	0.91856	0.41125	0.91152	43
18	0.34694	0.93789	0.36325	0.93169	0.37946	0.92521	0.39555	0.91845	0.41151	0.91140	42
19	0.34721	0.93779	0.36352	0.93159	0.37973	0.92510	0.39581	0.91833	0.41178	0.91128	41
20	0.34748	0.93769	0.36379	0.93148	0.37999	0.92499	0.39608	0.91822	0.41204	0.91116	40
21	0.34775	0.93759	0.36406	0.93137	0.38026	0.92488	0.39635	0.91810	0.41231	0.91104	39
22	0.34803	0.93748	0.36434	0.93127	0.38053	0.92477	0.39661	0.91799	0.41257	0.91092	38
23	0.34830	0.93738	0.36461	0.93116	0.38080	0.92466	0.39688	0.91787	0.41284	0.91080	37
24	0.34857	0.93728	0.36488	0.93106	0.38107	0.92455	0.39715	0.91775	0.41310	0.91068	36
25	0.34884	0.93718	0.36515	0.93095	0.38134	0.92444	0.39741	0.91764	0.41337	0.91056	35
26	0.34912	0.93708	0.36542	0.93084	0.38161	0.92432	0.39768	0.91752	0.41363	0.91044	34
27	0.34939	0.93698	0.36569	0.93074	0.38188	0.92421	0.39795	0.91741	0.41390	0.91032	33
28	0.34966	0.93688	0.36596	0.93063	0.38215	0.92410	0.39822	0.91729	0.41416	0.91020	32
29	0.34993	0.93677	0.36623	0.93052	0.38241	0.92399	0.39848	0.91718	0.41443	0.91008	31
30	0.35021	0.93667	0.36650	0.93042	0.38268	0.92388	0.39875	0.91706	0.41469	0.90996	30
31	0.35048	0.93657	0.36677	0.93031	0.38295	0.92377	0.39902	0.91694	0.41496	0.90984	29
32	0.35075	0.93647	0.36704	0.93020	0.38322	0.92366	0.39928	0.91683	0.41522	0.90972	28
33	0.35102	0.93637	0.36731	0.93010	0.38349	0.92355	0.39955	0.91671	0.41549	0.90960	27
34	0.35130	0.93626	0.36758	0.92999	0.38376	0.92343	0.39982	0.91660	0.41575	0.90948	26
35	0.35157	0.93616	0.36785	0.92988	0.38403	0.92332	0.40008	0.91648	0.41602	0.90936	25
36	0.35184	0.93606	0.36812	0.92978	0.38430	0.92321	0.40035	0.91636	0.41628	0.90924	24
37	0.35211	0.93596	0.36839	0.92967	0.38456	0.92310	0.40062	0.91625	0.41655	0.90911	23
38	0.35239	0.93585	0.36867	0.92956	0.38483	0.92299	0.40088	0.91613	0.41681	0.90899	22
39	0.35266	0.93575	0.36894	0.92945	0.38510	0.92287	0.40115	0.91601	0.41707	0.90887	21
40	0.35293	0.93565	0.36921	0.92935	0.38537	0.92276	0.40141	0.91590	0.41734	0.90875	20
41	0.35320	0.93555	0.36948	0.92924	0.38564	0.92265	0.40168	0.91578	0.41760	0.90863	19
42	0.35347	0.93544	0.36975	0.92913	0.38591	0.92254	0.40195	0.91566	0.41787	0.90851	18
43	0.35375	0.93534	0.37002	0.92902	0.38617	0.92243	0.40221	0.91555	0.41813	0.90839	17
44	0.35402	0.93524	0.37029	0.92892	0.38644	0.92231	0.40248	0.91543	0.41840	0.90826	16
45	0.35429	0.93514	0.37056	0.92881	0.38671	0.92220	0.40275	0.91531	0.41866	0.90814	15
46	0.35456	0.93503	0.37083	0.92870	0.38698	0.92209	0.40301	0.91519	0.41892	0.90802	14
47	0.35484	0.93493	0.37110	0.92859	0.38725	0.92198	0.40328	0.91508	0.41919	0.90790	13
48	0.35511	0.93483	0.37137	0.92849	0.38752	0.92186	0.40355	0.91496	0.41945	0.90778	12
49	0.35538	0.93472	0.37164	0.92838	0.38778	0.92175	0.40381	0.91484	0.41972	0.90766	11
50	0.35565	0.93462	0.37191	0.92827	0.38805	0.92164	0.40408	0.91472	0.41998	0.90753	10
51	0.35592	0.93452	0.37218	0.92816	0.38832	0.92152	0.40434	0.91461	0.42024	0.90741	9
52	0.35619	0.93441	0.37245	0.92805	0.38859	0.92141	0.40461	0.91449	0.42051	0.90729	8
53	0.35647	0.93431	0.37272	0.92794	0.38886	0.92130	0.40488	0.91437	0.42077	0.90717	7
54	0.35674	0.93420	0.37299	0.92784	0.38912	0.92119	0.40514	0.91425	0.42104	0.90704	6
55	0.35701	0.93410	0.37326	0.92773	0.38939	0.92107	0.40541	0.91414	0.42130	0.90692	5
56	0.35728	0.93400	0.37353	0.92762	0.38966	0.92096	0.40567	0.91402	0.42156	0.90680	4
57	0.35755	0.93389	0.37380	0.92751	0.38993	0.92085	0.40594	0.91390	0.42183	0.90668	3
58	0.35782	0.93379	0.37407	0.92740	0.39020	0.92073	0.40621	0.91378	0.42209	0.90655	2
59	0.35810	0.93368	0.37434	0.92729	0.39046	0.92062	0.40647	0.91366	0.42235	0.90643	1
60	0.35837	0.93358	0.37461	0.92718	0.39073	0.92050	0.40674	0.91355	0.42262	0.90631	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	69°		68°		67°		66°		65°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	25°		26°		27°		28°		29°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.42262	0.90631	0.43837	0.89879	0.45399	0.89101	0.46947	0.88295	0.48481	0.87462	60
1	0.42288	0.90618	0.43863	0.89867	0.45425	0.89087	0.46973	0.88281	0.48506	0.87448	59
2	0.42315	0.90606	0.43889	0.89854	0.45451	0.89074	0.46999	0.88267	0.48532	0.87434	58
3	0.42341	0.90594	0.43916	0.89841	0.45477	0.89061	0.47024	0.88254	0.48557	0.87420	57
4	0.42367	0.90582	0.43942	0.89828	0.45503	0.89048	0.47050	0.88240	0.48583	0.87406	56
5	0.42394	0.90569	0.43968	0.89816	0.45529	0.89035	0.47076	0.88226	0.48608	0.87391	55
6	0.42420	0.90557	0.43994	0.89803	0.45554	0.89021	0.47101	0.88213	0.48634	0.87377	54
7	0.42446	0.90545	0.44020	0.89790	0.45580	0.89008	0.47127	0.88199	0.48659	0.87363	53
8	0.42473	0.90532	0.44046	0.89777	0.45606	0.88995	0.47153	0.88185	0.48684	0.87349	52
9	0.42499	0.90520	0.44072	0.89764	0.45632	0.88981	0.47178	0.88172	0.48710	0.87335	51
10	0.42525	0.90507	0.44098	0.89752	0.45658	0.88968	0.47204	0.88158	0.48735	0.87321	50
11	0.42552	0.90495	0.44124	0.89739	0.45684	0.88955	0.47229	0.88144	0.48761	0.87306	49
12	0.42578	0.90483	0.44151	0.89726	0.45710	0.88942	0.47255	0.88130	0.48786	0.87292	48
13	0.42604	0.90470	0.44177	0.89713	0.45736	0.88928	0.47281	0.88117	0.48811	0.87278	47
14	0.42631	0.90458	0.44203	0.89700	0.45762	0.88915	0.47306	0.88103	0.48837	0.87264	46
15	0.42657	0.90446	0.44229	0.89687	0.45787	0.88902	0.47332	0.88089	0.48862	0.87250	45
16	0.42683	0.90433	0.44255	0.89674	0.45813	0.88888	0.47358	0.88075	0.48888	0.87235	44
17	0.42709	0.90421	0.44281	0.89662	0.45839	0.88875	0.47383	0.88062	0.48913	0.87221	43
18	0.42736	0.90408	0.44307	0.89649	0.45865	0.88862	0.47409	0.88048	0.48938	0.87207	42
19	0.42762	0.90396	0.44333	0.89636	0.45891	0.88848	0.47434	0.88034	0.48964	0.87193	41
20	0.42788	0.90383	0.44359	0.89623	0.45917	0.88835	0.47460	0.88020	0.48989	0.87178	40
21	0.42815	0.90371	0.44385	0.89610	0.45942	0.88822	0.47486	0.88006	0.49014	0.87164	39
22	0.42841	0.90358	0.44411	0.89597	0.45968	0.88808	0.47511	0.87993	0.49040	0.87150	38
23	0.42867	0.90346	0.44437	0.89584	0.45994	0.88795	0.47537	0.87979	0.49065	0.87136	37
24	0.42894	0.90334	0.44464	0.89571	0.46020	0.88782	0.47562	0.87965	0.49090	0.87121	36
25	0.42920	0.90321	0.44490	0.89558	0.46046	0.88768	0.47588	0.87951	0.49116	0.87107	35
26	0.42946	0.90309	0.44516	0.89545	0.46072	0.88755	0.47614	0.87937	0.49141	0.87093	34
27	0.42972	0.90296	0.44542	0.89532	0.46097	0.88741	0.47639	0.87923	0.49166	0.87079	33
28	0.42999	0.90284	0.44568	0.89519	0.46123	0.88728	0.47665	0.87909	0.49192	0.87064	32
29	0.43025	0.90271	0.44594	0.89506	0.46149	0.88715	0.47690	0.87896	0.49217	0.87050	31
30	0.43051	0.90259	0.44620	0.89493	0.46175	0.88701	0.47716	0.87882	0.49242	0.87036	30
31	0.43077	0.90246	0.44646	0.89480	0.46201	0.88688	0.47741	0.87868	0.49268	0.87021	29
32	0.43104	0.90233	0.44672	0.89467	0.46226	0.88674	0.47767	0.87854	0.49293	0.87007	28
33	0.43130	0.90221	0.44698	0.89454	0.46252	0.88661	0.47793	0.87840	0.49318	0.86993	27
34	0.43156	0.90208	0.44724	0.89441	0.46278	0.88647	0.47818	0.87826	0.49344	0.86978	26
35	0.43182	0.90196	0.44750	0.89428	0.46304	0.88634	0.47844	0.87812	0.49369	0.86964	25
36	0.43209	0.90183	0.44776	0.89415	0.46330	0.88620	0.47869	0.87798	0.49394	0.86949	24
37	0.43235	0.90171	0.44802	0.89402	0.46355	0.88607	0.47895	0.87784	0.49419	0.86935	23
38	0.43261	0.90158	0.44828	0.89389	0.46381	0.88593	0.47920	0.87770	0.49445	0.86921	22
39	0.43287	0.90146	0.44854	0.89376	0.46407	0.88580	0.47946	0.87756	0.49470	0.86906	21
40	0.43313	0.90133	0.44880	0.89363	0.46433	0.88566	0.47971	0.87743	0.49495	0.86892	20
41	0.43340	0.90120	0.44906	0.89350	0.46458	0.88553	0.47997	0.87729	0.49521	0.86878	19
42	0.43366	0.90108	0.44932	0.89337	0.46484	0.88539	0.48022	0.87715	0.49546	0.86863	18
43	0.43392	0.90095	0.44958	0.89324	0.46510	0.88526	0.48048	0.87701	0.49571	0.86849	17
44	0.43418	0.90082	0.44984	0.89311	0.46536	0.88512	0.48073	0.87687	0.49596	0.86834	16
45	0.43445	0.90070	0.45010	0.89298	0.46561	0.88499	0.48099	0.87673	0.49622	0.86820	15
46	0.43471	0.90057	0.45036	0.89285	0.46587	0.88485	0.48124	0.87659	0.49647	0.86805	14
47	0.43497	0.90045	0.45062	0.89272	0.46613	0.88472	0.48150	0.87645	0.49672	0.86791	13
48	0.43523	0.90032	0.45088	0.89259	0.46639	0.88458	0.48175	0.87631	0.49697	0.86777	12
49	0.43549	0.90019	0.45114	0.89245	0.46664	0.88445	0.48201	0.87617	0.49723	0.86762	11
50	0.43575	0.90007	0.45140	0.89232	0.46690	0.88431	0.48226	0.87603	0.49748	0.86748	10
51	0.43602	0.89994	0.45166	0.89219	0.46716	0.88417	0.48252	0.87589	0.49773	0.86733	9
52	0.43628	0.89981	0.45192	0.89206	0.46742	0.88404	0.48277	0.87575	0.49798	0.86719	8
53	0.43654	0.89968	0.45218	0.89193	0.46767	0.88390	0.48303	0.87561	0.49824	0.86704	7
54	0.43680	0.89956	0.45243	0.89180	0.46793	0.88377	0.48328	0.87546	0.49849	0.86690	6
55	0.43706	0.89943	0.45269	0.89167	0.46819	0.88363	0.48354	0.87532	0.49874	0.86675	5
56	0.43733	0.89930	0.45295	0.89153	0.46844	0.88349	0.48379	0.87518	0.49899	0.86661	4
57	0.43759	0.89918	0.45321	0.89140	0.46870	0.88336	0.48405	0.87504	0.49924	0.86646	3
58	0.43785	0.89905	0.45347	0.89127	0.46896	0.88322	0.48430	0.87490	0.49950	0.86632	2
59	0.43811	0.89892	0.45373	0.89114	0.46921	0.88308	0.48456	0.87476	0.49975	0.86617	1
60	0.43837	0.89879	0.45399	0.89101	0.46947	0.88295	0.48481	0.87462	0.50000	0.86603	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	64°		63°		62°		61°		60°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	30°		31°		32°		33°		34°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.50000	0.86603	0.51504	0.85717	0.52992	0.84805	0.54464	0.83867	0.55919	0.82904	60
1	0.50025	0.86588	0.51529	0.85702	0.53017	0.84789	0.54488	0.83851	0.55943	0.82887	59
2	0.50050	0.86573	0.51554	0.85687	0.53041	0.84774	0.54513	0.83835	0.55968	0.82871	58
3	0.50076	0.86559	0.51579	0.85672	0.53066	0.84759	0.54537	0.83819	0.55992	0.82855	57
4	0.50101	0.86544	0.51604	0.85657	0.53091	0.84743	0.54561	0.83804	0.56016	0.82839	56
5	0.50126	0.86530	0.51628	0.85642	0.53115	0.84728	0.54586	0.83788	0.56040	0.82822	55
6	0.50151	0.86515	0.51653	0.85627	0.53140	0.84712	0.54610	0.83772	0.56064	0.82806	54
7	0.50176	0.86501	0.51678	0.85612	0.53164	0.84697	0.54635	0.83756	0.56088	0.82790	53
8	0.50201	0.86486	0.51703	0.85597	0.53189	0.84681	0.54659	0.83740	0.56112	0.82773	52
9	0.50227	0.86471	0.51728	0.85582	0.53214	0.84666	0.54683	0.83724	0.56136	0.82757	51
10	0.50252	0.86457	0.51753	0.85567	0.53238	0.84650	0.54708	0.83708	0.56160	0.82741	50
11	0.50277	0.86442	0.51778	0.85551	0.53263	0.84635	0.54732	0.83692	0.56184	0.82724	49
12	0.50302	0.86427	0.51803	0.85536	0.53288	0.84619	0.54756	0.83676	0.56208	0.82708	48
13	0.50327	0.86413	0.51828	0.85521	0.53312	0.84604	0.54781	0.83660	0.56232	0.82692	47
14	0.50352	0.86398	0.51852	0.85506	0.53337	0.84588	0.54805	0.83645	0.56256	0.82675	46
15	0.50377	0.86384	0.51877	0.85491	0.53361	0.84573	0.54829	0.83629	0.56280	0.82659	45
16	0.50403	0.86369	0.51902	0.85476	0.53386	0.84557	0.54854	0.83613	0.56305	0.82643	44
17	0.50428	0.86354	0.51927	0.85461	0.53411	0.84542	0.54878	0.83597	0.56329	0.82626	43
18	0.50453	0.86340	0.51952	0.85446	0.53435	0.84526	0.54902	0.83581	0.56353	0.82610	42
19	0.50478	0.86325	0.51977	0.85431	0.53460	0.84511	0.54927	0.83565	0.56377	0.82593	41
20	0.50503	0.86310	0.52002	0.85416	0.53484	0.84495	0.54951	0.83549	0.56401	0.82577	40
21	0.50528	0.86295	0.52026	0.85401	0.53509	0.84480	0.54975	0.83533	0.56425	0.82561	39
22	0.50553	0.86281	0.52051	0.85385	0.53534	0.84464	0.54999	0.83517	0.56449	0.82544	38
23	0.50578	0.86266	0.52076	0.85370	0.53558	0.84448	0.55024	0.83501	0.56473	0.82528	37
24	0.50603	0.86251	0.52101	0.85355	0.53583	0.84433	0.55048	0.83485	0.56497	0.82511	36
25	0.50628	0.86237	0.52126	0.85340	0.53607	0.84417	0.55072	0.83469	0.56521	0.82495	35
26	0.50654	0.86222	0.52151	0.85325	0.53632	0.84402	0.55097	0.83453	0.56545	0.82478	34
27	0.50679	0.86207	0.52175	0.85310	0.53656	0.84386	0.55121	0.83437	0.56569	0.82462	33
28	0.50704	0.86192	0.52200	0.85294	0.53681	0.84370	0.55145	0.83421	0.56593	0.82446	32
29	0.50729	0.86178	0.52225	0.85279	0.53705	0.84355	0.55169	0.83405	0.56617	0.82429	31
30	0.50754	0.86163	0.52250	0.85264	0.53730	0.84339	0.55194	0.83389	0.56641	0.82413	30
31	0.50779	0.86148	0.52275	0.85249	0.53754	0.84324	0.55218	0.83373	0.56665	0.82396	29
32	0.50804	0.86133	0.52299	0.85234	0.53779	0.84308	0.55242	0.83356	0.56689	0.82380	28
33	0.50829	0.86119	0.52324	0.85218	0.53804	0.84292	0.55266	0.83340	0.56713	0.82363	27
34	0.50854	0.86104	0.52349	0.85203	0.53828	0.84277	0.55291	0.83324	0.56736	0.82347	26
35	0.50879	0.86089	0.52374	0.85188	0.53853	0.84261	0.55315	0.83308	0.56760	0.82330	25
36	0.50904	0.86074	0.52399	0.85173	0.53877	0.84245	0.55339	0.83292	0.56784	0.82314	24
37	0.50929	0.86059	0.52423	0.85157	0.53902	0.84230	0.55363	0.83276	0.56808	0.82297	23
38	0.50954	0.86045	0.52448	0.85142	0.53926	0.84214	0.55388	0.83260	0.56832	0.82281	22
39	0.50979	0.86030	0.52473	0.85127	0.53951	0.84198	0.55412	0.83244	0.56856	0.82264	21
40	0.51004	0.86015	0.52498	0.85112	0.53975	0.84182	0.55436	0.83228	0.56880	0.82248	20
41	0.51029	0.86000	0.52522	0.85096	0.54000	0.84167	0.55460	0.83212	0.56904	0.82231	19
42	0.51054	0.85985	0.52547	0.85081	0.54024	0.84151	0.55484	0.83195	0.56928	0.82214	18
43	0.51079	0.85970	0.52572	0.85066	0.54049	0.84135	0.55509	0.83179	0.56952	0.82198	17
44	0.51104	0.85956	0.52597	0.85051	0.54073	0.84120	0.55533	0.83163	0.56976	0.82181	16
45	0.51129	0.85941	0.52621	0.85035	0.54097	0.84104	0.55557	0.83147	0.57000	0.82165	15
46	0.51154	0.85926	0.52646	0.85020	0.54122	0.84088	0.55581	0.83131	0.57024	0.82148	14
47	0.51179	0.85911	0.52671	0.85005	0.54146	0.84072	0.55605	0.83115	0.57047	0.82132	13
48	0.51204	0.85896	0.52696	0.84989	0.54171	0.84057	0.55630	0.83098	0.57071	0.82115	12
49	0.51229	0.85881	0.52720	0.84974	0.54195	0.84041	0.55654	0.83082	0.57095	0.82098	11
50	0.51254	0.85866	0.52745	0.84959	0.54220	0.84025	0.55678	0.83066	0.57119	0.82082	10
51	0.51279	0.85851	0.52770	0.84943	0.54244	0.84009	0.55702	0.83050	0.57143	0.82065	9
52	0.51304	0.85836	0.52794	0.84928	0.54269	0.83994	0.55726	0.83034	0.57167	0.82048	8
53	0.51329	0.85821	0.52819	0.84913	0.54293	0.83978	0.55750	0.83017	0.57191	0.82032	7
54	0.51354	0.85806	0.52844	0.84897	0.54317	0.83962	0.55775	0.83001	0.57215	0.82015	6
55	0.51379	0.85792	0.52869	0.84882	0.54342	0.83946	0.55799	0.82985	0.57238	0.81999	5
56	0.51404	0.85777	0.52893	0.84866	0.54366	0.83930	0.55823	0.82969	0.57262	0.81982	4
57	0.51429	0.85762	0.52918	0.84851	0.54391	0.83915	0.55847	0.82953	0.57286	0.81965	3
58	0.51454	0.85747	0.52943	0.84836	0.54415	0.83899	0.55871	0.82936	0.57310	0.81949	2
59	0.51479	0.85732	0.52967	0.84820	0.54440	0.83883	0.55895	0.82920	0.57334	0.81932	1
60	0.51504	0.85717	0.52992	0.84805	0.54464	0.83867	0.55919	0.82904	0.57358	0.81915	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	59°		58°		57°		56°		55°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	35° SIN	35° COS	36° SIN	36° COS	37° SIN	37° COS	38° SIN	38° COS	39° SIN	39° COS	
0	0.57358	0.81915	0.58779	0.80902	0.60182	0.79864	0.61566	0.78801	0.62932	0.77715	60
1	0.57381	0.81899	0.58802	0.80885	0.60205	0.79846	0.61589	0.78783	0.62955	0.77696	59
2	0.57405	0.81882	0.58826	0.80867	0.60228	0.79829	0.61612	0.78765	0.62977	0.77678	58
3	0.57429	0.81865	0.58849	0.80850	0.60251	0.79811	0.61635	0.78747	0.63000	0.77660	57
4	0.57453	0.81848	0.58873	0.80833	0.60274	0.79793	0.61658	0.78729	0.63022	0.77641	56
5	0.57477	0.81832	0.58896	0.80816	0.60298	0.79776	0.61681	0.78711	0.63045	0.77623	55
6	0.57501	0.81815	0.58920	0.80799	0.60321	0.79758	0.61704	0.78694	0.63068	0.77605	54
7	0.57524	0.81798	0.58943	0.80782	0.60344	0.79741	0.61726	0.78676	0.63090	0.77586	53
8	0.57548	0.81782	0.58967	0.80765	0.60367	0.79723	0.61749	0.78658	0.63113	0.77568	52
9	0.57572	0.81765	0.58990	0.80748	0.60390	0.79706	0.61772	0.78640	0.63135	0.77550	51
10	0.57596	0.81748	0.59014	0.80730	0.60414	0.79688	0.61795	0.78622	0.63158	0.77531	50
11	0.57619	0.81731	0.59037	0.80713	0.60437	0.79671	0.61818	0.78604	0.63180	0.77513	49
12	0.57643	0.81714	0.59061	0.80696	0.60460	0.79653	0.61841	0.78586	0.63203	0.77494	48
13	0.57667	0.81698	0.59084	0.80679	0.60483	0.79635	0.61864	0.78568	0.63225	0.77476	47
14	0.57691	0.81681	0.59108	0.80662	0.60506	0.79618	0.61887	0.78550	0.63248	0.77458	46
15	0.57715	0.81664	0.59131	0.80644	0.60529	0.79600	0.61909	0.78532	0.63271	0.77439	45
16	0.57738	0.81647	0.59154	0.80627	0.60553	0.79583	0.61932	0.78514	0.63293	0.77421	44
17	0.57762	0.81631	0.59178	0.80610	0.60576	0.79565	0.61955	0.78496	0.63316	0.77402	43
18	0.57786	0.81614	0.59201	0.80593	0.60599	0.79547	0.61978	0.78478	0.63338	0.77384	42
19	0.57810	0.81597	0.59225	0.80576	0.60622	0.79530	0.62001	0.78460	0.63361	0.77366	41
20	0.57833	0.81580	0.59248	0.80558	0.60645	0.79512	0.62024	0.78442	0.63383	0.77347	40
21	0.57857	0.81563	0.59272	0.80541	0.60668	0.79494	0.62046	0.78424	0.63406	0.77329	39
22	0.57881	0.81546	0.59295	0.80524	0.60691	0.79477	0.62069	0.78405	0.63428	0.77310	38
23	0.57904	0.81530	0.59318	0.80507	0.60714	0.79459	0.62092	0.78387	0.63451	0.77292	37
24	0.57928	0.81513	0.59342	0.80489	0.60738	0.79441	0.62115	0.78369	0.63473	0.77273	36
25	0.57952	0.81496	0.59365	0.80472	0.60761	0.79424	0.62138	0.78351	0.63496	0.77255	35
26	0.57976	0.81479	0.59389	0.80455	0.60784	0.79406	0.62160	0.78333	0.63518	0.77236	34
27	0.57999	0.81462	0.59412	0.80438	0.60807	0.79388	0.62183	0.78315	0.63540	0.77218	33
28	0.58023	0.81445	0.59436	0.80420	0.60830	0.79371	0.62206	0.78297	0.63563	0.77199	32
29	0.58047	0.81428	0.59459	0.80403	0.60853	0.79353	0.62229	0.78279	0.63585	0.77181	31
30	0.58070	0.81412	0.59482	0.80386	0.60876	0.79335	0.62251	0.78261	0.63608	0.77162	30
31	0.58094	0.81395	0.59506	0.80368	0.60899	0.79318	0.62274	0.78243	0.63630	0.77144	29
32	0.58118	0.81378	0.59529	0.80351	0.60922	0.79300	0.62297	0.78225	0.63653	0.77125	28
33	0.58141	0.81361	0.59552	0.80334	0.60945	0.79282	0.62320	0.78206	0.63675	0.77107	27
34	0.58165	0.81344	0.59576	0.80316	0.60968	0.79264	0.62342	0.78188	0.63698	0.77088	26
35	0.58189	0.81327	0.59599	0.80299	0.60991	0.79247	0.62365	0.78170	0.63720	0.77070	25
36	0.58212	0.81310	0.59622	0.80282	0.61015	0.79229	0.62388	0.78152	0.63742	0.77051	24
37	0.58236	0.81293	0.59646	0.80264	0.61038	0.79211	0.62411	0.78134	0.63765	0.77033	23
38	0.58260	0.81276	0.59669	0.80247	0.61061	0.79193	0.62433	0.78116	0.63787	0.77014	22
39	0.58283	0.81259	0.59693	0.80230	0.61084	0.79176	0.62456	0.78098	0.63810	0.76996	21
40	0.58307	0.81242	0.59716	0.80212	0.61107	0.79158	0.62479	0.78079	0.63832	0.76977	20
41	0.58330	0.81225	0.59739	0.80195	0.61130	0.79140	0.62502	0.78061	0.63854	0.76959	19
42	0.58354	0.81208	0.59763	0.80178	0.61153	0.79122	0.62524	0.78043	0.63877	0.76940	18
43	0.58378	0.81191	0.59786	0.80160	0.61176	0.79105	0.62547	0.78025	0.63899	0.76921	17
44	0.58401	0.81174	0.59809	0.80143	0.61199	0.79087	0.62570	0.78007	0.63922	0.76903	16
45	0.58425	0.81157	0.59832	0.80125	0.61222	0.79069	0.62592	0.77988	0.63944	0.76884	15
46	0.58449	0.81140	0.59856	0.80108	0.61245	0.79051	0.62615	0.77970	0.63966	0.76866	14
47	0.58472	0.81123	0.59879	0.80091	0.61268	0.79033	0.62638	0.77952	0.63989	0.76847	13
48	0.58496	0.81106	0.59902	0.80073	0.61291	0.79016	0.62660	0.77934	0.64011	0.76828	12
49	0.58519	0.81089	0.59926	0.80056	0.61314	0.78998	0.62683	0.77916	0.64033	0.76810	11
50	0.58543	0.81072	0.59949	0.80038	0.61337	0.78980	0.62706	0.77897	0.64056	0.76791	10
51	0.58567	0.81055	0.59972	0.80021	0.61360	0.78962	0.62728	0.77879	0.64078	0.76772	9
52	0.58590	0.81038	0.59995	0.80003	0.61383	0.78944	0.62751	0.77861	0.64100	0.76754	8
53	0.58614	0.81021	0.60019	0.79986	0.61406	0.78926	0.62774	0.77843	0.64123	0.76735	7
54	0.58637	0.81004	0.60042	0.79968	0.61429	0.78908	0.62796	0.77824	0.64145	0.76717	6
55	0.58661	0.80987	0.60065	0.79951	0.61451	0.78891	0.62819	0.77806	0.64167	0.76698	5
56	0.58684	0.80970	0.60089	0.79934	0.61474	0.78873	0.62842	0.77788	0.64190	0.76679	4
57	0.58708	0.80953	0.60112	0.79916	0.61497	0.78855	0.62864	0.77769	0.64212	0.76661	3
58	0.58731	0.80936	0.60135	0.79899	0.61520	0.78837	0.62887	0.77751	0.64234	0.76642	2
59	0.58755	0.80919	0.60158	0.79881	0.61543	0.78819	0.62909	0.77733	0.64256	0.76623	1
60	0.58779	0.80902	0.60182	0.79864	0.61566	0.78801	0.62932	0.77715	0.64279	0.76604	0
	COS 54°	SIN 54°	COS 53°	SIN 53°	COS 52°	SIN 52°	COS 51°	SIN 51°	COS 50°	SIN 50°	MIN

E. NATURAL SINES AND COSINES—CONTINUED

MIN	40° SIN	40° COS	41° SIN	41° COS	42° SIN	42° COS	43° SIN	43° COS	44° SIN	44° COS	
0	0.64279	0.76604	0.65606	0.75471	0.66913	0.74314	0.68200	0.73135	0.69466	0.71934	60
1	0.64301	0.76586	0.65628	0.75452	0.66935	0.74295	0.68221	0.73116	0.69487	0.71914	59
2	0.64323	0.76567	0.65650	0.75433	0.66956	0.74276	0.68242	0.73096	0.69508	0.71894	58
3	0.64346	0.76548	0.65672	0.75414	0.66978	0.74256	0.68264	0.73076	0.69529	0.71873	57
4	0.64368	0.76530	0.65694	0.75395	0.66999	0.74237	0.68285	0.73056	0.69549	0.71853	56
5	0.64390	0.76511	0.65716	0.75375	0.67021	0.74217	0.68306	0.73036	0.69570	0.71833	55
6	0.64412	0.76492	0.65738	0.75356	0.67043	0.74198	0.68327	0.73016	0.69591	0.71813	54
7	0.64435	0.76473	0.65759	0.75337	0.67064	0.74178	0.68349	0.72996	0.69612	0.71792	53
8	0.64457	0.76455	0.65781	0.75318	0.67086	0.74159	0.68370	0.72976	0.69633	0.71772	52
9	0.64479	0.76436	0.65803	0.75299	0.67107	0.74139	0.68391	0.72957	0.69654	0.71752	51
10	0.64501	0.76417	0.65825	0.75280	0.67129	0.74120	0.68412	0.72937	0.69675	0.71732	50
11	0.64524	0.76398	0.65847	0.75261	0.67151	0.74100	0.68434	0.72917	0.69696	0.71711	49
12	0.64546	0.76380	0.65869	0.75241	0.67172	0.74080	0.68455	0.72897	0.69717	0.71691	48
13	0.64568	0.76361	0.65891	0.75222	0.67194	0.74061	0.68476	0.72877	0.69737	0.71671	47
14	0.64590	0.76342	0.65913	0.75203	0.67215	0.74041	0.68497	0.72857	0.69758	0.71650	46
15	0.64612	0.76323	0.65935	0.75184	0.67237	0.74022	0.68518	0.72837	0.69779	0.71630	45
16	0.64635	0.76304	0.65956	0.75165	0.67258	0.74002	0.68539	0.72817	0.69800	0.71610	44
17	0.64657	0.76286	0.65978	0.75146	0.67280	0.73983	0.68561	0.72797	0.69821	0.71590	43
18	0.64679	0.76267	0.66000	0.75126	0.67301	0.73963	0.68582	0.72777	0.69842	0.71569	42
19	0.64701	0.76248	0.66022	0.75107	0.67323	0.73944	0.68603	0.72757	0.69862	0.71549	41
20	0.64723	0.76229	0.66044	0.75088	0.67344	0.73924	0.68624	0.72737	0.69883	0.71529	40
21	0.64746	0.76210	0.66066	0.75069	0.67366	0.73904	0.68645	0.72717	0.69904	0.71508	39
22	0.64768	0.76192	0.66088	0.75050	0.67387	0.73885	0.68666	0.72697	0.69925	0.71488	38
23	0.64790	0.76173	0.66109	0.75030	0.67409	0.73865	0.68688	0.72677	0.69946	0.71468	37
24	0.64812	0.76154	0.66131	0.75011	0.67430	0.73846	0.68709	0.72657	0.69966	0.71447	36
25	0.64834	0.76135	0.66153	0.74992	0.67452	0.73826	0.68730	0.72637	0.69987	0.71427	35
26	0.64856	0.76116	0.66175	0.74973	0.67473	0.73806	0.68751	0.72617	0.70008	0.71407	34
27	0.64878	0.76097	0.66197	0.74953	0.67495	0.73787	0.68772	0.72597	0.70029	0.71386	33
28	0.64901	0.76078	0.66218	0.74934	0.67516	0.73767	0.68793	0.72577	0.70049	0.71366	32
29	0.64923	0.76059	0.66240	0.74915	0.67538	0.73747	0.68814	0.72557	0.70070	0.71345	31
30	0.64945	0.76041	0.66262	0.74896	0.67559	0.73728	0.68835	0.72537	0.70091	0.71325	30
31	0.64967	0.76022	0.66284	0.74876	0.67580	0.73708	0.68857	0.72517	0.70112	0.71305	29
32	0.64989	0.76003	0.66306	0.74857	0.67602	0.73688	0.68878	0.72497	0.70132	0.71284	28
33	0.65011	0.75984	0.66327	0.74838	0.67623	0.73669	0.68899	0.72477	0.70153	0.71264	27
34	0.65033	0.75965	0.66349	0.74818	0.67645	0.73649	0.68920	0.72457	0.70174	0.71243	26
35	0.65055	0.75946	0.66371	0.74799	0.67666	0.73629	0.68941	0.72437	0.70195	0.71223	25
36	0.65077	0.75927	0.66393	0.74780	0.67688	0.73610	0.68962	0.72417	0.70215	0.71203	24
37	0.65100	0.75908	0.66414	0.74760	0.67709	0.73590	0.68983	0.72397	0.70236	0.71182	23
38	0.65122	0.75889	0.66436	0.74741	0.67730	0.73570	0.69004	0.72377	0.70257	0.71162	22
39	0.65144	0.75870	0.66458	0.74722	0.67752	0.73551	0.69025	0.72357	0.70277	0.71141	21
40	0.65166	0.75851	0.66480	0.74703	0.67773	0.73531	0.69046	0.72337	0.70298	0.71121	20
41	0.65188	0.75832	0.66501	0.74683	0.67795	0.73511	0.69067	0.72317	0.70319	0.71100	19
42	0.65210	0.75813	0.66523	0.74664	0.67816	0.73491	0.69088	0.72297	0.70339	0.71080	18
43	0.65232	0.75794	0.66545	0.74644	0.67837	0.73472	0.69109	0.72277	0.70360	0.71059	17
44	0.65254	0.75775	0.66566	0.74625	0.67859	0.73452	0.69130	0.72257	0.70381	0.71039	16
45	0.65276	0.75756	0.66588	0.74606	0.67880	0.73432	0.69151	0.72236	0.70401	0.71019	15
46	0.65298	0.75738	0.66610	0.74586	0.67901	0.73413	0.69172	0.72216	0.70422	0.70998	14
47	0.65320	0.75719	0.66632	0.74567	0.67923	0.73393	0.69193	0.72196	0.70443	0.70978	13
48	0.65342	0.75700	0.66653	0.74548	0.67944	0.73373	0.69214	0.72176	0.70463	0.70957	12
49	0.65364	0.75680	0.66675	0.74528	0.67965	0.73353	0.69235	0.72156	0.70484	0.70937	11
50	0.65386	0.75661	0.66697	0.74509	0.67987	0.73333	0.69256	0.72136	0.70505	0.70916	10
51	0.65408	0.75642	0.66718	0.74489	0.68008	0.73314	0.69277	0.72116	0.70525	0.70896	9
52	0.65430	0.75623	0.66740	0.74470	0.68029	0.73294	0.69298	0.72095	0.70546	0.70875	8
53	0.65452	0.75604	0.66762	0.74451	0.68051	0.73274	0.69319	0.72075	0.70567	0.70855	7
54	0.65474	0.75585	0.66783	0.74431	0.68072	0.73254	0.69340	0.72055	0.70587	0.70834	6
55	0.65496	0.75566	0.66805	0.74412	0.68093	0.73234	0.69361	0.72035	0.70608	0.70813	5
56	0.65518	0.75547	0.66827	0.74392	0.68115	0.73215	0.69382	0.72015	0.70628	0.70793	4
57	0.65540	0.75528	0.66848	0.74373	0.68136	0.73195	0.69403	0.71995	0.70649	0.70772	3
58	0.65562	0.75509	0.66870	0.74353	0.68157	0.73175	0.69424	0.71974	0.70670	0.70752	2
59	0.65584	0.75490	0.66891	0.74334	0.68179	0.73155	0.69445	0.71954	0.70690	0.70731	1
60	0.65606	0.75471	0.66913	0.74314	0.68200	0.73135	0.69466	0.71934	0.70711	0.70711	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	49°		48°		47°		46°		45°		

F. NATURAL TANGENTS AND COTANGENTS

MIN	0°		1°		2°		3°		4°		
	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	
0	0000000	0000000	0.01746	57.2900	0.03492	28.6363	0.05241	19.0811	0.06993	14.3007	60
1	0.00029	3437.75	0.01775	56.3506	0.03521	28.3994	0.05270	18.9755	0.07022	14.2411	59
2	0.00058	1718.87	0.01804	55.4415	0.03550	28.1664	0.05299	18.8711	0.07051	14.1821	58
3	0.00087	1145.92	0.01833	54.5613	0.03579	27.9372	0.05328	18.7678	0.07080	14.1235	57
4	0.00116	859.436	0.01862	53.7086	0.03609	27.7117	0.05357	18.6656	0.07110	14.0655	56
5	0.00145	687.549	0.01891	52.8821	0.03638	27.4899	0.05387	18.5645	0.07139	14.0079	55
6	0.00175	572.957	0.01920	52.0807	0.03667	27.2715	0.05416	18.4645	0.07168	13.9507	54
7	0.00204	491.106	0.01949	51.3032	0.03696	27.0566	0.05445	18.3655	0.07197	13.8940	53
8	0.00233	429.718	0.01978	50.5485	0.03725	26.8450	0.05474	18.2677	0.07227	13.8378	52
9	0.00262	381.971	0.02007	49.8157	0.03754	26.6367	0.05503	18.1708	0.07256	13.7821	51
10	0.00291	343.774	0.02036	49.1039	0.03783	26.4316	0.05533	18.0750	0.07285	13.7267	50
11	0.00320	312.521	0.02066	48.4121	0.03812	26.2296	0.05562	17.9802	0.07314	13.6719	49
12	0.00349	286.478	0.02095	47.7395	0.03842	26.0307	0.05591	17.8863	0.07344	13.6174	48
13	0.00378	264.441	0.02124	47.0853	0.03871	25.8348	0.05620	17.7934	0.07373	13.5634	47
14	0.00407	245.552	0.02153	46.4489	0.03900	25.6418	0.05649	17.7015	0.07402	13.5098	46
15	0.00436	229.182	0.02182	45.8294	0.03929	25.4517	0.05678	17.6106	0.07431	13.4566	45
16	0.00465	214.858	0.02211	45.2261	0.03958	25.2644	0.05708	17.5205	0.07461	13.4039	44
17	0.00495	202.219	0.02240	44.6386	0.03987	25.0798	0.05737	17.4314	0.07490	13.3515	43
18	0.00524	190.984	0.02269	44.0661	0.04016	24.8978	0.05766	17.3432	0.07519	13.2996	42
19	0.00553	180.932	0.02298	43.5081	0.04046	24.7185	0.05795	17.2558	0.07548	13.2480	41
20	0.00582	171.885	0.02328	42.9641	0.04075	24.5418	0.05824	17.1693	0.07578	13.1969	40
21	0.00611	163.700	0.02357	42.4335	0.04104	24.3675	0.05854	17.0837	0.07607	13.1461	39
22	0.00640	156.259	0.02386	41.9158	0.04133	24.1957	0.05883	16.9990	0.07636	13.0958	38
23	0.00669	149.465	0.02415	41.4106	0.04162	24.0263	0.05912	16.9150	0.07665	13.0458	37
24	0.00698	143.237	0.02444	40.9174	0.04191	23.8593	0.05941	16.8319	0.07695	12.9962	36
25	0.00727	137.507	0.02473	40.4358	0.04220	23.6945	0.05970	16.7496	0.07724	12.9469	35
26	0.00756	132.219	0.02502	39.9655	0.04250	23.5321	0.05999	16.6681	0.07753	12.8981	34
27	0.00785	127.321	0.02531	39.5059	0.04279	23.3718	0.06029	16.5874	0.07782	12.8496	33
28	0.00815	122.774	0.02560	39.0568	0.04308	23.2137	0.06058	16.5075	0.07812	12.8014	32
29	0.00844	118.540	0.02589	38.6177	0.04337	23.0577	0.06087	16.4283	0.07841	12.7536	31
30	0.00873	114.589	0.02619	38.1885	0.04366	22.9038	0.06116	16.3499	0.07870	12.7062	30
31	0.00902	110.892	0.02648	37.7686	0.04395	22.7519	0.06145	16.2722	0.07899	12.6591	29
32	0.00931	107.426	0.02677	37.3579	0.04424	22.6020	0.06175	16.1952	0.07929	12.6124	28
33	0.00960	104.171	0.02706	36.9560	0.04454	22.4541	0.06204	16.1190	0.07958	12.5660	27
34	0.00989	101.107	0.02735	36.5627	0.04483	22.3081	0.06233	16.0435	0.07987	12.5199	26
35	0.01018	98.2179	0.02764	36.1776	0.04512	22.1640	0.06262	15.9687	0.08017	12.4742	25
36	0.01047	95.4895	0.02793	35.8006	0.04541	22.0217	0.06291	15.8945	0.08046	12.4288	24
37	0.01076	92.9085	0.02822	35.4313	0.04570	21.8813	0.06321	15.8211	0.08075	12.3838	23
38	0.01105	90.4633	0.02851	35.0695	0.04599	21.7426	0.06350	15.7483	0.08104	12.3390	22
39	0.01135	88.1436	0.02881	34.7151	0.04628	21.6056	0.06379	15.6762	0.08134	12.2946	21
40	0.01164	85.9398	0.02910	34.3678	0.04658	21.4704	0.06408	15.6048	0.08163	12.2505	20
41	0.01193	83.8435	0.02939	34.0273	0.04687	21.3369	0.06438	15.5340	0.08192	12.2067	19
42	0.01222	81.8470	0.02968	33.6935	0.04716	21.2049	0.06467	15.4638	0.08221	12.1632	18
43	0.01251	79.9434	0.02997	33.3662	0.04745	21.0747	0.06496	15.3943	0.08251	12.1201	17
44	0.01280	78.1263	0.03026	33.0452	0.04774	20.9460	0.06525	15.3254	0.08280	12.0772	16
45	0.01309	76.3900	0.03055	32.7303	0.04803	20.8188	0.06554	15.2571	0.08309	12.0346	15
46	0.01338	74.7292	0.03084	32.4213	0.04833	20.6932	0.06584	15.1893	0.08339	11.9923	14
47	0.01367	73.1390	0.03114	32.1181	0.04862	20.5691	0.06613	15.1222	0.08368	11.9504	13
48	0.01396	71.6151	0.03143	31.8205	0.04891	20.4465	0.06642	15.0557	0.08397	11.9087	12
49	0.01425	70.1533	0.03172	31.5284	0.04920	20.3253	0.06671	14.9898	0.08427	11.8673	11
50	0.01455	68.7501	0.03201	31.2416	0.04949	20.2056	0.06700	14.9244	0.08456	11.8262	10
51	0.01484	67.4019	0.03230	30.9599	0.04978	20.0872	0.06730	14.8596	0.08485	11.7853	9
52	0.01513	66.1055	0.03259	30.6833	0.05007	19.9702	0.06759	14.7954	0.08514	11.7448	8
53	0.01542	64.8580	0.03288	30.4116	0.05037	19.8546	0.06788	14.7317	0.08544	11.7045	7
54	0.01571	63.6567	0.03317	30.1446	0.05066	19.7403	0.06817	14.6685	0.08573	11.6645	6
55	0.01600	62.4992	0.03346	29.8823	0.05095	19.6273	0.06847	14.6059	0.08602	11.6248	5
56	0.01629	61.3829	0.03376	29.6245	0.05124	19.5156	0.06876	14.5438	0.08632	11.5853	4
57	0.01658	60.3058	0.03405	29.3711	0.05153	19.4051	0.06905	14.4823	0.08661	11.5461	3
58	0.01687	59.2659	0.03434	29.1220	0.05182	19.2959	0.06934	14.4212	0.08690	11.5072	2
59	0.01716	58.2612	0.03463	28.8771	0.05212	19.1879	0.06963	14.3607	0.08720	11.4685	1
60	0.01746	57.2900	0.03492	28.6363	0.05241	19.0811	0.06993	14.3007	0.08749	11.4301	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	89°		88°		87°		86°		85°		

F. NATURAL TANGENTS AND COTANGENTS–CONTINUED

MIN	5°		6°		7°		8°		9°		
	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	
0	0.08749	11.4301	0.10510	9.51436	0.12278	8.14435	0.14054	7.11537	0.15838	6.31375	60
1	0.08778	11.3919	0.10540	9.48781	0.12308	8.12481	0.14084	7.10038	0.15868	6.30189	59
2	0.08807	11.3540	0.10569	9.46141	0.12338	8.10536	0.14113	7.08546	0.15898	6.29007	58
3	0.08837	11.3163	0.10599	9.43515	0.12367	8.08600	0.14143	7.07059	0.15928	6.27829	57
4	0.08866	11.2789	0.10628	9.40904	0.12397	8.06674	0.14173	7.05579	0.15958	6.26655	56
5	0.08895	11.2417	0.10657	9.38307	0.12426	8.04756	0.14202	7.04105	0.15988	6.25486	55
6	0.08925	11.2048	0.10687	9.35724	0.12456	8.02848	0.14232	7.02637	0.16017	6.24321	54
7	0.08954	11.1681	0.10716	9.33155	0.12485	8.00948	0.14262	7.01174	0.16047	6.23160	53
8	0.08983	11.1316	0.10746	9.30599	0.12515	7.99058	0.14291	6.99718	0.16077	6.22003	52
9	0.09013	11.0954	0.10775	9.28058	0.12544	7.97176	0.14321	6.98268	0.16107	6.20851	51
10	0.09042	11.0594	0.10805	9.25530	0.12574	7.95302	0.14351	6.96823	0.16137	6.19703	50
11	0.09071	11.0237	0.10834	9.23016	0.12603	7.93438	0.14381	6.95385	0.16167	6.18559	49
12	0.09101	10.9882	0.10863	9.20516	0.12633	7.91582	0.14410	6.93952	0.16196	6.17419	48
13	0.09130	10.9529	0.10893	9.18028	0.12662	7.89734	0.14440	6.92525	0.16226	6.16283	47
14	0.09159	10.9178	0.10922	9.15554	0.12692	7.87895	0.14470	6.91104	0.16256	6.15151	46
15	0.09189	10.8829	0.10952	9.13093	0.12722	7.86064	0.14499	6.89688	0.16286	6.14023	45
16	0.09218	10.8483	0.10981	9.10646	0.12751	7.84242	0.14529	6.88278	0.16316	6.12899	44
17	0.09247	10.8139	0.11011	9.08211	0.12781	7.82428	0.14559	6.86874	0.16346	6.11779	43
18	0.09277	10.7797	0.11040	9.05789	0.12810	7.80622	0.14588	6.85475	0.16376	6.10664	42
19	0.09306	10.7457	0.11070	9.03379	0.12840	7.78825	0.14618	6.84082	0.16405	6.09552	41
20	0.09335	10.7119	0.11099	9.00983	0.12869	7.77035	0.14648	6.82694	0.16435	6.08444	40
21	0.09365	10.6783	0.11128	8.98598	0.12899	7.75254	0.14678	6.81312	0.16465	6.07340	39
22	0.09394	10.6450	0.11158	8.96227	0.12929	7.73480	0.14707	6.79936	0.16495	6.06240	38
23	0.09423	10.6118	0.11187	8.93867	0.12958	7.71715	0.14737	6.78564	0.16525	6.05143	37
24	0.09453	10.5789	0.11217	8.91520	0.12988	7.69957	0.14767	6.77199	0.16555	6.04051	36
25	0.09482	10.5462	0.11246	8.89185	0.13017	7.68208	0.14796	6.75838	0.16585	6.02962	35
26	0.09511	10.5136	0.11276	8.86862	0.13047	7.66466	0.14826	6.74483	0.16615	6.01878	34
27	0.09541	10.4813	0.11305	8.84551	0.13076	7.64732	0.14856	6.73133	0.16645	6.00797	33
28	0.09570	10.4491	0.11335	8.82252	0.13106	7.63005	0.14886	6.71789	0.16674	5.99720	32
29	0.09600	10.4172	0.11364	8.79964	0.13136	7.61287	0.14915	6.70450	0.16704	5.98646	31
30	0.09629	10.3854	0.11394	8.77689	0.13165	7.59575	0.14945	6.69116	0.16734	5.97576	30
31	0.09658	10.3538	0.11423	8.75425	0.13195	7.57872	0.14975	6.67787	0.16764	5.96510	29
32	0.09688	10.3224	0.11452	8.73172	0.13224	7.56176	0.15005	6.66463	0.16794	5.95448	28
33	0.09717	10.2913	0.11482	8.70931	0.13254	7.54487	0.15034	6.65144	0.16824	5.94390	27
34	0.09746	10.2602	0.11511	8.68701	0.13284	7.52806	0.15064	6.63831	0.16854	5.93335	26
35	0.09776	10.2294	0.11541	8.66482	0.13313	7.51132	0.15094	6.62523	0.16884	5.92283	25
36	0.09805	10.1988	0.11570	8.64275	0.13343	7.49465	0.15124	6.61219	0.16914	5.91236	24
37	0.09834	10.1683	0.11600	8.62078	0.13372	7.47806	0.15153	6.59921	0.16944	5.90191	23
38	0.09864	10.1381	0.11629	8.59893	0.13402	7.46154	0.15183	6.58627	0.16974	5.89151	22
39	0.09893	10.1080	0.11659	8.57718	0.13432	7.44509	0.15213	6.57339	0.17004	5.88114	21
40	0.09923	10.0780	0.11688	8.55555	0.13461	7.42871	0.15243	6.56055	0.17033	5.87080	20
41	0.09952	10.0483	0.11718	8.53402	0.13491	7.41240	0.15272	6.54777	0.17063	5.86051	19
42	0.09981	10.0187	0.11747	8.51259	0.13521	7.39616	0.15302	6.53503	0.17093	5.85024	18
43	0.10011	9.98931	0.11777	8.49128	0.13550	7.37999	0.15332	6.52234	0.17123	5.84001	17
44	0.10040	9.96007	0.11806	8.47007	0.13580	7.36389	0.15362	6.50970	0.17153	5.82982	16
45	0.10069	9.93101	0.11836	8.44896	0.13609	7.34786	0.15391	6.49710	0.17183	5.81966	15
46	0.10099	9.90211	0.11865	8.42795	0.13639	7.33190	0.15421	6.48456	0.17213	5.80953	14
47	0.10128	9.87338	0.11895	8.40705	0.13669	7.31600	0.15451	6.47206	0.17243	5.79944	13
48	0.10158	9.84482	0.11924	8.38625	0.13698	7.30018	0.15481	6.45961	0.17273	5.78938	12
49	0.10187	9.81641	0.11954	8.36555	0.13728	7.28442	0.15511	6.44720	0.17303	5.77936	11
50	0.10216	9.78817	0.11983	8.34496	0.13758	7.26873	0.15540	6.43484	0.17333	5.76937	10
51	0.10246	9.76009	0.12013	8.32446	0.13787	7.25310	0.15570	6.42253	0.17363	5.75941	9
52	0.10275	9.73217	0.12042	8.30406	0.13817	7.23754	0.15600	6.41026	0.17393	5.74949	8
53	0.10305	9.70441	0.12072	8.28376	0.13846	7.22204	0.15630	6.39804	0.17423	5.73960	7
54	0.10334	9.67680	0.12101	8.26355	0.13876	7.20661	0.15660	6.38587	0.17453	5.72974	6
55	0.10363	9.64935	0.12131	8.24345	0.13906	7.19125	0.15689	6.37374	0.17483	5.71992	5
56	0.10393	9.62205	0.12160	8.22344	0.13935	7.17594	0.15719	6.36165	0.17513	5.71013	4
57	0.10422	9.59490	0.12190	8.20352	0.13965	7.16071	0.15749	6.34961	0.17543	5.70037	3
58	0.10452	9.56791	0.12219	8.18370	0.13995	7.14553	0.15779	6.33761	0.17573	5.69064	2
59	0.10481	9.54106	0.12249	8.16398	0.14024	7.13042	0.15809	6.32566	0.17603	5.68094	1
60	0.10510	9.51436	0.12278	8.14435	0.14054	7.11537	0.15838	6.31375	0.17633	5.67128	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	84°		83°		82°		81°		80°		

