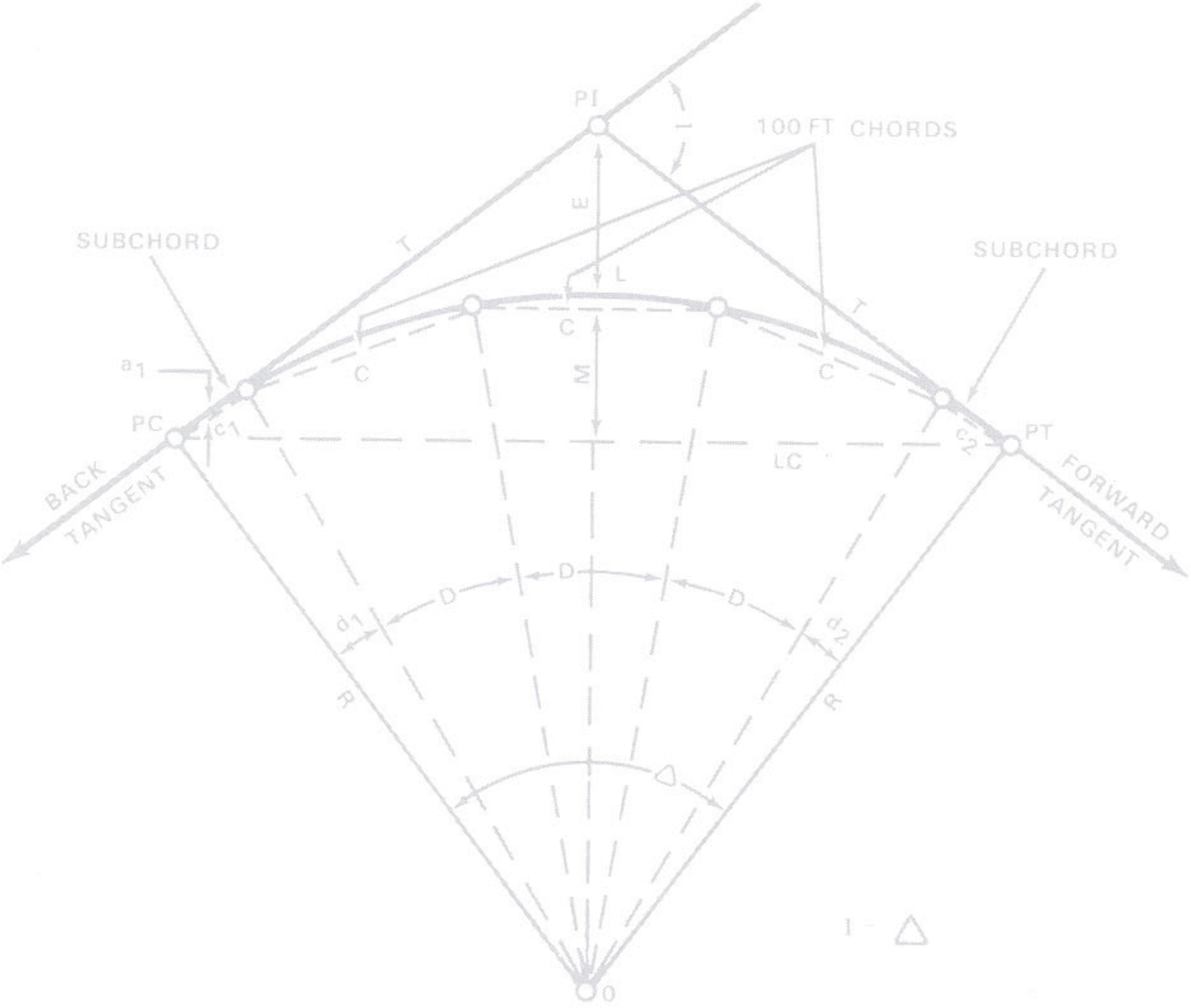
DEPARTMENT OF THE ARMY

FM 5-233

CONSTRUCTION SURVEYING



JANUARY 1985

DISTRIBUTION RESTRICTION. This publication contains technical or operational information that is for official Government use only. Distribution is limited to US Government agencies. Requests from outside the US Government for release of this publication under the Freedom of Information Act or the Foreign Military Sales Program must be made to HQ, TRADOC, Fort Monroe, VA 23651.

FIELD MANUAL
No. 5-233

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC, 4 JANUARY 1985

CONSTRUCTION SURVEYING

TABLE OF CONTENTS

This manual supersedes TM 5-233, 14 October 1968.

DISTRIBUTION RESTRICTION: Approved for public release; distribution is unlimited.

LIST OF FIGURES AND TABLES

Figures

Tables

Acknowledgements

Acknowledgement is made to the following associations and companies for their permission to use in this manual the text and tables listed below.

Pages 3-25 through 3-28 and table A-9, Functions of the Ten-Chord Spiral, from A.R.E.A. Manual, Volume I. Copyright 1911 and 1950 by the American Railway Engineering Association. Reprinted by permission of the American Railway Engineering Association.

Table A-7, Deflections and Chords for 25-, 50-, and 100-Foot Arcs, from Route Surveys and Constructions by Harry Rubey. Copyright 1956 by Harry Rubey. Reprinted by permission of the Macmillan Publishing Co., Inc.

PREFACE

Purpose and Scope

This manual is a guide for engineering personnel conducting surveys in support of military construction. In addition to mathematical considerations, this manual offers a comprehensive analysis of problems which are typical in military surveying. It may be used for both training and reference.

Application

The material contained in this manual is applicable without modification to both nuclear and nonnuclear warfare.

User Information

Users of this publication are encouraged to recommend changes and submit comments for its improvement. Comments should be keyed to the specific page, paragraph, and line of text in which the change is recommended. Reasons will be provided for each comment to insure understanding and complete evaluation. Comments should be prepared, using DA Form 2028 (Recommended Changes to Publications and Blank Forms), and forwarded directly to the Commandant, US Army Engineer School, ATTN: ATZA-TD-P, Fort Belvoir, Virginina 22060-5291.

CHAPTER 1

SURVEY OBJECTIVES

DUTIES OF THE CONSTRUCTION SURVEYOR

In support of construction activities, the surveyor obtains the reconnaissance and preliminary data which are necessary at the planning stage. During the construction phase, the surveyor supports the effort as needed. Typical duties of the construction surveyor include—

- Determining distances, areas, and angles.
- Establishing reference points for both horizontal and vertical control.
- Setting stakes or otherwise marking lines, grades, and principal points.
- Determining profiles of the ground along given lines (centerlines and/or cross-section lines) to provide data for cuts, fills, and earthwork volumes.
- Preparing large-scale topographic maps using plane table or transit-stadia data to provide information for drainage and site design.
- Laying out structures, culverts, and bridge lines.
- Determining the vertical and horizontal placement of utilities.

ACCURACY OF SURVEYS

The precision of measurements varies with the type of work and the purpose of a survey. Location surveys require more accuracy than reconnaissance surveys, and the erection of structural steel requires greater precision in measurement than the initial grading of a roadbed.

The officer or NCO in charge of a project usually determines the degree of accuracy. The surveyor makes a practical analysis and chooses appropriate methods and procedures for each type of measurement. The surveyor must consider the allowable time, the tactical situation, the capabilities of construction forces, and the current conditions. The best surveyor is the one who runs a survey to the order of precision which is required by the job with a minimum of time, not the one who insists on extreme precision at all times.

Surveyors must always be on the alert for probable cumulative or systematic errors, which could be the result of maladjustment or calibration of equipment or error-producing practices. Laying out the foundations for certain types of machinery and establishing angular limits for fire on training ranges are examples of conditions which might demand a high degree of precision from the surveyor.

For the most part, the construction surveyor will not have to work to the most precise limits of the equipment. However, the surveyor should recognize the limits of the validity in the results. The surveyor cannot expect resultant data to have a greater degree of accuracy than that of the least precise measurement involved. The surveyor must analyze both angular and linear measurements, which are a part of the survey problem, in order to maintain comparable precision throughout.

FIELD NOTES

The quality and character of the surveyor's field notes are as important as the use of instruments. The comprehensiveness, neatness, and reliability of the surveyor's field notes measure ability. Numerical data, sketches, and explanatory notes must be so clear that they can be interpreted in only one way, the correct way. Office entries, such as computed or corrected values, should be clearly distinguishable from original material. This is often done by making office entries in red ink. Some good rules to follow in taking field notes are—

- Use a sharp, hard pencil (4H preferred).
- Do not crowd the data entered. Use additional pages.
- Keep sketches plain and uncluttered.
- Record numerical values so they always indicate the degree of precision to which a measurement is taken. For example, rod readings taken to the nearest 0.01 foot should be recorded as 5.30 feet, not as 5.3 feet.
- Use explanatory notes to supplement numerical data and sketches. These notes often replace sketches and are usually placed on the right-hand page on the same line as the numerical data they explain.
- Follow the basic note-keeping rules covered in TM 5-232.

METRIC SYSTEM

The military surveyor may work from data based upon the metric system of measurement or convert data into metric equivalents. Tables A-13 and A-14 in appendix A provide metric conversions.

CHAPTER 2

ROAD SURVEYING

Section I. RECONNAISSANCE SURVEY

PREPARATION AND SCOPE

The reconnaissance survey is an extensive study of an entire area that might be used for a road or airfield. Its purpose is to eliminate those routes or sites which are impractical or unfeasible and to identify the more promising routes or sites.

Existing maps and aerial photographs may be of great help. Contour maps show the terrain features and the relief of an area. Aerial photographs show up-to-date planimetric details.

The reconnaissance survey must include all possible routes and sites. The reconnaissance survey report should summarize all the collected information, including a description of each route or site, a conclusion on the economy of its use, and, where possible, appropriate maps and aerial photographs.

Design

Design and military characteristics should be considered during the reconnaissance survey. Keep in mind that future operations may require an expanded road net. A study of the route plans and specifications is necessary. If these are unavailable, use the following as guides.

- Locate portions of the new road along or over existing roads, railroads, or trails, whenever possible.
- Locate the road on high-bearing-strength soil that is stable and easily drained, avoiding swamps, marshes, and organic soil.
- Locate the road along ridges and streamlines, keeping drainage structures to a minimum. Keep the grade well above the high waterline when following a stream.
- Select a route as near to sources of material as practical, and locate the road along contour lines to avoid unnecessary earth work.
- Locate the road on the sunny side of hills and canyons, and on that side of the canyon wall where the inclination of the strata tends to support the road rather than cause the road to slide into the canyon.
- Locate roads in forward combat zones so that they are concealed and protected from enemy fire. This may at times conflict with engineering considerations.
- Select locations which conserve engineer assets, avoiding rockwork and excessive clearing.
- Avoid sharp curves and locations which involve bridging.

Roadway Criteria

To insure satisfactory results, study the engineering specifications of the road to be built. If these are not available, use the information provided in table 2-1.

Table 2-1. Road specifications

WIDTHS

One-way road—11.5 feet or 3.5 meters minimum.

Two-way road—23 feet or 7.0 meters minimum.

Shoulders (each side)—4 feet or 1.5 meters minimum.

Clearing—6 feet or 2 meters each side of roadway.

GRADES

Absolute maximum—determined by the lowest maximum gradeability of vehicles using the road.

Normal maximum—10 percent.

Desired maximum—less than 6 percent; on sharp curves, less than 4 percent.

HORIZONTAL CURVES

Desired minimum radius—150 feet or 46 meters.

Absolute minimum radius—80 feet or 25 meters.

VERTICAL CURVES

Minimum length on hill summits—125 feet or 40 meters per 4 percent algebraic difference in grades.

Minimum length in hollows—100 feet or 30 meters per 4 percent algebraic difference in grades.

SIGHT DISTANCES

Absolute nonpassing minimum—200 feet or 60 meters.

Absolute passing minimum—350 feet or 110 meters.

SLOPES

Shoulders—¾ inch per foot (in/ft) or 6 percent.

Crown (gravel and dirt)—½ to ¾ in/ft or 4 to 6 percent.

Crown (paved)—¼ to ½ in/ft or 2 to 4 percent.

Cut and fill—variable, but normally about 1 ½ to 1.

DRAINAGE

Take advantage of natural drainage.

Locate above high waterline near streams or creeks.

Grade at least 5 feet or 1.6 meters above groundwater table.

TRAFFIC

Overhead clearance—14 feet or 4.3 meters minimum.

Traffic volume—2,000 vehicles per lane per day.

Load capacity—sustain 18,000 pound equivalent axle load.

Turnouts (single lane)—minimum every ¼ mile or 0.4 kilometers recommended.

COLLECTION OF DATA

Upon completion, the reconnaissance survey should support the routes surveyed and provide a basis of study showing the advantages and disadvantages of all routes reconnoitered. Typical data collected in a reconnaissance survey are—

- Sketches of all routes reconnoitered.
- Reports of feasible routes. Data on clearing and grubbing.
- The number of stream crossings involving bridge spans exceeding 20 feet or 6 meters.
- The approximate number of culverts and spans less than 20 feet or 6 meters.
- Descriptions and sizes of marsh areas and other natural obstacles.
- Unusual grade and alignment problems encountered.
- Anticipated effects of landslides, melting snow, and rainfall.
- Soil conditions and stream and substrata conditions at proposed bridge sites.
- Discrepancies noted in maps or aerial photographs.
- Availability of local materials, equipment, transportation facilities, and labor.
- Photographs or sketches of reference points, control points, structure sites, terrain obstacles, and any unusual conditions.

USE OF MAPS

The procurement of maps is a very important phase of the reconnaissance. The surveyor should locate and use all existing maps, including up-to-date aerial photographs of the area to be reconnoitered. Large scale topographic maps are desirable because they depict the terrain in the greatest detail. The maps, with overlays, serve as worksheets for plotting trial alignments and approximate grades and distances.

The surveyor begins a map study by marking the limiting boundaries and specified terminals directly on the map. Between boundaries and specified terminals, the surveyor observes the existing routes, ridge lines, water courses, mountain gaps, and similar control features. The surveyor must also look for terrain which will allow moderate grades, simplicity of alignment, and a balance between cut and fill.

After closer inspection, the routes that appear to fit the situation are classified. As further study shows disadvantages of each route, the surveyor lowers the classification. The routes to be further reconnoitered in the field are marked using pencils of different colors to denote priority or preference. Taking advantage of the existing terrain conditions to keep excavation to a minimum, the surveyor determines grades, estimates the amount of clearing to be done on each route, and marks stream crossings and marsh areas for possible fords, bridges, or culvert crossings.

Section II. PRELIMINARY SURVEY

PREPARATION AND SCOPE

The preliminary survey is a detailed study of a route tentatively selected on the basis of reconnaissance survey information and recommendations. It runs a traverse along a proposed route, establishes levels, records topography, and plots results. It also determines the final location from this plot or preliminary map. The size and scope of the project will determine the nature and depth of the preliminary survey for most military construction.

PERSONNEL

The survey effort establishes a traverse with control and reference points, or it may expand to include leveling and topographic detail. Normally, obtaining the traverse, leveling, and topographic data are separate survey efforts, but this does not preclude combining them to make the most efficient use of personnel and equipment.

Traverse Party

The traverse party establishes the traverse line along the proposed route by setting and referencing control points, measuring distances, numbering stations, and establishing points of intersection. The party also makes the necessary ties to an existing control, if available or required. When no control is available, the party may assign a starting value for control purposes which can later be tied to a control point established by geodetic surveyors.

Level Party

The level party establishes benchmarks and determines the elevation of selected points along the route to provide control for future surveys, such as the preparation of a topographic map or profile and cross-section leveling. The level party takes rod readings and records elevations to the nearest 0.01 foot or 0.001 meter. It sets the benchmarks in a place well out of the area of construction and marks them in such a way that they will remain in place throughout the whole project.

If there is no established vertical control point available, establish an arbitrary elevation that may be tied to a vertical control point later. An assigned value for an arbitrary elevation must be large enough to avoid negative elevations at any point on the project.

Topographic Party

The topographic party secures enough relief and planimetric detail within the prescribed area to locate any obstacles and allow preparation of rough profiles and cross sections. Computations made from the data determine the final location. The instruments and personnel combinations used vary with survey purpose, terrain, and available time. A transit-stadia party, plane table party, or combination of both may be used.

Transit-Stadia Party. The transit-stadia party is effective in open country where comparatively long, clear sights can be obtained without excessive brush cutting.

Plane Table Party. The plane table party is used where terrain is irregular. For short route surveys, the procedure is much the same as in the transit-stadia method, except that the fieldwork and the drawing of the map are carried on simultaneously.

Section III. FINAL LOCATION SURVEY

PREPARATION AND SCOPE

Prior to the final location survey, 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 are made and used as guidance for the final location phase. The instrument party carefully establishes the final location in the field using the paper location prepared from the preliminary survey. The surveyor should not make any changes without the authority of the officer-in-charge.

RUNNING THE CENTERLINE

The centerline may vary from the paper location due to objects or conditions that were not previously considered. The final centerline determines all the construction lines. The surveyor marks the stations, runs the levels, and sets the grades.

The centerline starts at station 0+00. The surveyor numbers the stations consecutively and sets them at the full 100-foot or 30-meter stations. The surveyor also sets stakes at important points along the centerline. These may be culvert locations, road intersections, beginnings and ends of curves, or breaks in the grade. When measurements are made in feet, these stations are numbered from the last full station (+00). They are called plus stations. A station numbered 4+44.75 would be 44.75 feet away from station 4+00 and 444.75 feet from the beginning of the project.

When using the metric system, the total distance from the beginning of the project would be 135.56 meters and would be numbered 135.56.

REFERENCE STAKES

Referencing of stations is described in TM 5-232.The control points established by the location survey determine the construction layout. Therefore, these points must be carefully referenced. The surveyor should set the control point references far enough from the construction to avoid disturbance.

PROFILE AND CROSS SECTIONS

After the centerline of the road, including the horizontal curves, has been staked, the next step in the road layout is the determination of elevations along the centerline and laterally across the road. The surveyor performs these operations, known as profile leveling and cross-section leveling, as separate operations but at the same time as the elevation of points along a centerline or other fixed lines.

The interval usually coincides with the station interval, but shorter intervals may be necessary due to abrupt changes in terrain. The plotting of centerline elevations is known as a profile. From this profile, the design engineer determines the grade of the road.

The cross-section elevations make it possible to plot views of the road across the road at right angles. These plotted cross sections determine the volume of earthwork to be moved. The surveyor establishes the cross-section lines at regular stations, at any plus station, and at intermediate breaks in the ground and lays out the short crosslines by eye and long crosslines at a 90-degree angle to the centerline with an instrument.

All elevations at abrupt changes or breaks in the ground are measured with a rod and level, and distances from the centerline are measured with a tape. In rough country, the surveyor uses the hand level to obtain cross sections if the centerline elevations have been determined using the engineer level.

Section IV. CONSTRUCTION LAYOUT SURVEY

PREPARATION AND SCOPE

The construction layout is an instrument survey. It provides the alignment, grades, and locations which guide the construction operations. The construction operations include clearing, grubbing, stripping, drainage, rough grading, finish grading, and surfacing. The command must keep the surveyors sufficiently ahead of the construction activity in both time and distance to guarantee uninterrupted progress of the construction effort. Note the following suggested distances.

- Keep centerline established 1,500 feet or 450 meters ahead of clearing and grubbing.
- Keep rough grade established and slope stakes set 1,000 feet or 300 meters ahead of stripping and rough grading.
- Set stakes to exact grade, 500 feet or 150 meters ahead of finish grading and surfacing.

ALIGNMENT

The surveyor must place the alignment markers ahead of the crews engaged in the various phases of construction. The surveyor may do a hasty alignment, marked by flags and rods, suitable for guiding the clearing and grubbing operations. However, a deliberate location of the centerline is necessary for the final grading and surfacing operations.

The surveyor marks the curves and minor structures concurrently with the layout of the centerline. Major structures such as tunnels and bridges involve a site survey. The general demarcation of the site boundaries is carried on with the establishment of the route alignment. The layout of the site proper is a separate survey.

SETTING GRADE STAKES

Grade stakes indicate the exact grade elevation to the construction force. The surveyor consults the construction plans to determine the exact elevation of the subgrade and the distance from the centerline to the edges of the shoulder.

Preliminary Subgrade Stakes

The surveyor sets preliminary subgrade stakes on the centerline and other grade lines, as required. First, the surveyor determines the amount of cut or fill required at the centerline station. The amount of cut or fill is equal to the grade rod minus the ground rod. The grade rod is equal to the height of instrument minus the subgrade elevation at the station. The ground rod is the foresight reading at the station. If the result of this computation is a positive value, it indicates the amount of cut required. If it is negative, it indicates the amount of fill.

For example, given a height of instrument (HI) of 115.5 feet, a subgrade elevation of 108.6 feet, and a ground rod reading of 3.1 feet, the grade rod = 115.5 feet -108.6 = +6.9 and cut or fill = 6.9 -3.1 = +3.8, indicating a cut of 3.8 feet. The surveyor records the result in the field notes and on the back of the grade stake as $C\,3^{\underline{8}}$ (figure 2-1, example a). Sometimes, it is necessary to mark stakes to the nearest whole or half foot to assist the earthmoving crew. In the example given, the surveyor would measure up 0.2 foot on the stake and mark it as in figure 2-1, example b. If at this stake a fill of 3.8 feet was required, the surveyor would measure up 0.3 foot and mark the stake as in figure 2-1, example c. Figure 2-1, example d, shows a case where the actual subgrade alignment could be marked on the stake. The number under the cut or fill represents the distance the stake is from the road centerline. The surveyor normally makes rod readings and computations to the nearest 0.1 foot or 0.01 meter.

During rough grading operations, the construction crew determines the grades for the edges of the traveled way, roadbed, and ditch lines. However, if the road is to be superelevated or is in rough terrain, the survey crew must provide stakes for all grade lines. These would include the centerline, the edge of the traveled way, the edges of the roadbed, and possibly, the centerline of the ditches. The surveyor sets those stakes by measuring the appropriate distance off the centerline and determines the amount of cut or fill as outlined. The surveyor offsets the stakes along the traveled way, roadbed, and ditches to avoid their being destroyed during grading operations. The construction foreman, not the surveyor, makes the decision as to how many and where grade stakes are required.

Final Grade Stakes

Once the rough grading is completed, the surveyor sets the final grade stakes (blue tops). The elevation of the final grade is determined and the value of the grade rod reading is computed. The surveyor uses a rod target to set the grade rod reading on the rod. The rod is held on the top of the stake. The stake is driven into the ground until the horizontal crosshair bisects the target and the top of the stake is at final grade. The surveyor marks the top of the stake with a blue lumber crayon to distinguish it from other stakes.

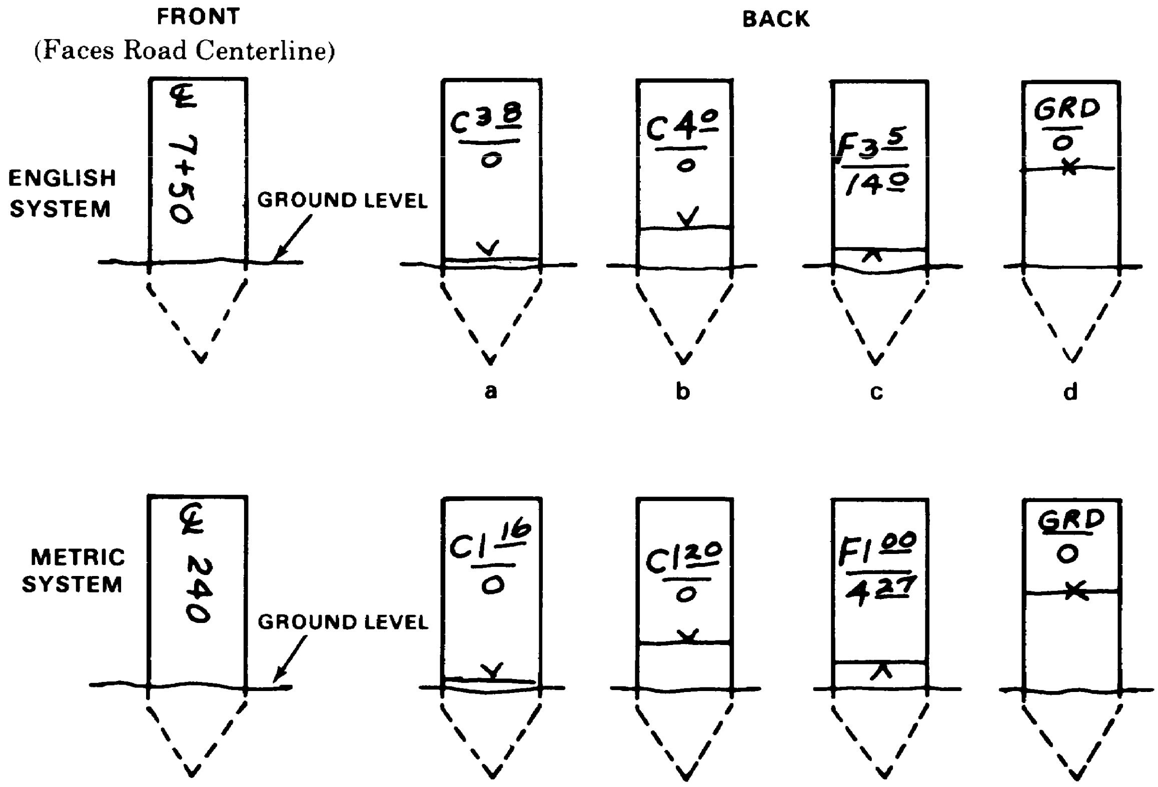


Figure 2-1. Grade stakes

The surveyor should provide blue tops on all grade lines. However, the final decision as to what stakes are required lies with the construction foreman. To set final grade, the surveyor normally makes rod readings and computations to 0.01 foot or 0.001 meter.

Special Cases

Where grade stakes cannot be driven, as in hard coral or rock areas, the surveyor must use ingenuity to set and preserve grade markings under existing conditions. Often, such markings are made on the rock itself with a chisel or a lumber crayon.

SETTING SLOPE STAKES

Slope stakes indicate the intersection of cut or fill slopes with the natural groundline. They indicate the earthwork limits on each side of the centerline.

Level Section

When the ground is level transversely to the centerline of the road, the cut or fill at the slope stake will be the same as at the center, except for the addition of the crown. On fill sections, the distance from the center stake to the slope stake is determined by multiplying the center cut by the ratio of the slope (for example, horizontal distance to vertical distance) of the side slopes and adding one half the width of the roadbed. On cut sections, the surveyor can find the distance from the center stake to the slope stake by multiplying the ratio of slope by the center cut and adding the distance from the centerline to the outside edge of the ditch.

In either case, if the ground is level, the slope stake on the right side of the road will be the same distance from the centerline as the one on the left side of the road. On superelevated sections, the surveyor must add the widening factor to determine the distance from the centerline to the slope stake. This is because the widening factor is not the same for both sides of the road, and the slope stakes will not be the same distance from the centerline.

Transversely Sloping Ground

When the ground is not level transversely, the cut or fill will be different for various points depending upon their distance from the centerline. The surveyor must determine the point, on each side of the centerline, whose distance from the center is equal to the cut or fill at that point multiplied by the slope ratio and added to one half the roadbed width for fills, and the slope ratio multiplied by the distance from the centerline to the outside of the ditches for cuts.

A trial and error method must be used. The surveyor will soon attain proficiency in approximating the correct position of the slope stake, and the number of trials can generally be reduced to two or three. The surveyor will mark the cut or fill on the slope stake and record it in the notebook as the numerator of a fraction whose denominator is the distance out from the centerline. Three-level, five-level, and irregular sections present this problem. Figures 2-2 through 2-5 illustrate the procedure involved in setting slope stakes on sloping ground for three typical cases.

Cut Section

The cut section in figure 2-2 has the level set up with an HI of 388.3 feet. The subgrade elevation at this centerline station is set at 372.5 feet for a 23-foot roadbed with 1.5:1 side slopes, 4-foot shoulders, and 7-foot ditches. The “grade rod” is the difference between these two elevations or 388.3 -372.5 = +15.8 feet. The rodman now holds the rod on the ground at the foot of the center grade stake and obtains a reading of 6.3 feet, a “ground rod.” The recorder subtracts 6.3 from the grade rod of 15.8, which gives +9.5 feet or a center cut of 9.5 feet. On slope stakes, the cut or fill and the distance out from the centerline are written facing the center of the road. The backs of the slope stakes show the station and the slope ratio to be used.

The recorder estimates the trial distance by multiplying the cut at the centerline (9.5) by the slope ratio (1.5) and adding the distance from the centerline to the outside edge of the ditch (22.5).

9.5 x 1.5+ 22.5= 36.8 (to the nearest tenth of a foot)

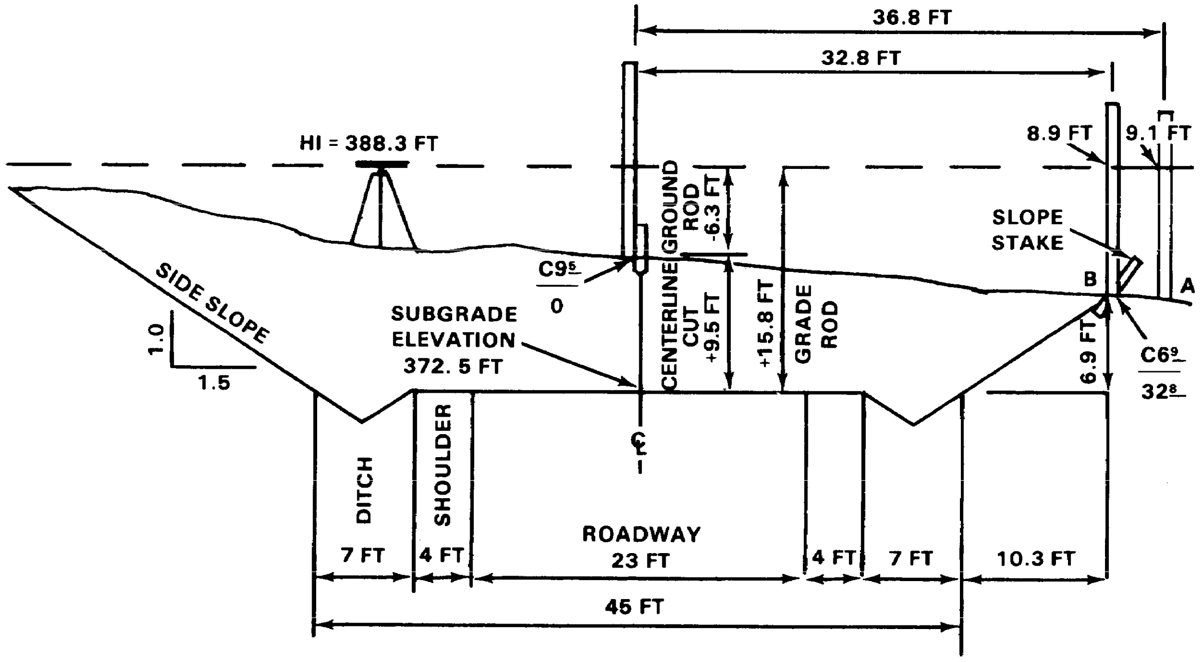


Figure 2-2. Setting slope stakes

The rodman now moves to the right at right angles to the centerline the trial distance (36.8 feet). The rod is held at A and a reading of 9.1 is obtained, which, when subtracted from the grade rod of 15.8, gives a cut of 6.7 feet. The recorder then computes what the distance from the centerline to A should be. This is done by multiplying the cut of 6.7 by the slope ratio and adding one half the roadbed width, which gives 32.6 feet.

However, the distance to A was measured as 36.8 feet instead of 32.6, so the position at A is too far from the centerline. Another trial is made by moving the rod to 32.6 feet from the centerline (B), where a reading of 8.9 is made. The cut at B is now 15.8- 8.9= +6.9, and the calculated distance from the center is 6.9 x 1.5 + 22.5 = 32.8 feet. The distance actually measured is 32.8 feet. Therefore, B is the correct location of the slope stake and is marked C6^{9}. Since moving the rod one or two tenths of a foot would not materially change its reading, greater accuracy is unnecessary. After a few trials, the rodman locates the slope stake on the left in a similar manner. The instrumentman verifies the figures by computation. When placed in the ground, the stakes will appear as in figure 2-3.

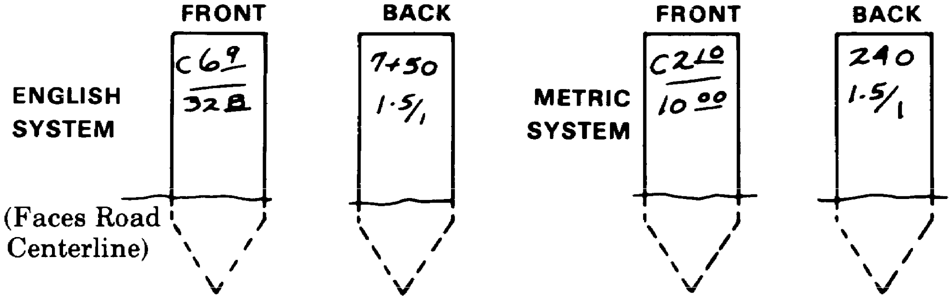


Figure 2-3. Marking slope stakes

Fill Section (HI Above Grade Elevation)

Figure 2-4 illustrates a fill with the HI of the level set up above the subgrade elevation of the 31-foot roadbed. In this case, the grade rod will always be less, numerically, than rod readings on the ground. The grade rod in this problem is +2.8; the rod reading at the center stake is 6.5; and the difference is 2.8-6.5= -3.7 feet. The minus sign indicates a center fill. The rodman finds the positions of the slope stakes by trial, as previously explained.

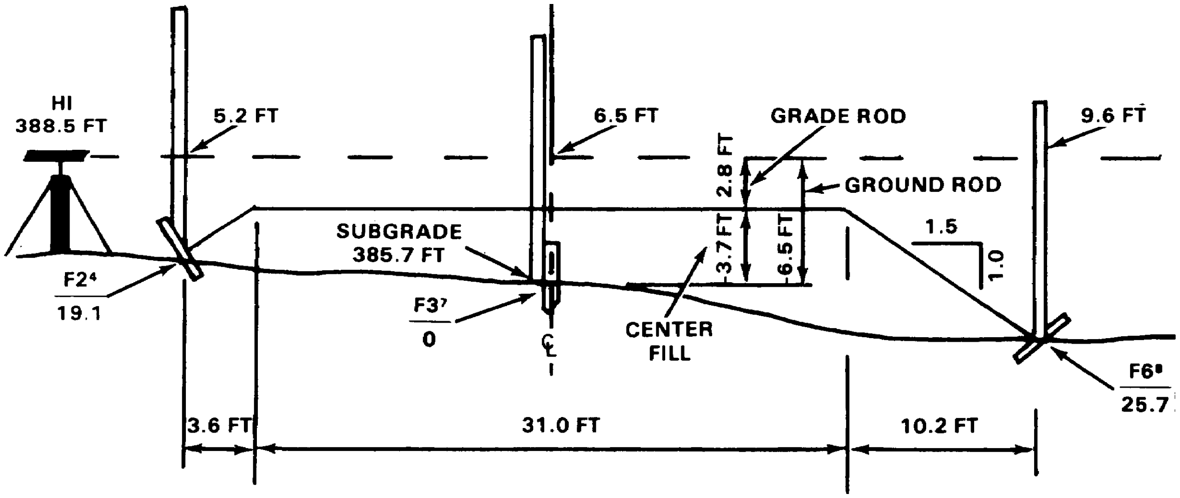


Figure 2-4. Slope stakes (HI above grade elevation)

Fill Section (HI Below Grade Elevation)

Figure 2-5 illustrates a fill with the HI of the level below the grade elevation of the future roadbed. Therefore, the grade rod has a negative value. Adding the negative ground rod to the negative grade rod will give a greater negative value for the fill. For example, at the center stake, the fill equals (-2.40 meters) + (-2.35 meters) or -4.75 meters. Otherwise, this case is similar to the preceding ones.

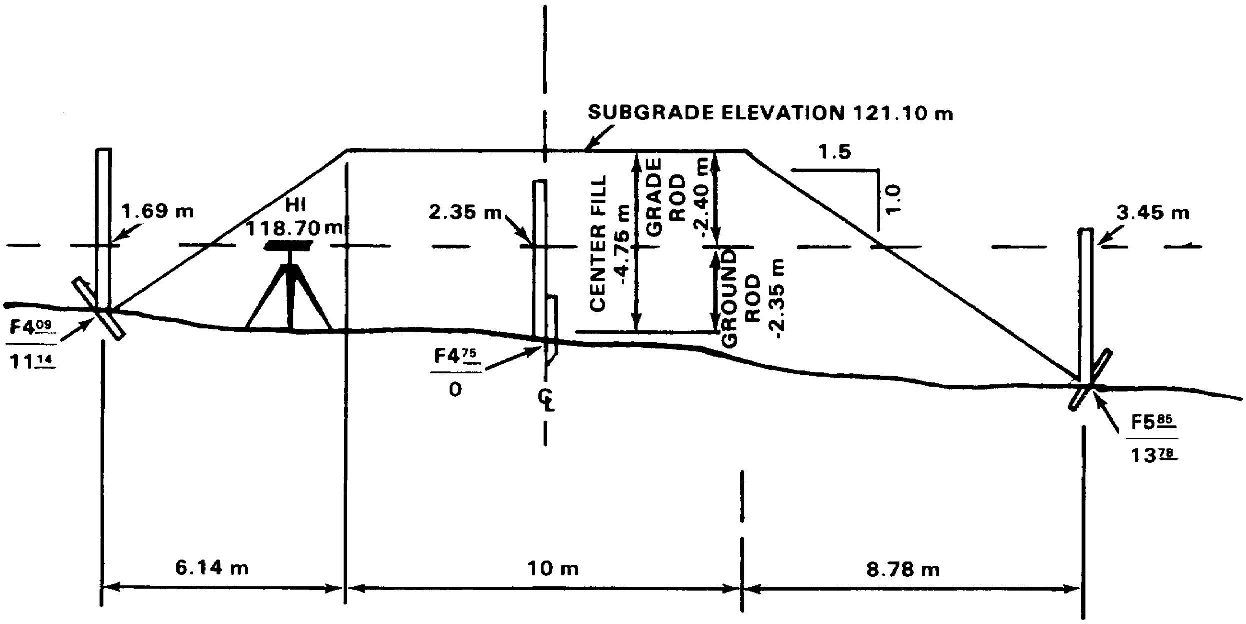


Figure 2-5. Slope stakes (HI below grade elevation)

CULVERT LOCATION

To establish the layout of a site such as a culvert, the surveyor locates the intersection of the roadway centerline and a line defining the direction of the culvert. Generally, culverts are designed to conform with natural drainage lines. The surveyor places stakes to mark the inlet and outlet points, and any cut or fill, if needed, is marked on them. The construction plans for the site are carefully followed, and the alignment and grade stakes are set on the centerlines beyond the work area. Thus, any line stake which is disturbed or destroyed during the work can be replaced easily.

The surveyor should also set a benchmark near the site, but outside of the work area, to reestablish grades. Figure 2-6 shows atypical layout for a culvert site. Circumstances or practical considerations may dictate that certain types of surveys will be eliminated or combined. For example, the location and construction surveys may be run simultaneously. (Refer to TM 5-330.)

DRAINAGE

The construction of drainage facilities is an important part of any project. The surveyor must anticipate drainage problems and gather enough field data to indicate the best design and location for needed drainage structures. (Refer to TM 5-330.)

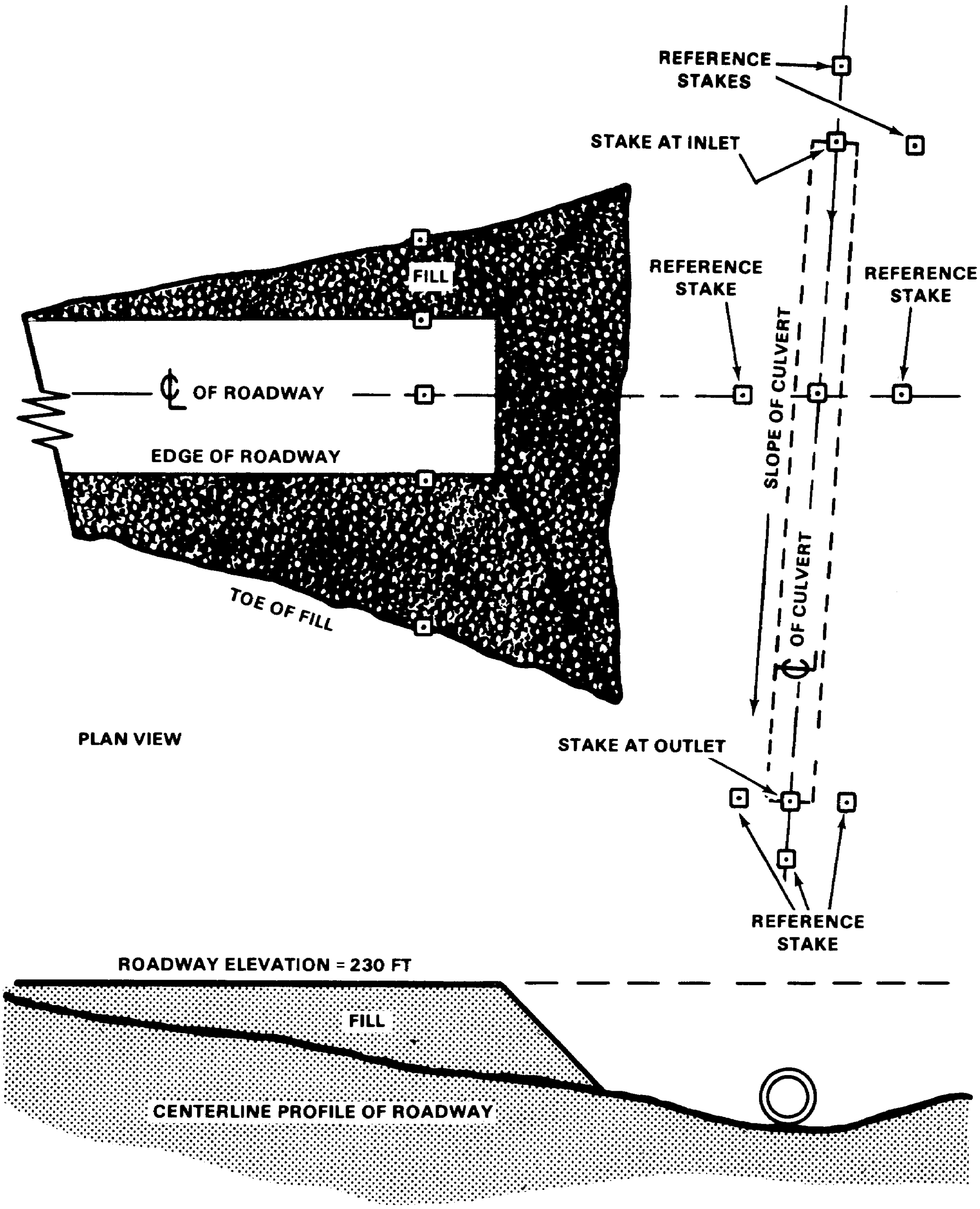


Figure 2-6. Layout of a culvert

The problem of adequate drainage is important to the location, design, and construction of almost any type of military installation. Proper drainage is of primary importance with respect to the operational requirements and the desired useful life of an installation. Inadequate drainage causes most road and airfield failures. The surveyor must see that these and similar facilities are well drained to function efficiently during inclement weather. Temporary drainage during construction operations cannot be ignored since it is vital to prevent construction delays due to standing water or saturated working areas.

Proper drainage is an essential part of road construction. Poor drainage results in mud, washouts, and heaves, all of which are expensive in terms of delays and repairs to both roads and vehicles.

CHAPTER 3

CURVES

Section I. SIMPLE HORIZONTAL CURVES

CURVE POINTS

By studying TM 5-232, the surveyor learns to locate points using angles and distances. In construction surveying, the surveyor must often establish the line of a curve for road layout or some other construction.

The surveyor can establish curves of short radius, usually less than one tape length, by holding one end of the tape at the center of the circle and swinging the tape in an arc, marking as many points as desired.

As the radius and length of curve increases, the tape becomes impractical, and the surveyor must use other methods. Measured angles and straight line distances are usually picked to locate selected points, known as stations, on the circumference of the arc.

TYPES OF HORIZONTAL CURVES

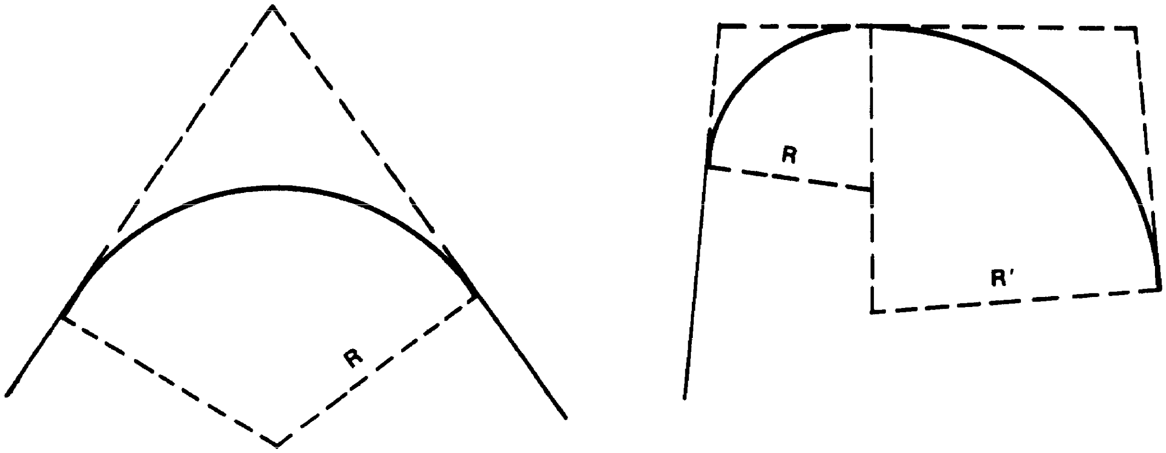
A curve may be simple, compound, reverse, or spiral (figure 3-l). Compound and reverse curves are treated as a combination of two or more simple curves, whereas the spiral curve is based on a varying radius.

Simple

The simple curve is an arc of a circle. It is the most commonly used. The radius of the circle determines the “sharpness” or “flatness” of the curve. The larger the radius, the “flatter” the curve.

Compound

Surveyors often have to use a compound curve because of the terrain. This curve normally consists of two simple curves curving in the same direction and joined together.



SIMPLE CURVE

COMPOUND CURVE

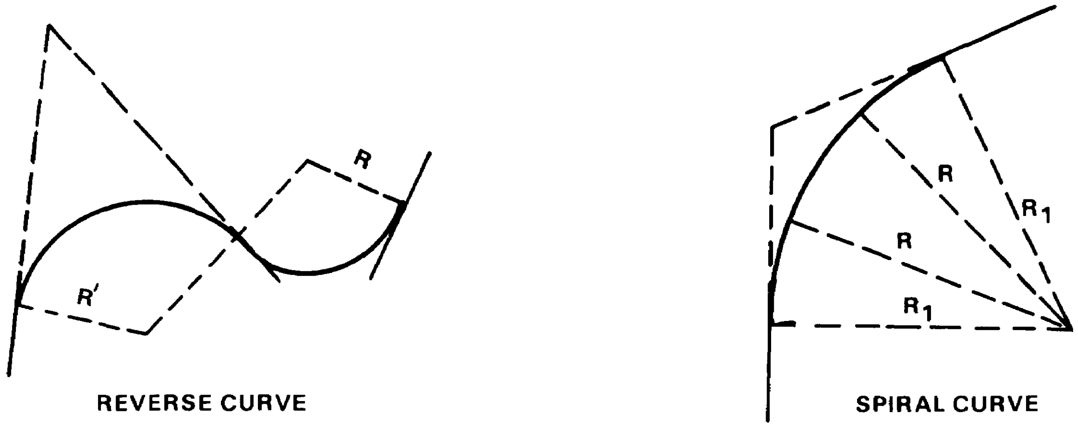
Figure 3-1. Horizontal curves

Reverse

A reverse curve consists of two simple curves joined together but curving in opposite directions. For safety reasons, the surveyor should not use this curve unless absolutely necessary.

Spiral

The spiral is a curve with varying radius used on railroads and somemodern highways. It provides a transition from the tangent to a simple curve or between simple curves in a compound curve.



REVERSE CURVE

SPIRAL CURVE

Figure 3-1. Horizontal curves (continued)

STATIONING

On route surveys, the surveyor numbers the stations forward from the beginning of the project. For example, 0+00 indicates the beginning of the project. The 15+52.96 would indicate a point 1,552,96 feet from the beginning. A full station is 100 feet or 30 meters, making 15+00 and 16+00 full stations. A plus station indicates a point between full stations. (15+52.96 is a plus station.) When using the metric system, the surveyor does not use the plus system of numbering stations. The station number simply becomes the distance from the beginning of the project.

ELEMENTS OF A SIMPLE CURVE

Figure 3-2 shows the elements of a simple curve. They are described as follows, and their abbreviations are given in parentheses.

Point of Intersection (PI)

The point of intersection marks the point where the back and forward tangents intersect. The surveyor indicates it one of the stations on the preliminary traverse.

Intersecting Angle (I)

The intersecting angle is the deflection angle at the PI. The surveyor either computes its value from the preliminary traverse station angles or measures it in the field.

Radius (R)

The radius is the radius of the circle of which the curve is an arc.

Point of Curvature (PC)

The point of curvature is the point where the circular curve begins. The back tangent is tangent to the curve at this point.

Point of Tangency (PT)

The point of tangency is the end of the curve. The forward tangent is tangent to the curve at this point.

Length of Curve (L)

The length of curve is the distance from the PC to the PT measured along the curve.

Tangent Distance (T)

The tangent distance is the distance along the tangents from the PI to the PC or PT. These distances are equal on a simple curve.

Central Angle (Δ)

The central angle is the angle formed by two radii drawn from the center of the circle (0) to the PC and PT. The central angle is equal in value to the I angle.

Long Chord (LC)

The long chord is the chord from the PC to the PT.

External Distance (E)

The external distance is the distance from the PI to the midpoint of the curve. The external distance bisects the interior angle at the PI.

Middle Ordinate (M)

The middle ordinate is the distance from the midpoint of the curve to the midpoint of the long chord. The extension of the middle ordinate bisects the central angle.