F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

MIN	10° TAN	10° COT	11° TAN	11° COT	12° TAN	12° COT	13° TAN	13° COT	14° TAN	14° COT	
0	0.17633	5.67128	0.19438	5.14455	0.21256	4.70463	0.23087	4.33148	0.24933	4.01078	60
1	0.17663	5.66165	0.19468	5.13658	0.21286	4.69791	0.23117	4.32573	0.24964	4.00582	59
2	0.17693	5.65205	0.19498	5.12862	0.21316	4.69121	0.23148	4.32001	0.24995	4.00086	58
3	0.17723	5.64248	0.19529	5.12069	0.21347	4.68452	0.23179	4.31430	0.25026	3.99592	57
4	0.17753	5.63295	0.19559	5.11279	0.21377	4.67786	0.23209	4.30860	0.25056	3.99099	56
5	0.17783	5.62344	0.19589	5.10490	0.21408	4.67121	0.23240	4.30291	0.25087	3.98607	55
6	0.17813	5.61397	0.19619	5.09704	0.21438	4.66458	0.23271	4.29724	0.25118	3.98117	54
7	0.17843	5.60452	0.19649	5.08921	0.21469	4.65797	0.23301	4.29159	0.25149	3.97627	53
8	0.17873	5.59511	0.19680	5.08139	0.21499	4.65138	0.23332	4.28595	0.25180	3.97139	52
9	0.17903	5.58573	0.19710	5.07360	0.21529	4.64480	0.23363	4.28032	0.25211	3.96651	51
10	0.17933	5.57638	0.19740	5.06584	0.21560	4.63825	0.23393	4.27471	0.25242	3.96165	50
11	0.17963	5.56706	0.19770	5.05809	0.21590	4.63171	0.23424	4.26911	0.25273	3.95680	49
12	0.17993	5.55777	0.19801	5.05037	0.21621	4.62518	0.23455	4.26352	0.25304	3.95196	48
13	0.18023	5.54851	0.19831	5.04267	0.21651	4.61868	0.23485	4.25795	0.25335	3.94713	47
14	0.18053	5.53927	0.19861	5.03499	0.21682	4.61219	0.23516	4.25239	0.25366	3.94232	46
15	0.18083	5.53007	0.19891	5.02734	0.21712	4.60572	0.23547	4.24685	0.25397	3.93751	45
16	0.18113	5.52090	0.19921	5.01971	0.21743	4.59927	0.23578	4.24132	0.25428	3.93271	44
17	0.18143	5.51176	0.19952	5.01210	0.21773	4.59283	0.23608	4.23580	0.25459	3.92793	43
18	0.18173	5.50264	0.19982	5.00451	0.21804	4.58641	0.23639	4.23030	0.25490	3.92316	42
19	0.18203	5.49356	0.20012	4.99695	0.21834	4.58001	0.23670	4.22481	0.25521	3.91839	41
20	0.18233	5.48451	0.20042	4.98940	0.21864	4.57363	0.23700	4.21933	0.25552	3.91364	40
21	0.18263	5.47548	0.20073	4.98188	0.21895	4.56726	0.23731	4.21387	0.25583	3.90890	39
22	0.18293	5.46648	0.20103	4.97438	0.21925	4.56091	0.23762	4.20842	0.25614	3.90417	38
23	0.18323	5.45751	0.20133	4.96690	0.21956	4.55458	0.23793	4.20298	0.25645	3.89945	37
24	0.18353	5.44857	0.20164	4.95945	0.21986	4.54826	0.23823	4.19756	0.25676	3.89474	36
25	0.18384	5.43966	0.20194	4.95201	0.22017	4.54196	0.23854	4.19215	0.25707	3.89004	35
26	0.18414	5.43077	0.20224	4.94460	0.22047	4.53568	0.23885	4.18675	0.25738	3.88536	34
27	0.18444	5.42192	0.20254	4.93721	0.22078	4.52941	0.23916	4.18137	0.25769	3.88068	33
28	0.18474	5.41309	0.20285	4.92984	0.22108	4.52316	0.23946	4.17600	0.25800	3.87601	32
29	0.18504	5.40429	0.20315	4.92249	0.22139	4.51693	0.23977	4.17064	0.25831	3.87136	31
30	0.18534	5.39552	0.20345	4.91516	0.22169	4.51071	0.24008	4.16530	0.25862	3.86671	30
31	0.18564	5.38677	0.20376	4.90785	0.22200	4.50451	0.24039	4.15997	0.25893	3.86208	29
32	0.18594	5.37805	0.20406	4.90056	0.22231	4.49832	0.24069	4.15465	0.25924	3.85745	28
33	0.18624	5.36936	0.20436	4.89330	0.22261	4.49215	0.24100	4.14934	0.25955	3.85284	27
34	0.18654	5.36070	0.20466	4.88605	0.22292	4.48600	0.24131	4.14405	0.25986	3.84824	26
35	0.18684	5.35206	0.20497	4.87882	0.22322	4.47986	0.24162	4.13877	0.26017	3.84364	25
36	0.18714	5.34345	0.20527	4.87162	0.22353	4.47374	0.24193	4.13350	0.26048	3.83906	24
37	0.18745	5.33487	0.20557	4.86444	0.22383	4.46764	0.24223	4.12825	0.26079	3.83449	23
38	0.18775	5.32631	0.20588	4.85727	0.22414	4.46155	0.24254	4.12301	0.26110	3.82992	22
39	0.18805	5.31778	0.20618	4.85013	0.22444	4.45548	0.24285	4.11778	0.26141	3.82537	21
40	0.18835	5.30928	0.20648	4.84300	0.22475	4.44942	0.24316	4.11256	0.26172	3.82083	20
41	0.18865	5.30080	0.20679	4.83590	0.22505	4.44338	0.24347	4.10736	0.26203	3.81630	19
42	0.18895	5.29235	0.20709	4.82882	0.22536	4.43735	0.24377	4.10216	0.26235	3.81177	18
43	0.18925	5.28393	0.20739	4.82175	0.22567	4.43134	0.24408	4.09699	0.26266	3.80726	17
44	0.18955	5.27553	0.20770	4.81471	0.22597	4.42534	0.24439	4.09182	0.26297	3.80276	16
45	0.18986	5.26715	0.20800	4.80769	0.22628	4.41936	0.24470	4.08666	0.26328	3.79827	15
46	0.19016	5.25880	0.20830	4.80068	0.22658	4.41340	0.24501	4.08152	0.26359	3.79378	14
47	0.19046	5.25048	0.20861	4.79370	0.22689	4.40745	0.24532	4.07639	0.26390	3.78931	13
48	0.19076	5.24218	0.20891	4.78673	0.22719	4.40152	0.24562	4.07127	0.26421	3.78485	12
49	0.19106	5.23391	0.20921	4.77978	0.22750	4.39560	0.24593	4.06616	0.26452	3.78040	11
50	0.19136	5.22566	0.20952	4.77286	0.22781	4.38969	0.24624	4.06107	0.26483	3.77595	10
51	0.19166	5.21744	0.20982	4.76595	0.22811	4.38381	0.24655	4.05599	0.26515	3.77152	9
52	0.19197	5.20925	0.21013	4.75906	0.22842	4.37793	0.24686	4.05092	0.26546	3.76709	8
53	0.19227	5.20107	0.21043	4.75219	0.22872	4.37207	0.24717	4.04586	0.26577	3.76268	7
54	0.19257	5.19293	0.21073	4.74534	0.22903	4.36623	0.24747	4.04081	0.26608	3.75828	6
55	0.19287	5.18480	0.21104	4.73851	0.22934	4.36040	0.24778	4.03578	0.26639	3.75388	5
56	0.19317	5.17671	0.21134	4.73170	0.22964	4.35459	0.24809	4.03076	0.26670	3.74950	4
57	0.19347	5.16863	0.21164	4.72490	0.22995	4.34879	0.24840	4.02574	0.26701	3.74512	3
58	0.19378	5.16058	0.21195	4.71813	0.23026	4.34300	0.24871	4.02074	0.26733	3.74075	2
59	0.19408	5.15256	0.21225	4.71137	0.23056	4.33723	0.24902	4.01576	0.26764	3.73640	1
60	0.19438	5.14455	0.21256	4.70463	0.23087	4.33148	0.24933	4.01078	0.26795	3.73205	0
	79° COT	79° TAN	78° COT	78° TAN	77° COT	77° TAN	76° COT	76° TAN	75° COT	75° TAN	MIN

F. NATURAL TANGENTS AND COTANGENTS–CONTINUED

MIN	15° TAN	15° COT	16° TAN	16° COT	17° TAN	17° COT	18° TAN	18° COT	19° TAN	19° COT	
0	0.26795	3.73205	0.28675	3.48741	0.30573	3.27085	0.32492	3.07768	0.34433	2.90421	60
1	0.26826	3.72771	0.28706	3.48359	0.30605	3.26745	0.32524	3.07464	0.34465	2.90147	59
2	0.26857	3.72338	0.28738	3.47977	0.30637	3.26406	0.32556	3.07160	0.34498	2.89873	58
3	0.26888	3.71907	0.28769	3.47596	0.30669	3.26067	0.32588	3.06857	0.34530	2.89600	57
4	0.26920	3.71476	0.28801	3.47216	0.30700	3.25729	0.32621	3.06554	0.34563	2.89327	56
5	0.26951	3.71046	0.28832	3.46837	0.30732	3.25392	0.32653	3.06252	0.34596	2.89055	55
6	0.26982	3.70616	0.28864	3.46458	0.30764	3.25055	0.32685	3.05950	0.34628	2.88783	54
7	0.27013	3.70188	0.28895	3.46080	0.30796	3.24719	0.32717	3.05649	0.34661	2.88511	53
8	0.27044	3.69761	0.28927	3.45703	0.30828	3.24383	0.32749	3.05349	0.34693	2.88240	52
9	0.27076	3.69335	0.28958	3.45327	0.30860	3.24049	0.32782	3.05049	0.34726	2.87970	51
10	0.27107	3.68909	0.28990	3.44951	0.30891	3.23714	0.32814	3.04749	0.34758	2.87700	50
11	0.27138	3.68485	0.29021	3.44576	0.30923	3.23381	0.32846	3.04450	0.34791	2.87430	49
12	0.27169	3.68061	0.29053	3.44202	0.30955	3.23048	0.32878	3.04152	0.34824	2.87161	48
13	0.27201	3.67638	0.29084	3.43829	0.30987	3.22715	0.32911	3.03854	0.34856	2.86892	47
14	0.27232	3.67217	0.29116	3.43456	0.31019	3.22384	0.32943	3.03556	0.34889	2.86624	46
15	0.27263	3.66796	0.29147	3.43084	0.31051	3.22053	0.32975	3.03260	0.34922	2.86356	45
16	0.27294	3.66376	0.29179	3.42713	0.31083	3.21722	0.33007	3.02963	0.34954	2.86089	44
17	0.27326	3.65957	0.29210	3.42343	0.31115	3.21392	0.33040	3.02667	0.34987	2.85822	43
18	0.27357	3.65538	0.29242	3.41973	0.31147	3.21063	0.33072	3.02372	0.35020	2.85555	42
19	0.27388	3.65121	0.29274	3.41604	0.31178	3.20734	0.33104	3.02077	0.35052	2.85289	41
20	0.27419	3.64705	0.29305	3.41236	0.31210	3.20406	0.33136	3.01783	0.35085	2.85023	40
21	0.27451	3.64289	0.29337	3.40869	0.31242	3.20079	0.33169	3.01489	0.35118	2.84758	39
22	0.27482	3.63874	0.29368	3.40502	0.31274	3.19752	0.33201	3.01196	0.35150	2.84494	38
23	0.27513	3.63461	0.29400	3.40136	0.31306	3.19426	0.33233	3.00903	0.35183	2.84229	37
24	0.27545	3.63048	0.29432	3.39771	0.31338	3.19100	0.33266	3.00611	0.35216	2.83965	36
25	0.27576	3.62636	0.29463	3.39406	0.31370	3.18775	0.33298	3.00319	0.35248	2.83702	35
26	0.27607	3.62224	0.29495	3.39042	0.31402	3.18451	0.33330	3.00028	0.35281	2.83439	34
27	0.27638	3.61814	0.29526	3.38679	0.31434	3.18127	0.33363	2.99738	0.35314	2.83176	33
28	0.27670	3.61405	0.29558	3.38317	0.31466	3.17804	0.33395	2.99447	0.35346	2.82914	32
29	0.27701	3.60996	0.29590	3.37955	0.31498	3.17481	0.33427	2.99158	0.35379	2.82653	31
30	0.27732	3.60588	0.29621	3.37594	0.31530	3.17159	0.33460	2.98868	0.35412	2.82391	30
31	0.27764	3.60181	0.29653	3.37234	0.31562	3.16838	0.33492	2.98580	0.35445	2.82130	29
32	0.27795	3.59775	0.29685	3.36875	0.31594	3.16517	0.33524	2.98292	0.35477	2.81870	28
33	0.27826	3.59370	0.29716	3.36516	0.31626	3.16197	0.33557	2.98004	0.35510	2.81610	27
34	0.27858	3.58966	0.29748	3.36158	0.31658	3.15877	0.33589	2.97717	0.35543	2.81350	26
35	0.27889	3.58562	0.29780	3.35800	0.31690	3.15558	0.33621	2.97430	0.35576	2.81091	25
36	0.27921	3.58160	0.29811	3.35443	0.31722	3.15240	0.33654	2.97144	0.35608	2.80833	24
37	0.27952	3.57758	0.29843	3.35087	0.31754	3.14922	0.33686	2.96858	0.35641	2.80574	23
38	0.27983	3.57357	0.29875	3.34732	0.31786	3.14605	0.33718	2.96573	0.35674	2.80316	22
39	0.28015	3.56957	0.29906	3.34377	0.31818	3.14288	0.33751	2.96288	0.35707	2.80059	21
40	0.28046	3.56557	0.29938	3.34023	0.31850	3.13972	0.33783	2.96004	0.35740	2.79802	20
41	0.28077	3.56159	0.29970	3.33670	0.31882	3.13656	0.33816	2.95721	0.35772	2.79545	19
42	0.28109	3.55761	0.30001	3.33317	0.31914	3.13341	0.33848	2.95437	0.35805	2.79289	18
43	0.28140	3.55364	0.30033	3.32965	0.31946	3.13027	0.33881	2.95155	0.35838	2.79033	17
44	0.28172	3.54968	0.30065	3.32614	0.31978	3.12713	0.33913	2.94872	0.35871	2.78778	16
45	0.28203	3.54573	0.30097	3.32264	0.32010	3.12400	0.33945	2.94591	0.35904	2.78523	15
46	0.28234	3.54179	0.30128	3.31914	0.32042	3.12087	0.33978	2.94309	0.35937	2.78269	14
47	0.28266	3.53785	0.30160	3.31565	0.32074	3.11775	0.34010	2.94028	0.35969	2.78014	13
48	0.28297	3.53393	0.30192	3.31216	0.32106	3.11464	0.34043	2.93748	0.36002	2.77761	12
49	0.28329	3.53001	0.30224	3.30868	0.32139	3.11153	0.34075	2.93468	0.36035	2.77507	11
50	0.28360	3.52609	0.30255	3.30521	0.32171	3.10842	0.34108	2.93189	0.36068	2.77254	10
51	0.28391	3.52219	0.30287	3.30174	0.32203	3.10532	0.34140	2.92910	0.36101	2.77002	9
52	0.28423	3.51829	0.30319	3.29829	0.32235	3.10223	0.34173	2.92632	0.36134	2.76750	8
53	0.28454	3.51441	0.30351	3.29483	0.32267	3.09914	0.34205	2.92354	0.36167	2.76498	7
54	0.28486	3.51053	0.30382	3.29139	0.32299	3.09606	0.34238	2.92076	0.36199	2.76247	6
55	0.28517	3.50666	0.30414	3.28795	0.32331	3.09298	0.34270	2.91799	0.36232	2.75996	5
56	0.28549	3.50279	0.30446	3.28452	0.32363	3.08991	0.34303	2.91523	0.36265	2.75746	4
57	0.28580	3.49894	0.30478	3.28109	0.32396	3.08685	0.34335	2.91246	0.36298	2.75496	3
58	0.28612	3.49509	0.30509	3.27767	0.32428	3.08379	0.34368	2.90971	0.36331	2.75246	2
59	0.28643	3.49125	0.30541	3.27426	0.32460	3.08073	0.34400	2.90696	0.36364	2.74997	1
60	0.28675	3.48741	0.30573	3.27085	0.32492	3.07768	0.34433	2.90421	0.36397	2.74748	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	74°		73°		72°		71°		70°		

F. NATURAL TANGENTS AND COTANGENTS–CONTINUED

MIN	20° TAN	20° COT	21° TAN	21° COT	22° TAN	22° COT	23° TAN	23° COT	24° TAN	24° COT	
0	0.36397	2.74748	0.38386	2.60509	0.40403	2.47509	0.42447	2.35585	0.44523	2.24604	60
1	0.36430	2.74499	0.38420	2.60283	0.40436	2.47302	0.42482	2.35395	0.44558	2.24428	59
2	0.36463	2.74251	0.38453	2.60057	0.40470	2.47095	0.42516	2.35205	0.44593	2.24252	58
3	0.36496	2.74004	0.38487	2.59831	0.40504	2.46888	0.42551	2.35015	0.44627	2.24077	57
4	0.36529	2.73756	0.38520	2.59606	0.40538	2.46682	0.42585	2.34825	0.44662	2.23902	56
5	0.36562	2.73509	0.38553	2.59381	0.40572	2.46476	0.42619	2.34636	0.44697	2.23727	55
6	0.36595	2.73263	0.38587	2.59156	0.40606	2.46270	0.42654	2.34447	0.44732	2.23553	54
7	0.36628	2.73017	0.38620	2.58932	0.40640	2.46065	0.42688	2.34258	0.44767	2.23378	53
8	0.36661	2.72771	0.38654	2.58708	0.40674	2.45860	0.42722	2.34069	0.44802	2.23204	52
9	0.36694	2.72526	0.38687	2.58484	0.40707	2.45655	0.42757	2.33881	0.44837	2.23030	51
10	0.36727	2.72281	0.38721	2.58261	0.40741	2.45451	0.42791	2.33693	0.44872	2.22857	50
11	0.36760	2.72036	0.38754	2.58038	0.40775	2.45246	0.42826	2.33505	0.44907	2.22683	49
12	0.36793	2.71792	0.38787	2.57815	0.40809	2.45043	0.42860	2.33317	0.44942	2.22510	48
13	0.36826	2.71548	0.38821	2.57593	0.40843	2.44839	0.42894	2.33130	0.44977	2.22337	47
14	0.36859	2.71305	0.38854	2.57371	0.40877	2.44636	0.42929	2.32943	0.45012	2.22164	46
15	0.36892	2.71062	0.38888	2.57150	0.40911	2.44433	0.42963	2.32756	0.45047	2.21992	45
16	0.36925	2.70819	0.38921	2.56928	0.40945	2.44230	0.42998	2.32570	0.45082	2.21819	44
17	0.36958	2.70577	0.38955	2.56707	0.40979	2.44027	0.43032	2.32383	0.45117	2.21647	43
18	0.36991	2.70335	0.38988	2.56487	0.41013	2.43825	0.43067	2.32197	0.45152	2.21475	42
19	0.37024	2.70094	0.39022	2.56266	0.41047	2.43623	0.43101	2.32012	0.45187	2.21304	41
20	0.37057	2.69853	0.39055	2.56046	0.41081	2.43422	0.43136	2.31826	0.45222	2.21132	40
21	0.37090	2.69612	0.39089	2.55827	0.41115	2.43220	0.43170	2.31641	0.45257	2.20961	39
22	0.37123	2.69371	0.39122	2.55608	0.41149	2.43019	0.43205	2.31456	0.45292	2.20790	38
23	0.37157	2.69131	0.39156	2.55389	0.41183	2.42819	0.43239	2.31271	0.45327	2.20619	37
24	0.37190	2.68892	0.39190	2.55170	0.41217	2.42618	0.43274	2.31086	0.45362	2.20449	36
25	0.37223	2.68653	0.39223	2.54952	0.41251	2.42418	0.43308	2.30902	0.45397	2.20278	35
26	0.37256	2.68414	0.39257	2.54734	0.41285	2.42218	0.43343	2.30718	0.45432	2.20108	34
27	0.37289	2.68175	0.39290	2.54516	0.41319	2.42019	0.43378	2.30534	0.45467	2.19938	33
28	0.37322	2.67937	0.39324	2.54299	0.41353	2.41819	0.43412	2.30351	0.45502	2.19769	32
29	0.37355	2.67700	0.39357	2.54082	0.41387	2.41620	0.43447	2.30167	0.45538	2.19599	31
30	0.37388	2.67462	0.39391	2.53865	0.41421	2.41421	0.43481	2.29984	0.45573	2.19430	30
31	0.37422	2.67225	0.39425	2.53648	0.41455	2.41223	0.43516	2.29801	0.45608	2.19261	29
32	0.37455	2.66989	0.39458	2.53432	0.41490	2.41025	0.43550	2.29619	0.45643	2.19092	28
33	0.37488	2.66752	0.39492	2.53217	0.41524	2.40827	0.43585	2.29437	0.45678	2.18923	27
34	0.37521	2.66516	0.39526	2.53001	0.41558	2.40629	0.43620	2.29254	0.45713	2.18755	26
35	0.37554	2.66281	0.39559	2.52786	0.41592	2.40432	0.43654	2.29073	0.45748	2.18587	25
36	0.37588	2.66046	0.39593	2.52571	0.41626	2.40235	0.43689	2.28891	0.45784	2.18419	24
37	0.37621	2.65811	0.39626	2.52357	0.41660	2.40038	0.43724	2.28710	0.45819	2.18251	23
38	0.37654	2.65576	0.39660	2.52142	0.41694	2.39841	0.43758	2.28528	0.45854	2.18084	22
39	0.37687	2.65342	0.39694	2.51929	0.41728	2.39645	0.43793	2.28348	0.45889	2.17916	21
40	0.37720	2.65109	0.39727	2.51715	0.41763	2.39449	0.43828	2.28167	0.45924	2.17749	20
41	0.37754	2.64875	0.39761	2.51502	0.41797	2.39253	0.43862	2.27987	0.45960	2.17582	19
42	0.37787	2.64642	0.39795	2.51289	0.41831	2.39058	0.43897	2.27806	0.45995	2.17416	18
43	0.37820	2.64410	0.39829	2.51076	0.41865	2.38863	0.43932	2.27626	0.46030	2.17249	17
44	0.37853	2.64177	0.39862	2.50864	0.41899	2.38668	0.43966	2.27447	0.46065	2.17083	16
45	0.37887	2.63945	0.39896	2.50652	0.41933	2.38473	0.44001	2.27267	0.46101	2.16917	15
46	0.37920	2.63714	0.39930	2.50440	0.41968	2.38279	0.44036	2.27088	0.46136	2.16751	14
47	0.37953	2.63483	0.39963	2.50229	0.42002	2.38084	0.44071	2.26909	0.46171	2.16585	13
48	0.37986	2.63252	0.39997	2.50018	0.42036	2.37891	0.44105	2.26730	0.46206	2.16420	12
49	0.38020	2.63021	0.40031	2.49807	0.42070	2.37697	0.44140	2.26552	0.46242	2.16255	11
50	0.38053	2.62791	0.40065	2.49597	0.42105	2.37504	0.44175	2.26374	0.46277	2.16090	10
51	0.38086	2.62561	0.40098	2.49386	0.42139	2.37311	0.44210	2.26196	0.46312	2.15925	9
52	0.38120	2.62332	0.40132	2.49177	0.42173	2.37118	0.44244	2.26018	0.46348	2.15760	8
53	0.38153	2.62103	0.40166	2.48967	0.42207	2.36925	0.44279	2.25840	0.46383	2.15596	7
54	0.38186	2.61874	0.40200	2.48758	0.42242	2.36733	0.44314	2.25663	0.46418	2.15432	6
55	0.38220	2.61646	0.40234	2.48549	0.42276	2.36541	0.44349	2.25486	0.46454	2.15268	5
56	0.38253	2.61418	0.40267	2.48340	0.42310	2.36349	0.44384	2.25309	0.46489	2.15104	4
57	0.38286	2.61190	0.40301	2.48132	0.42345	2.36158	0.44418	2.25132	0.46525	2.14940	3
58	0.38320	2.60963	0.40335	2.47924	0.42379	2.35967	0.44453	2.24956	0.46560	2.14777	2
59	0.38353	2.60736	0.40369	2.47716	0.42413	2.35776	0.44488	2.24780	0.46595	2.14614	1
60	0.38386	2.60509	0.40403	2.47509	0.42447	2.35585	0.44523	2.24604	0.46631	2.14451	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	69°		68°		67°		66°		65°		

F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

MIN	25° TAN	25° COT	26° TAN	26° COT	27° TAN	27° COT	28° TAN	28° COT	29° TAN	29° COT	
0	0.46631	2.14451	0.48773	2.05030	0.50953	1.96261	0.53171	1.88073	0.55431	1.80405	60
1	0.46666	2.14288	0.48809	2.04879	0.50989	1.96120	0.53208	1.87941	0.55469	1.80281	59
2	0.46702	2.14125	0.48845	2.04728	0.51026	1.95979	0.53246	1.87809	0.55507	1.80158	58
3	0.46737	2.13963	0.48881	2.04577	0.51063	1.95838	0.53283	1.87677	0.55545	1.80034	57
4	0.46772	2.13801	0.48917	2.04426	0.51099	1.95698	0.53320	1.87546	0.55583	1.79911	56
5	0.46808	2.13639	0.48953	2.04276	0.51136	1.95557	0.53358	1.87415	0.55621	1.79788	55
6	0.46843	2.13477	0.48989	2.04125	0.51173	1.95417	0.53395	1.87283	0.55659	1.79665	54
7	0.46879	2.13316	0.49026	2.03975	0.51209	1.95277	0.53432	1.87152	0.55697	1.79542	53
8	0.46914	2.13154	0.49062	2.03825	0.51246	1.95137	0.53470	1.87021	0.55736	1.79419	52
9	0.46950	2.12993	0.49098	2.03675	0.51283	1.94997	0.53507	1.86891	0.55774	1.79296	51
10	0.46985	2.12832	0.49134	2.03526	0.51319	1.94858	0.53545	1.86760	0.55812	1.79174	50
11	0.47021	2.12671	0.49170	2.03376	0.51356	1.94718	0.53582	1.86630	0.55850	1.79051	49
12	0.47056	2.12511	0.49206	2.03227	0.51393	1.94579	0.53620	1.86499	0.55888	1.78929	48
13	0.47092	2.12350	0.49242	2.03078	0.51430	1.94440	0.53657	1.86369	0.55926	1.78807	47
14	0.47128	2.12190	0.49278	2.02929	0.51467	1.94301	0.53694	1.86239	0.55964	1.78685	46
15	0.47163	2.12030	0.49315	2.02780	0.51503	1.94162	0.53732	1.86109	0.56003	1.78563	45
16	0.47199	2.11871	0.49351	2.02631	0.51540	1.94023	0.53769	1.85979	0.56041	1.78441	44
17	0.47234	2.11711	0.49387	2.02483	0.51577	1.93885	0.53807	1.85850	0.56079	1.78319	43
18	0.47270	2.11552	0.49423	2.02335	0.51614	1.93746	0.53844	1.85720	0.56117	1.78198	42
19	0.47305	2.11392	0.49459	2.02187	0.51651	1.93608	0.53882	1.85591	0.56156	1.78077	41
20	0.47341	2.11233	0.49495	2.02039	0.51688	1.93470	0.53920	1.85462	0.56194	1.77955	40
21	0.47377	2.11075	0.49532	2.01891	0.51724	1.93332	0.53957	1.85333	0.56232	1.77834	39
22	0.47412	2.10916	0.49568	2.01743	0.51761	1.93195	0.53995	1.85204	0.56270	1.77713	38
23	0.47448	2.10758	0.49604	2.01596	0.51798	1.93057	0.54032	1.85075	0.56309	1.77592	37
24	0.47483	2.10600	0.49640	2.01449	0.51835	1.92920	0.54070	1.84946	0.56347	1.77471	36
25	0.47519	2.10442	0.49677	2.01302	0.51872	1.92782	0.54107	1.84818	0.56385	1.77351	35
26	0.47555	2.10284	0.49713	2.01155	0.51909	1.92645	0.54145	1.84689	0.56424	1.77230	34
27	0.47590	2.10126	0.49749	2.01008	0.51946	1.92508	0.54183	1.84561	0.56462	1.77110	33
28	0.47626	2.09969	0.49786	2.00862	0.51983	1.92371	0.54220	1.84433	0.56501	1.76990	32
29	0.47662	2.09811	0.49822	2.00715	0.52020	1.92235	0.54258	1.84305	0.56539	1.76869	31
30	0.47698	2.09654	0.49858	2.00569	0.52057	1.92098	0.54296	1.84177	0.56577	1.76749	30
31	0.47733	2.09498	0.49894	2.00423	0.52094	1.91962	0.54333	1.84049	0.56616	1.76629	29
32	0.47769	2.09341	0.49931	2.00277	0.52131	1.91826	0.54371	1.83922	0.56654	1.76510	28
33	0.47805	2.09184	0.49967	2.00131	0.52168	1.91690	0.54409	1.83794	0.56693	1.76390	27
34	0.47840	2.09028	0.50004	1.99986	0.52205	1.91554	0.54446	1.83667	0.56731	1.76271	26
35	0.47876	2.08872	0.50040	1.99841	0.52242	1.91418	0.54484	1.83540	0.56769	1.76151	25
36	0.47912	2.08716	0.50076	1.99695	0.52279	1.91282	0.54522	1.83413	0.56808	1.76032	24
37	0.47948	2.08560	0.50113	1.99550	0.52316	1.91147	0.54560	1.83286	0.56846	1.75913	23
38	0.47984	2.08405	0.50149	1.99406	0.52353	1.91012	0.54597	1.83159	0.56885	1.75794	22
39	0.48019	2.08250	0.50185	1.99261	0.52390	1.90876	0.54635	1.83033	0.56923	1.75675	21
40	0.48055	2.08094	0.50222	1.99116	0.52427	1.90741	0.54673	1.82906	0.56962	1.75556	20
41	0.48091	2.07939	0.50258	1.98972	0.52464	1.90607	0.54711	1.82780	0.57000	1.75437	19
42	0.48127	2.07785	0.50295	1.98828	0.52501	1.90472	0.54748	1.82654	0.57039	1.75319	18
43	0.48163	2.07630	0.50331	1.98684	0.52538	1.90337	0.54786	1.82528	0.57078	1.75200	17
44	0.48198	2.07476	0.50368	1.98540	0.52575	1.90203	0.54824	1.82402	0.57116	1.75082	16
45	0.48234	2.07321	0.50404	1.98396	0.52613	1.90069	0.54862	1.82276	0.57155	1.74964	15
46	0.48270	2.07167	0.50441	1.98253	0.52650	1.89935	0.54900	1.82150	0.57193	1.74846	14
47	0.48306	2.07014	0.50477	1.98110	0.52687	1.89801	0.54938	1.82025	0.57232	1.74728	13
48	0.48342	2.06860	0.50514	1.97966	0.52724	1.89667	0.54975	1.81899	0.57271	1.74610	12
49	0.48378	2.06706	0.50550	1.97823	0.52761	1.89533	0.55013	1.81774	0.57309	1.74492	11
50	0.48414	2.06553	0.50587	1.97681	0.52798	1.89400	0.55051	1.81649	0.57348	1.74375	10
51	0.48450	2.06400	0.50623	1.97538	0.52836	1.89266	0.55089	1.81524	0.57386	1.74257	9
52	0.48486	2.06247	0.50660	1.97395	0.52873	1.89133	0.55127	1.81399	0.57425	1.74140	8
53	0.48521	2.06094	0.50696	1.97253	0.52910	1.89000	0.55165	1.81274	0.57464	1.74022	7
54	0.48557	2.05942	0.50733	1.97111	0.52947	1.88867	0.55203	1.81150	0.57503	1.73905	6
55	0.48593	2.05790	0.50769	1.96969	0.52985	1.88734	0.55241	1.81025	0.57541	1.73788	5
56	0.48629	2.05637	0.50806	1.96827	0.53022	1.88602	0.55279	1.80901	0.57580	1.73671	4
57	0.48665	2.05485	0.50843	1.96685	0.53059	1.88469	0.55317	1.80777	0.57619	1.73555	3
58	0.48701	2.05333	0.50879	1.96544	0.53096	1.88337	0.55355	1.80653	0.57657	1.73438	2
59	0.48737	2.05182	0.50916	1.96402	0.53134	1.88205	0.55393	1.80529	0.57696	1.73321	1
60	0.48773	2.05030	0.50953	1.96261	0.53171	1.88073	0.55431	1.80405	0.57735	1.73205	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	64°		63°		62°		61°		60°		

F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

MIN	30° TAN	30° COT	31° TAN	31° COT	32° TAN	32° COT	33° TAN	33° COT	34° TAN	34° COT	
0	0.57735	1.73205	0.60086	1.66428	0.62487	1.60033	0.64941	1.53986	0.67451	1.48256	60
1	0.57774	1.73089	0.60126	1.66318	0.62527	1.59930	0.64982	1.53888	0.67493	1.48163	59
2	0.57813	1.72973	0.60165	1.66209	0.62568	1.59826	0.65024	1.53791	0.67536	1.48070	58
3	0.57851	1.72857	0.60205	1.66099	0.62608	1.59723	0.65065	1.53693	0.67578	1.47977	57
4	0.57890	1.72741	0.60245	1.65990	0.62649	1.59620	0.65106	1.53595	0.67620	1.47885	56
5	0.57929	1.72625	0.60284	1.65881	0.62689	1.59517	0.65148	1.53497	0.67663	1.47792	55
6	0.57968	1.72509	0.60324	1.65772	0.62730	1.59414	0.65189	1.53400	0.67705	1.47699	54
7	0.58007	1.72393	0.60364	1.65663	0.62770	1.59311	0.65231	1.53302	0.67748	1.47607	53
8	0.58046	1.72278	0.60403	1.65554	0.62811	1.59208	0.65272	1.53205	0.67790	1.47514	52
9	0.58085	1.72163	0.60443	1.65445	0.62852	1.59105	0.65314	1.53107	0.67832	1.47422	51
10	0.58124	1.72047	0.60483	1.65337	0.62892	1.59002	0.65355	1.53010	0.67875	1.47330	50
11	0.58162	1.71932	0.60522	1.65228	0.62933	1.58900	0.65397	1.52913	0.67917	1.47238	49
12	0.58201	1.71817	0.60562	1.65120	0.62973	1.58797	0.65438	1.52816	0.67960	1.47146	48
13	0.58240	1.71702	0.60602	1.65011	0.63014	1.58695	0.65480	1.52719	0.68002	1.47053	47
14	0.58279	1.71588	0.60642	1.64903	0.63055	1.58593	0.65521	1.52622	0.68045	1.46962	46
15	0.58318	1.71473	0.60681	1.64795	0.63095	1.58490	0.65563	1.52525	0.68088	1.46870	45
16	0.58357	1.71358	0.60721	1.64687	0.63136	1.58388	0.65604	1.52429	0.68130	1.46778	44
17	0.58396	1.71244	0.60761	1.64579	0.63177	1.58286	0.65646	1.52332	0.68173	1.46686	43
18	0.58435	1.71129	0.60801	1.64471	0.63217	1.58184	0.65688	1.52235	0.68215	1.46595	42
19	0.58474	1.71015	0.60841	1.64363	0.63258	1.58083	0.65729	1.52139	0.68258	1.46503	41
20	0.58513	1.70901	0.60881	1.64256	0.63299	1.57981	0.65771	1.52043	0.68301	1.46411	40
21	0.58552	1.70787	0.60921	1.64148	0.63340	1.57879	0.65813	1.51946	0.68343	1.46320	39
22	0.58591	1.70673	0.60960	1.64041	0.63380	1.57778	0.65854	1.51850	0.68386	1.46229	38
23	0.58631	1.70560	0.61000	1.63934	0.63421	1.57676	0.65896	1.51754	0.68429	1.46137	37
24	0.58670	1.70446	0.61040	1.63826	0.63462	1.57575	0.65938	1.51658	0.68471	1.46046	36
25	0.58709	1.70332	0.61080	1.63719	0.63503	1.57474	0.65980	1.51562	0.68514	1.45955	35
26	0.58748	1.70219	0.61120	1.63612	0.63544	1.57372	0.66021	1.51466	0.68557	1.45864	34
27	0.58787	1.70106	0.61160	1.63505	0.63584	1.57271	0.66063	1.51370	0.68600	1.45773	33
28	0.58826	1.69992	0.61200	1.63398	0.63625	1.57170	0.66105	1.51275	0.68642	1.45682	32
29	0.58865	1.69879	0.61240	1.63292	0.63666	1.57069	0.66147	1.51179	0.68685	1.45592	31
30	0.58905	1.69766	0.61280	1.63185	0.63707	1.56969	0.66189	1.51084	0.68728	1.45501	30
31	0.58944	1.69653	0.61320	1.63079	0.63748	1.56868	0.66230	1.50988	0.68771	1.45410	29
32	0.58983	1.69541	0.61360	1.62972	0.63789	1.56767	0.66272	1.50893	0.68814	1.45320	28
33	0.59022	1.69428	0.61400	1.62866	0.63830	1.56667	0.66314	1.50797	0.68857	1.45229	27
34	0.59061	1.69316	0.61440	1.62760	0.63871	1.56566	0.66356	1.50702	0.68900	1.45139	26
35	0.59101	1.69203	0.61480	1.62654	0.63912	1.56466	0.66398	1.50607	0.68942	1.45049	25
36	0.59140	1.69091	0.61520	1.62548	0.63953	1.56366	0.66440	1.50512	0.68985	1.44958	24
37	0.59179	1.68979	0.61561	1.62442	0.63994	1.56265	0.66482	1.50417	0.69028	1.44868	23
38	0.59218	1.68866	0.61601	1.62336	0.64035	1.56165	0.66524	1.50322	0.69071	1.44778	22
39	0.59258	1.68754	0.61641	1.62230	0.64076	1.56065	0.66566	1.50228	0.69114	1.44688	21
40	0.59297	1.68643	0.61681	1.62125	0.64117	1.55966	0.66608	1.50133	0.69157	1.44598	20
41	0.59336	1.68531	0.61721	1.62019	0.64158	1.55866	0.66650	1.50038	0.69200	1.44508	19
42	0.59376	1.68419	0.61761	1.61914	0.64199	1.55766	0.66692	1.49944	0.69243	1.44418	18
43	0.59415	1.68308	0.61801	1.61808	0.64240	1.55666	0.66734	1.49849	0.69286	1.44329	17
44	0.59454	1.68196	0.61842	1.61703	0.64281	1.55567	0.66776	1.49755	0.69329	1.44239	16
45	0.59494	1.68085	0.61882	1.61598	0.64322	1.55467	0.66818	1.49661	0.69372	1.44149	15
46	0.59533	1.67974	0.61922	1.61493	0.64363	1.55368	0.66860	1.49566	0.69416	1.44060	14
47	0.59573	1.67863	0.61962	1.61388	0.64404	1.55269	0.66902	1.49472	0.69459	1.43970	13
48	0.59612	1.67752	0.62003	1.61283	0.64446	1.55170	0.66944	1.49378	0.69502	1.43881	12
49	0.59651	1.67641	0.62043	1.61179	0.64487	1.55071	0.66986	1.49284	0.69545	1.43792	11
50	0.59691	1.67530	0.62083	1.61074	0.64528	1.54972	0.67028	1.49190	0.69588	1.43703	10
51	0.59730	1.67419	0.62124	1.60970	0.64569	1.54873	0.67071	1.49097	0.69631	1.43614	9
52	0.59770	1.67309	0.62164	1.60865	0.64610	1.54774	0.67113	1.49003	0.69675	1.43525	8
53	0.59809	1.67198	0.62204	1.60761	0.64652	1.54675	0.67155	1.48909	0.69718	1.43436	7
54	0.59849	1.67088	0.62245	1.60657	0.64693	1.54576	0.67197	1.48816	0.69761	1.43347	6
55	0.59888	1.66978	0.62285	1.60553	0.64734	1.54478	0.67239	1.48722	0.69804	1.43258	5
56	0.59928	1.66867	0.62325	1.60449	0.64775	1.54379	0.67282	1.48629	0.69847	1.43169	4
57	0.59967	1.66757	0.62366	1.60345	0.64817	1.54281	0.67324	1.48536	0.69891	1.43080	3
58	0.60007	1.66647	0.62406	1.60241	0.64858	1.54183	0.67366	1.48442	0.69934	1.42992	2
59	0.60046	1.66538	0.62446	1.60137	0.64899	1.54085	0.67409	1.48349	0.69977	1.42903	1
60	0.60086	1.66428	0.62487	1.60033	0.64941	1.53986	0.67451	1.48256	0.70021	1.42815	0
	COT 59°	TAN 59°	COT 58°	TAN 58°	COT 57°	TAN 57°	COT 56°	TAN 56°	COT 55°	TAN 55°	MIN

F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

MIN	35° TAN	35° COT	36° TAN	36° COT	37° TAN	37° COT	38° TAN	38° COT	39° TAN	39° COT	
0	0.70021	1.42815	0.72654	1.37638	0.75355	1.32704	0.78129	1.27994	0.80978	1.23490	60
1	0.70064	1.42726	0.72699	1.37554	0.75401	1.32624	0.78175	1.27917	0.81027	1.23416	59
2	0.70107	1.42638	0.72743	1.37470	0.75447	1.32544	0.78222	1.27841	0.81075	1.23343	58
3	0.70151	1.42550	0.72788	1.37386	0.75492	1.32464	0.78269	1.27764	0.81123	1.23270	57
4	0.70194	1.42462	0.72832	1.37302	0.75538	1.32384	0.78316	1.27688	0.81171	1.23196	56
5	0.70238	1.42374	0.72877	1.37218	0.75584	1.32304	0.78363	1.27611	0.81220	1.23123	55
6	0.70281	1.42286	0.72921	1.37134	0.75629	1.32224	0.78410	1.27535	0.81268	1.23050	54
7	0.70325	1.42198	0.72966	1.37050	0.75675	1.32144	0.78457	1.27458	0.81316	1.22977	53
8	0.70368	1.42110	0.73010	1.36967	0.75721	1.32064	0.78504	1.27382	0.81364	1.22904	52
9	0.70412	1.42022	0.73055	1.36883	0.75767	1.31984	0.78551	1.27306	0.81413	1.22831	51
10	0.70455	1.41934	0.73100	1.36800	0.75812	1.31904	0.78598	1.27230	0.81461	1.22758	50
11	0.70499	1.41847	0.73144	1.36716	0.75858	1.31825	0.78645	1.27153	0.81510	1.22685	49
12	0.70542	1.41759	0.73189	1.36633	0.75904	1.31745	0.78692	1.27077	0.81558	1.22612	48
13	0.70586	1.41672	0.73234	1.36549	0.75950	1.31666	0.78739	1.27001	0.81606	1.22539	47
14	0.70629	1.41584	0.73278	1.36466	0.75996	1.31586	0.78786	1.26925	0.81655	1.22467	46
15	0.70673	1.41497	0.73323	1.36383	0.76042	1.31507	0.78834	1.26849	0.81703	1.22394	45
16	0.70717	1.41409	0.73368	1.36300	0.76088	1.31427	0.78881	1.26774	0.81752	1.22321	44
17	0.70760	1.41322	0.73413	1.36217	0.76134	1.31348	0.78928	1.26698	0.81800	1.22249	43
18	0.70804	1.41235	0.73457	1.36134	0.76180	1.31269	0.78975	1.26622	0.81849	1.22176	42
19	0.70848	1.41148	0.73502	1.36051	0.76226	1.31190	0.79022	1.26546	0.81898	1.22104	41
20	0.70891	1.41061	0.73547	1.35968	0.76272	1.31110	0.79070	1.26471	0.81946	1.22031	40
21	0.70935	1.40974	0.73592	1.35885	0.76318	1.31031	0.79117	1.26395	0.81995	1.21959	39
22	0.70979	1.40887	0.73637	1.35802	0.76364	1.30952	0.79164	1.26319	0.82044	1.21886	38
23	0.71023	1.40800	0.73681	1.35719	0.76410	1.30873	0.79212	1.26244	0.82092	1.21814	37
24	0.71066	1.40714	0.73726	1.35637	0.76456	1.30795	0.79259	1.26169	0.82141	1.21742	36
25	0.71110	1.40627	0.73771	1.35554	0.76502	1.30716	0.79306	1.26093	0.82190	1.21670	35
26	0.71154	1.40540	0.73816	1.35472	0.76548	1.30637	0.79354	1.26018	0.82238	1.21598	34
27	0.71198	1.40454	0.73861	1.35389	0.76594	1.30558	0.79401	1.25943	0.82287	1.21526	33
28	0.71242	1.40367	0.73906	1.35307	0.76640	1.30480	0.79449	1.25867	0.82336	1.21454	32
29	0.71285	1.40281	0.73951	1.35224	0.76686	1.30401	0.79496	1.25792	0.82385	1.21382	31
30	0.71329	1.40195	0.73996	1.35142	0.76733	1.30323	0.79544	1.25717	0.82434	1.21310	30
31	0.71373	1.40109	0.74041	1.35060	0.76779	1.30244	0.79591	1.25642	0.82483	1.21238	29
32	0.71417	1.40022	0.74086	1.34978	0.76825	1.30166	0.79639	1.25567	0.82531	1.21166	28
33	0.71461	1.39936	0.74131	1.34896	0.76871	1.30087	0.79686	1.25492	0.82580	1.21094	27
34	0.71505	1.39850	0.74176	1.34814	0.76918	1.30009	0.79734	1.25417	0.82629	1.21023	26
35	0.71549	1.39764	0.74221	1.34732	0.76964	1.29931	0.79781	1.25343	0.82678	1.20951	25
36	0.71593	1.39679	0.74267	1.34650	0.77010	1.29853	0.79829	1.25268	0.82727	1.20879	24
37	0.71637	1.39593	0.74312	1.34568	0.77057	1.29775	0.79877	1.25193	0.82776	1.20808	23
38	0.71681	1.39507	0.74357	1.34487	0.77103	1.29696	0.79924	1.25118	0.82825	1.20736	22
39	0.71725	1.39421	0.74402	1.34405	0.77149	1.29618	0.79972	1.25044	0.82874	1.20665	21
40	0.71769	1.39336	0.74447	1.34323	0.77196	1.29541	0.80020	1.24969	0.82923	1.20593	20
41	0.71813	1.39250	0.74492	1.34242	0.77242	1.29463	0.80067	1.24895	0.82972	1.20522	19
42	0.71857	1.39165	0.74538	1.34160	0.77289	1.29385	0.80115	1.24820	0.83022	1.20451	18
43	0.71901	1.39079	0.74583	1.34079	0.77335	1.29307	0.80163	1.24746	0.83071	1.20379	17
44	0.71946	1.38994	0.74628	1.33998	0.77382	1.29229	0.80211	1.24672	0.83120	1.20308	16
45	0.71990	1.38909	0.74674	1.33916	0.77428	1.29152	0.80258	1.24597	0.83169	1.20237	15
46	0.72034	1.38824	0.74719	1.33835	0.77475	1.29074	0.80306	1.24523	0.83218	1.20166	14
47	0.72078	1.38738	0.74764	1.33754	0.77521	1.28997	0.80354	1.24449	0.83268	1.20095	13
48	0.72122	1.38653	0.74810	1.33673	0.77568	1.28919	0.80402	1.24375	0.83317	1.20024	12
49	0.72167	1.38568	0.74855	1.33592	0.77615	1.28842	0.80450	1.24301	0.83366	1.19953	11
50	0.72211	1.38484	0.74900	1.33511	0.77661	1.28764	0.80498	1.24227	0.83415	1.19882	10
51	0.72255	1.38399	0.74946	1.33430	0.77708	1.28687	0.80546	1.24153	0.83465	1.19811	9
52	0.72299	1.38314	0.74991	1.33349	0.77754	1.28610	0.80594	1.24079	0.83514	1.19740	8
53	0.72344	1.38229	0.75037	1.33268	0.77801	1.28533	0.80642	1.24005	0.83564	1.19669	7
54	0.72388	1.38145	0.75082	1.33187	0.77848	1.28456	0.80690	1.23931	0.83613	1.19599	6
55	0.72432	1.38060	0.75128	1.33107	0.77895	1.28379	0.80738	1.23858	0.83662	1.19528	5
56	0.72477	1.37976	0.75173	1.33026	0.77941	1.28302	0.80786	1.23784	0.83712	1.19457	4
57	0.72521	1.37891	0.75219	1.32946	0.77988	1.28225	0.80834	1.23710	0.83761	1.19387	3
58	0.72565	1.37807	0.75264	1.32865	0.78035	1.28148	0.80882	1.23637	0.83811	1.19316	2
59	0.72610	1.37722	0.75310	1.32785	0.78082	1.28071	0.80930	1.23563	0.83860	1.19246	1
60	0.72654	1.37638	0.75355	1.32704	0.78129	1.27994	0.80978	1.23490	0.83910	1.19175	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	54°		53°		52°		51°		50°		