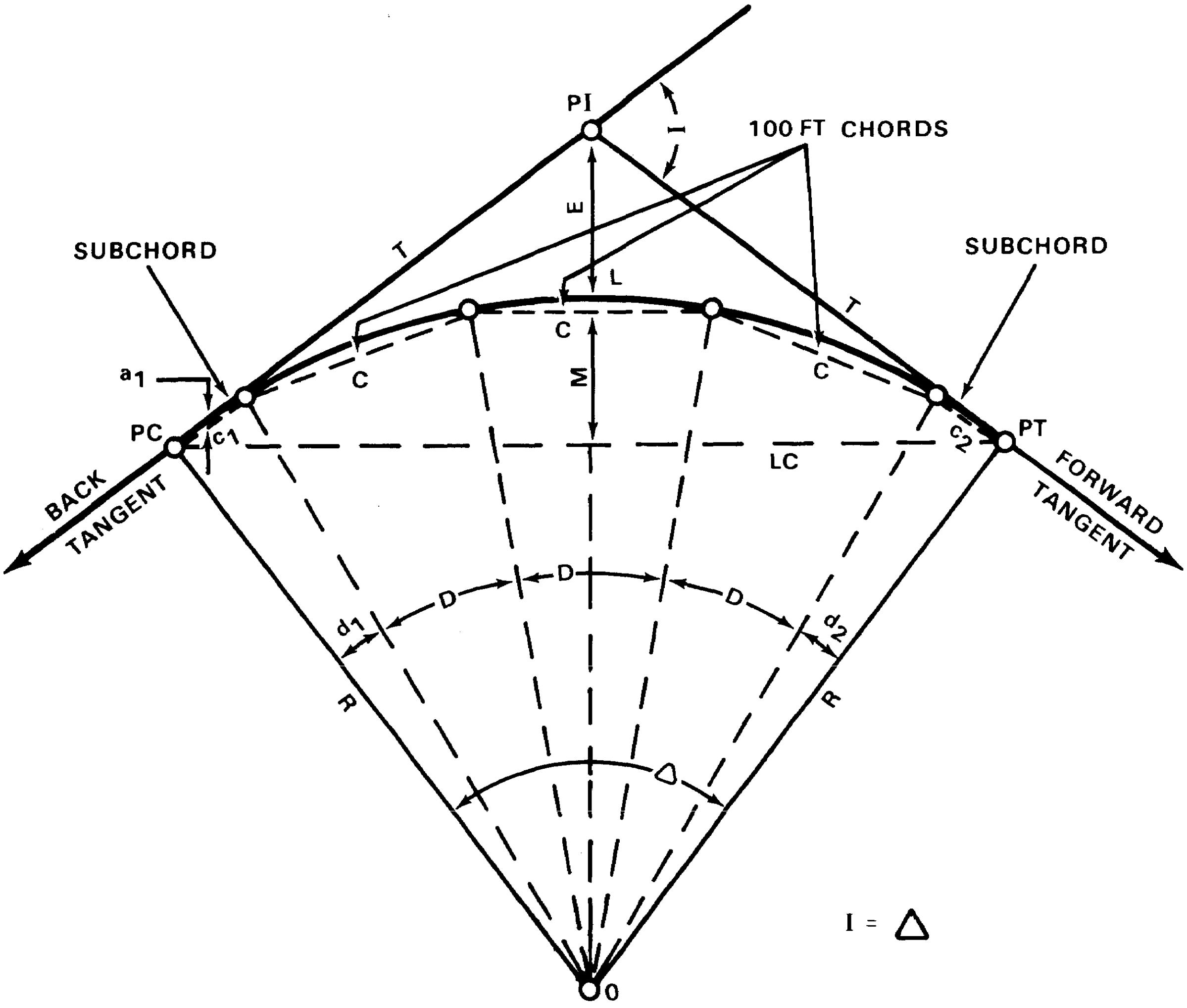
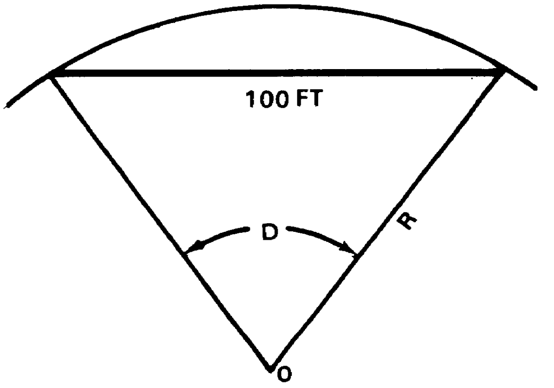


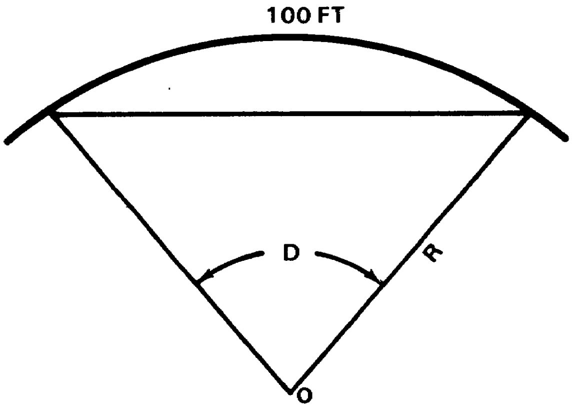
Figure 3-2. Elements of a simple curve

Degree of Curve (D)

The degree of curve defines the “sharpness” or “flatness” of the curve (figure 3-3). There are two definitions commonly in use for degree of curve, the arc definition and the chord definition.



CHORD definition



ARC definition

Figure 3-3. Degree of curve

Arc definition. The arc definition states that the degree of curve (D) is the angle formed by two radii drawn from the center of the circle (point O, figure 3-3) to the ends of an arc 100 feet or 30.48 meters long. In this definition, the degree of curve and radius are inversely proportional using the following formula:

$$\frac{\text{Degree of Curve}}{360^\circ} :: \frac{\text{Length of Arc}}{\text{Circumference}}$$

$$\text{Circumference} = 2\,\pi\ \text{Radius}$$

$$\pi = 3.141592654$$

As the degree of curve increases, the radius decreases. It should be noted that for a given intersecting angle or central angle, when using the arc definition, all the elements of the curve are inversely proportioned to the degree of curve. This definition is primarily used by civilian engineers in highway construction.

English system. Substituting D = 1^0 and length of arc = 100 feet, we obtain—

$$\frac{1^\circ}{360^\circ} :: \frac{100}{2\pi R} = \frac{1}{360} :: \frac{100}{6.283185308\ R}$$

Therefore, R = 36,000 divided by 6.283185308
R = 5,729.58 ft

Metric system. In the metric system, using a 30.48-meter length of arc and substituting D = 1°, we obtain—

$$\frac{1^\circ}{360^\circ} :: \frac{30.48}{2\pi R} = \frac{1}{360} :: \frac{30.48}{6.283185308\ R}$$

Therefore, R = 10,972.8 divided by 6.283185308
R = 1,746.38 m

Chord definition. The chord definition states that the degree of curve is the angle formed by two radii drawn from the center of the circle (point O, figure 3-3) to the ends of a chord 100 feet or 30.48 meters long. The radius is computed by the following formula:

$$R = \frac{50\text{ ft}}{\text{Sin } \frac{1}{2}\text{ D}} \text{ or } \frac{15.24\text{ m}}{\text{Sin } \frac{1}{2}\text{ D}}$$

The radius and the degree of curve are not inversely proportional even though, as in the arc definition, the larger the degree of curve the “sharper” the curve and the shorter the radius. The chord definition is used primarily on railroads in civilian practice and for both roads and railroads by the military.

English system. Substituting D = 1^0 and given Sin ½ 1 = 0.0087265355.

$$R = \frac{50ft}{\sin \frac{1}{2} D} \text{ or } \frac{50}{0.0087265355}$$

R = 5,729.65 ft

Metric system. Using a chord 30.48 meters long, the surveyor computes R by the formula

$$R = \frac{15.24\ m}{0.0087265355}$$

Substituting D = 1° and given Sin ½ 1^0= 0.0087265335, solve for R as follows:

$$R = \frac{15.24}{0.0087265355}$$

R = 1,746.40 m

Chords

On curves with long radii, it is impractical to stake the curve by locating the center of the circle and swinging the arc with a tape. The surveyor lays these curves out by staking the ends of a series of chords (figure 3-4). Since the ends of the chords lie on the circumference of the curve, the surveyor defines the arc in the field. The length of the chords varies with the degree of curve. To reduce the discrepancy between the arc distance and chord distance, the surveyor uses the following chord lengths:

Degree of Curve		Radius Feet	Radius Meters	Chord Feet	Lengths Meters
from	1 - 3	5,730 - 1,910	1,745 - 585	100	30
	3 - 8	1,910 - 720	585 - 220	50	15
	8 - 16	720 - 360	220 - 110	25	7.5
over	16	360 - 150	110 - 45	10	3

The chord lengths above are the maximum distances in which the discrepancy between the arc length and chord length will fall within the allowable error for taping, which is 0.02 foot per 100 feet on most construction surveys. Depending upon the terrain and the needs of the project foremen, the surveyor may stake out the curve with shorter or longer chords than recommended.

Deflection Angles

The deflection angles are the angles between a tangent and the ends of the chords from the PC. The surveyor uses them to locate the direction in which the chords are to be laid out. The total of the deflection angles is always equal to one half of the I angle. This total serves as a check on the computed deflection angles.

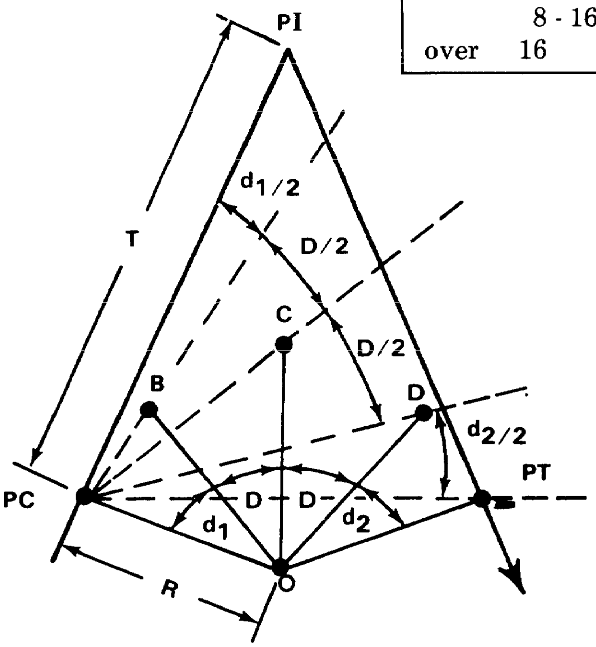


Figure 3-4. Deflection angles

SIMPLE CURVE FORMULAS

The following formulas are used in the computation of a simple curve. All of the formulas, except those noted, apply to both the arc and chord definitions.

$$R = \frac{5729.58\ \text{ft}}{D} \text{ or } \frac{1746.38\ \text{m}}{D} \text{ (arc definition)}$$

$$D = \frac{5729.58\ \text{ft}}{R} \text{ or } \frac{1746.38\ \text{m}}{R} \text{ (arc definition)}$$

$$R = \frac{50\ \text{ft}}{\text{Sin } \frac{1}{2} D} \text{ or } \frac{15.24\ \text{m}}{\text{Sin } \frac{1}{2} D} \text{ (chord definition)}$$

$$\text{Sin } \frac{1}{2} D = \frac{50\ \text{ft}}{R} \text{ or Sin } \frac{1}{2} D = \frac{15.24\ \text{m}}{R} \text{ (chord definition)}$$

$$T = R \text{ (Tan } \frac{1}{2} I)$$

$$L = \left(\frac{I}{D}\right) 100\ \text{ft or } L = \left(\frac{I}{D}\right) 30.48\text{m}$$

L is the distance around the arc for the arc definition, or the distance along the chords for the chord definition.

$$PC = PI - T$$

$$PT = PC + L$$

$$E = R \left(\frac{1}{\text{Cos } \frac{1}{2} I} - 1\right) \text{ or } E = T \text{ (Tan } \frac{1}{4} I)$$

$$M = R \text{ (l-COs } \frac{1}{2} I)$$

$$LC = 2 R \text{ (Sin} \frac{1}{2} I)$$

In the following formulas, C equals the chord length and d equals the deflection angle. All the formulas are exact for the arc definition and approximate for the chord definition.

$$d = \left(\frac{D}{2}\right)\left(\frac{C}{100\ \text{ft}}\right) \text{ or } d = \left(\frac{D}{2}\right)\left(\frac{C}{30.48\ \text{m}}\right)$$

This formula gives an answer in degrees.

d = 0.3 (C)(D) in the English system or

$$\frac{(0.3 \text{ x } D)\ (C)}{,3048}$$

in the metric system. The answer will be in minutes.

SOLUTION OF A SIMPLE CURVE

To solve a simple curve, the surveyor must know three elements. The first two are the PI station value and the I angle. The third is the degree of curve, which is given in the project specifications or computed using one of the elements limited by the terrain (see section II). The surveyor normally determines the PI and I angle on the preliminary traverse for the road. This may also be done by triangulation when the PI is inaccessible.

Chord Definition

The six-place natural trigonometric functions from table A-1 were used in the example. When a calculator is used to obtain the trigonometric functions, the results may vary slightly. Assume that the following is known: PI = 18+00, I = 45, and D = 15°.

Chord Definition (Feet)

$$R = \frac{50\text{ ft}}{\text{Sin } \tfrac{1}{2} D} = \frac{50}{0.130526} = 383.07\text{ ft}$$

$$T = R\,(\text{Tan } \tfrac{1}{2} I) = 383.07 \times 0.414214 = 158.67\text{ ft}$$

$$L = \left(\frac{I}{D}\right) 100\text{ ft} = \frac{45}{15} \times 100 = 300.00\text{ ft}$$

PC = PI - T = 1,800 - 158.67 = 1,641.33 or station 16+41.33

PT = PC + L = 1,641.33 + 300 = 1,941.33 or station 19+41.33

$$E = R\left(\frac{1}{\text{Cos } \tfrac{1}{2} I} - 1\right) = 383.07\left(\frac{1}{0.923880} - 1\right)$$

$$= 31.56\text{ ft}$$

$$M = R\,(1 - \text{Cos } \tfrac{1}{2} I) = 383.07\,(1 - 0.923880) = 29.16\text{ ft}$$

$$LC = 2\,R\,(\text{Sin } \tfrac{1}{2} I) = 2 \times 383.07\,(0.382683) = 293.19\text{ ft}$$

Chords. Since the degree of curve is 15 degrees, the chord length is 25 feet. The surveyor customarily places the first stake after the PC at a plus station divisible by the chord length. The surveyor stakes the centerline of the road at intervals of 10,25,50 or 100 feet between curves. Thus, the level party is not confused when profile levels are run on the centerline. The first stake after the PC for this curve will be at station 16+50. Therefore, the first chord length or subchord is 8.67 feet. Similarly, there will be a subchord at the end of the curve from station 19+25 to the PT. This subchord will be 16,33 feet. The surveyor designates the subchord at the beginning, C_1, and at the end, C_2 (figure 3-2).

Deflection Angles. After the subchords have been determined, the surveyor computes the deflection angles using the formulas on page 3-6. Technically, the formulas for the arc definitions are not exact for the chord definition. However, when a one-minute instrument is used to stake the curve, the surveyor may use them for either definition. The deflection angles are—

$$d = 0.3'\ CD$$

$$d_{std} = 0.3 \times 25 \times 15° = 112.5' \text{ or } 1°52.5'$$

$$d_1 = 0.3X\ 8.67X\ 15° = 0°39.015'$$

$$d_2 = 0.3 \times 16.33 \times 15° = 73.485' \text{ or } 1°13.485'$$

The number of full chords is computed by subtracting the first plus station divisible by the chord length from the last plus station divisible by the chord length and dividing the difference by the standard (std) chord length. Thus, we have (19+25 - 16+50)-25 equals 11 full chords. Since there are 11 chords of 25 feet, the sum of the deflection angles for 25-foot chords is 11 x 1°52.5' = 20°37.5'.

The sum of d_1, d_2, and the deflections for the full chords is—

d_1 = 0°39.015'
d_2 = 1°13.485'
d_{std} = 20°37.500'
Total 22°30.000'

The surveyor should note that the total of the deflection angles is equal to one half of the I angle. If the total deflection does not equal one half of I, a mistake has been made in the calculations. After the total deflection has been decided, the surveyor determines the angles for each station on the curve. In this step, they are rounded off to the smallest reading of the instrument to be used in the field. For this problem, the surveyor must assume that a one-minute instrument is to be used. The curve station deflection angles are listed on page 3-8.

STATION	CHORD LENGTH	DEFLECTION ANGLES
PC 16+41.33		
+50	C_1 8.67	d_1 0° 39.015′ or 0° 39′
		d_{std} + 1° 52.500′
+75	C_{std} 25	2° 31.515′ or 2° 32′
		+ 1° 52.500′
17+00	25	4° 24.015′ or 4° 24′
		+ 1° 52.500′
+25	25	6° 16.515′ or 6° 17′
		+ 1° 52.500′
+50	25	8° 9.015′ or 8° 09′
		+ 1° 52.500′
+75	25	10° 1.515′ or 10° 02′
		+ 1° 52.500′
18+00	25	11° 54.015′ or 11° 54′
		+ 1° 52.500′
+25	25	13° 46.515′ or 13° 47′
		+ 1° 52.500′
+50	25	15° 39.015′ or 15° 39′
		+ 1° 52.500′
+75	25	17° 31.515′ or 17° 32′
		+ 1° 52.500′
19+00	25	19° 24.015′ or 19° 24′
		+ 1° 52.500′
+25	25	21° 26.515′ or 21° 27′
		d_2 + 1° 13.485′
PT 19+41.33	C_2 16.33	22° 30.000′ or 22° 30′

Special Cases. The curve that was just solved had an I angle and degree of curve whose values were whole degrees. When the I angle and degree of curve consist of degrees and minutes, the procedure in solving the curve does not change, but the surveyor must take care in substituting these values into the formulas for length and deflection angles. For example, if I = 42° 15’ and D = 5° 37’, the surveyor must change the minutes in each angle to a decimal part of a degree, or D = 42.25000°, I = 5.61667°. To obtain the required accuracy, the surveyor should convert values to five decimal places.

An alternate method for computing the length is to convert the I angle and degree of curve to minutes; thus, 42° 15’ = 2,535 minutes and 5° 37’ = 337 minutes. Substituting into the length formula gives

$$L = \frac{2,535}{337} \times 100 = 752.23 \text{ feet.}$$

This method gives an exact result. If the surveyor converts the minutes to a decimal part of a degree to the nearest five places, the same result is obtained.

Since the total of the deflection angles should be one half of the I angle, a problem arises when the I angle contains an odd number of minutes and the instrument used is a one-minute instrument. Since the surveyor normally stakes the PT prior to running the curve, the total deflection will be a check on the PT. Therefore, the surveyor should compute to the nearest 0.5 degree. If the total deflection checks to the nearest minute in the field, it can be considered correct.

Curve Tables

The surveyor can simplify the computation of simple curves by using tables. Table A-5 lists long chords, middle ordinates, externals, and tangents for a l-degree curve with a radius of 5,730 feet for various angles of intersection. Table A-6 lists the tangent, external distance corrections (chord definition) for various angles of intersection and degrees of curve.

Arc Definition. Since the degree of curve by arc definition is inversely proportional to the other functions of the curve, the values for a one-degree curve are divided by the degree of curve to obtain the element desired. For example, table A-5 lists the tangent distance and external distance for an I angle of 75 degrees to be 4,396.7 feet and 1,492,5 feet, respectively. Dividing by 15 degrees, the degree of curve, the surveyor obtains a tangent distance of 293.11 feet and an external distance of 99.50 feet.

Chord Definition. To convert these values to the chord definition, the surveyor uses the values in table A-5. From table A-6, a correction of 0.83 feet is obtained for the tangent distance and for the external distance, 0.29 feet.

The surveyor adds the corrections to the tangent distance and external distance obtained from table A-5. This gives a tangent distance of 293.94 feet and an external distance of 99.79 feet for the chord definition.

After the tangent and external distances are extracted from the tables, the surveyor computes the remainder of the curve.

COMPARISON OF ARC AND CHORD DEFINITIONS

Misunderstandings occur between surveyors in the field concerning the arc and chord definitions. It must be remembered that one definition is no better than the other.

Different Elements

Two different circles are involved in comparing two curves with the same degree of curve. The difference is that one is computed by the arc definition and the other by the chord definition. Since the two curves have different radii, the other elements are also different.

5,730-Foot Definition

Some engineers prefer to use a value of 5,730 feet for the radius of a l-degree curve, and the arc definition formulas. When compared with the pure arc method using 5,729.58, the 5,730 method produces discrepancies of less than one part in 10,000 parts. This is much better than the accuracy of the measurements made in the field and is acceptable in all but the most extreme cases. Table A-5 is based on this definition.

CURVE LAYOUT

The following is the procedure to lay out a curve using a one-minute instrument with a horizontal circle that reads to the right. The values are the same as those used to demonstrate the solution of a simple curve (pages 3-6 through 3-8).

Setting PC and PT

With the instrument at the PI, the instrumentman sights on the preceding PI and keeps the head tapeman on line while the tangent distance is measured. A stake is set on line and marked to show the PC and its station value.

The instrumentman now points the instrument on the forward PI, and the tangent distance is measured to set and mark a stake for the PT.

Laying Out Curve from PC

The procedure for laying out a curve from the PC is described as follows. Note that the procedure varies depending on whether the road curves to the left or to the right.

Road Curves to Right. The instrument is set up at the PC with the horizontal circle at 0°00' on the PI.

(1) The angle to the PT is measured if the PT can be seen. This angle will equal one half of the I angle if the PC and PT are located properly.

(2) Without touching the lower motion, the first deflection angle, d_1 (0° 39'), is set on the horizontal circle. The instrumentman keeps the head tapeman on line while the first subchord distance, C_1 (8.67 feet), is measured from the PC to set and mark station 16+50.

(3) The instrumentman now sets the second deflection angle, $d_1 + d_{std}$ (2° 32'), on the horizontal circle. The tapemen measure the standard chord (25 feet) from the previously set station (16+50) while the instrument man keeps the head tapeman on line to set station 16+75.

(4) The succeeding stations are staked out in the same manner. If the work is done correctly, the last deflection angle will point on the PT, and the last distance will be the subchord length, C_2 (16.33 feet), to the PT.

Road Curves to Left. As in the procedures noted, the instrument occupies the PC and is set at 0°00' pointing on the PI.

(1) The angle is measured to the PT, if possible, and subtracted from 360 degrees. The result will equal one half the I angle if the PC and PT are positioned properly.

(2) The first deflection, d_1 (0° 39'), is subtracted from 360 degrees, and the remainder is set on the horizontal circle. The first subchord, C_1 (8.67 feet), is measured from the PC, and a stake is set on line and marked for station 16+50.

(3) The remaining stations are set by continuing to subtract their deflection angles from 360 degrees and setting the results on the horizontal circles. The chord distances are measured from the previously set station.

(4) The last station set before the PT should be C_2 (16.33 feet from the PT), and its deflection should equal the angle measured in (1) above plus the last deflection, d_2 (1° 14').

Laying Out Curve from Intermediate Setup

When it is impossible to stake the entire curve from the PC, the surveyor must use an adaptation of the above procedure.

(1) Stake out as many stations from the PC as possible.

(2) Move the instrument forward to any station on the curve.

(3) Pick another station already in place, and set the deflection angle for that station on the horizontal circle. Sight that station with the instruments telescope in the reverse position.

(4) Plunge the telescope, and set the remaining stations as if the instrument was set over the PC.

Laying Out Curve from PT

If a setup on the curve has been made and it is still impossible to set all the remaining stations due to some obstruction, the surveyor can "back in" the remainder of the curve from the PT. Although this procedure has been set up as a method to avoid obstructions, it is widely used for laying out curves. When using the "backing in method," the surveyor sets approximately one half the curve stations from the PC and the remainder from the PT. With this method, any error in the curve is in its center where it is less noticeable.

Road Curves to Right. Occupy the PT, and sight the PI with one half of the I angle on the horizontal circle. The instrument is now oriented so that if the PC is sighted, the instrument will read 0°00'.

The remaining stations can be set by using their deflections and chord distances from the PC or in their reverse order from the PT.

Road Curves to Left. Occupy the PT and sight the PI with 360 degrees minus one half of the I angle on the horizontal circle. The instrument should read 0° 00' if the PC is sighted.

Set the remaining stations by using their deflections and chord distances as if computed from the PC or by computing the deflections in reverse order from the PT.

CHORD CORRECTIONS

Frequently, the surveyor must lay out curves more precisely than is possible by using the chord lengths previously described.

To eliminate the discrepancy between chord and arc lengths, the chords must be corrected using the values taken from the nomography in table A-11. This gives the corrections to be applied if the curve was computed by the arc definition.

Table A-10 gives the corrections to be applied if the curve was computed by the chord definition. The surveyor should recall that the length of a curve computed by the chord definition was the length along the chords. Figure 3-5 illustrates the example given in table A-9. The chord distance from station 18+00 to station 19+00 is 100 feet. The nominal length of the subchords is 50 feet.

INTERMEDIATE STAKE

If the surveyor desires to place a stake at station 18+50, a correction must be applied to the chords, since the distance from 18+00 through 18+50 to 19+00 is greater than the chord from 18+00 to 19+00. Therefore, a correction must be applied to the subchords to keep station 19+00 100 feet from 18+00. In figure 3-5, if the chord length is nominally 50 feet, then the correction is 0.19 feet. The chord distance from 18+00 to 18+50 and 18+50 to 19+00 would be 50.19.

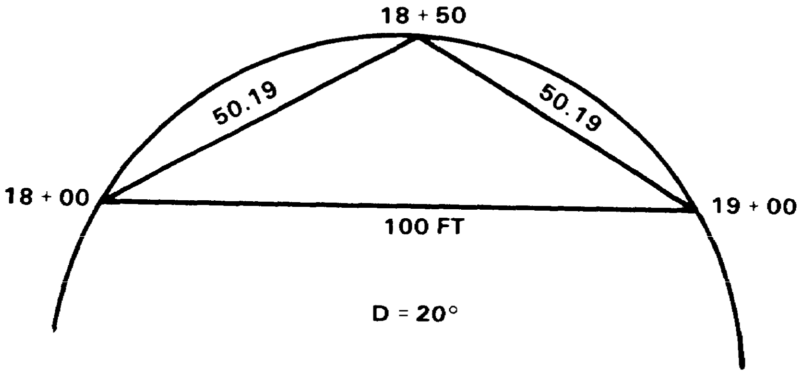


Figure 3-5. Subchord corrections

Section II. OBSTACLES TO CURVE LOCATION

TERRAIN RESTRICTIONS

To solve a simple curve, the surveyor must know three parts. Normally, these will be the PI, I angle, and degree of curve. Sometimes, however, the terrain features limit the size of various elements of the curve. If this happens, the surveyor must determine the degree of curve from the limiting factor.

Inaccessible PI

Under certain conditions, it may be impossible or impractical to occupy the PI. In this case, the surveyor locates the curve elements by using the following steps (figure 3-6).

(1) Mark two intervisible points A and B, one on each of the tangents, so that line AB (a random line connecting the tangents) will clear the obstruction.

(2) Measure angles a and b by setting up at both A and B.

(3) Measure the distance AB.

(4) Compute inaccessible distances AV and BV as follows:

$$I = a + b$$

$$K = 180° - I$$

$$AV = \frac{AB \text{ Sin } b}{\text{Sin } K}$$

$$BV = \frac{AB \text{ Sin } b}{\text{Sin } K}$$

$$PI = \text{Sta } A + AV$$

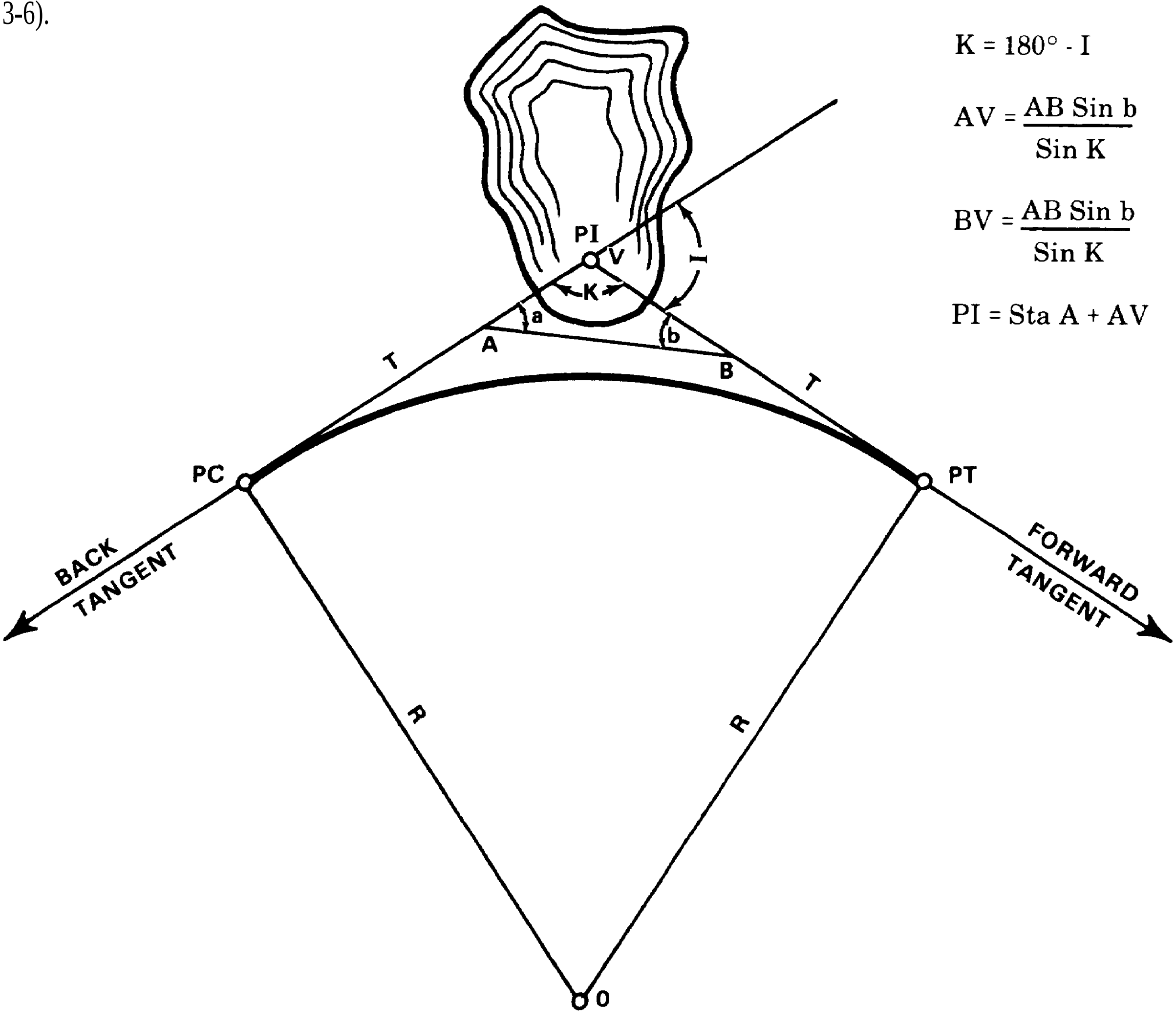


Figure 3-6. Inaccessible PI

(5) Determine the tangent distance from the PI to the PC on the basis of the degree of curve or other given limiting factor.

(6) Locate the PC at a distance T minus AV from the point A and the PT at distance T minus BV from point B.

(7) Proceed with the curve computation and layout.

Inaccessible PC

When the PC is inaccessible, as illustrated in figure 3-7, and both the PI and PT are set and readily accessible, the surveyor must establish the location of an offset station at the PC.

(1) Place the instrument on the PT and back the curve in as far as possible.

(2) Select one of the stations (for example, "P") on the curve, so that a line PQ, parallel to the tangent line AV, will clear the obstacle at the PC.

(3) Compute and record the length of line PW so that point W is on the tangent line AV and line PW is perpendicular to the tangent. The length of line PW = R (l - Cos d_p), where dp is that portion of the central angle subtended by AP and equal to two times the deflection angle of P.

(4) Establish point W on the tangent line by setting the instrument at the PI and laying off angle V (V = 180° - I). This sights the instrument along the tangent

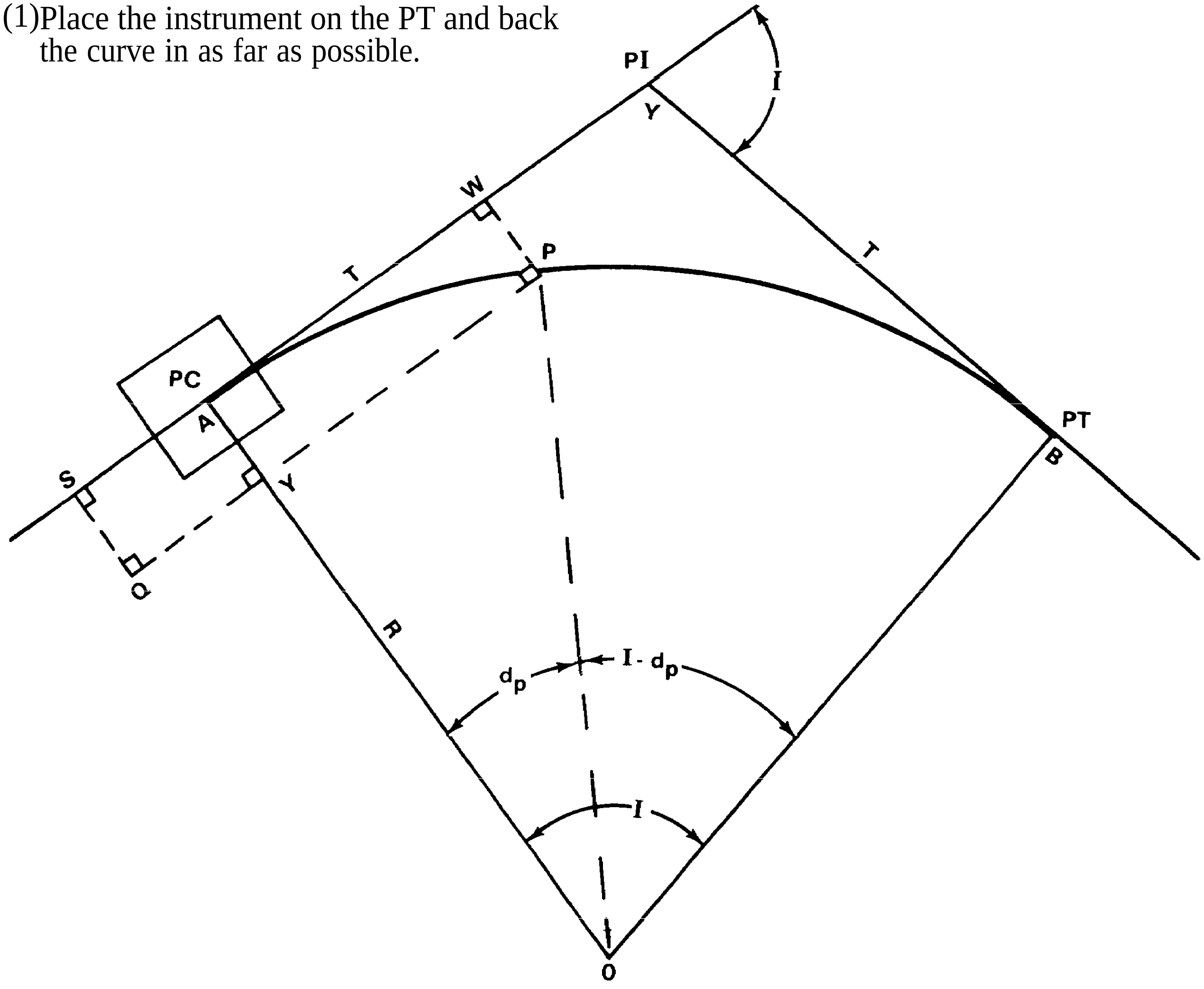


Figure 3-7. Inaccessible PC

AV. Swing a tape using the computed length of line PW and the line of sight to set point W.

(5) Measure and record the length of line VW along the tangent.

(6) Place the instrument at point P. Backsight point W and lay off a 90-degree angle to sight along line PQ, parallel to AV.

(7) Measure along this line of sight to a point Q beyond the obstacle. Set point Q, and record the distance PQ.

(8) Place the instrument at point Q, backsight P, and lay off a 90-degree angle to sight along line QS. Measure, along this line of sight, a distance QS equals PW, and set point S. Note that the station number of point S = PI - (line VW + line PQ).

(9) Set an offset PC at point Y by measuring from point Q toward point P a distance equal to the station of the PC minus station S. To set the PC after the obstacle has been removed, place the instrument at point Y, backsight point Q, lay off a 90-degree angle and a distance from Y to the PC equal to line PW and QS. Carefully set reference points for points Q, S, Y, and W to insure points are available to set the PC after clearing and construction have begun.

Inaccessible PT

When the PT is inaccessible, as illustrated in figure 3-8, and both the PI and PC are readily accessible, the surveyor must establish an

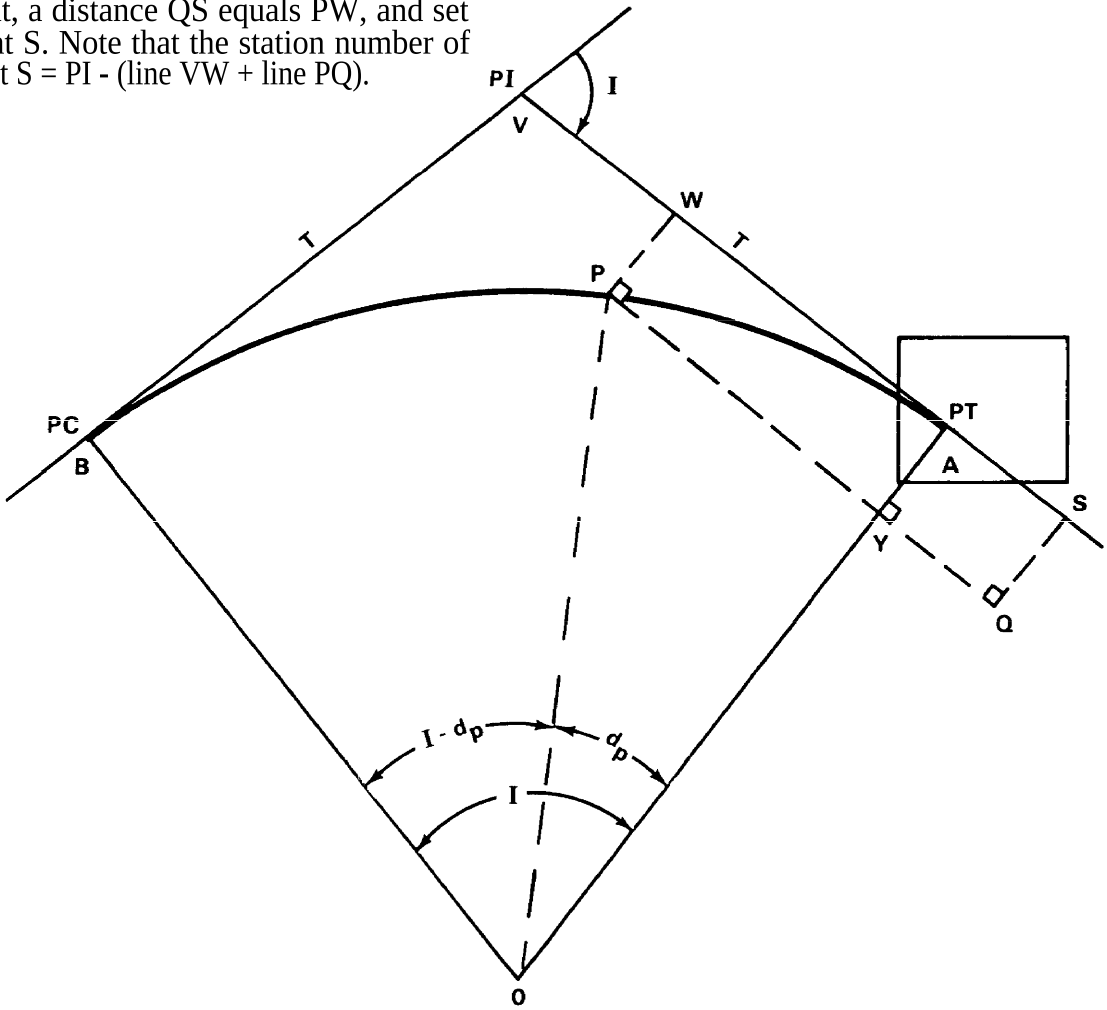


Figure 3-8. Inaccessible PT

offset station at the PT using the method for inaccessible PC with the following exceptions.

(1) Letter the curve so that point A is at the PT instead of the PC (see figure 3-8).

(2) Lay the curve in as far as possible from the PC instead of the PT.

(3) Angle d_p is the angle at the center of the curve between point P and the PT, which is equal to two times the difference between the deflection at P and one half of I. Follow the steps for inaccessible PC to set lines PQ and QS. Note that the station at point S equals the computed station value of PT plus YQ.

(4) Use station S to number the stations of the alignment ahead.

Obstacle on Curve

Some curves have obstacles large enough to interfere with the line of sight and taping. Normally, only a few stations are affected. The surveyor should not waste too much time on preliminary work. Figure 3-9 illustrates a method of bypassing an obstacle on a curve.

(1) Set the instrument over the PC with the horizontal circle at $0^{0}00'$, and sight on the PI.

Check I/2 from the PI to the PT, if possible.

(2) Set as many stations on the curve as possible before the obstacle, point b.

(3) Set the instrument over the PT with the plates at the value of I/2. Sight on the PI.

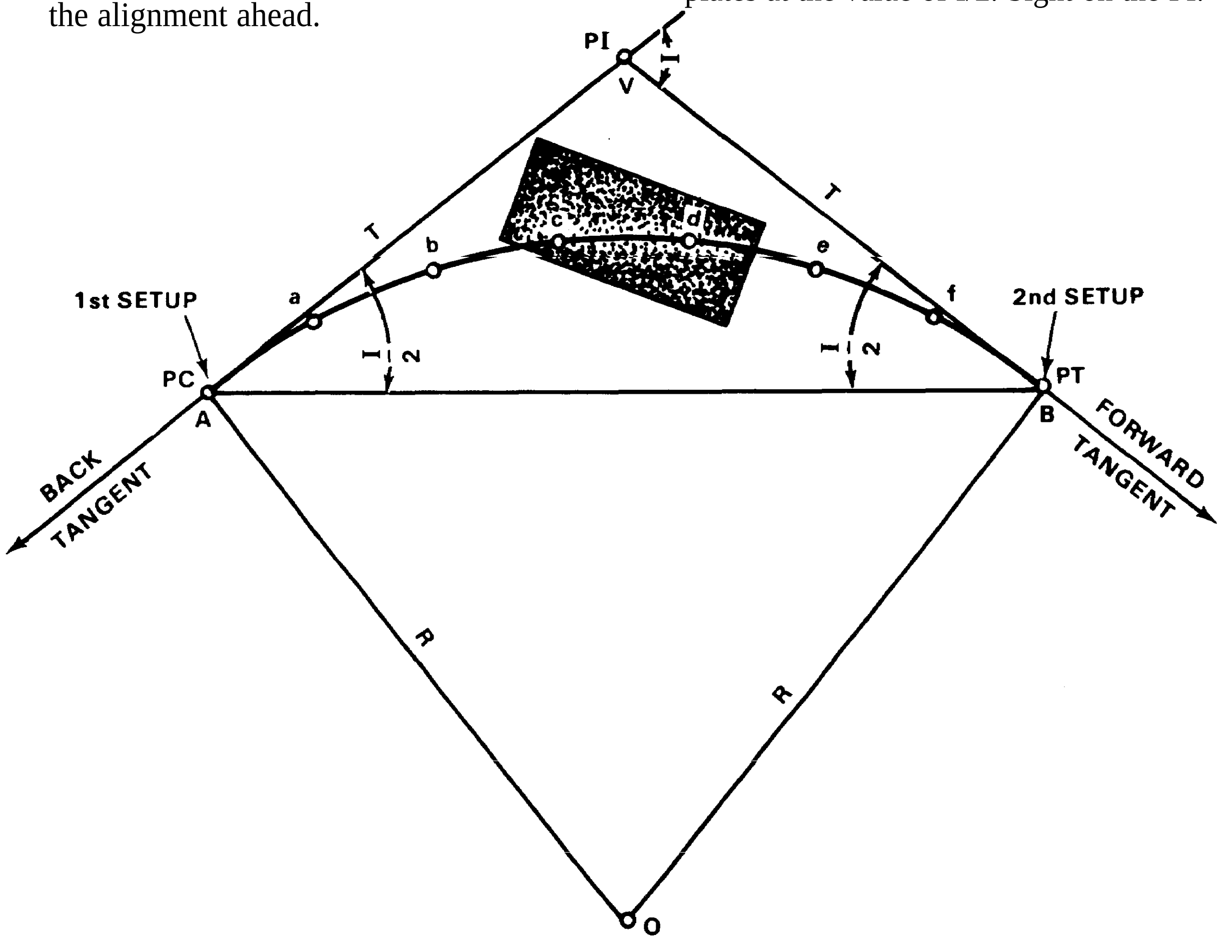


Figure 3-9. Obstacle on a curve

(4) Back in as many stations as possible beyond the obstacle, point e.

(5) After the obstacle is removed, the obstructed stations c and d can be set.

CURVE THROUGH FIXED POINT

Because of topographic features or other obstacles, the surveyor may find it necessary to determine the radius of a curve which will pass through or avoid a fixed point and connect two given tangents. This may be accomplished as follows (figure 3-10):

(1) Given the PI and the I angle from the preliminary traverse, place the instrument on the PI and measure angle d, so that angle d is the angle between the fixed point and the tangent line that lies on the same side of the curve as the fixed point.

(2) Measure line y, the distance from the PI to the fixed point.

(3) Compute angles c, b, and a in triangle COP.

$c = 90 - (d + I/2)$

To find angle b, first solve for angle e

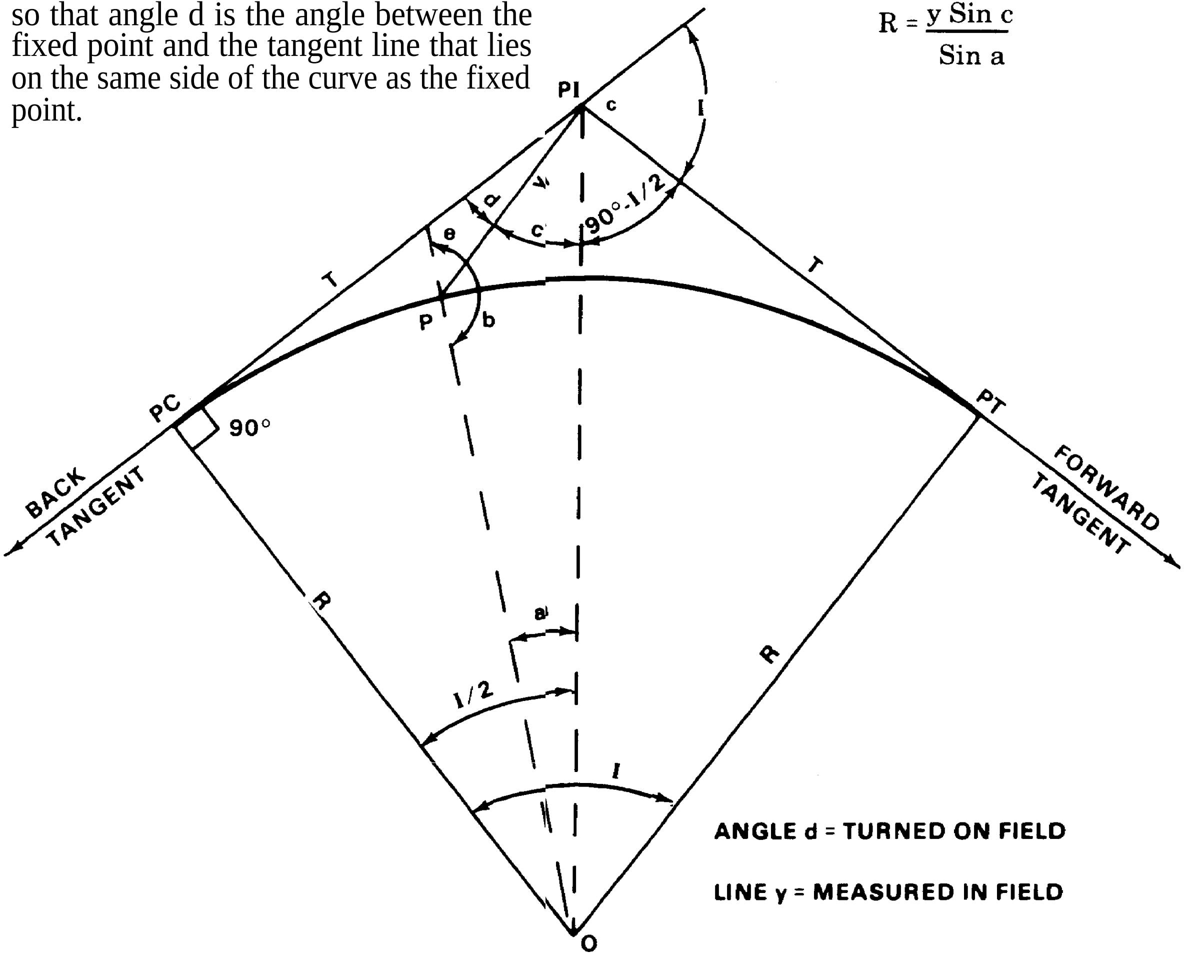
$$\text{Sin } e = \frac{\text{Sin } c}{\text{Cos } I/2}$$

Angle b = 180°- angle e

$a = 180° - (b + c)$

(4) Compute the radius of the desired curve using the formula

$$R = \frac{y \text{ Sin } c}{\text{Sin } a}$$



ANGLE d = TURNED ON FIELD

LINE y = MEASURED IN FIELD

Figure 3-10. Curve through a fixed point

(5) Compute the degree of curve to *five decimal places,* using the following formulas:

(arc method) $D = 5{,}729.58\ \text{ft}/R$

$D = 1{,}746.385\ \text{meters}/R$

(chord method) $\sin D = 2\ (50\ \text{feet}/R)$

$\sin D = 2\ (15.24\ \text{meters}/R)$

(6) Compute the remaining elements of the curve and the deflection angles, and stake the curve.

LIMITING FACTORS

In some cases, the surveyor may have to use elements other than the radius as the limiting factor in determining the size of the curve. These are usually the tangent T, external E, or middle ordinate M. When any limiting factor is given, it will usually be presented in the form of T equals some value x, $T \geqslant x$ or $T \leqslant x$. In any case, the first step is to determine the radius using one of the following formulas:

Given: Tangent; then $R = T/(\tan \frac{1}{2}I)$
External; then $R = E/[(1/\cos \frac{1}{2}I) - 1]$
Middle Ordinate; then $R = M/(1 - \cos \frac{1}{2}I)$

The surveyor next determines D. If the limiting factor is presented in the form T equals some value x, the surveyor must compute D, hold to five decimal places, and compute the remainder of the curve. If the limiting factor is presented as ≥, then D is rounded down to the nearest ½ degree. For example, if $E \geqslant 50$ feet, the surveyor would round down to the nearest ½ degree, recompute E, and compute the rest of the curve data using the rounded value of D, The new value of E will be equal to or greater than 50 feet.

If the limiting factor is ≤, the D is rounded is to the nearest ½ degree. For example, if $M \leqslant 45$ feet, then D would be rounded up to the nearest ½ degree, M would be recomputed, and the rest of the curve data computed using the rounded value of D. The new value of M will be equal to or less than 45 feet.

The surveyor may also use the values from table B-5 to compute the value of D. This is done by dividing the tabulated value of tangent, external, or middle ordinate for a 1-degree curve by the given value of the limiting factor. For example, given a limiting tangent $T \leqslant 45$ feet and I = 20°20’, the T for a 1-degree curve from table B-5 is 1,027.6 and D = 1,027.6/45.00 = 22.836°. Rounded up to the nearest half degree, D = 23°. Use this rounded value to recompute D, T and the rest of the curve data.

Section III.
COMPOUND AND REVERSE CURVES

COMPOUND CURVES

A compound curve is two or more simple curves which have different centers, bend in the same direction, lie on the same side of their common tangent, and connect to form a continuous arc. The point where the two curves connect (namely, the point at which the PT of the first curve equals the PC of the second curve) is referred to as the point of compound curvature (PCC).

Since their tangent lengths vary, compound curves fit the topography much better than simple curves. These curves easily adapt to mountainous terrain or areas cut by large, winding rivers. However, since compound curves are more hazardous than simple curves, they should never be used where a simple curve will do.

Compound Curve Data

The computation of compound curves presents two basic problems. The first is where the compound curve is to be laid out between two successive PIs on the preliminary traverse. The second is where the curve is to be laid in between two successive tangents on the preliminary traverse. (See figure 3-11.)

Compound Curve between Successive PIs. The calculations and procedure for laying out a compound curve between successive PIs are outlined in the following steps. This procedure is illustrated in figure 3-11a.

(1) Determine the PI of the first curve at point A from field data or previous computations.

(2) Obtain I_1, I_2, and distance AB from the field data.

(3) Determine the value of D_1, the D for the first curve. This may be computed from a limiting factor based on a scaled value from the road plan or furnished by the project engineer.

(4) Compute R_1, the radius of the first curve as shown on pages 3-6 through 3-8.

(5) Compute T_1, the tangent of the first curve.

$$T_1 = R_1 (\text{Tan } \tfrac{1}{2} I)$$

(6) Compute T_2, the tangent of the second curve.

$$T_2 = AB - T_1$$

(7) Compute R_2, the radius of the second curve.

$$R_2 = \frac{T_2}{\text{Tan } \tfrac{1}{2} I}$$

(8) Compute D_2 for the second curve. Since the tangent for the second curve must be held exact, the value of D_2 must be carried to five decimal places.

(9) Compare D_1 and D_2. They should not differ by more than 3 degrees, If they vary by more than 3 degrees, the surveyor should consider changing the configuration of the curve.

(l0) If the two Ds are acceptable, then compute the remaining data and deflection angles for the first curve.

(11) Compute the PI of the second curve. Since the PCC is at the same station as the PT of the first curve, then $PI_2 = PT_1 + T_2$.

(12) Compute the remaining data and deflection angles for the second curve, and lay in the curves.

Compound Curve between Successive Tangents. The following steps explain the laying out of a compound curve between successive tangents. This procedure is illustrated in figure 3-llb.

(1) Determine the PI and I angle from the field data and/or previous computations.

(2) Determine the value of I_1 and distance AB. The surveyor may do this by field measurements or by scaling the distance and angle from the plan and profile sheet.

(3) Compute angle C.

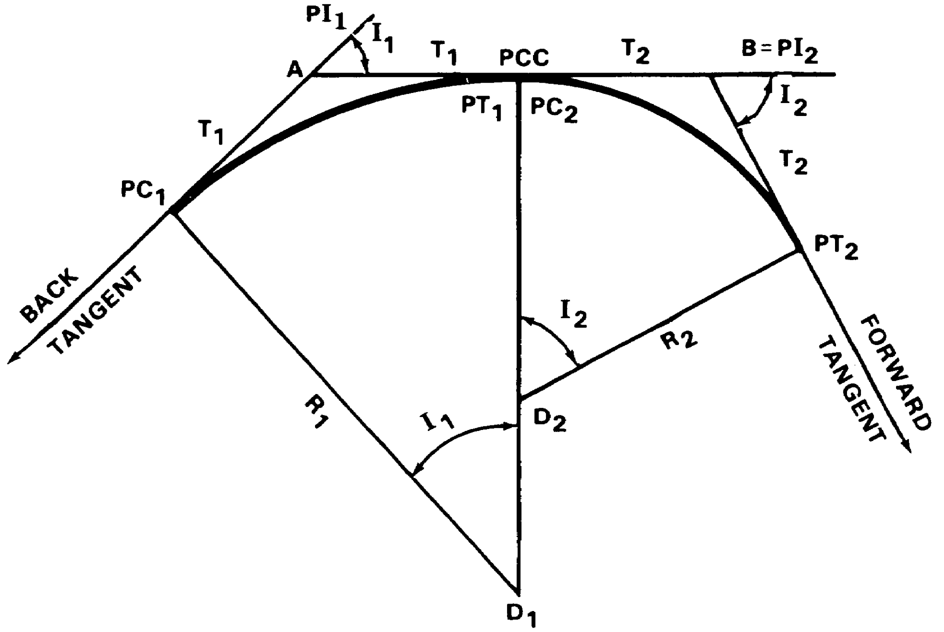
$$C = 180 - I$$

(4) Compute I_2.

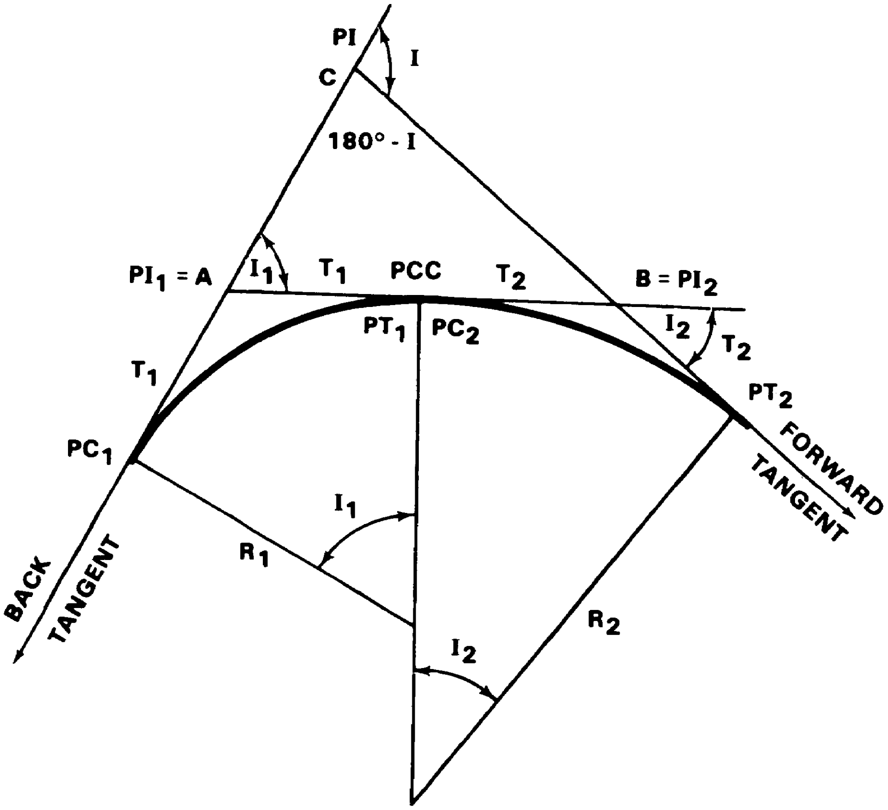
$$I2=180-(I_1+C)$$

(5) Compute line AC.

$$AC = \frac{AB \text{ Sin } I2}{\text{Sin } C}$$



a. BETWEEN SUCCESSIVE PIs



b. BETWEEN SUCCESSIVE TANGENTS

Figure 3-11. Compound curves

(6) Compute line BC.

$$BC = \frac{AB \sin I_1}{\sin C}$$

(7) Compute the station of PI_1.

$PI_1 = PI - AC$

(8) Determine D_1 and compute R_1 and T_1 for the first curve as described on pages 3-6 through 3-8.

(9) Compute T_2 and R_2 as described on pages 3-6 through 3-8.

(10) Compute D_2 according to the formulas on pages 3-6 through 3-8.

(11) Compute the station at PC.

$PC_1 = PI - (AC + T_1)$

(12) Compute the remaining curve data and deflection angles for the first curve.

(13) Compute PI_2.

$PI_2 = PT_1 + T_2$

(14) Compute the remaining curve data and deflection angles for the second curve, and stake out the curves.

Staking Compound Curves

Care must be taken when staking a curve in the field. Two procedures for staking compound curves are described.

Compound Curve between Successive PIs. Stake the first curve as described on pages 3-10 and 3-11.

(1) Verify the PCC and PT_2 by placing the instrument on the PCC, sighting on PI_2, and laying off $I_2/2$. The resulting line-of-sight should intercept PT_2.

(2) Stake the second curve in the same manner as the first.

Compound Curve between Successive Tangents. Place the instrument at the PI and sight along the back tangent.

(1) Lay out a distance AC from the PI along the back tangent, and set PI_1.

(2) Continue along the back tangent from PI_2 a distance T_1, and set PC_1.

(3) Sight along the forward tangent with the instrument still at the PI.

(4) Lay out a distance BC from the PI along the forward tangent, and set PI_2.

(5) Continue along the forward tangent from PI a distance T_2, and set PT_2.

(6) Check the location of PI_1 and PI_2 by either measuring the distance between the two PIs and comparing the measured distance to the computed length of line AB, or by placing the instrument at PI_1, sighting the PI, and laying off I_1. The resulting line-of-sight should intercept PI_2.

(7) Stake the curves as outlined on pages 3-10 and 3-11.

REVERSE CURVES

A reverse curve is composed of two or more simple curves turning in opposite directions. Their points of intersection lie on opposite ends of a common tangent, and the PT of the first curve is coincident with the PC of the second. This point is called the point of reverse curvature (PRC).

Reverse curves are useful when laying out such things as pipelines, flumes, and levees. The surveyor may also use them on low-speed roads and railroads. They cannot be used on high-speed roads or railroads since they cannot be properly superelevated at the PRC. They are sometimes used on canals, but only with extreme caution, since they make the canal difficult to navigate and contribute to erosion.

Reverse Curve Data

The computation of reverse curves presents three basic problems. The first is where the reverse curve is to be laid out between two successive PIs. (See figure 3-12.) In this case, the surveyor performs the computations in exactly the same manner as a compound curve between successive PIs. The second is where the curve is to be laid out so it connects two parallel tangents (figure 3-13). The third problem is where the reverse curve is to be laid out so that it connects diverging tangents (figure 3-14).

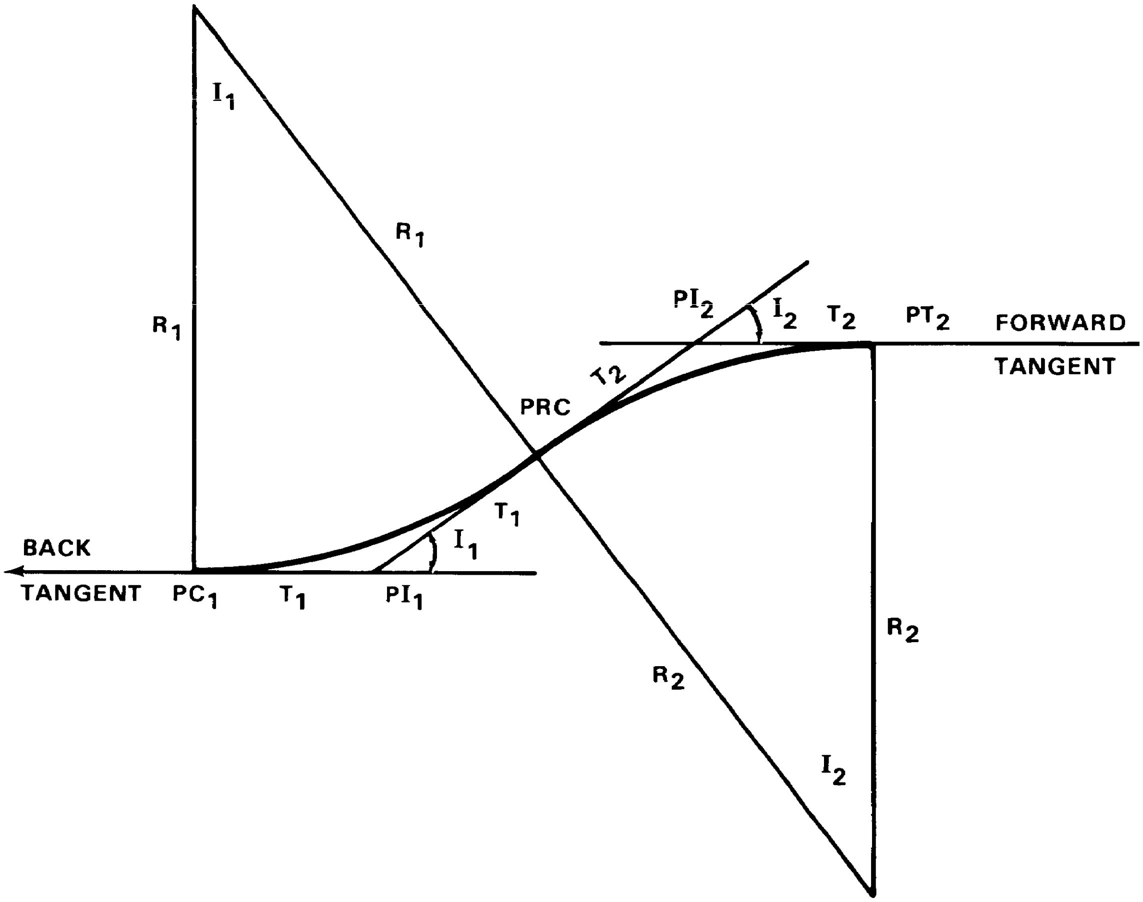


Figure 3-12. Reverse curve between successive PIs

Connecting Parallel Tangents

Figure 3-13 illustrates a reverse curve connecting two parallel tangents. The PC and PT are located as follows.

(1) Measure p, the perpendicular distance between tangents.

(2) Locate the PRC and measure m_1 and m_2. (If conditions permit, the PRC can be at the midpoint between the two tangents. This will reduce computation, since both arcs will be identical.)

(3) Determine R_1.

(4) Compute I_1.

$$\text{Cos } I_1 = \frac{R_1 - m_1}{R_1}$$

(5) Compute L_1 from

$$L_1 = R_1 \text{ Sin } I_1$$

R_2, I_2, and L_2 are determined in the same way as R_1, I_1, and L_1. If the PRC is to be the midpoint, the values for arc 2 will be the same as for arc 1.

(6) Stake each of the arcs the same as a simple curve. If necessary, the surveyor can easily determine other curve components. For example, the surveyor needs a reverse curve to connect two parallel tangents. No obstructions exist so it can be made up of two equal arcs. The degree of curve for both must be 5°. The surveyor measures the distance p and finds it to be 225.00 feet.

$m_1 = m_2$ and $L_1 = L_2$

$R_1 = R2$ and $I_1 = I_2$

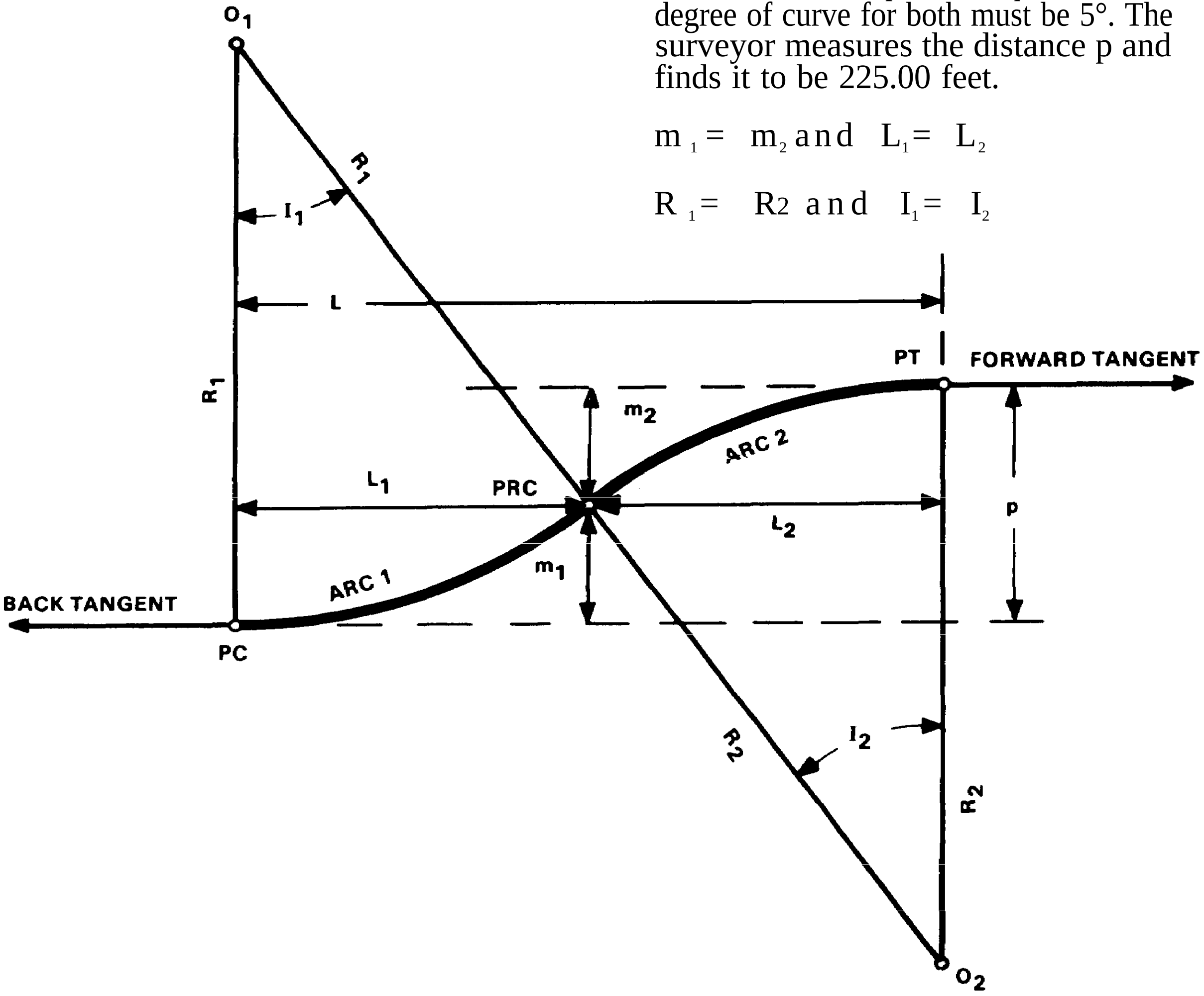


Figure 3-13. Reverse curve connecting parallel tangents

$$R_1 = \frac{50 \text{ ft}}{\text{Sin } ½ \text{ D}} = \frac{50 \text{ ft}}{0.043619} = 1{,}146.29 \text{ ft}$$

$$\text{Cos } I_1 = \frac{R_1 - m_1}{R_1} = \frac{1{,}033.79}{1{,}146.29} = 0.901857$$

$I_1 = 25° 36'$

$L_1 = R_1 \text{ Sin } I_1 = 1{,}146.29 \times 0.432086 = 495.30$ ft

(7) The PC and PT are located by measuring off L_1 and L_2.

Connecting Diverging Tangents

The connection of two diverging tangents by a reverse curve is illustrated in figure 3-14. Due to possible obstruction or topographic consideration, one simple curve could not be used between the tangents. The PT has been moved back beyond the PI. However, the I angle still exists as in a simple curve. The controlling dimensions in this curve are the distance T_s to locate the PT and the values of R_1 and R_2, which are computed from the specified degree of curve for each arc.

(1) Measure I at the PI.

(2) Measure T_s to locate the PT as the point where the curve is to join the forward tangent. In some cases, the PT position will be specified, but T_s must still be measured for the computations.

(3) Perform the following calculations:

Determine R_1 and R_2. If practical, have R_1 equal R_2.

Angle s = 180-(90+I)=90-I

$m = T_s(\text{Tan I})$

$$L = \frac{T_s}{\text{Cos I}}$$

angle e = I_1 (by similar triangles)

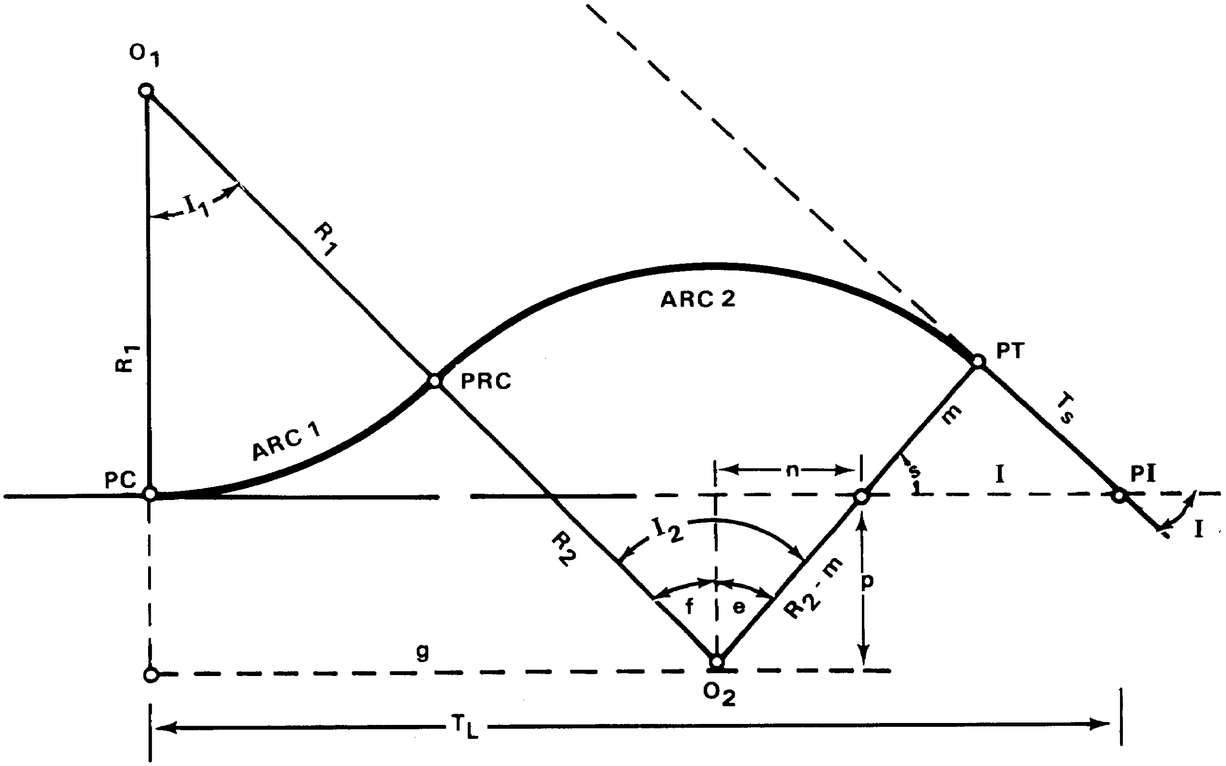


Figure 3-14. Reverse curve connecting diverging tangents

angle f = I_1 (by similar triangles)

therefore, $I_2 = I + I_1$

$n = (R_2 - m) \text{ Sin } e$

$p = (R_2 - m) \text{ Cos } e$

Determine g by establishing the value of I_1.

$$\text{Cos } I_1 = \frac{R_1 + p}{R_1 + R_2}$$

Knowing Cos I_1, determine Sin I_1.

$$g = (R_1 + R_2) \text{ Sin } I_1$$

$$T_L = g + n + L$$

(4) Measure T_L from the PI to locate the PC.

(5) Stake arc 1 to PRC from PC.

(6) Set instrument at the PT and verify the PRC (invert the telescope, sight on PI, plunge, and turn angle $I_2/2$).

(7) Stake arc 2 to the PRC from PT.

For example, in figure 3-14, a reverse curve is to connect two diverging tangents with both arcs having a 5-degree curve. The surveyor locates the PI and measures the I angle as 41 degrees. The PT location is specified and the T_s is measured as 550 feet.

$$R_1 = R_2 = \frac{50 \text{ ft}}{\text{Sin } \frac{1}{2} D} = \frac{50}{0.043619} = 1{,}146.29 \text{ ft}$$

$$\text{Angle } s = 90° - I = 49°$$

$$m = T_s \text{ Tan } I = 550 \times 0.869287 = 478.11 \text{ ft}$$

$$L = \frac{T_s}{\text{Cos } I} = \frac{550}{0.754710} = 728.76 \text{ ft}$$

$$n = (R_2 - m) \text{ Sin } I = (1{,}146.29 - 478.11)\ 0.656059 = 438.37 \text{ ft}$$

$$p = (R_2 - m) \text{ Cos } I = (1{,}146.29 - 478.11)\ 0.754710 = 504.28 \text{ ft}$$

$$\text{Cos } I_1 = \frac{R_1 + p}{R_1 + R_2} = \frac{1{,}146.29 + 504.28}{1{,}146.29 + 1{,}146.29} = 0.719962$$

$$I_1 = 43° 57'$$

$$g = (R_1 + R_2) \text{ sin } I_1 = (2{,}292.58)\ 0.694030 = 1{,}591.12 \text{ ft}$$

$$T_L = g + n + L = 1{,}591.12 + 438.37 + 728.76 = 2{,}758.25 \text{ ft}$$

The PC is located by measuring T_L. The curve is staked using 5-degree curve computations.

Section IV. TRANSITION SPIRALS

SPIRAL CURVES

In engineering construction, the surveyor often inserts a transition curve, also known as a spiral curve, between a circular curve and the tangent to that curve. The spiral is a curve of varying radius used to gradually increase the curvature of a road or railroad. Spiral curves are used primarily to reduce skidding and steering difficulties by gradual transition between straight-line and turning motion, and/or to provide a method for adequately superelevating curves.

The spiral curve is designed to provide for a gradual superelevation of the outer pavement edge of the road to counteract the centrifugal force of vehicles as they pass. The best spiral curve is one in which the superelevation increases uniformly with the length of the spiral from the TS or the point where the spiral curve leaves the tangent.

The curvature of a spiral must increase uniformly from its beginning to its end. At the beginning, where it leaves the tangent, its curvature is zero; at the end, where it joins the circular curve, it has the same degree of curvature as the circular curve it intercepts.

Theory of A.R.E.A. 10-Chord Spiral

The spiral of the American Railway Engineering Association, known as the A.R.E.A. spiral, retains nearly all the characteristics of the cubic spiral. In the cubic spiral, the lengths have been considered as measured along the spiral curve itself, but measurements in the field must be taken by chords. Recognizing this fact, in the A.R.E.A. spiral the length of spiral is measured by 10 equal chords, so that the theoretical curve is brought into harmony with field practice. This 10-chord spiral closely approximates the cubic spiral. Basically, the two curves coincide up to the point where $\Delta = 15$ degrees. The exact formulas for this A.R.E.A. 10-chord spiral, when Δ does not exeed 45 degrees, are given on pages 3-27 and 3-28.

Spiral Elements

Figures 3-15 and 3-16 show the notations applied to elements of a simple circular curve with spirals connecting it to the tangents.

TS = the point of change from tangent to spiral

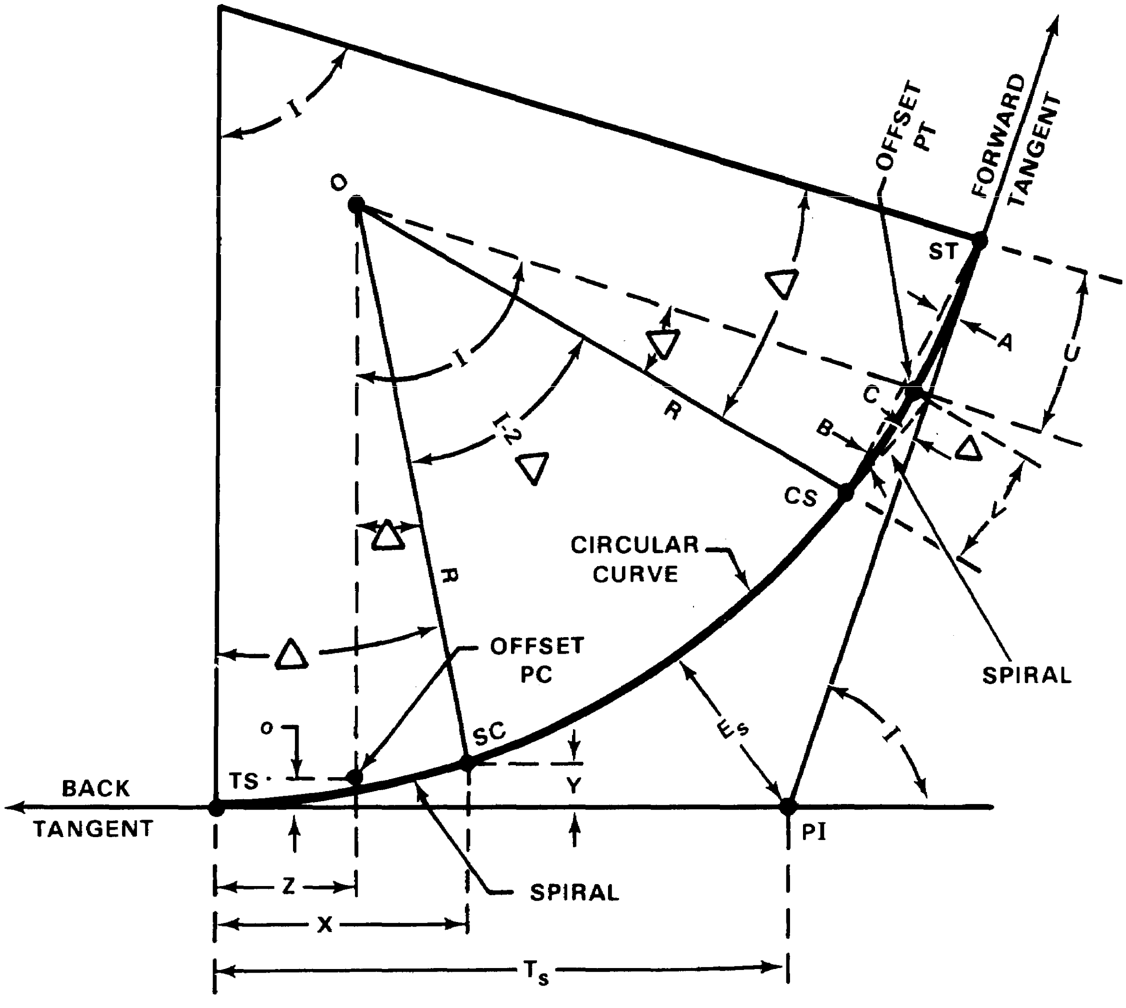


Figure 3-15. Simple curve connected to its tangent with spirals

SC = the point of change from spiral to circular curve

CS = the point of change from circular curve to spiral

ST = the point of change from spiral to tangent

SS = the point of change from one spiral to another (not shown in figure 3-15 or figure 3-16)

The symbols PC and PT, TS and ST, and SC and CS become transposed when the direction of stationing is changed.

a = the angle between the tangent at the TS and the chord from the TS to any point on the spiral

A = the angle between the tangent at the TS and the chord from the TS to the SC

b = the angle at any point on the spiral between the tangent at that point and the chord from the TS

B = the angle at the SC between the chord from the TS and the tangent at the SC

c = the chord from any point on the spiral to the TS

C = the chord from the TS to the SC

d = the degree of curve at any point on the spiral

D = the degree of curve of the circular arc

f = the angle between any chord of the spiral (calculated when necessary) and the tangent through the TS

I = the angle of the deflection between initial and final tangents; the total central angle of the circular curve and spirals

k = the increase in degree of curve per station on the spiral

L = the length of the spiral in feet from the TS to any given point on the spiral

L_s = the length of the spiral in feet from the TS to the SC, measured in 10 equal chords

o = the ordinate of the offsetted PC; the distance between the tangent and a parallel tangent to the offsetted curve

r = the radius of the osculating circle at any given point of the spiral

R = the radius of the central circular curve

s = the length of the spiral in stations from the TS to any given point

S = the length of the spiral in stations from the TS to the SC

u = the distance on the tangent from the TS to the intersection with a tangent through any given point on the spiral

U = the distance on the tangent from the TS to the intersection with a tangent through the SC; the longer spiral tangent

v = the distance on the tangent through any given point from that point to the intersection with the tangent through the TS

V = the distance on the tangent through the SC from the SC to the intersection with the tangent through the TS; the shorter spiral tangent

x = the tangent distance from the TS to any point on the spiral

X = the tangent distance from the TS to the SC

y = the tangent offset of any point on the spiral

Y = the tangent offset of the SC

Z = the tangent distance from the TS to the offsetted PC (Z = X/2, approximately)

δ = the central angle of the spiral from the TS to any given point

Δ = the central angle of the whole spiral

T_s = the tangent distance of the spiraled curve; distance from TS to PI, the point of intersection of tangents

E_s = the external distance of the offsetted curve

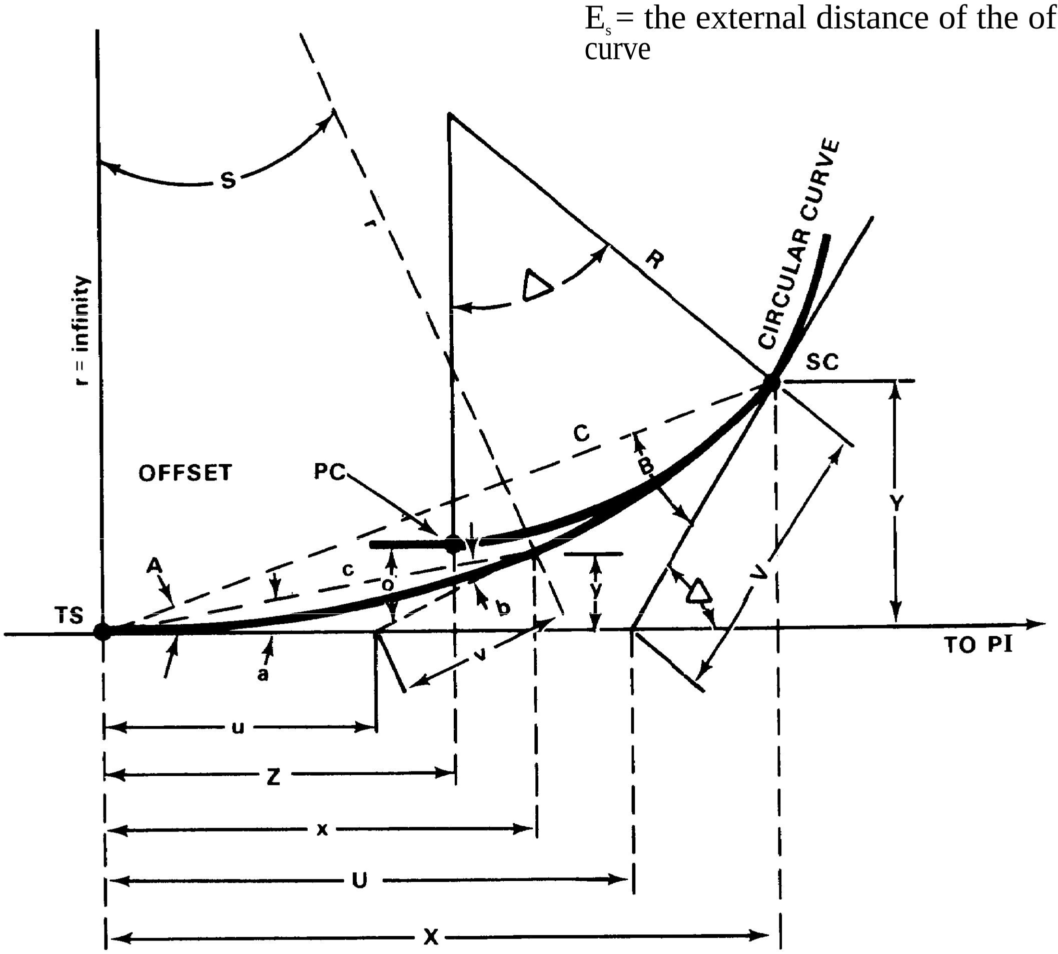


Figure 3-16. Enlargement of spiral of figure 3-15

Spiral Formulas

The following formulas are for the exact determination of the functions of the 10-chord spiral when the central angle , Δ, does not exceed 45 degrees. These are suitable for the compilation of tables and for accurate fieldwork.

(1) $d = ks = \frac{kL}{100}$

(2) $D = kS = \frac{kL_s}{100}$

(3) $\delta = \frac{ks^2}{2} = \frac{d_s}{2} = \frac{kL^2}{20,000} = \frac{dL}{200}$

(4) $\frac{ks^2}{2} = \frac{DS}{2} = \frac{kL_s}{20,000} = \frac{DL_s}{200}$

(5) $A = (\Delta/3) - 0.00297\ \Delta^3$ seconds

(6) $B = \Delta - A$

(7) $C = L_s\ (\text{Cos}\ 0.3\ \Delta + 0.004\ \text{Exsec}\ \tfrac{3}{4}\ \Delta)$

$(\text{Exsec}\ \Delta = 1\ \text{Tan}\ \tfrac{1}{2}\ (\Delta))$

(8) $X = C \text{ Cos } A$

(9) $Y = C \text{ Sin } A$

(10) $U = C\left(\frac{\text{Sin } B}{\text{Sin } \Delta}\right)$

(11) $V = C\left(\frac{\text{Sin } A}{\text{Sin } \Delta}\right)$

(12) $R = \frac{50 \text{ ft}}{\text{Sin } \frac{1}{2} D}$ (chord definition)

(13) $Z = X - (R \text{ Sin } \Delta)$

(14) $o = Y - (R \text{ Vers } \Delta)$

$(\text{Vers } \Delta = 1 - \text{Cos } \Delta)$

(15) $T_s = (R + o) \text{ Tan } (\frac{1}{2} I) + Z$

(16) $Es = (R + o) \text{ Exsec } (\frac{1}{2} I) + o$

$(\text{Exsec } (\frac{1}{2} I) = \text{Tan } (\frac{1}{2} I) (\text{Tan } (\frac{1}{4} I)))$

Empirical Formulas

For use in the field, the following formulas are sufficiently accurate for practical purposes when Δ does not exceed 15 degrees.

$a = \delta/3$ (degrees)

$A = \Delta/3$ (degrees)

$a = 10 ks^2$ (minutes)

$S = 10 kS^2$ (minutes)

Spiral Lengths

Different factors must be taken into account when calculating spiral lengths for highway and railroad layout.

Highways. Spirals applied to highway layout must be long enough to permit the effects of centrifugal force to be adequately compensated for by proper superelevation. The minimum transition spiral length for any degree of curvature and design speed is obtained from the the relationship $L_s = 1.6V^3/R$, in which L_s is the minimum spiral length in feet, V is the design speed in miles per hour, and R is the radius of curvature of the simple curve. This equation is not mathematically exact but an approximation based on years of observation and road tests.

Table 3-1 is compiled from the above equation for multiples of 50 feet. When spirals are inserted between the arcs of a compound curve, use $L_s = 1.6V^3/R_a$. R_a represents the radius of a curve of a degree equal to the difference in degrees of curvature of the circular arcs.

Railroads Spirals applied to railroad layout must be long enough to permit an increase in superelevation not exceeding 1 ¼ inches per second for the maximum speed of train operation. The minimum length is determined from the equation $L_s = 1.17$ EV. E is the full theoretical superelevation of the curve in inches, V is the speed in miles per hour, and L_s is the spiral length in feet.

This length of spiral provides the best riding conditions by maintaining the desired relationship between the amount of superelevation and the degree of curvature. The degree of curvature increases uniformly throughout the length of the spiral. The same equation is used to compute the length of a spiral between the arcs of a compound curve. In such a case, E is the difference between the superelevations of the two circular arcs.

SPIRAL CALCULATIONS

Spiral elements are readily computed from the formulas given on pages 3-25 and 3-26. To use these formulas, certain data must be known. These data are normally obtained from location plans or by field measurements.

The following computations are for a spiral when D, V, PI station, and I are known.

D = 4°

I = 24°10’

Table 3-1. Recommended superelevation and minimum transition lengths

D	30 mph		40 mph		50 mph		60 mph		70 mph	
	θ	Ls	θ	Ls	θ	Ls	θ	Ls	θ	Ls
1-00	0	0	0	0	0	0	0	0	0	0
1-30	.01	150	.02	150	.02	150	.04	150	.05	150
2-00	.01	150	.02	150	.03	150	.05	150	.06	200
2-30	.01	150	.03	150	.04	150	.06	150	.08	250
3-00	.02	150	.03	150	.05	150	.07	200	.09	300
3-30	.02	150	.04	150	.06	150	.08	200	.10	350
4	.02	150	.04	150	.06	150	.09	250	.10	400
5	.03	150	.05	150	.08	150	.10	300		
6	.03	150	.06	150	.10	200	.10	350		
7	.04	150	.07	150	.10	250				
8	.05	150	.08	150	.10	300				
9	.05	150	.09	150	.10	300				
10	.06	150	.10	200						
11	.06	150	.10	200						
12	.07	150	.10	200						
13	.07	150	.10	250						
14	.08	150	.10	250						
15	.09	150								
16	.09	150								
17	.10	150								
18	.10	150								
19	.10	150								
20	.10	150								
21	.10	150								
22	.10	150								
23	.10	150								
24	.10	200								
25	.10	200								

PI station = 42+61.70

V = 60 mph

Determining L_s

(1) Assuming that this is a highway spiral, use either the equation on page 3-28 or table 3-1.

(2) From table 3-1, when D = 4° and V = 60 mph, the value for Ls is 250 feet.

Determining Δ

(1) $\Delta = \frac{DL_s}{200}$

(2) $\Delta = \frac{4\ (250)}{200} = 50$

Determining o

(1) o = Y - (R Vers Δ)

(2) From page 3-28,

$R = \frac{50\ \text{ft}}{\text{Sin } ½\ D°}$

$R = \frac{50\ \text{ft}}{.0348994}$

R = 1,432.69 ft

Using $\Delta = 5°$, we find (see table A-9),
$Y = 0.029073 \times L_s$

$Y = 0.029073 \times 250$

$Y = 7.27$ ft

(3) $o = Y - (R \text{ Vers } \Delta)$

$(\text{Vers } \Delta = 1 - \text{Cos } \Delta)$

$o = 7.27 - (1{,}432.69 \times 0.00381)$

$o = 1.81$ ft

Determining Z

(l) $Z = X - (R \text{ Sin } A)$

(2) From table A-9 we see that

$X = .999243 \times L_s$
$X = .999243 \times 250$

$X = 249.81$ ft

$R = 1{,}432.69$ ft

$\text{Sin } 5° = 0.08716$

(3) $Z = 249.81 - (1{,}432.69 X\ 0.08716)$

$Z = 124.94$ ft

Determining T_s

(l) $T_s = (R + o) \text{ Tan}(½ I) + Z$

(2) From the previous steps, R = 1,432.69 feet, o = 1.81 feet, and Z = 124.94 feet.

(3) $\text{Tan } \frac{1}{2} . \frac{\text{Tan } 24° 10'}{2} = \text{Tan } 12^0 05' = 0.21408$

(4) $T_s = (1{,}432.69 + 1.81)(0.21408) + 124.94$

$T_s = 432.04$ ft

Determining Length of the Circular Arc (L_a)

(1) $L_a = \frac{I - 2\Delta}{D} \times 100$

(2) $I = 24° 10' = 24.16667°$

$A = 5”$

$D = 4°$

(3) $L, = \frac{24.16667 - 10}{4} \times 100 = 354.17$ ft

Determining Chord Length

(1) Chord length $= \frac{L_s}{10}$

(2) Chord $\frac{\text{length} = 250}{10}$ ft

Determining Station Values

With the data above, the curve points are calculated as follows:

Station PI	= 42 + 61.70	
Station TS	= -4 + 32.04	= T_s
Station TS	= 38+ 29.66	
	+2 + 50.()()	= L,
Station SC	= 40 + 79.66	
	+3 + 54.17	= L_a
Station CS	= 44+ 33.83	
	+2 + 50.()()	= L_s
Station ST	= 46+ 83,83	

Determining Deflection Angles

One of the principal characteristics of the spiral is that the deflection angles vary as the square of the distance along the curve.

$$\frac{a}{A} \therefore \frac{L^2}{L_s^2}$$

From this equation, the following relationships are obtained:

$a_1 = \frac{(1)^2}{(10)^2} A$, $a_2 = 4a_1$, $a_3 = 9a, = 16a_1, \ldots a_9 = 81a_1$, and $a_{10} = 100a_1 = A$. The deflection angles to the various points on the spiral from the TS or ST are $a_1, a_2, a_3 \ldots a_9$ and a_{10}. Using these relationships, the deflection angles for the spirals and the circular arc are computed for the example spiral curve.

Page 3-27 states that

$$D = \frac{kL_s}{100}.$$

Hence, $k = \frac{D(100)}{L_s} = \frac{D(100)}{250} = 1.6$

Page 3-28 states that $a = ks^2$.

Station	Deflection Angle	
38 + 29.66 (TS)	a_o	= 0° 00′
+ 54.66	$a_1 = 10ks^2 = 10(1.6)(0.25)^2$	= 0° 01′
+ 79.66	$a_2 = 4a_1$	= 0° 04′
39 + 04.66	$a_3 = 9a_1$	= 0°0 9′
+ 29.66	$a_4 = 16a_1$	= 0° 16′
39 + 54.66	$a_5 = 25a_1$	= 0° 25′
+ 79.66	$a_6 = 36a_1$	= 0° 36′
40 + 04.66	$a_7 = 49a_1$	= 0° 49′
+ 29.66	$a_8 = 64a_1$	= 1° 04′
+ 54.66	$a_9 = 81a_1$	= 1° 21′
40 + 79.66 (SC)	$a_{10} = 100a_1 = A = \Delta/3$	= 1° 40′
41 + 00.00	$d_1 = 0.3c_1D = 0.3'\ (20.34)(4)$	= 0° 24.4′
42	$d_2 = d_1 + D/2$	= 2° 24.4′
43	$d_3 = d_2 + D/2$	= 4° 24.4′
44	$d_4 = d_3 + D/2$	= 6° 24.4′
+ 33.83 (CS)	$d_5 = d_4 + 0.3c_2D$ $= 6^\circ\ 24.4' + 0.3'\ (33.83)(4)$ $= \frac{I-2\Delta}{2}$ $= \frac{24^\circ\ 10' - 10^\circ}{2}$	= 7° 05′
+ 33.83 (CS)	$a_{10} = A = \frac{\Delta}{3} = \frac{5}{3}$	= 1° 40′
+ 58.83	$a_9 = 81a_1$	= 1° 21′
+ 83.83	$a_8 = 64a_1$	= 1° 04′
45 + 08.83	$a_7 = 49a_1$	= 0° 49′
+ 33.83	$a_6 = 36a_1$	= 0° 36′
+ 58.83	$a_5 = 25a_1$	= 0° 25′
+ 83.83	$a_4 = 16a_1$	= 0° 16′
46 + 08.83	$a_3 = 9a_1$	= 0° 09′
+ 33.83	$a_2 = 4a_1$	= 0° 04′
+ 58.83	$a_1 = 10ks^2 = 10(1.6)(0.25)^2$	= 0° 01′
+ 83.83 (ST)	a_0	= 0° 00′

SPIRAL CURVE LAYOUT

The following is the procedure to lay out a spiral curve, using a one-minute instrument with a horizontal circle that reads to the right. Figure 3-17 illustrates this procedure.

Setting TS and ST

With the instrument at the PI, the instrumentman sights along the back tangent and keeps the head tapeman on line while the tangent distance (T_s) is measured. A stake is

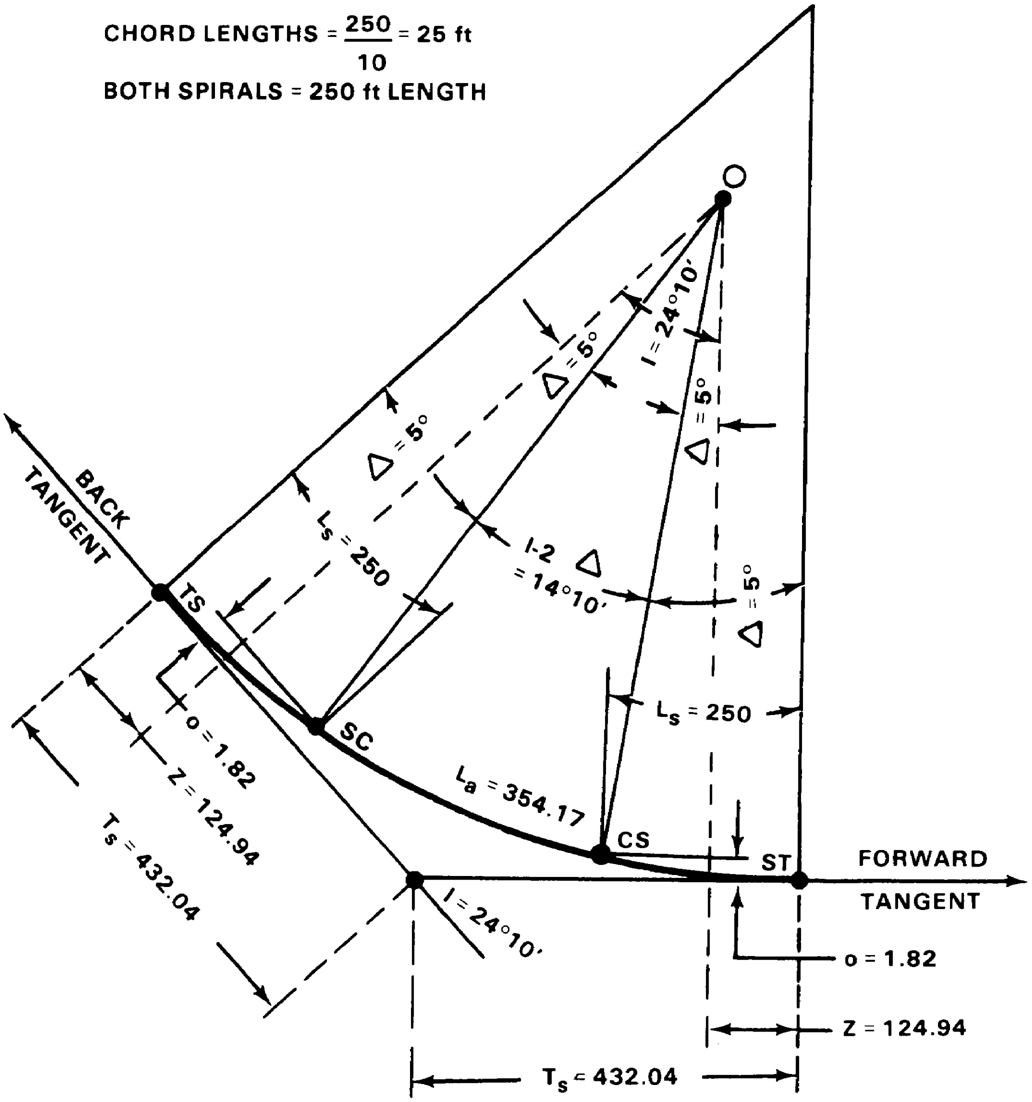


Figure 3-17. Staking a spiraled circular curve

set on line and marked to show the TS and its station value.

The instrumentman now sights along the forward tangent to measure and set the ST.

Laying Out First Spiral from TS to SC

Set up the instrument at the TS, pointing on the PI, with 0°00’ on the horizontal circle.

(1) Check the angle to the ST, if possible. The angle should equal one half of the I angle if the TS and ST are located properly.

(2) The first deflection (a_1/0°01’) is subtracted from 360 degrees, and the remainder is set on the horizontal circle. Measure the standard spiral chord length (25 feet) from the TS, and set the first spiral station (38 + 54.66) on line.

(3) The remaining spiral stations are set by subtracting their deflection angles from 360 degrees and measuring 25 feet from the previously set station.

Laying Out Circular Arc from SC to CS

Set up the instrument at the SC with a value of A minus A (5° 00’- 1°40’ = 3° 20’) on the horizontal circle. Sight the TS with the instrument telescope in the reverse position.

(1) Plunge the telescope. Rotate the telescope until 0°00’ is read on the horizontal circle. The instrument is now sighted along the tangent to the circular arc at the SC.

(2) The first deflection (d_1/0° 24’) is subtracted from 360 degrees, and the remainder is set on the horizontal circle. The first subchord (c_1/ 20.34 feet) is measured from the SC, and a stake is set on line and marked for station 41+00.

(3) The remaining circular arc stations are set by subtracting their deflection angles from 360 degrees and measuring the corresponding chord distance from the previously set station.

Laying Out Second Spiral from ST to CS

Set up the instrument at the ST, pointing on the PI, with 0°00’ on the horizontal circle.

(1) Check the angle to the CS. The angle should equal 1° 40’ if the CS is located properly.

(2) Set the spiral stations using their deflection angles in reverse order and the standard spiral chord length (25 feet).

Correct any error encountered by adjusting the circular arc chords from the SC to the CS.

Intermediate Setup

When the instrument must be moved to an intermediate point on the spiral, the deflection angles computed from the TS cannot be used for the remainder of the spiral. In this respect, a spiral differs from a circular curve.

Calculating Deflection Angles Following are the procedures for calculating the deflection angles and staking the spiral.

Example: D = 4°
Ls = 250 ft (for highways)
V =60 mph
I = 24°10’
Point 5 = intermediate point

(1) Calculate the deflection angles for the first five points These angles are: a_1 = 0° 01’, a_2 =0°04’, a_3 =0°09’, a_4 =0° 16’, and a_5 = 0°25’.

(2) The deflection angles for points 6, 7,8,9, and 10, with the instrument at point 5, are

calculated with the use of table 3-2. Table 3-2 is read as follows: with the instrument at any point, coefficients are obtained which, when multiplied by a_1, give the deflection angles to the other points of the spiral. Therefore, with the instrument at point 5, the coefficients for points 6,7,8,9, and 10 are 16, 34, 54, 76, and 100, respectively.

Multiply these coefficients by a_1 to obtain the deflection angles. These angles are a6 = 16a_1=0° 16’, a_7= 34a_1=0034’, a_8= 54a_1= 0°54’, a_9= 76a_1= 1°16’, and a_{10}= 100a_1= 1^{0}40’.

(3) Table 3-2 is also used to orient the instrument over point 5 with a backsight on the TS. The angular value from point 5 to point zero (TS) equals the coefficient from table 3-2 times a_1. This angle equals 50a_1= 0° 50’.

Staking. Stake the first five points according to the procedure shown on page 3-33. Check point 5 by repetition to insure accuracy.