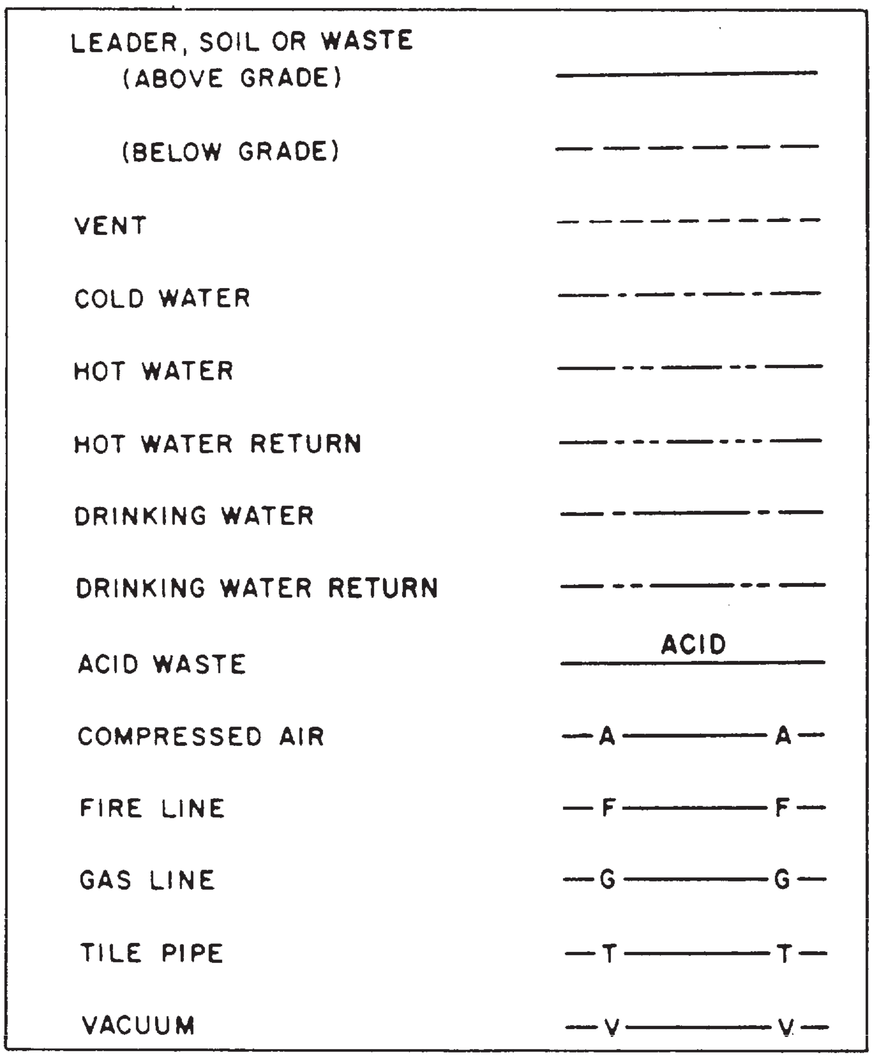
F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

MIN	40° TAN	40° COT	41° TAN	41° COT	42° TAN	42° COT	43° TAN	43° COT	44° TAN	44° COT	
0	0.83910	1.19175	0.86929	1.15037	0.90040	1.11061	0.93252	1.07237	0.96569	1.03553	60
1	0.83960	1.19105	0.86980	1.14969	0.90093	1.10996	0.93306	1.07174	0.96625	1.03493	59
2	0.84009	1.19035	0.87031	1.14902	0.90146	1.10931	0.93360	1.07112	0.96681	1.03433	58
3	0.84059	1.18964	0.87082	1.14834	0.90199	1.10867	0.93415	1.07049	0.96738	1.03372	57
4	0.84108	1.18894	0.87133	1.14767	0.90251	1.10802	0.93469	1.06987	0.96794	1.03312	56
5	0.84158	1.18824	0.87184	1.14699	0.90304	1.10737	0.93524	1.06925	0.96850	1.03252	55
6	0.84208	1.18754	0.87236	1.14632	0.90357	1.10672	0.93578	1.06862	0.96907	1.03192	54
7	0.84258	1.18684	0.87287	1.14565	0.90410	1.10607	0.93633	1.06800	0.96963	1.03132	53
8	0.84307	1.18614	0.87338	1.14498	0.90463	1.10543	0.93688	1.06738	0.97020	1.03072	52
9	0.84357	1.18544	0.87389	1.14430	0.90516	1.10478	0.93742	1.06676	0.97076	1.03012	51
10	0.84407	1.18474	0.87441	1.14363	0.90569	1.10414	0.93797	1.06613	0.97133	1.02952	50
11	0.84457	1.18404	0.87492	1.14296	0.90621	1.10349	0.93852	1.06551	0.97189	1.02892	49
12	0.84507	1.18334	0.87543	1.14229	0.90674	1.10285	0.93906	1.06489	0.97246	1.02832	48
13	0.84556	1.18264	0.87595	1.14162	0.90727	1.10220	0.93961	1.06427	0.97302	1.02772	47
14	0.84606	1.18194	0.87646	1.14095	0.90781	1.10156	0.94016	1.06365	0.97359	1.02713	46
15	0.84656	1.18125	0.87698	1.14028	0.90834	1.10091	0.94071	1.06303	0.97416	1.02653	45
16	0.84706	1.18055	0.87749	1.13961	0.90887	1.10027	0.94125	1.06241	0.97472	1.02593	44
17	0.84756	1.17986	0.87801	1.13894	0.90940	1.09963	0.94180	1.06179	0.97529	1.02533	43
18	0.84806	1.17916	0.87852	1.13828	0.90993	1.09899	0.94235	1.06117	0.97586	1.02474	42
19	0.84856	1.17846	0.87904	1.13761	0.91046	1.09834	0.94290	1.06056	0.97643	1.02414	41
20	0.84906	1.17777	0.87955	1.13694	0.91099	1.09770	0.94345	1.05994	0.97700	1.02355	40
21	0.84956	1.17708	0.88007	1.13627	0.91153	1.09706	0.94400	1.05932	0.97756	1.02295	39
22	0.85006	1.17638	0.88059	1.13561	0.91206	1.09642	0.94455	1.05870	0.97813	1.02236	38
23	0.85057	1.17569	0.88110	1.13494	0.91259	1.09578	0.94510	1.05809	0.97870	1.02176	37
24	0.85107	1.17500	0.88162	1.13428	0.91313	1.09514	0.94565	1.05747	0.97927	1.02117	36
25	0.85157	1.17430	0.88214	1.13361	0.91366	1.09450	0.94620	1.05685	0.97984	1.02057	35
26	0.85207	1.17361	0.88265	1.13295	0.91419	1.09386	0.94676	1.05624	0.98041	1.01998	34
27	0.85257	1.17292	0.88317	1.13228	0.91473	1.09322	0.94731	1.05562	0.98098	1.01939	33
28	0.85308	1.17223	0.88369	1.13162	0.91526	1.09258	0.94786	1.05501	0.98155	1.01879	32
29	0.85358	1.17154	0.88421	1.13096	0.91580	1.09195	0.94841	1.05439	0.98213	1.01820	31
30	0.85408	1.17085	0.88473	1.13029	0.91633	1.09131	0.94896	1.05378	0.98270	1.01761	30
31	0.85458	1.17016	0.88524	1.12963	0.91687	1.09067	0.94952	1.05317	0.98327	1.01702	29
32	0.85509	1.16947	0.88576	1.12897	0.91740	1.09003	0.95007	1.05255	0.98384	1.01642	28
33	0.85559	1.16878	0.88628	1.12831	0.91794	1.08940	0.95062	1.05194	0.98441	1.01583	27
34	0.85609	1.16809	0.88680	1.12765	0.91847	1.08876	0.95118	1.05133	0.98499	1.01524	26
35	0.85660	1.16741	0.88732	1.12699	0.91901	1.08813	0.95173	1.05072	0.98556	1.01465	25
36	0.85710	1.16672	0.88784	1.12633	0.91955	1.08749	0.95229	1.05010	0.98613	1.01406	24
37	0.85761	1.16603	0.88836	1.12567	0.92008	1.08686	0.95284	1.04949	0.98671	1.01347	23
38	0.85811	1.16535	0.88888	1.12501	0.92062	1.08622	0.95340	1.04888	0.98728	1.01288	22
39	0.85862	1.16466	0.88940	1.12435	0.92116	1.08559	0.95395	1.04827	0.98786	1.01229	21
40	0.85912	1.16398	0.88992	1.12369	0.92170	1.08496	0.95451	1.04766	0.98843	1.01170	20
41	0.85963	1.16329	0.89045	1.12303	0.92224	1.08432	0.95506	1.04705	0.98901	1.01112	19
42	0.86014	1.16261	0.89097	1.12238	0.92277	1.08369	0.95562	1.04644	0.98958	1.01053	18
43	0.86064	1.16192	0.89149	1.12172	0.92331	1.08306	0.95618	1.04583	0.99016	1.00994	17
44	0.86115	1.16124	0.89201	1.12106	0.92385	1.08243	0.95673	1.04522	0.99073	1.00935	16
45	0.86166	1.16056	0.89253	1.12041	0.92439	1.08179	0.95729	1.04461	0.99131	1.00876	15
46	0.86216	1.15987	0.89306	1.11975	0.92493	1.08116	0.95785	1.04401	0.99189	1.00818	14
47	0.86267	1.15919	0.89358	1.11909	0.92547	1.08053	0.95841	1.04340	0.99247	1.00759	13
48	0.86318	1.15851	0.89410	1.11844	0.92601	1.07990	0.95897	1.04279	0.99304	1.00701	12
49	0.86368	1.15783	0.89463	1.11778	0.92655	1.07927	0.95952	1.04218	0.99362	1.00642	11
50	0.86419	1.15715	0.89515	1.11713	0.92709	1.07864	0.96008	1.04158	0.99420	1.00583	10
51	0.86470	1.15647	0.89567	1.11648	0.92763	1.07801	0.96064	1.04097	0.99478	1.00525	9
52	0.86521	1.15579	0.89620	1.11582	0.92817	1.07738	0.96120	1.04036	0.99536	1.00467	8
53	0.86572	1.15511	0.89672	1.11517	0.92872	1.07676	0.96176	1.03976	0.99594	1.00408	7
54	0.86623	1.15443	0.89725	1.11452	0.92926	1.07613	0.96232	1.03915	0.99652	1.00350	6
55	0.86674	1.15375	0.89777	1.11387	0.92980	1.07550	0.96288	1.03855	0.99710	1.00291	5
56	0.86725	1.15308	0.89830	1.11321	0.93034	1.07487	0.96344	1.03794	0.99768	1.00233	4
57	0.86776	1.15240	0.89883	1.11256	0.93088	1.07425	0.96400	1.03734	0.99826	1.00175	3
58	0.86827	1.15172	0.89935	1.11191	0.93143	1.07362	0.96457	1.03674	0.99884	1.00116	2
59	0.86878	1.15104	0.89988	1.11126	0.93197	1.07299	0.96513	1.03613	0.99942	1.00058	1
60	0.86929	1.15037	0.90040	1.11061	0.93252	1.07237	0.96569	1.03553	1.00000	1.00000	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	49°		48°		47°		46°		45°		

APPENDIX IV

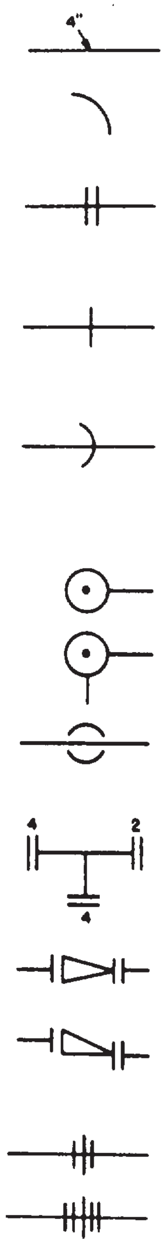
USEFUL DRAFTING SYMBOLS

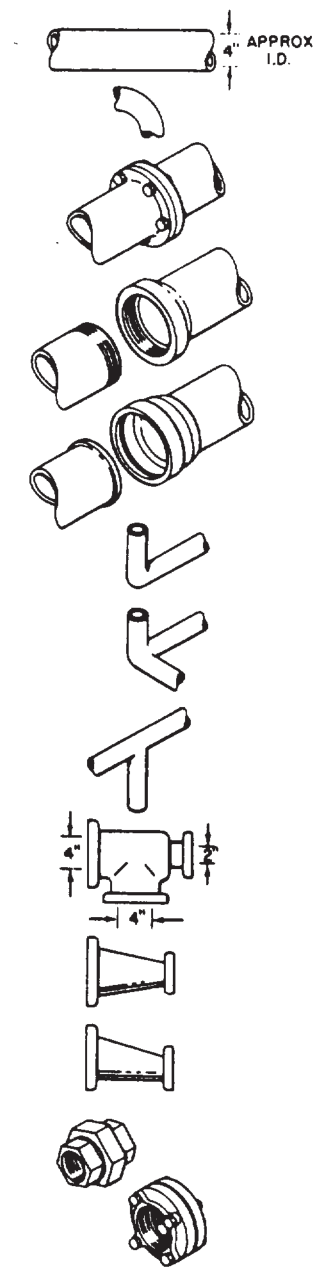
A. MECHANICAL (PLUMBING) SYMBOLS



Line symbols for piping.

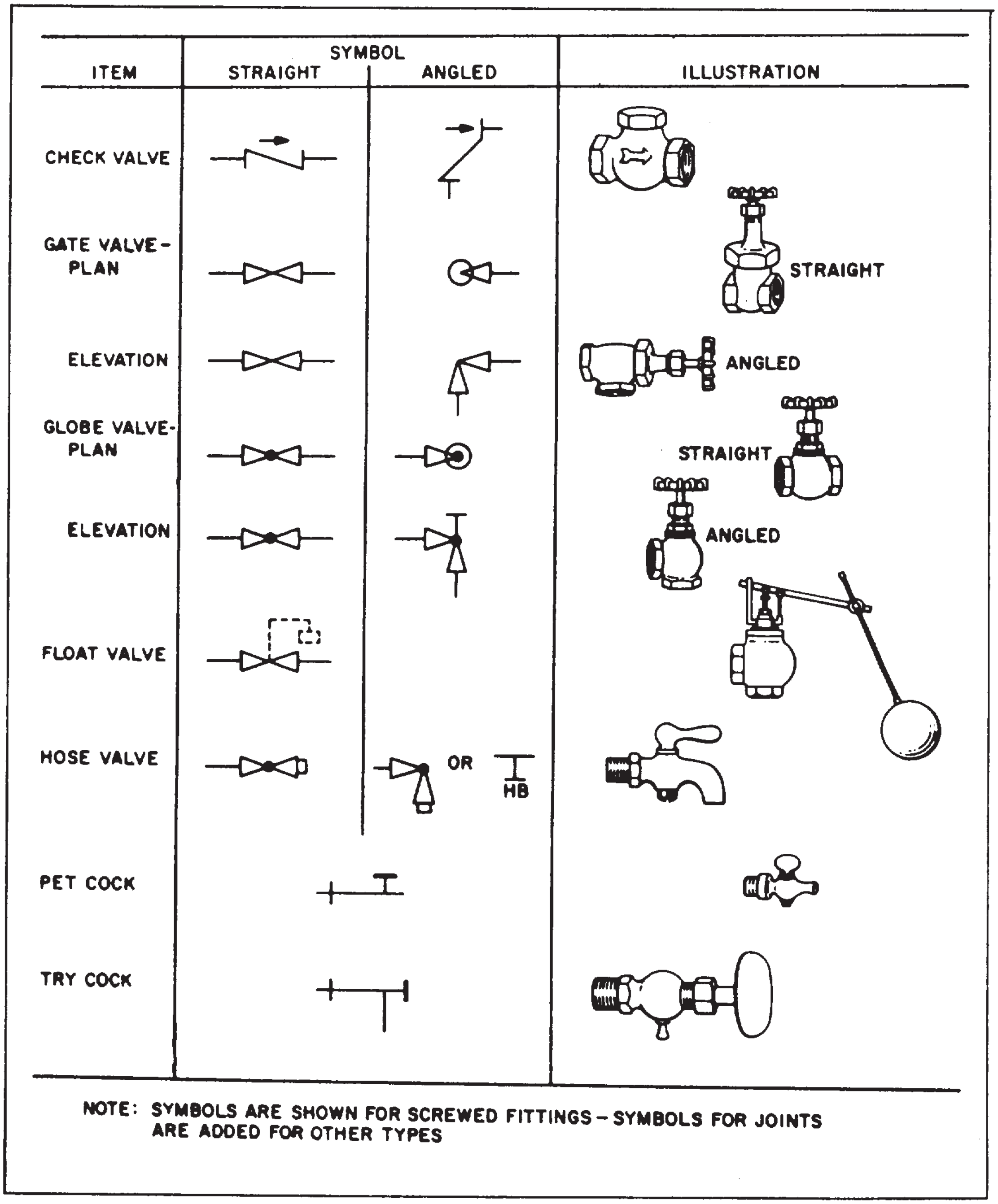
ITEM	SYMBOL	SAMPLE APPLICATION (S)	ILLUSTRATION
PIPE	SINGLE LINE IN SHAPE OF PIPE—USUALLY WITH NOMINAL SIZE NOTED		
JOINT—FLANGED	DOUBLE LINE		
SCREWED	SINGLE LINE		
BELL AND SPIGOT	CURVED LINE		
OUTLET TURNED UP	CIRCLE AND DOT		
OUTLET TURNED DOWN	SEMICIRCLE		
REDUCING OR ENLARGING FITTING	NOMINAL SIZE NOTED AT JOINT		
REDUCER CONCENTRIC	TRIANGLE		
ECCENTRIC	TRIANGLE		
UNION SCREWED	LINE		
FLANGED	LINE		





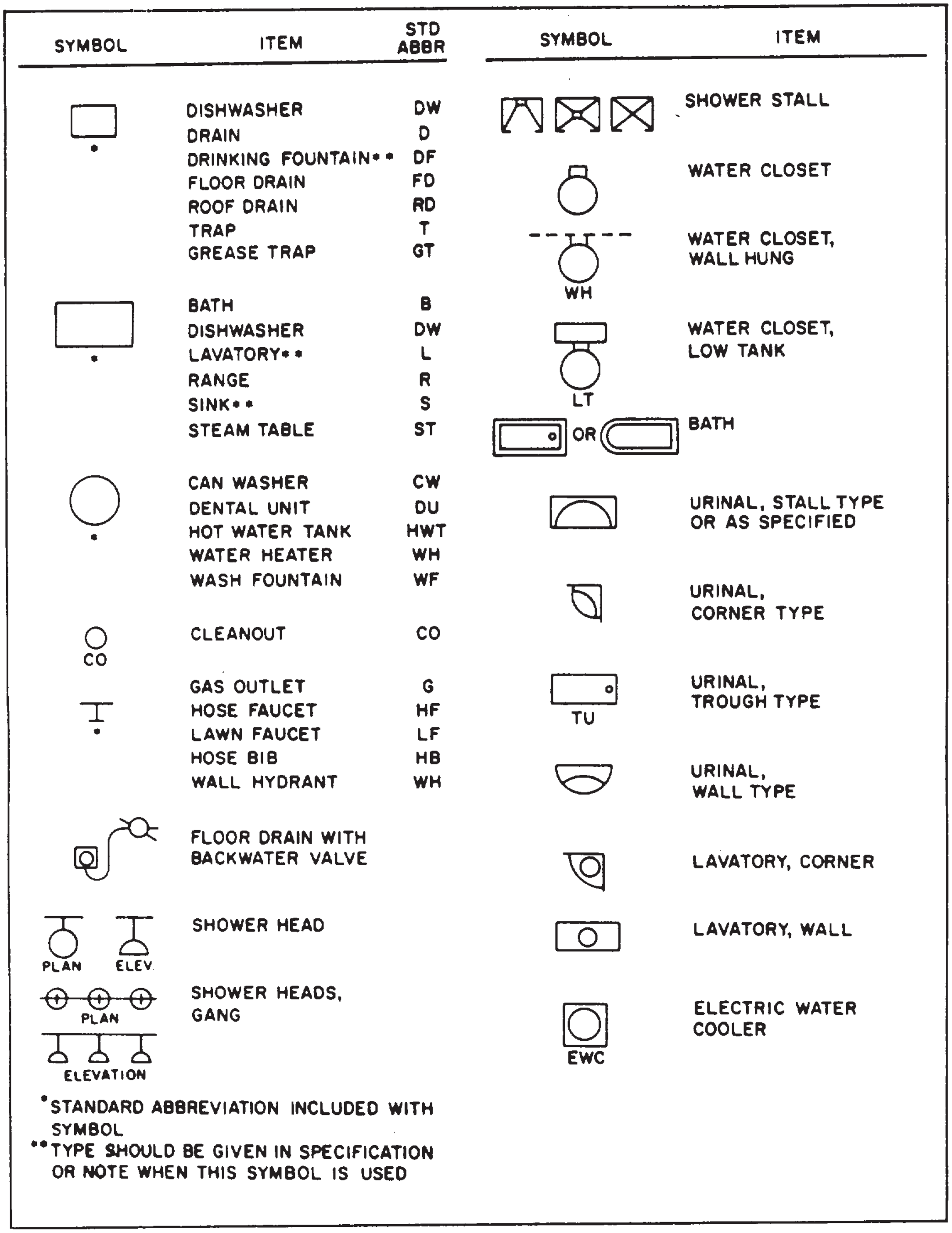
Pipe-fitting symbols.

A. MECHANICAL (PLUMBING) SYMBOLS—CONTINUED



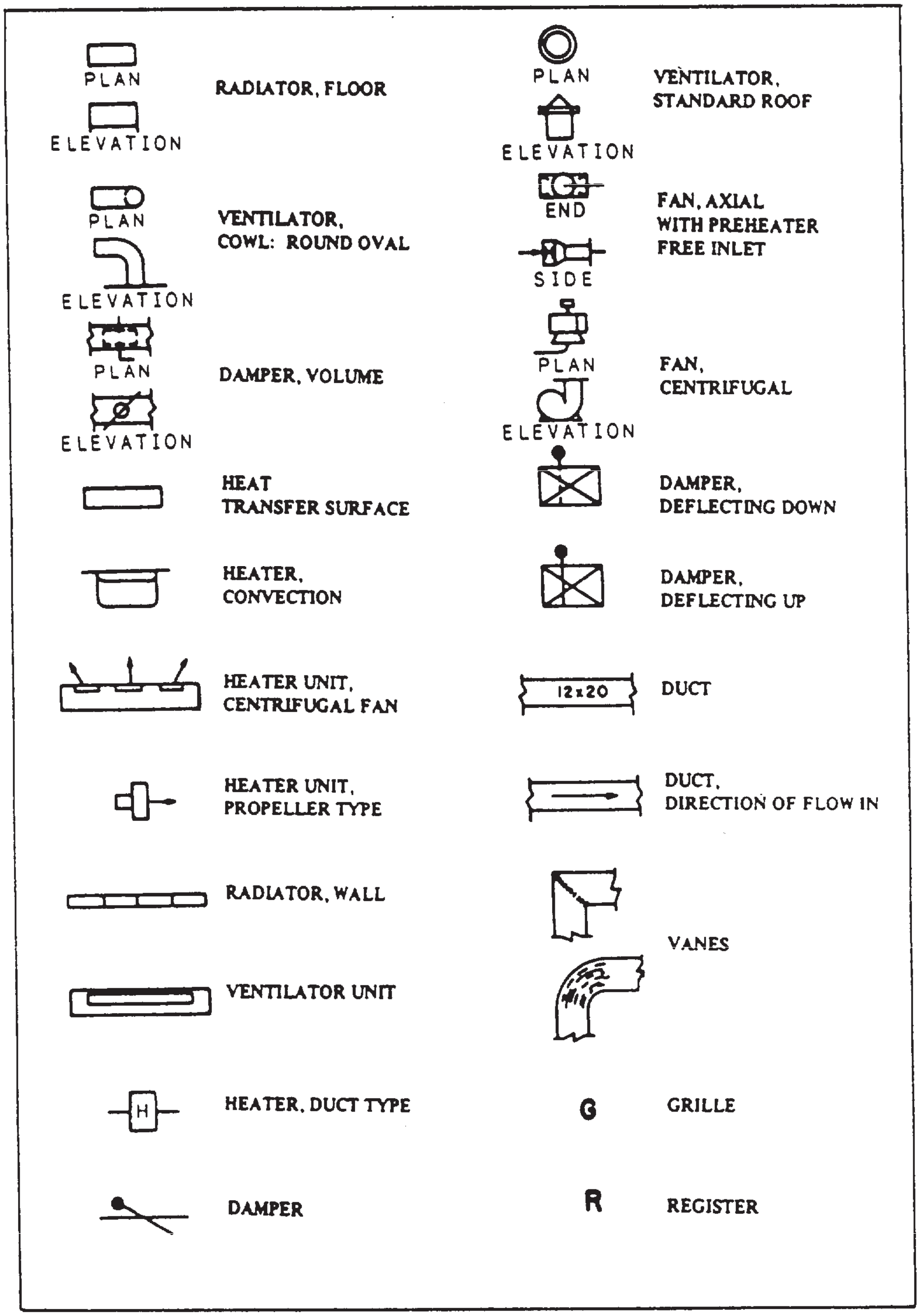
Valve symbols.

A. MECHANICAL (PLUMBING) SYMBOLS—CONTINUED



Symbols for plumbing fixtures.

B. HEATING SYMBOLS



B. HEATING SYMBOLS—CONTINUED

AIR–RELIEF LINE	
BOILER BLOW OFF	
COMPRESSED AIR	
CONDENSATE OR VACUUM PUMP DISCHARGE	
FEEDWATER PUMP DISCHARGE	
FUEL–OIL FLOW	
FUEL–OIL RETURN	
FUEL–OIL TANK VENT	
HIGH–PRESSURE RETURN	
HIGH–PRESSURE STEAM	
HOT–WATER HEATING RETURN	
HOT–WATER HEATING SUPPLY	
LOW–PRESSURE RETURN	
LOW–PRESSURE STEAM	
MAKE–UP WATER	
MEDIUM PRESSURE RETURN	
MEDIUM PRESSURE STEAD	

B. HEATING SYMBOLS—CONTINUED

RELIEF VALVE
(EITHER PRESSURE OR VACUUM)

BOILER RETURN TRAP

BLAST THERMOSTATIC TRAP

FLOAT TRAP

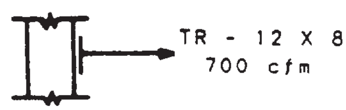
FLOAT AND THERMOSTATIC TRAP

THERMOSTATIC TRAP

LOUVER OPENING

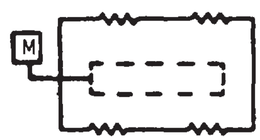
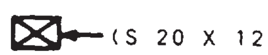
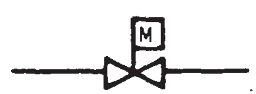
SUPPLY OUTLET CEILING
(INDICATE TYPE)

SUPPLY OUTLET WALL
(INDICATE TYPE)

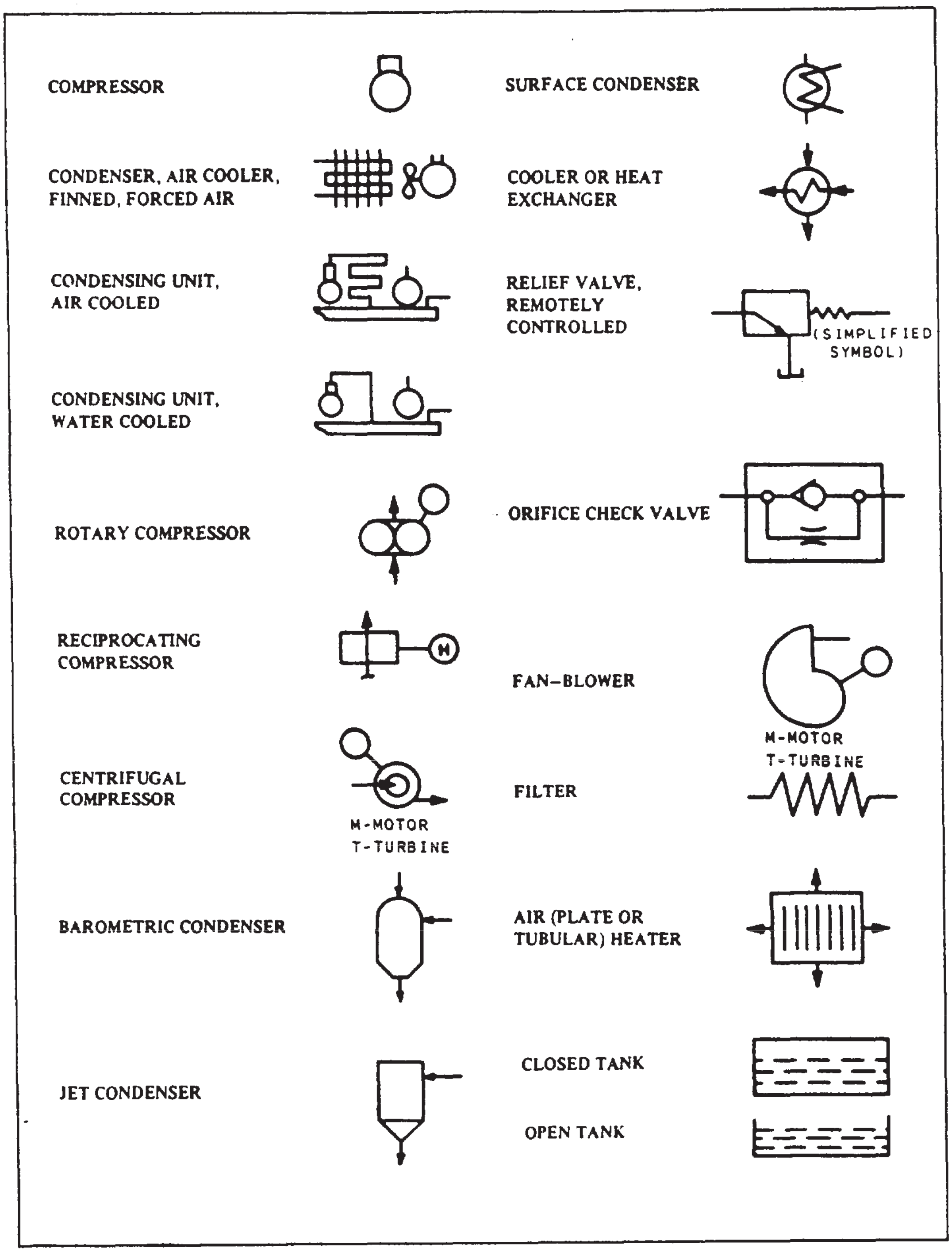


VOLUME DAMPER

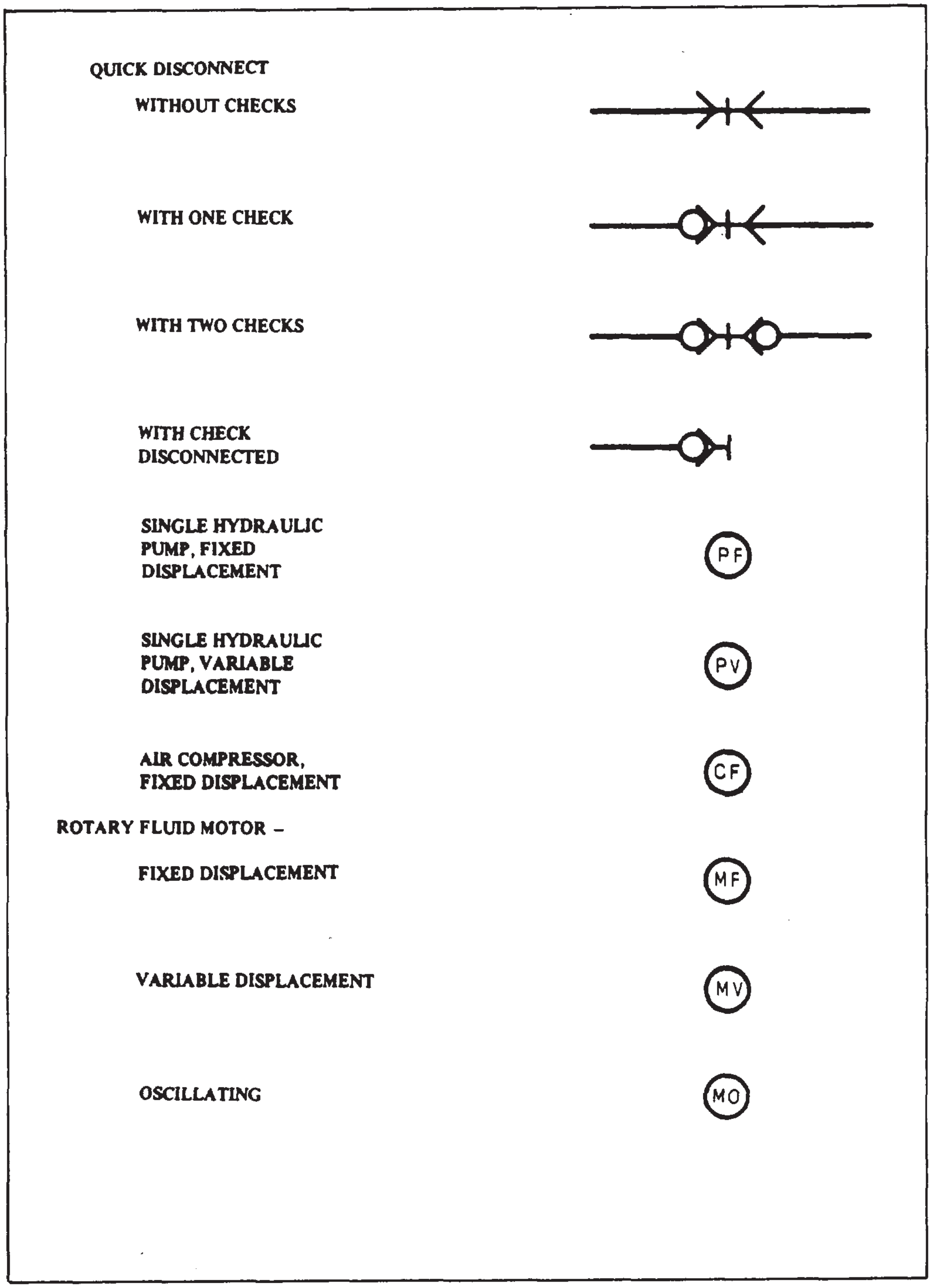
CAPILLARY TUBE

HEAT EXCHANGER	
PUMP	
THERMOMETER	
THERMOSTAT	
AUTOMATIC DAMPERS	
DUCT SECTION (EXHAUST OR RETURN)	
DUCT SECTION (SUPPLY)	
MOTOR OPERATED VALVE	

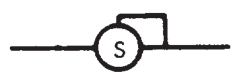
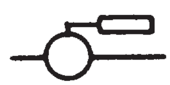
B. HEATING SYMBOLS—CONTINUED



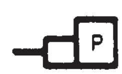
B. HEATING SYMBOLS—CONTINUED



C. AIR-CONDITIONING AND REFRIGERATION SYMBOLS

SCALE TRAP	
SPRAY POND	
THERMAL BULB	
THERMOSTAT (REMOTE BULB)	
VALVES –	
AUTOMATIC EXPANSION	
COMPRESSOR SUCTION PRESSURE LIMITING, THROTTLING TYPE (COMPRESSOR SIDE)	
CONSTANT PRESSURE, SUCTION	
EVAPORATOR PRESSURE REGULATING, SNAP ACTION	
EVAPORATOR PRESSURE REGULATING, THERMOSTATIC THROTTLING TYPE	
EVAPORATOR PRESSURE REGULATING, THROTTLING TYPE (EVAPORATOR SIDE)	

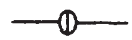
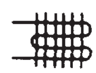
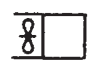
C. AIR-CONDITIONING AND REFRIGERATION SYMBOLS–CONTINUED

IMMERSION COOLING UNIT	
LOW SIDE FLOAT	
MOTOR–COMPRESSOR, ENCLOSED CRANKCASE, RECIPROCATING, DIRECT CONNECTED	
MOTOR–COMPRESSOR, ENCLOSED CRANKCASE, ROTARY, DIRECT CONNECTED	
MOTOR–COMPRESSOR, SEALED CRANKCASE, RECIPROCATING	
MOTOR–COMPRESSOR, SEALED CRANKCASE, ROTARY	
PRESSURESTAT	
PRESSURE SWITCH	
PRESSURE SWITCH WITH HIGH PRESSURE CUT–OUT	
RECEIVER, HORIZONTAL	
RECEIVER, VERTICAL	

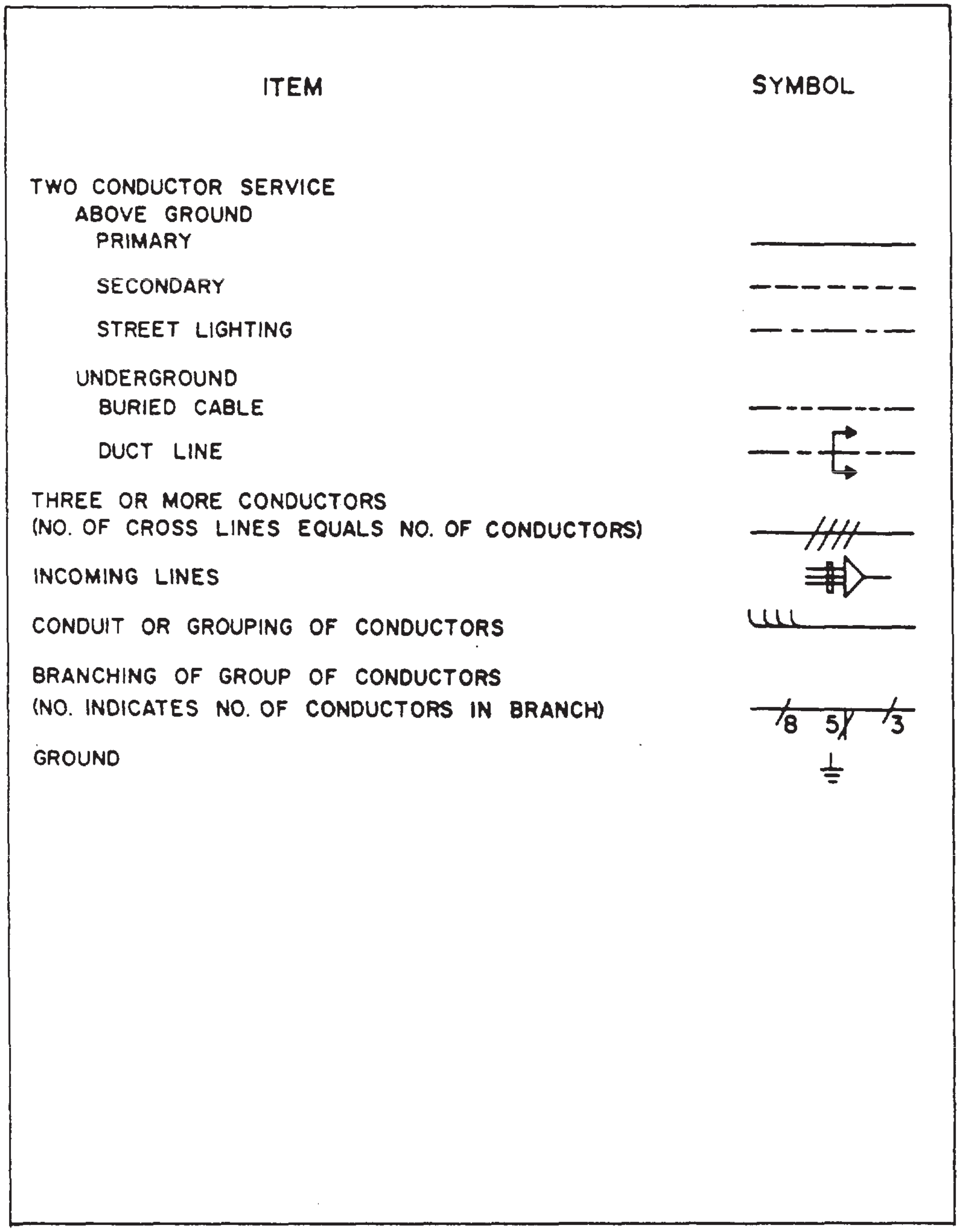
C. AIR-CONDITIONING AND REFRIGERATION SYMBOLS-CONTINUED

CIRCULATING CHILLED OR HOT-WATER FLOW	———— CH ————
CIRCULATING CHILLED OR HOT-WATER RETURN	—— —— —— CHR —— —— ——
CONDENSER WATER FLOW	———— C ————
CONDENSER WATER RETURN	—— —— —— CR —— —— ——
MAKE-UP WATER	——— – ——— – ——— – ———
HUMIDIFICATION LINE	—— – ——— H ——— – ——
DRAIN	———— D ————
BRINE RETURN	—— —— —— BR —— —— ——
BRINE SUPPLY	———— B ————
REFRIGERANT DISCHARGE	———— RD ————
REFRIGERANT LIQUID	———— RL ————
REFRIGERANT SUCTION	—— —— —— RS —— —— ——

C. AIR-CONDITIONING AND REFRIGERATION SYMBOLS—CONTINUED

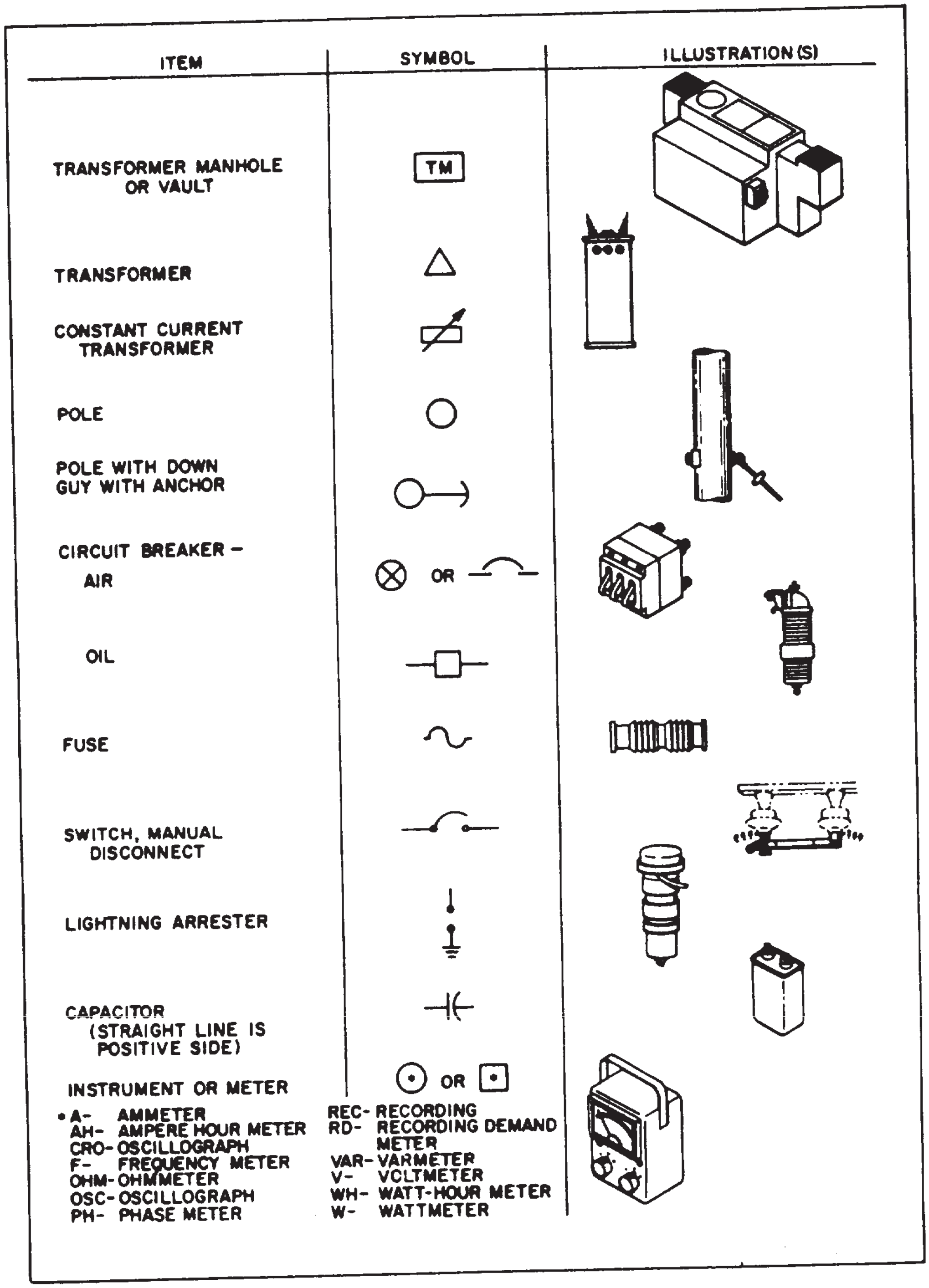
EVAPORATIVE CONDENSER	
EVAPORATOR, CIRCULAR, CEILING TYPE, FINNED	
EVAPORATOR, MANIFOLDED, BARE TUBE, GRAVITY AIR	
EVAPORATOR, MANIFOLDED, FINNED, FORCED AIR	
EVAPORATOR, MANIFOLDED, FINNED, GRAVITY AIR	
EVAPORATOR, PLATE COILS, HEADERED OR MANIFOLD	
FILTER, LINE	
FILTER & STRAINER, LINE	
FINNED TYPE COOLING UNIT, NATURAL CONVECTION	
FORCED CONVECTION COOLING UNIT	
GAUGE	
HIGH SIDE FLOAT	
HAND EXPANSION	
MAGNETIC STOP	
SNAP ACTION	
SUCTION VAPOR REGULATING	
THERMO SUCTION	
THERMOSTATIC EXPANSION	

D. ELECTRICAL SYMBOLS

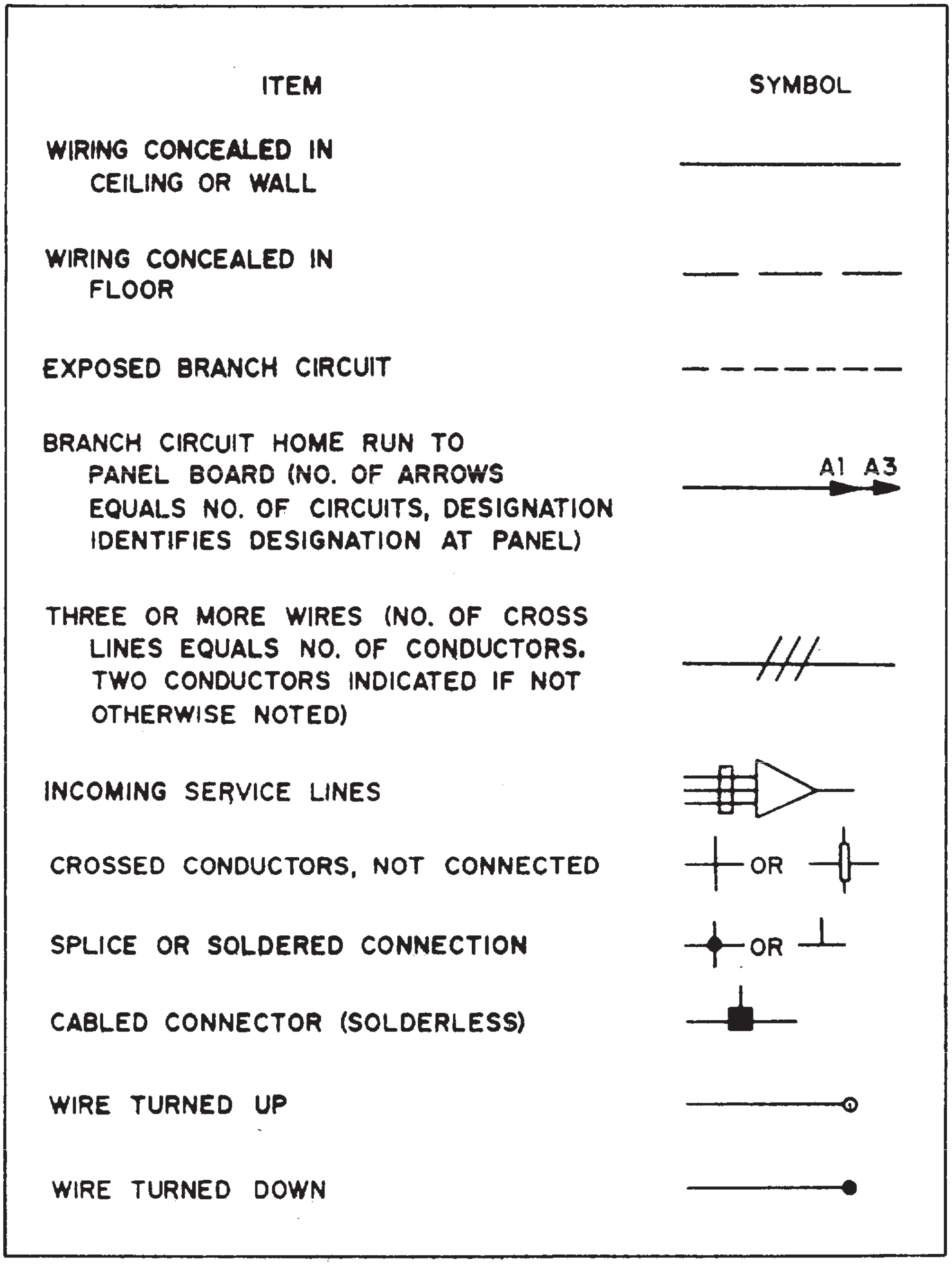


Line symbols for electric power distribution.

D. ELECTRICAL SYMBOLS—CONTINUED



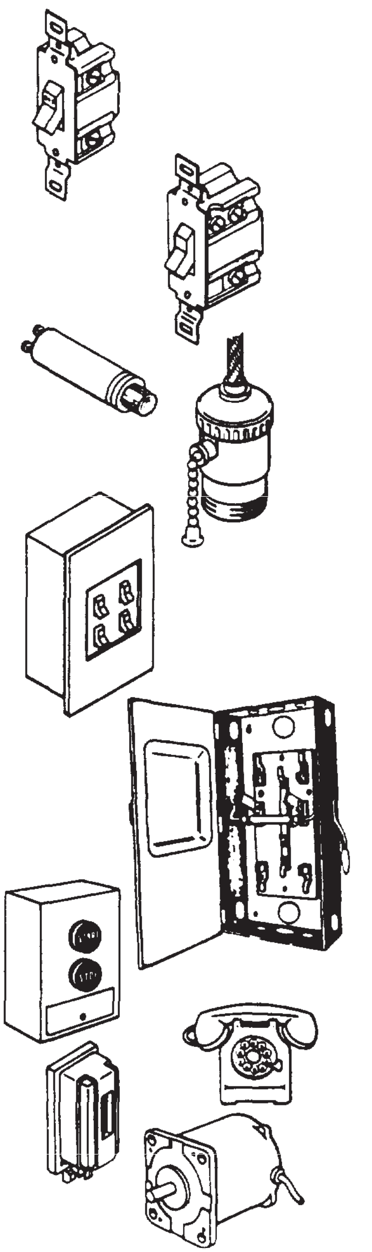
Conventional symbols for electric distribution equipment.



Line symbols for electrical wiring.