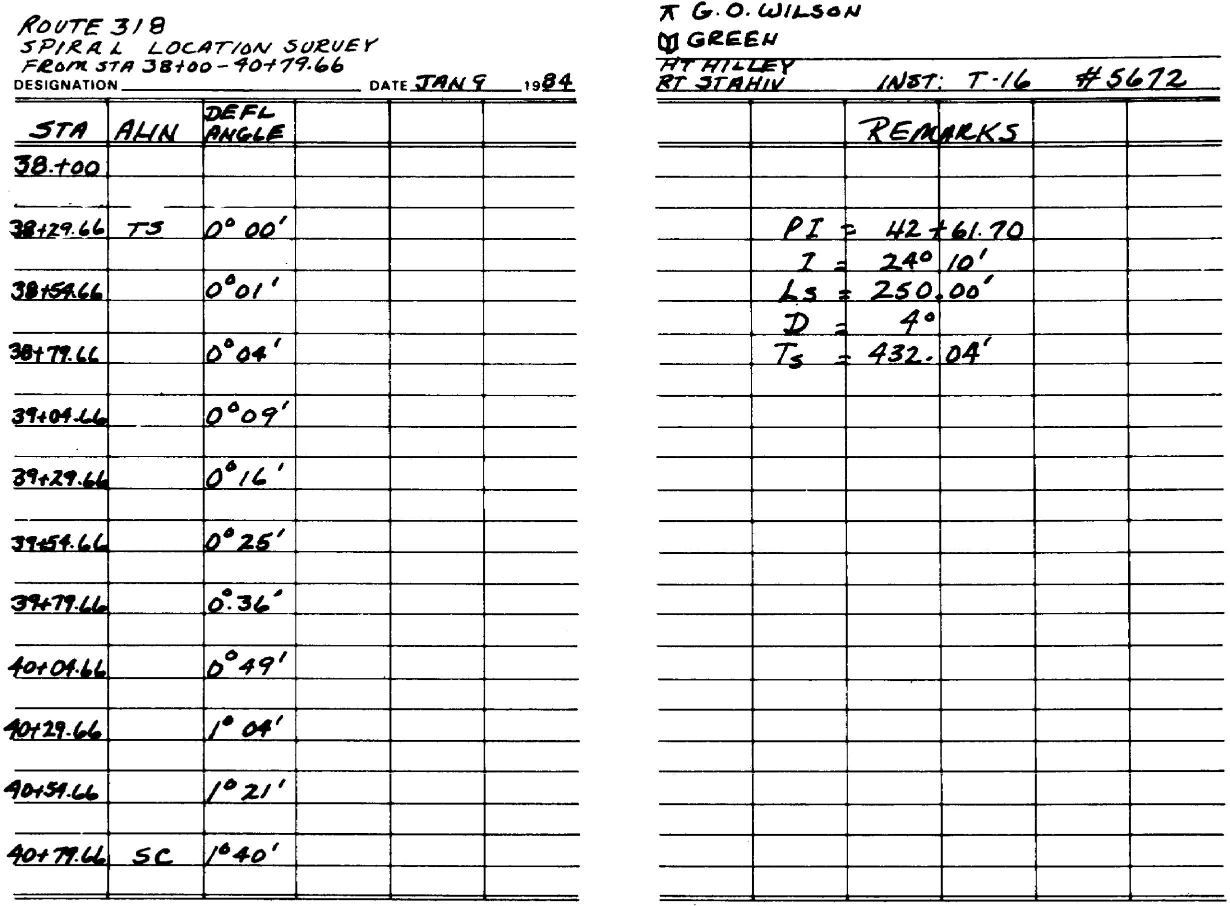
Set up the instrument over point 5. Set the horizontal circle at the angular value determined above. With the telescope inverted, sight on the TS (point zero).

Plunge the telescope, and stake the remainder of the curve (points 6, 7, 8, 9, and 10) by subtracting the deflection angles from 360 degrees.

Table 3-2. Coefficients of a_1 for deflection angles to chord points

Deflection angle to chord-point number	Transit at chord-point number										
	0 TS	1	2	3	4	5	6	7	8	9	10 SC
OTS	0	2	8	18	32	50	72	98	128	162	200
1	1	0	5	14	27	44	65	90	119	152	189
2	4	4	0	8	20	36	56	80	108	140	176
3	9	10	7	0	11	26	45	68	95	126	161
4	16	18	16	10	0	14	32	54	80	110	144
5	25	28	27	22	13	0	17	38	63	92	125
6	36	40	40	36	28	16	0	20	44	72	104
7	49	54	55	52	45	34	19	0	23	50	81
8	64	70	72	70	64	54	40	22	0	26	56
9	81	88	91	90	85	76	63	46	25	0	29
10SC	100	108	112	112	108	100	88	72	52	28	0

Field Notes for Spirals. Figure 3-18 shows a typical page of data recorded for the layout of a spiral. The data were obtained from the calculations shown on page 3-31.



ROUTE 318
SPIRAL LOCATION SURVEY
FROM STA 38+00 - 40+79.66
DESIGNATION ______ DATE JAN 9 1984

STA	ALIN	DEFL ANGLE			
38+00					
38+29.66	TS	0° 00′			
38+54.66		0°01′			
38+79.66		0°04′			
39+04.66		0°09′			
39+29.66		0°16′			
39+54.66		0°25′			
39+79.66		0°36′			
40+04.66		0°49′			
40+29.66		1° 04′			
40+54.66		1°21′			
40+79.66	SC	1°40′			

⊼ G.O. WILSON
📖 GREEN
HT HILLEY
RT STAHIV
INST: T-16 #5672

REMARKS

PI = 42+61.70
I = 24° 10′
L_s = 250.00′
D = 4°
T_s = 432.04′

Figure 3-18. Sample of spiral field notes

Section V. VERTICAL CURVES

FUNCTION AND TYPES

When two grade lines intersect, there is a vertical change of direction. To insure safe and comfortable travel, the surveyor rounds off the intersection by inserting a vertical parabolic curve. The parabolic curve provides a gradual direction change from one grade to the next.

A vertical curve connecting a descending grade with an ascending grade, or with one descending less sharply, is called a sag or invert curve. An ascending grade followed by a descending grade, or one ascending less sharply, is joined by a summit or overt curve.

COMPUTATIONS

In order to achieve a smooth change of direction when laying out vertical curves, the grade must be brought up through a series of elevations. The surveyor normally determines elevation for vertical curves for the beginning (point of vertical curvature or PVC), the end (point of vertical tangency or PVT), and all full stations. At times, the surveyor may desire additional points, but this will depend on construction requirements.

Length of Curve

The elevations are vertical offsets to the tangent (straightline design grade) elevations. Grades G_1 and G_2 are given as percentages of rise for 100 feet of horizontal distance. The surveyor identifies grades as plus or minus, depending on whether they are ascending or descending in the direction of the survey. The length of the vertical curve (L) is the horizontal distance (in 100-foot stations) from PVC to PVT. Usually, the curve extends ½ L stations on each side of the point of vertical intersection (PVI) and is most conveniently divided into full station increments.

A sag curve is illustrated in figure 3-20. The surveyor can derive the curve data as follows (with BV and CV being the grade lines to be connected).

Determine values of G_1 and G_2, the original grades. To arrive at the minimum curve length (L) in stations, divide the algebraic difference of G_1 and G_2 (AG) by the rate of change (r), which is normally included in the design criteria. When the rate of change (r) is not given, use the following formulas to compute L:

(Summit Curve)

$$L = 125 \text{ ft} \frac{(G_2\text{-}G_1)}{4} \text{ or } L = 38.10 \text{ m } \frac{(G_2\text{-}G_1)}{4}$$

(Sag Curve)

$$L = 100 \text{ ft} \frac{(G_2\text{-}G_1)}{4} \text{ or } L = 30.48 \text{ m } \frac{(G_2\text{-}G_1)}{4}$$

If L does not come out to a whole number of stations from this formula, it is usually extended to the nearest whole number. Note that this reduces the rate of change. Thus, L = 4.8 stations would be extended to 5 stations, and the value of r computed from $r = \Delta G/L$. These formulas are for road design only. The surveyor must use different formulas for railroad and airfield design.

Station Interval

Once the length of curve is determined, the surveyor selects an appropriate station interval (SI). The first factor to be considered is the terrain. The rougher the terrain, the smaller the station interval. The second consideration is to select an interval which will place a station at the center of the curve with the same number of stations on both sides of the curve. For example, a 300-foot curve could not be staked at 100-foot intervals but could be staked at 10-, 25-, 30-, 50-, or 75-foot intervals. The surveyor often uses the same intervals as those recommended for horizontal curves, that is 10, 25, 50, and 100 feet.

Since the PVI is the only fixed station, the next step is to compute the station value of the PVC, PVT, and all stations on the curve.

PVC = PVI - L/2
PVT = PVI + L/2

Other stations are determined by starting at the PVI, adding the SI, and continuing until the PVT is reached.

Tangent Elevations

Compute tangent elevations PVC, PVT, and all stations along the curve. Since the PVI is the fixed point on the tangents, the surveyor computes the station elevations as follows:

Elev PVC = Elev PVI + (-1 x L/2 x G_1)

Elev PVT = Elev PVI + (L/2 x G_2)

The surveyor may find the elevation of the stations along the back tangent as follows:

Elev of sta = Elev of PVC + (distance from the PVC x G_1).

The elevation of the stations along the forward tangent is found as follows:

Elev of sta = Elev of PVI + (distance from the PVI x G_2)

Vertical Maximum

The parabola bisects a line joining the PVI and the midpoint of the chord drawn between the PVC and PVT. In figure 3-19, line VE =

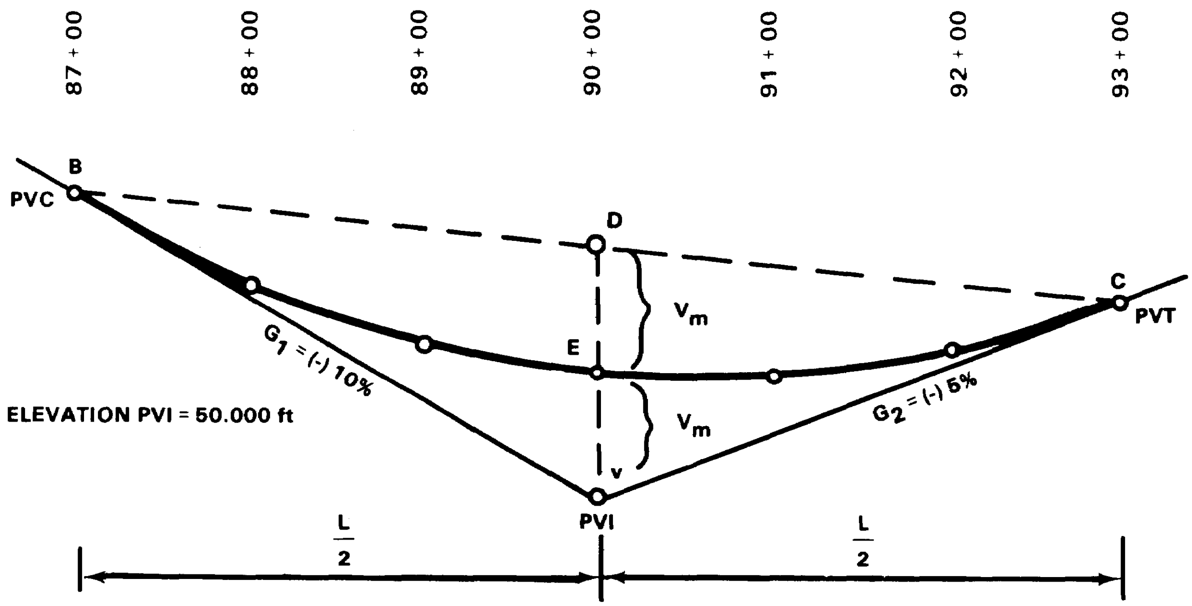


Figure 3-19. Grade lines connected by a vertical curve

DE and is referred to as the vertical maximum (Vm). The value of Vm is computed as follows: (L= length in 100-foot stations. In a 600-foot curve, L = 6.)

$$Vm = L/8\ (G_2 - G_1) \text{ or}$$

$$Vm = \tfrac{1}{2}\left(\left(\frac{\text{Elev PVC} + \text{Elev PVT}}{2}\right) - \text{Elev PVI}\right)$$

In practice, the surveyor should compute the value of Vm using both formulas, since working both provides a check on the Vm, the elevation of the PVC, and the elevation of the PVT.

Vertical Offset. The value of the vertical offset is the distance between the tangent line and the road grade. This value varies as the square of the distance from the PVC or PVT and is computed using the formula:

$$\text{Vertical Offset} = (\text{Distance})^2 \text{ x Vm}$$

A parabolic curve presents a mirror image. This means that the second half of the curve is identical to the first half, and the offsets are the same for both sides of the curve.

Station Elevation. Next, the surveyor computes the elevation of the road grade at each of the stations along the curve. The elevation of the curve at any station is equal to the tangent elevation at that station plus or minus the vertical offset for that station, The sign of the offset depends upon the sign of Vm (plus for a sag curve and minus for a summit curve).

First and Second Differences. As a final step, the surveyor determines the values of the first and second differences. The first differences are the differences in elevation between successive stations along the curve, namely, the elevation of the second station minus the elevation of the first station, the elevation of the third station minus the elevation of the second, and so on. The second differences are the differences between the differences in elevation (the first differences), and they are computed in the same sequence as the first differences.

The surveyor must take great care to observe and record the algebraic sign of both the first and second differences. The second differences provide a check on the rate of change per station along the curve and a check on the computations. The second differences should all be equal. However, they may vary by one or two in the last decimal place due to rounding off in the computations. When this happens, they should form a pattern. If they vary too much and/or do not form a pattern, the surveyor has made an error in the computation.

Example: A vertical curve connects grade lines G_1 and G_2 (figure 3-19). The maximum allowable slope (r) is 2.5 percent. Grades G_1 and G_2 are found to be -10 and +5.

$$L = \frac{\Delta G}{r} = \frac{15}{2.5} = 6 \text{ stations}$$

$$V_m = \frac{\Delta G \times L}{8} = \frac{(15)(6)}{8} = 11.25 \text{ ft}$$

The vertical offsets for each station are computed as in figure 3-20. The first and second differences are determined as a check. Figure 3-21 illustrates the solution of a summit curve with offsets for 50-foot intervals.

High and Low Points

The surveyor uses the high or low point of a vertical curve to determine the direction and amount of runoff, in the case of summit curves, and to locate the low point for drainage.

When the tangent grades are equal, the high or low point will be at the center of the curve. When the tangent grades are both plus, the low point is at the PVC and the high point at the PVT. When both tangent grades are minus, the high point is at the PVC and the low point at the PVT. When unequal plus and

VERTICAL CURVE

DATA

G 1	-10 %
G 2	+5 %
S.I.	100 ft.
L	6 (600 ft.)
Vm	+11.25
P.V.C.	87+00
P.V.I.	90+00 (elev. = 50.00)
P.V.T.	92+00

COMPUTATIONS

STATION	TAN. ELEV.	COMPUTATION	OFFSET	CURVE ELEV.	1st DIFF.	2d DIFF.
87+00	80.00		+	80.00		
88+00	70.00	$(1/3)^2 \times 11.25$	1.25	71.25	-8.15	2.50
89+00	60.00	$(2/3)^2 \times 11.25$	5.00	65.00	-6.25	2.50
90+00	50.00	$(3/3)^2 \times 11.25$	11.25	61.25	-3.15	2.50
91+00	55.00	$(2/3)^2 \times 11.25$	5.00	60.00	-1.25	2.50
92+00	60.00	$(1/3)^2 \times 11.25$	1.25	61.25	+1.25	2.50
93+00	65.00			65.00	+3.75	

FORMULAE

Vm = L/8(G2 - G1)

$$Vm = \frac{1}{2}\left[\frac{\text{ELEV. P.C.} + \text{ELEV. P.T.}}{2} - \text{ELEV. P.I.}\right]$$

OFFSET ≐ (DIST.)^2 x Vm

SKETCH

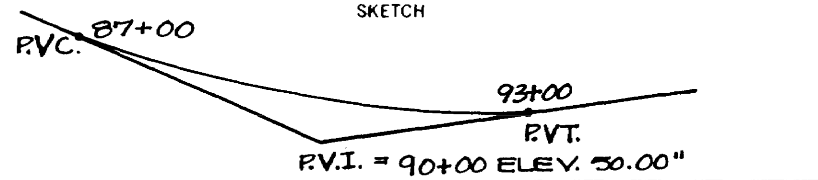


Figure 3-20. Typical solution of a sag curve

minus tangent grades are encountered, the high or low point will fall on the side of the curve that has the flatter gradient.

Horizontal Distance. The surveyor determines the distance (x, expressed in stations) between the PVC or PVT and the high or low point by the following formula:

$$x = G\frac{L}{(G_2 - G_1)}$$

G is the flatter of the two gradients and L is the number of curve stations.

Vertical Distance. The surveyor computes the difference in elevation (y) between the PVC or PVT and the high or low point by the formula

$$y = \frac{-(G_2 - G_1)}{2L}(x^2) + Gx$$

Example: From the curve in figure 3-21, $G_1 = +3.2\%$, $G_2 = -1.6\%$ L = 4 (400). Since G_2 is the flatter gradient, the high point will fall between the PVI and the PVT.

$$x = G\frac{L}{G_2 - G_1} = -1.6\frac{4}{-1.6 - (+3.2)} = 1.3333 \text{ sta}$$

$$= 133.33 \text{ feet}$$

PVT - x = sta of high point
(16+00) - 133.33 = 14+66.67

$$y = \frac{-(G_2 - G_1)}{2L}(x^2) + Gx$$

Elev PT + y = elev high point
128.00 + 1.07 = 129.07

VERTICAL CURVE

DATA		COMPUTATIONS						
		STATION	TAN. ELEV.	COMPUTATION	OFFSET	CURVE ELEV.	1st DIFF.	2d DIFF.
G_1	+3.2 %	12+00	124.80	—	—	124.800		
		+50	126.40	$(1/4)^2$ X Vm	-0.150	126.250	-1.450	-0.300
G_2	-1.6 %	13+00	128.00	$(2/4)^2$ X Vm	-0.600	127.400	-1.150	-0.300
		+50	129.60	$(3/4)^2$ X Vm	-1.350	128.250	-0.850	-0.300
S.I.	50′	14+00	131.20	$(4/4)^2$ X Vm	-2.400	128.800	-0.550	-0.300
		+50	130.40	$(3/4)^2$ X Vm	-1.350	129.050	-0.250	-0.300
L	400′	15+00	129.60	$(2/4)^2$ X Vm	-0.600	129.000	+0.050	-0.300
		+50	128.80	$(1/4)^2$ X Vm	-0.150	128.650	+0.350	-0.300
Vm	-2.400	16+00	128.00	—	—	128.000	+0.650	
P.V.C.	12+00							
P.V.I.	14+00 ELEV. 131.20							
P.V.T.	16+00							

FORMULAE

Vm = L/8(G2 - G1)

$$Vm = \frac{1}{2}\left[\frac{\text{ELEV. P.C.} + \text{ELEV. P.T.}}{2} - \text{ELEV. P.I.}\right]$$

OFFSET = $(\text{DIST.})^2$ x Vm

SKETCH

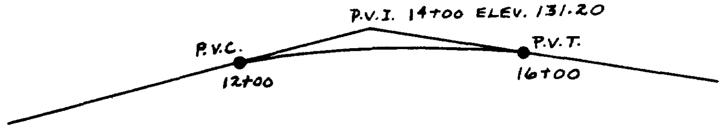


Figure 3-21. Typical solution of a summit curve

CHAPTER 4

EARTHWORK

Section I. PLANNING OF EARTHWORK OPERATIONS

IMPORTANCE

In road, railroad, and airfield construction, the movement of large volumes of earth (earthwork) is one of the most important construction operations. It requires a great amount of engineering effort.

The planning, scheduling, and supervising of earthwork operations are of major importance in obtaining an efficiently operated construction project. To plan a schedule, the quantities of clearing, grubbing, and stripping, as well as the quantities and positions of cuts and fills, must be known. Then, the most efficient type and number of pieces of earthmoving equipment can be chosen, the proper number of personnel assigned, and the appropriate time allotted.

Earthwork computations involve the calculation of volumes or quantities, the determination of final grades, the balancing of cuts and fills, and the planning of the most economical haul of material. The surveyor uses field notes and established grade to plot the cross sections at regular stations and at any plus stations which may have been established at critical intermediate points. The line representing the existing ground surface and those lines representing the proposed cut or fill enclose cross-section areas. The surveyor uses these areas and the measured distances along the centerline to compute earthwork volumes.

CROSS SECTIONS

The cross section used in earthwork computations is a vertical section. It is perpendicular to the centerline at full and plus stations and represents the boundaries of a proposed or existing cut or fill. Typical cross sections for a roadbed are illustrated in figure 4-1.

The determination of cross-section areas is simplified when the sections are plotted on cross-section paper. This is usually done to the same vertical and horizontal scale, standard practice being 1 inch equals 10 feet. However, if the vertical cut or fill is small in comparison with the width, the surveyor may use an exaggerated vertical scale to gain additional precision in plotting such sections.

The surveyor must take care, however, when computing areas of this type of plotted section that the proper area is obtained. For example, a 1 inch equals 10 foot scale, both vertical and

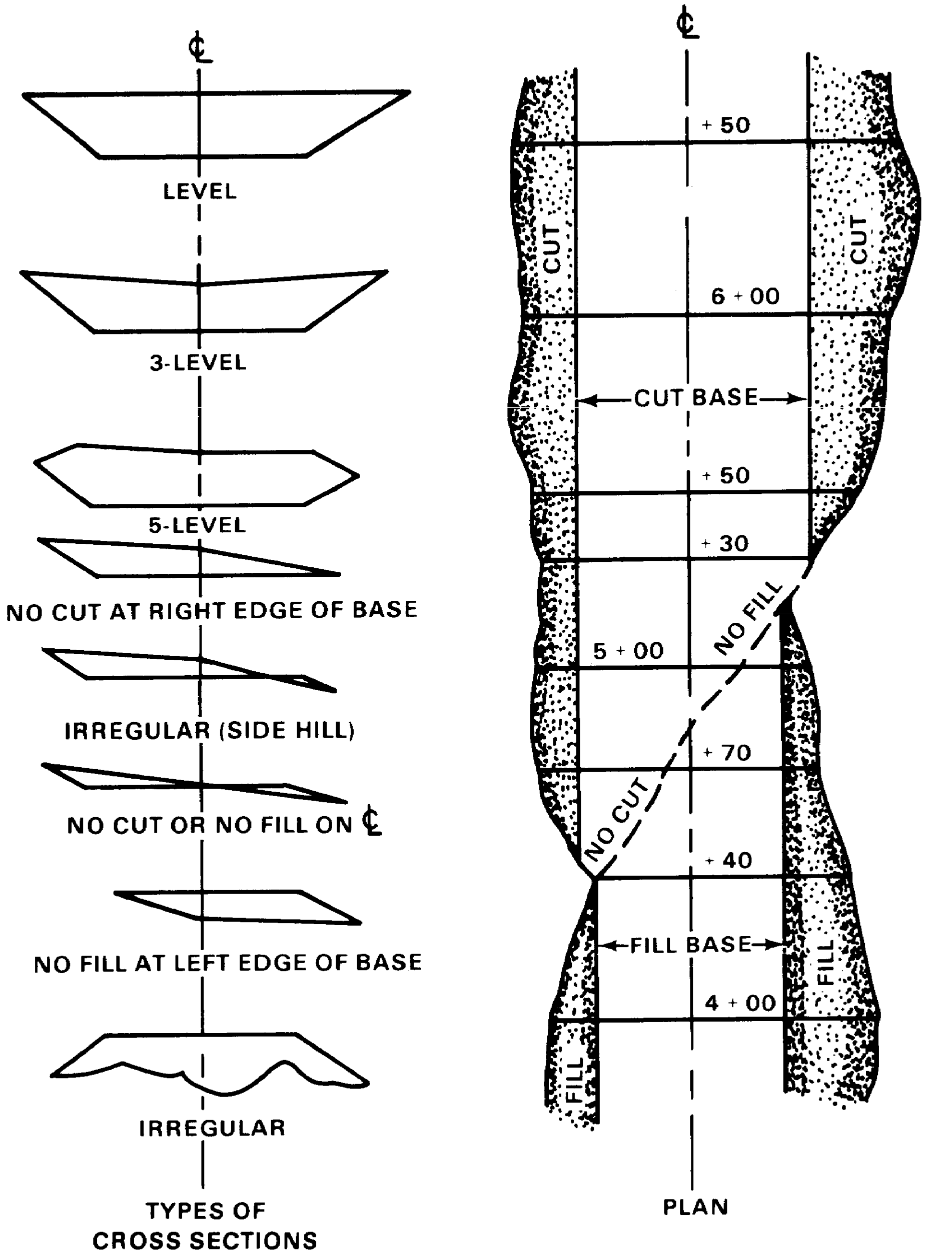
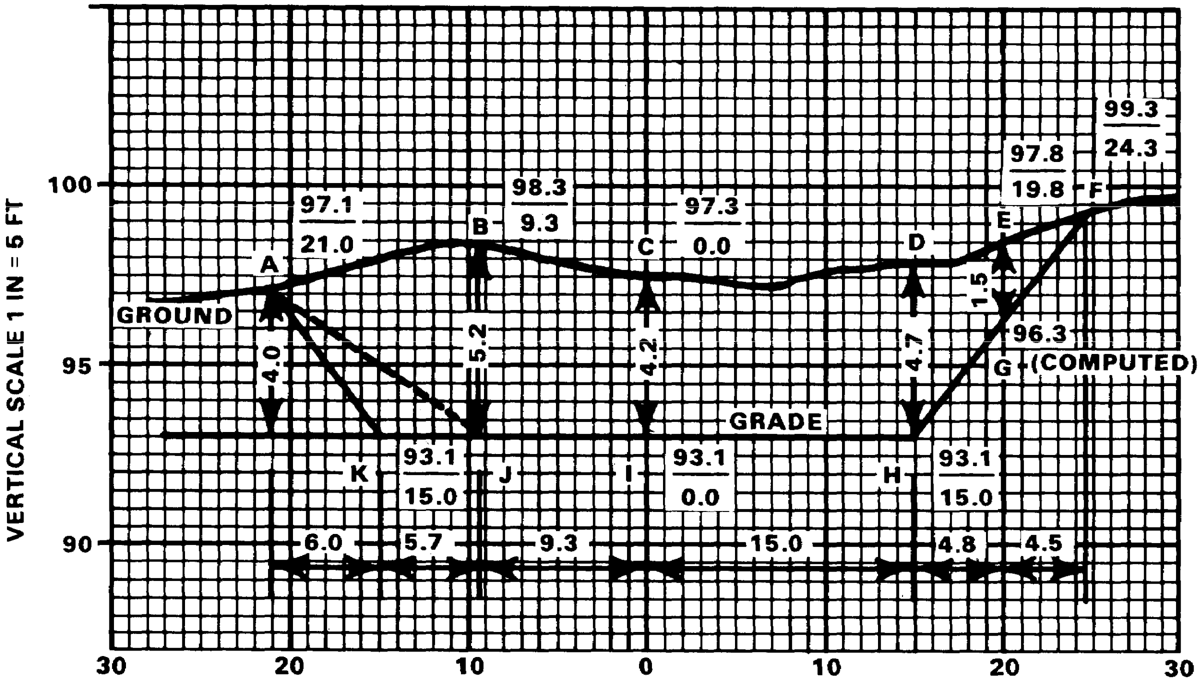


Figure 4-1. Typical cross sections

horizontal, yields 100 square feet, but 1 inch equals 10 foot horizontal and 1 inch equals 2 foot vertical yields only 20 square feet. An exaggerated vertical scale is used in figure 4-2 to illustrate a five-level section.

The side slopes of a cross section are expressed by a ratio of horizontal distance to vertical distance. A 1 ½:1 side slope indicates a slope extending 1 ½ feet horizontally per foot of vertical rise or fall. Slopes may be inclined more or less sharply than this, such as 3:1, 2:1, or 1:1. The surveyor usually determines the slope by the design specifications based on the stability of the soil in cut or fill. However, the need for economy in construction operations must often be considered. For example, cut slopes may be flattened more than is required by soil characteristics solely to produce enough material for a nearby fill. This practice is more economical than operating a borrow pit to obtain this material.



HORIZONTAL SCALE 1 IN = 10 FT

AREA = 175.0 SQ FT BY COUNTING SQUARES

AREA = 170.5 SQ FT BY TRAPEZOIDS AND TRIANGLES

Figure 4-2. Area of irregular cross sections

Section II. AREAS

AREA COMPUTATION

The surveyor can determnecross-section areas for construction earthwork volumes by one of the following methods: the counting squares method, the geometric method (geometry of trapezoids and triangles), the stripper method, or the double-meridian-distance method. The stripper and counting-the-squares methods are simple and given approximate results, while the other methods give results as accurate as the cross-section field data will permit. Standard practice requires that cut and fill areas of a cross section, where both occur simultaneously, be determined separately.

Counting-Squares Method

To make a hasty approximation of a cross-section area plotted on cross-section paper, count the number of squares enclosed by the boundary lines of the section. Then multiply the total number of counted squares by the number of square feet represented by a single square.

For example, the cross section in figure 4-2 encloses approximately 350 1/10-inch squares or 3.5 l-inch squares. The scales of the cross section indicate that one 1/l0-inch square represents 1 foot horizontally and 6 inches vertically, or one half of a square foot in area. Therefore, the approximate area of the cross section is 350 divided by 2 equals 175 square feet. Using the l-inch square, which represents 10 feet horizontally and 5 feet vertically or 50 square feet in area, the cross-section area is approximately 3.5 x 50 = 175 square feet.

Geometric Method

To compute the area of a cross section by the geometric method, sometimes called the trapezoidal method, subdivide the area into simple geometrical figures, calculate each area according to its geometry, and total the results. There is no set rule for performing the subdivisions. The computer selects those subdivisions which will produce the most direct and accurate results. Figure 4-3a illustrates the subdivision of a typical three-level section into five triangles. Figure 4-3b illustrates the subdivision of a five-level section into two triangles and two trapezoids. The following computations apply to the geometric method in figure 4-2. Basic formulas are as follows.

$$A = \frac{bh}{2} \text{ (area of a triangle)}$$

$$A = h \, \frac{(b_1 + b_2)}{2} \text{ (area of a trapezoid)}$$

A = area; b, b_1, and b_2 = the lengths of the bases; and h = the perpendicular distance, or height, between parallel bases for a trapezoid and from base to vertex for a triangle.

square feet

2A of triangle AJK = 5.7 x 4.0 = 22.8
2A of triangle ABJ = 5.2 (5.7+ 6.0) = 60.8
2A of trapezoid BCIJ = 9.3 (5.2+ 4.2) = 87.4
2A of trapezoid CDHI = 15.0 (4.2+ 4.7;= 133.5
2A of trapezoid DEGH = 4.8 (4.7+ 1.5)= 29.8
2A of triangle EFG = 1.5 x 4.5 = 6.8
Total (double area of AFHK) = 341.1

Area of the cross section = 341.1 ÷2 = 170.5

Note that the computation is simplified by adding all the numerical products for triangles and trapezoids together and then dividing the total by 2. The dashed line, AJ, is added to subdivide quadrilateral ABJK into two triangles, AJK and ABJ.

Stripper Method

To determine the area of a plotted cross section by strip measurements, subdivide the area into strips by vertical lines spaced at regular intervals. Measure the total length of these lines by cumulatively marking the length of each line along the edge of a stripper made of paper or plastic. Then, multiply the cumulative total of the average base lengths by the width of the strip. Regular

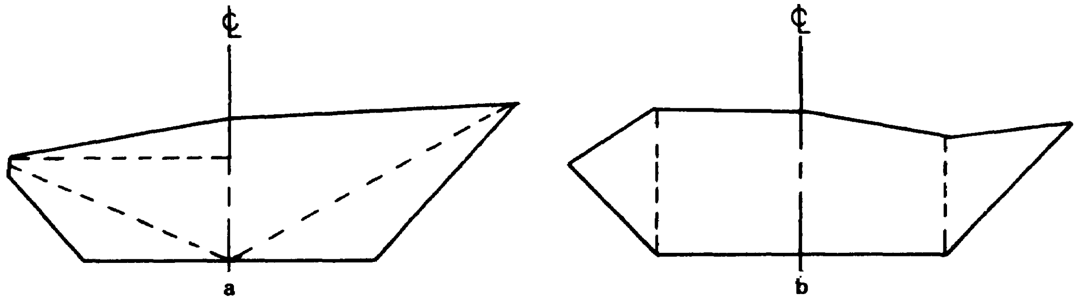


Figure 4-3. Subdividing cross sections

intervals of 3, 5, or 10 feet, depending upon the roughness of the ground, give satisfactory results for strip widths. Due regard must be given to the horizontal and vertical scales of the cross section. The procedure is illustrated in figure 4-4.

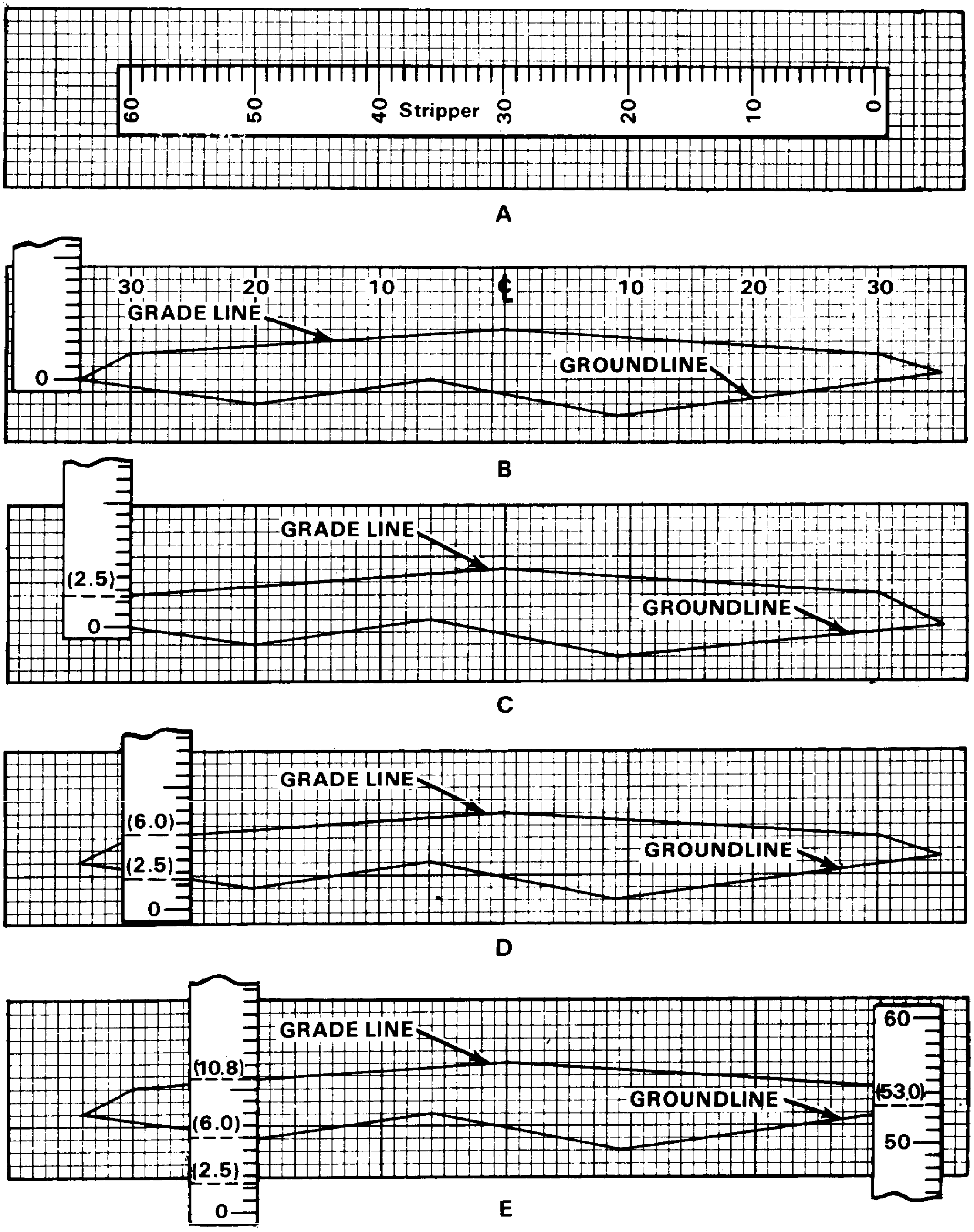


Figure 4-4. Cross-section area by stripper method

The stripper shown is 5 squares wide by 60 squares long. Its zero index is placed at the intersection of the ground and side-slope line of the section.

The stripper is moved an interval of 5 squares to the right with zero reading at the bottom. It is then moved another 5 squares to the right with the previous top reading (2.5) now adjacent to the bottom line. The stripper is again moved 5 squares to the right for another interval with the previous top reading (6.0) adjacent to the bottom line.

This process of moving 5 squares to the right and bringing the top reading to the bottom line is continued until the stripper reaches the right edge of the cross section with a final reading of 53.0. Multiply this last reading (53.0) by the strip width used (5) to get the number of squares in the section (265.0). To find the area of the cross section in square feet, multiply the number of squares by the area in square feet of one square.

Double-Meridian-Distance Method

The double-meridian-distance (DMD) method gives a more precise value for a cross-section area than the stripper method. It does, however, involve more effort and time. It is essential that the elevations (latitudes) and the distance from the centerline (departures) of all points on the cross section be known.

The method is based on the theory that the area of a right triangle equals one half of the product of the two sides. Since latitudes and departures are at right angles to each other, the area bounded by the distance, the latitude, and the departure is a right angle. The surveyor can determine this area by taking one half of the product of the latitude and the departure. However, depending on its location, the triangle may add to or subtract from the total area of the irregular figure.

To avoid determining a plus or minus area for each triangle, a slight refinement is made. The departure is added twice. It is first added when determining the DMD of the course and second, when determining the next course's DMD. Multiplying the DMD of each course by its latitude results in twice the area, but the sign of this product illustrates whether the area adds to or subtracts from the figure area.

A step-by-step procedure to work out a DMD area is given below and illustrated in figure 4-5.

(1) Compute and record all the latitudes and departures.

(2) Select the far left station (D) as the first point and D-E as the first course to avoid negative areas in the DMD.

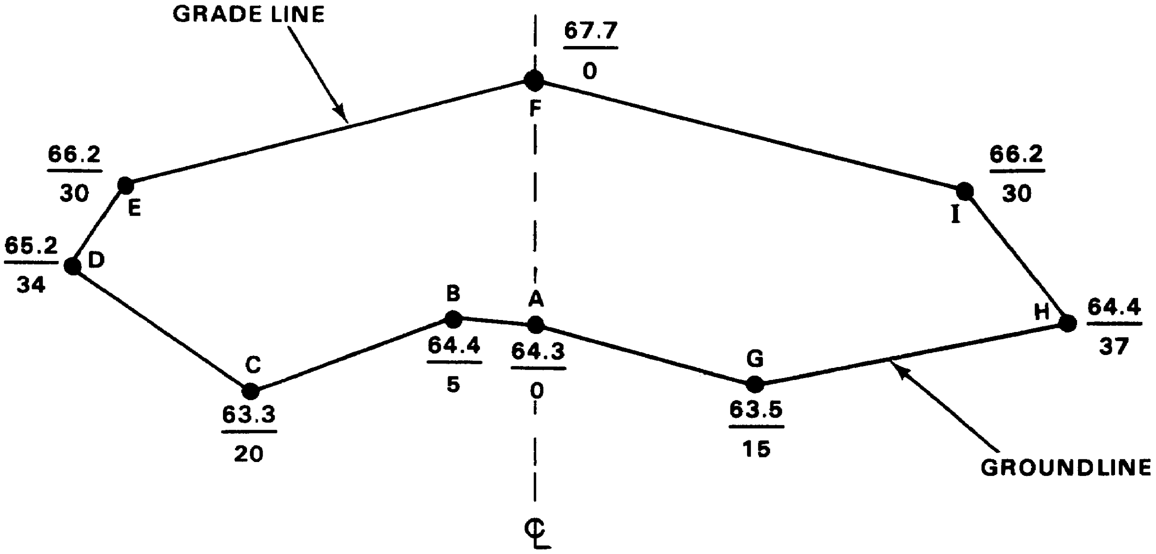
(3) The DMD of the first course equals the departure of the course itself, 4.0.

(4) The DMD of any other course (E-F) equals the DMD of the preceding course (D-E) plus the departure of the preceding course (D-E) and the departure of the course (E-F) itself or 4.0 + 4.0 + 30,0 = 38.0. For the next course (F-I), the same procedure is followed. Add together the DMD of the preceding course, the departure of the preceding course, and the departure of the course itself, or 38.0 + 30.0 + 30.0 = 98.0.

(5) The DMD of the last course is numerically equal to its departure but with the opposite sign (+14.0).

(6) Multiply each DMD value by its latitude. Positive products are entered under north double areas and negative products under south double areas.

(7) The sum of all north double areas minus the sum of all the south double areas, DISREGARDING THE SIGNS, equals twice the cross-section areas. Divide this double area by 2 to get the true cross-section area.



Course	Latitude	Departure	D.M.D.	North Double Area (+)	South Double Area (−)
D-E	+1.0	+4.0	4.0	4.0	
E-F	+1.5	+30.0	38.0	57.0	
F-I	-1.5	+30.0	98.0		147.0
I-H	-1.8	+ 7.0	135.0		243.0
H-G	-0.9	-22.0	120.0		108.0
G-A	+0.8	-15.0	83.0	66.4	
A-B	+0.1	- 5.0	63.0	6.3	
B-C	- 1.1	-15.0	43.0		47.3
C-D	+1.9	-14.0	14.0	26.6	
				+160.3	-545.3

Difference = 545.3 − 160.3 = 385.0

Area: $385.0/2 = 192.5\ ft^2$

Figure 4-5. Cross-section area by double-meridian-distance method

AREA BY PLANIMETER

The surveyor uses a polar planimeter to measure the area of a plotted figure. There are two types of planimeters. One has a fixed scale, and one has an adjustable scale. Basically, the surveyor uses both in the same way, with the exception that the fixed scale cannot be adjusted to yield a 1:1 ratio when tracing areas.

Operation

The planimeter (figure 4-6) touches the paper at four points: the anchor point (B), the tracing point (A), the drum (C), and the support wheel (G). The adjustable tracing arm (E) is graduated to permit adjustment to the scale of the plotted figure. This adjustment provides a direct ratio between the area traced by the tracing point and the revolutions of the roller. The scale screws, Fl, F2, and F3, are used to accomplish the proper adjustment of the tracing arm scale. Proper scale settings are provided with each instrument. If the scale setting provided yields an area that is too large, the scale reading must be increased and vice versa.

As the planimeter encircles the area to be measured, the drum (C) revolves and records the answer in tens and hundreds. A vernier (M) is mounted adjacent to the drum and enables a single unit (ones) reading. The disk (D) is attached to the drum by a worm gear, counting the number of drum revolutions and giving the thousands reading. The surveyor must first read the disk for thousands, then the drum for hundreds and tens, and finally, the vernier for single units (ones).

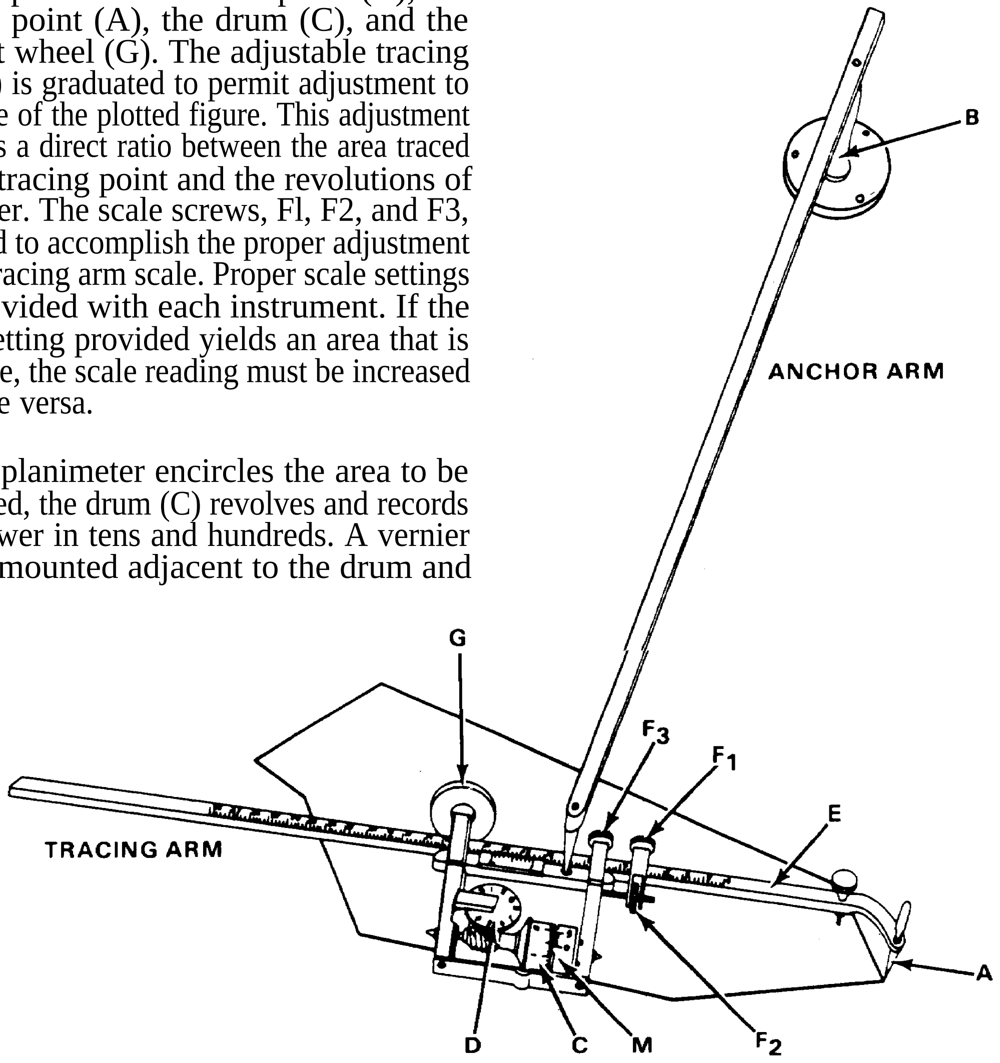


Figure 4-6. Polar planimeter

Procedures

The following are rules for using a planimeter,

- Always measure cut and fill areas separately.

- Check the accuracy of the planimeter as a measuring device to guard against errors due to temperature changes and other noncompensating factors. A simple method of testing its consistency of operation is to trace an area of 1 square inch with the arm set for a 1:1 ratio. The disk, drum, and vernier combined should read 1.000 for this area.

- Before measuring a specific area, determine the scale of the plot and set the adjustable arm of the planimeter according to the chart in the planimeter case. Check the setting by carefully tracing a known area, such as five large squares on the cross-section paper, and verifying the reading on the disk, drum, and vernier. If the reading is inconsistent with the known area, readjust the arm settings until a satisfactory reading is obtained.

- To measure an area, set the anchor point of the adjusted planimeter at a convenient position outside the plotted area; place the tracing point on a selected point on the perimeter of the cross section; take an initial reading from the disk, drum, and vernier; continue tracing the perimeter clockwise, keeping the tracing point carefully on the line being followed; and when the tracing point closes on the initial point, again take a reading from the disk, drum, and vernier. The difference between the initial reading and the final reading gives a value proportional to the area being traced.

- Make two independent measurements of the area to insure accurate results. Make the second measurement with the tracing point placed at a point on the opposite side of the first measurement. This procedure gives two compensating readings. The mean of these readings is more accurate than either one individually.

- To measure plotted areas larger than the capacity of the planimeter, divide the areas into sections and measure each separately.

Section III. EARTH AND ROCK EXCAVATION

CLASSES OF EXCAVATED MATERIAL

Excavated material is usually classified as common excavation, loose rock, and solid rock. Although classifying excavation material is not a survey function, the surveyor must differentiate among the different types so excavation records will match the construction work. When performing surveys to determine quantities of excavated materials, the surveyor must record common excavation, loose-rock excavation, and solid-rock excavation data separately in the field notes.

Common excavation involves the moving of earth or of earth with detached boulders less than one-half cubic yard in volume. Loose-rock excavation involves the moving of consolidated materials which have been loosened without blasting with picks, bars, or simple air and mechanical devices. Solid-rock excavation involves the moving of rock from solid beds or the breaking up of boulders measuring 1 cubic yard or more by means of explosives.

BORROW PITS

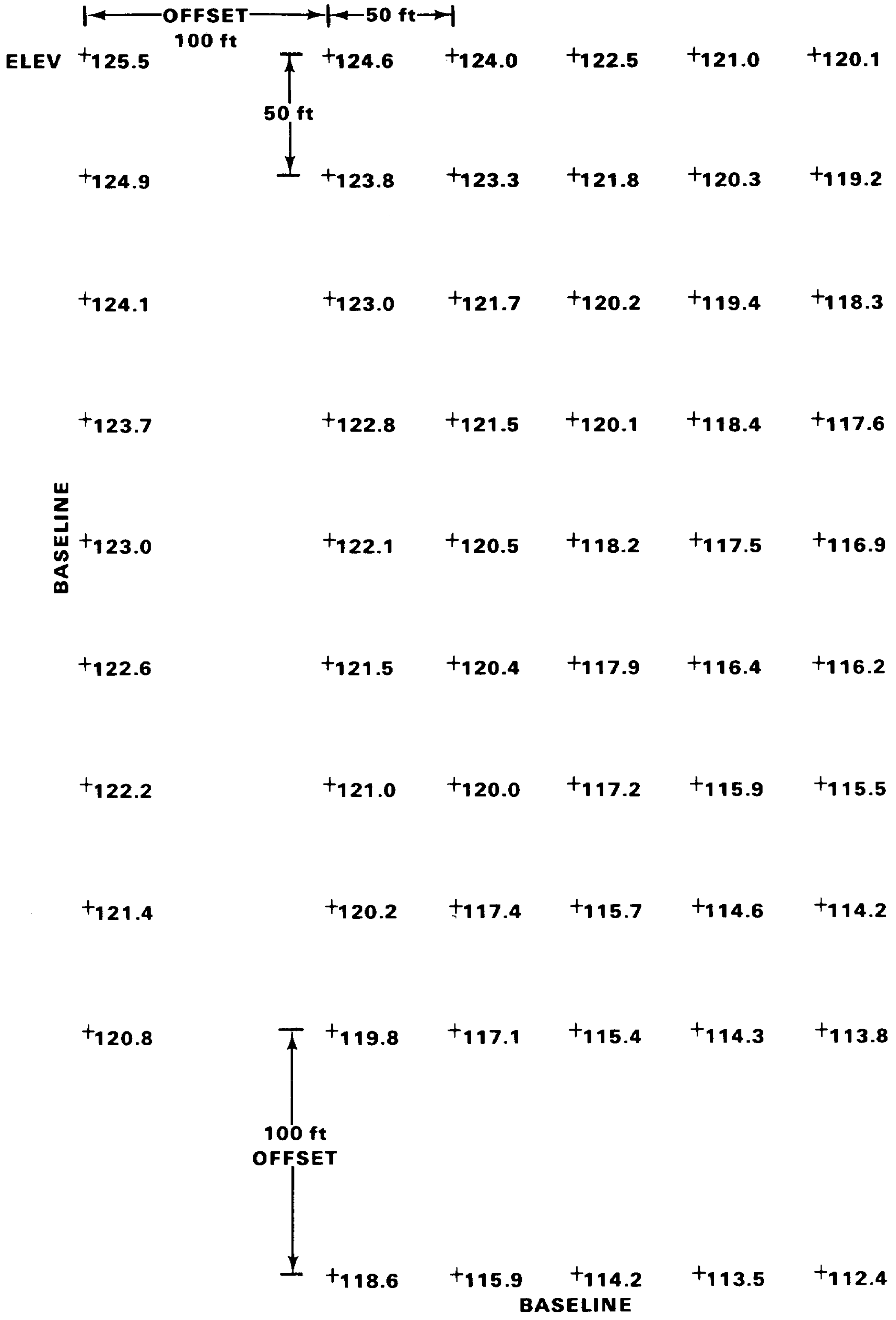
When there is an imbalance in the volume of cuts and fills in construction projects, it is often necessary to borrow the required fill dirt from borrow pits outside the construction limits but near the fill site. Any time the haul distance between the last available dirt and the fill site becomes too far, it is cheaper to establish a borrow pit.