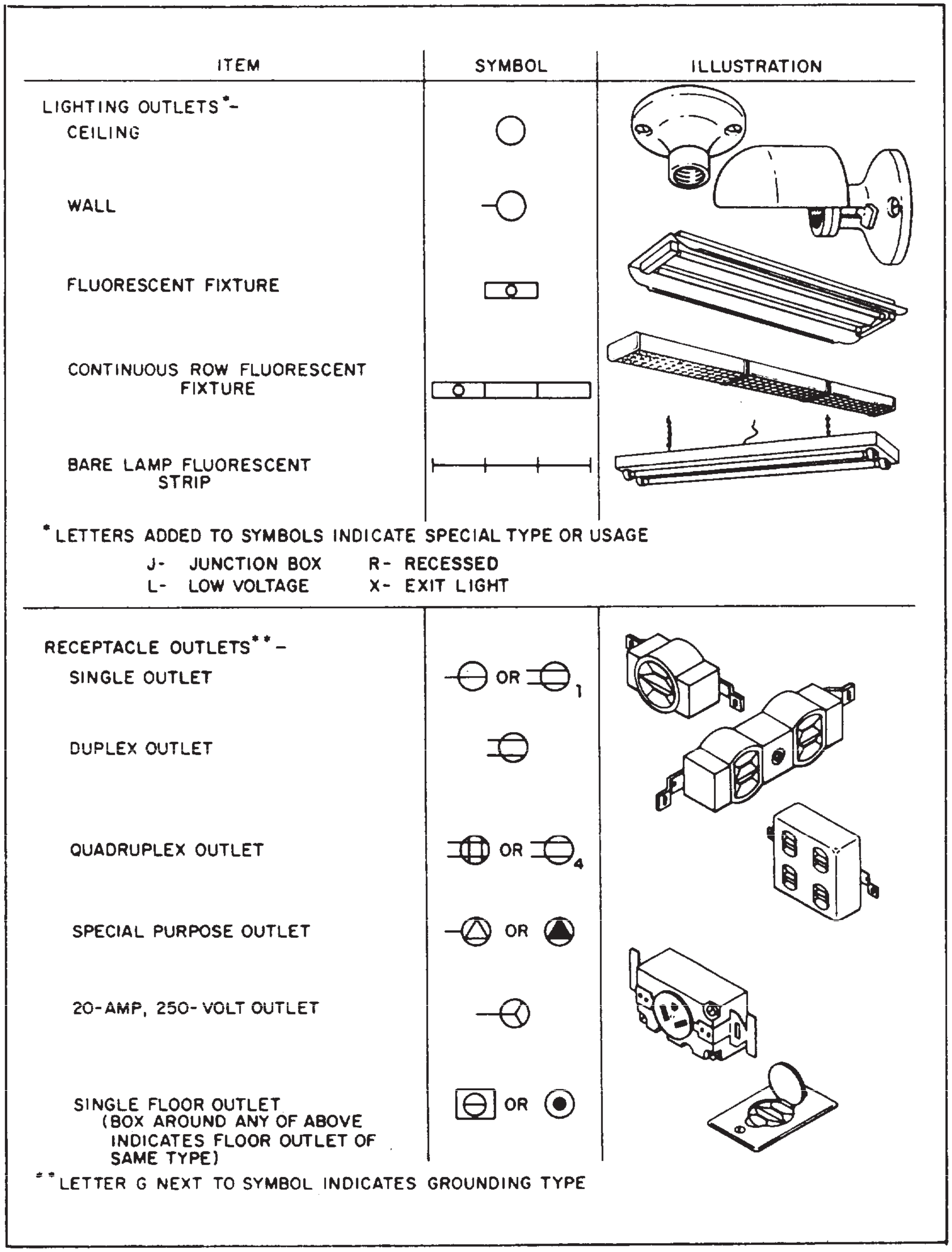
ITEM	SYMBOL
SWITCHES –	
SINGLE POLE SWITCH	S
DOUBLE POLE SWITCH	S_2
THREE WAY SWITCH	S_3
SWITCH AND PILOT LAMP	S_P
CEILING PULL SWITCH	Ⓢ
PANEL BOARDS AND RELATED EQUIPMENT	
PANEL BOARD AND CABINET	
SWITCHBOARD, CONTROL STATION OR SUBSTATION	
SERVICE SWITCH OR CIRCUIT BREAKER	■ OR ■ OR ⊗
EXTERNALLY OPERATED DISCONNECT SWITCH	
MOTOR CONTROLLER	⊠ OR MC
MISCELLANEOUS –	
TELEPHONE	
THERMOSTAT	—Ⓣ
MOTOR	Ⓜ

ILLUSTRATION

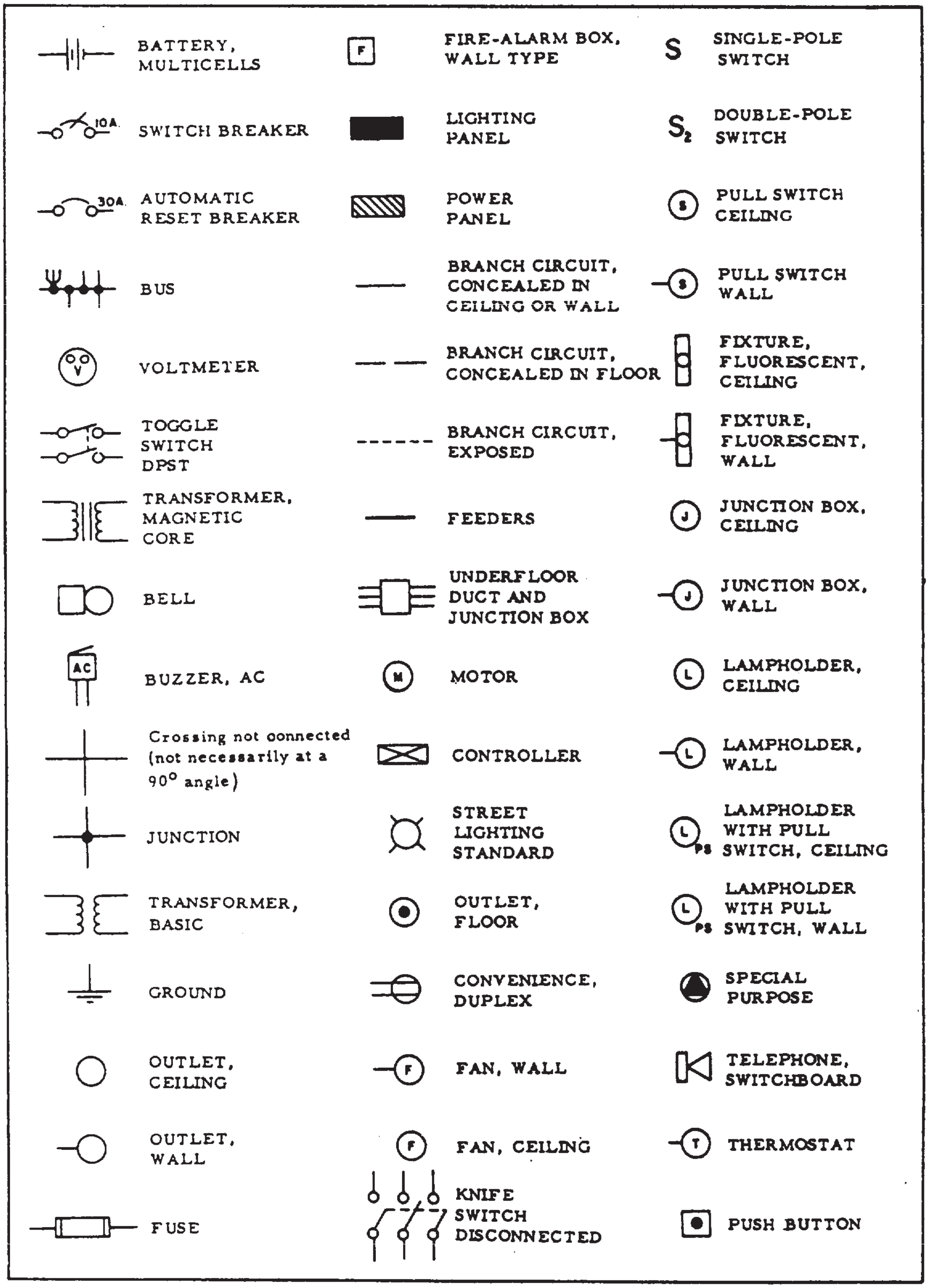


Symbols for electrical fixtures and controls.

D. ELECTRICAL SYMBOLS—CONTINUED



Symbols for electrical fixtures and controls—Continued.



Common types of electrical symbols.

APPENDIX V

SAMPLE SURVEY FIELD NOTES

Although some field notes are already explained in this training manual, these sample notes are presented so that you can see how the series of different field notes are indexed and arranged in a field notebook.

Keeping good notes is not only an art, it is a science as well. Art will make your notes pretty to look at, but it will not make them correct or meaningful. You must decide, BEFORE YOU GO INTO THE FIELD, how you want to run your survey and how to record your observations. You must also have decided what information you must record in order to make your notes meaningful. Keep in mind that extraneous entries in your notes can do just as much harm as omission of pertinent data. Before making any entry in your notebook, make certain that the entry, whether a sketch, remark, or other information, is necessary and will contribute to the completeness of the notes. On the following pages are samples of the types of notes kept, not of how they must be kept. It is really the surveyor who determines what to record and how to do it. Usually the chief of the party prescribes how notes on his project are to be kept. Above all, decide on your notekeeping procedures and format before you go out on your survey. The headings, members of party, instrument identification, weather, and so forth, may all be entered before you leave the office.

Figure AV-1 is a sample of the front page of a notebook. The front page is to be filled out as required by your unit. If possible, keep a separate book for each major project.

Figure AV-2 is a sample index. The index pages of the notebook must reflect all projects, by page number, recorded in the book. REMEMBER: Always keep your index up to date.

An example of recording horizontal measurement is shown in figure AV-3. To record taping problems, record distance measured (by parts of tapes, if measured) going from one station to the next. Record in the direction in which measured; that is, down for forward measurements, up for backward measurements.

Do not forget the page check (fig. AV-4), which is to be made at the bottom of each page. If notes exceed one page, this check also must be made on the page where notes end, When you make a page check on direct level circuit, you check only the accuracy of the arithmetic, not the accuracy of the level shots.

Profile and cross-section level notes (figs. AV-5 and AV-6) are best recorded from the bottom of the page UP. The left-hand side of the page should contain columns for STA, BS(+), HI, FS(–), and elevation. The right side, as shown, has left, ℄, and right columns. The top number is ground elevation at that point, the center number is rod reading, and the bottom number is the perpendicular distance to the center line. Slope stakes (fig. AV-7), as profile notes, are best recorded from the bottom of the page UP, as shown on this set of sample notes. Entries for STA 7 + 50 indicate the following:

	L	℄	R
Amount of cut or fill . . .	C 0.3	F 0.0	F 0.8
Ground rod	3.8	4.1	4.9
Dist of slope stake from ℄	22.6	0	16.6

See figure AV-8. Building corner numbers on the sketch must agree with the designation on the left side of the page. Grade rod setting is computed in the field. Batter elevations are entered in the first column on the right-hand page—after having been computed at the jobsite. Sketch must show all pertinent data for locating the building.

DEPARTMENT OF THE NAVY

THIRTY FIRST NAVAL CONSTRUCTION REGIMENT
NMCB FOUR

LEVEL, TRANSIT, AND GENERAL SURVEY
RECORD BOOK

PORT HUENEME, CALIFORNIA
LOCALITY

BLDG & ROAD LAYOUT, NORTH DRIVE
PROJECT

BOOK 2 OF 4

THEODOLITE WILD T 16
INSTRUMENT

EA2 W.J. BROWN
CHIEF OF PARTY

IMPORTANT
On the opposite page, print the address to which this book is to be returned, if lost.

Figure AV-1.-Front page of a notebook.

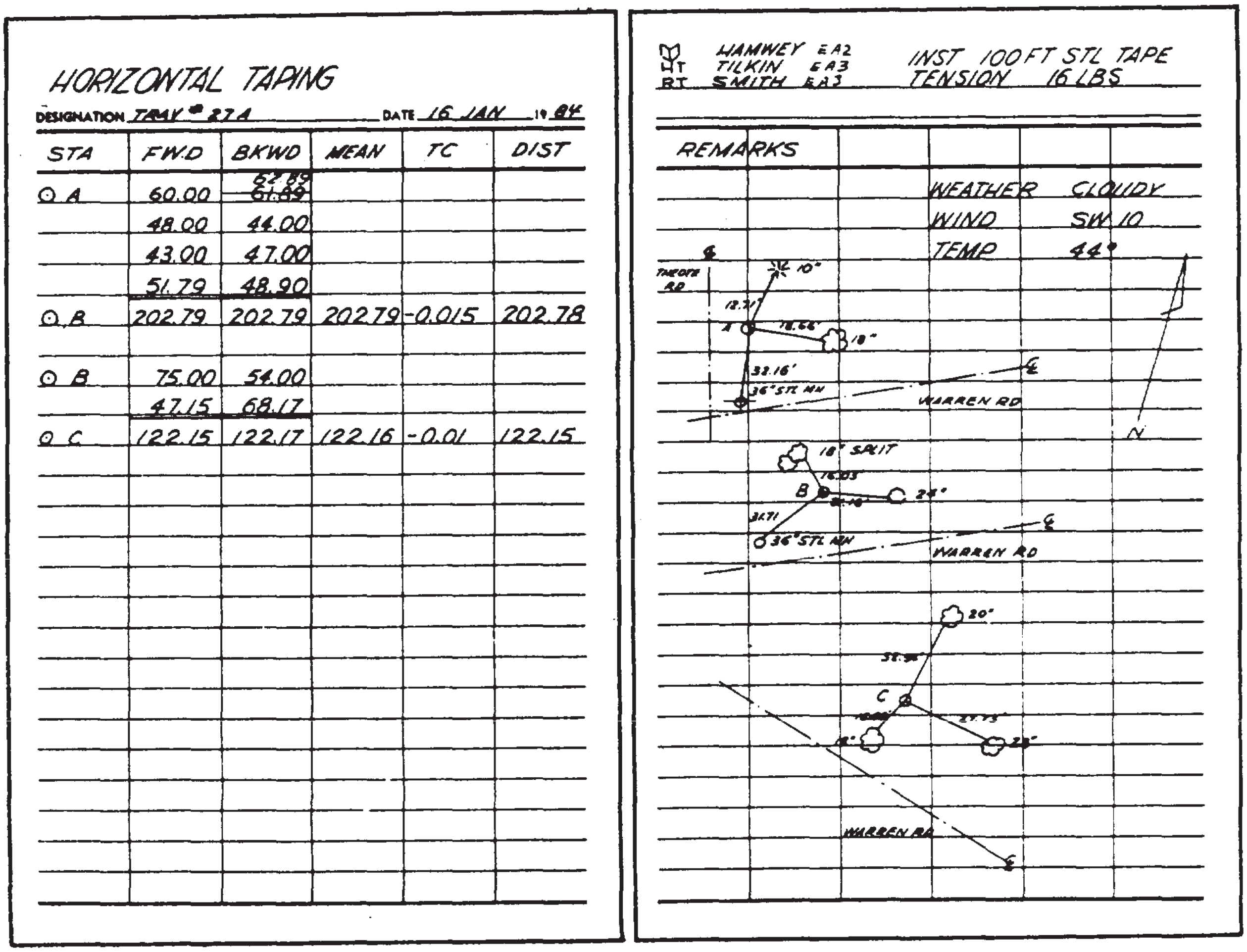
INDEX

DESIGNATION ______________ DATE ____________ 19___

PAGE	PROJECT	DATE
6	HORIZONTAL TAPING - TRAV 27-A	16 JAN 84
10	DIRECT LEVEL CIRCUIT - BM61 TO BM63	12 JAN 84
11	HORIZON CLOSURE - TRAV #2	25 JAN 84
17	STATION ANGLE TRAV - TRAV #12	15 FEB 84
18	DEFL ANGLE TRAV - TRAV #12-A	17 FEB 84
19	TRIANGULATION - ELEV OF WATER TOW	13 FEB 84
20	TRIG ELEVATION - HT OF FLAG POLE	15 FEB 84
21	MCCOY AVE EXT'D - HOR & CONTROL	20 FEB 84
22	-"- HORIZ TAPING	22 FEB 84
23	-"- DIFF LEVELING	24 FEB 84
24	-"- HOR CURVE LAYOUT	20 MAR 84
25	-"- PROF & CR SECT LEVELS	21 MAR 84
26	-"- PROF LEV (SEWER LINE)	23 MAR 84
27	-"- SLOPE STAKES	30 MAR 84
28	BLDG T2855 - BLDG LAYOUT	1 APR 84
29	PLANETABLE MAPPING PROBLEM	10 APR 84

	LOCATION
S. DRIVE	PORT HUENEME, CALIFORNIA
PI AREA	-"-
AREA K	-"-
N. DRIVE	-"-
N. DRIVE	-"-
PI AREA	-"-
PI AREA	-"-
N. DRIVE	-"-
-"-	-"-
-"-	-"-
-"-	-"-
-"-	-"-
-"-	-"-
-"-	-"-
S. DRIVE	-"-
N. DRIVE	-"-

Figure AV-2.-Index.



HORIZONTAL TAPING

DESIGNATION TRAV # 27A DATE 16 JAN 19 84

STA	FWD	BKWD	MEAN	TC	DIST
⊙ A	60.00	~~61.89~~ 62.89			
	48.00	44.00			
	43.00	47.00			
	51.79	48.90			
⊙ B	202.79	202.79	202.79	-0.015	202.78
⊙ B	75.00	54.00			
	47.15	68.17			
⊙ C	122.15	122.17	122.16	-0.01	122.15

Figure AV-3.-Horizontal measurement.

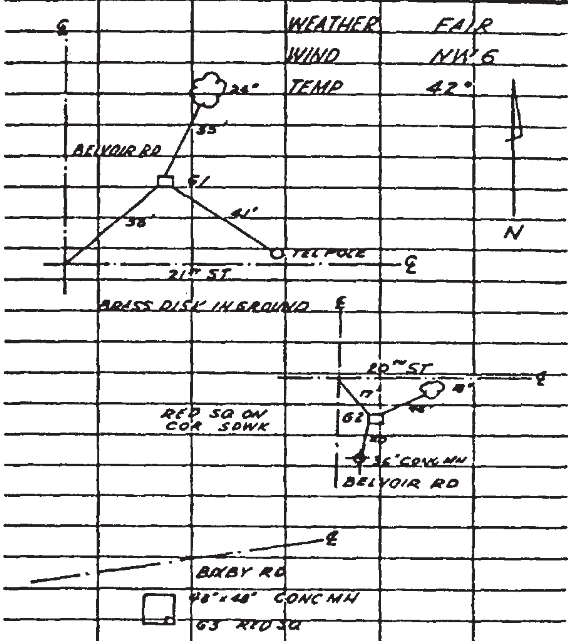
DIRECT LEVEL CIRCUIT

DESIGNATION BM G1 TO BM G2 DATE 12 JAN 19 84

STA	BS	HI	FS	ELEV	DISTANCE BS	DISTANCE FS
BM G1	4.71			100.00	75	
		104.71				
TP 1	6.03		0.79	103.92	110	70
		109.95				
TP 2	12.06		3.68	106.27	94	110
		118.33				
BM G2	2.20		4.49	113.84	240	96
		116.04				
TP 3	1.43		7.12	108.92 ~~108.82~~	163	242
		110.35 ~~110.25~~				
TP 4	5.01		10.33	100.02 ~~99.92~~	93	166
		105.03 ~~104.93~~				
TP 5	3.64		2.99	102.04 ~~101.94~~	110	95
		105.68 ~~105.58~~		~~101.94~~		
BM G3			3.16	102.52 ~~102.42~~		112
	35.08		32.66	2.32 ~~2.42~~	885	891
	32.56 ~~32.66~~				1776	
	2.52 ~~2.42~~ ←		PC	↑		

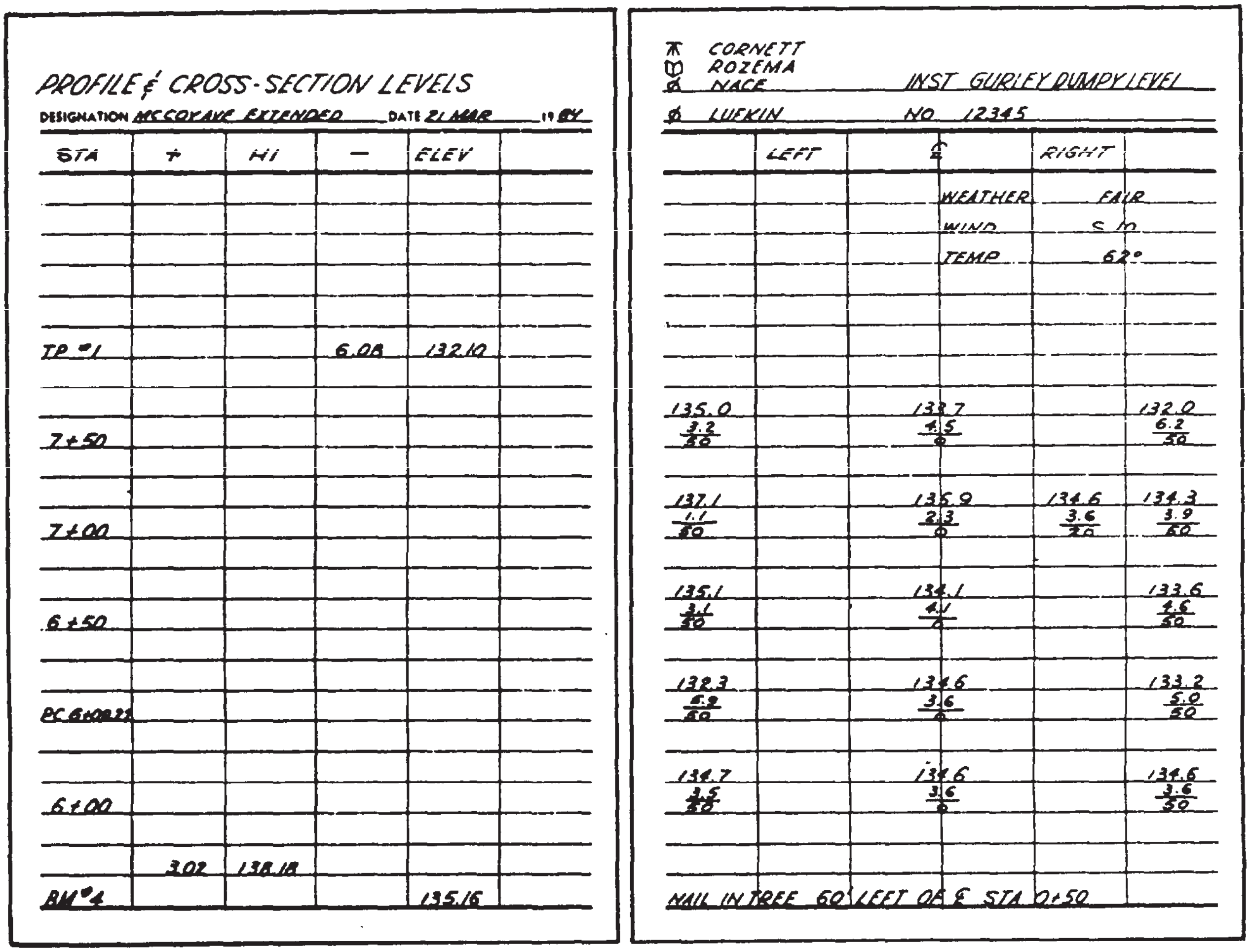
⊼ ⏀ JONES EA2 INST DIETZGEN DUMPY LEVEL
ϕ KURTT EA3 NO 1234

REMARKS



AE = .05√NI = .05√33
AE = .03

Figure AV-4.-Page check.



PROFILE & CROSS-SECTION LEVELS

DESIGNATION MC COY AVE EXTENDED DATE 21 MAR 19 84

⊼ CORNETT
Ø ROZEMA
Ø NACE INST GURLEY DUMPY LEVEL
Ø LUFKIN NO 12345

WEATHER FAIR
WIND S 10
TEMP 62°

STA	+	HI	−	ELEV	LEFT		℄	RIGHT	
TP #1			6.08	132.10					
7+50					135.0 / 3.2 / 50		133.7 / 4.5 / 0		132.0 / 6.2 / 50
7+00					137.1 / 1.1 / 50		135.9 / 2.3 / 0	134.6 / 3.6 / 20	134.3 / 3.9 / 50
6+50					135.1 / 3.1 / 50		134.1 / 4.1 / 0		133.6 / 4.6 / 50
PC 6+08.25					132.3 / 5.9 / 50		134.6 / 3.6 / 0		133.2 / 5.0 / 50
6+00					134.7 / 3.5 / 50		134.6 / 3.6 / 0		134.6 / 3.6 / 50
	3.02	138.18							
BM #4				135.16	NAIL IN TREE 60' LEFT OF ℄ STA 0+50				

Figure AV-5.-Profile and cross-section levels.

PROFILE LEVELS (SEWER LINE)

DESIGNATION MC COY AVE EXTENDED DATE 23 MAR 19 84

STA	+	HI	−	ELEV	TP ELEV
BM #4	3.02	138.18			135.16
0+00			3.6	134.6	
+21			5.1	133.1	
+50			3.6	134.6	
1+00			4.1	134.1	
+50			2.3	135.9	
+78			4.6	133.6	
2+00			4.5	133.7	
+50			6.1	132.1	
3+00			5.8	132.4	
4+00			5.7	132.5	
+10			5.0	133.2	
+60			6.0	132.2	
+76			5.9	132.3	
5+00			6.0	132.18	
TP #1	1.79	133.29	6.68		131.50
6+00			2.3	131.0	
TP #2			4.76		128.53

⊼ BACK
▢ SNIPES
ϕ KURTT
ϕ MATHEWS

INST GURLEY DUMPY LEVEL
NO 123

REMARKS
NAIL IN TREE 60' LEFT OF ℄ NEAR 0+50
℄ OF ROUTE 611
BOTTOM OF DITCH
WEATHER FAIR
WIND SS
TEMP 60
TOP OF HUB @ STA 6+00
ON STONE

Figure AV-6.-Additional example, profile levels.

SLOPE STAKES

DESIGNATION MC COY AVE EXTENDED DATE 30 MAR 19 84

STA	+	HI	−	ELEV	GRADE ELEV
TP #1			3.10	133.10	
7+50					132.10
7+00					132.60
6+50					133.10
PC 6+09.77					133.60
6+00					134.10
	1.04	136.20			
BM #4				135.16	

MANGAS
SNIPES
LUEKIN
STADELMAN

INST. GURLEY DUMPY LEVEL NO. 1453

GRADE ROD	LEFT	℄	RIGHT
		WEATHER	CLOUDY
		WIND	S 10
		TEMP	70°
TOP OF HUB STA 3+00			
	C 0.3	F 0.0	F 0.8
4.1	3.8 / 23.2	4.1 / 0	4.9 / 16.6
	C 2.0	F 1.1	F 3.0
3.6	1.6 / 26.0	4.7 / 0	6.6 / 21.0
	C 2.6	F 2.9	F 4.1
3.1	0.5 / 33.2	6.0 / 0	7.2 / 23.2
	C 1.0	F 0.5	F 1.5
2.6	1.6 / 24.0	3.1 / 0	4.1 / 18.0
	F 1.0	F 1.6	F 2.1
2.1	3.1 / 17.0	3.7 / 0	4.2 / 19.2

NAIL IN TREE 60' LEFT OF ℄ AT STA 0+50

Figure AV-7.-Slope stakes.

BUILDING LAYOUT

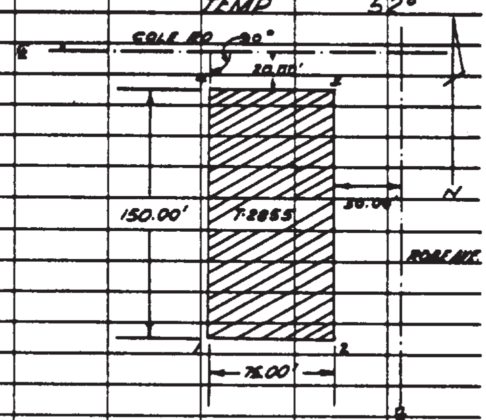
DESIGNATION BLDG T-2855 DATE 1 APR 19 84

STA	BS	HI	FS	ELEV	GRADE ROD
BM 18	5.22	35.22		30.00	
1			4.26	30.96	
2			4.14	31.08	
3			4.68	30.54	
4			4.52	30.70	
1					2.64
2					2.64
3					2.64
4					2.64

⊼ SNIPES
TILKIN
LUEKIN
ɸ COWART

INST K&E LEVEL / K&E 1' TRANSIT
NO 451206/4219

BATTER ELEV	REMARKS				
			WEATHER	FAIR	
			WIND	S 8	
			TEMP	52°	
32.58					
32.58					
32.58					
32.58					



NOTE : BATTERBOARD ELEVATION 1.5' ABOVE HIGHEST CORNER.
BATTERBOARD ELEVATION IS TOP OF FOUNDATION.

Figure AV-8.-Building layout.

APPENDIX VI

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Assignment Questions

<u>Information</u>: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Mathematics and Units of Measurement." Pages 1-1 through 1-35.

1-1. Which of the following mathematical branches deals, in part, with the theory of space and figures in space?

1. Arithmetic
2. Trigonometry
3. Geometry
4. Algebra

1-2. Which, if any, of the following expressions is an irrational number?

1. $\sqrt{2}$
2. $\sqrt{25/9}$
3. 5 2/7
4. None of the above

1-3. In fractions, the rule of ensuring that the denominators are alike applies to which of the following actions?

1. Multiplying fractions
2. Subtracting fractions only
3. Dividing fractions
4. Both adding and subtracting fractions

1-4. Which of the following fractions is the equivalent of 7/9?

1. 9/7
2. 21/27
3. 35/42
4. 126/288

1-5. What is the relationship between $\sqrt{20}$ and $2\sqrt{5}$?

1. They are rational numbers
2. They are imaginary numbers
3. They are equivalent
4. They are reciprocals of each other

1-6. When is the exponent of a number NOT required to be written?

1. When the exponent has been reduced to its lowest term
2. When the value of the exponent is 0
3. When the number has been raised to its highest power and its value is 0
4. When the value of the exponent is 1

1-7. When using the arithmetic extraction method, what is the first step you should take to determine the square root of a number?

1. Divide the number into two-digit groups working away from the decimal point in both directions
2. Divide the number into single-digit groups to the left of the decimal point
3. Divide the number into two-digit groups working only to the left of the decimal point
4. Determine the square root of the first digit of the number

1-8. When using the arithmetic extraction method to determine the square root of 368.42, what is the divisor you should use to determine the third digit of the result?

1. 29
2. 381
3. 389
4. 3829

1-9. Which of the following terms is the equivalent of $\sqrt{16^3}$?

1. 16^{-3}
2. $16^{-1/3}$
3. $16^{2/3}$
4. $16^{3/2}$

1-10. Solve $\sqrt{8\ 1/2}$.

1. 2.0000
2. 2.0615
3. 2.8284
4. 2.9155

1-11. To find the reciprocal of a fraction, you should take which of the following actions?

1. Divide the fraction by 1
2. Multiply the fraction by 1
3. Invert the fraction only
4. Invert the fraction and divide by 1

1-12. The use of a ratio would NOT be appropriate for which of the following comparisons?

1. Weight to volume of construction material
2. The rate a person reads to the rate that the average person reads
3. The acreage contained in one parcel of land to acreage contained in another
4. The weight of a construction material to the standard weight of a like material

1-13 Which of the following ratio? is expressed correctly in its final form?

1. 9.03 m/ 2.61 m
2. 2.5 ft : 17.5 ft
3. 9.03 : 2.61
4. 60 mi / 1 hr

1-14 Which of the following expressions represent(s) a correctly written proportion?

1. 3:9 / 11:33
2. 3:9 = 11:33
3. 3:9::33:11
4. Both 2 and 3 above

1-15. Which of the following equations is a linear equation?

1. $4x^2 = 16$
2. $y^2 + 16y = 0$
3. $1/4x^2 + 16 = 1$
4. $x/2 + 6x = 13$

A. ALL SIDES ARE EQUAL B. OPPOSITE SIDES ARE PARALLEL C. ALL INTERIOR ANGLES ARE EQUAL D. ONLY TWO SIDES ARE PARALLEL

Figure 1A

IN ANSWERING QUESTIONS 1-16 THROUGH 1-18, SELECT THE CHARACTERISTIC FROM FIGURE 1A THAT APPLIES TO THE GEOMETRIC FIGURE LISTED.

1-16. Trapezoid.

1. A and B
2. B and C
3. c and D
4. D only

1-17. oblong.

1. A and B
2. B and C
3. C and D
4. D only

1-18. Rhombus.

1. A and B
2. B and C
3. C and D
4. D only

1-19. What is the total area of a rectangular parking lot that measures 310 ft by 784 ft?

1. 299,209 sq ft
2. 243,040 sq ft
3. 121,304 sq ft
4. 24,304 sq ft

1-20 What is the area of a right triangle if the sides adjacent to the right angle measure 5 and 8 feet long?

1. 13 sq ft
2. 20 sq ft
3. 26 sq ft
4. 40 sq ft

IN ANSWERING QUESTIONS 1-21 THROUGH 1-23, REFER TO FIGURES 1-8, 1-9, and 1-10 IN YOUR TEXT.

1-21. Assume that triangle ABC in Figure 1-8 has the following dimensions:

AC = 5 1/2 in
AD = 4 1/2 in
BD = 2 1/2 in
CD = 3 in

What is the area of this triangle?

1. 5 1/2 sq in
2. 7 sq in
3. 10 sq in
4. 10 1/2 sq in

1-22. Assume that rhomboid ABCD in figure 1-9 has the following dimensions:

AD = 7 1/2 in
CD = 4 3/4 in
EC = 6 in
AE = 4 1/2 in

What is the area of this rhomboid?

1. 27 sq in
2. 30 1/2 sq in
3. 33 3/4 sq in
4. 37 1/2 sq in

1-23. Assume that the trapezoid in figure 1-10 has the following dimensions:

AD = 5 in
BC = 3 in
CF = 3 in

What is the area of the trapezoid?

1. 8 sq in
2. 12 sq in
3. 16 sq in
4. 24 sq in

1-24. A circle with a diameter of 5 inches will have what area in square inches?

1. 12.6
2. 15.7
3. 19.6
4. 31.4

1-25. A circle with a circumference of 12 inches will have what area in square inches?

1. 11.46
2. 11.56
3. 12.45
4. 12.46

1-26. If the diameter of the circle in textbook figure 1-13 is 4 inches and the central angle of the sector portion is 60 degrees, what is the area of the sector?

1. 1.0944 sq in
2. 2.0944 sq in
3. 2.1416 sq in
4. 3.1416 sq in

1-27. What is the area of an equilateral octagon whose 1 1/2-inch sides are tangent to an inscribed circle with a diameter of 3 1/2 inches?

1. 10 sq in
2. 10 1/4 sq in
3. 10 1/2 sq in
4. 10 3/4 sq in

1-28. What is the approximate area of an ellipse in which the major axis is 8 feet long and the minor axis is 4 feet long?

1. 12 Sq ft
2. 16 sq ft
3. 25 sq ft
4. 32 sq ft

A. $V = Bh$
B. $V = 1/3\pi r^2 h$
C. $V = 1/3\pi h\ (r_1^2 + r_1 r_2 + r_2^2)$
D. $V = 4/3\pi r^3$

Figure 1B

IN ANSWERING QUESTIONS 1-29 THROUGH 1-34, SELECT THE FORMULA FROM FIGURE 1B THAT YOU SHOULD USE TO DETERMINE THE VOLUME OF THE GIVEN GEOMETRIC FIGURE.

1-29. Cylinder.

1. A
2. B
3. C
4. D

1-30. Frustum of a cone.

1. A
2. B
3. C
4. D

1-31. Cone.

1. A
2. B
3. C
4. D

1-32. Parallelepipeds.

1. A
2. B
3. C
4. D

1-33. Sphere.

1. A
2. B
3. C
4. D

1-34. Triangular prism.

1. A
2. B
3. C
4. D

1-35. What is the reciprocal function of cos 25°?

1. Ccs 25°
2. Cot 25°
3. Sec 25°
4. Sin 25°

1-36. What function of the 45° angle in textbook figure 1-21 is represented by the line DB?

1. conversed sine
2. Cosine
3. cotangent
4. cosecant

1-37. What angle is the complement of 75°?

1. 15°
2. 75°
3. 90°
4. 105°

1-38. When expressed as a function of another angle, cos 40° equals what value?

1. Sec 140°
2. Sin 140°
3. Sec 50°
4. Sin 50°

1-39. What angle is the supplement of 145°?

1. 10°
2. 35°
3. 45°
4. 55°

1-40. The value of -cos 118° is equal to which of the following values?

1. Cos 62°
2. Sin 62°
3. Sin 118°
4. Cos 180°

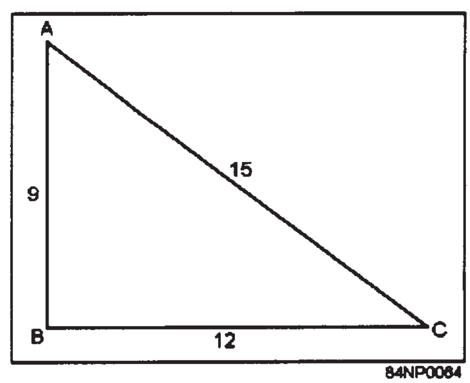


Figure 1C

IN ANSWERING QUESTIONS 1-41 AND 1-42, REFER TO FIGURE 1C.

1-41. What is the cosine of angle A?

1. 0.60000
2. 0.75000
3. 0.80000
4. 1.33333

1-42. What is the tangent of angle C?

1. 0.60000
2. 0.75000
3. 0.80000
4. 1.44444

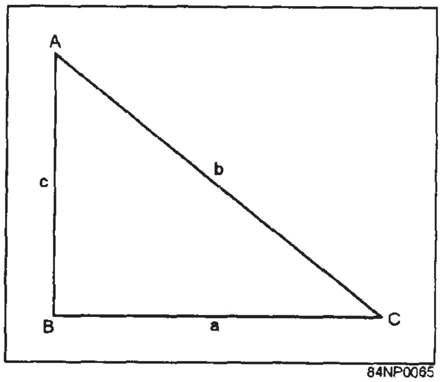


Figure 1D

IN ANSWERING QUESTIONS 1-43 THROUGH 1-45, REFER TO FIGURE ID. SELECT THE TRIGONOMETRIC FUNCTION FROM THE FOLLOWING LIST THAT SHOULD BE USED FOR THE SITUATION DESCRIBED.

A. SINE B. COSINE C. TANGENT D. COTANGENT

1-43. Determining the size of angle A if the lengths of sides a and b are known.

1. A
2. B
3. C
4. D

1-44. Determining the size of angle C if the lengths of sides a and b are known.

1. A
2. B
3. C
4. D

1-45. Determining the size of angle C if the lengths of sides b and c are known.

1. A
2. B
3. C
4. D

1-46. Which function of the ground-slope angle is the ratio of the horizontal distance to the slope distance?

1. Sine
2. Cosine
3. Tangent
4. Versed sine

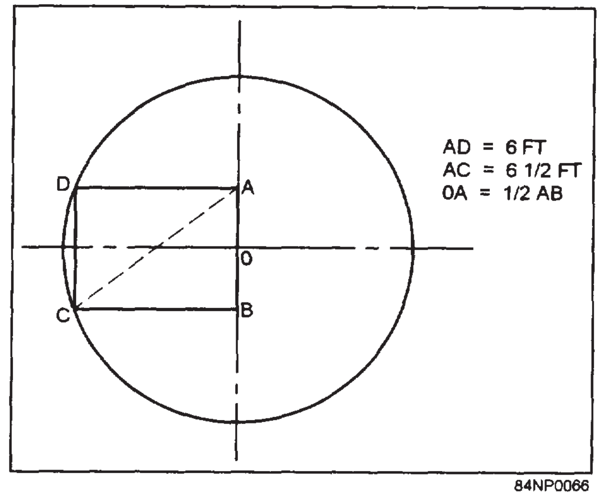


Figure 1E

IN ANSWERING QUESTIONS 1-47 AND 1-48, REFER TO FIGURE 1E.

1-47. How many square feet are contained in rectangle ABCD?

1. 12.00
2. 15.00
3. 37.50
4. 53.08

1-48. How many square feet are contained within the circle?

1. 9.62
2. 10.20
3. 19.25
4. 118.00

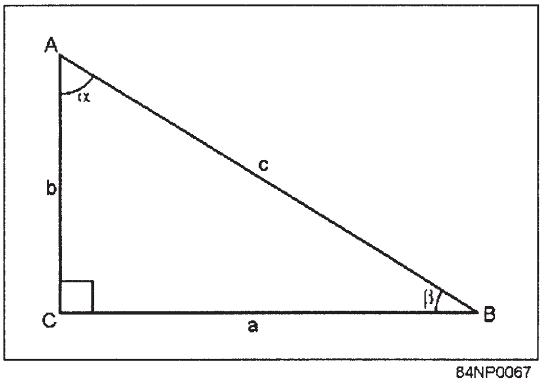


Figure 1F

IN ANSWERING QUESTIONS 1-49 THROUGH 1-51, REFER TO FIGURE 1F AND TO THE TABLE OF TRIGONOMETRIC FUNCTIONS LOCATED IN APPENDIX III OF YOUR TEXT.

1-49. How many degrees are contained in angle β if angle α = 55°?

1. 30°
2. 35°
3. 40°
4. 45°

1-50. What is the length of side b if side a = 6 feet and angle β = 30°?

1. 3.32 ft
2. 3.46 ft
3. 10.39 ft
4. 10.82 ft

1-51. What is the size of angle B if side b = 6 feet and side c = 20 feet?

1. 16°42′
2. 17°00′
3. 17°28′
4. 17°30′

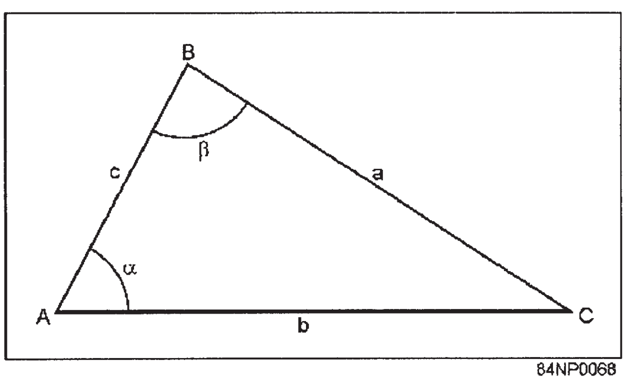


Figure 1G

IN ANSWERING QUESTIONS 1-52 THROUGH 1-56, REFER TO FIGURE 1G.

1-52. When given angle β and sides b and c, what law should you use to solve for all unknowns?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-53. When angle α and sides b and c are known, what law should you use to determine side a?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-54. When angle α and sides b and c are known, what law should you use to solve for all unknown angles?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-55. When side a and angles α and β are known, what law should you use to solve for all unknowns?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-56. When given sides a, b, and c, what law should you use to solve for all unknown angles?

1. Law of sines
2. Law of cosines
3. Law of tangents

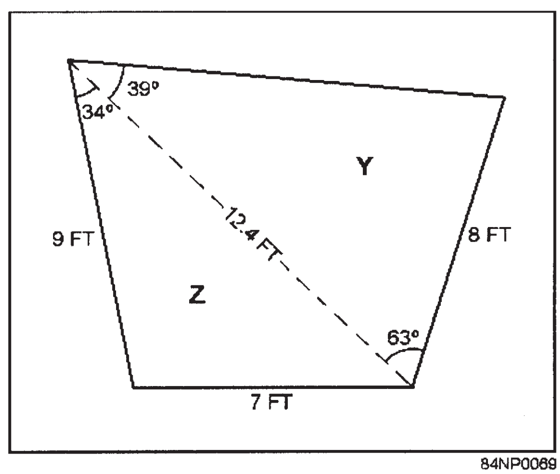


Figure 1H

IN ANSWERING QUESTIONS 1-57 AND 1-58, REFER TO FIGURE 1H.

1-57. The area of triangle Z is approximately equal to the square root of

1. 14
2. 67
3. 781
4. 957

1-58. The area of triangle Y is equal to

1. 49.6 sin 63°
2. 49.6 cos 63°
3. 99.2 sin 39°
4. 99.2 cos 39°

1-59. A distance of 1.25 statute miles is equivalent to how many (a) engineer's chains and (b) rods?

1. (a) 53 (b) 320
2. (a) 66 (b) 400
3. (a) 76 (b) 460
4. (a) 100 (b) 400

1-60. A linear distance of 0.68 kilometers is approximately equivalent to how many (a) meters and (b) nautical miles?

1. (a) 68 (b) 23.7
2. (a) 68 (b) 27.2
3. (a) 680 (b) 2.4
4. (a) 680 (b) 0.4

1-61. What is the area of a road 1,200 yards long and 22 feet wide?

1. 8,000 sq yd
2. 8,600 sq yd
3. 8,640 sq yd
4. 8,800 sq yd

1-62. A total of how many cubic yards of concrete are required for a retaining wall footing that measures 50 feet long, 15 feet wide, and 5 feet high?

1. 128
2. 130
3. 136
4. 139

1-63. What tension, in pounds, must be applied to a tape tension scale it you are required to apply 8 to 10 kilogram tension to an unsupported tape?

1. 8.6 to 10.0
2. 11.6 to 15.0
3. 17.6 to 22.0
4. 20.6 to 25.0

1-64. How many seconds are there in 0.44 minute of an arc?

1. 16.4
2. 26.4
3. 36.4
4. 46.4

1-65. How many degrees are there in 1.38 minutes?

1. 0.023
2. 0.033
3. 0.038
4. 0.41

1-66. 72.73 grads, converted into degrees, minutes, and seconds, equals

1. 57°17'25"
2. 59°27'17"
3. 65°27'25"
4. 68°39'17"

1-67. Approximately how many degrees are there in 4,300 roils?

1. 242
2. 245
3. 250
4. 255

1-68. Convert 95°F to degrees C.

1. 35°C
2. 34°C
3. 32°C
4. 30°C

1-69. It was determined that 435 linear feet of 2-inch by 4-inch lumber are required for formwork. How many board feet of lumber should be ordered for this job?

1. 278
2. 280
3. 286
4. 290

1-70. How many pints are there in 2,564 gallons?

1. 20,012
2. 20,112
3. 20,212
4. 20,512

1-71. How many liters are there in 100,000 U.S. gallons?

1. 368,500
2. 378,500
3. 388,500
4. 398,500

1-72. How many liters are there in 301 kiloliters?

1. 3,010
2. 30,100
3. 301,000
4. 3,010,000

1-73. Convert 135 horsepower to watts.

1. 100,710
2. 110,710
3. 120,610
4. 120,710

1-74. Convert 15.85 feet to the nearest 1/8 inch in carpenter's measure.

1. 15 ft 8 1/2 in
2. 15 ft 10 1/4 in
3. 15 ft 10 1/2 in
4. 15 ft 11 in

1-75. Approximately how many cubic yards of concrete are required for a 6-inch layer on a 3.5-acre parking lot?

1. 1,415
2. 2,830
3. 5,650
4. 16,950

ASSIGNMENT 2

Textbook Assignment: "Drafting Equipment." Pages 2-1 through 2-27.

2-1. A drawing is identified as technical or illustrative, depending on its

1. purpose
2. character
3. type
4. quality

2-2. The graphic representation of a utility system prepared by an EA is called a/an

1. industrial drawing
2. mechanical drawing
3. engineering survey
4. qualitative graph

2-3. The drawing of quantitative or qualitative display charts and graphs is characteristic of which of the following types of engineering drafting?

1. Construction
2. Topographic
3. Administrative
4. Each of the above

2-4. An engineering chart that shows relationships, rather than numerical values is called

1. quantitative
2. qualitative
3. visual
4. statistical

2-5. What type of engineering display chart is prepared to show the relationship between planned and actual work accomplishment?

1. Management information
2. Network analysis
3. Time-and-work
4. Progress

2-6. To provide uniform interpretation, all Navy drawings must be prepared according to which of the following manuals or standards?

1. NAVFAC design manuals
2. Military standards
3. DoD standards
4. All of the above

2-7. References to obsolete drawing symbols and unusual drawing features are normally found in what source(s)?

1. Architectural Graphic Standards
2. NAVFAC design manuals
3. Military standards
4. Explanatory notes and legends on the drawing

IN ANSWERING QUESTIONS 2-8 THROUGH 2-12, SELECT THE PUBLICATION FROM THE LIST THAT YOU SHOULD USE AS A REFERENCE TO LOCATE THE SUBJECT MATTER IDENTIFIED.

A.	MIL-HDBK-1006/1
B.	MIL-STD-12
C.	MIL-STD-17
D.	ANSI Y14.2

2-8. Mechanical symbols.

1. A
2. B
3. C
4. D

2-9. Policy and procedures for specifications preparation.

1. A
2. B
3. C
4. D

2-10. Abbreviations.

1. A
2. B
3. C
4. D

2-11. Line conventions and lettering.

1. A
2. B
3. C
4. D

2-12. Policy and procedures for project drawings.

1. A
2. B
3. C
4. D

2-13. A standard NMCB drafting kit contains sufficient supplies and equipment to outfit a total of how many drafters?

1. Ten
2. Two
3. Three
4. Five

2-14. Which of the following types of drafting media are used by SEABEE drafters?

1. Tracing paper, tracing cloth, and detail paper
2. Tracing paper, profile paper, and cross-section paper
3. Tracing cloth, film, and tracing paper
4. Tracing cloth, tracing paper, and graph paper

2-15. Compared with bristol board, illustration board differs in what respect?

1. It has only one white drawing surface
2. It is thinner and less rigid
3. It comes in a smaller size
4. It cannot be used for making small signs and charts

2-16. Which of the following grades of pencil lead is the hardest?

1. F
2. HB
3. 2H
4. 4B

2-17. Compared to an HB-grade pencil lead, an F-grade lead is

1. thinner and softer
2. thinner and harder
3. thicker and softer
4. thicker and harder

2-18. Which of the following types of erasers is best suited for removing unwanted smudges from ink drawings prepared on tracing vellum?

1. Vinyl
2. Pink pearl
3. Ruby red
4. Art gum

2-19. When erasing with an electric eraser, which of the following actions should you avoid taking because of the damage that may occur?

1. Erasing lightly penciled lines
2. Erasing heavily inked lines
3. Erasing closely spaced lines
4. Holding the eraser steady in one spot

2-20. To prevent fresh ink lines from spreading, what method should you use to prepare the surface of the drafting medium?

1. Cover it with a film of specially prepared chemical
2. Rub it with fine bone dust
3. Rub it with pulverized art gum particles
4. Scrape it lightly with a steel eraser

2-21. Concerning the use of drawing boards, which of the following statements accurately describes a correct procedure, method, or theory?

1. For a right-handed drafter, the working edge is the left vertical edge of the board
2. For any drafter the preferred working edge is the lower horizontal edge of the board
3. It is assumed that all edges of the board are perfectly square
4. The drawing surface of the board is leveled by adjusting the hinged attachment

2-22. Which of the following statements concerning the use, testing, or care of the T-square is an accurate guideline, procedure, or method?

1. To draw a long continuous vertical line, set the head of the T-square against the upper edge of the drawing board
2. To prevent warpage of the T-square when it is not in use, hang it vertically by the hole in its blade
3. To test a T-square, draw coinciding lines with both the top and bottom blade edges
4. To test a T-square, draw a continuous line using both vertical edges of the drawing board

2-23. Instead of using a T-square, some drafters prefer a parallel straightedge because it offers which of the following advantages?

1. It allows the drafter to produce cleaner drawings
2. It helps prevent ink blots on small drawings
3. It allows the drafter to work more accurately on large drawings
4. It helps keep drawings from sliding off an inclined drawing board

2-24. What is the most desirable source of illumination for drafting work?