Under some circumstances, it is not necessary to survey borrow pits. However, it is often necessary to buy the fill dirt. The surveyor must determine how much earth was removed from the borrow pit. This can be done by establishing a grid over the area to be excavated. The grid can beat any convenient interval (for example, 10-, 25-, 50-, or 100-foot squares).

Once the grid is staked, the surveyor can determine the elevation of each grid corner by leveling. The volume of earth that has been removed can be computed at any time by reestablishing the grid corners and determining their new elevation. The surveyor does this by subtracting the average elevation of the grid corners after excavation from the average elevation of the same grid corners before excavation and multiplying the difference by the number of square feet in the grid square.

When laying out the grid, the surveyor must lay out two baselines parallel to two adjacent sides of the grid for use in reestablishing the grid. The surveyor should place them far enough outside the area of excavation to avoid destruction but close enough to be convenient. (See figure 4-7.)

The surveyor should treat waste areas or dumps where excess material is deposited in the same manner as borrow pits, with the exception that the volume to be measured is the volume deposited, not excavated.



+125.5	+124.6	+124.0	+122.5	+121.0	+120.1
+124.9	+123.8	+123.3	+121.8	+120.3	+119.2
+124.1	+123.0	+121.7	+120.2	+119.4	+118.3
+123.7	+122.8	+121.5	+120.1	+118.4	+117.6
+123.0	+122.1	+120.5	+118.2	+117.5	+116.9
+122.6	+121.5	+120.4	+117.9	+116.4	+116.2
+122.2	+121.0	+120.0	+117.2	+115.9	+115.5
+121.4	+120.2	+117.4	+115.7	+114.6	+114.2
+120.8	+119.8	+117.1	+115.4	+114.3	+113.8
	+118.6	+115.9	+114.2	+113.5	+112.4

Figure 4-7. Typical grid layout for borrow pits

CHAPTER 5

BRIDGE SURVEYING

Section I. LOCATION

SURVEYS

Bridge surveying is necessary to locate a site, obtain information for design, and furnish lines and grades for construction. A reconnaissance survey is made at all possible sites. A preliminary survey is made at the best site to establish horizontal and vertical control and to obtain information for the bridge design and construction planning. A location survey is made to lay out the bridge according to the bridge plans. During the actual construction, the surveyor establishes any additional lines and grades required by the construction foreman.

The accuracy of measurements and the number and type of survey markers vary with the degree of precision demanded and the type of construction. Variations may range from hand-level and sketchboard work for a tactical bridge to precise measurements for a prefabricated steel bridge.

RECONNAISSANCE

Tentative bridge sites are selected by reconnaissance and the more promising ones are reconnoitered in detail. The selection of a bridge site is governed by both tactical and technical considerations. Tactical requirements fix the general area for the bridge site. Technical requirements fix the exact location and may sometimes eliminate sites that are tactically acceptable. For permanent construction, technical considerations govern the bridge location.

Access Roads

Maps or prepared overlays show existing roads and the distances of railheads from the bridge site. Descriptive symbols indicate the width, condition, and types of roads. The surveyor draws sketches of approach roads to be constructed on overlays and includes them in the reconnaissance report.

Bridge Length

The surveyor determines the length of the bridge crossing to estimate the materials required for construction. Depending on the distance and equipment available, the surveyor measures this distance with a tape, an electronic measuring device, or by stadia method.

Banks

The surveyor reports on the character and shape of the riverbanks. This includes the amount and type of vegetation; the slope, height, and composition of the banks; and pertinent dimensions of any natural dikes. The surveyor selects tentative abutment positions and measures the size and location of any usable abutments or piers for possible use in the proposed construction.

Character of the Flow

The surveyor determines stream velocity by timing a floating object over a measured course. High-water levels are determined by noting drift and marks on vegetation or piers, questioning local inhabitants, and consulting tide tables and local flood records.

Character of the River Bottom

The surveyor observes the character of the river bottom for each site and reports information on the design of intermediate supports. If a floating bridge is to be constructed, the surveyor determines the character of the river bottom so the holding power of anchors can be estimated.

Profile

The surveyor profiles the streambed or gap to facilitate the design of intermediate supports. The profile interval is measured by a tape or cable stretched horizontally across the stream or gap or by the instrument-stadia method. Vertical measurements for the profile are referenced to the horizontal tape, cable, or water surface. For floating bridges, profiles are required only for setting trestles near the shores.

Local Materials

The surveyor estimates and records quantities of local materials such as standing timber, sand and gravel beds, and available cement, water, and lumber.

SOUNDINGS

A survey is made to determine the relief of the bottom of the stream along the centerline and along lines on each side of the centerline. The surveyor must make soundings and determine the depth of each sounding in relation to the datum used for vertical control.

Location

The location of each sounding is referenced to control stations onshore. The design engineer specifies the distance from the centerline and intervals between soundings. Unless otherwise specified, intervals between soundings are 25 feet for a fairly uniform streambed and 10 feet for an irregular streambed. For more accurate location of soundings, the surveyor should use the intersection method. This would include setting instruments on the ends of a baseline on shore and reading simultaneous angles.

Procedures

Figure 5-1 shows one method of taking soundings. The instrument is set up over C and sighted on F. A sounding boat travels on the range line, CF, from the far shore toward the near shore. The instrumentman signals the sounding crew until they are online at the proper distance as measured by tape or stadia. The sounding crew proceeds along the centerline, CF, taking readings at the specified intervals. In shallow water, direct rod readings can be taken for profile elevations by setting the instrument near the river's edge. In deeper rivers, the depth of water is measured directly from the boat, using the most suitable measuring device.

The surveyor records the data obtained by the sounding and ground crews in order to provide a complete set of profile notes for the construction design. To establish profiles on each side of the centerline, stakes are set at a specified distance from the centerline at B, D, E, and G. Using the same procedure as for the centerline soundings, the surveyor sets up the instrument at B, then at D, and sights on E and G, respectively.

FOUNDATION INVESTIGATION

Data on foundation investigations serve as the basis for determining bearing capacities and substructure design. Subsurface investigations are made by borings, test pits, trenches, and field tests. The surveyor must often make measurements incident to these investigations. The surveyor's duties include referencing boreholes and test pits to nearby instrument stations and recording elevations of strata encountered at the various sites. These data are used in preparing a profile illustrating subsurface conditions.

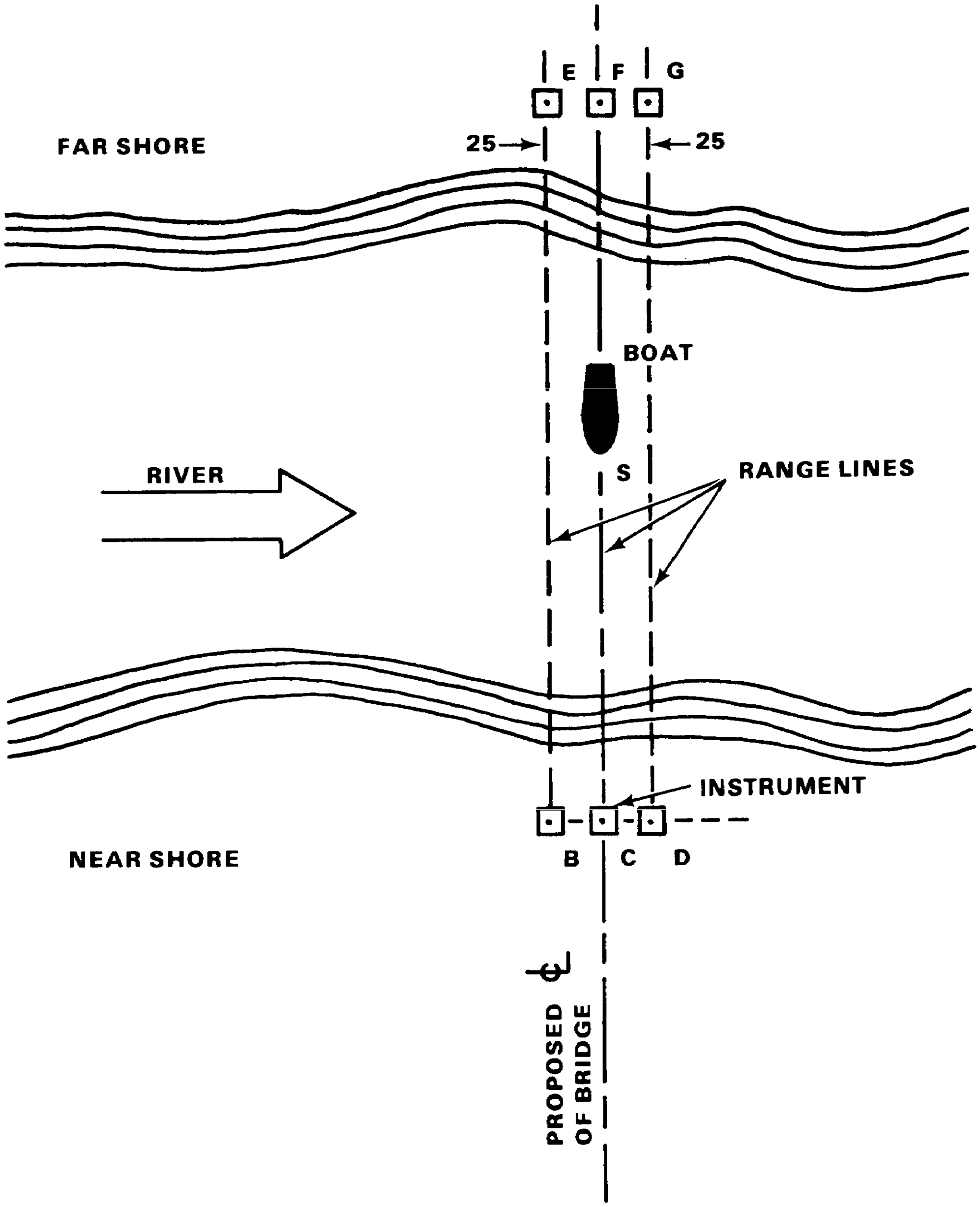


Figure 5-1. Taking soundings

Section II. BRIDGE SITE LAYOUT

ABUTMENTS

Construction plans show whether the abutments are pile-bent or crib-bent. The surveyor checks the layout after excavation and before any concrete is poured. The surveyor must also check abutment elevations and, in the case of concrete, establish lines for setting forms. Care must be taken to stake abutments according to the construction plans. The distance between abutments must be within steel fabrication limits, especially for prefabricated sections. The surveyor then ties abutment stakes to a horizontal control system.

The survey procedure for setting an abutment at right angles to the bridge centerline is illustrated in figure 5-2. The foundation, ABCD, is shown in the plan. AB is the face,

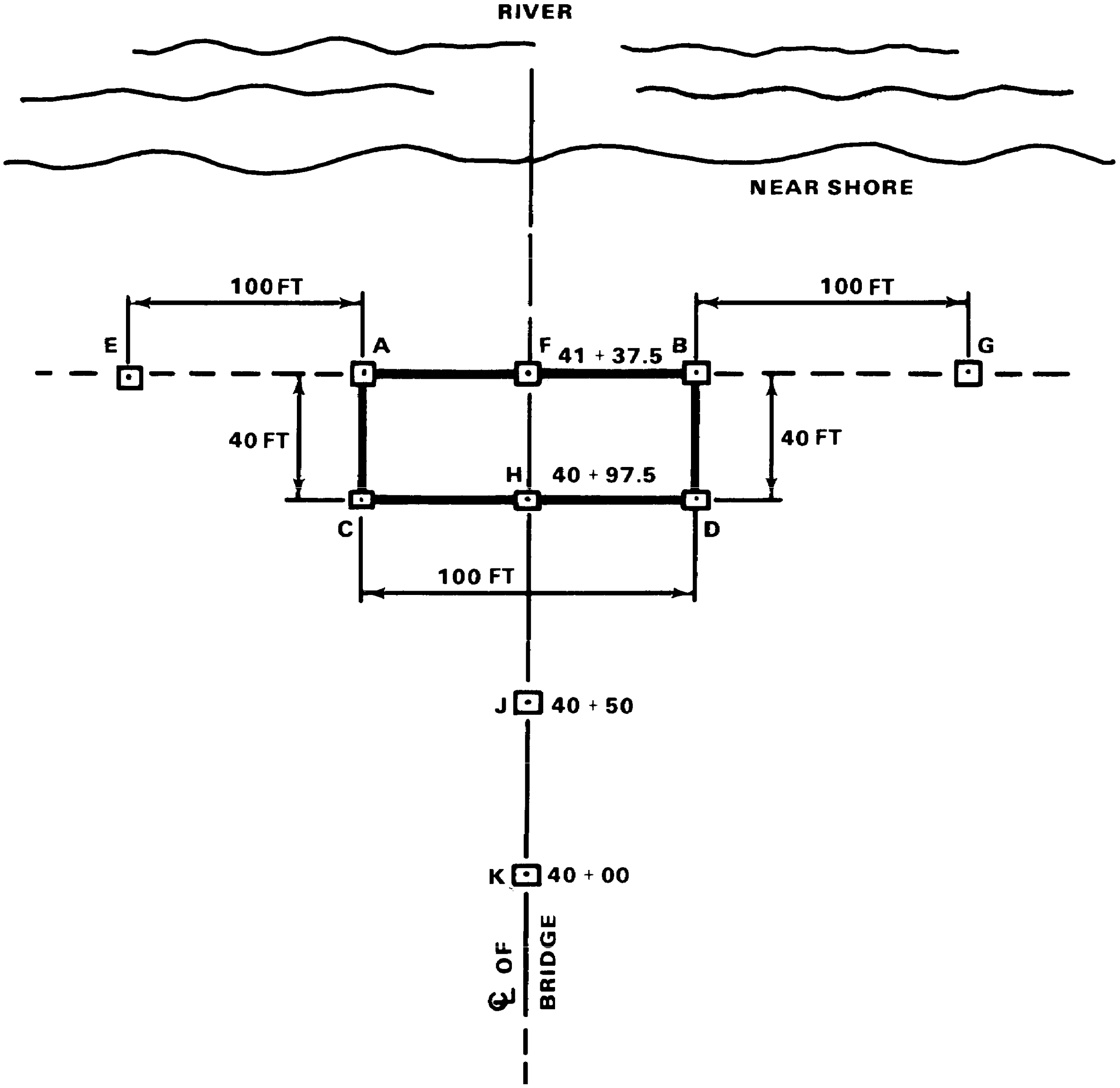


Figure 5-2. Staking an abutment

and points J and K are established near the site on the centerline of the bridge. The staking is done as follows:

(1) Set the instrument at point H (station 40+97.5). Sight on point J. Invert the instrument and use a tape to locate point F.

(2) Turn 90-degree angles and use a tape to locate points C and D.

(3) Move the instrument to point F (station 41+37.5), sight on H, and turn 90-degree angles to locate points A and B. Locate points E and G in line with points A and B, respectively, and use as horizontal control points.

WING WALLS

The procedure for laying out wing walls is merely an extension of the layout of an abutment. The surveyor sets the instrument at B (figure 5-3), sights on G, and turns the wing angle. Points L and M are located at any convenient distance along this line.

The surveyor sets the instrument at A and locates points N and O. Since points A and B may be lost or damaged during construction, the surveyor locates two points (L and M; N and O) on the line of sight of the front of each wing wall. To relocate point A, the instrument is set at point O and sighted through point N. The surveyor may also locate point A by setting the instrument up on N, sighting on O, and inverting.

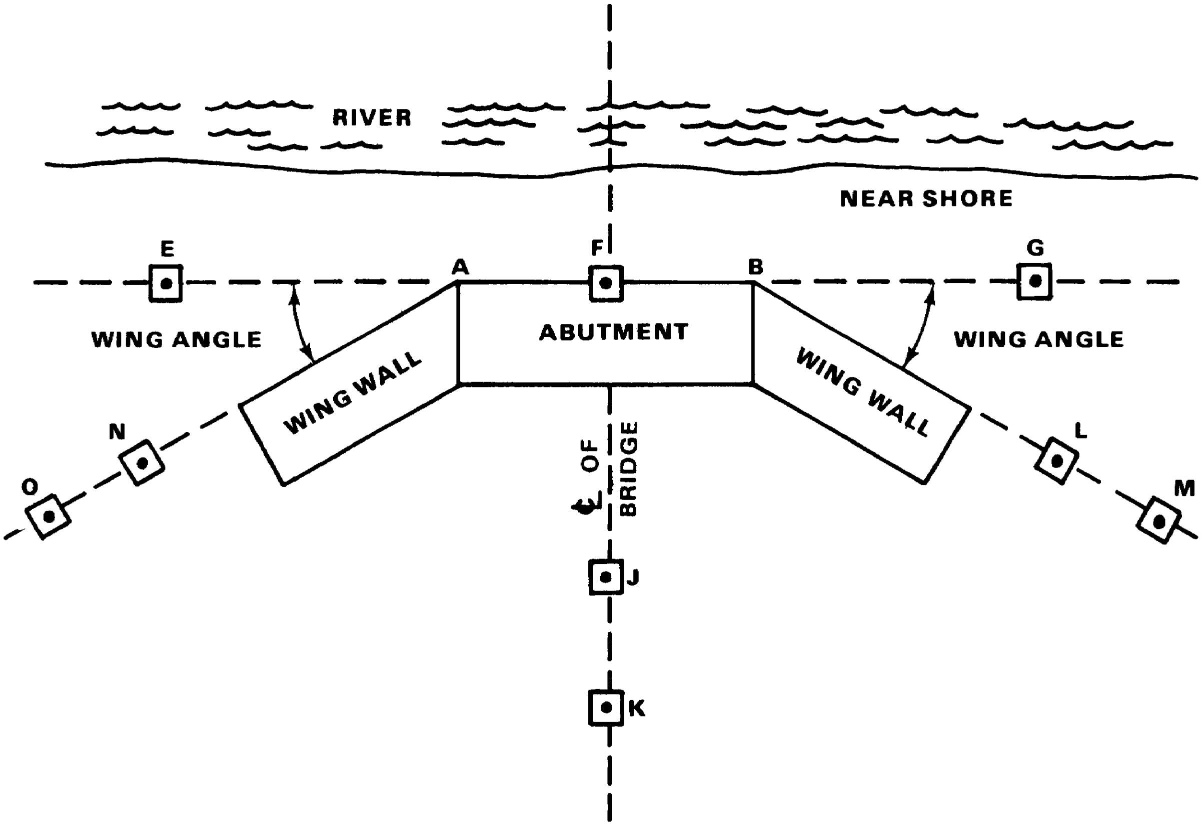


Figure 5-3. Staking wing walls

PIERS

After the centerline of the bridge is established, the surveyor locates the piers by taping. If taping is impractical, they can be located by triangulation. The surveyor sets stakes establishing the centerline (C and E) on each side of theriver. The surveyor lays out CD and EF approximately at right angles to the centerline as shown in figure 5-4. For well-proportioned triangles, the length of the baselines should equal at least one-half CE.

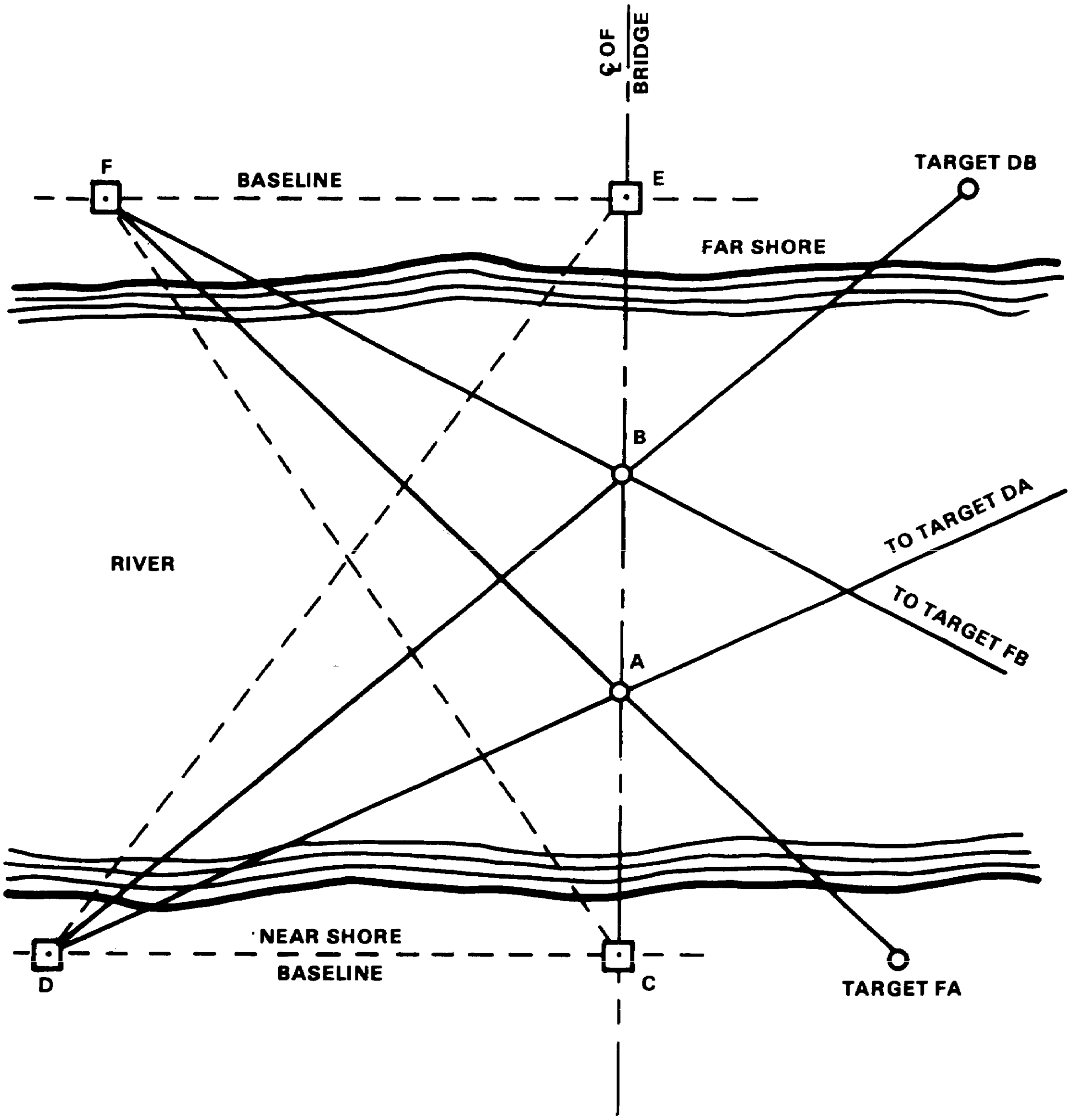


Figure 5-4. Locating piers

To locate piers at A and B, the surveyor should follow these steps.

(1) Establish and carefully reference baselines CD and EF.

(2) Measure the length of each baseline commensurate with the required precision of line CE.

(3) Measure all angles of the triangles CDE and EFC.

(4) Compute the distance CE from the triangle CDE and check it against the same distance computed from the triangle EFC. The difference in computed length must be within the prescribed limits of error.

The difference in computed length must be within the prescribed limits of error.

(5) Compute angles BDC, ADC, BFE, and AFE. (Since A and B are located by the construction plans, it is possible to determine their distance from C and E.)

(6) Draw a triangulation diagram, showing computed angles and distances and measured angles and distances.

(7) Turn computed angles BDC, ADC, BFE, and AFE.

(8) Set targets DA and DB on the far shore and FB and FA on the near shore, so that the intersecting lines can be reestablished without turning angles. Carefully reference these points.

(9) Use two instruments to position crib piers. They will occupy two points such as F and D simultaneously. The intersection of sights FA and DA locates the pier A.

PILES

The surveyor positions piles, records pile-driving data, and marks piles for cutoff as specified by the construction plans.

Figure 5-5 shows points A and B established as a reference line 10 feet from the centerline of the bridge. A wire rope is stretched between these points with a piece of tape or a cable clip marking each pile-bent position, such as C and D. The surveyor can locate the upstream pile, pile number 1, by measuring the offset (4 feet) from the line AB at C. A template, designed to space the piles properly (3 feet in the figure) and nailed to pile number 1 after the pile is driven, is then floated into position. The surveyor positions the rest of the piles using the template.

If it is impractical to stretch a cable to the far shore, the surveyor sets up an instrument at some convenient distance from the centerline of the bridge and positions the template by sighting on a mark located the same distance from the centerline of the template. The surveyor determines the distance of the template from the shore, either by angle measuring or taping. During driving, the surveyor must keep a complete record of the following:

- Location and number of piles.
- Dimensions.
- Kind of wood.
- Total penetration.
- Average drop of hammer.
- Average penetration under last five blows.
- Penetration under last blow.
- Amount of cutoff.

Elevations are marked on the two end piles. Two 3- by 12-inch planks are nailed to guide the saw in cutting piles to the specified height.

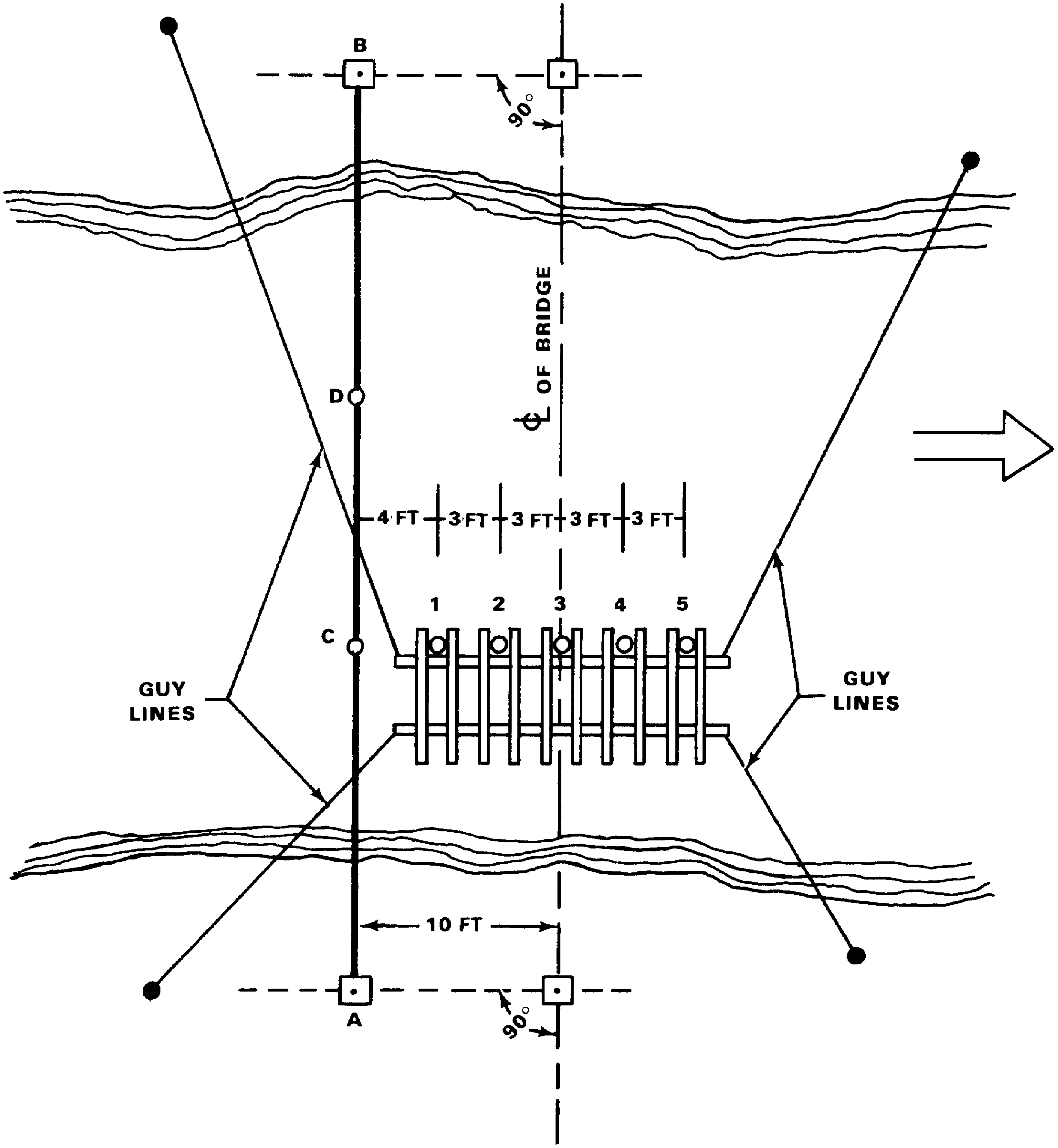


Figure 5-5. Positioning piles

CHAPTER 6

SITE LAYOUT

Section I. BUILDING LAYOUT

OBJECTIVES

The objectives of surveying for building construction are to lay out the proposed structure according to prepared plans and to mark the controlling points of the structure in the manner that is most useful to the construction forces. This marking consists of indicating the corners of the building and other horizontal and vertical positions by means of stakes, batter boards with string lines, drill holes, cut-and-fill notations, and similar conventional methods.

The actual layout of the building is usually preceded by some form of reconnaissance and location survey. The following procedures are typical of major building projects:

- Performing reconnaissance (aerial, map, and ground).
- Selecting site (paper and instrument).
- Establishing control (horizontal and vertical).
- Taking topography (plane table or transit stadia).

ORIENTATION

The building and its foundation are positioned according to the controlling dimensions and references appearing on prepared plans. The dimensions and references include the overall length and width of the structure, distances to road centerlines and to other structures, measurements within the structure itself, and miscellaneous determinations concerning the approaches and rights-of-way.

LAYOUT OF A SIMPLE BUILDING

The plans for construction of a building give the location and elevation of the work relative to existing utilities and survey control marks. The dimensions of the building are part of the necessary data for establishing line and grade. Figure 6-1 illustrates atypical building layout using the following steps.

(1) Establish baseline AB and locate CD by measurement.

(2) At point C, turn 90 degrees from B and locate corner stakes E and F by measurement.

(3) Locate points H and G from point D in the same way.

(4) Check diagonals (EH and FG) by the formula $c = \sqrt{a^2 + b^2}$ (where c is the diagonal and a and b, the two sides).

(5) Install batter boards.

(6) Establish line and grade.

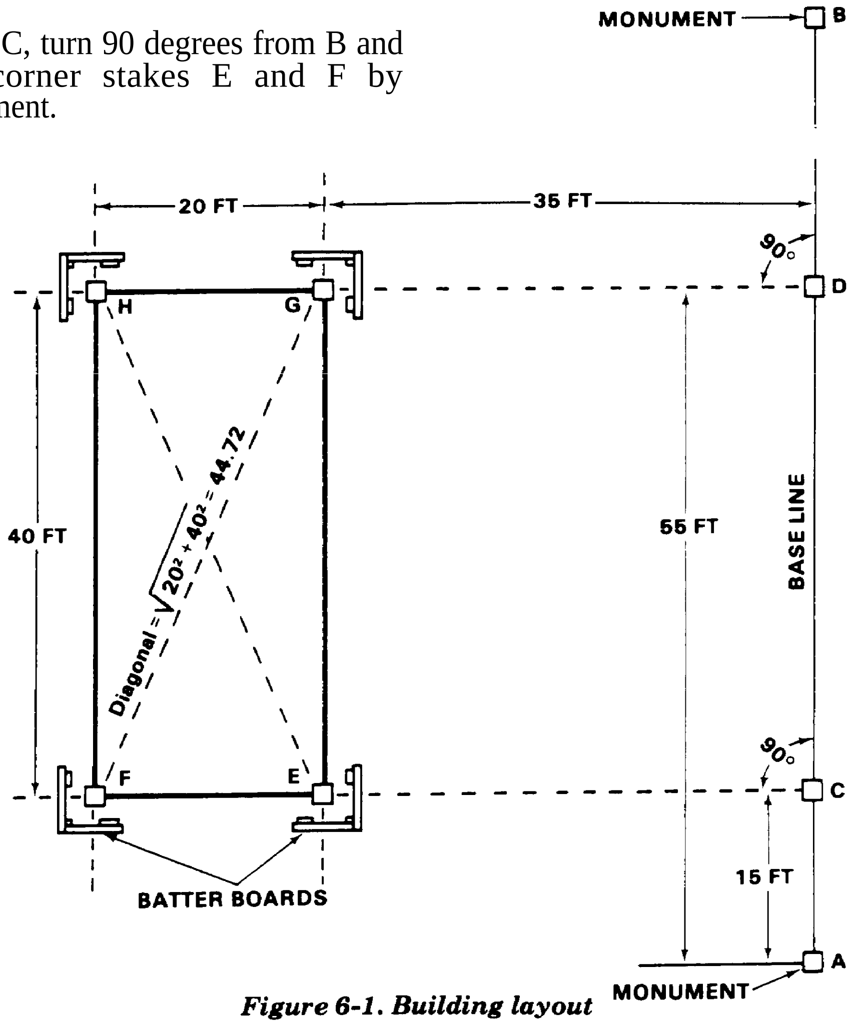


Figure 6-1. Building layout

BATTER BOARDS

The surveyor locates the corners of the building and determines the elevation of its foundation by carrying forward elevations from a benchmark, or other point of known elevation, to the foundation. To mark the general location, the surveyor sets stakes or slats. These will guide the initial excavation and rough grading. However, the stakes will be disturbed or destroyed during this work, and somemore suitable marks must be placed to continue the construction. These suitable marks are called batter boards. The surveyor uses these temporary devices to mark the outline and grade of the structure and any special construction inside or outside.

Placement

Batter boards of two 2- by 4-inch stakes driven into the ground and a crosspiece of 1- by 6-inch lumber naled to each stake. The surveyor drives the stakes about 3 to 4 feet away from the building line so they will not be disturbed by the construction but will be far enough apart to straddle the line to be marked. Note that in figure 6-2 only three stakes, one of them being a common post for two directions, are driven on outside corners. The length of the stakes is determined by the required gradeline. They must be long enough to accept the 1- by 6-inch crosspiece to mark the grade. The surveyor cuts the 1- by 6-inch crosspiece long enough to join both stakes and nails it firmly to them after the grade has ben established. The top of the crosspiece becomes the mark fromwhich the grade will be measured.

Use of Instrument. The surveyor sets all batter boards for one structure to the same grade or level line. An instrument is used to locate the building lines and mark them on the top edge of the crosspiece. A nail is driven at each of these marked points. A cord stretched over the top edge of two batter boards and held against the nails defines the building line and grade elevation.

Use of Cord. Sometimes, an instrument is not available for marking the building line on the batter boards. If the corner stakes have not been disturbed, the surveyor can transfer the building line to the batter boards by stretching a cord over the batter boards and using plumb bobs held over the corner stakes. The surveyor moves the cord on each batter board until it just touches both plumb bob strings, marks the position of the cords, and drives in the nails.

Procedures

The surveyor sets and marks the batter boards as follows:

(1) After the corner stakes are laid out, drive 2- by 4-inch stakes 3 to 4 feet outside of

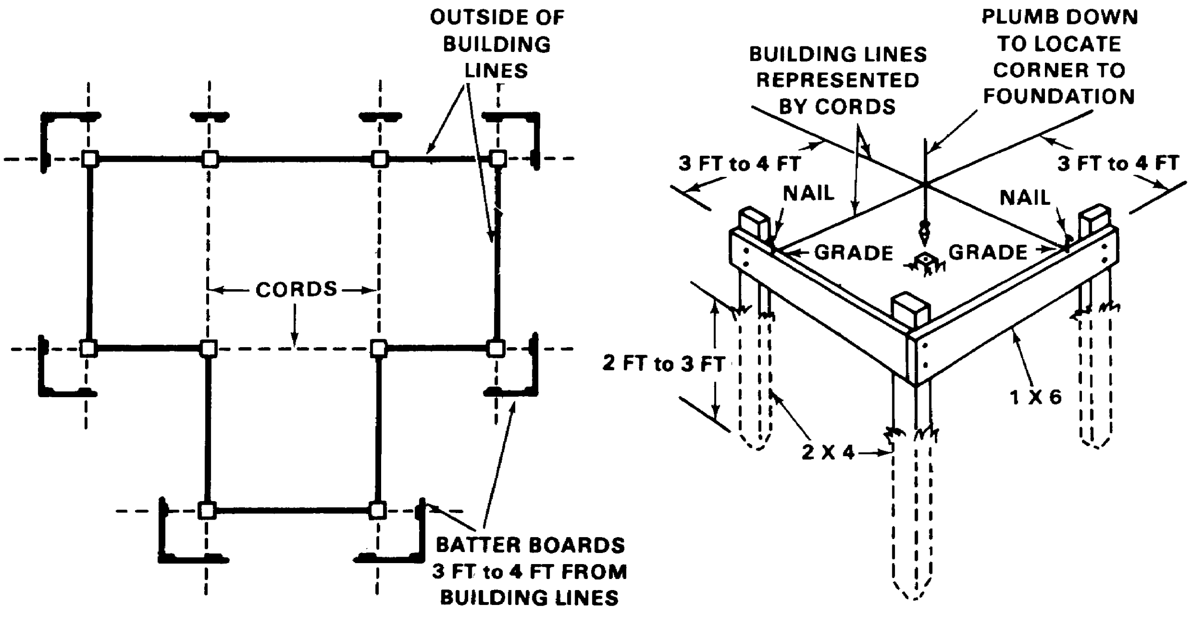


Figure 6-2. Batter boards

each corner. These are selected to bring all crosspieces to the same elevation.

(2) The surveyor marks these stakes 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. Use a level to mark the same grade or elevation on all stakes.

(3) Nail 1- by 6-inch boards to the stakes to the top edge of the boards and flush with the grade marks. Mark the distance in crayon on these boards.

(4) Locate the prolongation of the building lines on the batter boards by using an instrument or a line and plumb bob.

(5) Drive nails into the top edges of the batter boards to mark the building line.

INTERIOR TRANSFER OF LINE AND GRADE

Occasionally, it is necessary to transfer lines and grades from outside to inside a building and to the upper stories for establishing wall faces, floor levels, and columns or for setting machinery precisely. The surveyor does this by traversing and leveling.

Location

The surveyor locates instrument stations outside of the building to establish a line that, when extended, will intersect the building at a window or doorway. The instrument is set on the station farthest from the building and sighted on the point nearest the building. The surveyor transfers the line to the building by sighting the instrument on a plumb bob held in an upper-story window.

From this point, the line is extended in any direction inside the building by setting up on the point and using the outside stations as a backsight. The line is prolonged by double centering. Because of the short sights used, the surveyor may accurately set an angle that is to be turned to clear an obstruction and then measure by repetition.

Direct Leveling

To transfer vertical control into a building, the surveyor uses direct leveling, if possible. For elevation transfer to an upper story, a steel tape is suspended with a weight attached to the lower or zero end. To insure accuracy, the weight should approximately equal the normal tension of the fully supported tape minus one half of the weight of the suspended portion of the tape. A level is set up on the first floor, and a reading is taken on the suspended tape.

Another reading is taken on the tape with a level set on the upper floor. This gives data from which the HI of the instrument on the upper floor are computed. A rod is now held on some point on the upper floor to be used as a benchmark and its elevation determined. The surveyor may also establish elevations on the second floor by using the rod upside down (often called an inverted rod) and marking the elevation on a wall.

Section II. UTILITIES LAYOUT

DRAINAGE

Utilities drainage refers to the sewer systems for surface water and liquid waste. The design and location of a drainage or storm sewer system will depend upon the size and topography of the area to be drained, the intensity of rainfall expected, the runoff characteristics of the area, and the location of the disposal point. The area to be drained includes the installation and any area around it that will drain into the installation. The intensity of the rainfall in inches per hour is based on records of past storms. The runoff characteristics are determined by the type of soil and ground cover.

DESIGN AND LOCATION

Using the factors mentioned and the best available topographic map of the area, the surveyor designs and locates the sewer lines on paper. Once the paper location is accomplished, the centerline of the ditch is staked and profile levels run. The profile and grade lines are plotted and cut stakes set.

After the trench is dug, batter boards are set for the alignment of pipes and placement of manholes or drop inlets. The surveyor usually places batter boards for sewer alignment at intervals of 10 to 25 feet and sets them on edge across the trench (figure 6-3). Then the surveyor determines the interval between batter boards, the station number, and the elevation of the sewer grade at each batter board.

The term sewer grade is interchangeable with such other terms as invert grade, pipe grade, flow line, and grade line elevation. They all mean the same thing, the elevation of the low point on the inside circumference of the pipe. All sewer lines are designed with this elevation as the controlling factor. The surveyor must set all grade marks on the batter boards between two successive manholes at the same distance above the invert grade.

Battens

The surveyor nails battens (small pieces of wood) to the batter boards to indicate sewer alignment. All battens are set vertically on the same side of the batter boards, with the same edges directly over the centerline of the sewer. As work progresses, the surveyor must check the alignment of these battens frequently. This is done by sighting past the edges marking the centerline. Any batten that has been moved or disturbed will be visible immediately.

Sighting Cords

The surveyor uses a sighting cord stretched parallel to the centerline of the sewer at a uniform distance above the invert grade to transfer line and grade into the trench. After computing the invert elevation, the surveyor adds an even number of feet to establish the elevation of the cord at each batter board. This position is marked on the centerline edge of each batten by a nail. The sighting

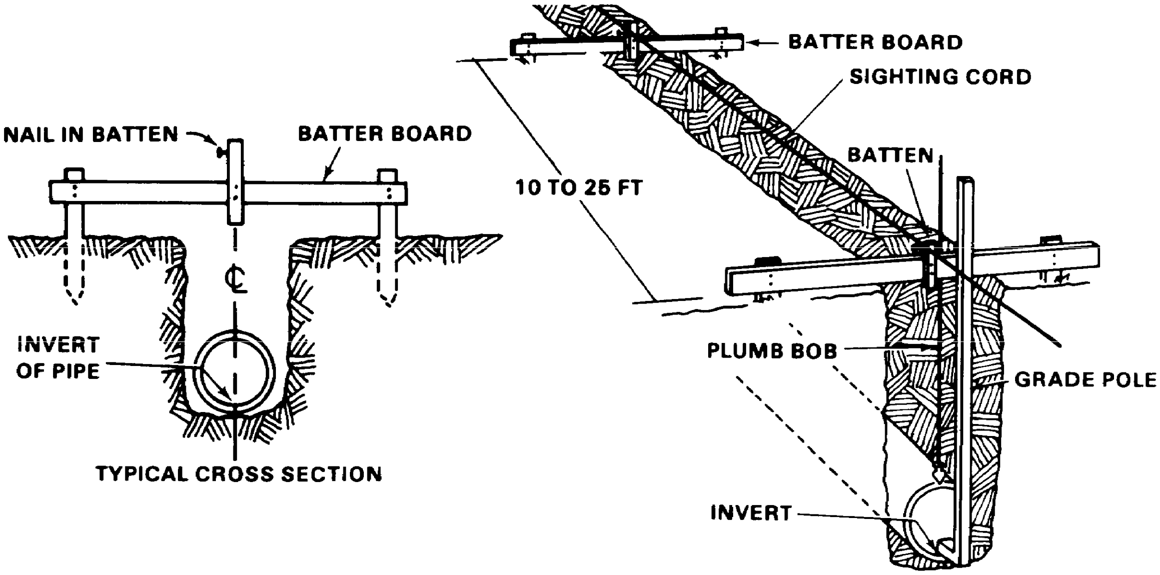


Figure 6-3. Sewer alignment

cord is fastened to the battens at these nails and this establishes the alignment of the sewer. The centerline is directly below the cord, and the sewer invert grade is at the selected distance below the cord.

Grade Transfer

To transfer the grade, usually in feet or feet and inches, from the sighting cord to the pipe, the surveyor uses a rod or stick called a grade pole, with a mark at a distance from the foot piece equal to the distance between the sighting cord and the invert grade (figure 6-3). The foot piece is placed on the invert of the pipe, and the rod plumb is held. The pipe end is then raised or lowered until the mark on the grade pole is on a horizontal line with the cord. A plumb line is held lightly against the cord and the pipe shifted sideways until its crown is directly below the point of the plumb bob. The grade pole is again placed in position, held plumb, and its mark checked against the cord.

CHAPTER 7

TRAVERSE

Section I. SELECTION OF TRAVERSE

DEFINITION

A traverse is a series of straight lines called traverse legs. The surveyor uses them to connect a series of selected points called traverse stations (TS). The surveyor makes distance and angle measurements and uses them to compute the relative positions of the traverse stations on some system of coordinates.

STARTING CONTROL

Since the purpose of a traverse is to locate points relative to each other on a common grid, the surveyor needs certain elements of starting data, such as the coordinates of a starting point and an azimuth to an azimuth mark. There are several ways in which the starting data can be obtained, and the surveyor should make an effort to use the best data available to begin a traverse. The different variations in starting control are grouped into several general categories.

Known Control Available

Survey control is available in the form of existing stations with the station data published in a trigonometric list, or higher headquarters may establish the station and provide the station data. The surveyor obtains the azimuth to an azimuth mark (starting direction) by referring to a trigonometric list or computing from known coordinates.

Maps Available

When survey control is not available in the area, the surveyor must assume the coordinate of the starting station. The assumed data approximates the correct coordinate as closely as possible to facilitate operations. When a map of the area is available, the approximate coordinate of the starting station is scaled from the map. (For survey purposes, starting data scaled from a map are considered to be assumed data.) The surveyor determines the starting direction by scaling it from the map.

No Maps Available

When neither survey control nor maps are available, the coordinate of the starting point is assumed. The surveyor determines the starting direction by the most accurate means available.

TYPES OF TRAVERSE

Construction surveying makes use of two basic types of traverse—open traverse and closed traverse.

Open Traverse

An open traverse (figure 7-1) originates at a starting station, proceeds to its destination, and ends at a station whose relative position is not previously known. The open traverse is the least desirable type of traverse because it provides no check on fieldwork or starting data. For this reason, the planning of a traverse always provides for closure of the traverse. Traverses are closed in all cases where time permits.

Closed Traverse

A closed traverse starts at a point and ends at the same point or at a point whose relative position is known. The surveyor adjusts the measurements by computations to minimize the effect of accidental errors made in the measurements. Large errors are corrected.

Traverse closed on starting point. A traverse which starts at a given point, proceeds to its destination, and returns to the starting point without crossing itself in the process is referred to as a loop traverse (figure 7-2). The surveyor uses this type of traverse to provide control of a tract or parcel boundary, and data for the area computation within the boundary. This type of traverse is also used if there is little or no existing control in the area and only the relative position of the points is required.

A loop traverse starts and ends on a station of assumed coordinates and azimuth without affecting the computations, area, or relative position of the stations. If, however, the coordinates must be tied to an existing grid system, the traverse starts from a known station and azimuth on that system. While the loop traverse provides some check upon the fieldwork and computations, it does not provide for a check of starting data or insure detection of all the systematic errors that may occur in the survey.

Traverse closed on second known point. A traverse closed on a second known point begins at a point of known coordinates, moves through the required point(s), and terminates at a second point of known coordinates. The surveyor prefers this type of traverse because it provides a check on the fieldwork, computations, and starting data. It also provides a basis for comparison to determine the overall accuracy of the work.

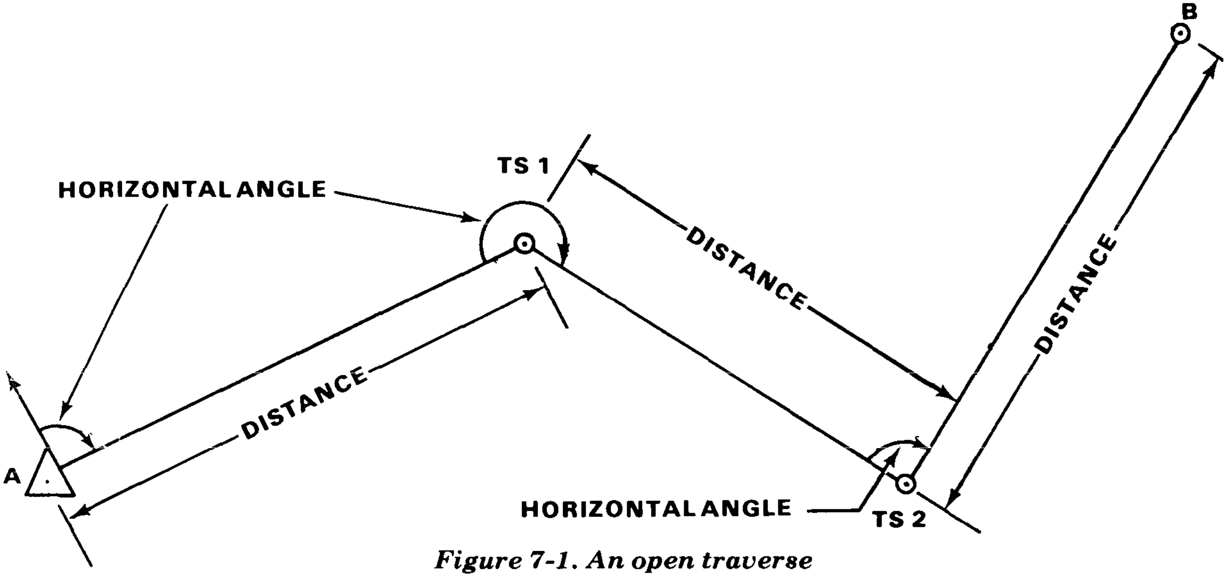


Figure 7-1. An open traverse

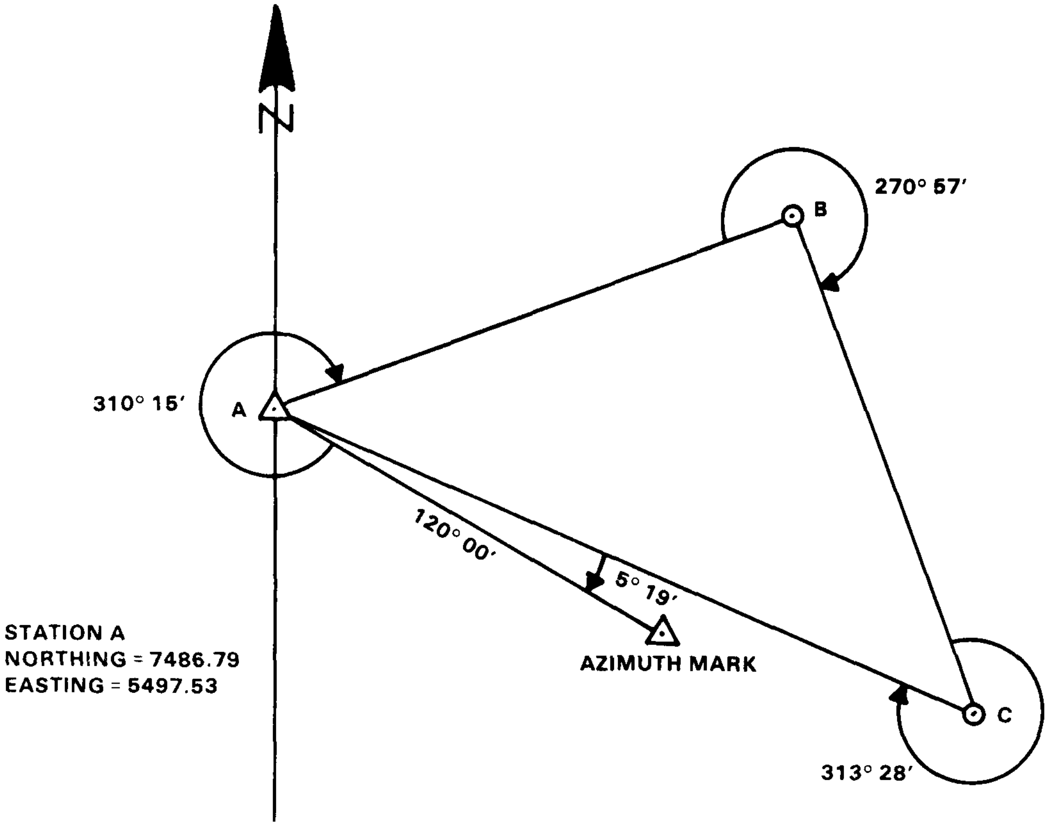


Figure 7-2. A loop traverse

Section II. FIELD SURVEY

FIELDWORK

In a traverse, three stations are considered to be of immediate significance. Surveyors refer to these stations as the rear station, the occupied station, and the forward station. The rear station is the station from which the surveyors performing the traverse have just moved or a point to which the azimuth is known. The occupied station is the station at which the party is located and over which the instrument is set. The immediate destination of the party is the forward station or the next station in succession.