1. Direct sunlight
2. Adjustable fluorescent table lamps
3. Overhead ceiling lights
4. Natural light

2-25. Assuming that a drafter is right-handed, the lighting should be from what direction?

1. Left-front
2. Right-front
3. Over the right shoulder
4. Over the left shoulder

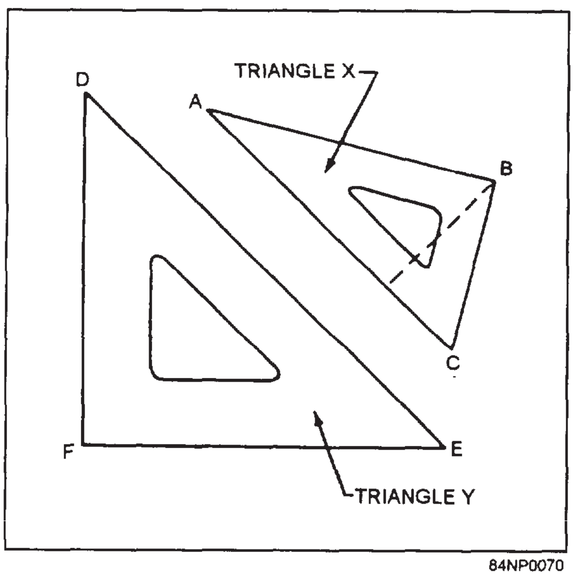


Figure 2A

IN ANSWERING QUESTIONS 2-26 AND 2-27, REFER TO TRIANGLES X AND Y IN FIGURE 2A.

2-26. The size of a 30°-60° triangle (X) is designated by the

1. length of AB
2. length of BC
3. size of angle A or C
4. perimeter of the triangle

2-27. The size of a 45° triangle (Y) is designated by the

1. length of DE
2. length of DF or EF, whichever you prefer
3. perimeter of the triangle
4. size of angle D or E

2-28. Assume that you are testing the straightness of a 45° triangle. The first step you should take is to place the triangle against a T-square and draw a vertical line. The next step is to take what actions?

1. Rotate the triangle and draw another vertical line, which should coincide with the first line
2. Slide the triangle to the left (or right) and draw an intersecting 45° line, which can be tested for accuracy with a protractor
3. Reverse the triangle and draw another vertical line along the same edge. This line should coincide with the first
4. Reverse the T-sauare and draw another vertical line along the same edge. This line should coincide with the first

2-29. In which of the following ways are circular protractors graduated?

1. Clockwise from 0° to 90° and 180° to 270°, and counterclockwise from 360° to 270° and 180° to 90°
2. Clockwise and counterclockwise from 0° to 180°
3. Clockwise and counterclockwise from 0° to 360°
4. Clockwise in quadrants from 0° to 90°

2-30. Without estimating, what is the minimum angle that can be set on the adjustable triangle shown in textbook figure 2-13?

1. 30 seconds
2. 15 seconds
3. 30 minutes
4. 1 degree

2-31. For which of the following shapes should you NOT use french curves?

1. Spirals
2. Ellipses
3. Parabolas
4. Circular arcs

IN ANSWERING QUESTIONS 2-32 THROUGH 2-35, REFER TO TEXTBOOK FIGURE 2-15.

2-32. Of the following instruments, which one is held in a set position by friction?

1. C
2. F
3. J
4. L

2-33. A series of eight circles with a diameter of 1/2 inch to 10 inches is drawn from a single center. What instruments should you use to ink the circles?

1. B and C
2. B, C, and D
3. B, C, and I
4. B, C, I, and K

2-34. Which of the following instruments require setscrew adjustment of the nibs ?

1. B, C, F, and G
2. B, F, G, and K
3. B, C, K, and L
4. F, G, K, and L

2-35. Of the following instruments, which one should you use to divide a 7 1/2-inch line into 20 equal segments?

1. A
2. C
3. J
4. K

2-36. Bringing together the points of dividers by bending the leg joints is a means of testing for

1. sharpness of the points
2. correct length of the points
3. alignment of the dividers
4. correct adjustment of the friction joints

2-37. When divider points become slightly uneven in length, what should you do to repair them?

1. Grind the points separately, in a horizontal position, by rubbing them on a whetstone
2. Hold the points vertically together and grind them lightly by drawing them back and forth against a whetstone
3. Grind the points separately, in a horizontal position, by twirling them against a whetstone
4. Replace the needlepoints

2-38. In what way, if any, should the needles of compasses and dividers compare in point size?

1. Those of the compass should be slightly larger
2. Those of the compass should be slightly smaller
3. They should be the same size
4. None; the size does not matter

2-39. Which of the following methods should you use to protect drawing instruments against corrosion?

1. Clean them with a soft cloth and coat them with a light film of oil
2. Polish them occasionally with metal polish
3. Clean them often with a chemical provided by the manufacturer of the instrument
4. Rub them lightly with emery paper and apply a light film of oil

IN ANSWERING QUESTIONS 2-40 THROUGH 2-44, SELECT THE DRAFTING INSTRUMENT FROM THE FOLLOWING LIST THAT SHOULD BE USED TO PERFORM THE DRAWING TASK LISTED.

A. HAIRSPRING DIVIDERS
B. DROP BOW PEN
C. PROPORTIONAL DIVIDERS
D. BEAM COMPASS

2-40. Ink a 3/32-inch radius circle.

1. A
2. B
3. C
4. D

2-41. Draw a circular arc that has a 30-inch radius.

1. A
2. B
3. C
4. D

2-42. Reduce or enlarge a drawing.

1. A
2. B
3. C
4. D

2-43. Transfer a measurement from one scale to another.

1. A
2. B
3. C
4. D

2-44. Draw a 60-inch radius circle.

1. A
2. B
3. C
4. D

2-45. The scale of 1/6,000 is equivalent to which of the following equations?

1. 1 in = 300 ft
2. 1 in = 500 ft
3. 1 in = 600 ft
4. 1 in = 1,000 ft

2-46. To show details of an object drawn to full scale on a drawing, you should present the details in what way?

1. Scaled up
2. Scaled down
3. Drawn to half scale
4. Drawn to full scale

2-47. Scales made of which of the following materials are the most accurate?

1. Plastic
2. Yellow hardwood
3. Boxwood
4. White pine

2-48. Which of the following scale shapes provides the most scale faces?

1. Two bevel
2. Opposite bevel
3. Four bevel
4. Triangular

IN ANSWERING QUESTIONS 2-49 THROUGH 2-52, SELECT THE TYPE OF SCALE FROM THE FOLLOWING LIST THAT YOU SHOULD USE TO ACCOMPLISH THE TASK LISTED.

A. METRIC SCALE
B. ENGINEER'S SCALE
C. ARCHITECT'S SCALE

2-49. Lay out drawing dimensions given in feet and inches.

1. A
2. B
3. C

2-50. Lay out drawing dimensions given in tenths of a foot.

1. A
2. B
3. C

2-51. Measure given dimensions to a scale of 1 cm = 50 m.

1. A
2. B
3. C

2-52. Measure given dimensions to a scale of 1 in = 200 ft.

1. A
2. B
3. C

2-53. What step must you take before using an engineer's scale for scaling when the scale is expressed as a fraction?

1. Determine the fractional equivalent of the scale on the engineer's scale
2. Multiply the scale numbers by 10
3. Multiply the scale numbers by 100
4. Multiply all measurements by 10

2-54. What scale on the engineer's scale should you use to determine that a line drawn 5 inches long is equivalent to 200 feet?

1. 10 scale
2. 20 scale
3. 40 scale
4. 50 scale

2-55. You want to draw the outline of a 200-foot by 200-foot rectangular area on an 8-inch by 10 1/2-inch sheet of paper. Which scale should you use to get the largest drawing that will fit on the paper?

1. 10 scale
2. 30 scale
3. 50 scale
4. 60 scale

2-56. Before using a map measure to determine the length of a pipeline on a SEABEE drawing, you should first take what step?

1. Adjust the tracing wheel with an odometer
2. Trace over the line to be measured
3. Set the scale indicator to the numerical scale indicated on the drawing
4. Trace over the graphical scale to ensure the accuracy of the reading

2-57. In what position should you hold the technical fountain pen when drawing a straight line?

1. Perpendicular to the drawing surface
2. Tilted slightly toward you
3. Tilted in the direction the line is drawn
4. Tilted opposite to the direction the line is drawn

ASSIGNMENT 3

Textbook Assignment: "Drafting: Fundamentals and Techniques; Reproduction Process." Pages 3-1 through 3-51.

3-1. For you to be positioned comfortably at your drawing board, your line of sight, in relation to the drawing surface, should be at approximately what angle?

1. 30°
2. 45°
3. 60°
4. 90°

3-2. If a drawing board has a severely marred drawing surface, you should cover the surface with which of the following materials?

1. A large sheet of butcher's paper
2. Two thicknesses of drawing paper
3. Laminated vinyl material
4. Self-adhesive linoleum

3-3. What step should you take to improve the surface of drawing paper that has become scratched from excessive erasing?

1. Rub the area smooth with your thumbnail
2. Rub the area lightly with pounce
3. Cover the damaged area with transparent tape
4. Apply a thin coating of clear acrylic spray

3-4. Which of the following drawing pencils should you select for the initial layout of a drawing?

1. 2B
2. F
3. H
4. 4H

3-5. When you view the back of a pencil drawing (on tracing paper) that is held against a light and see only indistinct lines, what, if anything, should you do?

1. Select a harder pencil to darken the lines
2. Select a softer pencil to darken the lines
3. Exert more pressure on the pencil used to prepare the drawing
4. Nothing; viewing the drawing from the back serves no purpose

3-6. You should always sharpen a pencil on its unlettered end for which of the following reasons?

1. To avoid breaking the lead
2. To retain the grade symbol
3. To retain the manufacturer's name
4. To permit easier dressing of the point

3-7. The mechanical pencil pointer produces what type of point?

1. Chisel
2. Elliptical
3. Conical
4. Wedge

3-8. A mechanical pencil has which of the following-advantages over a wooden pencil?

1. It is more comfortable to use
2. It does not need to be sharpened as frequently
3. It stays at a constant length
4. It uses leads that do not break as readily

3-9. When drawing a horizontal line, you should hold the pencil at what incline?

1. 30°
2. 45°
3. 60°
4. 75°

3-10. To draw vertical lines, you should (a) incline the pencil toward what part of the board and (b) draw the lines in what direction?

1. (a) Top (b) from bottom to top
2. (a) Top (b) from top to bottom
3. (a) Bottom (b) from bottom to top
4. (a) Bottom (b) from top to bottom

3-11. With a T-square as a base and using 30°-60° and 45° triangles in combination, inclined lines will be produced at which of the following angles?

1. 15° and 75°
2. 30° and 45°
3. 60° only
4. 30° and 60°

3-12. To lay off an angle from a given line, what marks on the protractor should you align for best accuracy?

1. Center mark and 0° mark only
2. 0° and 180° marks only
3. 0°, 180°, and center marks
4. 0°, 90° and 180° marks

3-13. In using a bow pencil to draw a circle, the drafter should take which of the following actions?

1. Rotate the bow pencil clockwise
2. Lean the bow pencil slightly forward
3. Apply even pressure
4. All of the above

3-14. When using a compass and pen attachment to draw a circle, what actions should you take to ensure proper ink flow?

1. Increase the forward incline of the compass
2. Adjust the needle leg of the compass to ensure it is perpendicular to the drawing surface
3. Adjust the pen leg of the compass to ensure that it is perpendicular to the drawing surface
4. Rub additional pounce into the drawing

3-15. A french curve is used to draw what types of lines?

1. Smooth, circular lines
2. Smooth, noncircular lines
3. Circular, parallel lines
4. Arcs of nonconcentric circles

3-16. In using a french curve to draw a line, what is the first step you should take?

1. Lightly sketch in the line between the plotted points
2. Avoid abrupt changes in curvature
3. Place the french curve so that it intersects at least two plotted points
4. Stop short of the last plotted point

3-17. When possible, you should use drafting templates for which of the following reasons?

1. They are as accurate as any other drawing method and usually much faster
2. They are not as accurate as other drawing methods but usually faster
3. They are more accurate than other drawing methods and usually faster
4. They are more accurate than other drawing methods although slower

3-18. Hairspring dividers are used for which of the following purposes?

1. Transferring measurements of different scales and stepping off a series of equal distances
2. Dividing lines into equal parts
3. Transferring measurements of the same scale and stepping off a series of equal distances
4. Both 2 and 3 above

3-19. Which of the following actions is NOT a proper use of the drafting scale?

1. To set a compass, mark the desired distance and adjust the instrument directly on the face of the scale
2. For measuring horizontal distances, point the desired scale face away from you
3. To measure distances, mark off short dashes at right angles to the scale face
4. To make successive measurements on a line, do not move the scale until necessary

3-20. Standard drawing sheet sizes are used for what primary reason?

1. To standardize the size of all drawings
2. To eliminate the waste of expensive tracing paper
3. To ensure that the supply department orders the correct sizes of trading paper
4. To facilitate filing

3-21. What are the dimensions of a size "C" sheet of drawing paper?

1. 11 in by 17 in
2. 17 in by 22 in
3. 22 in by 44 in
4. 34 in by 44 in

3-22. What are the actual dimensions inside the border lines on a size "D" sheet of drawing paper?

1. 20 in by 33 in
2. 21 in by 32 in
3. 21 in by 33 in
4. 21 in by 32½ in

3-23. On a sheet of "F" size drawing paper, what should be the dimensions between the trim lines?

1. 27½ in by 39½ in
2. 28 in by 40 in
3. 34 in by 44 in
4. 33½ in by 43½ in

3-24. What is the primary purpose of the title block on a drawing?

1. To describe the drawing
2. To tell who drew the drawing
3. To specify who is ultimately responsible for the drawing
4. To identify the drawing

3-25. The title block is generally located in what part of the drawing?

1. Lower right corner
2. Lower left corner
3. Lower center
4. Upper right corner

3-26. On a construction drawing, the revision block is placed at what corner of the drawing?

1. Lower right
2. Lower left
3. Upper right
4. Upper left

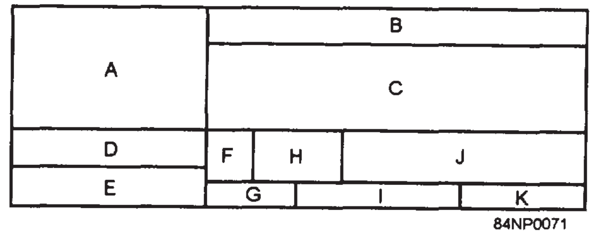


Figure 3A

IN ANSWERING QUESTIONS 3-27 THROUGH 3-29, REFER TO FIGURE 3A.

3-27. In what space should the terms "as shown, "as noted," or "none" be correctly entered?

1. E
2. G
3. I
4. J

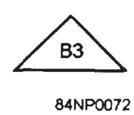
3-28. The five-digit number that identifies the government activity responsible for the design of the item is entered in what space?

1. D
2. E
3. F
4. H

3-29. What space holds the name of the drafter preparing the drawing?

1. A
2. D
3. E
4. J

3-30. What information about the drawing is indicated when the revision block contains the following symbol?



1. It is the third change incorporated in the second revision
2. It is the third change incorporated in the third revision
3. It is the second change incorporated in the second revision
4. It is the second change incorporated in the third revision

3-31. What feature do all the lines in the system of line conventions have in common?

1. They convey information
2. They are drawn with a pen guided by a straightedge
3. They are drawn with a compass
4. They are drawn freehand

3-32. How should construction lines be drawn?

1. Thick and dark
2. Dark enough to see, but light enough to erase easily
3. Thin and dark
4. With a soft pencil

3-33. To indicate the travel of a moving center, which of the following lines should you use?

1. Center lines
2. Phantom lines
3. Reference lines
4. Visible lines

3-34. What line is an example of a center line?

1. ————————————————
2. ——— - ——— - ——— - ———
3. - - - - - - - - - - - - - - -
4. ———— - - ———— - - ————

3-35. What line is a solid, thick line and defines the outlines of an object in a drawing?

1. Datum
2. Dimension
3. Extension
4. Visible

3-36. In a drawing of a certain view of an object, the features of the object that CANNOT be seen are indicated by what line?

1. ————————————————
2. ——— - ——— - ——— - ———
3. - - - - - - - - - - - - - - -
4. ———— - - ———— - - ————

3-37. How should arrowheads be drawn?

1. Between 1/4 and 1/2 in long, the length twice the spread, and filled in
2. Between 1/4 and 1/2 in long, the length twice the spread, and not filled in
3. Between 1/8 and 1/4 in long, the length three times the spread, and filled in
4. Between 1/8 and 1/4 in long, the length three times the spread, and not filled in

3-38. Drawing space is saved in certain large-scale detailed drawings by omitting unimportant parts that are continuous and have the same size and shape. What lines are used to indicate these omitted parts?

1. Section
2. Leader
3. Break
4. Cutting plane

3-39. The alternate positions of a switch handle can be indicated on a drawing by the use of what lines?

1. ————————————————
2. ——— - ——— - ——— - ———
3. - - - - - - - - - - - - - - -
4. ———— - - ———— - - ————

3-40. If an internal section of an object is needed, which of the following lines would indicate the plane from which the sectional view was taken?

1. Cutting plane
2. Sectional plane
3. Datum plane
4. Reference plane

IN ANSWERING QUESTIONS 3-41 THROUGH 3-44, SELECT THE TYPE OF LINE FROM THE FOLLOWING LIST THAT BEST MATCHES THE DESCRIPTION.

A. STITCH LINE
B. DATUM LINE
C. MATCH LINE

3-41. A line which indicates the plane from which an elevation is measured.

1. A
2. B
3. C

3-42. A line that connects corresponding points on different sheets of the same drawing.

1. A
2. B
3. C

3-43. The type of line that indicates sewing lines on an article.

1. A
2. B
3. C

3-44. A line that looks like a phantom line but is used differently.

1. A
2. B
3. C

3-45. In a pencil drawing, when should you draw the nonhorizontal and nonvertical lines?

1. After drawing the extension and dimension lines
2. After drawing the horizontal and vertical lines
3. Before drawing the horizontal and vertical lines
4. Before drawing any circles or arcs

3-46. On a drawing, which of the following lines are the last to be inked?

1. Horizontal lines
2. Vertical lines
3. Irregular curves
4. Border lines

3-47. As you practice freehand lettering, you develop “writer’s cramp.” What is the probable cause?

1. Applying excessive downward pressure on the pencil
2. Applying too little downward pressure on the pencil
3. Resting only the ball of the hand on the drawing board
4. Gripping the pencil too tightly

3-48. Which of the following pencil grades is most commonly used for freehand lettering on construction drawings?

1. 2B or 3B
2. B or H
3. F or H
4. H or 2H

3-49. What guidelines are used for lettering that requires only capitals?

1. Capline and baseline only
2. Capline and dropline only
3. Capline, waistline, and baseline
4. Capline, baseline, and dropline

3-50. If vertical guidelines are used to keep letters vertical, how should they be spaced along the horizontal guidelines?

1. Approximately every fifth letter
2. Approximately every two words
3. At the beginning, at the middle, and at the end of each line of lettering
4. At random

3-51. The number 6 on the inner circle of the Ames lettering instrument is aligned with the index on the outer circle. What is the distance between the capline and baseline produced by this setting?

1. 3/32 in
2. 3/16 in
3. 1/4 in
4. 3/8 in

3-52. For lowercase lettering, what is the normal spacing between continuous lines of lettering?

1. One half of the distance between the capline and dropline
2. Two thirds of the distance between the capline and baseline
3. Three times the distance between the capline and waistline
4. Equal to the distance between the capline and the baseline

3-53. Which of the following statements concerning the formation of single-stroke Gothic letters is NOT true?

1. Each letter is drawn by one single continuous stroke
2. All inclined strokes are drawn from the top down
3. All horizontal strokes are drawn from left to right
4. All curved strokes are drawn from above downward

3-54. To balance letters in words, which of the following actions should you take?

1. Extend the horizontal stroke of T when it precedes A
2. Compress the O to a narrower elliptical shape when it is between letters that have vertical strokes
3. Slightly compress the letter H
4. Place the central horizontal bar of H, F, and E slightly below center to create an optical illusion of widening

3-55. If the Ames lettering instrument is set on 8 to make capital letter guidelines for drawing notes, what number should be set on the instrument to produce guidelines for numerals that will be used in the same drawing notes?

1. 5
2. 6
3. 7
4. 8

3-56. Lowercase letters should NOT be used in which of the following situations?

1. For notes on maps
2. In combination with capitals on Navy drawings
3. On Navy drawings where the required size of lettering is more than one-fourth in high
4. On construction drawings and title blocks

3-57. A block of general notes on a drawing consists of several lines of lettering. Which of the following factors contributes the most to the appearance of the notes?

1. Spacing between letters and words
2. Formation of each letter
3. Size of the lettering
4. Spacing between the lines

3-58. In freehand Gothic lettering, the letters A and V in "HAVE" and the letters H and O in "HOLE" are properly spaced by moving the letters closer together.

1. True
2. False

3-59. For proper spacing of the letters in the word "NICKEL," you should provide less space between the letters N and I than the letters I and C.

1. True
2. False

3-60. When freehand lettering the word "WORK," you should provide the same amount of space between the letters W, O, and R.

1. True
2. False

3-61. For good appearance, the spacing between words should be equal to what size interval?

1. 1½ times the space occupied by the letter N
2. 1½ times the height of the capitals
3. The distance between the capline and the dropline
4. The space occupied by the letter O

3-62. As applied to lettering, what does the term "justifying" mean?

1. Adjusting words or letter spacing to make a line of lettering fit a given length
2. Spacing of letters for good appearance of words
3. Centering a line or lines of lettering about the center of a given area
4. Using sample lettering as a guide for centering

3-63. Using the templates in a standard Leroy lettering set, you can make letters of what maximum height?

1. 1½ in
2. 1¼ in
3. 1 in
4. ½ in

3-64. What part of the Leroy lettering set establishes line thickness of letters?

1. Ink reservoir
2. Tracing pin
3. Cleaning pin
4. Templates

3-65. What advantage does the adjustable scriber have over the standard fixed scriber?

1. Templates with larger lettering may be used
2. Larger pens may be inserted in the scriber to produce thicker lines
3. Templates with special types of lettering may be used
4. Inclined lettering may be produced with standard templates

3-66. Concerning the adjustment of the scriber, which of the following statements is a correct procedure?

1. Rough adjustment of the scriber adjustment screw should be made after the pen has been filled
2. The cleaning pen must be removed for proper rough adjustment
3. Rough adjustment should be made when the cleaning pen barely touches the paper, before the pen is filled
4. Final adjustment should be made after the locknut has been tightened

3-67. Which, if any, of the following requirements is necessary for reproduction rooms?

1. Lighting level equal to that of the drafting room
2. Sufficient room ventilation
3. Additional heat for protection of the reproduction paper
4. None of the above

3-68. In the reproduction of construction drawings, what process is most commonly used by the Navy?

1. Vacuum frames
2. Diazo or ammonia vapor
3. Sun frames
4. Photographic contact

3-69. Before using the Blu-Ray reproduction machine, all EAs should take which of the following actions?

1. Attend the formal school for operators
2. Obtain on-the-job training at one of the construction regiments
3. Acquire the necessary operator license
4. Become thoroughly familiar with the manufacturer’s operating and maintenance instructions

3-70. When making prints using the Model 842 printer, which of the following actions should you take?

1. Place the chemical side of the reproducing paper down
2. Run the original tracing through the machine before the reproducing paper
3. Feed the sensitized paper into the printer against the grain
4. Ensure that the leading edge of both the tracing and the sensitized paper are even, uncurled, and uncreased

3-71. What substance, solution, or cleaning method should you use to clean the glass-printing cylinder and lamps of the White printer?

1. Plain soap and water
2. Scouring powder and glass cleaner
3. Manufacturer’s recommended glass cleaner or an ammonia-water solution
4. Soap, water, and scouring pad

3-72. When the prints received from the Blu-Ray machine are too light, what action should you take?

1. Increase the speed
2. Decrease the speed
3. Increase the vapor
4. Decrease the vapor

3-73. What unit(s) of the printing section of the Ozalid machine carry(ies) the material around the revolving printing cylinder?

1. Pick-off assembly
2. Feed belts
3. Separator belts
4. Roller guide

3-74. Some Ozalid machines are equipped with a second ammonia supply system. What is the name of that system?

1. Second ammonia system
2. Second supply system
3. Anhydrous ammonia system
4. Hydrous ammonia system

3-75. What is the only positive method, if any, that you should use to obtain the correct speed for the Ozalid machine?

1. Consult the manufacturer’s manual
2. Check the label on the wrapper of the sensitized paper
3. Run one or more test strips
4. There is no positive method

ASSIGNMENT 4

Textbook Assignment: "Geometrical Construction." Pages 4-1 through 4-16. "Drafting:" Projections and Sketching." Pages 5-1 through 5-37.

4-1. What is the first step in drawing a line through a given point, P, parallel to line XY?

1. Place compass needlepoint on P; strike an arc intersecting XY at any point
2. Place compass needlepoint on P; strike an arc intersecting the approximate midpoint of line XY
3. Place compass needlepoint on any point along line XY; strike an arc through point P and line XY
4. Place compass needlepoint on X; strike an arc through Y and near point P

4-2. To construct a perpendicular from a given point, P, on line XY, you should first place the compass needle at what point(s) ?

1. P
2. X or Y
3. A point near the midpoint of PX and PY
4. Any convenient point along XY

4-3. What points on a line should be used as centers for the intersecting arcs drawn to bisect the line?

1. The center and one end
2. A random point and one end
3. A random point and the center
4. The two ends

4-4. Line XY is to be divided into 12 equal parts by geometric construction. Which of the following statements concerning this procedure is correct?

1. Ray line PY, drawn from Y, is the same length as XY
2. A compass should be set to spread equal to one twelfth of the length of XY
3. A line should be drawn from X to the 12th interval on ray line PY
4. The acute angle formed by XY and ray line PY should be 30° or less

4-5. From what point should you carry out the first step of the procedure to bisect or transfer angle XYZ? (Always use the middle letter as the apex.)

1. A random point on XY
2. A random point on YZ
3. The apex Y
4. The midpoint of arc XZ

4-6. In which, if any, of the following constructions is it necessary to draw an angle by using a protractor?

1. Constructing an equilateral triangle on a given inscribed circle
2. Constructing a right triangle for which the hypotenuse and one side are given
3. Constructing an equilateral triangle for which the length of one side is given
4. None of the above

4-7. Which of the following actions should be your first step in constructing a square geometrically when you are given only the length of its diagonal?

1. Lay out a horizontal line equal to one half of the given length
2. Lay out a vertical line equal to one half of the given length
3. Lay out a horizontal line equal to twice the given length
4. Lay out a horizontal line equal to the given length

4-8. In completing the drawing of a certain geometric figure, you have drawn the sides of the figure tangent to the points where two diameters (at right angles to each other) intersect a given circle. What geometric figure have you drawn?

1. A square in a given circumscribed circle
2. A square on a given inscribed circle
3. An equilateral triangle in a given circumscribed circle
4. An equilateral triangle on a given inscribed circle

4-9. When the length of the sides are not known, for which of the following geometric figures is it necessary to equally divide the circumference of the circle by trial and error with a compass?

1. A 5-sided irregular polygon inscribed in a given circle
2. A 5-sided regular polygon inscribed in a given circle
3. A 5-sided polygon inscribed on a given circle
4. Both 2 and 3 above

4-10. When two diameters of a circle are at right angles to each other, in which of the following geometric figures are all of the sides then drawn at 45° angles to the diameters?

1. A hexagon inscribed in a given circle
2. An octagon inscribed in a given circle
3. A pentagon inscribed in a given circle
4. A square inscribed in a given circle

4-11. In which of the following geometric figures are two of the sides drawn at 60° to the horizontal diameter of a given circle?

1. An equilateral triangle in a given circle
2. An equilateral triangle on a given circle
3. Both 1 and 2 above

4-12. Which of the following regular polygons may be constructed with only the length of one side given?

1. 5-sided polygon
2. 7-sided polygon
3. 9-sided polygon
4. All of the above

4-13. Assume that you have drawn a hexagonal bolt head from the given distance between its opposite corners. On the drawing, this distance is equal to the

1. diameter of the circle inscribed in the hexagon
2. diameter of the circle circumscribing the hexagon
3. diagonal of the square circumscribing the hexagon
4. side of the square circumscribing the hexagon

4-14. In the construction of a circle that is to pass through three given points, the center of the circle is determined by the intersection of what lines?

1. The perpendicular bisector of the longest line and the perpendicular line drawn from the end of the shortest line
2. The perpendicular bisector of the shortest line and the perpendicular line drawn from the end of the longest line
3. The perpendicular bisectors of the lines that connect the points
4. The tangents drawn through each point

4-15. To construct a line tangent to a circle at a given point on the circle, first set the compass

1. equal to the diameter of the circle
2. equal to the radius of the circle
3. to a distance less than the radius of the circle
4. to a distance greater than the radius and less than the diameter of the circle

4-16. To draw an arc of a given radius tangent to the sides of any angle, one of the essential steps of the procedure is to construct what two lines?

1. Two nonparallel lines at right angles to the sides of the angle
2. Two lines that are parallel to the sides of the angle at a distance equal to one half of the given radius
3. Two lines that are parallel to the sides of the angle at a distance equal to the given radius
4. Two parallel lines at right angles to the sides of the angle

4-17. In textbook figure 4-39, the radius O'P is equal to what distance?

1. Double the radius OP
2. The radius OP plus the radii of arcs CD and EF
3. The radius of arc CD plus AB
4. The radius of arc EF plus AB

4-18. In textbook fiqure 4-37, the compass spread O'P is equal to what distance?

1. AB
2. The radius OP minus AB
3. The radius of arc EF minus AB
4. The radius OP minus the radius of arc CD

4-19. In textbook figure 4-38, the radius OP is equal to what distance?

1. O'P
2. The line AB less the radius of arc CD
3. The line AB less the radius of arc EF
4. The sum of the radii of arcs CD and EF

4-20. What is the first step for constructing a compound curve, as shown in figure 4-40 of the textbook?

1. Draw the chords connecting AB, BC , CD, and DE
2. Erect a perpendicular bisector from A to B
3. Establish the random distance O_1A
4. Draw arc AB

4-21. Assume that you just constructed the ogee curve skown in figure 4-42 of the textbook. Which of the following points was NOT established by geometric construction?

1. C
2. D
3. E
4. O_1

4-22. When using the pin-and-string method to construct an ellipse, which of the following points should you use to determine the length of the string before drawing the perimeter of the ellipse?

1. Both end points of the minor axis and one focus point
2. Both end points of the major axis and one focus point
3. Both foci points and one end point of the minor axis
4. Both foci points and one end point of the major axis

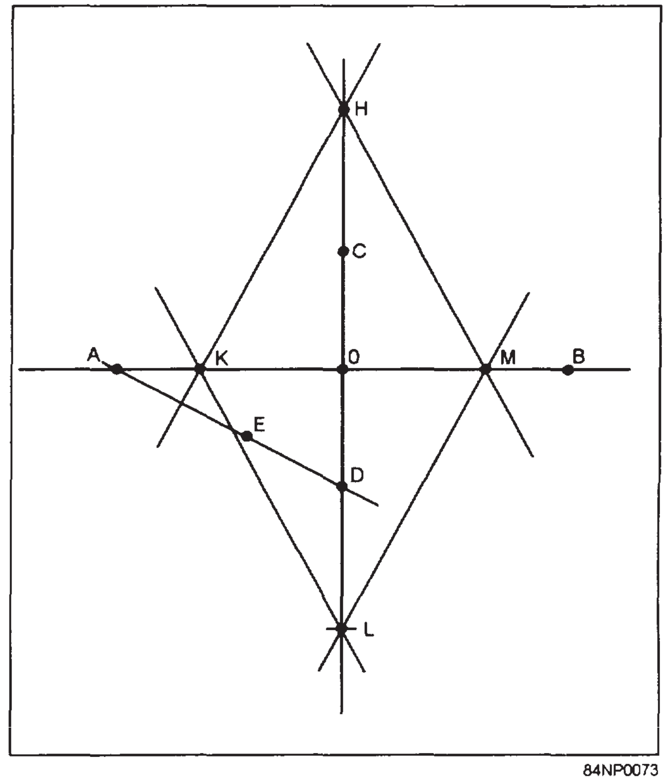


Figure 4A

IN ANSWERING QUESTIONS 4-23 AND 4-24, REFER TO FIGURE 4A WHICH SHOWS THE CONSTRUCTION LINES USED FOR DRAWING AN ELLIPSE BY THE FOUR-CENTER METHOD.

4-23. Line DE is equivalent to which of the following lines or distances?

1. Line DO
2. Line KO
3. Line AO minus line AK
4. Line AO minus line DO

4-24. Which of the following descriptions describes point K correctly?

1. The end point of line KO, which is on the minor axis
2. The intersection of line AO with the perpendicular bisector of line AE
3. The intersection of line KO with the perpendicular bisector of line AD
4. The end point of line KO, which is equal to the difference in lengths of lines AO and DO

4-25. In which of the following types of projection do the lines of sight converge?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-26. In which of the following types of projection is the plane of projection between the point of sight and the object?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-27. Which of the following types of projection involve only two-dimensional views of an object?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-28. In which of the following types of projection is the point of sight located at infinity?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-29. In an orthographic projection, which of the following views are the principal planes of projection?

1. Top, bottom, and side
2. Front, rear, and top
3. Front, bottom, and side
4. Front, top, and side

4-30. What is the most common orthographic projection used in the United States?

1. First-angle
2. Second-angle
3. Third-angle
4. Fourth-angle

4-31. Which of the following planes in the third-angle projection is considered to be in the plane of the drawing paper?

1. Horizontal
2. Vertical
3. Profile
4. Third-angle

4-32. How should views be spaced on tracing paper?

1. So they give the appearance of a balanced drawing
2. So they conserve as much paper as possible
3. In a manner that depicts a clear and concise picture of the object being drawn
4. In a manner that facilitates the projection of the views

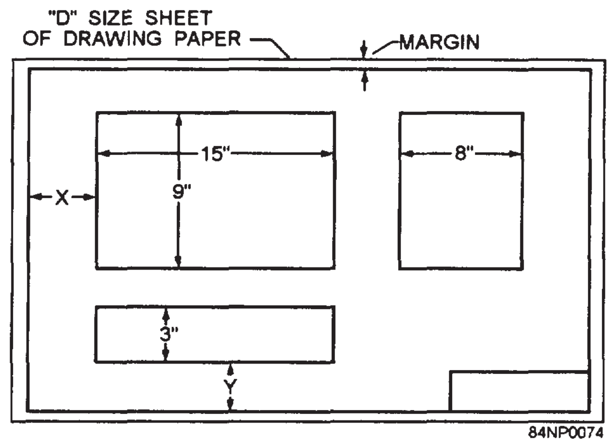


Figure 4B

IN ANSWERING QUESTIONS 4-33 AND 4-34, REFER TO FIGURE 4B.

4-33. The distance X is equal to

1. 3 in
2. 3 1/3 in
3. 4 in
4. 4 1/3 in

4-34. The distance Y is equal to

1. 2 in
2. 2 1/3 in
3. 3 in
4. 3 1/3 in

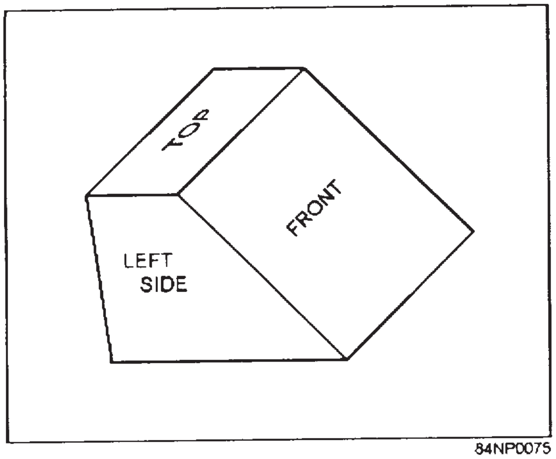
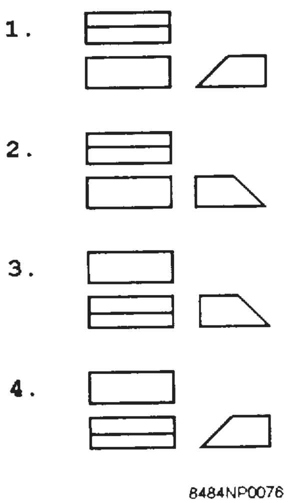


Figure 4C

IN ANSWERING QUESTION 4-35, REFER TO FIGURE 4C.

4-35. Which of the following arrangements is proper for the front-, top-, and right-side views?



4-36. Which of the following descriptions applies to a non-normal line?

1. It is curved
2. It is perpendicular to a plane of projection
3. It is oblique to one or more of the planes of projection
4. It is always shown at its true length

4-37. In multi-view orthographic projection, how should circles appear?

1. As ellipses Only
2. As either circles or ellipses, depending on the view
3. In their true shape, but their size may be distorted
4. Always in their true size and shape

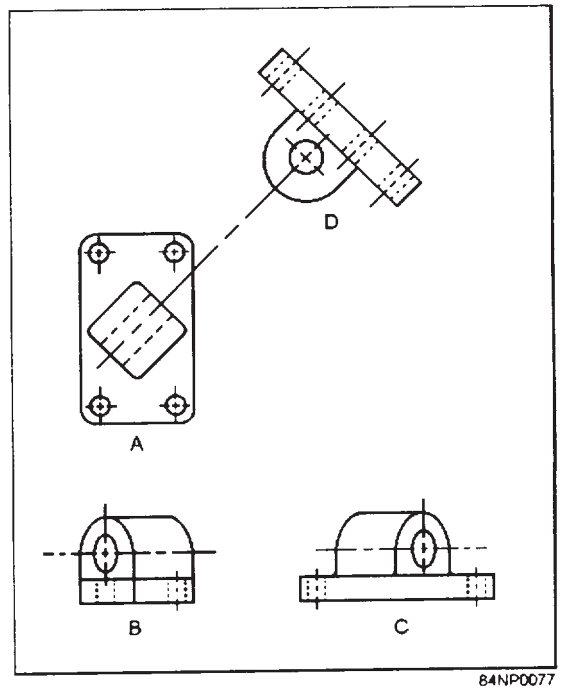


Figure 4D

IN ANSWERING QUESTION 4-38, REFER TO FIGURE 4D.

4-38. What drawing shows an auxiliary view of the object?

1. A
2. B
3. C
4. D

4-39. An auxiliary view to a three-view drawing is required if the object has what characteristics?

1. More than four sides
2. No symmetrical sides
3. A detail that is on a plane parallel to a regular plane of projection
4. A surface where the true shape cannot be shown by a regular plane of projection

IN ANSWERING QUESTIONS 4-40 THROUGH 4-43, SELECT THE CHARACTERISTIC FROM THE FOLLOWING LIST THAT IDENTIFIES OR APPLIES TO THE AUXILIARY VIEW GIVEN AS THE QUESTION.

A. PROJECTED FROM THE FRONT VIEW
B. PROJECTED FROM A SIDE VIEW
C. PROJECTED FROM THE TOP VIEW

4-40. Front.

1. A
2. B
3. C

4-41. Right side.

1. A
2. B
3. C

4-42. Elevation.

1. A
2. B
3. c

4-43. Left side.

1. A
2. B
3. C

IN ANSWERING QUESTIONS 4-44 AND 4-45, REFER TO FIGURE 5-25 IN THE TEXTBOOK.

4-44. The rear auxiliary view could also have been projected from which of the following views?

1. Top
2. Front
3. Rear
4. Left side

4-45. The line BD appears in its true length in the rear auxiliary view and in what other view, if any?

1. The right side
2. The top
3. The front
4. None

4-46. What type of section view gives a complete cross-sectional view of an object?

1. Complete section
2. Full section
3. Full plane section
4. Plane section

4-47. In half-sectioning a cylinder, how far should you extend the cutting plane?

1. Half the diameter of the cylinder
2. Half the radius of the cylinder
3. Half the circumference of the cylinder
4. A quarter of the circumference of the cylinder

4-48. A section consisting of less than a half-section is referred to as what type of section?

1. Partial
2. Detail
3. Offset
4. Quarter

4-49. At what angle from the horizontal should diagonal hatching be drawn in an orthographic projection?

1. 15°
2. 30°
3. 45°
4. 60°

4-50. In an isometric drawing, what is the angle that each line of the axis forms with the adjacent line?

1. 45°
2. 60°
3. 90°
4. 120°

4-51. In an isometric projection, the object is inclined to conform with which of the following characteristics?

1. All surfaces make the same angle with the plane of projection
2. The face makes an angle of 30° with the plane of projection
3. The face makes an angle of 60° with the plane of projection
4. Each edge forms an angle of 45° with the plane of projection

4-52. Which of the following descriptions most accurately applies to the lines of projection in an isometric drawing?

1. Converging
2. Diverging
3. Parallel to the plane of projection
4. Perpendicular to the plane of projection

4-53. What method is used for drawing non-isometric lines whose ends do not fall on isometric lines or planes?

1. Corresponding end points
2. Conjugate axis
3. Orthographic
4. Section lining

4-54. When transferring an angle to an isometric view, which of the following guidelines should you use?

1. Represent the angle in its true size in the isometric view
2. Use the same method as when transferring a non-isometric line
3. Label the angle with its actual size as appearing on the isometric drawing
4. Reduce the size of the angle by one fifth

4-55. A figure appearing as a circle in regular multi-view view will take what shape in an isometric view?

1. Line
2. Circle
3. Oval
4. Ellipse

4-56. When an object is to be drawn in oblique projection, how should the front surface be positioned?

1. Perpendicular to the plane of projection
2. Parallel to the plane of projection
3. At an angle of 45° to the plane of projection
4. At an angle of either 30° or 60° to the plane of projection

IN ANSWERING QUESTIONS 4-57 THROUGH 4-60, SELECT THE OBLIQUE PROJECTION FROM THE FOLLOWING LIST THAT HAS THE CHARACTERISTICS LISTED.

A. CABINET ONLY
B. CAVALIER ONLY
C. CABINET AND CAVALIER

4-57. Front surface drawn in orthographic projection.

1. A
2. B
3. C

4-58. Oblique projection drawn to actual or dimensional length.

1. A
2. B
3. C

4-59. Oblique projection foreshortened by one half.

1. A
2. B
3. C

4-60. Single view showing length, width, and thickness of an object.

1. A
2. B
3. C

4-61. To save time, sketching to scale is commonly done with the aid of which of the following materials or implements?

1. Engineer's scale
2. Cross-section paper
3. Dividers
4. Draftsman's triangles

4-62. When freehand sketching, you should hold the pencil in what manner?

1. Between your middle and index fingers
2. With your index finger as close to the point as possible
3. Below your hand and between your thumb and fingers
4. With a relaxed grip about an inch from the point

4-63. When freehand sketching of an object, each line should be drawn in what manner?

1. With one complete stroke of the pencil
2. With the arm held in one position
3. With a series of short strokes of the pencil
4. With a wrist movement, rather than an arm movement

4-64. When sketching a long, straight vertical line, you should first place a dot at each end of the line. What is your next step?

1. Connect the dots with a series of short pencil strokes
2. Connect the dots with one long pencil stroke
3. Place additional dots at intermediate points along the line, then connect the dots with a series of short pencil strokes
4. Place additional dots at intermediate points along the line, then connect the dots with one long pencil stroke

4-65. To divide lines and areas into equal parts, you should use what process?

1. Visual approximation
2. Arbitrary estimation
3. Geometric construction
4. Dividing and redividing

4-66 What is the basic angle you should use when sketching?

1. 30°
2. 60°
3. 45°
4. 90°

4-67. Which of the following items will serve as a substitute for a pencil compass?

1. Pencil, piece of string, and a thumbtack
2. Pencil, rubberband, and a thumbtack
3. Two pencils and a rubberband
4. Two pencils and a piece of paper

4-68. One method of freehand sketching of a circle calls for you rotate the-paper with one hand. What part of your hand serves as the pivot point?

1. The side
2. Index finger only
3. Second finger only
4. Either the index or second finger, whichever is easier

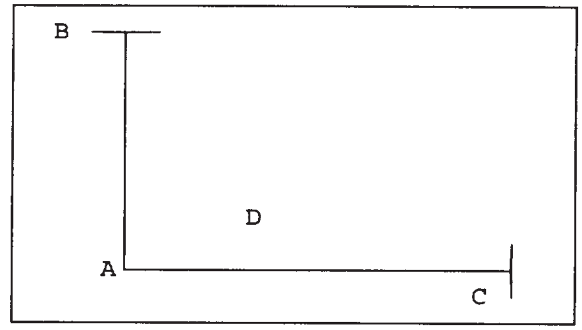


Figure 4E

IN ANSWERING QUESTIONS 4-69 AND 4-70, YOU ARE DFUIWING A CURVE TANGENT TO STRAIGHT LINES AND HAVE PROCEEDED AS FAR AS SHOWN IN FIGURE 4E.

4-69. What should your next step be?

1. Placing a dot at D
2. Sketching a light curve through D between B and C
3. Drawing a straight line between B and C
4. Drawing a straight line from A through D midway between B and C

4-70. What is the preferred way to sketch the curve after you place the dot or X through which the curve is to pass?

1. Start at B, and proceed through the dot or X, and end at C
2. Start at C, proceed through the dot or X, and end at D
3. Start at the dot or X and sketch to C, return to the dot or X, and then sketch to B
4. Start at D, proceed to C, back to D, and then to B

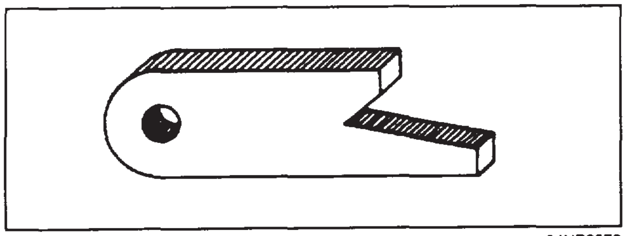


Figure 4F

IN ANSWERING QUESTION 4-71, REFER TO FIGURE 4F.

4-71. If you are sketching the object shown, what step should you take first?

1. Draw a circle
2. Draw a rectangular block
3. Draw light guidelines to represent the outlines of the object
4. Draw the details

4-72. Pictorial sketches differ from orthographic sketches in which of the following ways?

1. Pictorial sketches are normally drawn to scale while orthographic sketches are not
2. Pictorial sketches deal with volumes, rather than planes
3. Pictorial sketches are usually less detailed than orthographic sketches
4. Pictorial sketches require the use of mechanical aids in their preparation

4-73. What is the primary use of overlay sketches?

1. Preliminary design
2. Changes in design
3. Planning purposes
4. Supplementing previously drawn sketches

ASSIGNMENT 5

Textbook Assignment: "Wood and Light Frame Structures." Pages 6-1 through 6-51.

5-1. Of all the construction material, what material is considered the most often used and the most important?

1. Wood
2. Steel
3. Concrete
4. Plastic

5-2. In small construction projects that do NOT have written specifications included, where should you be able to find the type and classification of wood?

1. In the drawings themselves
2. In the bill of materials
3. In the special standards
4. In the special information sheets attached to the drawings

5-3. In construction, the terms "wood," "lumber" and "timber" have distinct and separate meanings. Which of the following definitions is an accurate description?

1. Wood is a soft, nonfibrous substance
2. Timber is lumber with a dimension of not less than 5 inches
3. Lumber is trees that have not been cut
4. Wood is lumber that has been made into manufactured products

5-4. "Millwork" is best defined by which of the following descriptions?

1. Wood selected for sawmill work
2. Timber made into lumber
3. Lumber made into manufactured products
4. Wood after it has been through the sawmill

5-5. In what way, if any, can the nominal size of lumber be compared to its dressed size?

1. It is larger
2. It is the same
3. It is smaller
4. It cannot be compared

5-6. What designation applies to wood surfaced on two sides only?

1. S2S
2. S2E
3. SS2
4. 2SS

5-7. In which of the following ways is lumber designated on drawings and purchase orders?

1. Dressed only
2. Nominal only
3. Dressed or nominal, whichever you chose

IN ANSWERING QUESTIONS 5-8 AND 5-9, REFER TO TABLE 6-2 IN YOUR TEXTBOOK.

5-8. What are the dressed dimensions of a 1- by 8-inch board?

1. 1 by 8 in
2. 1 by 7 1/2 in
3. 3/4 by 7 1/2 in
4. 3/4 by 7 1/4 in

5-9. What are the dressed dimensions of a 2- by 4-inch, S4S board?

1. 2 by 4 in
2. 2 by 3 1/2 in
3. 1 1/2 by 3 1/2 in
4. 1 1/2 by 3 1/4 in

5-10. Manufactured lumber, when classified according to its use, falls into what three categories?

1. Boards, dimension, and timbers
2. Rough, dressed, and worked
3. Yard, structural, and factory
4. Boards, shop, and yard

5-11. When you want lumber to show its natural finish, what grade(s) should you use?

1. A only
2. B only
3. A or B, whichever you prefer
4. C

5-12. When grain-tight lumber is required, what type of lumber is normally used?

1. No. 1 common
2. No. 2 common
3. Grade A select
4. Grade B select

5-13. Which type of lumber is primarily graded by its allowable stresses?

1. Factory
2. Structural
3. Shop
4. Yard

5-14. To find the board foot measurement of lumber, what formula should you use?

1. $\frac{Thickness(in.) \times width(in.) \times length(in.)}{144}$

2. $\frac{Thickness(in.) \times width(in.) \times length(in.)}{12}$

3. $\frac{Thickness(in.) \times width(in.) \times length(ft)}{144}$

4. $\frac{Thickness(in.) \times width(in.) \times length(ft)}{12}$

5-15. When computing the amount of board feet in a dressed 2- by 4-inch board, which of the following dimensions should you use?

1. 1 3/4 by 3/4 in
2. 2 by 4 in
3. 1 5/8 by 3 5/8 in
4. 1 7/8 by 3 5/8 in

5-16. When you are laminating lumber, how are the laminations (pieces) fastened together?

1. Nailed and glued together, with the grain of all pieces running perpendicular
2. Nailed or glued together, with the grain of all pieces running parallel
3. Nailed, bolted, or glued together, with the grain of all pieces running perpendicular
4. Nailed, bolted, or glued together, with the grain of all pieces running parallel

5-17. Which of the following characteristics applies to plywood?

1. Punctureproof
2. Resists splitting
3. Pound for pound one of the strongest materials available
4. Both 2 and 3 above

5-18. Plywood is used for which of the following purposes?

1. Formwork
2. Sheathing
3. Furniture
4. Each of the above

5-19. What are the two most common sizes of plywood sheets available for use in construction?

1. 3 by 6 ft and 4 by 8 ft
2. 4 by 8 ft and 4 by 10 ft
3. 4 by 8 ft and 4 by 12 ft
4. 4 by 10 ft and 4 by 12 ft

5-20. How are plywood panel grades generally designated?

1. By the grade of veneer on the face only
2. By the kind of glue only
3. By the grade of veneer on the face and back only
4. By the kind of glue and the grade of veneer on the face and back

IN ANSWERING QUESTION 5-21, REFER TO FIGURE 6-6 IN YOUR TEXTBOOK.

5-21. What plywood veneer grade allows knotholes up to 2 1/2 inches in width and under certain conditions up to 3 inches?

1. A
2. B
3. D
4. N

5-22. When index numbers 48/24 appear on a grading identification stamp, what does the number 24 represent?

1. Minimum on-center spacing of supports for subfloors
2. Maximum on-center spacing of supports for roof decking
3. Maximum on-center spacing of supports for subfloors
4. Maximum on-center spacing of supports for wall studs

5-23. Which of the following types of plywood panels is/are recommended for use in cabinets?