Horizontal Angles

Always measure horizontal angles at the occupied station by sighting the instrument at the rear station and measuring the clockwise angles to the forward station. To measure horizontal angles, make instrument pointings to the lowest visible point of the target which marks the rear and forward stations.

Distance

Measure the distance in a straight line between the occupied station and the forward station. Use horizontal taping procedures or electronic distance measuring equipment.

TRAVERSE STATIONS

The surveyor selects sites for traverse stations as the traverse progresses. The surveyor locates the stations in such a way that at any one station both the rear and forward stations are visible.

Selection of Stations

If the distance is measured with tape, the line between stations must be free of obstacles for the taping team. The surveyor should keep the number of stations in a traverse to a minimum to reduce the accumulation of instrumental errors and the amount of computing required. Short traverse legs require the establishment and use of a greater number of stations and may cause excessive errors in azimuth because small errors in centering the instrument, in station marking equipment, and in instrument pointings are magnified and absorbed in the azimuth closure as errors in angle measurement.

Station Markers

Traverse station markers are usually 2- by 2-inch wooden stakes, 6 inches or more in length. The surveyor drives these stakes, called hubs, flush with the ground. The center of the top of the hub is marked with a surveyor's tack or with an X to designate the exact point of reference for angular and linear measurements.

To assist in recovering the station, the surveyor drives a reference (witness) stake into the ground so that it slopes toward the station. The surveyor must write the identification of the station on the reference stake with a lumber crayon or china marking pencil or on a tag attached to the stake. Signal cloth may also be tied to the reference stake to further assist in identifying or recovering the station.

Station Signals

A signal must be erected over survey stations to provide a sighting point for the instrument operator and to serve as a reference for tape alignment by the taping team. The most commonly used signal is the range pole.

When measuring angles, the surveyor places the tapered point of the range pole on the station mark and uses a rod level to make the pole vertical for observations. The surveyor should check the verticality of the pole by verifying that the bubble remains centered at other points on the range pole. The range pole is maintained in a vertical position throughout the observation period either by use of a range pole tripod or by someone holding the pole. To prevent the measurement of angles to the wrong point, the surveyor places the range pole in a vertical position only when it is being used to mark a survey station.

ORGANIZATION OF TRAVERSE PARTY

The number of personnel available to perform survey operations depends on the unit's Table of Organization and Equipment (TOE). The organization of these people into a traverse party and the duties assigned to each member will depend on the unit's Standing Operating Procedure (SOP). The organization and duties of traverse party members are based on the functional requirements of the traverse.

Chief of the Party

The chief of the party selects and marks the locations for the traverse stations and supervises the work of the other members of the party. The chief of the party also assists in the reconnaissance and planning of the survey.

Instrument Operator

The instrument operator measures the horizontal angles at each traverse station.

Recorder

The recorder keeps the field notes (see appendix B) for the party in a field notebook, and records the angles measured by the instrument operator, the distances measured by the tapeman, and all other data pertaining to the survey. The recorder is usually the party member designated to check the taped distances by pacing between traverse stations.

Tapemen

Two tapemen measure the distance from one traverse station to the next.

Rodman
The rodman assists the chief of the party in marking the traverse stations, removes the target from the rear station when signaled by the instrument operator, and moves the target forward to the next traverse station.

Variations
The number of party members maybe reduced by combining the positions of party chief, instrument operator, and recorder. It is possible that one of the tapemen may double as a rodman, but it is best to have two tapemen and a separate rodman.

It is possible to reduce the number of personnel in a traverse party, but there should be two tapemen and a separate rodman.

Section III. COMPUTATIONS

AZIMUTH COMPUTATION

The azimuth of a line is defined as the horizontal angle, measured clockwise, from a base direction to the line in question. Depending upon the starting data and the desired results, the base direction used will be grid north. In extreme circumstances, the starting azimuth may even be a magnetic azimuth. In order for a traverse to be computed, the surveyor determines an azimuth for each leg of the traverse (figure 7-2).

The surveyor must determine an azimuth for each leg of the traverse.

The azimuth for each succeeding leg of the traverse is determined by adding the value of the measured angle at the occupied station to the azimuth from the occupied station to the rear station. The example which follows illustrates this procedure. It should be noted that on occupation of each successive station, the first step is to compute the back azimuth of the preceding traverse leg (the azimuth from the occupied station to the rear station).

Example

Given:

Azimuth from station A to azimuth mark (Az)	120°00’
Angle azimuth mark-A-B	310°15’
Angle A-B-C	270°57’
Angle B-C-A	313°28’
Angle C-A-azimuth mark	5“ 19’

Required:
All leg azimuths

Solution

At station A

Az from A to Az mark	120° 00′
(+) Angle Az mark-A-B	310° 15′
	430° 15′
(-) Full circle	360° 00′
Az line A-B	70° 15′
(+) 180 to determine back Az	180° 00′
Back Az line A-B	250° 15′
(+) Angle A-B-C	270° 57′
	521° 12′
(-) Full circle	360° 00′
Az B-C	161° 12′
(+) 180 to determine back Az	180° 00′
Back Az line B-C	341° 12′
(+) Angle B-C-A	313° 28′
	654° 40′
(-) Full circle	360° 00′
Az line C-A	294° 40′
(-) 180 to determine back Az	180° 00′
Back Az line C-A	114° 40′
(+) Angle C-A-Az mark	5° 19′
AZ line A-Az mark (note error)	119° 59′

AZIMUTH ADJUSTMENT

The surveyor must determine the need for adjustment before beginning final coordinate computations. If the angular error of closure falls within computed allowable error, the surveyor may adjust the azimuths of the traverse.

Allowable Angular Error (AE)

The allowable angular error is determined by the formula AE = 1' $\sqrt{N}$, or 20" per station. whichever is less, where N is the number of traverse stations. If azimuth error does not fall within allowable error, the surveyor must reobserve the station angles of the traverse in the field.

In the example given, N equals 3.

$AE = 1'\sqrt{3} = 1.73'$ or $104''$
$AE = 20'' \times 3 = 60''$

Therefore, 60 seconds is the allowable error.

Azimuth Corrections

Prior to determining a correction, the surveyor computes the actual error. The azimuth error is obtained by subtracting the computed closing azimuth from the known closing azimuth. This subtraction provides the angular error with the appropriate sign. By reversing this sign, the azimuth correction with the appropriate sign is obtained. For example, the azimuth from point A to an azimuth mark is 120°00'. The closing azimuth of a traverse to the same azimuth mark is determined to be 119°59'. This falls within allowable limits, so the surveyor may compute the error and correction as follows:

Azimuth error = computed azimuth - known azimuth
= 119°59'-120°00' = -00°01'
Azimuth correction = + 00°01'

Application of Azimuth Corrections

Since traverse adjustment is based on the assumption that errors present have accumulated gradually and systematically throughout the traverse, the azimuth correction is applied accordingly. The correction is distributed equally among the angles of the traverse with any remainder distributed to the larger angles. For example, assume that the traverse for which the azimuth correction was determined consists of three traverse legs and four angles.

Station	Measured Angle
A	310°15’
B	270°57’
c	313°28’
A (closing)	5°19’

The azimuth correction is divided by the total number of angles. (In this case, + 01’ ÷4 = 15” per angle.) Each of the four angles is increased by 15 seconds.

Station	Measured Angle	Azimuth Correction	Adjusted Angle
A	310°15’	+15”	310°15’15”
B	270°57’	+15”	270°57’15”
c	313°28’	+15”	313°28’15”
A	5°19’	+15”	5°19’15”

Action After Adjustment

After the angles are adjusted, the surveyor computes adjusted azimuth of each leg of the traverse by using the starting azimuth and the adjusted angles at each traverse station. The surveyor should compute the adjusted azimuth throughout the entire traverse and check against the correct azimuth to the closing azimuth mark before beginning any further traverse computations.

AZIMUTH-BEARING ANGLE RELATIONSHIP

Since the functions (sine, cosine, tangent, and so on) of the azimuth and the bearing are numerically the same, the surveyor may use either one to compute the traverse. The choice of which is to be used will depend upon the computer and the equipment available.

Azimuth and Bearing

If a calculator with angular functions is available, the use of the azimuth would obviously be easier, since it eliminates the need to compute the bearing. If such a calculator is not available and the functions must be determined from tables, it is necessary to compute the bearing angles since the tabulation of functions is normally published for angles of O degrees to 90 degrees. The bearing of a line is the acute angle (angle less than 90 degrees) formed by the line in question and the northsouth line through the occupied point. Figure 7-3 illustrates the relationship between the azimuth of a line and its bearing.

Quadrants

The manner in which bearing angles are computed from a given azimuth depends on the quadrant in which the azimuth lies. Figure 7-4 shows the four quadrants and their relationship to each other. When the azimuth is in the first quadrant, O degrees to 90 degrees, the bearing is equal to the azimuth. When the azimuth is in the second quadrant, 90 degrees to 180 degrees, the bearing is equal to 180 degrees minus the azimuth. When the azimuth is in the third quadrant, 180 degrees to 270 degrees, the bearing is equal to the azimuth minus 180 degrees. When the azimuth is in the fourth quadrant, 270 degrees to 360 degrees, the bearing is equal to 360 degrees minus the azimuth.

Since the numerical values of the bearings repeat in each quadrant, the surveyor must label them and indicate into which quadrant they fall. This is done by indicating whether the bearing angle is measured from the north or south line and whether it is east or west of that line. For example, a line with an azimuth of 341°12’30” falls in the fourth or northwest quadrant and its bearing is N 18°47’ 30”W.

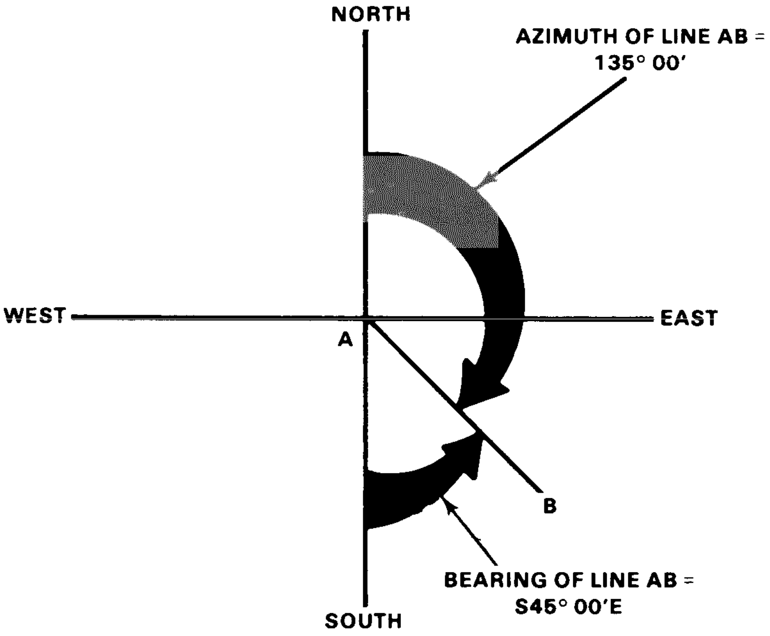


Figure 7-3. Relationship of azimuth and bearing

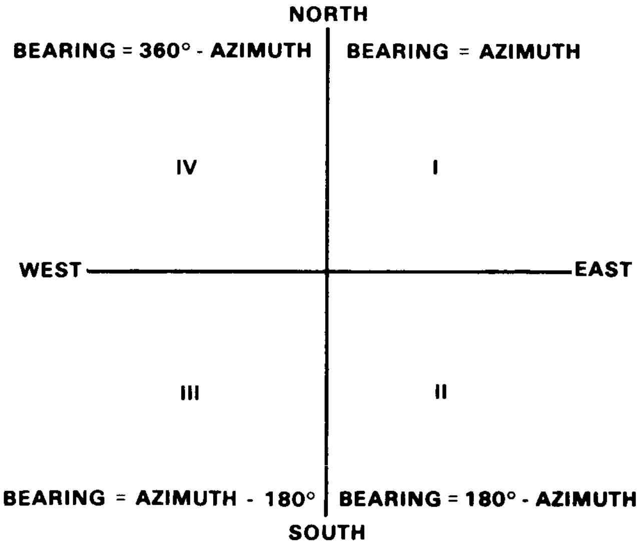


Figure 7-4. Determination of a bearing angle

COORDINATE COMPUTATIONS

If the coordinate of a point and the azimuth and distance from that point to a second point are known, the surveyor can compute the coordinate of the second point. In figure 7-5, the coordinate of station A is known and the coordinate of B is to be determined. The azimuth and distance from station A to B are determined by measuring the horizontal angle from the azimuth mark to station B and the distance from station A to B. The grid casting and northing lines through both stations are shown.

Since the grid is a rectangular system and the casting and northing lines form right angles at the point of intersection, the computation of the difference in northing (side dN) and difference in casting (side dE) employs the formulas for the computation of a right triangle. The distance from A to B is the hypotenuse of the triangle, and the bearing angle (azimuth) is the known angle. The following formulas are used to compute dN and dE:

dN = Cos Azimuth x Distance
dE = Sin Azimuth x Distance

In figure 7-5, the traverse leg falls in the first (northeast) quadrant since the value of the casting increases as the line goes east, and the value of the northing increases as it goes north. Both the dE and dN are positive and are added to the casting and northing of station A to obtain the coordinate of station B.

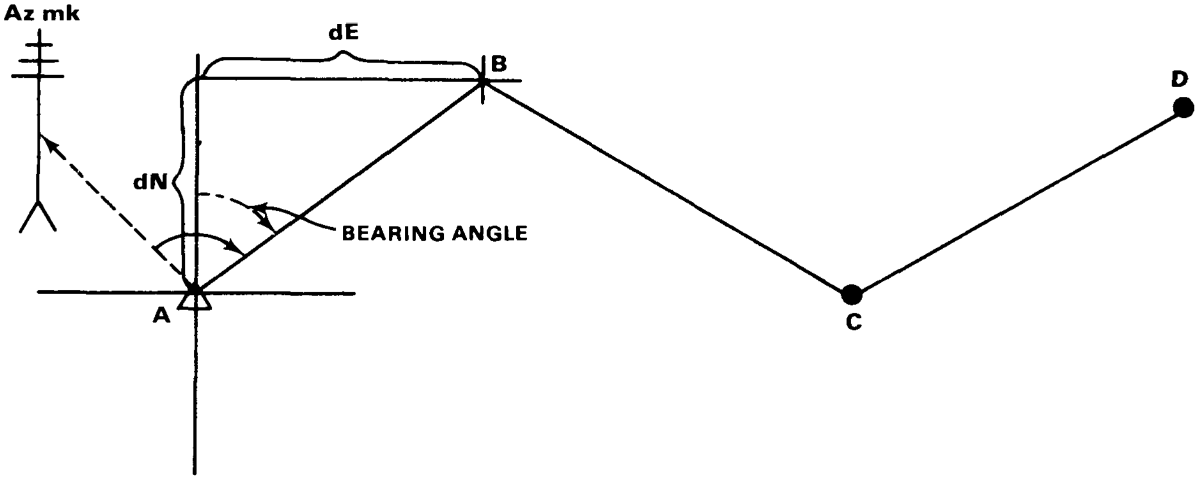


Figure 7-5. Requirements for dN and dE

If the surveyor uses a calculator with trigonometric functions to compute the traverse, the azimuth is entered directly and the machine provides the correct sign of the function and the dN and dE. If the functions are taken from tables, the computer provides the sign of the function by inspection. All lines going north have positive dNs; south lines have negative. Lines going east have positive dEs; west lines have negative. Figure 7-6 illustrates the relationship of quadrant to sign.

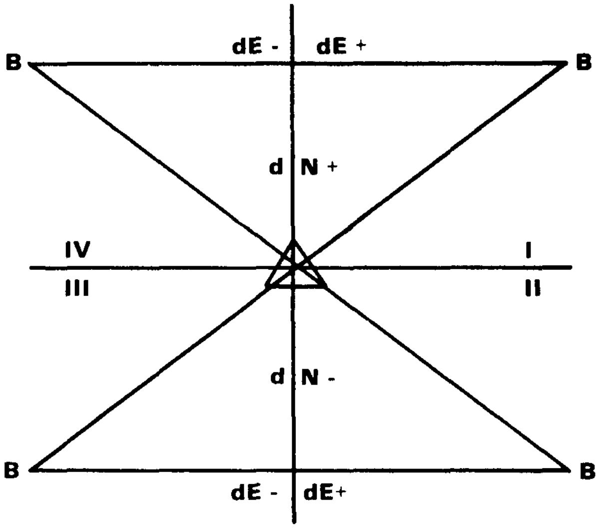


Figure 7-6. Relationship by quadrant and sign

DETERMINATION OF dN AND dE

In figure 7-7 (page 7-13), the azimuth from A-B is 70°15’15” and the distance is 568.78.

dN = Cos 70°15’15” X 568.78
dN = +0.337848X 568.78= +192.16
dE = Sin 70°15’15” x 568.78
dE = +0.941200X 568.78 = +535.34

The azimuth from B-C is 161°12’30” and the distance is 548.74 (note SE quadrant).

dN = Cos 161°12’30” X 548.74
dN = -0.946696X 548.74= -519.49
dE = Sin 161°12’30” x 548.74
dE = +0.322128X 548.74 = +176.76

The azimuth from C-A is 294°40’45”, and the distance is 783.74 (note NW quadrant).

dN = Cos 294°40’45” X 783.74
dN = 0.417537X 783.74 = +327.24
dE = Sin 294°40’45” x 783.74
dE = -0.908660X 783.74= -712.15

ACCURACY AND SPECIFICATIONS

The overall accuracy of a traverse depends on the equipment and methods used in the measurements, the accuracy achieved, and the accuracy of the starting and closing data.

An accuracy ratio of 1:5,000 is normally sought in construction surveying. In obtaining horizontal distances, an accuracy of at least 0.02 foot per 100 feet must be obtained. When using a one-minute instrument, the surveyor turns the horizontal angles once in each position, namely, one direct and one indirect, with angular closure of 20 seconds per station or 1’ $\sqrt{\text{number of stations}}$. whichever is less.

Linear Error

To determine the acceptability of a traverse, the surveyor must compute the linear error of closure and the allowable error or the accuracy ratio or both. The first step in either case is to determine the linear error in dN and dE. In the case of a loop traverse, the algebraic sum of the dNs should equal zero. Any discrepancy is the linear error in dN. The same is true for dEs.

Linear Error dN (eN) = -0.09
Linear Error dE (eE) = -0.05

The surveyor computes the linear error of closure (eL) using the Pythagorean theorum.

$$\text{Linear Error (eL)} = \sqrt{(eN)^2 + (eE)^2}$$

$$eL = \sqrt{(-0.09)^2 + (-0.05)^2}$$

$$eL = \sqrt{0.0106} = 0.1029$$

Allowable Error

The surveyor then computes the allowable error (AE) using the appropriate accuracy ratio (1/5,000 or 1/3,000) and the total length of the traverse.

$$\frac{1}{5{,}000} :: \frac{AE}{\text{Length of Traverse}}$$

$$AE = \frac{1 \text{ x Length of Traverse}}{5{,}000}$$

$$AE = \frac{1 \text{ x } 1901.26}{5{,}000} = 0.3802$$

Compare this to the linear error of closure. If the AE is greater than the eL, the traverse is good and can be adjusted. If it is not good, it must be rerun.

Ratio of Accuracy

The ratio of accuracy provides a method of determining the traverse accuracy and comparing it to established standards. The ratio of accuracy is the ratio of the eL to the total length of the traverse, after it is reduced to a common ratio and rounded down.

$$\frac{eL}{\text{Total Length}} = \frac{0.1029}{1{,}901.26} = \frac{0.1029 \div 0.1029}{1{,}901.26 \div 0.1029}$$

$$= \frac{1}{18{,}476.77} \text{ or } \frac{1}{18{,}000}$$

If the accuracy ratio does not fall within allowable limits, the traverse must be rerun. It is very possible that the distances as measured are correct and that the error can be attributed to large, compensating angular errors.

COORDINATE ADJUSTMENT

The surveyor makes the adjustment of the traverse using the compass rule. The compass rule says that, for any leg of the traverse, the correction to be given to the dN or dE is to the total correction for dN or dE as the length of the leg is to the total length of the traverse. The total correction for dN or dE is numerically equal to the eN or eE, but with the opposite sign.

Formulas

In figure 7-7, the dN is -0.09 and the dE is -0.05 and the total corrections are +0.09 and +0.05, respectively. Note the following formulas:

dN Correction per station =

$$\frac{\text{Total dN Correction}}{\text{Length of Traverse}} \text{ x Distance to Station}$$

dE Correction per station =

$$\frac{\text{Total dE Correction}}{\text{Length of Traverse}} \text{ x Distance to Station}$$

For the first leg in the traverse in figure 7-7, the corrections are computed as follows:

$$\text{dN Correction} = \frac{+0.09}{1{,}901.26} \text{ x } 568.78 = +0.03$$

$$\text{dE Correction} = \frac{+0.05}{1{,}901.26} \text{ x } 568.78 = +0.01$$

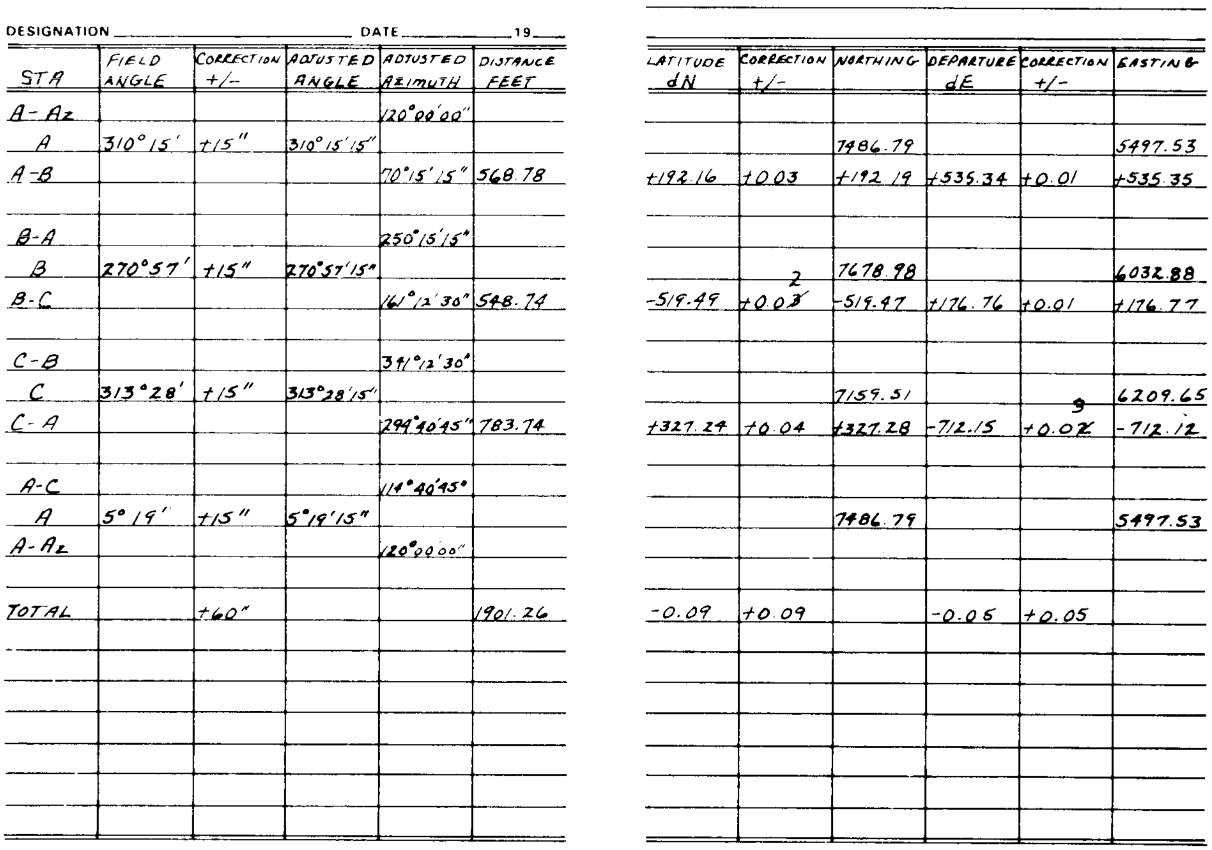
Loop Traverse

When adjusting a loop traverse, the surveyor applies the correction to the dNs and dEs prior to computing the coordinates. The total correction must equal the total error. Sometimes, due to round off, the total correction will not equal the total error. If this happens and the difference is one, reduce the correction to the shortest line or increase the longest line. When the error is greater than one, you may arbitrarily reduce/increase the corrections until the total correction equals the total error.

The coordinate of the previous station ±dN± correction equals the coordinate of the next station. From figure 7-7, you compute as follows:

Sta A	7,486.79	5,497.53
	+ 192.19	+ 535.35
Sta B	7,678.98	6,032.88

When adjusting a traverse that starts and ends on two different stations, the surveyor computes the coordinates before the error is determined. In this case, the correction per leg is determined in the same manner as shown, but the correction is applied directly to the coordinates. The correction to be applied after the first leg is equal to the correction computed for the first leg. The correction to be applied after the second leg is equal to the correction for the first leg plus the correction computed for the second leg. The correction for the third leg equals the first correction plus the second correction plus the correction computed for the third leg and so on throughout the traverse. The last correction must be equal to the total correction required.



DESIGNATION ____________ DATE ________ 19____

STA	FIELD ANGLE	CORRECTION +/-	ADJUSTED ANGLE	ADJUSTED AZIMUTH	DISTANCE FEET	LATITUDE dN	CORRECTION +/-	NORTHING	DEPARTURE dE	CORRECTION +/-	EASTING
A-Az				120°00'00"							
A	310°15'	+15"	310°15'15"					7486.79			5497.53
A-B				70°15'15"	568.78	+192.16	+0.03	+192.19	+535.34	+0.01	+535.35
B-A				250°15'15"							
B	270°57'	+15"	270°57'15"					7678.98			6032.88
B-C				161°12'30"	548.74	-519.49	+0.0~~3~~2	-519.47	+176.76	+0.01	+176.77
C-B				341°12'30"							
C	313°28'	+15"	313°28'15"					7159.51			6209.65
C-A				294°40'45"	783.74	+327.24	+0.04	+327.28	-712.15	+0.0~~2~~9	-712.12
A-C				114°40'45"							
A	5°19'	+15"	5°19'15"					7486.79			5497.53
A-Az				120°00'00"							
TOTAL		+60"			1901.26	-0.09	+0.09		-0.05	+0.05	

Figure 7-7. Traverse computation of a loop traverse

APPENDIX A
TABLES

LIST OF FIGURES AND TABLES

Table A-1. Natural trigonometric functions

0°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.000 000	4.85	0.000 000	4.85			1.000 000	.00	60′
01	.000 291	4.85	.000 291	4.83	3 437.746 674		1.000 000	.00	59
02	.000 582	4.85	.000 582	4.85	1 718.873 192		1.000 000	.00	58
03	.000 873	4.85	.000 873	4.85	1 145.915 295		1.000 000	.02	57
04	.001 164	4.83	.000 164	4.83	859.436 305		0.999 999	.00	56
05	.001 454	4.85	.001 454	4.85	687.548 889		.999 999	.02	55
06	.001 745	4.85	.001 745	4.85	572.957 213		.999 998	.00	54
07	.002 036	4.85	.002 036	4.85	491.106 003		.999 998	.02	53
08	.002 327	4.85	.002 327	4.85	429.717 571		.999 997	.00	52
09	.002 618	4.85	.002 618	4.85	381.970 991		.999 997	.02	51
10	0.002 909	4.85	0.002 909	4.85	343.773 708		0.999 996	.02	50
11	.003 200	4.85	.003 200	4.85	312.521 367		.999 995	.02	49
12	.003 491	4.85	.003 491	4.85	286.477 734		.999 994	.02	48
13	.003 782	4.83	.003 782	4.83	264.440 799		.999 993	.02	47
14	.004 072	4.85	.004 072	4.85	245.551 983		.999 992	.03	46
15	.004 363	4.85	.004 363	4.85	229.181 664		.999 990	.02	45
16	.004 654	4.85	.004 654	4.85	214.857 622		.999 989	.02	44
17	.004 945	4.85	.004 945	4.85	202.218 750		.999 988	.03	43
18	.005 236	4.85	.005 236	4.85	190.984 186		.999 986	.02	42
19	.005 527	4.85	.005 527	4.85	180.932 198		.999 985	.03	41
20	0.005 818	4.85	0.005 818	4.85	171.885 399		0.999 983	.03	40
21	.006 109	4.83	.006 109	4.85	163.700 191		.999 981	.02	39
22	.006 399	4.85	.006 400	4.85	156.259 084		.999 980	.03	38
23	.006 690	4.85	.006 691	4.83	149.465 021		.999 978	.02	37
24	.006 981	4.85	.006 981	4.85	143.237 122		.999 976	.03	36
25	.007 272	4.85	.007 272	4.85	137.507 447		.999 974	.05	35
26	.007 563	4.85	.007 563	4.85	132.218 503		.999 971	.03	34
27	.007 854	4.85	.007 854	4.85	127.321 336		.999 969	.03	33
28	.008 145	4.85	.008 145	4.85	122.773 955		.999 967	.05	32
29	.008 436	4.85	.008 436	4.85	118.540 180		.999 964	.03	31
30	0.008 727	4.83	0.008 727	4.85	114.588 650		0.999 962	.05	30
31	.009 017	4.85	.009 018	4.85	110.892 051		.999 959	.03	29
32	.009 308	4.85	.009 309	4.85	107.370 558		.999 957	.05	28
33	.009 599	4.85	.009 600	4.85	104.170 945		.999 954	.05	27
34	.009 890	4.85	.009 891	4.83	101.106 902		.999 951	.05	26
35	.010 181	4.85	.010 181	4.85	98.217 943		.999 948	.05	25
36	.010 472	4.85	.010 472	4.85	95.489 475		.999 945	.05	24
37	.010 763	4.85	.010 763	4.85	92.908 487		.999 942	.05	23
38	.011 054	4.83	.011 054	4.85	90.463 336		.999 939	.05	22
39	.011 344	4.85	.011 345	4.85	88.143 572		.999 936	.07	21
40	0.011 635	4.85	0.011 636	4.85	85.939 791		0.999 932	.05	20
41	.011 926	4.85	.011 927	4.85	83.843 507		.999 929	.07	19
42	.012 217	4.85	.012 218	4.85	81.847 041		.999 925	.05	18
43	.012 508	4.85	.012 509	4.85	79.943 430		.999 922	.07	17
44	.012 799	4.85	.012 800	4.85	78.126 342		.999 918	.07	16
45	.013 090	4.83	.013 091	4.85	76.390 009		.999 914	.07	15
46	.013 380	4.85	.013 382	4.85	74.729 165		.999 910	.05	14
47	.013 671	4.85	.013 673	4.85	73.138 991		.999 907	.07	13
48	.013 962	4.85	.013 964	4.83	71.615 070		.999 903	.08	12
49	.014 253	4.85	.014 254	4.85	70.153 346		.999 898	.07	11
50	0.014 544	4.85	0.014 545	4.85	68.750 087		0.999 894	.07	10
51	.014 835	4.85	.014 836	4.85	67.401 854		.999 890	.07	09
52	.015 126	4.83	.015 127	4.85	66.105 473		.999 886	.08	08
53	.015 416	4.85	.015 418	4.85	64.858 008		.999 881	.08	07
54	.015 707	4.85	.015 709	4.85	63.656 741		.999 877	.08	06
55	.015 998	4.85	.016 000	4.85	62.499 154		.999 872	.08	05
56	.016 289	4.85	.016 291	4.85	61.382 905		.999 867	.07	04
57	.016 580	4.85	.016 582	4.85	60.305 820		.999 863	.08	03
58	.016 871	4.85	.016 873	4.85	59.265 872		.999 858	.08	02
59	.017 162	4.83	.017 164	4.85	58.261 174		.999 853	.08	01
60	0.017 452		0.017 455		57.289 962		0.999 848		00
	Cos	d."	Cot	d."	Tan	d."	Sin	d."	

Table A-1. Natural trigonometric functions (continued)

1°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.017 452	4.85	0.017 455	4.85	57.289 962		0.999 848	.08	60′
01	.017 743	4.85	.017 746	4.85	56.350 590		.999 843	.10	59
02	.018 034	4.85	.018 037	4.85	55.441 517		.999 837	.08	58
03	.018 325	4.85	.018 328	4.85	54.561 300		.999 832	.08	57
04	.018 616	4.85	.018 619	4.85	53.708 588		.999 827	.10	56
05	.018 907	4.83	.018 910	4.85	52.882 109		.999 821	.08	55
06	.019 197	4.85	.019 201	4.85	52.080 673		.999 816	.10	54
07	.019 488	4.85	.019 492	4.85	51.303 157		.999 810	.10	53
08	.019 779	4.85	.019 783	4.85	50.548 506		.999 804	.08	52
09	.020 070	4.85	.020 074	4.85	49.815 726		.999 799	.10	51
10	0.020 361	4.85	0.020 365	4.85	49.103 881		0.999 793	.10	50
11	.020 652	4.83	.020 656	4.85	48.412 084		.999 787	.10	49
12	.020 942	4.85	.020 947	4.85	47.739 501		.999 781	.10	48
13	.021 233	4.85	.021 238	4.85	47.085 343		.999 775	.12	47
14	.021 524	4.85	.021 529	4.85	46.448 862		.999 768	.10	46
15	.021 815	4.85	.021 820	4.85	45.829 351		.999 762	.10	45
16	.022 106	4.85	.022 111	4.85	45.226 141		.999 756	.12	44
17	.022 397	4.83	.022 402	4.85	44.638 596		.999 749	.10	43
18	.022 687	4.85	.022 693	4.85	44.066 113		.999 743	.12	42
19	.022 978	4.85	.022 984	4.85	43.508 122		.999 736	.12	41
20	0.023 269	4.85	0.023 275	4.85	42.964 077		0.999 729	.12	40
21	.023 560	4.85	.023 566	4.85	42.433 464		.999 722	.10	39
22	.023 851	4.83	.023 857	4.85	41.915 799		.999 716	.12	38
23	.024 141	4.85	.024 148	4.85	41.410 588		.999 709	.13	37
24	.024 432	4.85	.024 439	4.87	40.917 412		.999 701	.12	36
25	.024 723	4.85	.024 731	4.85	40.435 837		.999 694	.12	35
26	.025 014	4.85	.025 022	4.85	39.965 461		.999 687	.12	34
27	.025 305	4.83	.025 313	4.85	39.505 895		.999 680	.13	33
28	.025 595	4.85	.025 604	4.85	39.056 771		.999 672	.12	32
29	.025 886	4.85	.025 895	4.85	38.617 738		.999 665	.13	31
30	0.026 177	4.85	0.026 186	4.85	38.188 459		0.999 657	.12	30
31	.026 468	4.85	.026 477	4.85	37.768 613		.999 650	.13	29
32	.026 759	4.83	.026 768	4.85	37.357 892		.999 642	.13	28
33	.027 049	4.85	.027 059	4.85	36.956 001		.999 634	.13	27
34	.027 340	4.85	.027 350	4.85	36.562 659		.999 626	.13	26
35	.027 631	4.85	.027 641	4.87	36.177 596		.999 618	.13	25
36	.027 922	4.83	.027 933	4.85	35.800 553		.999 610	.13	24
37	.028 212	4.83	.028 224	4.85	35.431 282		.999 602	.13	23
38	.028 503	4.85	.028 515	4.85	35.069 546		.999 594	.15	22
39	.028 794	4.85	.028 806	4.85	34.715 115		.999 585	.13	21
40	0.029 085	4.83	0.029 097	4.85	34.367 771		0.999 577	.15	20
41	.029 375	4.85	.029 388	4.85	34.027 303		.999 568	.13	19
42	.029 666	4.85	.029 679	4.85	33.693 509		.999 560	.15	18
43	.029 957	4.85	.029 970	4.87	33.366 194		.999 551	.15	17
44	.030 248	4.85	.030 262	4.85	33.045 173		.999 542	.13	16
45	.030 539	4.83	.030 553	4.85	32.730 264		.999 534	.15	15
46	.030 829	4.85	.030 844	4.85	32.421 295		.999 525	.15	14
47	.031 120	4.85	.031 135	4.85	32.118 099		.999 516	.15	13
48	.031 411	4.85	.031 426	4.85	31.820 516		.999 507	.17	12
49	.031 702	4.83	.031 717	4.87	31.528 392		.999 497	.15	11
50	0.031 992	4.85	0.032 009	4.85	31.241 577		0.999 488	.15	10
51	.032 283	4.85	.032 300	4.85	30.959 928		.999 479	.17	09
52	.032 574	4.83	.032 591	4.85	30.683 307		.999 469	.15	08
53	.032 864	4.85	.032 882	4.85	30.411 580		.999 460	.17	07
54	.033 155	4.85	.033 173	4.87	30.144 619		.999 450	.15	06
55	.033 446	4.85	.033 465	4.85	29.882 299		.999 441	.17	05
56	.033 737	4.83	.033 756	4.85	29.624 499		.999 431	.17	04
57	.034 027	4.85	.034 047	4.85	29.371 106		.999 421	.17	03
58	.034 318	4.85	.034 338	4.85	29.122 005		.999 411	.17	02
59	.034 609	4.83	.034 630	4.85	28.877 089		.999 401	.17	01
60	0.034 899		0.034 921		28.636 253		0.999 391		00
	Cos	d."	Cot	d."	Tan	d."	Sin	d."	

Table A-1. Natural trigonometric functions (continued)

2°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.034 899	4.85	0.034 921	4.85	28.6363		0.999 391	.17	60′
01	.035 190	4.85	.035 212	4.85	28.3994		.999 381	.18	59
02	.035 481	4.85	.035 503	4.87	28.1664		.999 370	.17	58
03	.035 772	4.83	.035 795	4.85	27.9372		.999 360	.17	57
04	.036 062	4.85	.036 086	4.85	27.7117		.999 350	.18	56
05	.036 353	4.85	.036 377	4.85	27.4899		.999 339	.18	55
06	.036 644	4.83	.036 668	4.87	27.2715		.999 328	.17	54
07	.036 934	4.85	.036 960	4.85	27.0566		.999 318	.18	53
08	.037 225	4.85	.037 251	4.85	26.8450		.999 307	.18	52
09	.037 516	4.83	.037 542	4.87	26.6367		.999 296	.18	51
10	0.037 806	4.85	0.037 834	4.85	26.4316		0.999 285	.18	50
11	.038 097	4.85	.038 125	4.85	26.2296		.999 274	.18	49
12	.038 388	4.83	.038 416	4.85	26.0307		.999 263	.18	48
13	.038 678	4.85	.038 707	4.87	25.8348		.999 252	.20	47
14	.038 969	4.85	.038 999	4.85	25.6418		.999 240	.18	46
15	.039 260	4.83	.039 290	4.85	25.4517		.999 229	.18	45
16	.039 550	4.85	.039 581	4.87	25.2644		.999 218	.20	44
17	.039 841	4.85	.039 873	4.85	25.0798		.999 206	.20	43
18	.040 132	4.83	.040 164	4.87	24.8978		.999 194	.18	42
19	.040 422	4.85	.040 456	4.85	24.7185		.999 183	.20	41
20	0.040 713	4.85	0.040 747	4.85	24.5418		0.999 171	.20	40
21	.041 004	4.83	.041 038	4.87	24.3675		.999 159	.20	39
22	.041 294	4.85	.041 330	4.85	24.1957		.999 147	.20	38
23	.041 585	4.85	.041 621	4.85	24.0263		.999 135	.20	37
24	.041 876	4.83	.041 912	4.87	23.8593		.999 123	.20	36
25	.042 166	4.85	.042 204	4.85	23.6945		.999 111	.22	35
26	.042 457	4.85	.042 495	4.87	23.5321		.999 098	.20	34
27	.042 748	4.83	.042 787	4.85	23.3718		.999 086	.22	33
28	.043 038	4.85	.043 078	4.87	23.2137		.999 073	.20	32
29	.043 329	4.83	.043 370	4.85	23.0577		.999 061	.22	31
30	0.043 619	4.85	0.043 661	4.85	22.9038		0.999 048	.22	30
31	.043 910	4.85	.043 952	4.87	22.7519		.999 035	.20	29
32	.044 201	4.83	.044 244	4.85	22.6020		.999 023	.22	28
33	.044 491	4.83	.044 535	4.87	22.4541		.999 010	.22	27
34	.044 782	4.85	.044 827	4.85	22.3081		.998 997	.22	26
35	.045 072	4.85	.045 118	4.87	22.1640		.998 984	.22	25
36	.045 363	4.85	.045 410	4.85	22.0217		.998 971	.23	24
37	.045 654	4.83	.045 701	4.87	21.8813		.998 957	.22	23
38	.045 944	4.85	.045 993	4.85	21.7426		.998 944	.22	22
39	.046 235	4.83	.046 284	4.87	21.6056		.998 931	.23	21
40	0.046 525	4.85	0.046 576	4.85	21.4704		0.998 917	.22	20
41	.046 816	4.83	.046 867	4.87	21.3369		.998 904	.23	19
42	.047 106	4.85	.047 159	4.85	21.2049		.998 890	.23	18
43	.047 397	4.85	.047 450	4.87	21.0747		.998 876	.23	17
44	.047 688	4.83	.047 742	4.85	20.9460		.998 862	.23	16
45	.047 978	4.83	.048 033	4.87	20.8188		.998 848	.23	15
46	.048 269	4.83	.048 325	4.87	20.6932		.998 834	.23	14
47	.048 559	4.85	.048 617	4.85	20.5691		.998 820	.23	13
48	.048 850	4.83	.048 908	4.87	20.4465		.998 806	.23	12
49	.049 140	4.85	.049 200	4.85	20.3253		.998 792	.23	11
50	0.049 431	4.83	0.049 491	4.87	20.2056		0.998 778	.25	10
51	.049 721	4.85	.049 783	4.87	20.0872		.998 763	.23	09
52	.050 012	4.83	.050 075	4.85	19.9702		.998 749	.25	08
53	.050 302	4.85	.050 366	4.87	19.8546		.998 734	.25	07
54	.050 593	4.83	.050 658	4.85	19.7403		.998 719	.23	06
55	.050 883	4.85	.050 949	4.87	19.6273		.998 705	.25	05
56	.051 174	4.83	.051 241	4.87	19.5156		.998 690	.25	04
57	.051 464	4.85	.051 533	4.85	19.4051		.998 675	.25	03
58	.051 755	4.83	.051 824	4.87	19.2959		.998 660	.25	02
59	.052 045	4.85	.052 116	4.87	19.1879		.998 645	.25	01
60	0.052 336		0.052 408		19.0811		0.998 630		00
	Cos	d."	Cot	d."	Tan	d."	Sin	d."	

Table A-1. Natural trigonometric functions (continued)

3°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.052 336	4.83	0.052 408	4.85	19.0811	17.60	0.998 630	.27	60′
01	.052 626	4.85	.052 699	4.87	18.9755	17.40	.998 614	.25	59
02	.052 917	4.83	.052 991	4.87	18.8711	17.22	.998 599	.27	58
03	.053 207	4.85	.053 283	4.87	18.7678	17.03	.998 583	.25	57
04	.053 498	4.83	.053 575	4.85	18.6656	16.85	.998 568	.27	56
05	.053 788	4.85	.053 866	4.87	18.5645	16.66	.998 552	.25	55
06	.054 079	4.83	.054 158	4.87	18.4645	16.50	.988 537	.27	54
07	.054 369	4.85	.054 450	4.87	18.3655	16.30	.998 521	.27	53
08	.054 660	4.83	.054 742	4.85	18.2677	16.15	.998 505	.27	52
09	.054 950	4.85	.055 033	4.87	18.1708	15.97	.998 489	.27	51
10	0.055 241	4.83	0.055 325	4.87	18.0750	15.80	0.998 473	.27	50
11	.055 501	4.85	.055 617	4.87	17.9802	15.65	.998 457	.27	49
12	.055 822	4.83	.055 909	4.85	17.8863	15.48	.998 441	.28	48
13	.056 112	4.83	.056 200	4.87	17.7934	15.32	.998 424	.27	47
14	.056 402	4.85	.056 492	4.87	17.7015	15.15	.998 408	.27	46
15	.056 693	4.83	.056 784	4.87	17.6106	15.02	.998 392	.28	45
16	.056 983	4.85	.057 076	4.87	17.5205	14.85	.998 375	.27	44
17	.057 274	4.83	.057 368	4.87	17.4314	14.70	.998 359	.28	43
18	.057 564	4.83	.057 660	4.85	17.3432	14.57	.998 342	.28	42
19	.057 854	4.85	.057 951	4.87	17.2558	14.42	.998 325	.28	41
20	0.058 145	4.83	0.058 243	4.87	17.1693	14.27	0.998 308	.28	40
21	.058 435	4.85	.058 535	4.87	17.0837	14.12	.998 291	.28	39
22	.058 726	4.83	.058 827	4.87	16.9990	14.00	.998 274	.28	38
23	.059 016	4.83	.059 119	4.87	16.9150	13.85	.998 257	.28	37
24	.059 306	4.85	.059 411	4.87	16.8319	13.72	.998 240	.28	36
25	.059 597	4.83	.059 703	4.87	16.7496	13.58	.998 223	.30	35
26	.059 887	4.83	.059 995	4.87	16.6681	13.45	.998 205	.28	34
27	.060 177	4.85	.060 287	4.87	16.5874	13.32	.998 188	.30	33
28	.060 468	4.83	.060 579	4.87	16.5075	13.20	.998 170	.28	32
29	.060 758	4.85	.060 871	4.87	16.4283	13.07	.998 153	.30	31
30	0.061 049	4.83	0.061 163	4.87	16.3499	12.95	0.998 135	.30	30
31	.061 339	4.83	.061 455	4.87	16.2722	12.83	.998 117	.30	29
32	.061 629	4.85	.061 747	4.87	16.1952	12.70	.998 099	.30	28
33	.061 920	4.83	.062 039	4.87	16.1190	12.58	.998 081	.30	27
34	.062 210	4.83	.062 331	4.87	16.0435	12.47	.998 063	.30	26
35	.062 500	4.85	.062 623	4.87	15.9687	12.37	.998 045	.30	25
36	.062 791	4.83	.062 915	4.87	15.8945	12.23	.998 027	.32	24
37	.063 081	4.83	.063 207	4.87	15.8211	12.13	.998 008	.30	23
38	.063 371	4.83	.063 499	4.87	15.7483	12.02	.997 990	.30	22
39	.063 661	4.85	.063 791	4.87	15.6762	11.90	.997 972	.32	21
40	0.063 952	4.83	0.064 083	4.87	15.6048	11.80	0.997 953	.32	20
41	.064 242	4.83	.064 375	4.87	15.5340	11.70	.997 934	.30	19
42	.064 532	4.85	.064 667	4.87	15.4638	11.58	.997 916	.32	18
43	.064 823	4.83	.064 959	4.87	15.3943	11.48	.997 897	.32	17
44	.065 113	4.83	.065 251	4.87	15.3254	11.38	.997 878	.32	16
45	.065 403	4.83	.065 543	4.88	15.2571	11.30	.997 859	.32	15
46	.065 693	4.85	.065 836	4.87	15.1893	11.18	.997 840	.32	14
47	.065 984	4.83	.066 128	4.87	15.1222	11.08	.997 821	.33	13
48	.066 274	4.83	.066 420	4.87	15.0557	10.98	.997 801	.32	12
49	.066 564	4.83	.066 712	4.87	14.9898	10.90	.997 782	.32	11
50	0.066 854	4.85	0.067 004	4.87	14.9244	10.80	0.997 763	.33	10
51	.067 145	4.83	.067 296	4.88	14.8596	10.70	.997 743	.32	09
52	.067 435	4.83	.067 589	4.87	14.7954	10.62	.997 724	.33	08
53	.067 725	4.83	.067 881	4.87	14.7317	10.53	.997 704	.33	07
54	.068 015	4.83	.068 173	4.87	14.6685	10.43	.997 684	.33	06
55	.068 306	4.83	.068 465	4.88	14.6059	10.35	.997 665	.32	05
56	.068 596	4.83	.068 758	4.87	14.5438	10.25	.997 645	.33	04
57	.068 886	4.83	.069 050	4.87	14.4823	10.18	.997 625	.33	03
58	.069 176	4.83	.069 342	4.88	14.4212	10.08	.997 604	.35	02
59	.069 466	4.83	.069 635	4.87	14.3607	10.00	.997 584	.33	01
60	0.069 756		0.069 927		14.3007		0.997 564		00
	Cos	d."	Cot	d."	Tan	d."	Sin	d."	