1. Standard plywood sheathing
2. Decorative panels only
3. Overlaid panels only
4. Decorative panels and overlaid panels

5-24. Which of the following types of wood substitutes provides good fire resistance?

1. Fiberboard
2. Gypsum wallboard
3. Particleboard
4. Hardboard

5-25. The type and amount of wood treatment is normally given in the project specifications. When no written specifications exist, where should you be able to find the wood treatment required?

1. Bill of materials
2. Commercial standards
3. Drawings
4. American Plywood Association

5-26. In platform construction, what is the first wood structural member to be set in place?

1. Header
2. Joist
3. Soleplate
4. Sill

5-27. What is the difference between a common joist and a cripple joist?

1. A cripple joist extends the full span, but a common joist does not
2. A common joist extends the full span, but a cripple joist does not
3. A cripple joist may be supported by a girder, but a common joist is never supported by a girder
4. Common joists are supported by pilasters, while cripple joists are not

5-28. At a door opening in an exterior wood-framed wall, the names of the horizontal members that connect at the (a) top and (b) bottom of the cripple studs are

1. (a) header (b) soleplate
2. (a) top plates (b) soleplate
3. (a) top plates (b) header
4. (a) header (b) sill

5-29. Frame structures are commonly brat.ad by use of which of the following methods?

1. Diagonal bracing
2. Let-in bracing
3. Cut-in bracing
4. All of the above

5-30. What is the rise per unit of run for a 1/4 pitch roof?

1. 12 in
2. 6 in
3. 8 in
4. 4 in

5-31. What is the rafter whose lower end rests on the top plate and whose upper end rests against a hip rafter?

1. Common
2. Valley jack
3. Hip jack
4. Cripple jack

5-32. What rafter does NOT meet either the top plate or the ridgeboard?

1. Common jack
2. Cripple jack
3. Valley jack
4. Hip jack

5-33. For what purpose are purlins used in wood frame construction?

1. To serve as a nailer for roofing
2. To act as a structural connector
3. To support rafters
4. To serve as bracing for rafters

5-34. On flat or nearly flat roofs, what type of roof covering is generally used?

1. Galvanized iron sheets
2. Asphalt shingles
3. Tile
4. Built-up

5-35. On a built-up roof, what material provides the weathering surface?

1. Asphalt shingles
2. Aggregate
3. Roofing felt
4. Asphalt binder

5-36. On a boxed cornice, what is the trim that is nailed to the rafter ends?

1. Frieze
2. Crown molding
3. Fascia
4. Plancier

5-37. A gable roof has a total of how many eaves?

1. Five
2. Two
3. Three
4. Four

5-38. What type of common siding comes in lengths of more than 4 feet and widths of 8 inches or less?

1. Bevel
2. Drop
3. Clapboard

5-39. In an attic, which of the following conditions is NOT prevented by the installation of vapor barriers and insulation?

1. Heat loss
2. Heat gain
3. Moisture seepage
4. Condensation

5-40. What elements are the two principal parts of a stairway?

1. Stringers and risers
2. Treads and risers
3. Treads and stringers
4. Stringers and nosing

5-41. What type of stairway continues in a straight line from one floor to the next?

1. Change
2. Cleat (open-riser)
3. Platform
4. Straight-flight

5-42. A platform is needed between floors in what type of stairway?

1. Straight-flight
2. Platform
3. Reverse
4. Directional

5-43. In a structure, what are the two categories of stairs?

1. Principal and service
2. Main and porch
3. Basement and attic
4. Front and rear

5-44. What stairs extend between floors above the basement and below the attic?

1. Basement
2. Porch
3. Attic
4. Principal

5-45. Which of the following types of stairs is a service stair?

1. Porch
2. Principal
3. Personnel
4. Equipment

5-46. Into what two types, if any, is finish flooring broadly divided?

1. Resilient and carpet
2. Wood and concrete
3. Resilient and wood
4. None; it is not divided

5-47. What is the primary difference between exterior and interior flush doors?

1. An exterior flush door always swings to the outside of a building
2. Exterior flush doors have a solid core
3. Plywood is never used as the outside face of an exterior flush door
4. Interior flush doors may be fabricated on the construction site, but exterior flush doors are always factory-assembled

5-48. What are the principal parts of the frame of an inside door?

1. Head jamb and side jambs only
2. Head and side jams and head and side casings
3. Sill, head jamb, and side casings
4. Sill, side jambs, and head casing

5-49. What part of a window forms a frame for the glass?

1. Casement
2. Sash
3. Frame
4. Finish

5-50. What type of window contains several horizontal hinged sashes that open and close together?

1. Casement
2. Louver
3. Jalousie
4. Double-hung

5-51. In construction drawings, the window schedule provides what type of information?

1. Type of windows
2. Size of windows
3. Number of panes of glass for each window
4. Each of the above

5-52. When the figure 6/12 appears on one of the lights in the window schedule, the dimensions of the glass are what type?

1. Nominal
2. Rough
3. Actual
4. Finish

5-53. In interior trim, which of the following items is/are considered to be the most prominent?

1. Inside door casing only
2. Window casing only
3. Inside door and window casings
4. Doorframes

5-54. In the building construction trade, which of the following items are considered to be hardware?

1. Sliding door supports
2. Fastenings for screens
3. Strike plates
4. All of the above

5-55. Of the following materials, which are considered to be finishing hardware?

1. Fastenings for screens
2. Sliding door supports
3. Folding door supports
4. Automatic exit devices

5-56. Which of the following materials is/are considered to be rough hardware?

1. Special window hardware
2. Strike plates
3. Push plates
4. Escutcheon plates

5-57. Nails are classified according to what factor(s)?

1. Use and form
2. Length and thickness
3. Composition
4. Holding power

5-58. What type of nail is made from finer wire and has a smaller head than the common nail?

1. Box
2. Finishing
3. Plasterboard
4. Roofing

5-59. What type of nail has two functions: maximum holding power and easy withdrawal?

1. Roofing
2. Finishing
3. Box
4. Duplex

5-60. Which of the following characteristics should be included in a description of a roofing nail?

1. Round shafted, galvanized, short body, large head
2. Square shafted, galvanized steel, long body, medium-sized head
3. Specially hardened steel, noncorrosive
4. Triangular shafted, nongalvanized

5-61. The body of what type of nail is usually grooved or spiraled?

1. Plasterboard
2. Concrete
3. Masonry
4. Roofing

5-62. When used to describe the length of wire nails, a penny is indicated by what symbol?

1. a
2. b
3. c
4. d

5-63. The thickness of a wire nail is expressed by what designation(s)?

1. Number only
2. Letter only
3. Both number and letter
4. Size

5-64. What type of a nail is longer than 6 inches?

1. Roofing
2. Spike
3. Concrete
4. Plasterboard

5-65. Wood screws are designated according to what factors?

1. Type of head and material
2. Length and thickness
3. Type of thread
4. Body diameter

5-66. When ordinary wood screws are too short or too light or where spikes do NOT hold securely, what type of screw should be used?

1. Lag bolt
2. Special purpose
3. General purpose
4. Thread-cutting

5-67. What type of screw is self-tapping?

1. wood
2. Sheet metal
3. Lag
4. Brass

5-68. Sheet metal screws can fasten metal up to what maximum thickness?

1. 28 gauge
2. 30 gauge
3. 32 gauge
4. 34 gauge

5-69. What type of screws are used to fasten metals up to one-fourth inch thick?

1. Sheet metal
2. Thread-cutting
3. Lag
4. Flathead brass

5-70. What type of bolts, because of their lack of strength, are used only for fastening light pieces?

1. Carriage
2. Machine
3. Stove
4. Expansion

5-71. Of the following types of bolts, which should be used to fasten load-bearing members?

1. Lag
2. Expansion
3. Stove
4. Carriage

5-72. What type of bolt has a square section below the head that embeds into the wood to keep the bolt from turning?

1. Carriage
2. Expansion
3. Machine
4. Stove

ASSIGNMENT 6

Textbook Assignment: "Concrete and Masonry." Pages 7-1 through 7-34.

6-1. Concrete is a synthetic construction material made by properly mixing together which of the following ingredients?

1. Water and cement only
2. Water, cement, and sand only
3. Water, cement, and gravel only
4. Water, cement, sand, and gravel or crushed stone

6-2. What is the name of the chemical reaction responsible for the hardening of concrete?

1. Dehydration
2. Hydration
3. Oxidation
4. Deoxidation

6-3. The chemical reaction that causes concrete to harden occurs between which of the following ingredients?

1. Cement and sand
2. Cement and gravel
3. Cement and water
4. Gravel and sand

6-4. What factor controls the strength, durability, and watertightness of concrete?

1. The amount of sand
2. The size and shape of the coarse aggregate
3. The proportion of sand to gravel
4. The proportion of water to cement

6-5. The tensile strength of concrete, in comparison to compressive strength, is

1. higher
2. lower
3. approximately the same

6-6. To ensure that concrete is watertight as possible, you should take which of the following actions?

1. Add more water
2. Add less water
3. Use only the amount of water required to attain the necessary workability
4. Add more sand to fill any voids

6-7. The extent to which concrete resists deterioration caused by exposure to service conditions is called

1. strength
2. compressibility
3. flexibility
4. durability

6-8. Which of the following materials are placed in concrete to produce reinforced concrete?

1. Steel bars
2. Steels rods
3. Steel strands, wire, and welded wire mesh
4. All of the above

6-9. What reinforced concrete structural member supports and distributes building loads to the ground?

1. Plain slab
2. Footing
3. Beam
4. column

6-10. In addition to the principal reinforcement, what other steel reinforcing is used in tied columns?

1. Vertical reinforcing
2. Lateral ties
3. Spiral reinforcing
4. Mats

6-11. The diameter of reinforcing bars increase from one size to the next by what increment?

1. 1/16 in
2. 1/8 in
3. 1/4 in
4. 3/8 in

6-12. Where, if anywhere, in a simple beam (a beam resting freely on two supports near its ends) is there NO stress?

1. Top
2. Bottom
3. Exact center
4. Nowhere; all areas have some stress

6-13. When a reinforcing bar is bent too sharply, what might occur?

1. The bar would crack or be weakened
2. The bar will not adhere to the concrete
3. Concrete strength would be reduced
4. Hydration would not occur

6-14. When not dimensioned on the drawings, what is the minimum length of a lap splice for (a) No. 3 bars and (b) No. 6 bars?

1. (a) 11.25 in (b) 22.50 in
2. (a) 12.00 in (b) 22.50 in
3. (a) 22.50 in (b) 12.00 in
4. (a) 22.50 in (b) 11.25 in

6-15. What pattern sizes are available in square pattern welded-wire fabric?

1. 1 by 1 in, 2 by 2 in, and 3 by 3 in
2. 2 by 2 in, 3 by 3 in, 4 by 4 in, and 5 by 5 in
3. 2 by 2 in, 3 by 3 in, 4 by 4 in, and 6 by 6 in
4. 3 by 3 in, 5 by 5 in, and 6 by 6 in

6-16. When concrete structural members are fabricated at locations other than the final position of use, they are known by what term?

1. preconstructed
2. Cast-in-place
3. Prefabricated
4. Precast

6-17. What term is concrete cast in its final position of use known by?

1. Preconstructed
2. Cast-in-place
3. Prefabricated
4. Precast

IN ANSWERING QUESTIONS 6-18 THROUGH 6-21, SELECT THE PRECAST STRUCTURAL MEMBER FROM THE FOLLOWING LIST WHICH BEST FITS THE USE DESCRIBED.

A. FLOOR OR ROOF DECK
B. DECK PANEL FOR A LARGE PIER
c. INSULATED EXTERIOR WALL

6-18. Tongue-and-groove panel.

1. A
2. B
3. C

6-19. Sandwich panel.

1. A
2. B
3. C

6-20. Double-T slab.

1. A
2. B
3. C

6-21. Channel slab.

1. A
2. B
3. C

6-22. What terms correctly refer to the small, closely spaced beams used in (a) floor and (b) roof construction?

1. (a) Joists (b) purlins
2. (a) Joists (b) joists
3. (a) Purlins (b) purlins
4. (a) Purlins (b) joists

6-23. What primary difference, if any, exists between the beams and girders?

1. Beams are shorter than girders
2. Beams are used for different purposes than girders
3. Beams are made of different material than girders
4. Nothing; they are the same

6-24. Unless the ends of beams are rectangular, most of them will be of what cross-sectional shape?

1. Single T
2. Double T
3. I
4. C

6-25. In hollow precast columns, what material is put in the core to help hold the column upright?

1. Concrete
2. Looped rod
3. Grout
4. Heavy cardboard

6-26. Of the following advantages of precasting identical concrete members, which is considered to be the most important?

1. Less required storage space
2. Faster erection time
3. Reusable forms
4. Quality-controlled concrete

6-27. Of the following descriptions, which most accurately describes pretensioning of concrete members?

1. After the concrete has been placed and has reached a specified strength, reinforcement strands are pulled through formed channels, and a predetermined amount of stress is applied
2. Reinforcement strands are pulled through inflated tubes and are stressed before placement of the concrete
3. Reinforcement strands are stressed to a predetermined point before placement of the concrete and are released just before the concrete has set
4. Reinforcement strands are placed in the forms and are stressed to a predetermined point before the concrete is placed; the strands are then released after the concrete has reached a specified strength

6-28. In what part of a prestressed beam does the tensioned steel produce high compression?

1. Upper
2. Lower
3. Exact center
4. Approximate center

6-29. What condition occurs when a load (force) is placed on a prestressed beam?

1. The camber is forced out, leaving a beam with positive deflection
2. The upward bow is increased
3. The camber is forced out, leaving a level beam with no deflection
4. The upward bow is forced out, creating deflection in the beam

6-30. What is the approximate weight of conventional concrete?

1. 175 lb/cu ft
2. 150 lb/cu ft
3. 130 lb/cu ft
4. 115 lb/cu ft

IN ANSWERING QUESTIONS 6-31 THROUGH 6-35, SELECT THE TYPE OF CONCRETE FROM THE FOLLOWING LIST THAT BEST MATCHES THE CHARACTERISTIC GIVEN.

A. HEAVYWEIGHT CONCRETE
B. SEMI-LIGHTWEIGHT CONCRETE
C. INSULATING LIGHTWEIGHT CONCRETE
D. STRUCTUTWL LIGHTWEIGHT CONCRETE

6-31. Weighs 115 to 140 lb/cu ft and has a compressive strength comparable to normal concrete.

1. A
2. B
3. C
4. D

6-32. Weighs 20 to 70 lb/cu ft and is used for fireproofing.

1. A
2. B
3. C
4. D

6-33. Weighs up to 400 lb/cu ft.

1. A
2. B
3. C
4. D

6-34. Weighs up to 115 lb/cu ft and is used to decrease the dead-load weight of structural members.

1. A
2. B
3. C
4. D

6-35. Normally has a compressive strength of 1,000 psi or less.

1. A
2. B
3. C
4. D

6-36. In what type of construction are concrete walls poured horizontally, lifted upright, and then secured in place?

1. Tilt-up
2. Lift-up
3. Cast-in-place
4. Prefab

6-37. In tilt-up panel construction, where is additional reinforcement generally needed?

1. At the top
2. At the bottom
3. Around the edges
4. Around any openings

6-38. For what purpose are inserts placed in the tilt-up panels?

1. For vertical support
2. For picking up or tilting
3. For extra reinforcement
4. For horizontal support

6-39. In a tilt-up panel, the inserts are installed in what manner?

1. Independent of the reinforcement
2. Tied to reinforcement
3. Welded to reinforcement
4. Tied to the panel forms

6-40. What is the strongest method of connecting panels together?

1. A butted connection using grout or gasket
2. A cast-in-place column with the panel-reinforcing steel tied into the column
3. Steel columns welded to steel angles or plates secured in the panel
4. Precast columns tied with the panel

6-41. To provide waterproofing in all panel joints, you should use what material?

1. Heavy plastic film
2. Heavy asphalt-laminated barriers
3. Polyethylene (6-mil)
4. Expansion joint

6-42. What is the purpose of contraction joints?

1. To prevent buckling due to expansion of the reinforcing steel caused by temperature changes
2. To prevent cracking due to shrinkage of the reinforcing steel
3. To prevent cracking due to shrinkage caused by temperature changes
4. To prevent buckling due to expansion of the concrete caused by temperature changes

6-43. Expansion joints are also known as what kind of joints?

1. Construction
2. Shrinkage
3. Contraction
4. Isolation

6-44. Placing plastic concrete into spaces enclosed by forms is referred to by what term?

1. Casting
2. Precasting
3. Molding
4. Premolding

6-45. The part of a wall form that shapes and retains the concrete until it sets is known by what term?

1. Brace
2. Wale
3. stud
4. Sheathing

6-46. In formwork, what devices are usually used to reinforce wall forms against concrete displacement?

1. Sheathing
2. Wales
3. Ties
4. Spreaders

6-47. Which of the followinq devices combines the functions of wire ties and wooden spreaders?

1. Tie holder
2. Snap tie
3. Tie spreader
4. Bar tie

6-48. What type of wall-form tie consists of an inner section and two threaded outer sections?

1. Snap tie
2. Bar tie
3. Tie rod
4. Tie spreader

6-49. For concrete column forms, (a) what is the name of the members that brace against bursting pressure, and (b) where is the bursting pressure greatest?

1. (a) Ties (b) middle
2. (a) Yokes (b) top
3. (a) Yokes (b) bottom
4. (a) Ties (b) top

6-50. In masonry construction, what is the most common concrete masonry unit used?

1. Concrete block
2. Clay tile
3. Stone
4. Brick

6-51. Which of the following requirements for concrete blocks measures the ability to carry loads and withstand structural stresses?

1. Absorption
2. Moisture content
3. Density
4. Compressive strength

6-52. What is the actual size, in inches, of an 8- by 8- by 16-inch CMU?

1. 7 1/2 by 7 1/2 by 15 1/2
2. 7 5/8 by 7 5/8 by 15 5/8
3. 8 by 8 by 16
4. 8 1/4 by 8 1/4 by 16 1/4

6-53. In concrete masonry construction, what part of the block is the face shell?

1. Material that forms the partitions between the cores
2. Holes between the webs
3. Long sides of the block unit
4. Recessed end of the block units

6-54. To minimize cutting and fitting, you should maximize modular planning by the use of which of the following size of block units?

1. Full-size units only
2. Half-size units only
3. Full-size and quarter-size units
4. Full-size and half-size units

6-55. Which of the following parts is best described as the solid side of a building tile?

1. Shell
2. Web
3. Cell
4. Core

6-56. In addition to the thickness of the shell and webs of tile, the compressive strength of tile depends upon which of the following factors?

1. Materials used and method of manufacture
2. The opening and cell size
3. Its resistance to abrasion
4. Its resistance to deterioration

6-57. When building tiles are used in construction that is exposed to the weather, mortar should be prepared only from which of the following materials?

1. Waterproofed cement
2. Portland cement-lime
3. Masonry cement
4. Both 2 and 3 above

6-58. The use of structural load-bearing tile is restricted by which of the following factors?

1. Fire rating of the tiles
2. Weight and sizes of the tiles
3. Availability of the material
4. Building codes and specifications

6-59. Which of the following stone masonry descriptions best describes the term "rubble"?

1. The faces of stone are square and placed in position so the finished surfaces will present a continuous plane surface appearance
2. The stones used are left in their natural state without any kind of shaping
3. The stones are unprocessed and laid in courses without consideration of size or weight
4. The stones are roughly squared and laid in such a manner to produce approximately continuous horizontal bed joints

6-60. Of the following types of stonework, which one is considered to be the crudest?

1. Coursed ashlar
2. Coursed rubble
3. Random ashlar
4. Random rubble

6-61. Which, if any, of the following materials is used in mortar mix to prevent staining of the stones?

1. Ordinary portland cement
2. White portland cement
3. Lime added to the mixed cement
4. None of the above

6-62. What standard dimensions, in inches, are of building brick?

1. 1 1/4 by 3 3/4 by 8
2. 1 1/2 by 3 3/4 by 8
3. 1 3/4 by 3 3/4 by 8
4. 2 1/4 by 3 3/4 by 8

6-63. Common brick is best described as

1. unglazed, uniform in color, and made from select clay
2. unglazed, variable in color, and made from inferior clay
3. unglazed, variable in color, and made from pit-run clay
4. glazed, uniform in color, and made from select clay

6-64. Brick that is designed to withstand exposure to below-freezing temperatures in a moist climate is what classification?

1. SW
2. MW
3. NW
4. MC

6-65. Which of the following types of brick should be used as the backing course for a cavity wall?

1. Face
2. Kiln-run
3. Glazed
4. Fire

6-66. What type of brick is made of special clay and is designed to withstand high temperatures?

1. Press
2. Clinker
3. Glazed
4. Fire

6-67. Structural bonding of brick walls causes the entire assembly to act as a single unit. This method of bonding is accomplished by which of the following means?

1. Adhesion of grout to adjacent wythes of masonry
2. Embedding metal ties in connecting joints
3. Interlocking of the masonry units
4. All of the above

6-68. The simplest pattern bond made up entirely of stretchers is referred to by what name?

1. Stack
2. Common
3. Running
4. English

6-69. In which of the following pattern bonds must you place a three-quarter brick at the corner of each header course?

1. Common
2. English
3. Block
4. Stack

6-70. An English bond pattern wall is composed of alternate courses of what types of brick?

1. Three-quarter and blind headers
2. Stretchers and bull-headers
3. Headers and stretchers
4. Headers and rigid steel ties

6-71. In masonry construction, which of the following statements best describes the term "soldier"?

1. A unit laid flat with its longest dimension perpendicular to the wall
2. A brick laid on its end so that its longest dimension is parallel to the vertical axis of the face of the wall
3. A unit laid with its longest dimension parallel to the face of the wall
4. One of the continuous horizontal layers of masonry which, bonded together, form the masonry structure

ASSIGNMENT 7

Textbook Assignment: "Mechanical Systems and Plan." Pages 8-1 through 8-24. "Electrical Systems and Plan." Pages 9-1 through 9-19. "Construction Drawings." Pages 10-1 through 10-33.

7-1. The system of pipes, fixtures, and appurtenances used inside a building for supplying water and removing wastes is known by what general term?

1. Mechanical systems
2. Plumbing
3. Water distribution
4. Piping

7-2. When working with mechanical plans, you must become familiar with which of the following codes?

1. National Plumbing Code and National Electrical Code®
2. National Plumbing Code and local NAVFAC codes
3. Local codes and National Plumbing Code
4. Local codes and ANSI codes

7-3. Copper is widely used for tubing in piping systems for which of the following reasons?

1. It is less costly than other types of pipe
2. It is available in two wall thicknesses and is faster to install
3. It does not rust and is resistant to scale particles in the pipe
4. Fittings are screwed to the pipe which allows for faster completion of the piping system

7-4. Which of the following types of copper tubing is frequently used as replacement piping because of its flexibility?

1. Type K
2. Type L, hard tempered
3. Type M
4. Type L, soft tempered

7-5. Which of the following advantages does plastic pipe have over metal?

1. Flexibility
2. High resistance to rupture and total resistance to rust
3. It can be installed either above or below ground
4. All of the above

7-6. What type of polyvinyl chloride pipe can be used in both cold-water and hot-water systems?

1. PVC
2. APVC
3. CPVC
4. PVC-C

7-7. Galvanized steel pipe sizes are based on what nominal size?

1. Inside diameter
2. Outside diameter
3. Wall thickness
4. Inside radius

7-8. What type of fitting should be used for joining straight runs of dissimilar metal pipe that require easy disconnection?

1. Union
2. Coupling
3. Dielectric union
4. Dielectric coupling

7-9. For what type of pipes should (a) solvent welded and (b) sweated joints be used?

1. (a) Galvanized (b) plastic
2. (a) Plastic (b) copper
3. (a) Plastic (b) galvanized
4. (a) Copper (b) plastic

IN ANSWERING QUESTIONS 7-10 THROUGH 7-13, SELECT THE TYPE OF VALVE FROM THE FOLLOWING LIST THAT BEST MATCHES THE DESCRIPTION GIVEN IN THE QUESTION.

A. GLOVE VALVE
B. GATE VALVE
C. CHECK VALVE

7-10. This valve has a wedge-shaped, movable plug that fits tightly against the seat when closed.

1. A
2. B
3. C

7-11. This valve is well suited for use when a regulated flow is required.

1. A
2. B
3. C

7-12. This valve must be operated in the fully open position.

1. A
2. B
3. C

7-13. This valve is used to prevent backflow in a pipeline.

1. A
2. B
3. C

7-14. On water mains, thrust blocks should be installed for what purpose?

1. To prevent pipe displacement caused by high water pressure
2. To prevent pipe ruptures caused by high water pressure
3. To prevent sagging due to the weight of the piping material
4. To prevent sagging due to the weight of the pipe and the water contained in the pipe

7-15. Which of the following types of piping is becoming increasingly popular for use in underground sanitary sewage systems?

1. Cast iron
2. polyvinyl chloride
3. Concrete
4. Wrought iron

7-16. To make a 22 1/2-degree change in pipe direction, what cast-iron fitting should you use?

1. Combination Y and 1/8 bend
2. 1/4 bend
3. Short sweep 1/4 bend
4. 1/16 bend

7-17. What fittings are used in waste pipe systems to catch and hold water, thereby forming a seal to prevent sewer gases from backing up into a building?

1. Traps
2. Street ells
3. Valves
4. All of the above

7-18. In what way, if any, do waste stacks differ from soil stacks?

1. Waste stacks carry human waste, soil stacks do not
2. Soil stacks carry human waste, waste stacks do not
3. Waste stacks empty into building drains, soil stacks empty into building sewers
4. None

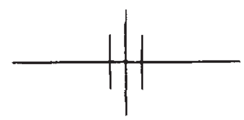
7-19. Under most local codes, what is the minimum distance that a building drain must extend beyond the building wall?

1. 2 ft
2. 3 ft
3. 6 ft
4. 10 ft

7-20. In a plumbing plan, which of the following symols should be used for a hot-water line?

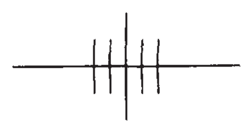
1. ____________________________
2. _______ - _______ - _______
3. -
4. ______ -- _______ -- _______

7-21. What symbol should you use to show a screwed joint in a piping plan?

1. 

2. 

84NP0079

3. 

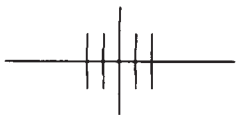
4. 

7-22. What symbol should you use to show a screwed union in a piping plan?

1. 

2. 

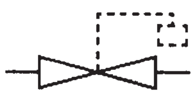
84NP0079

3. 

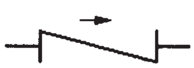
4. 

7-23. What valve symbol should you use for a gate valve?

1. 

2. 

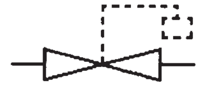
3. 

4. 

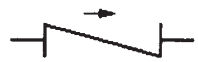
84NP0060

7-24. What valve symbol should you use for a hose valve?

1. 

2. 

3. 

4. 

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7-25. Which of the following descriptions best defines electrical distribution?

1. The transmission of power from the power plant to the substations
2. The delivery of power from the power plants or substations through feeders and mains to the building premises
3. The interior wiring of a building
4. The overhead power lines that extend from the substations to the buildings

7-26. Most land-based power systems use what type of electrical current?

1. Indirect
2. Direct
3. Alternating
4. Variable

IN ANSWERING QUESTIONS 7-27 and 7-28, REFER TO FIGURE 9-2 IN YOUR TEXTBOOK.

7-27. The installation of a transformer between the primary and secondary main to the motor pool serves what purpose?

1. To reduce voltage
2. To increase voltage
3. To increase current flow
4. To act as a safety device

7-28. What voltage is needed to operate the single-phase motor at the motor pool?

1. 110 V
2. 220 V
3. 330 V
4. 440 V

7-29. When the voltage remains constant, what happens to amperage when (a) resistance is decreased or (b) power consumption is decreased?

1. (a) It increases
   (b) it decreases
2. (a) It decreases
   (b) it decreases
3. (a) It increases
   (b) it increases
4. (a) It decreases
   (b) it increases

7-30. Which of the following reasons is NOT an advantage of installing electrical distribution systems underground, rather than overhead?

1. Underground installation costs are less
2. Underground lines are secure against high winds
3. Underground lines are less susceptible to enemy attack
4. Underground installation provides open land areas free from distribution systems

7-31. Electrical power is brought into a building through what device or conductor?

1. Panel board
2. Switchboard
3. Service drop
4. Service entrance

7-32. What electrical device automatically opens a circuit when the amperage exceeds the rated value for that device?

1. Panel box
2. Circuit breaker
3. Switch
4. Disconnect

7-33. Compared to a No. 4 AWG conductor, the size of a No. 16 AWG conductor is

1. smaller
2. equal
3. larger

7-34. What size wire is most frequently used for interior wiring?

1. No. 16 AWG
2. No. 12 AWG
3. No. 8 AWG
4. No. 6 AWG

7-35. In which of the following locations is ROMEX NOT authorized for use?

1. Embedded in concrete
2. In garages
3. In an explosives storage building
4. All of the above

7-36. Which of the following types of insulation should be used for installation in wet locations?

1. RH
2. RHW
3. RUH
4. Each of the above

7-37. Which, if any, of the following types of insulation is considered to be suitable for use in dry locations?

1. RHW
2. T
3. TW
4. None of the above

7-38. Instead of manually making a sharp bend in rigid aluminum conduit, which of the following fittings should you use?

1. Coupling
2. Conduit union
3. Condulet
4. Galvanized steel elbow

7-39. Which of the following types of conduit can be threaded?

1. Rigid
2. PVC
3. EMT
4. Greenfield

7-40. For installing a switch, which of the following outlet boxes should you use?

1. 4-inch octagon box
2. Gem box
3. Handy box
4. 4-inch square box

7-41. The National Electrical Code®
allows an outlet box to be recessed what maximum distance below the surface of a finished wall?

1. 1/16 inch
2. 1/8 inch
3. 1/4 inch
4. 1/2 inch

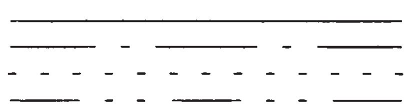
7-42. A ceiling light is controlled from two locations. To add a third location, which of the following types of switches must you use?

1. Single-pole
2. Two-pole
3. Three-way
4. Four-way

IN ANSWERING QUESTIONS 7-43 THROUGH 7-45, REFER TO APPENDIX IV OF YOUR TEXTBOOK.

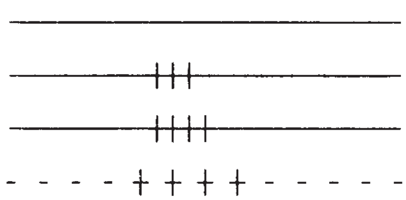
7-43. When preparing an electrical power distribution plan, which of the following symbols should you use to show aboveground two-conductor primary service lines?

1.
2.
3.
4.



7-44. For interior wiring, which of the following symbols should you use to show a four-conductor circuit installed in a ceiling?

1.
2.
3.
4.



7-45. Which of the following definitions best describes the symbol for a special-purpose receptacle outlet?

1. A circle inscribed in a triangle
2. A circle containing a smaller inscribed circle
3. A triangle
4. A solid triangle inscribed in a circle

7-46. In general, construction drawings are categorized according to which of the following factors?

1. The methods used to prepare them
2. Their intended purpose
3. The persons who will use them
4. The persons who prepared them

IN ANSWERING QUESTIONS 7-47 THROUGH 7-50, SELECT THE TYPE OF DRAWING THAT BEST MATCHES THE DESCRIPTION OR PURPOSE GIVEN.

A. PRESENTATION DRAWING
B. SHOP DRAWING
C. WORKING DRAWING
D. MASTER PLAN DRAWING

7-47. This drawing is also known as a project drawing. A set includes general, detail, and assembly drawings.

1. A
2. B
3. c
4. D

7-48. This drawing is prepared for minor field work such as a small portable building.

1. A
2. B
3. c
4. D

7-49. A perspective drawing showing how a proposed building will appear after it is constructed.

1. A
2. B
3. C
4. D

7-50. This drawing is a map used in long-range planning.

1. A
2. B
3. C
4. D

7-51. Where in a set of working drawings should you look to find an item that was too small to appear on a foundation plan?

1. General drawings
2. Detail drawings
3. Assembly drawings

7-52. Sets of initial working drawings that are provided to a customer for review and approval before completion of the final drawings are known by what name?

1. Presentation
2. Shop
3. Preliminary
4. Concept

7-53. Both red-lined drawings and as-built drawings reflect as-built conditions. What, if anything, is the difference between them?

1. Red-lined drawings are prepared by marking-up a copy of the original drawings during construction, whereas as-built drawings are prepared by making changes to the original (or sepia) drawings during or after project completion
2. Red-lined drawings are prepared by making changes to the original drawings during construction, whereas as-built drawings are made by marking-up a copy of the original drawings after project completion
3. Red-lined drawings are prepared from the as-built drawings
4. There is no difference between red-lined and as-built drawings

IN ANSWERING QUESTIONS 7-54 THROUGH 7-56, SELECT THE PUBLICATION THAT YOU SHOULD USE TO LOCATE THE REQUESTED INFORMATION.

A.	**NAVFAC P-34**
B.	**NAVFAC P-272, PART 1**
C.	**NAVFAC P-272, PART 2**
D.	**NAVFAC P-437**

7-54. Facility and assembly drawings for pre-engineered structures used by SEABEES at advanced bases.

1. A
2. B
3. C
4. D

7-55. Typical floor plan arrangements provided to an A/E firm preparing project drawings.

1. A
2. B
3. C
4. D

7-56. The crew size required to erect a pre-engineered building assembly.

1. A
2. B
3. c
4. D

7-57. Project drawings are required to have which of the following attributes?

1. They must be complete
2. They must be accurate
3. They must be explicit
4. All of the above

7-58. For NAVFACENGCOM drawings, which of the following title block formats is prescribed for use on F-size sheets?

1. Vertical only
2. Horizontal only
3. Vertical or horizontal

7-59. Because of the likelihood of future size reduction, what information must be prominently placed on all drawings at the time they are prepared?

1. A numeric scale
2. A graphic scale
3. A warning stating the drawing may be reduced in size
4. Both 2 and 3 above

7-60. When performing freehand lettering on an architectural floor plan drawing, you should use (a) what type of lettering and (b) what minimum size lettering?

1. (a) uppercase (b) 0.150 in
2. (a) Lowercase (b) 0.150 in
3. (a) uppercase (b) 0.156 in
4. (a) Lowercase (b) 0.156 in

7-61. As applied to dimensioning and tolerancing of drawings, which of the following statements is NOT correct?

1. Dimensions should not be subject to more than one interpretation
2. When a dimension has a tolerance, the tolerance is always applied directly to the dimension
3. Only those dimensions necessary for complete definition should be shown
4. The use of the reference dimensions should be avoided when possible

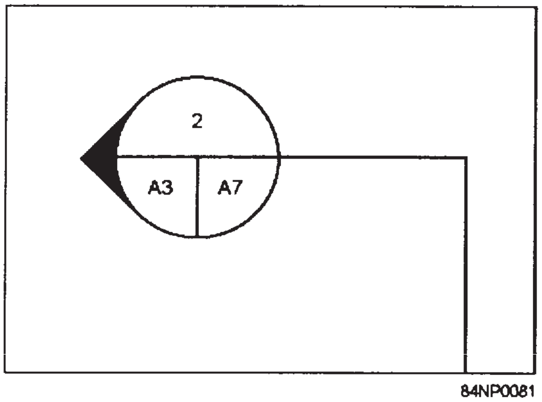


Figure 7A

IN ANSWERING QUESTIONS 7-62 AND 7-63, REFER TO THE WALL SECTION SYMBOL SHOWN IN FIGURE 7A.

7-62. What does the numeral "2" indicate?

1. The section number
2. The sheet number where the section is taken
3. The sheet number where the section is drawn

7-63. What does "A7" indicate?

1. The section number
2. The sheet number where the section is taken
3. The sheet number where the section is drawn

7-64. When using flat D-size sheets for a set of working drawings, where, on the first sheet of the set, should you place general notes?

1. Three inches below the space provided for the revision block
2. On the right side of the drawing
3. On the left side of the drawing
4. Anywhere that space permits

7-65. Of the following functions, which is NOT a function of working drawings in general?

1. To provide a basis for estimating material requirements
2. To complement the project specifications
3. To guide and instruct the construction personnel
4. To specify the type of equipment required during construction

7-66. What types of contours should be shown on a site plan drawing?

1. Existing only
2. Finished only
3. Existing and finished

7-67. On a site plan for a new building, which of the following elevations should be shown for the building?

1. Existing ground
2. Top of footing
3. Bottom of footing
4. Finished floor

7-68. At a minimum, when a new building is to be constructed parallel to the property lines, what total number of location dimensions should be shown on the site plan?

1. One
2. Two
3. Three
4. Four or more

7-69. In what main division of a set of project drawings for a new building should you look to find the types and sizes of the windows?

1. Civil
2. Architectural
3. Structural
4. Mechanical

7-70. To find the size and placement of reinforcing steel in the grade beams for a building, you should look in what main division of the drawings?

1. Civil
2. Architectural
3. Structural
4. Mechanical

7-71. In what main division should you look to find the ceiling height of each room in a building?

1. Civil
2. Architectural
3. Structural
4. Mechanical

7-72. For construction drawings, the dimension lines are always drawn broken for the insertion of the numerals.

1. True
2. False

7-73. When dimensioning a floor plan for a CMU building, you should dimension the interior block partitions in which of the following ways?

1. Face to face only
2. Center to center only
3. Face to center
4. Either face to face or center to center, depending upon your preference

7-74. In a set of drawings, a jamb detail provides the best graphical presentation of the framing and trim located above a door.

1. True
2. False

7-75. Which of the following divisions should contain a schedule of air-conditioning equipment used in a building?

1. Architectural
2. Structural
3. Mechanical
4. Plumbing

ASSIGNMENT 8

Textbook Assignment: "Elements of Surveying and Surveying Equipment." Pages 11-1 through 11-49.

8-1. In surveying, the relative horizontal positions of points are determined in relationship to which of the following elements-measured in the field?

1. Only from distances
2. Only from directions
3. From either distances or directions
4. From both distances and directions

8-2. In surveying, the vertical position of a point is determined in which of the following ways?

1. By measuring directly from a datum
2. By measuring indirectly from a da turn
3. By computation from differences in elevation that are measured directly or indirectly from a datum

8-3. In regard to results obtained with plane surveying methods, increasing the areas surveyed will have what effect on (a) accuracy and (b) precision?

1. (a) Increase (b) decrease
2. (a) Decrease (b) decrease
3. (a) Decrease (b) increase
4. (a) Increase (b) increase

8-4. When is a survey considered to be a geodetic survey?

1. When the earth's curvature must be considered
2. When the surface surveyed is water
3. When the data from the survey will be used for mapping
4. When the survey is either a ground or an aerial survey

IN ANSWERING QUESTIONS 8-5 THROUGH 8-9, SELECT THE TYPE OF SURVEY THAT SHOULD BE USED TO ACCOMPLISH THE TASKING DESCRIBED.

A.	TOPOGOPHIC SURVEY
B.	CONSTRUCTION SURVEY
C.	ROUTE SURVEY
D.	LAND SURVEY

8-5. Reestablishing an old property boundary from missing monuments.

1. A
2. B
3. C
4. D

8-6. Determining the directions and elevations of a new highway.

1. A
2. B
3. C
4. D

8-7. Laying out the corners of a new building.

1. A
2. B
3. C
4. D

8-8 Gathering data about the natural and man-made features of the land.

1. A
2. B
3. C
4. D

8-9 Gathering information needed to prepare as-built drawings for a completed project.

1. A
2. B
3. C
4. D

8-10. Which of the following types of surveys is also known as an engineering survey?

1. Route
2. Construction
3. Topographic
4. Cadastral

8-11. In surveying practice, which, if any, of the following tasks is considered to be an element of office work?

1. Computing and plotting necessary information
2. Taking measurements
3. Collecting engineering data
4. None of the above

8-12. When engineering data for a SEABEE construction project is being collected, which of the following items or information should be considered?

1. Climatology in the local area of the project site
2. Availability of labor and materials
3. Accessibility of construction equipment to the project site
4. All of the above

8-13. In general, which, if any, of the following actions will best predetermine field conditions and allow the selection of methods to be used for a survey?

1. Reviewing topographic maps
2. Site reconnaissance
3. Checking local weather conditions
4. None of the above

8-14. Which of the following factors makes the difference between a good surveyor and an exceptional surveyor?

1. The ability to collect data quickly
2. Consistent accuracy in fieldwork
3. The ability to exercise sound and mature common sense
4. The habit of ensuring that all survey results are verified before acceptance

8-15. Which of the following conditions must be considered when you determine the size of a field survey party?

1. The availability of equipment
2. The methods that will be used
3. The requirements of the survey
4. All of the above

8-16. A transit party should consist of at least what three persons?

1. Instrumentman, rodman, and note keeper
2. Rodman, head chainman, and party chief
3. Instrumentman, head chainman, and note keeper
4. Party chief, head chainman, and instrumentman

8-17. In a plane table party, the party chief functions as what team member?

1. Topographer
2. Rodman
3. Computer
4. Head chainman

8-18. In field notebooks, all lettering should be performed in a freehand Gothic style with which of the following grades of pencil lead?

1. 2H or 3H
2. 3H or 4H
3. 4H or 5H
4. F

IN ANSWERING QUESTIONS 8-19 THROUGH 8-21, SELECT THE PART OF THE FIELD NOTEBOOK FROM THE FOLLOWING LIST THAT SHOULD CONTAIN THE INFORMATION DESCRIBED.

A. FRONT COVER
B. INSIDE FRONT COVER
C. RIGHT-HAND PAGES

8-19. Name and location of the project, the types of measurements, and the designation of the survey unit.

1. A
2. B
3. C

8-20. List of party personnel and their duties.

1. A
2. B
3. C

8-21. Instructions for returning the notebook if it is lost.

1. A
2. B
3. C

8-22. In keeping field notes, which of the following procedures is/are mandatory?

1. Notes are never kept on individual scraps of paper for later transcription to notebooks
2. Erasures are never permitted; incorrect entries are lined-out and correct entries inserted
3. Rejected pages are neatly crossed-out and referenced to the substituted pages
4. All of the above

8-23. In a measured distance that required 200 measurements, the total error was -9 units. For this error to be adjusted, each measurement must be

1. increased by 0.450
2. increased by 0.045
3. decreased by 0.450
4. decreased by 0.045

8-24. A measured distance is 302.12 feet. This measurement contains what total number of significant figures?

1. Five
2. Two
3. Three
4. Four

8-25. If you round off 92.454 to three significant figures, what is the resulting number?

1. 92.4
2. 92.5
3. 92.40
4. 92.50

8-26. When drawing a property map, you should include which of the following items?

1. The length and direction of each boundary line
2. Reference points referred from an established coordinate system
3. Names of important details, such as roads, streams, and landmarks
4. All of the above

8-27. In an orientation symbol, a full-head arrow represents what direction or orientation information, if any?

1. Magnetic meridian
2. True meridian
3. Magnetic declination
4. None

8-28. Which of the following factors will influence the orientation of a map drawn on standard size drawing paper?

1. The shape of the mapped area
2. The size of the mapped area
3. The scale of the map
4. The purpose of the map

8-29. A map that should be used for making a model of an 18-hole golf course is known as what type?

1. Geographic
2. Planimetric
3. Topographic

8-30. An ordinary road map of the state of Florida is an example of what type of map?

1. Geographic
2. Planimetric
3. Topographic

8-31. A naval station base map that shows only the layout of buildings and roads is what type of map?

1. Geographic
2. Planimetric
3. Topographic

8-32. The various parts of a transit are divided into three major groups. Which of the following is NOT a major group?

1. Telescopic assembly
2. Upper plate assembly
3. Lower plate assembly
4. Leveling assembly

8-33. What part of a transit contains the graduated scale for determining the value of horizontal angles?

1. Upper plate
2. Lower plate
3. Alidade
4. Leveling head

8-34. What part of a transit is used for slow motion movement when the telescope is being centered on an object?

1. Clamp
2. Lower motion screw
3. Upper motion screw
4. Tangent screw

8-35. In addition to the two plate-level vials, the transit has a third level vial. What is the third vial used to level?

1. Tripod head
2. Standard
3. Footplate
4. Telescope

8-36. What part of a transit is graduated from 0° to 90° in four quadrants?

1. Horizontal circle
2. Vertical circle
3. A-vernier
4. Double vernier

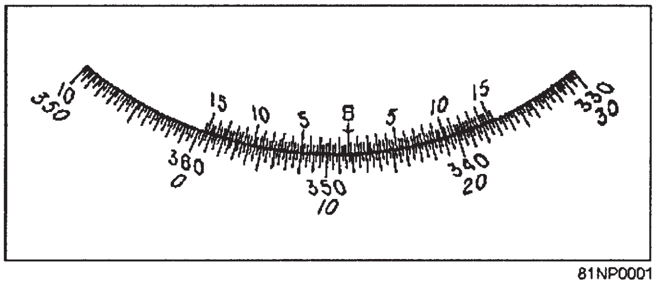


Figure 8A

IN ANSWERING QUESTIONS 8-37 AND 8-38, REFER TO FIGURE 8A.

8-37. The least reading of the horizontal scale shown is

1. 20 seconds
2. 30 seconds
3. 45 seconds
4. 1 minute

8-38. Reading clockwise, the vernier reads

1. 11°36’00”
2. 28°30’00”
3. 348°20’00”
4. 351°45’00”

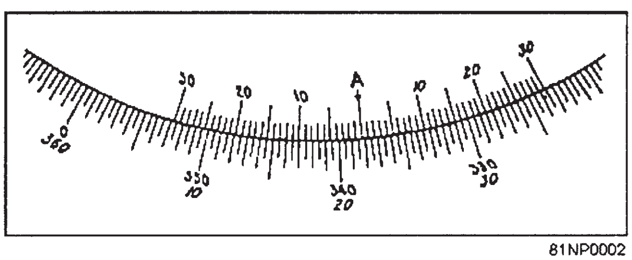


Figure 8B

IN ANSWERING QUESTIONS 8-39 AND 8-40, REFER TO FIGURE 8B.

8-39. The least reading of the horizontal scale shown is

1. 20 seconds
2. 30 seconds
3. 45 seconds
4. 1 minute

8-40. In a counterclockwise direction, the vernier reads

1. 341°45’
2. 338°15’
3. 39°10’
4. 21°47’

8-41. For a 1-minute theodolite, which of the following actions occur when the circle clamp is in the lever-down position?

1. The circle is clamped and turns with the telescope
2. The circle is clamped and the telescope turns independently
3. The circle is unclamped and the telescope turns independently
4. The circle is unclamped and turns with the telescope

8-42. The lower half of the vertical line on the reticle of a theodolite is split for what purpose?

1. To center triangular-shaped distant objects
2. To determine the width of distant objects
3. To center small distant objects
4. To determine the height of distant objects

8-43. What part of an engineer’s transit serves the same function as the tribrach of the theodolite?

1. Leveling assembly
2. Lower plate
3. Upper plate
4. Standard

8-44. What are the values read from the vertical circle of a theodolite called?

1. Vertical angles
2. Direct angles
3. Zenith distances
4. Direct distances

8-45. What part of a one-second theodolite is used to select whether the angle being read is a vertical or horizontal angle?

1. Circle tangent screw
2. Inverter knob (circle-selector)
3. Circle setting knob
4. Circular level

8-46. The difference between two diametrically opposite members on the circle of a one-second theodolite as viewed through the circle reading microscope is equal to plus or minus how many degrees?

1. 90°
2. 180°
3. 270°
4. 360°

8-47. What is the main difference between a wye level and a dumpy level?

1. Their magnifying power
2. The way they are used in the field
3. The way their telescopes are attached to the horizontal (level) bar
4. The way their horizontal bars are attached to the leveling head

8-48. What part(s) of a telescope should you adjust to bring the cross hairs and the object into clear focus?

1. Eyepiece
2. Focusing knob
3. Both 1 and 2 above
4. Reticle adjusting screw

8-49. The bubble of a level vial on a surveying instrument may become increasingly difficult to center because of what factor?

1. Temperature
2. Vial age
3. Humidity
4. Vial sensitivity

8-50. On a tilting level, which of the following screws is used to bring the bubble to the exact center?

1. Tangent
2. Micrometer
3. Leveling
4. Centering

8-51. You are setting up a military level. You can accomplish preliminary leveling by using which of the following parts?

1. The level vial and circular bubble
2. The leveling screws and the micrometer drum
3. The leveling screws and the circular bubble
4. The leveling screws and the level vial

8-52. The purpose of the compensator in a self-leveling level is to compensate for which of the following factors?

1. Misalignment of the vertical hair only
2. Misalignment of the horizontal hair only
3. Misalignment of both the vertical and horizontal hairs
4. A slight out-of-level of the telescope

8-53. In surveying, what instrument is often called the universal survey instrument?

1. Theodolite
2. Engineer's transit
3. Wye level
4. Automatic level

8-54. The Abney hand level differs from the plain hand level in that it has what additional part?

1. A spirit level
2. An eyepiece
3. An optical telescope
4. A graduated arc

8-55. Which of the followinq advantages does use of the plane-table and alidade provide over use of other surveying instruments?

1. The need to measure horizontal distances is eliminated
2. The need to measure vertical and horizontal angles is eliminated
3. Both 1 and 2 above
4. A completed sketch or map manuscript is produced in the field

8-56. Which of the following methods can be used to orient a plane table during fieldwork?

1. A transit
2. A magnetic compass
3. Sight on a point whose position is plotted on the plane table
4. Either 2 or 3 above, depending on preference

8-57. What is the maximum angle above the horizontal that a telescopic alidade is capable of measuring?

1. 15°
2. 30°
3. 45°
4. 60°

8-58. Which of the following alidade attachments is used for accurate leveling of the line of sight?

1. Circular level
2. Striding level
3. Right-angle prism
4. Vertical circle scale

8-59. What type of assembly, when attached to the alidade, makes it possible to determine horizontal distances and differences in elevation by the stadia method?

1. Ball and socket
2. Optical reading
3. Stadia arc
4. Exterior arc

8-60. Which of the following tools should you use when clearing away small saplings and vines?

1. Chain saw
2. Brush hook
3. Coping saw
4. Bull point

8-61. Which of the following tools is best suited for driving pipe markers into asphalt surfaces?

1. A hatchet
2. A single bit ax
3. A sledgehammer
4. A bull point

8-62. Which of the following tools should you use to lift a manhole cover?

1. A long-handled shovel
2. A crowbar
3. A long-bladed screwdriver
4. A machete

8-63. Which, if any, of the following devices is used to locate buried metal markers?

1. Dip needle
2. Mine detector
3. Probing steel
4. None of the above

8-64. Which of the following tapes should be used for the high-precision measurement of a base line that is in the vicinity of a high-voltage circuit?

1. Metallic
2. Nonmetallic
3. Steel
4. Invar

8-65. To run a traverse in steep terrain on a windy day, which of the following tripods should you use to support the transit?

1. Stilt-leg
2. Wide-frame rigid
3. Wide-frame jack-leg
4. Jack-leg

8-66. After you secure the restraining strap, what is the next step in setting up a tripod?

1. Hold one leg only close to your body
2. Hold two legs close to your body
3. Spread the legs 60° apart
4. Spread the legs until they form about a 50° to 60° angle with the horizontal

8-67. Which of the following actions is NOT a proper way to care for a tripod?

1. Applying pressure across the tripod legs when pressing the tripod into the ground
2. Adjusting the hinge joint without overtightening
3. Applying a light coat of oil on the metal parts of the tripod
4. Applying pressure along the tripod legs when pressing the tripod into the ground

8-68. The effectiveness of the plumb bob, cord, and target set as a precision instrument will be most impaired by what condition?