Table A-1. Natural trigonometric functions (continued)

4°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.069 756	4.85	0.069 927	4.87	14.3007	9.93	0.997 564	.33	60′
01	.070 047	4.83	.070 219	4.87	.2411	9.83	.997 544	.35	59
02	.070 337	4.83	.070 511	4.88	.1821	9.77	.997 523	.33	58
03	.070 627	4.83	.070 804	4.87	.1235	9.67	.997 503	.35	57
04	.070 917	4.83	.071 096	4.88	.0655	9.60	.997 482	.33	56
05	.071 207	4.83	.071 389	4.87	14.0079	9.53	.997 462	.35	55
06	.071 497	4.85	.071 681	4.87	13.9507	9.45	.997 441	.35	54
07	.071 788	4.83	.071 973	4.88	.8940	9.37	.997 420	.35	53
08	.072 078	4.83	.072 266	4.87	.8378	9.28	.997 399	.35	52
09	.072 368	4.83	.072 558	4.88	.7821	9.23	.997 378	.35	51
10	0.072 658	4.83	0.072 851	4.87	13.7267	9.13	0.997 357	.35	50
11	.072 948	4.83	.073 143	4.87	.6719	9.08	.997 336	.37	49
12	.073 238	4.83	.073 435	4.88	.6174	9.00	.997 314	.35	48
13	.073 528	4.83	.073 728	4.87	.5634	8.93	.997 293	.35	47
14	.073 818	4.83	.074 020	4.88	.5098	8.87	.997 272	.37	46
15	.074 108	4.85	.074 313	4.87	.4566	8.78	.997 250	.35	45
16	.074 399	4.83	.074 605	4.88	.4039	8.73	.997 229	.37	44
17	.074 689	4.83	.074 898	4.87	.3515	8.65	.997 207	.37	43
18	.074 979	4.83	.075 190	4.88	.2996	8.60	.997 185	.37	42
19	.075 269	4.83	.075 483	4.87	.2480	8.52	.997 163	.37	41
20	0.075 559	4.83	0.075 775	4.88	13.1969	8.47	0.997 141	.37	40
21	.075 849	4.83	.076 068	4.88	.1461	8.38	.997 119	.37	39
22	.076 139	4.83	.076 361	4.87	.0958	8.33	.997 097	.37	38
23	.076 429	4.83	.076 653	4.88	13.0458	8.27	.997 075	.37	37
24	.076 719	4.83	.076 946	4.87	12.9962	8.22	.997 053	.38	36
25	.077 009	4.83	.077 238	4.88	.9469	8.13	.997 030	.37	35
26	.077 299	4.83	.077 531	4.88	.8981	8.08	.997 008	.38	34
27	.077 589	4.83	.077 824	4.87	.8496	8.03	.996 985	.37	33
28	.077 879	4.83	.078 116	4.88	.8014	7.97	.996 963	.38	32
29	.078 169	4.83	.078 409	4.88	.7536	7.90	.996 940	.38	31
30	0.078 459	4.83	0.078 702	4.87	12.7062	7.85	0.996 917	.38	30
31	.078 749	4.83	.078 994	4.88	.6591	7.78	.996 894	.37	29
32	.079 039	4.83	.079 287	4.88	.6124	7.73	.996 872	.40	28
33	.079 329	4.83	.079 580	4.88	.5660	7.68	.996 848	.38	27
34	.079 619	4.83	.079 873	4.87	.5199	7.62	.996 825	.38	26
35	.079 909	4.83	.080 165	4.88	.4742	7.57	.996 802	.38	25
36	.080 199	4.83	.080 458	4.88	.4288	7.50	.996 779	.38	24
37	.080 489	4.83	.080 751	4.88	.3838	7.47	.996 756	.40	23
38	.080 779	4.83	.081 044	4.87	.3390	7.40	.996 732	.38	22
39	.081 069	4.83	.081 336	4.88	.2946	7.35	.996 709	.40	21
40	0.081 359	4.83	0.081 629	4.88	12.2505	7.30	0.996 685	.40	20
41	.081 649	4.83	.081 922	4.88	.2067	7.25	.996 661	.40	19
42	.081 939	4.82	.082 215	4.88	.1632	7.18	.996 637	.38	18
43	.082 228	4.83	.082 508	4.88	.1201	7.15	.996 614	.40	17
44	.082 518	4.83	.082 801	4.88	.0772	7.10	.996 590	.40	16
45	.082 808	4.83	.083 094	4.87	12.0346	7.05	.996 566	.42	15
46	.083 098	4.83	.083 386	4.88	11.9923	6.98	.996 541	.40	14
47	.083 388	4.83	.083 679	4.88	.9504	6.95	.996 517	.40	13
48	.083 678	4.83	.083 972	4.88	.9087	6.90	.996 493	.42	12
49	.083 968	4.83	.084 265	4.88	.8673	6.85	.996 468	.40	11
50	0.084 258	4.82	0.084 558	4.88	11.8262	6.82	0.996 444	.42	10
51	.084 547	4.83	.084 851	4.88	.7853	6.75	.996 419	.40	09
52	.084 837	4.83	.085 144	4.88	.7448	6.72	.996 395	.42	08
53	.085 127	4.83	.085 437	4.88	.7045	6.67	.996 370	.42	07
54	.085 417	4.83	.085 730	4.88	.6645	6.62	.996 345	.42	06
55	.085 707	4.83	.086 023	4.88	.6248	6.58	.996 320	.42	05
56	.085 997	4.82	.086 316	4.88	.5853	6.53	.996 295	.42	04
57	.086 286	4.83	.086 609	4.88	.5461	6.48	.996 270	.42	03
58	.086 576	4.83	.086 902	4.90	.5072	6.45	.996 245	.42	02
59	.086 866	4.83	.087 196	4.88	.4685	6.40	.996 220	.42	01
60	0.087 156		0.087 489		11.4301		0.996 195		00
	Cos	d"	Cot	d"	Tan	d"	Sin	d"	

Table A-1. Natural trigonometric functions (continued)

5°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.087 156	4.83	0.087 489	4.88	11.4301	6.37	0.996 195	.43	60′
01	.087 446	4.82	.087 782	4.88	.3919	6.32	.996 169	.42	59
02	.087 735	4.83	.088 075	4.88	.3540	6.28	.996 144	.43	58
03	.088 025	4.83	.088 368	4.88	.3163	6.23	.996 118	.42	57
04	.088 315	4.83	.088 661	4.88	.2789	6.20	.996 093	.43	56
05	.088 605	4.82	.088 954	4.90	.2417	6.15	.996 067	.43	55
06	.088 894	4.83	.089 248	4.88	.2048	6.12	.996 041	.43	54
07	.089 184	4.83	.089 541	4.88	.1681	6.08	.996 015	.43	53
08	.089 474	4.82	.089 834	4.88	.1316	6.03	.995 989	.43	52
09	.089 763	4.83	.090 127	4.90	.0954	6.00	.995 963	.43	51
10	0.090 053	4.83	0.090 421	4.88	11.0594	5.95	0.995 937	.43	50
11	.090 343	4.83	0.090 714	4.88	11.0237	5.92	.995 911	.45	49
12	.090 633	4.82	.091 007	4.88	10.9882	5.88	.995 884	.43	48
13	.090 922	4.83	.091 300	4.90	.9529	5.85	.995 858	.43	47
14	.091 212	4.83	.091 594	4.88	.9178	5.82	.995 832	.45	46
15	.091 502	4.82	.091 887	4.88	.8829	5.77	.995 805	.45	45
16	.091 791	4.83	.092 180	4.90	.8483	5.73	.995 778	.43	44
17	.092 081	4.83	.092 474	4.88	.8139	5.70	.995 752	.45	43
18	.092 371	4.82	.092 767	4.90	.7797	5.67	.995 725	.45	42
19	.092 660	4.83	.093 061	4.88	.7457	5.63	.995 698	.45	41
20	0.092 950	4.82	0.093 354	4.88	10.7119	5.60	0.995 671	.45	40
21	.093 239	4.83	.093 647	4.90	.6783	5.55	.995 644	.45	39
22	.093 529	4.83	.093 941	4.88	.6450	5.53	.995 617	.47	38
23	.093 819	4.82	.094 234	4.90	.6118	5.48	.995 589	.45	37
24	.094 108	4.83	.094 528	4.88	.5789	5.45	.995 562	.45	36
25	.094 398	4.82	.094 821	4.90	.5462	5.43	.995 535	.47	35
26	.094 687	4.83	.095 115	4.88	.5136	5.38	.995 507	.47	34
27	.094 977	4.83	.095 408	4.90	.4813	5.37	.995 479	.45	33
28	.095 267	4.82	.095 702	4.88	.4491	5.32	.995 452	.47	32
29	.095 556	4.83	.095 995	4.90	.4172	5.30	.995 424	.47	31
30	0.095 846	4.82	0.096 289	4.90	10.3854	5.27	0.995 396	.47	30
31	.096 135	4.83	.096 583	4.88	.3538	5.23	.995 368	.47	29
32	.096 425	4.82	.096 876	4.90	.3224	5.18	.995 340	.47	28
33	.096 714	4.83	.097 170	4.90	.2913	5.18	.995 312	.47	27
34	.097 004	4.82	.097 464	4.88	.2602	5.13	.995 284	.47	26
35	.097 293	4.83	.097 757	4.90	.2294	5.10	.995 256	.48	25
36	.097 583	4.82	.098 051	4.90	.1988	5.08	.995 227	.47	24
37	.097 872	4.83	.098 345	4.88	.1683	5.03	.995 199	.48	23
38	.098 162	4.82	.098 638	4.90	.1381	5.02	.995 170	.47	22
39	.098 451	4.83	.098 932	4.90	.1080	5.00	.995 142	.48	21
40	0.098 741	4.82	0.099 226	4.88	10.0780	4.95	0.995 113	.48	20
41	.099 030	4.83	.099 519	4.90	.0483	4.93	.995 084	.47	19
42	.099 320	4.82	.099 813	4.90	10.0187	4.90	.995 056	.48	18
43	.099 609	4.83	.100 107	4.90	9.9893	4.87	.995 027	.48	17
44	.099 899	4.82	.100 401	4.90	.9601	4.85	.994 998	.48	16
45	.100 188	4.82	.100 695	4.90	.9310	4.82	.994 969	.50	15
46	.100 477	4.83	.100 989	4.88	.9021	4.78	.994 939	.48	14
47	.100 767	4.82	.101 282	4.90	.8734	4.77	.994 910	.48	13
48	.101 056	4.83	.101 576	4.90	.8448	4.73	.994 881	.50	12
49	.101 346	4.82	.101 870	4.90	.8164	4.70	.994 851	.48	11
50	0.101 635	4.82	0.102 164	4.90	9.7882	4.68	0.994 822	.50	10
51	.101 924	4.83	.102 458	4.90	.7601	4.65	.994 792	.50	09
52	.102 214	4.82	.102 752	4.90	.7322	4.63	.994 762	.48	08
53	.102 503	4.83	.103 046	4.90	.7044	4.60	.994 733	.50	07
54	.102 793	4.82	.103 340	4.90	.6768	4.58	.994 703	.50	06
55	.103 082	4.82	.103 634	4.90	.6493	4.55	.994 673	.50	05
56	.103 371	4.83	.103 928	4.90	.6220	4.52	.994 643	.50	04
57	.103 661	4.82	.104 222	4.90	.5949	4.50	.994 613	.50	03
58	.103 950	4.82	.104 516	4.90	.5679	4.47	.994 583	.52	02
59	.104 239	4.82	.104 810	4.90	.5411	4.45	.994 552	.50	01
60	0.104 528		0.105 104		9.5144		0.994 522		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

6°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.104 528	4.83	0.105 104	4.90	9.514 36	44.25	0.944 522	.52	60
01	.104 818	4.82	.105 398	4.90	.487 81	44.00	.994 491	.50	59
02	.105 107	4.82	.105 692	4.92	.461 41	43.77	.994 461	.52	58
03	.105 396	4.83	.105 987	4.90	.435 15	43.52	.994 430	.50	57
04	.105 686	4.82	.106 281	4.90	.409 04	43.28	.994 400	.52	56
05	.105 975	4.82	.106 575	4.90	.383 07	43.05	.994 369	.52	55
06	.106 264	4.82	.106 869	4.90	.357 24	42.82	.994 338	.52	54
07	.106 553	4.83	.107 163	4.92	.331 55	42.60	.994 307	.52	53
08	.106 843	4.82	.107 458	4.90	.305 99	42.35	.994 276	.52	52
09	.107 132	4.82	.107 752	4.90	.280 58	42.13	.994 245	.52	51
10	0.107 421	4.82	0.108 046	4.90	9.255 30	41.90	0.994 214	.53	50
11	.107 710	4.82	.108 340	4.92	.230 16	41.67	.994 182	.52	49
12	.107 999	4.83	.108 635	4.90	.205 16	41.47	.994 151	.52	48
13	.108 289	4.82	.108 929	4.90	.180 28	41.23	.994 120	.52	47
14	.108 578	4.82	.109 223	4.92	.155 54	41.02	.994 088	.53	46
15	.108 867	4.82	.109 518	4.90	.130 93	40.78	.994 056	.52	45
16	.109 156	4.82	.109 812	4.92	.106 46	40.58	.994 025	.53	44
17	.109 445	4.82	.110 107	4.90	.082 11	40.37	.993 993	.53	43
18	.109 734	4.82	.110 401	4.90	.057 89	40.17	.993 961	.53	42
19	.110 023	4.83	.110 695	4.92	.033 79	39.93	.993 929	.53	41
20	0.110 313	4.82	0.110 990	4.90	9.009 83	39.75	0.993 897	.53	40
21	.110 602	4.82	.111 284	4.92	8.985 98	39.52	.993 865	.53	39
22	.110 891	4.82	.111 579	4.90	.962 27	39.33	.993 833	.55	38
23	.111 180	4.82	.111 873	4.92	.938 67	39.12	.993 800	.53	37
24	.111 469	4.82	.112 168	4.92	.915 20	38.92	.993 768	.55	36
25	.111 758	4.82	.112 463	4.90	.891 85	38.72	.993 735	.53	35
26	.112 047	4.82	.112 757	4.92	.868 62	38.52	.993 703	.55	34
27	.112 336	4.82	.113 052	4.90	.845 51	38.32	.993 670	.53	
28	.112 625	4.82	.113 346	4.92	.882 52	38.13	.993 638	.55	32
29	.112 914	4.82	.113 641	4.92	.799 64	37.92	.993 605	.55	31
30	0.113 203	4.82	0.113 936	4.90	8.776 89	37.73	0.993 572	.55	30
31	.113 492	4.82	.114 230	4.92	.754 25	37.55	.993 539	.55	29
32	.113 781	4.82	.114 525	4.92	.731 72	37.35	.993 506	.55	28
33	.114 070	4.82	.114 820	4.90	.709 31	37.17	.993 473	.57	27
34	.114 359	4.82	.115 114	4.92	.687 01	36.98	.993 439	.55	26
35	.114 648	4.82	.115 409	4.92	.664 82	36.78	.993 406	.55	25
36	.114 937	4.82	.115 704	4.92	.642 75	36.62	.993 373	.57	24
37	.115 226	4.82	.115 999	4.92	.620 78	36.42	.993 339	.55	23
38	.115 515	4.82	.116 294	4.90	.598 93	36.25	.993 306	.57	22
39	.115 804	4.82	.116 588	4.92	.577 18	36.05	.993 272	.57	21
40	0.116 093	4.82	0.116 883	4.92	8.555 55	35.88	0.993 238	.55	20
41	.116 382	4.82	.117 178	4.92	.534 02	35.72	.993 205	.57	19
42	.116 671	4.82	.117 473	4.92	.512 59	35.52	.993 171	.57	18
43	.116 960	4.82	.117 768	4.92	.491 28	35.35	.993 137	.57	17
44	.117 249	4.80	.118 063	4.92	.470 07	35.18	.993 103	.58	16
45	.117 537	4.82	.118 358	4.92	.448 96	35.02	.993 068	.57	15
46	.117 826	4.82	.118 653	4.92	.427 95	34.83	.993 034	.57	14
47	.118 115	4.82	.118 948	4.92	.407 05	34.67	.993 000	.57	13
48	.118 404	4.82	.119 243	4.92	.386 25	34.50	.992 966	.58	12
49	.118 693	4.82	.119 538	4.92	.365 55	34.32	.992 931	.58	11
50	0.118 982	4.80	0.119 833	4.92	8.344 96	34.17	0.992 896	.57	10
51	.119 270	4.82	.120 128	4.92	.324 46	34.00	.992 862	.58	09
52	.119 559	4.82	.120 423	4.92	.304 06	33.83	.992 827	.58	08
53	.119 848	4.82	.120 718	4.92	.283 76	33.68	.992 792	.58	07
54	.120 137	4.82	.121 013	4.92	.263 55	33.50	.992 757	.58	06
55	.120 426	4.80	.121 308	4.93	.243 45	33.35	.992 722	.58	05
56	.120 714	4.82	.121 604	4.92	.223 44	33.22	.992 687	.58	04
57	.121 003	4.82	.121 899	4.92	.205 52	33.03	.992 652	.58	03
58	.121 292	4.82	.122 194	4.92	.183 70	32.87	.992 617	.58	02
59	.121 581	4.80	.122 489	4.93	.163 98	32.72	.992 582	.60	01
60	0.121 869		0.122 785		8.144 35		0.992 546		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

7°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.121 869	4.82	0.122 785	4.92	8.144 35	32.57	0.992 546	.58	60′
01	.122 158	4.82	.123 080	4.92	.124 81	32.42	.992 511	.60	59
02	.122 447	4.80	.123 375	4.92	.105 36	32.27	.992 475	.60	58
03	.122 735	4.82	.123 670	4.93	.086 00	32.10	.992 439	.58	57
04	.123 024	4.82	.123 966	4.92	.066 74	31.97	.992 404	.60	56
05	.123 313	4.80	.124 261	4.93	.047 56	31.80	.992 368	.60	55
06	.123 601	4.82	.124 557	4.92	.028 48	31.67	.992 332	.60	54
07	.123 890	4.82	.124 852	4.92	.009 48	31.50	.992 296	.60	53
08	.124 179	4.80	.125 147	4.93	7.990 58	31.37	.992 260	.60	52
09	.124 467	4.82	.125 443	4.92	.971 76	31.23	.992 224	.62	51
10	0.124 756	4.82	0.125 738	4.93	7.953 02	31.07	0.992 187	.60	50
11	.125 045	4.80	.126 034	4.92	.934 38	30.93	.992 151	.60	49
12	.125 333	4.82	.126 329	4.93	.915 82	30.80	.992 115	.62	48
13	.125 622	4.80	.126 625	4.92	.897 34	30.65	.992 078	.60	47
14	.125 910	4.82	.126 920	4.93	.878 95	30.52	.992 042	.62	46
15	.126 199	4.82	.127 216	4.93	.860 64	30.37	.992 005	.62	45
16	.126 488	4.80	.127 512	4.92	.842 42	30.23	.991 968	.62	44
17	.176 776	4.82	.127 807	4.93	.824 28	30.10	.991 931	.62	43
18	.127 065	4.80	.128 103	4.93	.806 22	29.95	.991 894	.62	42
19	.127 353	4.82	.128 399	4.92	.788 25	29.83	.991 857	.62	41
20	0.127 642	4.80	.128 694	4.93	7.770 35	29.68	0.991 820	.62	40
21	.127 930	4.82	.128 990	4.93	.752 54	29.57	.991 783	.62	39
22	.128 219	4.80	.129 286	4.93	.734 80	29.42	.991 746	.62	38
23	.128 507	4.82	.129 582	4.92	.717 15	29.30	.991 709	.63	37
24	.128 796	4.80	.129 877	4.93	.699 57	29.15	.991 671	.62	36
25	.129 084	4.82	.130 173	4.93	.682 08	29.03	.991 634	.63	35
26	.129 373	4.80	.130 469	4.93	.664 66	28.90	.991 596	.63	34
27	.129 661	4.80	.130 765	4.93	.647 32	28.78	.991 558	.62	33
28	.129 949	4.82	.131 061	4.93	.630 05	28.63	.991 521	.63	32
29	.130 238	4.80	.131 357	4.92	.612 87	28.53	.991 483	.63	31
30	0.130 528	4.82	0.131 652	4.93	7.595 75	28.38	0.991 445	63	30
31	.130 815	4.80	.131 948	4.93	.578 72	28.27	.991 407	.63	29
32	.131 103	4.80	.132 244	4.93	.561 76	28.15	.998 369	.63	28
33	.131 391	4.82	.132 540	4.93	.544 87	28.02	.991 331	.65	27
34	.131 680	4.80	.132 836	4.93	.528 06	27.00	.991 292	.63	26
35	.131 968	4.80	.133 132	4.93	.511 32	27.78	.991 254	.63	25
36	.132 256	4.82	.133 428	4.95	.494 65	27.65	.991 216	.65	24
37	.132 545	4.80	.133 725	4.93	.478 06	27.53	.991 177	.65	23
38	.132 833	4.80	.134 021	4.93	.461 54	27.42	.991 138	.63	22
39	.133 121	4.82	.134 317	4.93	.445 09	27.30	.991 100	.65	21
40	0.133 410	4.80	0.134 613	4.93	7.428 71	27.18	0.991 061	.65	20
41	.133 698	4.80	.134 909	4.93	.412 40	27.07	.991 022	.65	19
42	.133 986	4.80	.135 205	4.95	.396 16	26.95	.990 083	.65	18
43	.134 274	4.82	.135 502	4.93	.379 99	26.83	.990 994	.65	17
44	.134 563	4.80	.135 798	4.93	.363 89	26.72	.990 905	.65	16
45	.134 851	4.80	.136 094	4.93	.347 86	26.60	.990 866	.65	15
46	.135 139	4.80	.136 390	4.95	.331 90	26.50	.990 827	.67	14
47	.135 427	4.82	.136 687	4.93	.316 00	26.37	.990 787	.65	13
48	.135 716	4.80	.136 983	4.93	.330 18	26.27	.990 748	.67	12
49	.136 004	4.80	.137 279	4.95	.284 42	26.15	.990 708	.65	11
50	0.136 292	4.80	0.137 576	4.93	7.268 73	26.05	0.990 669	.67	10
51	.136 580	4.80	.137 872	4.95	.253 10	25.93	.990 629	.67	09
52	.136 868	4.80	.138 169	4.93	.237 54	25.83	.990 589	.67	08
53	.137 156	4.82	.138 465	4.93	.222 04	25.72	.990 549	.67	07
54	.137 445	4.80	.138 761	4.95	.206 61	25.60	.990 509	.67	06
55	.137 733	4.80	.139 058	4.93	.191 25	25.52	.990 469	.67	05
56	.138 021	4.80	.139 354	4.95	.175 94	25.53	.990 429	.67	04
57	.138 309	4.80	.139 651	4.95	.160 71	25.30	.990 389	.67	03
58	.138 597	4.80	.139 948	4.93	.145 53	25.18	.990 349	.67	02
59	.138 883	4.80	.140 244	4.95	.130 42	25.08	.990 309	.68	01
60	0.139 173		0.140 541		7.115 37		0.099 268		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

8°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.139 173	4.80	0.140 541	4.93	7.113 37	24.98	0.990 268	.67	60′
01	.139 461	4.80	.140 837	4.95	.100 38	24.87	.990 228	.68	59
02	.139 749	4.80	.141 134	4.95	.085 46	24.78	.990 187	.68	58
03	.140 037	4.80	.141 431	4.95	.070 59	24.67	.990 146	.68	57
04	.140 325	4.80	.141 728	4.93	.055 79	24.57	.990 105	.67	56
05	.140 613	4.80	.142 024	4.95	.041 05	24.47	.990 065	.68	55
06	.140 901	4.80	.142 321	4.95	.026 37	24.38	.990 024	.68	54
07	.141 189	4.80	.142 618	4.95	.011 74	24.27	.989 983	.68	53
08	.141 477	4.80	.142 915	4.95	6.997 18	24.17	.989 942	.70	52
09	.141 765	4.80	.143 212	4.93	.982 68	24.08	.989 900	.68	51
10	0.142 053	4.80	0.143 508	4.95	6.968 23	23.97	0.989 859	.68	50
11	.142 341	4.80	.143 805	4.95	.953 85	23.88	.989 818	.70	49
12	.142 629	4.80	.144 102	4.95	.939 52	23.78	.989 776	.68	48
13	.142 917	4.80	.144 399	4.95	.925 25	23.68	.989 735	.70	47
14	.143 205	4.80	.144 696	4.95	.911 04	23.60	.989 693	.70	46
15	.143 493	4.78	.144 993	4.95	.896 88	23.50	.989 651	.68	45
16	.143 780	4.80	.145 290	4.95	.882 78	23.40	.989 610	.70	44
17	.144 068	4.80	.145 587	4.95	.868 74	23.32	.989 568	.70	43
18	.144 356	4.80	.145 884	4.95	.854 75	23.22	.989 526	.70	42
19	.144 644	4.80	.146 181	4.95	.840 82	23.13	.989 484	.70	41
20	0.144 932	4.80	0.146 478	4.97	6.826 94	23.03	0.989 442	.72	40
21	.145 220	4.78	.146 776	4.95	.813 12	22.93	.989 399	.70	39
22	.145 507	4.80	.147 073	4.95	.799 36	22.87	.989 357	.70	38
23	.145 795	4.80	.147 370	4.95	.785 64	22.75	.989 315	.72	37
24	.146 083	4.80	.147 667	4.95	.771 99	22.68	.989 272	.70	36
25	.146 371	4.80	.147 964	4.97	.758 38	22.58	.989 230	.72	35
26	.146 659	4.78	.148 262	4.95	.744 83	22.50	.989 187	.72	34
27	.146 946	4.80	.148 559	4.95	.731 33	22.40	.989 144	.70	33
28	.147 234	4.80	.148 856	4.97	.717 89	22.32	.989 102	.72	32
29	.147 522	4.78	.149 154	4.95	.704 50	22.23	.989 059	.72	31
30	0.147 809	4.80	0.149 451	4.95	6.691 16	22.15	.989 016	.72	30
31	.148 097	4.80	0.149 748	4.97	.677 87	22.07	.988 973	.72	29
32	.148 385	4.78	.150 046	4.95	.664 63	21.98	.988 930	.73	28
33	.148 672	4.80	.150 343	4.97	.651 44	21.88	.988 886	.72	27
34	.146 960	4.80	.150 641	4.95	.638 31	21.80	.988 843	.72	26
35	.149 248	4.78	.150 938	4.97	.625 23	21.73	.988 800	.73	25
36	.149 535	4.80	.151 236	4.95	.612 19	21.63	.988 756	.72	24
37	.149 823	4.80	.151 533	4.97	.599 21	21.57	.988 713	.73	23
38	.150 111	4.78	.151 831	4.97	.586 27	21.47	.988 669	.72	22
39	.150 398	4.80	.152 129	4.95	.573 39	21.40	.988 626	.73	21
40	0.150 686	4.78	0.152 426	4.97	6.560 55	21.30	.988 582	.73	20
41	.150 973	4.80	.152 724	4.97	.547 77	21.23	.988 538	.73	19
42	.151 261	4.78	.153 022	4.95	.535 03	21.15	.988 494	.73	18
43	.151 548	4.80	.153 319	4.97	.522 34	21.07	.988 450	.73	17
44	.151 836	4.78	.153 617	4.97	.509 70	21.00	.988 406	.73	16
45	.152 123	4.80	.153 915	4.97	.497 10	20.90	.988 362	.75	15
46	.152 411	4.78	.154 213	4.95	.484 56	20.83	.988 317	.73	14
47	.152 698	4.80	.154 510	4.97	.472 06	20.75	.988 273	.75	13
48	.152 986	4.78	.154 808	4.97	.459 61	20.68	.988 228	.73	12
49	.153 273	4.80	.155 106	4.97	.447 20	20.60	.998 184	.75	11
50	0.153 561	4.78	0.155 404	4.97	6.434 84	20.52	0.988 139	.75	10
51	.153 848	4.80	.155 702	4.97	.422 53	20.45	.988 094	.73	09
52	.154 136	4.78	.156 000	4.97	.410 26	20.37	.988 050	.75	08
53	.154 423	4.78	.156 298	4.97	.398 04	20.28	.988 005	.75	07
54	.154 710	4.80	.156 596	4.97	.385 87	20.22	.987 960	.75	06
55	.154 998	4.78	.156 894	4.97	.373 74	20.15	.987 915	.75	05
56	.155 285	4.78	.157 192	4.97	.361 65	20.07	.987 870	.77	04
57	.155 572	4.80	.157 490	4.97	.349 61	20.00	.987 824	.75	03
58	.155 860	4.78	.157 788	4.97	.337 61	19.92	.987 779	.75	02
59	.156 147	4.78	.158 086	4.97	.325 66	19.85	.987 734	.77	01
60	0.156 434		0.158 384		6.313 75		0.987 688		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

9°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.156 434	4.80	0.158 384	4.98	6.313 75	19.77	0.987 688	.75	60′
01	.156 722	4.78	.158 683	4.97	.301 89	19.70	.987 643	.77	59
02	.157 009	4.78	.158 981	4.97	.290 67	19.63	.987 597	.77	58
03	.157 296	4.80	.159 279	4.97	.278 29	19.57	.987 551	.75	57
04	.157 584	4.78	.159 577	4.98	.266 55	19.48	.987 506	.77	56
05	.157 871	4.78	.159 876	4.97	.254 86	19.42	.987 460	.77	55
06	.158 158	4.78	.160 174	4.97	.243 21	19.35	.987 414	.77	54
07	.158 445	4.78	.160 472	4.98	.231 60	19.28	.987 368	.77	53
08	.158 732	4.80	.160 771	4.97	.220 03	19.20	.987 322	.78	51
09	.159 020	4.78	.161 069	4.98	.208 51	19.13	.987 275	.77	51
10	0.159 307	4.78	0.161 368	4.97	6.197 03	19.07	0.987 229	.77	50
11	.159 594	4.78	.161 666	4.98	.185 59	19.00	.987 183	.78	49
12	.159 881	4.78	.161 965	4.97	.174 19	18.93	.987 136	.77	48
13	.160 168	4.78	.162 263	4.98	.162 83	18.87	.987 090	.78	47
14	.160 455	4.80	.162 562	4.97	.151 51	18.80	.987 043	.78	46
15	.160 743	4.78	.162 860	4.98	.140 23	18.73	.986 996	.77	45
16	.161 030	4.78	.163 159	4.98	.128 99	18.67	.986 950	.78	44
17	.161 317	4.78	.163 458	4.97	.117 79	18.58	.986 903	.78	43
18	.161 604	4.78	.163 756	4.98	.106 64	18.53	.986 856	.78	42
19	.161 891	4.78	.164 055	4.98	.095 52	18.47	.986 809	.78	41
20	0.162 178	4.78	0.164 354	4.97	6.084 44	18.40	0.986 762	.80	40
21	.162 465	4.78	.164 652	4.98	.073 40	18.33	.986 714	.78	39
22	.162 752	4.78	.164 951	4.98	.062 40	18.28	.986 667	.78	38
23	.163 039	4.78	.165 250	4.98	.051 43	18.20	.986 620	.80	37
24	.163 326	4.78	.165 549	4.98	.040 51	18.15	.986 572	.78	36
25	.163 613	4.78	.165 848	4.98	.029 62	18.07	.986 525	.80	35
26	.163 900	4.78	.166 147	4.98	.018 78	18.02	.986 477	.80	34
27	.164 187	4.78	.166 446	4.98	.007 97	17.95	.986 429	.80	33
28	.164 474	4.78	.166 745	4.98	5.997 20	17.90	.986 381	.78	32
29	.164 761	4.78	.167 044	4.98	.986 46	17.83	.986 334	.80	31
30	0.165 048	4.77	0.167 343	4.98	5.975 76	17.77	0.986 286	.80	30
31	.165 334	4.78	.167 642	4.98	.965 10	17.70	.986 238	.82	29
32	.165 621	4.78	.167 941	4.98	.954 48	17.63	.986 189	.80	28
33	.165 908	4.78	.168 240	4.98	.943 90	17.58	.986 141	.80	27
34	.166 195	4.78	.168 539	4.98	.933 35	17.53	.986 093	.80	26
35	.166 482	4.78	.168 838	4.98	.922 83	17.45	.986 045	.82	25
36	.166 769	4.78	.169 137	5.00	.912 36	17.42	.985 996	.82	24
37	.167 056	4.77	.169 437	4.98	.901 91	17.33	.985 947	.80	23
38	.167 342	4.78	.169 736	4.98	.891 51	17.28	.985 899	.82	22
39	.167 629	4.78	.170 035	4.98	.881 14	17.23	.985 850	.82	21
40	0.167 916	4.78	0.170 334	5.00	5.870 80	17.15	0.985 801	.82	20
41	.168 203	4.77	.170 634	4.98	.860 51	17.12	.985 752	.82	19
42	.168 489	4.78	.170 933	5.00	.850 24	17.05	.985 703	.82	18
43	.168 776	4.78	.171 233	4.98	.840 01	16.98	.985 654	.82	17
44	.169 063	4.78	.171 532	4.98	.829 82	16.93	.985 605	.82	16
45	.169 350	4.77	.171 831	5.00	.819 66	16.88	.985 556	.82	15
46	.169 636	4.78	.172 131	4.98	.809 53	16.82	.985 507	.83	14
47	.169 923	4.77	.172 430	5.00	.799 44	16.77	.985 457	.82	13
48	.170 209	4.78	.172 730	5.00	.789 38	16.70	.985 408	.83	12
49	.170 496	4.78	.173 030	4.98	.779 36	16.65	.985 358	.82	11
50	0.170 783	4.77	.173 329	5.00	5.769 37	16.60	0.985 309	.83	10
51	.171 069	4.78	.173 629	5.00	.759 41	16.53	.985 259	.83	09
52	.171 356	4.78	.173 929	4.98	.749 49	16.48	.985 209	.83	08
53	.171 643	4.77	.174 228	5.00	.739 60	16.43	.985 159	.83	07
54	.171 929	4.78	.174 528	5.00	.729 74	16.37	.985 109	.83	06
55	.172 216	4.77	.174 828	4.98	.719 92	16.32	.985 059	.83	05
56	.172 502	4.78	.175 127	5.00	.710 13	16.27	.985 009	.83	04
57	.172 789	4.77	.175 427	5.00	.700 37	16.22	.984 959	.83	03
58	.173 075	4.78	.175 727	5.00	.690 64	16.17	.984 909	.85	02
59	.173 362	4.77	.176 027	5.00	.680 94	16.10	.984 858	.83	01
60	0.173 648		0.176 327		5.671 28		0.984 808		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

10°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.173 648	4.78	0.176 327	5.00	5.671 28	16.07	0.984 808	.85	60′
01	.173 935	4.77	.176 627	5.00	.661 65	16.00	.984 757	.83	59
02	.174 221	4.78	.176 927	5.00	.652 05	15.95	.984 707	.85	58
03	.174 508	4.77	.177 227	5.00	.642 48	15.88	.984 656	.85	57
04	.174 794	4.77	.177 527	5.00	.632 95	15.85	.984 605	.85	56
05	.175 080	4.78	.177 827	5.00	.623 44	15.78	.984 554	.85	55
06	.175 367	4.77	.178 127	5.00	.613 97	15.75	.984 503	.85	54
07	.175 653	4.77	.178 427	5.00	.604 52	15.68	.984 452	.85	53
08	.175 939	4.78	.178 727	5.02	.595 11	15.63	.984 350	.87	51
09	.176 226	4.77	.179 028	5.00	.585 73	15.58	.984 350	.87	51
10	0.176 512	4.77	0.179 328	5.00	5.576 38	15.53	0.984 298	.85	50
11	.176 798	4.78	.179 628	5.00	.567 06	15.48	.984 247	.85	49
12	.177 085	4.77	.179 928	5.02	.557 77	15.43	.984 196	.87	48
13	.177 371	4.77	.180 229	5.00	.548 51	15.40	.984 144	.87	47
14	.177 657	4.78	.180 529	5.00	.539 27	15.33	.984 092	.85	46
15	.177 944	4.77	.180 829	5.02	.530 07	15.28	.984 041	.87	45
16	.178 230	4.77	.181 130	5.00	.520 90	15.23	.983 989	.87	44
17	.178 516	4.77	.181 430	5.02	.511 76	15.20	.983 937	.87	43
18	.178 802	4.77	.181 731	5.00	.502 64	15.13	.983 885	.87	42
19	.179 088	4.78	.182 031	5.02	.493 56	15.08	.983 833	.87	41
20	0.179 375	4.77	0.182 332	5.00	5.484 51	15.05	0.983 781	.87	40
21	.179 661	4.77	.182 632	5.02	.475 48	15.00	.983 729	.88	39
22	.179 947	4.77	.182 933	5.02	.466 48	14.95	.983 676	.87	38
23	.180 233	4.77	.183 234	5.00	.457 51	14.90	.983 624	.88	37
24	.180 519	4.77	.183 534	5.02	.448 57	14.85	.983 571	.87	36
25	.180 805	4.77	.183 835	5.02	.439 66	14.82	.983 519	.88	35
26	.181 091	4.77	.184 136	5.02	.430 77	14.75	.983 466	.87	34
27	.181 377	4.77	.184 437	5.00	.421 92	14.72	.983 414	.88	33
28	.181 663	4.78	.184 737	5.02	.413 09	14.67	.983 361	.88	32
29	.181 950	4.77	.185 038	5.02	.404 29	14.62	.983 308	.88	31
30	0.182 236	4.77	0.185 339	5.02	5.395 52	14.58	0.983 255	.88	30
31	.182 522	4.77	.185 640	5.02	.386 77	14.53	.983 202	.88	29
32	.182 808	4.77	.185 941	5.02	.378 05	14.48	.983 149	.88	28
33	.183 094	4.75	.186 242	5.02	.369 36	14.43	.983 096	.90	27
34	.183 379	4.77	.186 543	5.02	.360 70	14.40	.983 042	.88	26
35	.183 665	4.77	.186 844	5.02	.352 06	14.35	.982 989	.90	25
36	.183 951	4.77	.187 145	5.02	.343 45	14.30	.982 935	.88	24
37	.187 237	4.77	.187 446	5.02	.334 87	14.27	.982 882	.90	23
38	.184 523	4.77	.187 747	5.02	.326 31	14.22	.982 828	.90	22
39	.184 809	4.77	.188 048	5.02	.317 78	14.17	.982 774	.88	21
40	0.185 095	4.77	0.188 349	5.03	5.309 28	14.13	0.982 721	.90	20
41	.185 381	4.77	.188 651	5.02	.300 80	14.08	.982 667	.90	19
42	.185 667	4.75	.188 952	5.02	.292 35	14.03	.982 613	.90	18
43	.185 952	4.77	.189 253	5.03	.283 93	14.00	.982 559	.90	17
44	.186 238	4.77	.189 555	5.02	.275 53	13.97	.982 505	.92	16
45	.186 524	4.77	.189 856	5.02	.267 15	13.92	.982 450	.90	15
46	.186 810	4.77	.190 157	5.03	.258 80	13.87	.982 396	.90	14
47	.187 096	4.75	.190 459	5.02	.250 48	13.83	.982 342	.92	13
48	.187 381	4.77	.190 760	5.03	.242 18	13.78	.982 287	.90	12
49	.187 667	4.77	.191 062	5.02	.233 91	13.75	.982 233	.92	11
50	0.187 953	4.75	0.191 363	5.03	5.225 66	13.70	0.982 178	.92	10
51	.188 238	4.77	.191 665	5.02	.217 44	13.65	.982 123	.90	09
52	.188 524	4.77	.191 966	5.03	.209 25	13.63	.982 069	.92	08
53	.188 810	4.75	.192 268	5.03	.201 07	13.57	.982 014	.92	07
54	.189 095	4.77	.192 570	5.02	.192 93	13.55	.981 959	.92	06
55	.189 381	4.77	.192 871	5.03	.184 80	13.48	.981 904	.92	05
56	.189 667	4.75	.193 173	5.03	.176 71	13.47	.981 849	.93	04
57	.189 952	4.77	.193 475	5.03	.168 63	13.42	.981 793	.92	03
58	.190 238	4.75	.193 777	5.02	.160 58	13.37	.981 738	.92	02
59	.190 523	4.77	.194 078	5.03	.152 56	13.35	.981 683	.93	01
60	0.190 809		0.194 380		5.144 55		0.981 627		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

11°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.190 809	4.77	0.194 380	5.03	5.144 55	13.28	0.981 627	.92	60′
01	.191 095	4.75	.194 682	5.03	.136 58	13.27	.981 572	.93	59
02	.191 380	4.77	.194 984	5.03	.128 62	13.22	.981 516	.93	58
03	.191 666	4.75	.195 286	5.03	.120 69	13.17	.981 460	.92	57
04	.191 951	4.77	.195 588	5.03	.112 79	13.15	.981 405	.93	56
05	.192 237	4.75	.195 890	5.03	.104 90	13.10	.981 349	.93	55
06	.192 522	4.75	.196 192	5.03	.097 04	13.05	.981 293	.93	54
07	.192 807	4.77	.196 494	5.03	.089 21	13.03	.981 237	.95	53
08	.193 093	4.75	.196 796	5.05	.081 39	12.98	.981 180	.93	52
09	.193 379	4.77	.197 099	5.03	.073 60	12.93	.981 124	.93	51
10	0.193 664	4.75	0.197 401	5.03	5.065 84	12.92	0.981 068	.93	50
11	.193 949	4.75	.197 703	5.03	.058 09	12.87	.981 012	.95	49
12	.194 234	4.77	.198 005	5.05	.050 37	12.83	.980 955	.93	48
13	.194 520	4.75	.198 308	5.03	.042 67	12.80	.980 899	.95	47
14	.194 805	4.75	.198 610	5.03	.034 99	12.75	.980 842	.95	46
15	.195 090	4.77	.198 912	5.05	.027 34	12.72	.980 785	.95	45
16	.195 376	4.75	.199 215	5.03	.019 71	12.68	.980 728	.93	44
17	.195 661	4.75	.199 517	5.05	.012 10	12.65	.980 672	.95	43
18	.195 946	4.75	.199 820	5.03	.004 51	12.60	.980 615	.95	42
19	.196 231	4.77	.200 122	5.05	4.996 95	12.58	.980 558	.97	41
20	0.196 517	4.75	0.200 425	5.03	4.989 40	12.53	0.980 500	.95	40
21	.196 802	4.75	.200 727	5.05	.981 88	12.50	.980 443	.95	39
22	.197 087	4.75	.201 030	5.05	.974 38	12.47	.980 386	.95	38
23	.197 372	4.75	.201 333	5.03	.966 90	12.42	.980 329	.97	37
24	.197 657	4.75	.201 635	5.05	.959 45	12.40	.980 271	.95	36
25	.197 942	4.77	.201 938	5.05	.952 01	12.35	.980 214	.97	35
26	.198 228	4.75	.202 241	5.05	.944 60	12.32	.980 156	.97	34
27	.198 513	4.75	.202 544	5.05	.937 21	12.28	.980 098	.95	33
28	.198 798	4.75	.202 847	5.03	.929 84	12.25	.980 041	.97	32
29	.199 083	4.75	.203 149	5.05	.922 49	12.22	.979 983	.97	31
30	0.199 368	4.75	0.203 452	5.05	4.915 16	12.18	.979 925	.97	30
31	.199 653	4.75	.203 755	5.05	.907 85	12.15	.979 867	.97	29
32	.199 938	4.75	.204 058	5.05	.900 56	12.10	.979 809	.98	28
33	.200 223	4.75	.204 361	5.05	.893 30	12.08	.979 750	.97	27
34	.200 508	4.75	.204 664	5.05	.886 05	12.05	.979 692	.97	26
35	.200 793	4.75	.204 967	5.07	.878 82	12.00	.979 634	.98	25
36	.201 078	4.75	.205 271	5.05	.871 62	11.97	.979 575	.97	24
37	.201 363	4.75	.205 574	5.05	.864 44	11.95	.979 517	.98	23
38	.201 648	4.75	.205 877	5.05	.857 27	11.90	.979 458	.98	22
39	.201 933	4.75	.206 180	5.05	.850 13	11.88	.979 399	.97	21
40	0.202 218	4.73	0.206 483	5.07	4.843 00	11.83	0.979 341	.98	20
41	.202 502	4.75	.206 787	5.05	.835 90	11.80	.979 282	.98	19
42	.202 787	4.75	.207 090	5.05	.828 82	11.78	.979 223	.98	18
43	.203 072	4.75	.207 393	5.07	.821 75	11.73	.979 164	.98	17
44	.203 357	4.75	.207 697	5.05	.814 71	11.70	.979 105	1.00	16
45	.203 642	4.75	.208 000	5.07	.807 69	11.68	.979 045	.98	15
46	.203 927	4.73	.208 304	5.05	.800 68	11.63	.978 986	.98	14
47	.204 211	4.75	.208 607	5.07	.793 70	11.62	.978 927	1.00	13
48	.204 496	4.75	.208 911	5.05	.786 73	11.58	.978 867	.98	12
49	.204 781	4.73	.209 214	5.07	.779 78	11.53	.978 808	1.00	11
50	0.205 065	4.75	0.209 518	5.07	4.772 86	11.52	0.978 748	.98	10
51	.205 350	4.75	.209 822	5.07	.765 95	11.48	.978 689	1.00	09
52	.205 635	4.75	.210 126	5.05	.759 06	11.45	.978 629	1.00	08
53	.205 920	4.73	.210 429	5.07	.752 19	11.42	.978 569	1.00	07
54	.206 204	4.75	.210 733	5.0[illegible]	.745 34	11.38	.978 509	1.00	06
55	.206 489	4.73	.211 037	5.07	.738 51	11.35	.978 449	1.00	05
56	.206 773	4.75	.211 341	5.07	.731 70	11.33	.978 389	1.00	04
57	.207 058	4.75	.211 645	5.07	.724 90	11.28	.978 329	1.02	03
58	.207 343	4.73	.211 949	5.07	.718 13	11.27	.978 268	1.00	02
59	.207 627	4.75	.212 253	5.07	.711 37	11.23	.978 208	1.00	01
60	0.207 912		0.212 557		4.704 63		0.978 148		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

12°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.207 912	4.73	0.212 557	5.07	4.704 63	11.20	0.978 148	1.02	60′
01	.208 196	4.75	.212 861	5.07	.697 91	11.17	.978 087	1.02	59
02	.208 481	4.73	.213 165	5.07	.691 21	11.15	.978 026	1.00	58
03	.208 765	4.75	.213 469	5.07	.684 52	11.10	.977 966	1.02	57
04	.209 050	4.73	.213 773	5.07	.677 86	11.08	.977 905	1.00	56
05	.209 334	4.75	.214 077	5.07	.671 21	11.05	.977 844	1.02	55
06	.209 619	4.73	.214 381	5.08	.664 58	11.02	.977 783	1.02	54
07	.209 903	4.73	.214 686	5.07	.657 97	10.98	.977 722	1.02	53
08	.210 187	4.75	.214 990	5.07	.651 38	10.97	.977 661	1.02	52
09	.210 472	4.73	.215 294	5.08	.644 80	10.92	.977 600	1.02	51
10	0.210 756	4.73	0.215 599	5.07	4.638 25	10.90	0.977 539	1.03	50
11	.211 040	4.75	.215 903	5.08	.631 71	10.88	.977 477	1.02	49
12	.211 325	4.73	.216 208	5.07	.625 18	10.83	.977 416	1.03	48
13	.211 609	4.73	.216 512	5.08	.618 68	10.82	.977 354	1.02	47
14	.211 893	4.75	.216 817	5.07	.612 19	10.78	.977 293	1.03	46
15	.212 178	4.73	.217 121	5.08	.605 72	10.75	.977 231	1.03	45
16	.212 462	4.73	.217 426	5.08	.599 27	10.73	.977 169	1.02	44
17	.212 746	4.73	.217 731	5.07	.592 83	10.70	.977 108	1.03	43
18	.213 030	4.75	.218 035	5.08	.586 41	10.67	.977 046	1.03	42
19	.213 315	4.73	.218 340	5.08	.580 01	10.63	.976 984	1.05	41
20	0.213 599	4.73	0.218 645	5.08	4.573 63	10.62	0.976 921	1.03	40
21	.213 883	4.73	.218 950	5.07	.567 26	10.58	.976 859	1.03	39
22	.214 167	4.73	.219 254	5.08	.560 91	10.55	.976 797	1.03	38
23	.214 451	4.73	.219 559	5.08	.554 58	10.53	.976 735	1.05	37
24	.214 735	4.73	.219 864	5.08	.548 26	10.50	.976 672	1.03	36
25	.215 019	4.73	.220 169	5.08	.541 96	10.47	.976 610	1.05	35
26	.215 303	4.75	.220 474	5.08	.535 68	10.45	.976 547	1.03	34
27	.215 588	4.73	.220 779	5.08	.529 41	10.42	.976 485	1.05	33
28	.215 872	4.73	.221 084	5.08	.523 16	10.38	.976 422	1.05	32
29	.216 156	4.73	.221 389	5.10	.516 93	10.37	.976 359	1.05	31
30	0.216 440	4.73	0.221 695	5.08	4.510 71	10.33	0.976 296	1.05	30
31	.216 724	4.73	.222 000	5.08	.504 51	10.32	.976 233	1.05	29
32	.217 008	4.73	.222 305	5.08	.498 32	10.28	.976 170	1.05	28
33	.217 292	4.72	.222 610	5.10	.492 15	10.25	.976 107	1.05	27
34	.217 575	4.73	.222 916	5.08	.486 00	10.23	.976 044	1.07	26
35	.217 859	4.73	.223 221	5.08	.479 86	10.20	.975 980	1.05	25
36	.218 143	4.73	.223 526	5.10	.473 74	10.17	.975 917	1.07	24
37	.218 427	4.73	.223 832	5.08	.467 64	10.15	.975 853	1.05	23
38	.218 711	4.73	.224 137	5.10	.461 55	10.12	.975 790	1.07	22
39	.218 995	4.73	.224 443	5.08	.455 48	10.10	.975 726	1.07	21
40	0.219 279	4.72	0.224 748	5.10	4.449 42	10.07	0.975 662	1.07	20
41	.219 562	4.73	.225 054	5.10	.443 38	10.05	.975 598	1.05	19
42	.219 846	4.73	.225 360	5.08	.437 35	10.02	.975 535	1.07	18
43	.220 130	4.73	.225 665	5.10	.431 34	10.00	.975 471	1.08	17
44	.220 414	4.72	.225 971	5.10	.425 34	9.97	.975 406	1.07	16
45	.220 697	4.73	.226 277	5.10	.419 36	9.93	.975 342	1.07	15
46	.220 981	4.73	.226 583	5.10	.413 40	9.92	.975 278	1.07	14
47	.221 265	4.72	.226 889	5.08	.407 45	9.88	.975 214	1.08	13
48	.221 548	4.73	.227 194	5.10	.401 52	9.87	.975 149	1.07	12
49	.221 832	4.73	.227 500	5.10	.395 60	9.85	.975 085	1.08	11
50	0.222 116	4.72	0.227 806	5.10	4.389 69	9.80	0.975 020	1.07	10
51	.222 399	4.73	.228 112	5.10	.383 81	9.80	.974 956	1.08	09
52	.222 683	4.73	.377 418	5.10	.377 93	9.77	.974 891	1.08	08
53	.222 967	4.72	.228 724	5.12	.372 07	9.73	.974 826	1.08	07
54	.223 250	4.73	.229 031	5.10	.366 23	9.72	.974 761	1.08	06
55	.223 534	4.72	.229 337	5.10	.360 40	9.68	.974 696	1.08	05
56	.223 817	4.73	.229 643	5.10	.354 59	9.67	.974 631	1.08	04
57	.224 101	4.72	.229 949	5.10	.348 79	9.65	.974 566	1.08	03
58	.224 384	4.73	.230 255	5.12	.343 00	9.62	.974 501	1.10	02
59	.224 668	4.72	.230 562	5.10	.337 23	9.58	.974 435	1.08	01
60	0.224 951		0.230 868		4.331 48		0.974 370		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

13°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.224 951	4.72	0.230 868	5.12	4.331 48	9.58	0.974 370	1.08	60′
01	.225 234	4.73	.231 175	5.10	.325 73	9.53	.974 305	1.10	59
02	.225 518	4.72	.231 481	5.12	.320 01	9.52	.974 239	1.10	58
03	.225 801	4.73	.231 788	5.10	.314 30	9.50	.974 173	1.08	57
04	.226 085	4.72	.232 094	5.12	.308 60	9.48	.974 108	1.10	56
05	.226 368	4.72	.232 401	5.10	.302 91	9.45	.974 042	1.10	55
06	.226 651	4.73	.232 707	5.12	.297 24	9.42	.973 976	1.10	54
07	.226 935	4.72	.233 014	5.12	.291 59	9.40	.973 910	1.10	53
08	.227 218	4.72	.233 321	5.10	.285 95	9.38	.973 844	1.10	52
09	.227 501	4.72	.233 627	5.12	.280 32	9.35	.973 778	1.10	51
10	0.227 784	4.73	0.233 934	5.12	4.274 71	9.33	0.973 712	1.12	50
11	.228 068	4.72	.234 241	5.12	.269 11	9.32	.973 645	1.10	49
13	.228 351	4.72	.234 548	5.12	.263 52	9.28	.973 579	1.12	48
13	.228 634	4.72	.234 855	5.12	.257 95	9.27	.973 512	1.10	47
14	.228 917	4.72	.235 162	5.12	.252 39	9.23	.973 446	1.12	46
15	.229 200	4.73	.235 469	5.12	.246 85	9.22	.973 379	1.10	45
16	.229 484	4.72	.235 776	5.12	.241 32	9.20	.973 313	1.12	44
17	.229 767	4.72	.236 083	5.12	.235 80	9.17	.973 246	1.12	43
18	.230 050	4.72	.236 390	5.12	.230 30	9.15	.973 179	1.12	42
19	.230 333	4.72	.236 697	5.12	.224 81	9.13	.973 112	1.12	41
20	0.230 616	4.72	0.237 004	5.13	4.219 33	9.10	0.973 045	1.12	40
21	.230 899	4.72	.237 312	5.12	.213 87	9.08	.972 978	1.12	39
22	.231 182	4.72	.237 619	5.12	.208 42	9.07	.972 911	1.13	38
23	.231 465	4.72	.237 926	5.13	.202 98	9.03	.972 843	1.12	37
24	.231 748	4.72	.238 234	5.12	.197 56	9.02	.972 776	1.13	36
25	.232 031	4.72	.238 541	5.12	.192 15	9.00	.972 708	1.12	35
26	.232 314	4.72	.238 848	5.13	.186 75	8.97	.972 641	1.13	34
27	.232 597	4.72	.239 156	5.13	.181 37	8.95	.972 573	1.12	33
28	.232 880	4.72	.239 464	5.12	.176 00	8.93	.972 506	1.13	32
29	.233 163	4.70	.239 771	5.13	.170 64	8.90	.972 438	1.13	31
30	0.233 445	4.72	0.240 079	5.12	4.165 30	8.88	0.972 370	1.13	30
31	.233 728	4.72	.240 386	5.13	.159 97	8.87	.972 302	1.13	29
32	.234 011	4.72	.240 694	5.13	.154 65	8.85	.972 234	1.13	28
33	.234 294	4.72	.241 002	5.13	.149 34	8.82	.972 166	1.13	27
34	.234 577	4.70	.241 310	5.13	.144 05	8.80	.972 098	1.15	26
35	.234 859	4.72	.241 618	5.12	.138 77	8.78	.972 029	1.13	25
36	.235 142	4.72	.241 925	5.13	.133 50	8.75	.971 961	1.13	24
37	.235 425	4.72	.242 233	5.13	.128 25	8.73	.971 893	1.15	23
38	.235 708	4.70	.242 541	5.13	.123 01	8.72	.971 824	1.15	22
39	.235 990	4.72	.242 849	5.13	.117 78	8.70	.971 755	1.13	21
40	0.236 273	4.72	0.243 157	5.15	4.112 56	8.67	0.971 687	1.15	20
41	.236 556	4.70	.243 466	5.13	.107 36	8.67	.971 618	1.15	19
42	.236 838	4.72	.243 774	5.13	.102 16	8.62	.971 549	1.15	18
43	.237 121	4.70	.244 082	5.13	.096 99	8.62	.971 480	1.15	17
44	.237 403	4.72	.244 390	5.13	.091 82	8.60	.971 411	1.15	16
45	.237 686	4.70	.244 698	5.15	.086 66	8.57	.971 342	1.15	15
46	.237 968	4.72	.245 007	5.13	.081 52	8.55	.971 273	1.15	14
47	.238 251	4.70	.245 315	5.15	.076 39	8.53	.971 204	1.17	13
48	.238 533	4.72	.245 624	5.13	.071 27	8.52	.971 134	1.15	12
49	.238 816	4.70	.245 932	5.15	.066 16	8.48	.971 065	1.17	11
50	0.239 098	4.72	0.246 241	5.13	4.061 07	8.47	0.970 995	1.15	10
51	.239 381	4.70	.246 549	5.15	.055 99	8.45	.970 926	1.17	09
52	.239 663	4.72	.246 858	5.13	.050 92	8.43	.970 856	1.17	08
53	.239 946	4.70	.247 166	5.15	.045 86	8.42	.970 786	1.17	07
54	.240 228	4.70	.247 475	5.15	.040 81	8.38	.970 716	1.15	06
55	.240 510	4.72	.247 784	5.13	.035 78	8.37	.970 647	1.17	05
56	.240 793	4.70	.248 092	5.15	.030 76	8.37	.970 577	1.18	04
57	.241 075	4.70	.248 401	5.15	.025 74	8.33	.970 506	1.17	03
58	.241 357	4.72	.248 710	5.15	.020 74	8.30	.970 436	1.17	02
59	.241 640	4.70	.249 019	5.15	.015 76	8.30	.970 366	1.17	01
60	0.241 922		0.249 328		4.010 78		0.970 296		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