1. Faded paint on the target
2. Dust on any part of the set
3. A damaged or bent tip on the plumb bob
4. A worn leather sheath

8-69. Which of the following tape accessories should be used to hold the tape securely at an intermediate point?

1. Tape clamp handle
2. Tension scale
3. Taping stool
4. Staff

8-70. In high-precision measurement, which of the following tape accessories should be used to mark accurately the distance indicated by the tape graduation?

1. Tension scale
2. Taping stool
3. Staff
4. Tape thermometer

8-71. When target reading is being performed, what survey party member reads the rod?

1. Chainman
2. Instrumentman
3. Flagman
4. Rodman

8-72. During leveling operations, in which of the following soil conditions should you use a turning point plate?

1. Sandy or muddy soil
2. Compacted gravel
3. Ordinary stable soils
4. Rocky pasture land

8-73. The type of material to be used for survey point markers depends upon which of the following conditions?

1. The location of the point
2. Whether the point is temporary or permanent
3. Both 1 and 2 above
4. The discretion of the engineer officer

8-74. Which of the following types of markers is/are generally used for horizontal and vertical control stations?

1. Iron pipe filled with concrete
2. Bronze disks set in concrete
3. A hole drilled in concrete and filled with lead
4. Each of the above

8-75. What method should you use to permanently mark a station located on an asphaltic concrete surface?

1. Nail a spad into the surface
2. Drive a railroad spike into the surface
3. Spot paint the surface
4. Drive a wooden hub into the surface

ASSIGNMENT 9

Textbook Assignment: "Direct Linear Measurements and Field Survey Safety." Pages 12-1 through 12-32.

9-1. The instrumentman is moving his right arm, which is extended upward, to the right. What message is he signaling to the rodman?

1. The rodman must move the rod to the right
2. The rodman must move the top of the rod to the right until it is vertical
3. The rodman must move the rod to the left
4. The rodman must move the top of the rod to the left until it is vertical

9-2. An instrumentman extends both arms upward, what does this indicate to the rodman?

1. Move forward
2. Reverse the rod
3. Pick up the instrument
4. Face the rod

9-3. What actions should the rodman take in response to a boost-the-rod signal?

1. Raise the rod and hold it at a specified distance above the ground
2. Turn the rod upside down
3. Raise the rod slowly until the instrumentman has read the whole-foot mark
4. Move the top of the rod, in a short arc, towards the instrument

9-4. The instrumentman extends both arms out horizontally from his shoulders and waves them up and down. What message is he giving to the rodman?

1. Come in
2. Pick up the instrument
3. All right
4. Move forward

9-5. In clearing a chaining line, what should you do when a valuable tree lies directly in your path?

1. Triangulate around it
2. Find the owner and request the tree to cut down
3. Cut it down
4. Choose a different chaining line

9-6. What term is used to describe consecutive sights taken through a telescope for the purpose of keeping chainmen on line?

1. Running line
2. Bench mark
3. Foresight
4. Backsight

9-7. When an instrumentman takes a sight along a portion of a line that has already been run, he is taking a

1. horizontal control step
2. vertical control step
3. foresight
4. backsight

9-8. For what reason should a chainman use an indicator that is narrower than a range pole when holding on or plumbing over a point for short sights?

1. To enable the instrumentman to align the indicator exactly with the vertical cross hair of his instrument
2. To enable the instrument to sight beyond the point
3. To enable the chainman to carry out his duties without becoming fatigued
4. To enable the chainman to hold the indicator steady

9-9. When running a line from point A to point B, what action does the instrumentman take when he "plunges" the telescope?

1. Turns the telescope 180° to the right from a sight on point A to a sight on point B
2. Rotates the telescope vertically from a sight on point A to a sight on point B
3. Turns the telescope 180° to the left from a sight on point A to a sight on point B
4. Moves the telescope from point A to point B

9-10. When plumbing over a point, which of the following actions should you take to overcome the problem of wind blowing the plumb bob back and forth?

1. Rest the point of the plumb bob on the point being plumbed
2. Bounce the point of the plumb bob slightly up and down on the point being plumbed
3. Shorten the plumb bob cord
4. Have a second person hold the point of the plumb bob steady on the point being plumbed

9-11. You should mark the horizontal location of a point over which to plumb a transit by which of the following means?

1. A flag or chaining pin
2. A leveling rod or range pole
3. A precise marker driven or set in the top of a hub
4. A bull-point or spad

9-12. Survey control points are marked in the field by which of the following means?

1. Bronze disks set in concrete
2. Center-punched metal rods driven flush with the ground
3. Wooden stakes or soda pop tops and nails driven flush with the ground
4. Each of the above

9-13. In addition to an identifying symbol, what marking is usually placed on a bench mark constructed by surveyors to identify a point for a construction project?

1. The abbreviation for bench mark, BM
2. The elevation of the bench mark
3. A number showing the order in which the bench mark is to be considered
4. A number denoting the distance of the bench mark from the point of beginning

9-14. As survey control points are established in the field, in what manner are they recorded in the field notebook?

1. By sketch
2. By word description
3. By either 1 or 2, or a combination of both
4. By detailed drawing

9-15. When an important station is marked with a hub, measurements are made to one or more other points and recorded in a field notebook to assure what information?

1. The hub can be relocated if plowed up and displaced
2. The hub location is precisely determined
3. The reference points are located accurately
4. The elevation of the hub can be determined

9-16. A hub can be made conspicuous to operators of earthmoving equipment by which of the following methods?

1. Casting a monument over the hub
2. Flagging or barricading
3. Marking the hub with a tack
4. Elevating the hub

9-17. What tool is used to mark a terminal point in a chaining operation when the distance being measured is greater than the tape length?

1. Surveyor's arrow
2. Chaining pin
3. Philadelphia rod
4. Range pole

9-18. In a three-man chaining party operation, who keeps a complete record of all measurements made by the party?

1. Head chainman
2. Rear chainman
3. Stretcherman
4. Instrumentman

9-19. In beginning a horizontal chaining operation, the rear chainman, with one chaining pin, stations himself at the starting point. The head chainman then moves toward the distant point to be measured holding (a) what part of the tape, and (b) a total of how many chaining pins?

1. (a) The 100-ft end (b) 1
2. (a) The 100-ft end (b) 10
3. (a) The zero end (b) 1
4. (a) The zero end (b) 10

9-20. When the tape is pulled forward for measuring the next 100-foot increment , what becomes of the chaining pins that were stuck in the ground by the head chainman and rear chainman?

1. Both pins are pulled and carried to the next stations
2. The head chainman leaves his pin in the ground; the rear chainman pulls and carries his pin
3. The head chainman pulls and carries his pin; the rear chainman leaves his pin in the ground
4. Both pins are left in the ground

9-21. When the head chainman runs out of chaining pins, what total number of pins should the rear chainman have?

1. 0
2. 1
3. 9
4. 10

9-22. Which of the following devices helps you apply the correct tension to a tape that is supported at its ends only?

1. Taping stool
2. Spring balance
3. Scissors clamp
4. Chaining buck

9-23. Including the O-foot mark, a total of how many whole-foot marks are contained on a 100-foot plus tape?

1. 99
2. 100
3. 101
4. 102

9-24. You are measuring the exact length of a building using a minus tape. What is the length of the building if you are holding a 65-foot mark at the outer face of the end wall when the head chainman calls out "Minus point three six"?

1. 63.64 ft
2. 64.36 ft
3. 64.64 ft
4. 65.36 ft

9-25. When slope chaining, which of the following information can you obtain by direct reading?

1. Slope angle only
2. Slope angle and slope distance
3. Horizontal distance only
4. Slope angle and horizontal distance

9-26. In horizontal chaining operations, a call of "Mark" from the rear chainman signals the head chainman to take which of the following actions?

1. Pull the end of the tape
2. Stick a chaining pin into the ground
3. Measure the tension on the tape
4. Release his plumb bob

9-27. Two men are making a horizontal measurement on a slope. The chainman on the lower level determines at what height the chainman on the higher level will hold his tape by using what instrument?

1. A transit
2. A theodolite
3. A hand level
4. A plumb bob

9-28. In which of the following situations should the breaking tape method of measuring be used?

1. Determining the horizontal distance between points on terrain havinq a 6-to-1 slope ratio
2. Measuring the width of major access roads
3. Measuring horizontal distances in heavily wooded and obstructed areas
4. All of the above

9-29. A two-man party is using the breaking chain-procedure and a 100-foot tape to chain a line on a steep slope. When, if ever, does the rear chainman give the front chainman a chaining pin?

1. Each time a 25-ft distance only is measured
2. Each time a 50-ft distance only is measured
3. Each time an even-foot distance of less than 100 ft is measured
4. Never

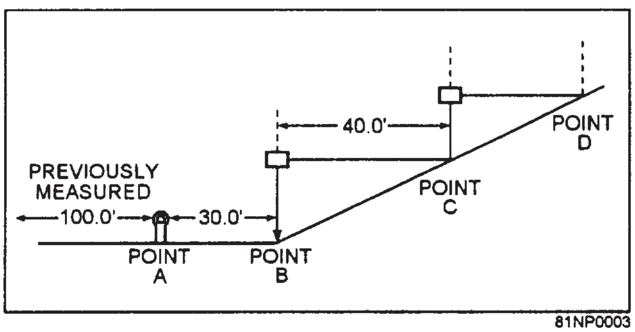


Figure 9A

IN ANSWERING QUESTION 9-30, REFER TO FIGURE 9A.

9-30. Assume that you continue measuring up the slope with a 100-foot tape. The head chainman is holding zero at point D. What is the horizontal distance between points C and D?

1. 10 ft
2. 15 ft
3. 25 ft
4. 30 ft

9-31. The standard error of a 100-foot tape can be determined in which of the following ways?

1. By calibration by the Bureau of Standards
2. By comparison with a length of a calibrated 100-foot tape
3. By comparison with a known 100-foot distance
4. By each of the above means

9-32. By calibrating a tape, you should remember that the standard tension and corresponding temperature for a 100-foot tape supported throughout is

1. 5 lb, 65°F
2. 10 lb, 68°F
3. 15 lb, 68°F
4. 20 lb, 65°F

9-33. A 100-foot tape has a standard error of 0.003 feet. What is the total error for a taped distance of 471.56 feet? (Round off to the nearest 0.01 foot.)

1. 0.00 ft
2. 0.01 ft
3. 0.02 ft
4. 0.05 ft

9-34. Under standard conditions, a tape indicates 100.00 feet when it actually should measure 99.996 feet . Using this tape, how far should you measure to set a point 450 feet away from another point?

1. 449.96 ft
2. 449.98 ft
3. 450.02 ft
4. 450.04 ft

9-35. A tape has a standard error which causes it to indicate 99.996 feet when it is actually measuring 100.00 feet. What is the actual distance between two points if the taped distance is 259.05 feet?

1. 259.04 ft
2. 259.05 ft
3. 259.06 ft
4. 260.00 ft

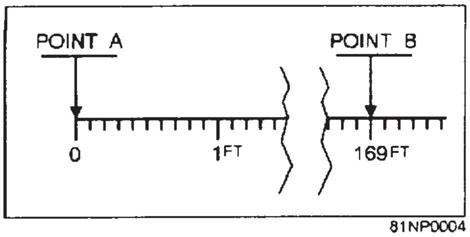


Figure 9B

IN ANSWERING QUESTIONS 9-36 and 9-37, REFER TO FIGURE 9B.

9-36. The steel tape shown is used to lay out the distance from point A to point B. If the thermometer attached to the tape reads 79°F, what is the actual distance laid to offset the effect of change in temperature?

1. 168.09 ft
2. 168.99 ft
3. 169.01 ft
4. 169.07 ft

9-37. At another time, the steel tape shown is used to measure the distance from point A to point B, but this time, the thermometer reads 35°F. How much should you add or subtract to the measurement in order to compensate for the change in temperature?

1. Add 0.02 ft
2. Subtract 0.02 ft
3. Add 0.04 ft
4. Subtract 0.04 ft

9-38. A 3-pound, 100-foot tape is used to measure a distance of 60 feet. If the chainman maintained a pull of 20 pounds, what is the correction of sag?

1. 0.02 ft
2. 0.03 ft
3. 0.04 ft
4. 0.05 ft

9-39. When is slope correction subtracted from the taped slope distance?

1. When taping uphill only
2. When taping downhill only
3. When applying the slope correction formula for 10% slopes Only
4. Always

9-40. When determining accurate slope correction, what is the maximum slope for which you should use this formula?

$$C_h = \frac{h^2}{2s}$$

1. 5%
2. 10%
3. 20%
4. 30%

9-41. The difference in elevation between two points is 4.0 feet. If the slope distance between the points is 125.00 feet, what is the horizontal distance?

1. 124.936 ft
2. 124.978 ft
3. 125.032 ft
4. 125.064 ft

9-42. Rules pertaining to the taking of chaining notes require that the notes reflect which of the following qualities?

1. Completeness
2. Accuracy
3. Legibility
4. All of the above

9-43. What is the proper way to correct an error in field notes?

1. Erase the error
2. Blot out the error
3. Draw a line through the error and enter the correct information above
4. Circle and initial the error

IN ANSWERING QUESTION 9-44, REFER TO FIGURE 12-17 IN YOUR TEXTBOOK.

9-44. What three types of corrections are made in the slope chaining measurements?

1. Tension, temperature, and humidity
2. Altitude, temperature, and wind
3. Hub, bench mark, and station
4. Tape, temperature, and slope

9-45. In which of the following ratios do the lengths of the sides indicate that the triangle is a right triangle?

1. 10:15:20
2. 18:24:30
3. 20:30:40
4. 25:30:40

IN ANSWERING QUESTION 9-46, REFER TO FIGURE 12-18 IN YOUR TEXTBOOK.

9-46. Assume that you are laying out a right angle, but you are using a 50-foot tape instead of a 100-foot tape, and the distance from D to C is 15 feet. You then set the tape with its 0-foot end on D and its 50-foot end on C. Your 50-foot tape will form two legs of a right triangle if the man running out the bight draws the tape taut while holding the 25-foot mark in contact with what other mark?

1. 20-ft mark
2. 30-ft mark
3. 35-ft mark
4. 40-ft mark

9-47. Computing the size of an angle by the chord method involves the partial solution of a triangle in which the only known values are which of the following measurements?

1. The sizes of two angles
2. The lengths of the sides
3. The sizes of two angles and length of one side
4. The lengths of two sides and the size of one angle

9-48. What method of computing the size of an angle X involves the partial solution of a right triangle in which X is an acute angle and two sides of the triangle (the side opposite X and the side adjacent to X) are measured?

1. Chord method
2. Sine method
3. Tangent method
4. Sum of squares method

9-49. Reading a tape upside down and obtaining, for example, 69 instead of 96 and leaving out an entire tape length are samples of

1. natural errors
2. instrumental errors
3. personal errors
4. mistakes

9-50. Concerning the care of steel tapes, three of the following statements represent correct guidelines. Which one does NOT?

1. Whenever a tape is laid across a gravel road, all drivers should be warned to slow their vehicles down before crossing over the tape
2. While dragging the tape, the head chainman should not ask someone else to help by picking up the free end
3. When given a choice between a tape which has a kink and one which does not, you should use the undamaged one when possible
4. When dragging a tape, keep it straight

9-51. In caring for and maintaining his steel tapes, a chainman should make it a practice to take which of the following steps?

1. Inspect all tapes weekly
2. Wipe them dry before storing them
3. Coat them from time to time with light rust-resistant oil
4. All of the above

9-52. Listed are the steps for splicinq a broken steel tape. Identify the proper sequence.

A. Align and rivet the repair stock at one end of the break.
B. Insert one rivet at a time and arrange rivets in a triangular pattern.
c. Place the repair stock on the face of the other section of the tape, using the calibration section as a measure for the break splice.
D. Use a three-edge file to partially cut through the surplus stock.

1. A, B, C, D
2. A, C, B, D
3. C, A, B, D
4. C, B, A, C

9-53. In which of the following ways are microwave and light wave EDM devices the same?

1. Both have interchangeable transmitters and receivers
2. Both require the application of corrections for atmospheric conditions
3. Both are used for the direct measurement of distances
4. Both should be used for only short distances of less than 600 feet

9-54. Which of the following descriptions is characteristic of most poisonous snakes found on the North American continent?

1. Brightly colored
2. Smaller than nonpoisonous snakes
3. Flat headed and thick bodied
4. Equipped with tail rattles

9-55. What North American poisonous snake shows its white inside mouth lining just before striking?

1. Copperhead
2. Rattler
3. Coral
4. Water moccasin

9-56. What symptom is usually the first to be noticed by someone who has come in contact with poison ivy or poison oak?

1. A cluster of large blisters
2. A deep red rash
3. An extreme itching
4. A cluster of small blisters

9-57. A poisonous plant has a juice that is nonvolatile. This means this plant is poisonous and the juice of this plant will

1. evaporate quickly
2. not stain clothing
3. not evaporate quickly
4. not nifect a person unless he atually touches the plant

9-58. Poisonous sumac can be distinguished from nonpoisonous sumac in what way?

1. It bears red berries
2. It has more leaves
3. It bears white fruit
4. It grows closer to the ground

9-59. The first-aid procedure for plant poisoning of the skin consists of which of the following steps?

1. Soaping and rinsing frequently
2. Applying a light coat of oil
3. Obtaining immediate medical care
4. Soaping with an alkaline laundry soap and not rinsing off

9-60. Of the following accident prevention guidelines or measures, which one is the most important to remember?

1. Never swing a machete within 10 ft of another person
2. Most accidents can be prevented by the application of common sense and good judgment
3. Never work in or on trees during high wind or thunderstorms
4. Properly sharpened axe blades are safer than blunt or nicked ones

9-61. While surveying, the members of a field party must work on and near a heavily traveled highway that they are forced to cross several times a day. They can reduce the danger of being struck by a moving vehicle by taking which of the following precautions?

1. Wearing brightly colored outer clothing
2. Detouring traffic away from the field party
3. Erecting conspicuous signs and barriers
4. All of the above

ASSIGNMENT 10

Textbook Assignment: "Horizontal Control." Pages 13-1 through 13-30.

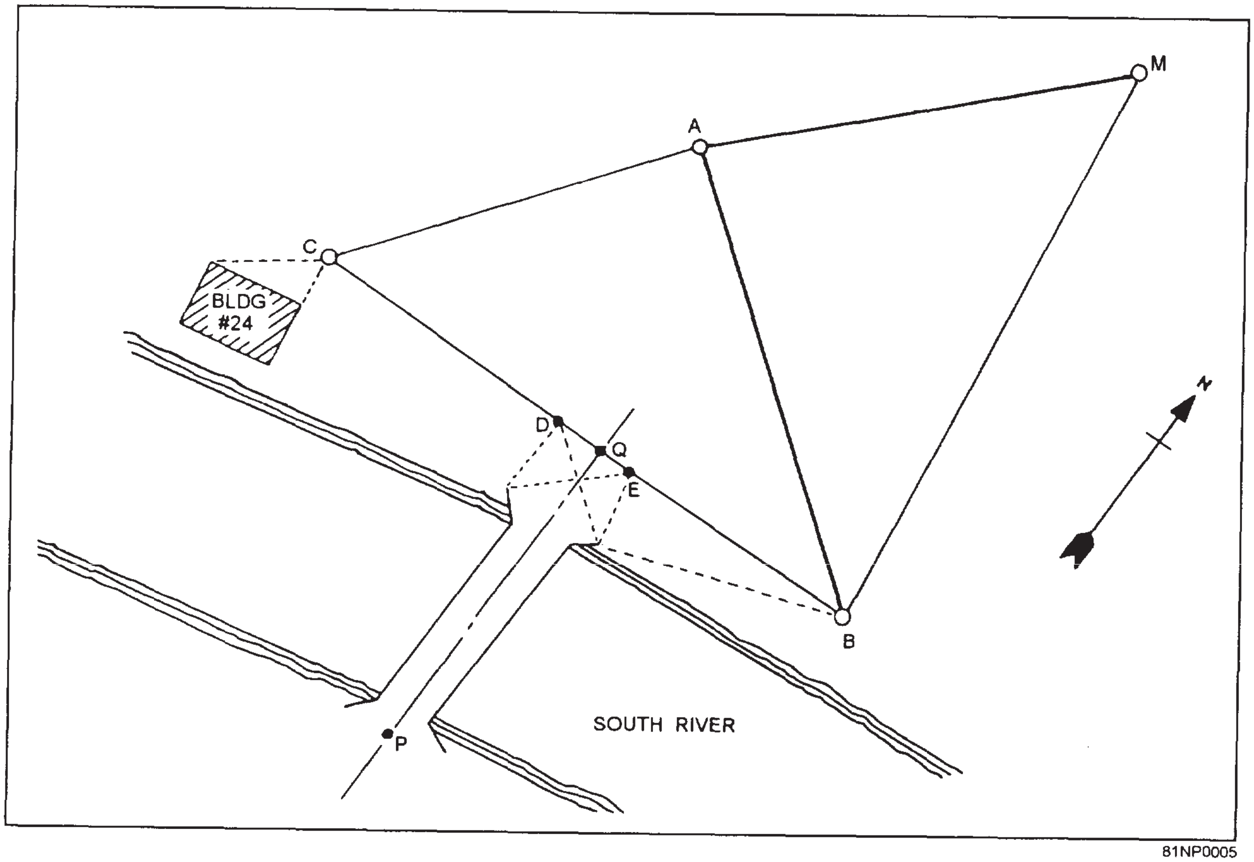


Figure 10A

IN ANSWERING QUESTIONS 10-1 THROUGH 10-3, REFER TO FIGURE 10A. POINT M IS A TRIANGULATION STATION MONUMENT.

10-1. What part of the triangulation network is the main control traverse?

1. ∆ ABM
2. ∆ ABC
3. ∆ CBM

10-2. What part of the network is the supplementary control traverse?

1. ∆ ABM only
2. ∆ ABC
3. ∆ CBM
4. ∆ ABM and line AC

10-3. What part of the network is the control line?

1. AM
2. AC
3. AB
4. BC

10-4. Direction measured between a traverse line and the preceding traverse line extended is direction by which of the following methods?

1. Azimuth
2. Exterior agle
3. Interior angle
4. Deflection angle

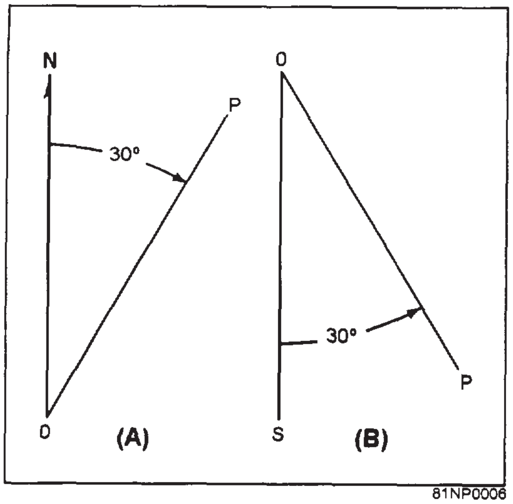


Figure 10B

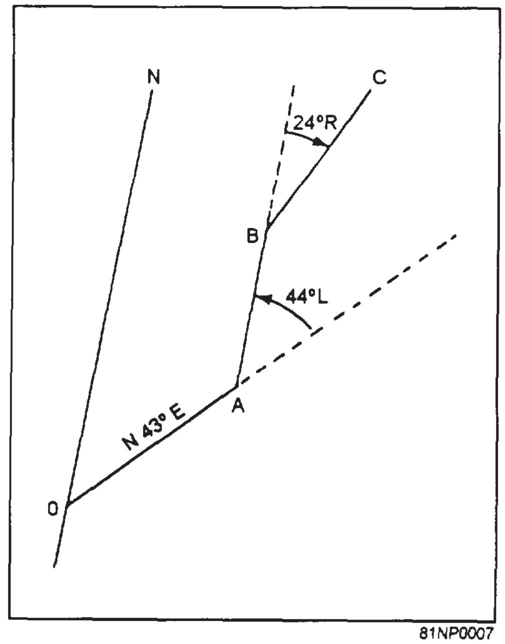


Figure 10C

IN ANSWERING QUESTION 10-5, REFER TO FIGURE 10B.

10-5. What are the respective bearings of traverse lines OP in A and B?

1. N30°E and S30°W
2. S30°W and N30°W
3. S30°E and N30°E
4. N30°E and S30°E

10-6. The bearing of line AB in a traverse is S27°26′W and the bearing of line BC is N10°17′W. What is the deflection angle between AB and BC?

1. 37°43′
2. 79°42′
3. 141°60′
4. 142°17′

IN ANSWERING QUESTION 10-7, REFER TO FIGURE 10C.

10-7. The directions of traverse lines AB and BC are indicated by deflection angles. Determine the bearing of BC.

1. N1°E
2. N20°E
3. N23°E
4. N43°E

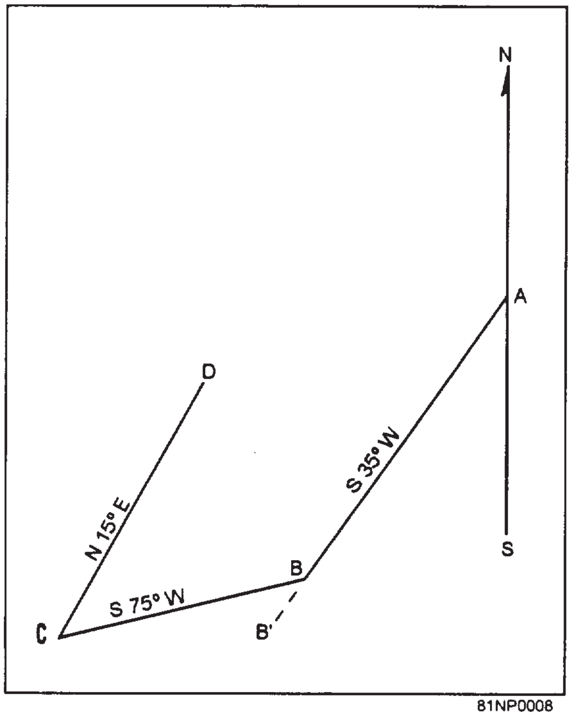


Figure 10D

IN ANSWERING QUESTIONS 10-8 THROUGH 10-10, REFER TO FIGURE 10D.

10-8. What is the size of the deflection angle between traverse lines BC and CD?

1. 60°
2. 90°
3. 105°
4. 120°

10-9. How many degrees are there in the exterior angle ABC?

1. 205°
2. 215°
3. 220°
4. 235°

10-10. How many degrees are there in the interior angle ABC?

1. 120°
2. 130°
3. 140°
4. 150°

10-11. To convert a bearing in the SE quadrant to the equivalent azimuth, you must use which of the following calculations?

1. Add 90° to the bearinq
2. Add 180° to the bearing
3. Subtract the bearing from 180°
4. Subtract the bearing from 360°

10-12. Assume that a measured forward bearing on a compass-tape survey was N15°35'W and the back bearing on the same line was S15°15'E. The difference was probably caused by which of the following conditions ?

1. Declination
2. Local attraction
3. An error in reading the compass
4. A defect in the compass mechanism

10-13. The magnetic declination at a given point on the surface of the earth is the horizontal angle that the magnetic meridian makes with what line?

1. The agonic line
2. The true meridian
3. The isogonic line
4. The assumed meridian

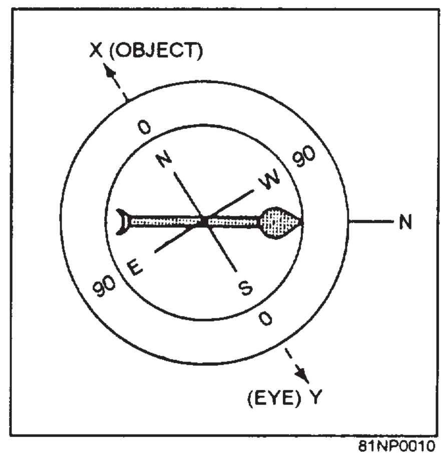


Figure 10E

IN ANSWERING QUESTIONS 10-14 THROUGH 10-16, REFER TO FIGURE 10E.

10-14. What is the approximate compass bearing of the object?

1. Due north
2. S70°W
3. S30°W
4. S30°E

10-15. What is the approximate magnetic bearing of the object if the local attraction is 20°E?

1. Due west
2. S50°W
3. Due south
4. N20°W

10-16. What is the approximate true bearing of the object if the local declination is 10°w and the local attraction is 20°E?

1. S80°W
2. S100°W
3. N80°W
4. N100°E

10-17. What method should you use to correct or convert a compass azimuth reading to a true azimuth reading when both local attraction and local declination are easterly?

1. Subtract the attraction and declination from the compass reading
2. Add the attraction and declination to the compass reading
3. Add the attraction to the compass reading, then subtract the declination from the sum
4. Add the declination to the compass reading, then subtract the attraction from the sum

10-18. When making a closed traverse compass-tape survey, for what reason should you first read and record the back bearing of a traverse line from the first setup point?

1. To offset local attraction
2. To get rid of declination
3. To check the accuracy of your compass
4. To verify the last bearing you will take

IN ANSWERING QUESTION 10-19, REFER TO FIGURE 13-8 IN YOUR TEXTBOOK.

10-19. Suppose that in the compass-tape survey field notes shown, the bearing AE is different from the bearing EA. This difference could have resulted from which of the following conditions?

1. Inaccuracy in reading the back bearing
2. Inaccuracy in reading the forward bearing
3. The difference in the strength of the local attractions at A and E
4. Each of the above

10-20. Station A bears N70°E (true) from station B and station C bears S10°W (true) from station B. What size of angle should be entered in the "computed interior angle" column of a compass-tape survey notebook page alongside the forward bearing of station C?

1. 60°
2. 80°
3. 120°
4. 240°

10-21. What is the sum of the interior angles in a closed traverse consisting of six traverse lines?

1. 360°
2. 540°
3. 720°
4. 1,080°

10-22. If a compass is in error when you are taking bearings at several different places and each error varies from the preceding one, the errors are probably due to which of the following factors?

1. A shifted movable circle
2. A bent frame
3. A bent pivot
4. A bent needle

10-23. The only compass available for taking bearings has an instrument error. What forward bearing should you use when the compass needle indicates a forward bearing of N22°W and a back bearing of S24°E?

1. S2°E
2. S46°W
3. N46°E
4. N23°W

10-24. You are using a compass that has an instrument error and is graduated for azimuths. What forward azimuth should you record when the compass needle indicates a forward azimuth of 37° and a back azimuth of 219°?

1. 37°
2. 38°
3. 91°
4. 128°

10-25. Which of the following defects is most likely to cause a compass to read incorrectly at both ends of its needle?

1. A bent pivot
2. A warped compass card
3. A bent needle
4. A blunt pivot point

10-26. A compass needle that is weak magnetically should be strengthened by which of the following methods?

1. Placing the magnet in an inductive field
2. Drawing the needle over a magnet
3. Placing the magnet in a shielded box
4. Heating the needle with a lighted match

10-27. A compass needle acts sluggishly although it has retained its full magnetism. Which of the following methods should you use to make the needle act smartly?

1. Sharpen its points
2. Sharpen the point on the pivot
3. Reshape it with a special tool
4. Demagnetize it

10-28. In setting up and leveling a transit, you have followed all of the correct procedures. You discover, however, that the plumb bob is still not quite directly over the station point. Which of the following actions should you take next?

1. Loosen two adjacent leveling screws to free the shifting plate and shift the transit head laterally
2. Replace the plumb bob
3. Adjust the tripod legs
4. Re-level the instrument

10-29. Before taking up a transit, which of the following actions should you take concerning the telescope and the vertical motion clamp?

1. Bring the telescope perpendicular to the vertical axis and firmly tighten the clamp
2. Point the telescope vertically upward and firmly tighten the clamp
3. Point the telescope vertically upward and loosen the clamp
4. Point the telescope vertically upward and lightly tighten the clamp

10-30. In which of the following ways are the horizontal limbs of transits numbered?

1. 0°-360° clockwise
2. 0°-360° clockwise, also 0°-90° by quadrants
3. 0°-360° clockwise, also 360°-0° counterclockwise
4. Each of the above

10-31. When you are turning a 40° horizontal angle by transit, what part will normally point to the number of degrees turned?

1. Zero on the A-vernier
2. Zero on the B-vernier
3. 0°-360° graduation on the horizontal limb
4. 40°-320° graduation on the horizontal limb

10-32. Releasing the upper motion of a transit enables you to take which of the following actions?

1. Hold the telescope in place
2. Rotate and train the telescope
3. Hold the horizontal limb in place
4. Rotate and align the horizontal limb

10-33. Which of the following steps should you normally take when turning a 20° horizontal angle from a reference line with a transit?

1. Clamp the lower motion to hold the telescope in place after training it on the reference line
2. Release the lower motion to rotate the telescope 20°
3. Align the 0°-360° graduation on the horizontal limb with the zero on the A-vernier
4. Align the 0°-360° graduation on the horizontal limb with the zero on the B-vernier

10-34. To fix the exact position of the horizontal limb with respect to the A-vernier, what transit screw, if any, should you use?

1. Telescope clamp screw
2. Upper motion tangent screw
3. Lower motion tangent screw
4. None

10-35. To detect accidental movement when measuring a number of horizontal angles from one setup, you should take which of the following steps?

1. Relevel the instrument and check the readings occasionally
2. Adjust the instrument before and after each reading
3. Train the instrument at some clearly defined object to serve as a reference mark for checking the sizes of the angles
4. Take the mean of the observed angles

10-36. The closing-the-horizon method of checking the accuracy of angular measurements is based on the geometrical fact that the sum of the

1. angles in a triangle are 180°
2. angles around a point are 360°
3. acute angles in a right triangle are 90°
4. interior angles of a closed five-course traverse are 540°

10-37. A vertical angle was recorded at +36°. This angle is a measurement of what type?

1. Inclination
2. Declination
3. Depression
4. Elevation

10-38. You are measuring a 30° angle with a 1-minute transit. To improve the precision of this measurement, you turn the angle a total of four times. If the plate reading after the fourth measurement is 119°59°, what is the size of the angle turned?

1. 29°45′45″
2. 29°59′45″
3. 30°00′15″
4. 30°45′15″

10-39. You have measured an angle using the repetition procedure. If the original measurement was 37°22′ and your sixth and last repeat was 224°12′42″, what is the mean angle?

1. 37°5′7″
2. 37°22′7″
3. 37°10′20″
4. 38°00′57″

10-40. Which of the following procedures is a method for extending a straight line?

1. Repeating angles
2. Averaging sets of backsight points
3. Double centering
4. Jiggling in

10-41. What step in the double-centering procedure is taken just before the instrument is rotated through 180° in the horizontal plane?

1. Plunging the telescope
2. Taking the first foresight
3. Taking the backsight
4. Taking the second foresight

10-42. When double centering results in two different extension points, what procedure should you use?

1. Extend your line through the first point
2. Extend your line through the second point
3. Extend your line through a point midway between the two extension points
4. Ignore both points and start over again

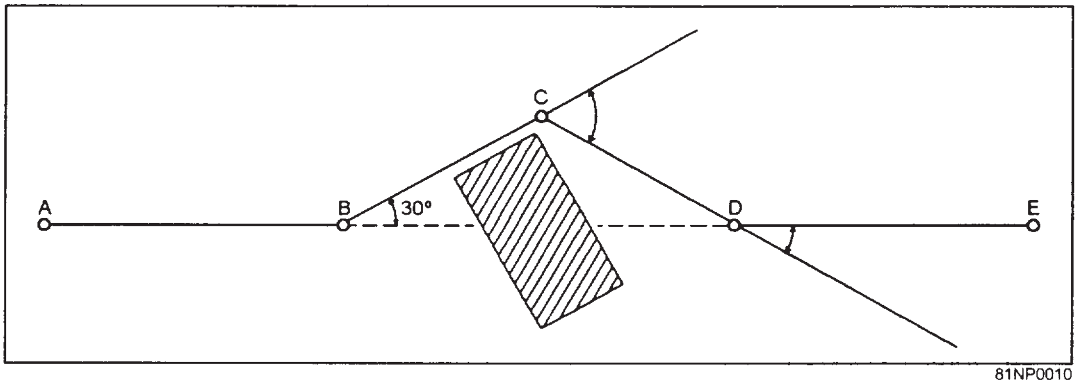


Figure 10F

IN ANSWERING QUESTIONS 10-43 THROUGH 10-46, REFER TO FIGURE 10F. YOU ARE RUNNING THE LINE AE AND THE POWERHOUSE IS IN YOUR WAY. WHILE AT SETUP B, YOU Discovered THAT A 30-DEGREE DEFLECTION ANGLE WILL CLEAR THE OBSTACLE. YOU DECIDED TO USE THIS ANGLE TO BYPASS THE POWERHOUSE.

10-43. What is your next step after recording the deflection angle at B?

1. Take a backsight at A and measure angle ABC
2. Move the instrument to D and measure the deflection angle at D
3. Move the instrument to C and measure the deflection angle at C
4. Move the instrument to A and measure angle BAC

10-44. If you use the angle offset method of bypassing an obstacle, what is the size of the deflection angle at C?

1. 30°
2. 45°
3. 60°
4. 75°

10-45. Which of the following distances is equal to CD?

1. AB
2. BD
3. DE
4. BC

10-46. What is the deflection angle at point D?

1. 30°L
2. 30°R
3. 60°L
4. 60°R

10-47. The angle offset and the perpendicular offset methods are useful in establishing a survey line under which of the following conditions?

1. When the length of the survey line cannot be determined by chaining
2. When the slope becomes great enough to require breaking chain
3. When the line of sight on the chosen survey line is obstructed
4. When the backsight distance is much less than the foresight distance

10-48. The "balancing in" process should be used to locate an intermediate point between two control points on a survey line under which of the following conditions?

1. When the distances from the intermediate point to the control points are approximately equal
2. When neither control point is visible from the other, and the other methods of bypassing an obstacle cannot be used
3. When the intermediate point is much closer to one of the control points than it is to the other
4. When the instrument adjustment has a known error

10-49. Moving a transit onto the straight line between two points by a trial-and-error method is referred to by which of the following terms ?

1. Bucking in only
2. Jiggling in only
3. Wiggling in only
4. Bucking in, jiggling in, wiggling in, and balancing in

IN ANSWERING QUESTION 10-50, REFER TO FIGURE 13-19C IN YOUR TEXTBOOK.

10-50. If deflection angles α and β are 4 and 6 minutes, respectively, and distance a equals 4 feet, how far should you set up the instrument from B′ so that it is exactly in line with points A and C?

1. 1.0 ft
2. 1.4 ft
3. 1.6 ft
4. 2.4 ft

10-51. For which of the following situations should the random line method be used?

1. To run a line between nonintervisible end points from an intermediate point from which both end points are visible
2. To run a line between nonintervisible end points when there is no intermediate point from which both end points are visible
3. To establish intermediate stations between nonintervisible end points
4. Both 2 and 3 above

10-52. What tying-in method should you use when locating the configuration of an irregular shoreline from a traverse line?

1. Swing offsets
2. Random lines
3. Range ties
4. Perpendicular offsets

10-53. What meaning is generally given to the term "setting a point"?

1. Establishing a point at a designated location
2. Relocating control points that have been destroyed
3. Locating reference lines for a displaced station
4. Setting the instrument upon a designated point

10-54. You can tie-in a point or set a point to two stations on a traverse by taking which of the following measurements?

1. Its angle and distance from one station
2. Two of its angles, one from each station
3. Its distance from one station and its angle from the other station
4. Each of the above

10-55. Two 50-foot tapes can be used to set a point that is designated by a distance from each of two traverse stations, provided that which of the following conditions exists?

1. The ground is absolutely level
2. The point is not more than 50 feet from either station
3. The tapes are marked off in hundredths of a foot
4. A rough survey is being made

10-56. You are setting a point at given distances from two stations on a traverse. Both distances are longer than your tapes. You could set this point by using which of the following methods?

1. Running the tapes out from both traverse stations and crossing them at the proper point
2. Using a transit and range pole to shoot to the new point
3. Using a transit, rod, and tape to lay off the appropriate distance to the point
4. Solving for one of the interior angles of the triangle and then using a transit, rod, and tape to lay off the appropriate distance to the point

10-57. Surveyors use straddlers for which of the following purposes?

1. To relocate control points that have been destroyed
2. To tie in a new traverse with reference to its angle to an old survey line
3. To tie in a point with reference to its angle from two stations
4. To locate the reference lines for a displaced station

10-58. You must set a marker at a certain point from traverse stations 3 + 00 and 4 + 25. The angle from the traverse line to station 3 + 00 and the distance between the point and station 4 + 25 are given. How should you proceed to set the point?

1. Solve for the other angle from the base line, and the distance of the point from the other station; then, set the point by using transit and tape. Check the distance and other angle from base line
2. Solve for the angle from the base line to the distance line and set the point by the use of transit and tape and check by measuring the base line
3. Lay out the lines to the point with tape and straddlers and check with a transit
4. Lay out the lines to the point with tape and straddlers and check by remeasuring one leg of the triangle

10-59. When tying in a point to a station on a traverse, which of the following conditions should you carefully consider?

1. The selected tie station should not be easily disturbed
2. The tie station must be visible from the point to be tied in
3. Both 1 and 2 above
4. The angle between the tie lines should be no greater than 90°

10-60. A closed traverse was to be 15,000 feet in length. The last course was to be 3,000 feet in length. After you turn the last deflection angle and progress 3,000 feet on the last course, you find that you are 3 feet from the starting point of the traverse. What is the order of precision?

1. First
2. Second
3. Third
4. Fourth

10-61. If precision of 1/20,000 is required, what is the maximum allowable error of closure for a traverse of 10,560 feet?

1. 0.437 ft
2. 0.528 ft
3. 0.759 ft
4. 1.255 ft

IN ANSWERING QUESTION 10-62, REFER TO TABLE 13-1 IN YOUR TEXTBOOK.

10-62. You are running a traverse of nine interior angles, and third-order degree of precision is required. Which of the following sums of the interior angles is acceptable?

1. 1259°59′30″
2. 1259°59′48″
3. 1260°01′ 12″
4. 1260°01′30″

10-63. A temperature correction applied to tape measurements is considered to be a typical precision specification for which of the following surveys?

1. Preliminary surveys
2. Land surveys where the value of the land is high
3. Highway location surveys
4. Both 2 and 3 above

10-64. Which of the following errors in a transit affects both horizontal and vertical angle measurements?

1. The line of sight through the telescope does not coincide with the true optical axis of the telescope
2. The horizontal axis of the telescope is not perpendicular to the vertical axis
3. The axis of each of the plate levels is not perpendicular to the vertical axis of the telescope
4. Each of the above

10-65. Errors that can lead to inaccurate surveying when you use a transit may include which of the following natural errors?

1. Tripod settlement
2. Unequal expansion of transit parts
3. Refraction
4. All of the above

10-66. Which of the following personal errors results in a larger error for inclined sights than for horizontal sights?

1. Failure to focus correctly
2. Failure to center the plate level bubbles exactly
3. Failure to plumb the transit exactly
4. Failure to line up the vertical cross hair with the true vertical axis of the sighted object

10-67. You are having difficulty aligning the transit cross hair with the vertical axis of the sighted object. Which of the following errors is most likely responsible for this difficulty?

1. Improper focusing
2. Not centering the plate level bubbles
3. Plumbing the transit poorly
4. Failure to align the vertical cross hair with the true axis of the object

10-68. Which of the following situations is considered a mistake in transit work?

1. Failure to record the direction in which an angle was turned
2. Turning a deflection angle in the wrong direction
3. Reading the wrong vernier
4. Each of the above

10-69. The carrying case for a transit or a theodolite is specifically designed for which of the following conditions?

1. To protect the instrument from extreme temperatures
2. To serve as a part of the instrument when it is set up for use in the field
3. To prevent excess motion when the instrument is being carried
4. All of the above

10-70. Which of the following actions should you take after an instrument has been exposed to rain and has been wiped down with a clean cloth or chamois leather?

1. Dry it in a heated room
2. Stow it right away in its case
3. Dry it thoroughly at ordinary room temperature

10-71. What is the recommended lubricant for surveying instruments at sub-zero temperatures?

1. Oil
2. Water
3. Petrol
4. Graphite

10-72. Which of the following statements describes the characteristics of an open traverse as compared to a closed connecting traverse?

1. An open traverse has only one previously determined end point, but a closed connecting traverse has two
2. Both types of traverses may not be used for preliminary surveys
3. An open traverse is open at both ends, but a closed connecting traverse forms a loop so that the ends are closed
4. A closed traverse provides fewer checks against error than an open traverse

10-73. In a lower order survey of a road center line, the exact route and station locations are selected so that provisions are made for which of the following conditions?

1. Only the rear station is visible from any station
2. Only the forward station is visible from any station
3. Both stations are visible from any one station and the maximum number of instrument setups can be kept
4. Both stations are visible from any one station and the number of instrument setups can be kept to a minimum

10-74. In double taping between traverse stations, you should use which of the following procedures?

1. Use only tapes that are calibrated
2. Ensure the stations are spaced so that the distance between stations is less than a full-tape length
3. Continue taping until the tie-in control point is reached; then retape all measurements
4. Retape line measurements not within allowable limits

10-75. Which of the following traverse stations may be a point with a known azimuth location?

1. Forward
2. Rear
3. Occupied

ASSIGNMENT 11

Textbook Assignment: "Direct Leveling and Basic Engineering Surveys." Pages 14-1 through 14-25.

11-1. Bench marks (BMs) share what common characteristic?

1. They are permanent
2. They are marked with a known elevation
3. They are constructed only from concrete or brass
4. They are used only for vertical control

11-2. To be used as elevation references in the development or expansion of a permanent naval station, you should establish monumented BMs in which of the following locations?

1. On all important structures, such as buildings and piers
2. At all road intersections
3. In a grid system 1 mile apart
4. In a grid system 1/2 mile apart

11-3. Level nets are established within a prescribed order of accuracy and are tied to what reference?

1. A BM
2. A traverse station
3. A datum
4. A horizontal control point

11-4. Mean sea level (MSL) differs from mean tide level (MTL) in what way?

1. MSL is the mean of tides observed in the open sea; MTL is the mean of inland tidewater observations
2. MSL is the result of averaging tabulated tide readings; MTL is taken from the tidal curve
3. MSL is the mean of a large number of points along a tidal curve; MTL is the mean of only the high and low points along the tidal curve
4. MSL is the datum used primarily in hydrographic surveys; MTL is used as a datum in any type of survey

11-5. The correct way to obtain the MSL value for a month's tide tabulated record is to add all daily sums for the month and to divide this total by the sum of what specific units of time in that month?

1. Minutes
2. Days
3. Hours
4. Weeks

11-6. What datum is generally used for measuring the height of a hill?

1. Mean sea level (MSL)
2. Mean high water (MHW)
3. Mean low water (MLW)
4. Mean low water springs (MLWS)

11-7. Assume you are engaged in a hydrographic survey of the water approaches to Naval Air Station, Adak, Alaska. Your soundings should refer to what datum?

1. MLLW
2. MWL
3. MTL
4. MLWS

11-8. What type of lubricant is recommended for use on engineer's levels in arctic regions?

1. Watch oil
2. Powdered graphite
3. Petroleum jelly
4. Mineral oil

11-9. The proper way to remove an engineer's level from its carrying case is to grasp it firmly by what part(s)?

1. The telescope
2. The footplate
3. The leveling head
4. The wye rings

11-10. When a level setup must be transferred to another point or station, what screws should be loosened slightly?

1. Leg and level
2. Leg and clamp
3. Level and clamp
4. Tangent and clamp

11-11. To help the instrumentman obtain accurate readings, the rodman should take which of the following actions?

1. Clean the top of the point and the rod shoe for a good contact
2. Plumb with both hands
3. Make sure the rod graduations are right side up and facing the instrumentman
4. All of the above

11-12. The proper care of a leveling rod includes which of the following actions?

1. Supporting the entire rod on a flat surface when laying the rod down flat
2. Rinsing any mud off with water and cleaning any grease off with a mild soap solution
3. Wiping it dry before storing it in a dry place
4. All of the above

11-13. On what basis should you select setup points to balance your shots in differential leveling?

1. All setup points are at about the same elevation
2. Backsight distances are about the same as foresight distances
3. All backsight distances are about the same
4. All foresight distances are about the same

11-14. You are setting up an engineer's level on a concrete surface. You mount the instrument on a tripod placed inside a floor triangle. This precaution will protect the tripod from which of the following accidents?

1. Turning
2. Moving laterally
3. Tipping over
4. Collapsing

IN ANSWERING QUESTION 11-15, REFER TO FIGURE 14-7 IN YOUR TEXTBOOK.

11-15. In what direction does the level vial bubble move when you turn the level screws as indicated?

1. Up
2. Down
3. Right
4. Left

11-16. The whole foot numbers on a Philadelphia rod are what color?

1. Red
2. White
3. Black
4. Yellow

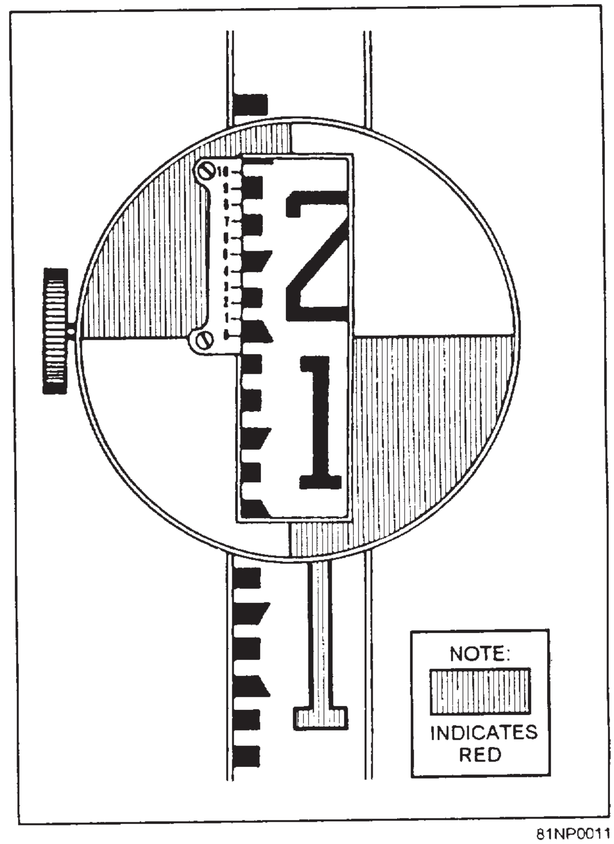


Figure 11A

IN ANSWERING QUESTION 11-171 REFER TO FIGURE 11A.

11-17. What is the target reading?

1. 1.125 ft
2. 1.154 ft
3. 1.5 ft
4. 112.0 ft

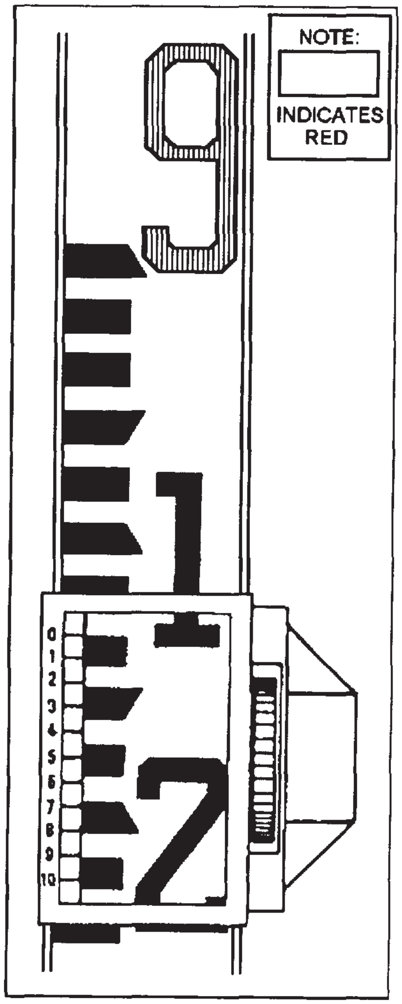


Figure 11B

IN ANSWERING QUESTION 11-18, REFER TO FIGURE 11B.

11-18. What is the target reading?

1. 8.128 ft
2. 9.120 ft
3. 9.128 ft
4. 279.0 ft

11-19. In leveling, which of the following statements best defines height of instrument (HI)?

1. The elevation of the horizontal line of sight
2. The vertical distance from the horizontal axis of the telescope to a point on the ground directly below the instrument
3. The vertical distance between the reference datum and the horizontal line of sight
4. The elevation of the reference datum minus the backsight rod reading

11-20. In determining the elevation of an unknown point, what arithmetic operation should you apply to the HI and FS?

1. Addition
2. Subtraction
3. Multiplication
4. Division

11-21. By using the technique of balancing shots, you can eliminate which of the following effect(s) in differential leveling?

1. Instrumental error
2. Curvature of the earth’s surface
3. Atmospheric refraction
4. All of the above

11-22. When turning points are being set up in ordinary precision leveling, what should be the maximum distance between the instrument and a TP?

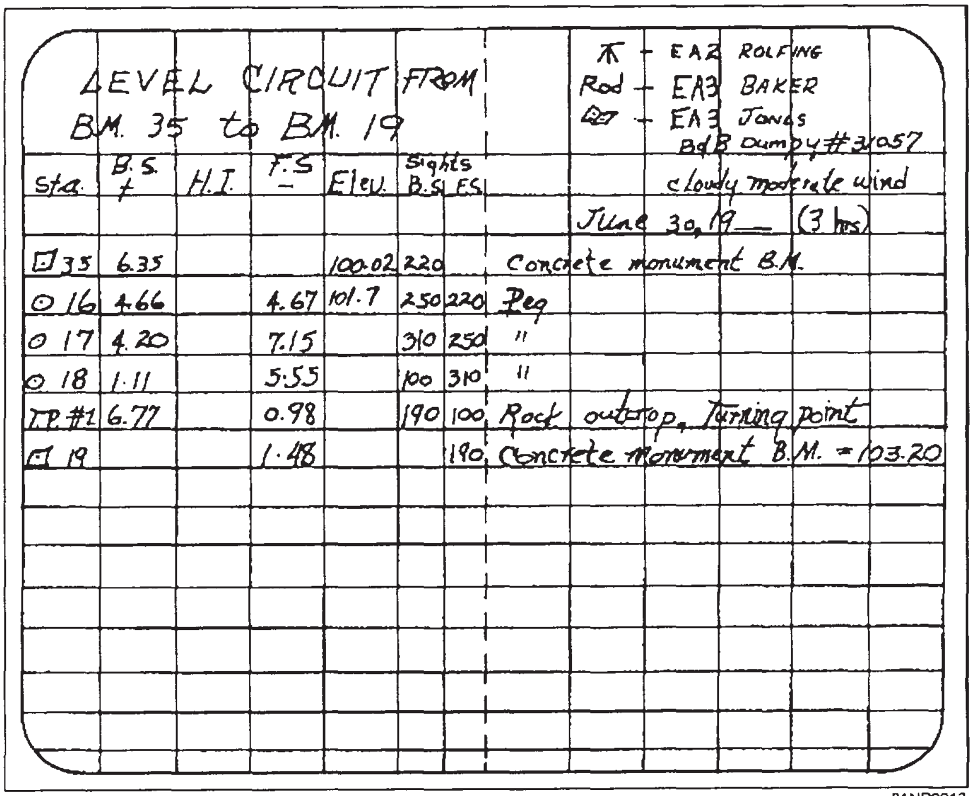
1. 200 ft
2. 300 ft
3. 600 ft
4. 1,000 ft

11-23. When turning points are located in sandy soil, you must set the level rod on a base. Which of the following bases is an acceptable choice?

1. A turning point plate
2. A turning point pin driven into the soil
3. A marlin spike driven into the soil
4. Each of the above

11-24. The original level run is rapidly rerun as a check in what type of leveling procedure?

1. Three-wire
2. Cross-section
3. Profile
4. Flying



LEVEL CIRCUIT FROM B.M. 35 to B.M. 19

⊼ – EA2 ROLFING
Rod – EA3 BAKER
– EA3 JONES
B&B Dumpy #31057
cloudy moderate wind
June 30, 19__ (3 hrs)

Sta.	B.S. +	H.I.	F.S −	Elev.	Sights B.S	Sights F.S	Remarks
⊡ 35	6.35			100.02	220		Concrete monument B.M.
⊙ 16	4.66		4.67	101.7	250	220	Peg
⊙ 17	4.20		7.15		310	250	"
⊙ 18	1.11		5.55		100	310	"
TP #1	6.77		0.98		190	100	Rock outcrop, Turning point
⊡ 19			1.48			190	Concrete monument B.M. = 103.20

81NP0013

Figure 11C

IN ANSWERING QUESTIONS 11-25 THROUGH 11-30, REFER TO FIGURE 11C.

11-25. What is the HI at station 16?

1. 100.02 ft
2. 106.35 ft
3. 106.36 ft
4. 106.37 ft

11-26. What is the elevation of turninq point #1?

1. 97.96 ft
2. 97.99 ft
3. 103.76 ft
4. 104.76 ft

11-27 What is the elevation of BM 19 as computed from the field notes?

1. 101.28 ft
2. 102.38 ft
3. 103.28 ft
4. 104.76 ft

11-28 What is the computed difference in elevation between BM 35 and BM 19?

1. 2.26 ft
2. 3.26 ft
3. 4.26 ft
4. 4.36 ft

11-29. What is the error of closure of the level circuit?

1. 0.08
2. 0.10
3. 3.18
4. 3.26

11-30. When corrected for error of closure, what is the adjusted elevation of TBM 17?

1. 99.17 ft
2. 99.25 ft
3. 101.67 ft
4. 101.75 ft

11-31. Simultaneous-reciprocal leveling requires which of the following level party personnel?

1. One levelman and one rodman
2. One levelman and two rodmen
3. Two levelmen and one rodman
4. Two levelmen and two rodmen

11-32. In profile leveling, rod readings taken from points that are neither BMs nor TPs are entered under what heading in the field notebook?

1. BS
2. FS
3. IFS
4. Remarks

11-33. You have run a line of levels from an initial BM to a final BM. You compute the elevation of the final BM to be 1,475.77 feet. The elevation of the initial BM is 1,502.36 feet. If the sum of the backlights is 16.32 feet, what is the sum of the foresights?

1. 10.27 ft
2. 26.59 ft
3. 32.06 ft
4. 42.91 ft

11-34. At what point(s) along a proposed highway are cross sections taken?

1. Every 25 ft
2. Every 50 ft
3. At regular stations only
4. At regular stations, at any point where there is a break on the ground, or at any interval desired

11-35. By which of the following methods is the HI in cross-section leveling determined when using a hand level?

1. By adding the instrumentman eyesight height to the center-line elevation from profile field notes
2. By adding the instrumentman eyesight height to a BM elevation
3. By adding the BS reading to a BM elevation
4. Each of the above

11-36. You are doing cross-section leveling for a highway road survey. The profile center-line elevation at station 25 + 00 is 112.5 feet and eye height is 5.3 feet. On a rod held 20 feet from the center line you read 11.2 feet. What is the elevation at this point?

1. 96.0 ft
2. 106.6 ft
3. 118.4 ft
4. 129.0 ft

11-37. What is a form of differential leveling in which a continuous check is maintained on the accuracy of the leveling procedure?

1. Three-wire
2. Double rodding
3. Cross-section
4. Profile

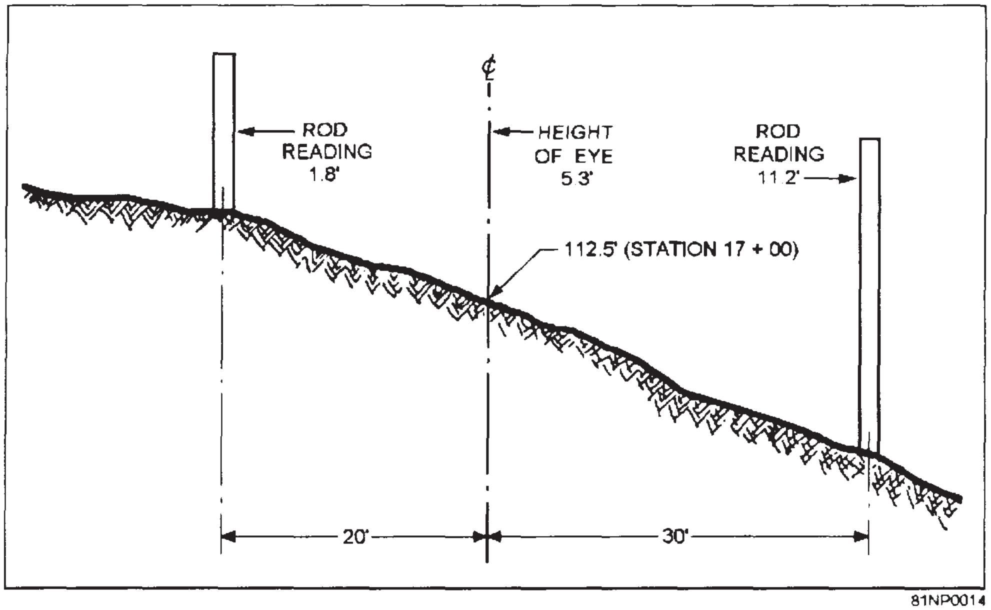


Figure 11D

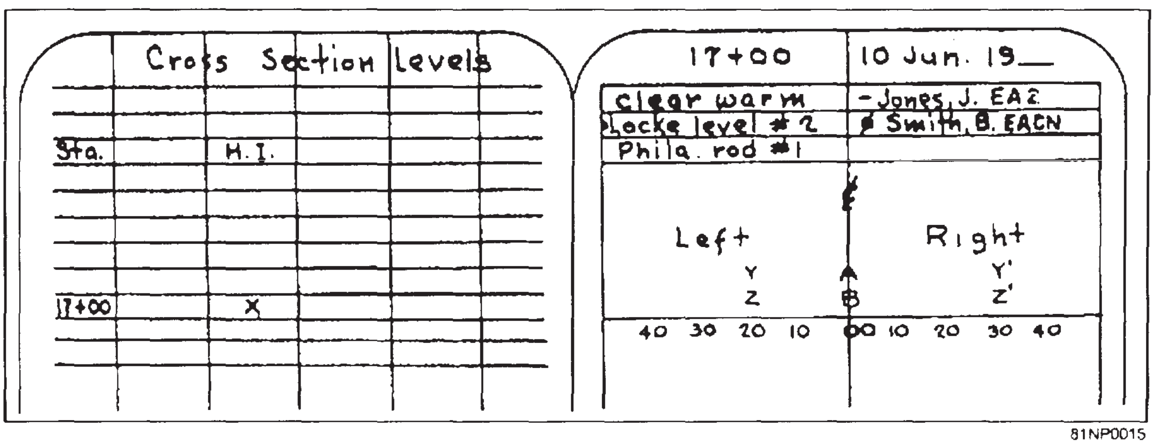


Figure 11E

IN ANSWERING QUESTIONS 11-38 THROUGH 11-41, REFER TO FIGURES 11D AND 11E.

11-38. What numerical values from figure 11D replace the letters A and B, respectively, in figure 11E?

1. 1.8; 11.2
2. 5.3; 112.5
3. 11.2; 1.8
4. 112.5; 5.3

11-39. What numerical value replaces the letter X in figure 11E?

1. 11.2
2. 107.2
3. 112.5
4. 117.8

11-40. What numerical values replace the letters Z and Z', respectively, in figure 11E?

1. 1.8; 11.2
2. 5.3; 112.5
3. 11.2; 1.8
4. 112.5; 5.3

11-41. What numerical values replace the letters Y and Y', respectively, in figure 11E?

1. 106.6; 116.0
2. 112.5; 117.8
3. 116.0; 106.6
4. 117.8; 112.5

11-42. If third order accuracy is specified, what is the maximum allowable error of closure for a level loop that is 7,826 feet long?

1. 0.042 ft
2. 0.061 ft
3. 0.608 ft
4. 4.423 ft

11-43. Recording a rod reading in the wrong column in a field book is classified as a

1. mistake
2. standard error
3. personal error
4. natural error

IN ANSWERING QUESTIONS 11-44 THROUGH 11-48, SELECT FROM THE FOLLOWING LIST THE CORRECTIVE MEASURE THAT YOU SHOULD TAKE DURING A LEVELING OPERATION TO AVOID ERRORS RESULTING FROM THE SITUATION GIVEN.

A. BALANCE BS AND FS DISTANCES
B. CALIBRATE ROD LENGTH
C. USE A TURNING POINT
D. AVOID VERY SMALL ROD READING

11-44. Level not in adjustment.

1. A
2. B
3. C
4. D

11-45. Unstable TP.

1. A
2. B
3. C
4. D

11-46. Wear and tear evident on the bottom of the rod.

1. A
2. B
3. C
4. D

11-47. Earth's curvature.

1. A
2. B
3. C
4. D

11-48. Atmospheric refraction.

1. A
2. B
3. C
4. D

11-49. Between errors and mistakes, the most importance difference, if any, is that

1. errors can be avoided
2. errors are caused by human negligence
3. mistakes can be avoided
4. there is no difference; the terms are synonymous

11-50. In third-order leveling, the starting and closing BMs must be of which of the following orders of accuracy?

1. First
2. Second or higher
3. Third or higher
4. Fourth or higher

ASSIGNMENT 12

Textbook Assignment: "Direct Leveling and Basic Engineering Surveys." Pages 14-25 through 14-47.

12-1. Fieldwork on the construction of a road being built on a 5-year-old naval air station would very likely begin with what type of survey?

1. Final location
2. Topographic
3. Reconnaissance
4. As-built

12-2. What is the first step in a reconnaissance survey?

1. A field trip to the desired location
2. A study of existing maps and aerial photographs
3. An instrument survey of the desired location
4. An inventory of available construction equipment

12-3. Direct air observation of an area to be reconnoitered offers what main advantage?

1. Acquiring information about the relief of the area
2. Providing a quick means of preparing sketches of the area
3. Speeding subsequent ground reconnaissance of the area
4. Providing a quick means of preparing maps of the area

12-4. A field reconnaissance party follows the route previously marked on a map to verify actual conditions on the ground. Which of the following conditions, relative to an engineering study, should be noted?

1. Soil conditions and washout areas
2. Vegetation and obstacles
3. Quarry sites and sand or gravel deposits
4. All of the above

12-5. Which of the following tasks in constructing a highway is part of the preliminary survey?

1. Establishing final grades and alignments
2. Computing the highway right-of-way
3. Running the traverse
4. Setting grade stakes

12-6. Your survey party is assigned the task of completing a reconnaissance survey of a 3-mile road in hilly, wooded terrain. For this survey, your party should carry which of the following equipment?

1. Lensatic compass
2. Brush hook
3. Hand level
4. All of the above

12-7. As the lead surveyor laying out the final location of a roadway center line, you suspect that the preliminary survey was in error regarding the exact location of the center line. Which of the following actions should you take?

1. Lay out the center line according to the preliminary data
2. Lay out the center line the way you know it should be
3. Lay out the center line and then report the reason for making the necessary change
4. Report the problem and receive authorization before making the location change

12-8. Which of the following details must be shown on a plan view of a proposed highway?

1. Curve design data
2. Gradient
3. Spot elevations
4. Typical cross section of the highway

12-9. When plotting a profile, you should use which of the following (a) horizontal and (b) vertical scales?

1. (a) 1" = 200′ (b) 1" = 20′
2. (a) 1" = 20′ (b) 1" = 200′
3. (a) 1" = 135′ (b) 1" = 15′
4. (a) 1" = 205′ (b) 1" = 20′

12-10. You have just plotted the profile of a road section from station 6 + 00 to station 9 + 81. The elevation of station 6 + 00 is 100.00 feet and that of station 9 + 81 is 93.30 feet. What is the gradient between these stations?

1. +1.76%
2. -1.76%
3. +17.60%
4. -17.60%

12-11. What kind of information is presented in the typical cross section of a proposed highway?

1. Design data for the highway
2. Details of the representative terrain over which the highway will be built
3. Factors establishing a need for the highway
4. Schedule of the office tasks to be performed before the construction of the highway

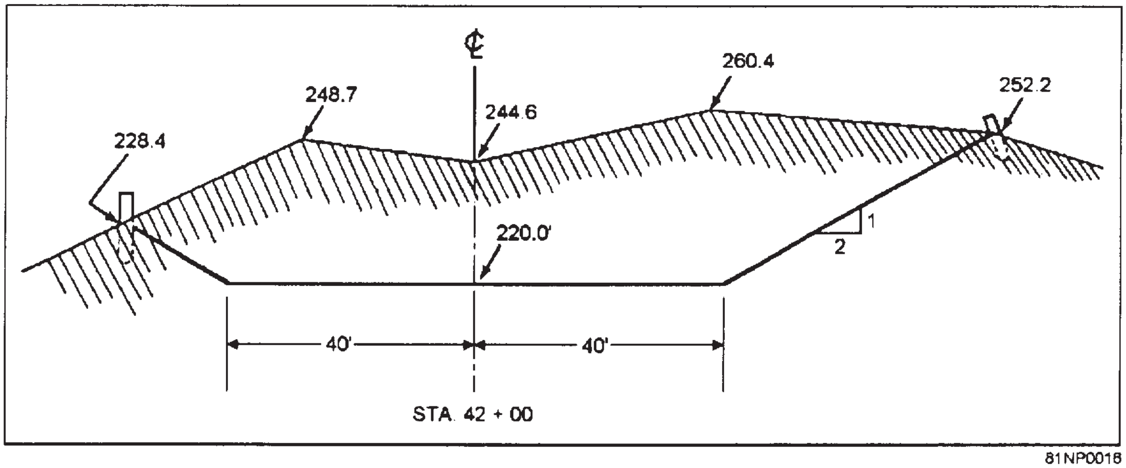


Figure 12A

IN ANSWERING QUESTIONS 12-12 THROUGH 12-15, REFER TO THE CROSS SECTION OF THE PROPOSED HIGHWAY SHOWN IN FIGURE 12A.

12-12. What is the finished grade elevation?

1. 260.4 ft
2. 248.7 ft
3. 244.6 ft
4. 220.0 ft

12-13. How should you write the side slope ratio?

1. 1:2
2. 2:1
3. 1/2
4. 2/1

12-14. What type of cross section is shown?

1. Level
2. Five-level
3. Three-level
4. Four-level

12-15. This cross section may also be called what type of section?

1. Regular
2. Irregular
3. Standard
4. Sidehill

12-16. On the cross-section paper most widely used in surveying offices, the horizontal lines are spaced how far apart?

1. 1/20 in
2. 1/10 in
3. 1/5 in
4. 1/4 in

12-17. After the surface elevations have been plotted on the cross-section paper, the points should be connected in which of the following ways?

1. By freehand curves
2. By freehand straight lines
3. By lines drawn with a straightedge
4. Either 2 or 3 above

12-18. In the plotting of cross sections, the vertical scale relates to the horizontal scale in which of the following manner?

1. The vertical scale must be equal to the horizontal scale
2. The vertical scale must be exaggerated from the horizontal scale
3. The vertical scale may be equal to the horizontal scale, or it may be exaggerated for clarity
4. The vertical scale is usually less than the horizontal scale, but it may be equal or exaggerated for clarity

IN ANSWERING QUESTIONS 12-19 THROUGH 12-21, REFER TO FIGURE 14-29 IN YOUR TEXTBOOK.

12-19. The plotted cross sections are called irregular for what reason?

1. Sections are plotted at a full station and at a section between two full stations
2. The vertical and horizontal scales are different
3. Intermediate elevations are plotted at varying distances from the center line
4. More elevations were plotted for the section at station 11 + 00 than for the section at station 11 + 43

12-20. Notice that the cross-section notes show only two ground elevations to the right of the center line at station 11 + 43. Assume that an additional reading could have been obtained at a point 10 feet to the right of the center line but was not. Refer to the plotted cross section of the station and furnish the entry for this point.

1. $\frac{10}{5.1}$ (80.1)
2. $\frac{10}{8.6}$ (67.0)
3. $\frac{10}{2.4}$ (74.3)
4. $\frac{10}{9.7}$ (67.0)

12-21. The HI for station 14 + 00 is

1. 76.70
2. 78.90
3. 81.60
4. 85.22

12-22. What points are plotted in a three-level section?

1. The roadway edges, slope stakes, and center line
2. The depth of cut or fill and the amount of earth to be moved
3. The left-hand slope stake, right-hand slope stake, and center line
4. The left-hand roadway edge, right-hand roadway edge, and center line

12-23. During what stage of a road construction project are "blue tops" used?

1. Rough grading
2. Clearing and grubbing
3. Final grading
4. Paving

12-24. The natural earth surface below the pavement of a highway is called the

1. final grade
2. finish grade
3. rough grade
4. subgrade

12-25. Which of the following markings on a grade stake indicates a cut of 2.6 feet?

1. C $2\underline{6}$
2. - $2\underline{6}$
3. V $2\underline{6}$
4. Each of the above

12-26. You wish to indicate a cut of 2.6 feet on a stake that is not a centerline stake. You should write the cut information on what part of the stake?

1. Front
2. Back
3. Right side
4. Left side

IN ANSWERING QUESTIONS 12-27 AND 12-28, YOU ARE SETTING GRADE STAKES BY THE PROCEDURE THAT INVOLVES COMPLETING THE NECESSARY COMPUTATIONS WHILE AT EACH STATION.

12-27. You can obtain the grade rod by taking the difference between what two measurements?

1. The HI and the ground elevation
2. The HI and the finished grade
3. The finished grade and the ground elevation
4. The width of the highway and the width of the fill or cut

12-28. You can obtain the amount of cut or fill for a given station by computing the sum of or difference between what two measurements?

1. The HI and the finished grade
2. The ground elevation and the ground rod
3. The ground rod and the grade rod
4. The HI and the ground rod

IN ANSWERING QUESTIONS 12-29 AND 12-30, YOU ARE SETTING A CENTERLINE GRADE STAKE AT A STATION WHERE THE EXISTING GROUND ELEVATION IS 98.6 FEET AND THE REQUIRED ELEVATION IS 110.3 FEET.

12-29. At this station, you obtain a reading of 6.3 feet. What is the (a) grade rod and (b) ground rod?

1. (a) 6.3 (b) 104.9
2. (a) 5.4 (b) 6.3
3. (a) 6.3 (b) 5.4
4. (a) 104.9 (b) 5.4

12-30. What information should you mark on the front of the grade stake?

1. C $5\underline{^{4}}$ and the station number
2. F $6\underline{^{3}}$ and the station number
3. ℄ and the station number
4. F $11\underline{^{7}}$ and the station number

12-31. What is the slope stake distance from the center line if W/2 . 18 feet, h = 6 feet, and the slope ratio is 2:1?

1. 21 ft
2. 24 ft
3. 30 ft
4. 42 ft

QUESTIONS 12-32 AND 12-33 PERTAIN TO THE SETTING OF SLOPE STAKES FOR A CUT SECTION. THE DISTANCE FROM THE CENTER LINE TO THE BEGINNING OF THE SIDE SLOPE IS 22 FEET. THERE IS A CROSSFALL OF 0.5 FEET AND A DITCH 2 1/2 FEET IN DEPTH. THE SIDE SLOPE AND BACK SLOPE RATIO IS 3:1, AND h IS 8 FEET.

12-32. What is the value of W/2?

1. 7.5 ft
2. 22.0 ft
3. 29.5 ft
4. 38.5 ft

12-33. What is the slope stake distance from the center line?

1. 24.0 ft
2. 29.0 ft
3. 44.0 ft
4. 62.5 ft

As rodman, you are setting slope stakes at station 7 + 00, and the instrumentman is 100 yards away. You have obtained the following information from notes and plans:

W/2 = 20 FEET
SLOPE RATIO = 2:1
FINISHED GRADE ELEVATION AT CENTER LINE = 156.3 FEET
GROUND ELEVATION AT CENTER LINE = 160.8 feet
HI = 165.0 FEET

Figure 12B

IN ANSWERING QUESTIONS 12-34 THROUGH 12-38, REFER TO FIGURE 12B.

12-34. What is the cut at center line?

1. 4.2 ft
2. 4.5 ft
3. 4.8 ft
4. 8.7 ft

12-35. What should the rod reading be at the center line?

1. 4.2 ft
2. 4.5 ft
3. 4.8 ft
4. 8.7 ft

12-36. What should your initial estimate of d be?

1. 20.0 ft
2. 28.4 ft
3. 29.0 ft
4. 40.0 ft

12-37. As you walk to the initial estimate of d, you observe a drop of approximately 3 feet in the ground elevation. Your second estimate of d is

1. 23.0 ft
2. 25.4 ft
3. 32.0 ft
4. 47.0 ft

12-38. At the second estimate of d, the rod reading is 7.2 feet. You know your second estimate of d is

1. correct
2. 0.5 ft short
3. 0.5 ft long
4. 1.0 ft long

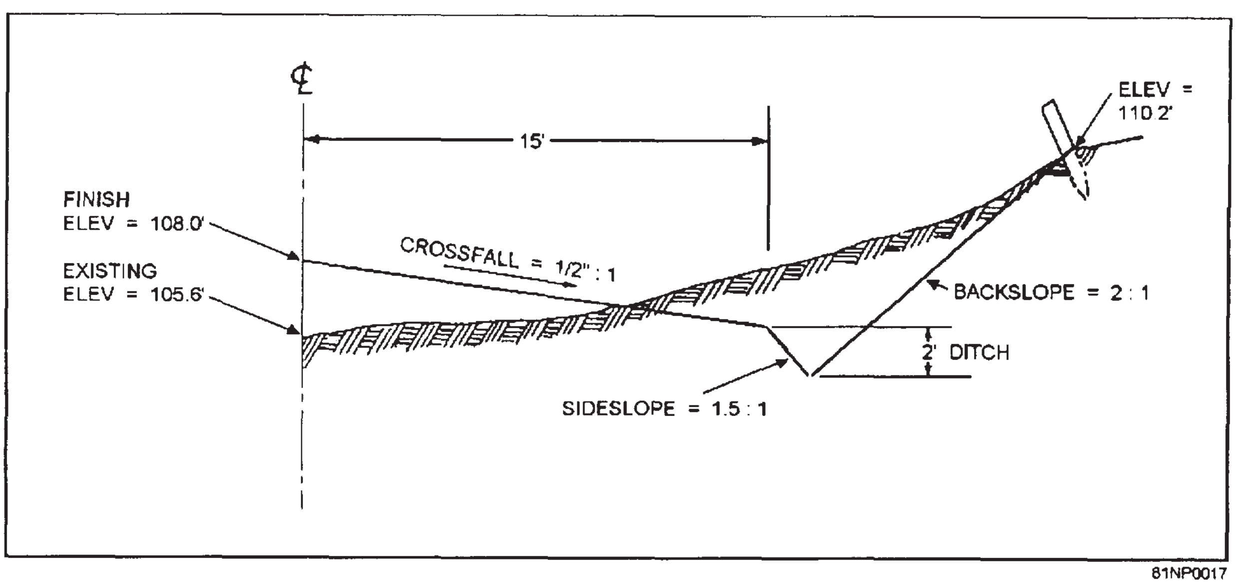


Figure 12C

IN ANSWERING QUESTIONS 12-39 AND 12-40, REFER TO FIGURE 12C.

12-39. What type of cross section is shown?

1. Level
2. Three-level
3. Five-level
4. Sidehill

12-40. What is the distance from the center line to the slope stake?

1. 25.4 ft
2. 27.4 ft
3. 27.6 ft
4. 32.4 ft

12-41. In curb construction, construction crews should obtain line and grade from which of the following sources?

1. Center-line stakes
2. Blue tops
3. Shoulder stakes
4. Offset hubs

12-42. Pavement stakeout is primarily dependent upon which of the following factors?

1. The type of instruments used to perform the stakeout
2. The type of equipment used for paving
3. The finish grade elevations
4. The directions from the construction crew leader

12-43. In checking the accuracy of a 9- by 12-foot rectangular layout by means of the Pythagorean theorem, you should find the diagonal to measure what distance?

1. 15 ft
2. 18 ft
3. 20 ft
4. 25 ft

12-44. The batter boards should be placed how far from the building lines so as not to interfere with construction?

1. 1 to 2 ft
2. 2 to 3 ft
3. 3 to 4 ft
4. 4 to 5 ft

12-45. When batter boards are used to preserve building lines, horizontal and vertical controls are provided by

1. cords stretched between the top edges of the batter boards
2. the side edges of the batter boards
3. the vertical edges of the batter boards
4. the top edges of the stakes that hold the batter boards

12-46. The invert elevation of an underground sewer pipe is taken at what point on the pipe?

1. Lowest outside surface
2. Highest inside surface
3. Lowest inside surface
4. Highest outside surface

12-47. For any construction project, what is the optimum time for the as-built survey to begin?

1. During the layout survey
2. As soon as stakeout is completed
3. Upon final project completion
4. During construction as the individual features are completed

12-48. Red flagging should be used on the legs of your instrument when you are surveying in the vicinity of which of the following areas?

1. Airstrips
2. Excavations
3. Logging operations
4. Blasting operations

12-49. Which of the following actions should you take when you are running a tape-transit traverse that crosses electric wires?

1. Stretch the tape above the wires
2. Ground one end of the tape
3. Break chain at the wires
4. Wear rubber gloves

12-50. Excavations that are what minimum depth, in feet, must be suitably braced and shored to prevent cave-ins?

1. 5
2. 2
3. 3
4. 4

ASSIGNMENT 13

Textbook Assignment: "Materials Testing: Soil and Concrete." pages 15-1 through 15-39. "Administration." Pages 16-1 through 16-14.

13-1. Which of the following substances is/are enclosed by the mineral grains in a soil mixture?

1. Air or gases only
2. Water only
3. Organic matter only
4. Voids containing air, gases, water, and organic matter or any combination of these

13-2. Rock is classified into how many groups?

1. One
2. Two
3. Three
4. Four

13-3. What type of rock is formed from the accumulation and cementing of plant and animal remains?

1. Metamorphic
2. Sedimentary
3. Igneous
4. Organic

13-4. By what process are residual and transported soils formed?

1. Disintegration
2. Weathering
3. Decomposition
4. Atmospheric exposure

IN ANSWERING QUESTIONS 13-5 THROUGH 13-7, SELECT THE KEY WORDS OR PHRASES THAT BEST MATCHES THE TYPE OF SOIL LISTED.

A. FRESHWATER LAKE
B. ESKERS
C. LOESS
D. IN-PLACE WEATHERING

13-5. Residual soil.

1. A
2. B
3. C
4. D

13-6. Lacustrine soil.

1. A
2. B
3. C
4. D

13-7. Glacial soil.

1. A
2. B
3. C
4. D

13-8. According to the Unified Soil Classification System, materials retained on the No. 200 sieve and passing the No. 4 sieve are classified as

1. coarse grained
2. sands
3. fines
4. medium fines

13-9. Which of the following bulky particle shapes is considered to be the most desirable for construction purposes because of its interlocking characteristic?

1. Rounded
2. Subrounded
3. Subangular
4. Angular

13-10. A well-graded soil consists of which of the following particle sizes?

1. Only intermediate sizes
2. Large and small sizes only
3. Uniformly graded sizes
4. A good representation of all sizes

13-11. A well-graded soil provides which of the following conditions?

1. Maximum displacement of particles
2. Maximum density and stability of particles
3. Minimum displacement of voids
4. Each of the above

13-12. In most inorganic soils, the specific gravity of the solid substance has what minimum to maximum range?

1. 2.60 and 2.65
2. 2.60 and 2.80
3. 2.65 and 3.00
4. 3.00 and 3.50

3-13. In which of the following ways can water enter a layer of soil mass?

1. By gravitational pull
2. By capillary action
3. By absorption
4. Each of the above

13-14. When soil is subjected to loading, what soil property has the greatest effect upon its behavior?

1. Specific gravity
2. Moisture content
3. Gradation
4. Plastic and liquid limits

13-15. Which of the following descriptions best defines the term "hygroscopic moisture"? (Hint: Your textbook contains a glossary.)

1. Soil water absorbed by the atmosphere
2. Absorbed moisture in soil at any time
3. Adsorbed moisture in air-dried soil
4. Thin films of water that freely move through soil

13-16. The term "moisture content" refers to which of the following factors?

1. The amount of free water in a soil sample
2. The proportion of the weight of water to the weight of wet soil expressed as a percentage
3. The amount of hydroscopic moisture in a soil sample
4. The proportion of the weight of water to the weight of dry soil expressed as a percentage

13-17. Which of the following properties of a fine-grained soil permits clay to be rolled into thin threads at a certain moisture content without crumbling?

1. Liquidity
2. Plasticity
3. Cohesiveness
4. Consistency

IN ANSWERING QUESTIONS 13-18 THROUGH 13-20, SELECT THE TERM THE THAT BEST MATCHES THE DESCRIPTION LISTED.

A.	LIQUID LIMIT
B.	PLASTIC LIMIT
C.	PLASTICITY INDEX
D.	SHRINKAGE LIMIT

13-18. The boundary in moisture content between the solid and semisolid state of the soil.

1. A
2. B
3. C
4. D

13-19. The moisture content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil.

1. A
2. B
3. C
4. D

13-20. The moisture content at the arbitrary limit between the plastic and semisolid state of a soil .

1. A
2. B
3. C
4. D

13-21. Which of the following constructions would be least affected by soil moisture?

1. An asphaltic-cement road laid on a sand-clay admixture
2. A concrete building foundation laid on a base of fine-grained soil
3. A concrete building foundation laid on a gravel base
4. An asphaltic-cement runway laid on a gravel-clay admixture

13-22. In the Unified Soil Classification System, what category of soil is identified by the presence of large amounts of organic material?

1. Coarse grained
2. Fine grained
3. Peat
4. Sand

13-23. When less than half of the coarse portion of a soil sample is retained on a No. 4 sieve, the sample is classified as what type of soil?

1. Sand
2. Gravel
3. Silt
4. Clay

13-24. When you dig test holes with the hand auger, the samples may be completely disturbed, but they are satisfactory for determining which of the following information?

1. Compaction capabilities
2. Moisture content
3. Soil profile
4. All of the above

13-25. A soil sample tagged CB-P3-1 was taken from which of the following locations?

1. Project CB, bag No. P3, pit No. 1
2. Project CB, pit No. 3, location No. 1
3. Construction battalion pit No. 3, area No. 1
4. Construction borrow pit No. P3, bag No. 1

13-26. Disturbed samples are satisfactory for use in which of the following tests?

1. Unconfined compression
2. Mechanical analysis
3. Specific gravity
4. Both 2 and 3 above

13-27. YOU are taking a moisture content sample that you know will be tested within the next 4 hours. At a minimum, what action, if any, should you take to prevent the evaporation of moisture from the soil?

1. Seal the canister with friction tape
2. Dip the canister in paraffin
3. Wrap the canister with a paraffin coated cloth
4. None, since the test will be performed within 1 day

13-28. Soil samples obtained by samplers are used for the testing of which of the following soil properties?

1. In-place density
2. Shear strength
3. Compressive strength
4. All of the above

13-29. A chunk sample would be best suited for sampling which of the following soil types?

1. Highly plastic
2. Cohesionless
3. Slightly plastic
4. Moderately cohesive

13-30. YOU are obtaining an undisturbed soil sample using the CBR mold. After removing the CBR mold and sample from the hole, which of the following steps should you take next ?

1. Trim out a ½-inch recess in the top of the mold
2. Coat the top of the sample with paraffin
3. Remove the upper collar of the mold
4. Trim out both ends of the mold before sealing the sample ends with paraffin

13-31. One way to be certain that a soil sample used is representative of the whole sample is by using which of the following methods?

1. Straining
2. Soaking
3. Halving
4. Quartering

13-32. When quartering a sample, what quarter(s), if any, should you discard?

1. Any single quarter
2. Two adjacent quarters
3. Two diagonally opposite quarters
4. None

13-33. For a complete soil test, identify the logical sequence of the following procedures.

A. Determine the specific gravity of representative samples.
B. Determine the moisture content of representative samples.
c. Determine moisture-density relationship.
D. Determine grain size and distribution.
E. Determine the field moisture content.
F. Determine Atterberg limits.

1. A, B, F, C, E, D
2. B, C, A, D, F, E
3. B, D, A, F, C, E
4. B, D, C, A, E, F

TEST	NATURAL SOIL MOISTURE CONTENT					
RUN NUMBER	1	2	3			
TARE NUMBER	6	7	9			
A. WEIGHT OF TARE + WET SOIL	196.4	187.3	209.6			gm
B. WEIGHT OF TARE + DRY SOIL	176.8	169.9	190.2			gm
C. WEIGHT OF WATER, W_w = (A - B)						gm
D. WEIGHT OF TARE	43.6	44.0	46.4			gm
E. WEIGHT OF DRY SOIL, W_s = (B - D)						gm
WATER CONTENT, w	%	%	%	%	%	

81NP0018

Figure 13A

IN ANSWERING QUESTIONS 13-34 THROUGH 13-37, REFER TO FIGURE 13A WHICH IS A TABLE OF VALUES FOR THREE MOISTURE CONTENT TESTS ON A TYPICAL SOIL SAMPLE. COMPUTE THE WATER CONTENT OF EACH RUN.

13-34. What is the dry weight of the soil in run number 1?

1. 176.8 g
2. 152.8 g
3. 143.6 g
4. 133.2 g

13-35. What is the weight of water in run number 2?

1. 17.4 g
2. 17.6 g
3. 18.4 g
4. 18.6 g

13-36. What is the water content of run number 3?

1. 13.0%
2. 13.2%
3. 13.5%
4. 17.4%

13-37. What is the average moisture content of the three runs?

1. 13.4%
2. 14.0%
3. 31.1%
4. 41.9%

13-38. The results of a sieve analysis shows 100% passing the 1 3/4-, 1½-, and 1¼-inch sieves and 99% passing the 1-inch sieve. What should be the first sieve size entered on the data sheet?

1. 1
2. 1¼
3. 1½
4. 1 3/4

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SIEVE ANALYSIS DATA

DATE: 11 July 19—

PROJECT:

EXCAVATION NUMBER: 2

SAMPLE NUMBER: FT-P1-1

DESCRIPTION OF SAMPLE: 25 lb. bag sample

PREWASHED: ☐ YES ☒ NO

WEIGHT ORIGINAL SAMPLE (gm): 1632.8

WEIGHT AFTER PREWASHING[1] (gm):

WASHING LOSS[1] (gm):

SIEVE OR SCREEN a	WEIGHT RETAINED ON SIEVE (gm) b	PASSING SIEVE WEIGHT (gm) c	PASSING SIEVE PERCENT d
*	0		100
3/4		1632.8	100.0
1/2	394.8	1238.0	
3/8	217.3	1020.7	
No. 4	176.2	844.5	
10	189.4	655.1	
20	362.1	293.0	
40	108.3	184.7	
100	140.2	44.5	
NUMBER 200	23.8	20.7	

A. WEIGHT SIEVED THROUGH NO. 200 (gm): 18.3

B. WASHING LOSS[1] (gm):

C. TOTAL PASSING NO. 200 (gm) (A + B): 18.3

TOTAL WEIGHT OF FRACTIONS (Total of all entries in Col. b + c):

ERROR (Original weight − total weight of fractions) (gm)

$\left(\frac{\text{Error (gm)}}{\text{Original weight (gm)}} \times 100\right) =$

PERCENT ERROR

$\left(\frac{\text{Error (gm)}}{\text{Original weight (gm)}} \times 100\right) =$

REMARKS:

TECHNICIAN (Signature):

COMPUTED BY (Signature):

CHECKED BY (Signature):

[1] For prewashed samples only

* Maximum particle size

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Figure 13B

IN ANSWERING QUESTIONS 13-39 THROUGH 13-42, REFER TO FIGURE 13-B.

13-39. What percentage of the material tested passed the No. 40 sieve?

1. 17.9%
2. 11.3%
3. 10.2%
4. 2.7%

13-40. What is the percentage of error in the soil sample?

1. 1.5%
2. 1.4%
3. 0.15%
4. 0.14%

13-41. The soil sample predominantly consists of what type of material?

1. Cobbles
2. Gravel
3. Sand
4. Fines

13-42. What is the percentage of gravels contained in the sample?

1. 48.3%
2. 51.7%
3. 62.5%
4. 88.7%

13-43. A sieve analysis data sheet shows that the original weight of a test sample exceeds the total weight of fractions, resulting in a percentage error that is smaller than the maximum permissible error. Which of the following actions should you take?

1. Disregard the value of the error
2. Rerun the test
3. Add the value of the error to the largest amount retained by any sieve
4. Add the value of the error to the smallest amount retained by any sieve

13-44. When is it necessary to prewash a sample before proceeding with a normal dry sieve analysis?

1. When the sample contains a surplus of superfine materials
2. When the sample has an undesirable water content
3. When the sample is too dry
4. When the sample contains too little superfine materials

13-45. During a sieve analysis, 2% of the material passed the No. 200 sieve. What subsequent test, if any, should you perform on the sample to determine this soil's susceptibility to frost?

1. Hydroscopic moisture content
2. Hydrometer analysis
3. Specific gravity
4. None

13-46. After a sieve analysis has been performed, which of the following materials should be tested for specific gravity of solids?

1. Only those larger than the No. 40 sieve
2. Only those retained on the No. 4 sieve
3. Only those passing the No. 4 sieve
4. Materials passing the No. 200 sieve

W_s	=	102.3
W_{bw}	=	536.1
W_{bws}	=	600.5
K	=	0.9975
G_a	=	2.58
G_m	=	2.58

Percent Gravel = 60%
Percent Sands and Fines = 40%

Figure 13C

IN ANSWERING QUESTIONS 13-47 AND 13-48, REFER TO THE DATA IN FIGURE 13C.

13-47. Find the specific gravity of solids.

1. 2.67
2. 2.69
3. 2.71
4. 2.73

13-48. Find the composite specific gravity.

1. 2.42
2. 2.52
3. 2.62
4. 2.64

13-49. Which of the following errors will have the greatest negative impact on the accuracy of a specific gravity test?

1. Loss of material
2. Misreading the thermometer by 1°
3. Not soaking a clean, sandy soil before exhausting the air from the volumetric flask
4. Failing to apply the correction factor (K)

13-50. What should be the surface appearance of a saturated-surface-dry soil sample?

1. Very wet
2. Damp
3. Very dry

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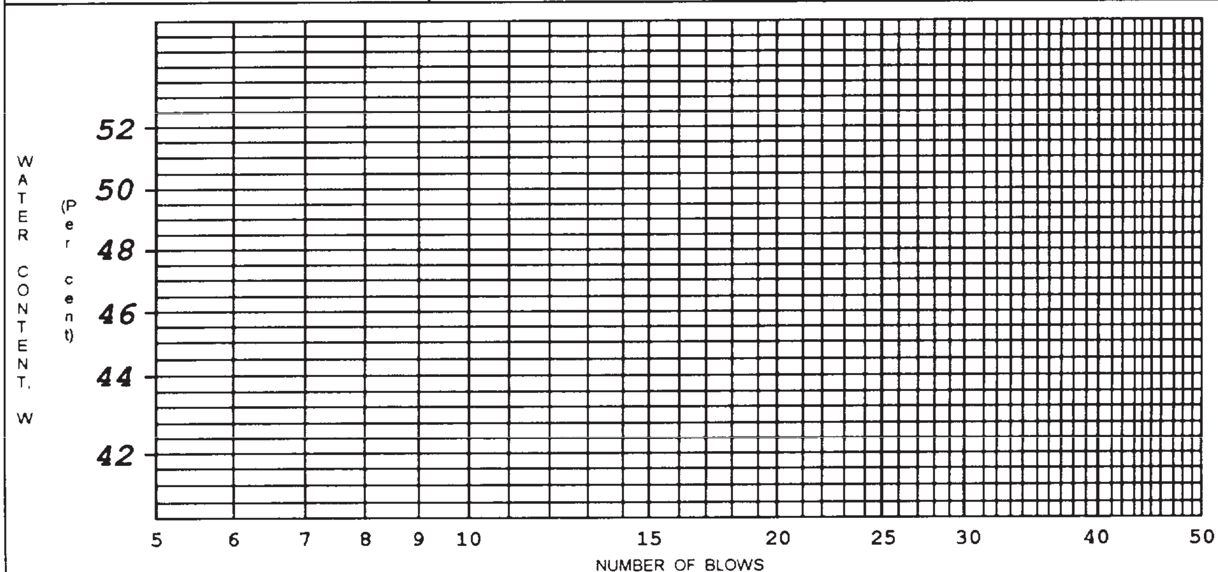
ATTERBERG LIMITS DETERMINATION		DATE
PROJECT	EXCAVATION NUMBER	SAMPLE NUMBER

LIQUID LIMIT, W_L						
RUN NUMBER	*1*	*2*	*3*	*4*	*5*	*6*
TARE NUMBER	*41*	*42*	*43*	*44*	*45*	*46*
A. WEIGHT OF WET SOIL + TARE	*43.96*	*41.78*	*43.92*	*41.51*	*43.38*	*43.73*
B. WEIGHT OF DRY SOIL + TARE	*41.07*	*38.84*	*40.92*	*38.45*	*40.23*	*34.16*
C. WEIGHT OF WATER, W_W *(A - B)*						
D. WEIGHT OF TARE	*34.04*	*32.06*	*34.29*	*31.88*	*33.76*	*34.16*
E. WEIGHT OF DRY SOIL, W_S *(B - D)*						
WATER CONTENT, $w = (\frac{W_W}{W_S} \times 100)$						
NUMBER OF BLOWS	*49-50-51*	*39-41*	*32-34*	*29-29*	*23-24-25*	*18-19*

W_L	W_P	I_P $(W_L - W_P)$
LL =	***PL = 42.0***	***PI =***



PLASTIC LIMIT, W_P					NATURAL WATER CONTENT
RUN NUMBER					
TARE NUMBER					
F. WEIGHT OF WET SOIL + TARE					
G. WEIGHT OF DRY SOIL + TARE					
H. WEIGHT OF WATER, Ww *(F - G)*					
I. WEIGHT OF TARE					
J. WEIGHT OF DRY SOIL, W_S *(G - I)*					
WATER CONTENT, $w = (\frac{W_W}{W_S} \times 100)$					
PLASTIC LIMIT, Ip *(Average w)*					

REMARKS		
TECHNICIAN *(Signature)*	COMPUTED BY *(Signature)*	CHECKED BY *(Signature)*

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Figure 13D

IN ANSWERING QUESTIONS 13-51 THROUGH 13-54, REFER TO FIGURE 13D.

13-51. What is the water content of run number 1?

1. 30.3
2. 38.5
3. 41.1
4. 43.2

13-52. What are the coordinates of run number 2?

1. 39 and 41.0
2. 39 and 41.1
3. 40 and 43.4
4. 41 and 43.4

13-53. What is the liquid limit of this soil sample?

1. 47.1
2. 48.0
3. 49.2
4. 49.8

13-54. What is the plasticity index of this soil sample?

1. 5.1
2. 5.5
3. 6.0
4. 7.2

13-55. The slump test measures what property of concrete?

1. Workability
2. Strength
3. Durability
4. Compressibility

13-56. To ensure a slump test specimen is a good representation of the concrete batch, you must take samples at two or more regularly spaced intervals during discharge from which portion of the batch?

1. First only
2. Middle only
3. First and middle
4. Last

13-57. In a slump test, each layer of concrete is rodded how many strokes?

1. 10
2. 15
3. 25
4. 30

13-58. When a slump test is performed, the entire procedure from the beginning of the sampling process through the removal of the slump cone from the specimen should NEVER exceed what maximum number of minutes?

1. 7½
2. 17½
3. 20
4. 22½

13-59. To what extent do the sampling procedures for cylinder specimens differ from those for slump tests?

1. Much different procedures are used
2. The same procedures are used
3. Nearly the same procedures are used, except that the samples are taken from the discharge of the first portion of the batch

13-60. When preparing standard size cylinder specimens, you should (a) fill the mold with what total number of layers, and (b) rod each layer with a total of how many strokes?

1. (a) 2 (b) 25
2. (a) 2 (b) 50
3. (a) 3 (b) 25
4. (a) 3 (b) so

13-61. When the maximum size of coarse aggregate is 3 inches, what should be the minimum cross-sectional dimensions of the beam specimen?

1. 6 in by 6 in
2. 6 in by 9 in
3. 9 in by 9 in
4. 9 in by 12 in

13-62. While the functions of all the other SEABEE ratings relate to the whole of a construction project, the EA's functions are related to only the site preparation and layout phases.

1. True
2. False

13-63. The responsibilities of an NMCB engineering division include which of the following tasks?

1. Providing as-built copies of drawings to customer activities
2. Maintaining construction project status boards
3. Both 1 and 2 above

13-64. The responsibilities of a battalion's monitoring/reporting division include which of the following tasks?

1. Maintaining project status records
2. Timekeeping and labor analysis
3. Preparing project completion letters
4. All of the above

13-65. The components of a PWD engineering division include which of the following branches?

1. Planning and estimating branch
2. Civil branch
3. Both 1 and 2 above
4. Inspection branch

13-66. A crew leader/supervisor who asks questions relative to assigned tasking is demonstrating weak leadership.

1. True
2. False

13-67. You are informed that your survey crew is not being efficient in performing assigned survey tasks. Which of the following conditions may be an underlying cause of this inefficiency?

1. Crew members were not properly briefed as to the scope of their assigned tasks
2. Each crew member did not understand his assigned responsibilities
3. The importance of assigned tasks in relation to overall mission of the unit was not emphasized
4. All of the above

13-68. Prints that are smaller than size B should be stored in a standard deep-drawer cabinet in which of the following ways?

1. On edge
2. Flat
3. Rolled
4. Folded

13-69. What is the final folded size of prints in accordion-pleat type of folds?

1. 8 3/8 by 10 7/8 inches
2. 8 1/2 by 11 inches
3. 8 3/4 by 11 inches
4. 9 by 11 inches

13-70. For easy reference, prints or drawings for active projects should be stored in which of the following ways?

1. In folders
2. In stick files
3. In deep-drawer cabinets
4. Rolled

13-71. Which of the following shore activities generally use the Standard Subject Identification Codes System for the filing of drawing records?

1. Public Works Centers
2. Naval Construction Battalion Centers
3. Naval Construction Regiments
4. All of the above

13-72. Which of the following information should always be recorded on the index card for your drawing files?

1. Drawing title and number
2. Cross-referenced correspondence relating to the drawing(s)
3. Name of agency that made the drawing
4. All of the above

13-73. As the librarian for the Engineering Technical Library, you are responsible for which of the following tasks?

1. Ensuring that the publications are all in their proper location
2. Maintaining an efficient check-out/check-in system
3. Taking action, as necessary, to ensure that any lost or missing required publications are obtained
4. All of the above

13-74. As an Engineering Aid, which of the following references should you consult to find all the requirements that you must satisfy for advancement to the next higher paygrade?

1. NAVEDTRA 10696
2. NAVFAC P-485
3. NAVEDTRA 71365
4. OPNAVINST 5110.4

13-75. Which of the following information does the Personnel Readiness Capability Program provide?

1. Information of skills of each crew member
2. Detailed personnel skill information to all levels of the Naval Construction Forces
3. Information to be used for better command and planning in matters of readiness, capability, training, and logistical support at all levels
4. All of the above