14°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.241 922	4.70	0.249 328	5.15	4.010 78	8.27	0.970 296	1.18	60
01	.242 204	4.70	.249 637	5.15	.005 82	8.27	.970 225	1.17	59
02	.242 486	4.72	.249 946	5.15	.000 86	8.23	.970 155	1.18	58
03	.242 769	4.70	.250 255	5.15	3.995 92	8.22	.970 084	1.17	57
04	.243 051	4.70	.250 564	5.15	.990 99	8.20	.970 014	1.18	56
05	.243 333	4.70	.250 873	5.17	.986 07	8.17	.969 943	1.18	55
06	.243 615	4.70	.251 183	5.15	.981 17	8.17	.969 872	1.18	54
07	.243 897	4.70	.251 492	5.15	.976 27	8.13	.969 801	1.18	53
08	.244 179	4.70	.251 801	5.17	.971 39	8.13	.969 730	1.18	52
09	.244 461	4.70	.252 111	5.15	.966 51	8.10	.969 659	1.18	51
10	0.244 743	4.70	0.252 420	5.15	3.961 65	8.08	0.969 588	1.18	50
11	.245 025	4.70	.252 729	5.17	.956 80	8.07	.969 517	1.20	49
12	.245 307	4.70	.253 039	5.15	.951 96	8.05	.969 445	1.18	48
13	.245 589	4.70	.253 348	5.17	.947 13	8.02	.969 374	1.20	47
14	.245 871	4.70	.253 658	5.17	.942 32	8.02	.969 302	1.18	46
15	.246 153	4.70	.253 968	5.15	.937 51	8.00	.969 231	1.20	45
16	.246 435	4.70	.254 277	5.17	.932 71	7.97	.969 159	1.18	44
17	.246 717	4.70	.254 587	5.17	.927 93	7.95	.969 088	1.20	43
18	.246 999	4.70	.254 897	5.17	.923 16	7.95	.969 016	1.20	42
19	.247 281	4.70	.255 207	5.15	.918 39	7.92	.968 944	1.20	41
20	0.247 563	4.70	0.255 516	5.17	3.913 64	7.90	0.968 872	1.20	40
21	.247 845	4.68	.255 826	5.17	.908 90	7.88	.968 800	1.20	39
22	.248 126	4.70	.256 136	5.17	.904 17	7.87	.968 728	1.22	38
23	.248 408	4.70	.256 446	5.17	.899 45	7.85	.968 655	1.20	37
24	.248 690	4.70	.256 756	5.17	.894 74	7.83	.968 583	1.20	36
25	.248 972	4.68	.257 066	5.18	.890 04	7.80	.968 511	1.22	35
26	.249 253	4.70	.257 377	5.17	.885 36	7.80	.968 438	1.20	34
27	.249 535	4.70	.257 687	5.17	.880 68	7.78	.968 366	1.22	33
28	.249 817	4.68	.257 997	5.17	.876 01	7.75	.968 293	1.22	32
29	.250 098	4.70	.258 307	5.18	.871 36	7.75	.968 220	1.20	31
30	0.250 380	4.70	0.258 618	5.17	3.866 71	7.72	0.968 148	1.22	30
31	.250 662	4.68	.258 928	5.17	.862 08	7.72	.968 075	1.22	29
32	.250 943	4.70	.259 238	5.18	.857 45	7.68	.968 002	1.22	28
33	.251 225	4.68	.259 549	5.17	.852 84	7.67	.967 929	1.22	27
34	.251 506	4.70	.259 859	5.18	.848 24	7.67	.967 856	1.23	26
35	.251 788	4.68	.260 170	5.17	.843 64	7.63	.967 782	1.22	25
36	.252 069	4.70	.260 480	5.18	.839 06	7.62	.967 709	1.22	24
37	.252 351	4.68	.260 791	5.18	.834 49	7.62	.967 636	1.23	23
38	.252 632	4.70	.261 102	5.18	.829 92	7.58	.967 562	1.22	22
39	.252 914	4.68	.261 413	5.17	.825 37	7.57	.967 489	1.23	21
40	0.253 195	4.70	0.261 723	5.18	3.820 83	7.55	0.967 415	1.22	20
41	.253 477	4.68	.262 034	5.18	.816 30	7.55	.967 342	1.23	19
42	.253 758	4.68	.262 345	5.18	.811 77	7.52	.967 268	1.23	18
43	.254 039	4.70	.262 656	5.18	.807 26	7.50	.967 194	1.23	17
44	.254 321	4.68	.262 967	5.18	.802 76	7.48	.967 120	1.23	16
45	.254 602	4.68	.263 278	5.18	.798 27	7.48	.967 046	1.23	15
46	.254 883	4.70	.263 589	5.18	.793 78	7.45	.966 972	1.23	14
47	.255 165	4.68	.263 900	5.18	.789 31	7.43	.966 898	1.25	13
48	.255 446	4.68	.264 211	5.20	.784 85	7.42	.966 823	1.23	12
49	.255 727	4.68	.264 523	5.18	.780 40	7.42	.966 749	1.23	11
50	0.256 008	4.68	0.264 834	5.18	3.775 95	7.38	0.966 675	1.25	10
51	.256 289	4.70	.265 145	5.20	.771 52	7.38	.966 600	1.23	09
52	.256 571	4.68	.265 457	5.18	.767 09	7.35	.966 526	1.25	08
53	.256 852	4.68	.265 768	5.18	.762 68	7.33	.966 451	1.25	07
54	.257 133	4.68	.266 079	5.20	.758 28	7.33	.966 376	1.25	06
55	.257 414	4.68	.266 391	5.18	.753 88	7.30	.966 301	1.25	05
56	.257 695	4.68	.266 702	5.20	.749 50	7.30	.966 226	1.25	04
57	.257 976	4.68	.267 014	5.20	.745 12	7.28	.966 151	1.25	03
58	.258 257	4.68	.267 326	5.18	.740 75	7.25	.966 076	1.25	02
59	.258 538	4.68	.267 637	5.20	.736 40	7.25	.966 001	1.25	01
60	0.258 819		0.267 949		3.732 05		0.965 926		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

15°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.258 819	4.68	0.267 949	5.20	3.732 05	7.23	0.965 926	1.27	60′
01	.259 100	4.68	.268 261	5.20	.727 71	7.22	.965 850	1.25	59
02	.259 381	4.68	.268 573	5.20	.723 38	7.18	.965 775	1.25	58
03	.259 662	4.68	.268 885	5.20	.719 07	7.18	.965 700	1.27	57
04	.259 943	4.68	.269 197	5.20	.714 76	7.17	.965 624	1.27	56
05	.260 224	4.68	.269 509	5.20	.710 46	7.17	.965 548	1.25	55
06	.260 505	4.67	.269 821	5.20	.706 16	7.13	.965 473	1.27	54
07	.260 785	4.68	.270 133	5.20	.701 88	7.12	.965 397	1.27	53
08	.261 066	4.68	.270 445	5.20	.697 61	7.10	.965 321	1.27	52
09	.261 347	4.68	.270 757	5.20	.693 35	7.10	.965 245	1.27	51
10	0.261 628	4.67	0.271 069	5.22	3.689 09	7.07	0.965 169	1.27	50
11	.261 908	4.68	.271 382	5.20	.684 85	7.07	.965 093	1.28	49
12	.262 189	4.68	.271 694	5.20	.680 61	7.05	.965 016	1.27	48
13	.262 470	4.68	.272 006	5.22	.676 38	7.02	.964 940	1.27	47
14	.262 751	4.67	.272 319	5.20	.672 17	7.02	.964 864	1.28	46
15	.263 031	4.68	.272 631	5.22	.667 96	7.00	.964 787	1.27	45
16	.263 312	4.67	.272 944	5.20	.663 76	6.98	.964 711	1.28	44
17	.263 592	4.68	.273 256	5.22	.659 57	6.98	.964 634	1.28	43
18	.263 873	4.68	.273 569	5.22	.655 38	6.95	.964 557	1.27	42
19	.264 154	4.67	.273 882	5.20	.651 21	6.93	.964 481	1.28	41
20	0.264 434	4.68	0.274 194	5.22	3.647 05	6.93	0.964 404	1.28	40
21	.264 715	4.67	.274 507	5.22	.642 89	6.92	.964 327	1.28	39
22	.264 995	4.68	.274 820	5.22	.638 74	6.88	.964 250	1.28	38
23	.265 276	4.67	.275 133	5.22	.634 61	6.88	.964 173	1.30	37
24	.265 556	4.68	.275 446	5.22	.630 48	6.87	.964 095	1.28	36
25	.265 837	4.67	.275 759	5.22	.626 36	6.87	.964 018	1.28	35
26	.266 117	4.67	.276 072	5.22	.622 24	6.83	.963 941	1.30	34
27	.266 397	4.68	.276 385	5.22	.618 14	6.82	.963 863	1.28	33
28	.266 678	4.67	.276 698	5.22	.614 05	6.82	.963 786	1.30	32
29	.266 958	4.67	.277 011	5.23	.609 96	6.80	.963 708	1.30	31
30	0.267 238	4.68	0.277 325	5.22	3.605 88	6.78	0.963 630	1.28	30
31	.267 519	4.67	.277 638	5.22	.601 81	6.77	.963 553	1.30	29
32	.267 799	4.67	.277 951	5.23	.597 75	6.75	.963 475	1.30	28
33	.268 079	4.67	.278 265	5.22	.593 70	6.73	.963 397	1.30	27
34	.268 359	4.68	.278 578	5.22	.589 66	6.73	.963 319	1.30	26
35	.268 640	4.67	.278 891	5.23	.585 62	6.70	.963 241	1.30	25
36	.268 920	4.67	.279 205	5.23	.581 60	6.70	.963 163	1.32	24
37	.269 200	4.67	.279 519	5.22	.577 58	6.68	.963 084	1.30	23
38	.269 480	4.67	.279 832	5.23	.573 57	6.67	.963 006	1.30	22
39	.269 760	4.67	.280 146	5.23	.569 57	6.67	.962 928	1.32	21
40	0.270 040	4.67	0.280 460	5.22	3.565 57	6.63	0.962 849	1.32	20
41	.270 320	4.67	.280 773	5.23	.561 59	6.63	.962 770	1.30	19
42	.270 600	4.67	.281 087	5.23	.557 61	6.62	.962 692	1.32	18
43	.270 880	4.67	.281 401	5.23	.553 64	6.60	.962 613	1.32	17
44	.271 160	4.67	.281 715	5.23	.549 68	6.58	.962 534	1.32	16
45	.271 440	4.67	.282 029	5.23	.545 73	6.57	.962 455	1.32	15
46	.271 720	4.67	.282 343	5.23	.541 79	6.57	.962 376	1.32	14
47	.272 000	4.67	.282 657	5.23	.537 85	6.53	.962 297	1.32	13
48	.272 280	4.67	.282 971	5.25	.533 93	6.53	.962 218	1.32	12
49	.272 560	4.67	.283 286	5.23	.530 01	6.53	.962 139	1.33	11
50	0.272 840	4.67	0.283 600	5.23	3.526 09	6.50	0.962 059	1.32	10
51	.273 120	4.67	.283 914	5.25	.522 19	6.50	.961 980	1.32	09
52	.273 400	4.65	.284 229	5.23	.518 29	6.47	.961 901	1.33	08
53	.273 679	4.67	.284 543	5.23	.514 41	6.47	.961 821	1.33	07
54	.273 959	4.67	.284 857	5.25	.510 53	6.45	.961 741	1.32	06
55	.274 239	4.67	.285 172	5.25	.506 66	6.45	.961 662	1.33	05
56	.274 519	4.65	.285 487	5.23	.502 79	6.42	.961 582	1.33	04
57	.274 798	4.67	.285 801	5.25	.498 94	6.42	.961 502	1.33	03
58	.275 078	4.67	.286 116	5.25	.495 09	6.40	.961 422	1.33	02
59	.275 358	4.65	.286 431	5.23	.491 25	6.40	.961 342	1.33	01
60	0.275 637		0.286 745		3.487 41		0.961 262		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

16°

	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	
00′	0.275 637	4.67	0.286 745	5.25	3.487 41	6.37	0.961 262	1.35	60′
01	.275 917	4.67	.287 060	5.25	.483 59	6.37	.961 181	1.33	59
02	.276 197	4.65	.287 375	5.25	.479 77	6.35	.961 101	1.33	58
03	.276 476	4.67	.287 690	5.25	.475 96	6.33	.961 021	1.35	57
04	.276 756	4.65	.288 005	5.25	.472 16	6.32	.960 940	1.33	56
05	.277 035	4.67	.238 320	5.25	.468 37	6.32	.960 860	1.35	55
06	.277 315	4.65	.288 635	5.25	.464 58	6.30	.960 779	1.35	54
07	.277 594	4.67	.288 950	5.27	.460 80	6.28	.960 698	1.33	53
08	.277 874	4.65	.289 266	5.25	.457 03	6.27	.960 618	1.35	52
09	.278 153	4.65	.289 581	5.25	.453 27	6.27	.960 537	1.35	51
10	0.278 432	4.67	0.289 896	5.25	3.440 51	6.25	0.960 456	1.35	50
11	.278 712	4.65	.290 211	5.27	.445 76	6.23	.960 375	1.35	49
12	.278 991	4.65	.290 527	5.25	.442 02	6.22	.960 294	1.37	48
13	.279 270	4.67	.290 842	5.27	.438 29	6.22	.960 212	1.35	47
14	.279 550	4.65	.291 158	5.25	.434 56	6.20	.960 131	1.35	46
15	.279 829	4.65	.291 473	5.27	.430 84	6.18	.960 050	1.37	45
16	.280 108	4.67	.291 789	5.27	.427 13	6.17	.959 968	1.35	44
17	.280 388	4.65	.292 105	5.25	.423 43	6.17	.959 887	1.37	43
18	.280 667	4.65	.292 420	5.27	.419 73	6.15	.959 805	1.35	42
19	.280 946	4.65	.292 736	5.27	.416 04	6.13	.959 724	1.37	41
20	0.281 225	4.65	0.293 052	5.27	3.412 36	6.12	0.959 642	1.37	40
21	.281 504	4.65	.293 368	5.27	.408 69	6.12	.959 560	1.37	39
22	.281 783	4.65	.293 684	5.27	.405 02	6.10	.959 478	1.37	38
23	.282 062	4.65	.294 000	5.27	.401 36	6.08	.959 396	1.37	37
24	.282 341	4.65	.294 316	5.27	.397 71	6.08	.959 314	1.37	36
25	.282 620	4.67	.294 632	5.27	.394 06	6.07	.959 232	1.37	35
26	.282 900	4.65	.294 948	5.28	.390 42	6.05	.959 150	1.38	34
27	.283 179	4.63	.295 265	5.27	.386 79	6.03	.959 067	1.37	33
28	.283 457	4.65	.295 581	5.27	.383 17	6.03	.958 985	1.38	32
29	.283 736	4.65	.295 897	5.27	.379 55	6.02	.958 902	1.37	31
30	0.284 015	4.65	0.296 213	5.28	3.375 94	6.00	0.958 820	1.38	30
31	.284 294	4.65	.296 530	5.27	.372 34	5.98	.958 737	1.38	29
32	.284 573	4.65	.296 846	5.28	.368 75	5.98	.958 654	1.37	28
33	.284 852	4.65	.297 163	5.28	.365 16	5.97	.958 572	1.38	27
34	.284 131	4.65	.297 480	5.27	.361 58	5.97	.958 489	1.38	26
35	.285 410	4.63	.297 796	5.28	.358 00	5.95	.958 406	1.38	25
36	.285 688	4.65	.298 113	5.28	.354 43	5.93	.958 323	1.40	24
37	.285 967	4.65	.298 430	5.28	.350 87	5.92	.958 239	1.38	23
38	.286 246	4.65	.298 747	5.27	.347 32	5.92	.958 156	1.38	22
39	.286 525	4.63	.299 063	5.28	.343 77	5.90	.958 073	1.38	21
40	0.286 803	4.65	0.299 380	5.28	3.340 23	5.88	0.957 990	1.40	20
41	.287 082	4.65	.299 697	5.28	.336 70	5.88	.957 906	1.40	19
42	.287 361	4.63	.300 014	5.28	.333 17	5.87	.957 822	1.38	18
43	.287 639	4.65	.300 331	5.30	.329 65	5.85	.957 739	1.40	17
44	.287 918	4.63	.300 649	5.28	.326 14	5.83	.957 655	1.40	16
45	.288 196	4.65	.300 966	5.28	.322 64	5.83	.957 571	1.40	15
46	.288 475	4.63	.301 283	5.28	.319 14	5.82	.957 487	1.38	14
47	.288 753	4.65	.301 600	5.30	.315 65	5.82	.957 404	1.42	13
48	.289 032	4.63	.301 918	5.28	.312 16	5.80	.957 319	1.40	12
49	.289 310	4.65	.302 235	5.30	.308 68	5.78	.957 235	1.40	11
50	0.289 589	4.63	0.302 553	5.28	3.305 21	5.78	0.957 151	1.40	10
51	.289 867	4.63	.302 870	5.30	.301 74	5.75	.957 067	1.40	09
52	.290 145	4.65	.303 188	5.30	.298 29	5.77	.956 983	1.42	08
53	.290 424	4.63	.303 506	5.28	.294 83	5.73	.956 898	1.40	07
54	.290 702	4.65	.303 823	5.30	.291 39	5.73	.956 814	1.42	06
55	.290 981	4.63	.304 141	5.30	.287 95	5.72	.956 729	1.42	05
56	.291 259	4.63	.304 459	5.30	.284 52	5.72	.956 644	1.40	04
57	.291 537	4.63	.304 777	5.30	.281 09	5.70	.956 560	1.42	03
58	.291 815	4.65	.305 095	5.30	.277 67	5.68	.956 475	1.42	02
59	.292 094	4.63	.305 413	5.30	.274 26	5.68	.956 390	1.42	01
60	0.292 372		0.305 731		3.270 85		0.956 305		00
	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	

Table A-1. Natural trigonometric functions (continued)

17°

		d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.292 372	4.63	0.305 731	5.30	3.270 85	5.67	0.956 305	1.42	60′
01	.292 650	4.63	.306 049	5.30	.267 45	5.65	.956 220	1.43	59
02	.292 928	4.63	.306 367	5.30	.264 06	5.65	.956 134	1.42	58
03	.293 206	4.63	.306 685	5.30	.260 67	5.63	.956 049	1.42	57
04	.293 484	4.63	.307 003	5.32	.257 29	5.62	.955 964	1.42	56
05	.293 762	4.63	.307 322	5.30	.253 92	5.62	.955 879	1.43	55
06	.294 040	4.63	.307 640	5.32	.250 55	5.60	.955 793	1.43	54
07	.294 318	4.63	.307 959	5.30	.247 19	5.60	.955 707	1.42	53
08	.294 596	4.63	.308 277	5.32	.243 83	5.57	.955 622	1.43	52
09	.294 874	4.63	.308 596	5.30	.240 49	5.58	.955 536	1.43	51
10	0.295 152	4.63	0.308 914	5.32	3.237 14	5.55	0.955 450	1.43	50
11	.295 430	4.63	.309 233	5.32	.233 81	5.55	.955 364	1.43	49
12	.295 708	4.63	.309 552	5.30	.230 48	5.55	.955 278	1.43	48
13	.295 986	4.63	.309 870	5.32	.227 15	5.52	.955 192	1.43	47
14	.296 264	4.63	.310 189	5.32	.223 84	5.52	.955 106	1.43	46
15	.296 542	4.62	.310 508	5.32	.220 53	5.52	.955 020	1.43	45
16	.296 819	4.63	.310 827	5.32	.217 22	5.50	.954 934	1.45	44
17	.297 097	4.63	.311 146	5.32	.213 92	5.48	.954 847	1.43	43
18	.297 375	4.63	.311 465	5.32	.210 63	5.48	.984 761	1.45	42
19	.297 653	4.62	.311 784	5.33	.207 34	5.47	.954 674	1.43	41
20	0.297 930	4.63	0.312 104	5.32	3.204 06	5.45	0.954 588	1.45	40
21	.298 208	4.63	.312 423	5.32	.200 79	5.45	.954 501	1.45	39
22	.298 486	4.62	.312 742	5.33	.197 52	5.43	.954 414	1.45	38
23	.298 763	4.63	.313 062	5.32	.194 26	5.43	.954 327	.145	37
24	.299 041	4.62	.313 381	5.32	.191 00	5.42	.954 240	1.45	36
25	.299 318	4.63	.313 700	5.33	.187 75	5.40	.954 153	1.45	35
26	.299 596	4.62	.314 020	5.33	.184 51	5.40	.954 066	1.45	34
27	.299 873	4.63	.314 340	5.32	.181 27	5.38	.953 979	1.45	33
28	.300 151	4.62	.314 659	5.33	.178 04	5.38	.953 892	1.47	32
29	.300 428	4.63	.314 979	5.33	.174 81	5.37	.953 804	1.45	31
30	0.300 706	4.62	0.315 299	5.33	3.171 59	5.35	0.953 717	1.47	30
31	.300 983	4.63	.315 619	5.33	.168 38	5.35	.953 629	1.45	29
32	.301 261	4.62	.315 939	5.32	.165 17	5.33	.953 542	1.47	28
33	.301 538	4.62	.316 258	5.33	.161 97	5.33	.953 454	1.47	27
34	.301 815	4.63	.316 578	5.35	.158 77	5.32	.953 366	1.45	26
35	.302 093	4.62	.316 899	5.33	.155 58	5.30	.953 279	1.47	25
36	.302 370	4.62	.317 219	5.33	.152 40	5.30	.953 191	1.47	24
37	.302 647	4.62	.317 539	5.33	.149 22	5.28	.953 103	1.47	23
38	.302 924	4.63	.317 859	5.33	.146 05	5.28	.953 015	1.48	22
39	.303 202	4.62	.318 179	5.35	.142 88	5.27	.952 926	1.47	21
40	0.303 479	4.62	0.318 500	5.33	3.139 72	5.27	0.952 838	1.47	20
41	.303 756	4.62	.318 820	5.35	.136 56	5.25	.952 750	1.48	19
42	.304 033	4.62	.319 141	5.33	.133 41	5.23	.952 661	1.47	18
43	.304 310	4.62	.319 461	5.35	.130 27	5.23	.952 573	1.48	17
44	.304 587	4.62	.319 782	5.35	.127 13	5.22	.952 484	1.47	16
45	.304 864	4.62	.320 103	5.33	.124 00	5.22	.952 396	1.48	15
46	.305 141	4.62	.320 423	5.35	.120 87	5.20	.952 307	1.48	14
47	.305 418	4.62	.320 744	5.35	.177 75	5.18	.952 218	1.48	13
48	.305 695	4.62	.321 065	5.35	.114 64	5.18	.952 129	1.48	12
49	.305 972	4.62	.321 386	5.35	.111 53	5.18	.952 040	1.48	11
50	0.306 249	4.62	0.321 707	5.35	3.108 42	5.17	0.951 951	1.48	10
51	.306 526	4.62	.322 028	5.35	.105 32	5.15	.951 862	1.48	09
52	.306 803	4.62	.322 349	5.35	.102 23	5.15	.951 773	1.48	08
53	.307 080	4.62	.322 670	5.35	.099 14	5.13	.951 684	1.50	07
54	.307 357	4.60	.322 991	5.35	.096 06	5.13	.951 594	1.48	06
55	.307 633	4.62	.323 312	5.37	.092 98	5.12	.951 505	1.50	05
56	.307 910	4.62	.323 634	5.35	.089 91	5.10	.951 415	1.48	04
57	.308 187	4.62	.323 955	5.37	.086 85	5.10	.951 326	1.50	03
58	.308 464	4.60	.324 277	5.35	.083 79	5.10	.951 236	1.50	02
59	.308 740	4.62	.324 598	5.37	.080 73	5.08	.951 146	1.48	01
60	0.309 017		0.324 920		3.077 68		0.951 057		00

Table A-1. Natural trigonometric functions (continued)

18°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.309 017	4.62	0.324 920	5.35	3.077 68	5.07	0.951 057	1.50	60′
01	.309 294	4.60	.325 241	5.37	.074 64	5.07	.950 967	1.50	59
02	.309 570	4.62	.325 563	5.37	.071 60	5.05	.950 877	1.52	58
03	.309 847	4.60	.325 885	5.37	.068 57	5.05	.950 786	1.50	57
04	.310 123	4.62	.326 207	5.35	.065 54	5.03	.950 696	1.50	56
05	.310 400	4.60	.326 528	5.37	.062 52	5.03	.950 606	1.50	55
06	.310 676	4.62	.326 850	5.37	.059 50	5.02	.950 516	1.52	54
07	.310 953	4.60	.327 172	5.37	.056 49	5.00	.950 425	1.50	53
08	.311 229	4.62	.327 494	5.38	.053 49	5.00	.950 335	1.52	52
09	.311 506	4.60	.327 817	5.37	.050 49	5.00	.950 244	1.50	51
10	0.311 782	4.62	0.328 139	5.37	3.047 49	4.98	0.950 154	1.52	50
11	.312 059	4.60	.328 461	5.37	.044 50	4.97	.950 063	1.52	49
12	.312 335	4.60	.328 783	5.38	.041 52	4.97	.949 972	1.52	48
13	.312 611	4.62	.329 106	5.37	.038 54	4.97	.949 881	1.52	47
14	.312 888	4.60	.329 428	5.38	.035 56	4.93	.949 790	1.52	46
15	.313 164	4.60	.329 751	5.37	.032 60	4.95	.949 699	1.52	45
16	.313 440	4.60	.330 073	5.38	.029 63	4.93	.949 608	1.52	44
17	.313 716	4.60	.330 396	5.37	.026 67	4.92	.949 517	1.53	43
18	.313 992	4.62	.330 718	5.38	.023 72	4.92	.949 425	1.52	42
19	.314 269	4.60	.331 041	5.38	.020 77	4.90	.940 334	1.52	41
20	0.314 545	4.60	0.331 364	5.38	3.017 83	4.90	0.949 243	1.53	40
21	.314 821	4.60	.331 687	5.38	.014 89	4.88	.949 151	1.53	39
22	.315 097	4.60	.332 010	5.38	.011 96	4.88	.949 059	1.52	38
23	.315 373	4.60	.332 333	5.38	.009 03	4.87	.948 968	1.53	37
24	.315 649	4.60	.332 656	5.38	.006 11	4.87	.948 876	1.53	36
25	.315 925	4.60	.332 979	5.38	.003 19	4.85	.948 784	1.53	35
26	.316 201	4.60	.333 302	5.38	.000 28	4.83	.948 692	1.53	34
27	.316 477	4.60	.333 625	5.40	2.997 38	4.85	.948 600	1.53	33
28	.316 753	4.60	.333 949	5.38	.994 47	4.82	.948 508	1.53	32
29	.317 029	4.60	.334 272	5.38	.991 58	4.83	.948 416	1.53	31
30	0.317 305	4.58	0.334 595	5.40	2.988 68	4.80	0.948 324	1.55	30
31	.317 580	4.60	.334 919	5.38	.985 80	4.80	.948 231	1.53	29
32	.317 856	4.60	.335 242	5.40	.982 92	4.80	.948 139	1.55	28
33	.318 132	4.60	.335 566	5.40	.980 04	4.78	.948 046	1.53	27
34	.318 408	4.60	.335 890	5.38	.977 17	4.78	.947 954	1.55	26
35	.318 684	4.58	.336 213	5.40	.974 30	4.77	.947 861	1.55	25
36	.318 959	4.60	.336 537	5.40	.971 44	4.77	.947 768	1.53	24
37	.319 235	4.60	.336 861	5.40	.968 58	4.75	.947 676	1.55	23
38	.319 511	4.58	.337 185	5.40	.965 73	4.75	.947 583	1.55	22
39	.319 786	4.60	.337 509	5.40	.962 88	4.73	.947 490	1.55	21
40	0.320 062	4.58	0.337 833	5.40	2.960 04	4.72	0.947 397	1.55	20
41	.320 337	4.60	.338 157	5.40	.957 21	4.73	.947 304	1.57	19
42	.320 613	4.60	.338 481	5.42	.954 37	4.70	.947 210	1.55	18
43	.320 889	4.58	.338 806	5.40	.951 55	4.72	.947 117	1.55	17
44	.321 164	4.58	.339 130	5.40	.948 72	4.68	.947 024	1.57	16
45	.321 439	4.60	.339 454	5.42	.945 91	4.70	.946 930	1.55	15
46	.321 715	4.58	.339 779	5.40	.943 09	4.68	.946 837	1.57	14
47	.321 990	4.60	.340 103	5.42	.940 28	4.67	.946 743	1.57	13
48	.322 266	4.58	.340 428	5.40	.937 48	4.67	.946 649	1.57	12
49	.322 541	4.58	.340 752	5.42	.934 68	4.65	.946 555	1.55	11
50	0.322 816	4.60	0.341 077	5.42	2.931 89	4.65	0.946 462	1.57	10
51	.323 092	4.58	.341 402	5.42	.929 10	4.63	.946 368	1.57	09
52	.323 367	4.58	.341 727	5.42	.926 32	4.63	.946 274	1.57	08
53	.323 642	4.58	.342 052	5.42	.923 54	4.63	.946 180	1.58	07
54	.323 917	4.60	.342 377	5.42	.920 76	4.62	.946 085	1.57	06
55	.324 193	4.58	.342 702	5.42	.917 99	4.60	.945 991	1.57	05
56	.324 468	4.58	.343 027	5.42	.915 23	4.62	.945 897	1.58	04
57	.324 743	4.58	.343 352	5.42	.912 46	4.58	.945 802	1.57	03
58	.325 018	4.58	.343 677	5.42	.909 71	4.58	.945 708	1.58	02
59	.325 293	4.58	.344 002	5.43	.906 96	4.58	.945 613	1.57	01
60	0.325 568		0.344 328		2.904 21		0.945 519		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

19°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.325 568	4.58	0.344 328	5.42	2.904 21	4.57	0.945 519	1.58	60′
01	.325 843	4.58	.344 653	5.42	.901 47	4.57	.945 424	1.58	59
02	.326 118	4.58	.344 978	5.43	.898 73	4.55	.945 329	1.58	58
03	.326 393	4.58	.345 304	5.43	.896 00	4.55	.945 234	1.58	57
04	.326 668	4.58	.345 630	5.42	.893 27	4.53	.945 189	1.58	56
05	.326 943	4.58	.345 955	5.43	.890 55	4.53	.945 044	1.58	55
06	.327 218	4.58	.346 281	5.43	.887 83	4.53	.944 949	1.58	54
07	.327 493	4.58	.346 607	5.43	.885 11	4.52	.944 854	1.60	53
08	.327 768	4.57	.346 933	5.43	.882 40	4.50	.944 758	1.58	52
09	.328 042	4.58	.347 259	5.43	.879 70	4.50	.944 663	1.58	51
10	0.328 317	4.58	0.347 585	5.43	2.877 00	4.50	0.944 568	1.60	50
11	.328 502	4.58	.347 911	5.43	.874 30	4.48	.944 472	1.60	49
12	.328 867	4.57	.348 237	5.43	.871 61	4.48	.944 376	1.58	48
13	.329 141	4.58	.348 563	5.43	.868 92	4.47	.944 281	1.60	47
14	.329 416	4.58	.348 889	5.45	.866 24	4.47	.944 185	1.60	46
15	.329 691	4.57	.349 216	5.43	.863 56	4.45	.944 089	1.60	45
16	.329 965	4.58	.349 542	5.43	.860 89	4.45	.943 993	1.60	44
17	.330 240	4.57	.349 868	5.45	.858 22	4.45	.943 897	1.60	43
18	.330 514	4.58	.350 195	5.45	.855 55	4.43	.943 801	1.60	42
19	.330 789	4.57	.350 522	5.43	.852 89	4.43	.943 705	1.60	41
20	0.331 063	4.58	0.350 848	5.45	2.850 23	4.42	0.943 609	1.62	40
21	.331 338	4.57	.351 175	5.45	.847 58	4.40	.943 512	1.60	39
22	.331 612	4.58	.351 502	5.45	.844 94	4.42	.943 416	1.62	38
23	.331 887	4.57	.351 829	5.45	.842 29	4.40	.943 319	1.60	37
24	.332 161	4.57	.352 156	5.45	.839 65	4.38	.943 223	1.62	36
25	.332 435	4.58	.352 483	5.45	.839 02	4.38	.943 126	1.62	35
26	.332 710	4.57	.352 810	5.45	.834 39	4.38	.943 029	1.62	34
27	.332 984	4.57	.353 137	5.45	.831 76	4.37	.942 932	1.60	33
28	.333 258	4.58	.353 464	5.45	.829 14	4.35	.942 836	1.62	32
29	.333 533	4.57	.353 791	5.47	.826 53	4.37	.942 739	1.63	31
30	0.333 807	4.57	0.354 119	5.45	2.823 91	4.35	0.942 641	1.62	30
31	.334 081	4.57	.354 446	5.45	.821 30	4.33	.942 544	1.62	29
32	.334 355	4.57	.354 773	5.45	.818 70	4.33	.942 447	1.62	28
33	.334 629	4.57	.355 101	5.47	.816 10	4.33	.942 350	1.63	27
34	.334 903	4.58	.355 429	5.45	.813 50	4.32	.942 252	1.62	26
35	.335 178	4.57	.355 756	5.47	.810 91	4.30	.942 155	1.63	25
36	.335 452	4.57	.356 084	5.47	.808 33	4.32	.942 057	1.62	24
37	.335 726	4.57	.356 412	5.47	.805 74	4.30	.941 960	1.63	23
38	.336 000	4.57	.356 740	5.47	.803 16	4.28	.941 862	1.63	22
39	.336 274	4.55	.357 068	5.47	.800 59	4.28	.941 764	1.63	21
40	0.336 547	4.57	0.357 396	5.47	2.798 02	4.28	0.941 666	1.62	20
41	.336 821	4.57	.357 724	5.47	.795 45	4.27	.941 569	1.63	19
42	.337 095	4.57	.358 052	5.47	.792 89	4.27	.941 471	1.65	18
43	.337 369	4.57	.358 380	5.47	.790 33	4.25	.911 372	1.63	17
44	.337 643	4.57	.358 708	5.48	.787 78	4.25	.941 274	1.63	16
45	.337 917	4.55	.359 037	5.47	.785 23	4.23	.941 176	1.63	15
46	.338 190	4.57	.359 365	5.48	.782 69	4.25	.941 078	1.65	14
47	.338 464	4.57	.359 694	5.47	.780 14	4.22	.940 979	1.63	13
48	.338 738	4.57	.360 022	5.48	.777 61	4.23	.940 881	1.65	12
49	.339 012	4.55	.360 351	5.47	.775 07	4.22	.940 782	1.63	11
50	0.339 285	4.57	0.360 679	5.48	2.772 54	4.20	0.940 684	1.65	10
51	.339 559	4.55	.361 008	5.48	.770 02	4.20	.940 585	1.65	09
52	.339 832	4.57	.361 337	5.48	.767 50	4.20	.940 486	1.65	08
53	.340 106	4.57	.361 666	5.48	.764 98	4.18	.940 387	1.65	07
54	.340 380	4.55	.361 995	5.48	.762 47	4.18	.940 288	1.65	06
55	.340 653	4.57	.362 324	5.48	.759 96	4.17	.940 189	1.65	05
56	.340 927	4.55	.362 653	5.48	.757 46	4.17	.940 090	1.65	04
57	.341 200	4.55	.362 982	5.50	.754 96	4.17	.939 991	1.67	03
58	.341 473	4.57	.363 312	5.48	.752 46	4.15	.939 891	1.65	02
59	.341 747	4.55	.363 641	5.48	.749 97	4.15	.939 792	1.65	01
60	0.342 020		0.363 970		2.747 48		0.939 693		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

20°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.342 020	4.55	0.363 970	5.50	2.747 477	41.40	0.939 693	1.67	60′
01	.342 293	4.57	.364 300	5.48	.744 993	41.35	.939 593	1.67	59
02	.342 567	4.55	.364 629	5.50	.742 512	41.28	.939 493	1.65	58
03	.342 840	4.55	.364 959	5.48	.740 035	41.22	.939 394	1.67	57
04	.343 113	4.57	.365 288	5.50	.737 562	41.15	.939 294	1.67	56
05	.343 387	4.55	.365 618	5.50	.735 093	41.08	.939 194	1.67	55
06	.343 660	4.55	.365 948	5.50	.732 628	41.02	.939 094	1.67	54
07	.343 933	4.55	.366 278	5.50	.730 167	40.95	.938 994	1.67	53
08	.344 206	4.55	.366 608	5.50	.727 710	40.88	.938 894	1.67	52
09	.344 479	4.55	.366 938	5.50	.725 257	40.82	.938 794	1.67	51
10	0.344 752	4.55	0.367 268	5.50	2.722 808	40.77	0.938 694	1.68	50
11	.345 025	4.55	.367 598	5.50	.720 362	40.70	.938 593	1.67	49
12	.345 298	4.55	.367 928	5.52	.717 920	40.62	.938 493	1.67	48
13	.345 571	4.55	.368 259	5.50	.715 483	40.57	.938 393	1.68	47
14	.345 844	4.55	.368 589	5.50	.713 049	40.50	.938 292	1.68	46
15	.346 117	4.55	.368 919	5.52	.710 619	40.45	.938 191	1.67	45
16	.346 390	4.55	.369 250	5.52	.708 192	40.37	.938 091	1.68	44
17	.346 663	4.55	.369 581	5.52	.705 770	40.32	.937 990	1.68	43
18	.346 936	4.53	.369 911	5.52	.703 351	40.25	.937 889	1.68	42
19	.347 208	4.55	.370 242	5.52	.700 936	40.18	.937 788	1.68	41
20	0.347 481	4.55	0.370 573	5.52	2.698 525	40.12	0.937 687	1.68	40
21	.347 754	4.55	.370 904	5.52	.696 118	40.05	.937 586	1.68	39
22	.348 027	4.53	.371 235	5.52	.693 715	40.00	.937 485	1.70	38
23	.348 299	4.55	.371 566	5.52	.691 315	39.93	.937 383	1.68	37
24	.348 572	4.55	.371 897	5.52	.688 919	39.87	.937 282	1.68	36
25	.348 845	4.53	.372 228	5.52	.686 527	39.82	.937 181	1.70	35
26	.349 117	4.55	.372 559	5.52	.684 138	39.73	.937 079	1.70	34
27	.349 390	4.53	.372 890	5.53	.681 754	39.70	.936 977	1.68	33
28	.349 662	4.55	.373 222	5.52	.679 372	39.62	.936 876	1.70	32
29	.349 935	4.53	.373 553	5.53	.676 995	39.57	.936 774	1.70	31
30	0.350 207	4.55	0.373 885	5.52	2.674 621	39.48	0.936 672	1.70	30
31	.350 480	4.53	.374 216	5.53	.672 252	39.45	.936 570	1.70	29
32	.350 752	4.55	.374 548	5.53	.669 885	39.37	.936 468	1.70	28
33	.351 025	4.53	.374 880	5.52	.667 523	39.32	.936 366	1.70	27
34	.351 297	4.53	.375 211	5.53	.665 164	39.25	.936 264	1.70	26
35	.351 569	4.55	.375 543	5.53	.662 809	39.20	.936 162	1.70	25
36	.351 842	4.53	.375 875	5.53	.660 457	39.13	.936 060	1.72	24
37	.352 114	4.53	.376 207	5.53	.658 109	39.07	.935 957	1.70	23
38	.352 386	4.53	.376 539	5.55	.655 765	39.02	.935 855	1.72	22
39	.352 658	4.55	.376 872	5.53	.653 424	38.95	.935 752	1.70	21
40	0.352 931	4.53	0.377 204	5.53	2.651 087	38.90	0.935 650	1.72	20
41	.353 203	4.53	.377 536	5.55	.648 753	38.83	.935 547	1.72	19
42	.353 475	4.53	.377 869	5.53	.646 423	38.77	.935 444	1.72	18
43	.353 747	4.53	.378 201	5.55	.644 097	38.72	.935 341	1.72	17
44	.354 019	4.53	.378 534	5.53	.641 774	38.65	.935 238	1.72	16
45	.354 291	4.53	.378 866	5.55	.639 455	38.60	.935 135	1.72	15
46	.354 563	4.53	.379 199	5.55	.637 139	38.53	.935 032	1.72	14
47	.354 835	4.53	.379 532	5.53	.634 827	38.47	.934 929	1.72	13
48	.355 107	4.53	.379 864	5.55	.632 519	38.42	.934 826	1.73	12
49	.355 379	4.53	.380 197	5.55	.630 214	38.37	.934 722	1.72	11
50	0.355 651	4.53	0.380 530	5.55	2.627 912	38.30	0.934 619	1.73	10
51	.355 923	4.52	.380 863	5.55	.625 614	38.28	.934 515	1.72	09
52	.356 194	4.53	.381 196	5.57	.623 320	38.18	.934 412	1.73	08
53	.356 466	4.53	.381 530	5.55	.621 029	38.13	.934 308	1.73	07
54	.356 738	4.53	.381 863	5.55	.618 741	38.07	.934 204	1.72	06
55	.357 010	4.52	.382 196	5.57	.616 457	38.00	.934 101	1.73	05
56	.357 281	4.53	.382 530	5.55	.614 177	37.95	.933 997	1.73	04
57	.357 553	4.53	.382 863	5.55	.611 900	37.90	.933 893	1.73	03
58	.357 825	4.52	.383 197	5.55	.609 626	37.83	.933 789	1.73	02
59	.358 096	4.53	.383 530	5.57	.607 356	37.78	.933 685	1.75	01
60	0.358 368		0.383 864		2.605 089		0.933 580		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

21°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.358 368	4.53	0.383 864	5.57	2.605 089	37.72	0.933 580	1.73	60′
01	.358 640	4.52	.384 198	5.57	.602 826	37.67	.933 476	1.73	59
02	.358 911	4.53	.384 532	5.57	.600 566	37.62	.933 372	1.75	58
03	.359 183	4.52	.384 866	5.57	.598 309	37.55	.933 267	1.73	57
04	.359 454	4.52	.385 200	5.57	.596 056	37.48	.933 168	1.75	56
05	.359 725	4.53	.385 534	5.57	.593 807	37.43	.933 058	1.73	55
06	.359 997	4.52	.385 868	5.57	.591 561	37.38	.932 954	1.75	54
07	.360 268	4.53	.386 202	5.57	.589 318	37.33	.932 849	1.75	53
08	.360 540	4.52	.386 536	5.58	.587 078	37.27	.932 744	1.75	52
09	.360 811	4.52	.386 871	5.57	.584 842	37.22	.932 639	1.75	51
10	0.361 082	4.52	0.387 205	5.58	2.582 609	37.15	.932 534	1.75	50
11	.361 353	4.53	.387 540	5.57	.580 380	37.10	.932 429	1.75	49
12	.361 625	4.52	.387 874	5.58	.578 154	37.05	.932 324	1.75	48
13	.361 896	4.52	.388 209	5.58	.575 931	36.98	.932 219	1.77	47
14	.362 167	4.52	.388 544	5.58	.573 712	36.93	.932 113	1.75	46
15	.362 438	4.52	.388 879	5.58	.571 496	36.88	.932 008	1.77	45
16	.362 709	4.52	.389 214	5.58	.569 283	36.82	.931 902	1.75	44
17	.362 980	4.52	.389 549	5.58	.567 074	36.78	.931 797	1.77	43
18	.363 251	4.52	.389 884	5.58	.564 867	36.70	.931 691	1.75	42
19	.363 522	4.52	.390 219	5.58	.562 665	36.67	.931 586	1.77	41
20	0.363 793	4.52	0.390 554	5.58	2.560 465	36.60	0.931 480	1.77	40
21	.364 064	4.52	.390 889	5.60	.558 269	36.55	.931 374	1.77	39
22	.364 335	4.52	.391 225	5.58	.556 076	36.50	.931 268	1.77	38
23	.364 606	4.52	.391 560	5.60	.553 886	36.45	.931 162	1.77	37
24	.364 877	4.52	.391 896	5.58	.551 699	36.38	.931 056	1.77	36
25	.365 148	4.50	.392 231	5.60	.549 516	36.33	.930 950	1.78	35
26	.365 418	4.52	.392 567	5.60	.547 336	36.28	.930 843	1.77	34
27	.365 689	4.52	.392 903	5.60	.545 459	36.23	.930 737	1.77	33
28	.365 960	4.52	.393 239	5.58	.542 985	36.17	.930 631	1.78	32
29	.366 231	4.50	.393 574	5.60	.540 815	36.12	.930 524	1.77	31
30	o.366 501	4.52	0.393 910	5.62	2.538 648	36.07	0.930 418	1.78	30
31	.366 772	4.50	.394 247	5.60	.536 484	36.02	.930 311	1.78	29
32	.367 042	4.52	.394 583	5.60	.534 323	35.97	.930 204	1.78	28
33	.367 313	4.52	.394 919	5.60	.532 165	35.90	.930 097	1.78	27
34	.367 584	4.50	.395 255	5.62	.530 011	35.85	.929 990	1.77	26
35	.367 854	4.52	.395 592	5.60	.527 860	35.80	.929 884	1.80	25
36	.368 125	4.50	.395 928	5.62	.525 712	35.75	.929 776	1.78	24
37	.368 395	4.50	.396 265	5.60	.523 567	35.70	.929 669	1.78	23
38	.368 665	4.52	.396 601	5.62	.521 425	35.65	.929 562	1.78	22
39	.368 936	4.50	.396 938	5.62	.519 286	35.58	.929 455	1.78	21
40	0.369 206	4.50	0.397 275	5.60	2.517 151	35.55	.929 348	1.80	20
41	.369 476	4.52	.397 611	5.62	.515 018	35.48	.929 240	1.78	19
42	.369 747	4.50	.397 948	5.62	.512 889	35.43	.929 133	1.80	18
43	.370 017	4.50	.398 285	5.62	.510 763	35.38	.929 025	1.80	17
44	.370 287	4.50	.398 622	5.63	.508 640	35.33	.928 917	1.78	16
45	.370 557	4.52	.398 960	5.62	.506 520	35.28	.928 810	1.80	15
46	.370 828	4.50	.399 297	5.62	.504 403	35.23	.928 702	1.80	14
47	.371 098	4.50	.399 634	5.62	.502 289	35.18	.928 594	1.80	13
48	.371 368	4.50	.399 971	5.63	.500 178	35.12	.928 486	1.80	12
49	.371 638	4.50	.400 309	5.62	.498 071	35.08	.928 378	1.80	11
50	0.371 908	4.50	0.400 646	5.63	2.495 966	35.02	0.928 270	1.82	10
51	.372 178	4.50	.400 984	5.63	.493 865	34.98	.928 161	1.80	09
52	.372 448	4.50	.401 322	5.63	.491 766	34.92	.928 053	1.80	08
53	.372 718	4.50	.401 660	5.62	.489 671	34.88	.927 945	1.82	07
54	.372 988	4.50	.401 997	5.63	.487 578	34.82	.927 836	1.80	06
55	.373 258	4.50	.402 335	5.63	.485 489	34.78	.927 728	1.82	05
56	.373 528	4.48	.402 673	5.63	.483 402	34.72	.927 619	1.82	04
57	.373 797	4.50	.403 011	5.65	.481 319	34.67	.927 510	1.80	03
58	.374 067	4.50	.403 350	5.63	.479 239	34.63	.927 402	1.82	02
59	.374 337	4.50	.403 688	5.63	.477 161	34.57	.927 293	1.82	01
60	0.374 607		0.404 026		2.475 087		0.927 184		00
	Cos	d"	Cot	d"	Tan	d"	Sin	d"	

Table A-1. Natural trigonometric functions (continued)

22°

Sin	d."	Tan	d."	Cot	d."	Cos	d."	
0.374 607	4.48	0.404 026	5.65	2.475 087	34.53	0.927 184	1.82	60'
.374 876	4.50	.404 365	5.63	.473 015	34.47	.927 075	1.82	59
.375 146	4.50	.404 703	5.65	.470 947	34.42	.926 966	1.82	58
.375 416	4.48	.405 042	5.63	.468 882	34.38	.926 857	1.83	57
.375 685	4.50	.405 380	5.65	.466 819	34.32	.920 747	1.82	56
.375 955	4.48	.405 719	5.65	.464 760	34.28	.926 638	1.82	55
.376 224	4.50	.406 058	5.65	.462 703	34.23	.926 529	1.83	54
.376 494	4.48	.406 397	5.65	.460 649	34.17	.926 419	1.82	53
.376 763	4.50	.406 736	5.65	.458 599	34.13	.926 310	1.83	52
.377 033	4.48	.407 075	5.65	.456 551	34.08	.926 200	1.83	51
0.377 302	4.48	0.407 414	5.65	2.454 506	34.03	0.926 090	1.83	50
.377 571	4.50	.407 753	5.65	.452 464	33.98	.925 980	1.82	49
.377 841	4.48	.408 092	5.67	.450 425	33.93	.925 871	1.83	48
.378 110	4.48	.408 432	5.65	.448 389	33.88	.925 761	1.83	47
.378 379	4.50	.408 771	5.67	.446 356	33.83	.925 651	1.83	46
.378 649	4.48	.409 111	5.65	.444 326	33.80	.925 541	1.85	45
.378 918	4.48	.409 450	5.67	.442 298	33.73	.925 430	1.83	44
.379 187	4.48	.409 790	5.67	.440 274	33.70	.925 320	1.83	43
.379 456	4.48	.410 130	5.67	.438 252	33.65	.925 210	1.85	42
.379 725	4.48	.410 470	5.67	.436 233	33.60	.925 099	1.83	41
0.379 994	4.48	0.410 810	5.67	2.434 217	33.55	0.924 989	1.85	40
.380 263	4.48	.411 150	5.67	.432 204	33.50	.924 878	1.83	39
.380 532	4.48	.411 490	5.67	.430 194	33.47	.924 768	1.85	38
.380 801	4.48	.411 830	5.67	.428 186	33.40	.924 657	1.85	37
.381 070	4.48	.412 170	5.68	.426 182	33.37	.924 546	1.85	36
.381 339	4.48	.412 511	5.67	.424 180	33.32	.924 435	1.85	35
.381 608	4.48	.412 851	5.68	.422 181	33.27	.924 324	1.85	34
.381 877	4.48	.413 192	5.67	.420 185	33.22	.924 213	1.85	33
.382 146	4.48	.413 532	5.68	.418 192	33.18	.924 102	1.85	32
.382 415	4.47	.413 873	5.68	.416 201	33.12	.923 991	1.85	31
0.382 683	4.48	0.414 214	5.67	2.414 214	33.08	.923 880	1.87	30
.382 952	4.48	.414 554	5.68	.412 229	33.03	.923 768	1.85	29
.383 221	4.48	.414 895	5.68	.410 247	33.00	.923 657	1.87	28
.383 490	4.47	.415 236	5.68	.408 267	32.93	.923 545	1.85	27
.383 758	4.48	.415 557	5.70	.406 291	32.90	.923 434	1.87	26
.384 027	4.47	.415 919	5.68	.404 317	32.85	.923 322	1.87	25
.384 295	4.48	.416 260	5.68	.402 346	32.82	.923 210	1.87	24
.384 564	4.47	.416 601	5.70	.400 377	32.75	.923 098	1.87	23
.384 832	4.48	.416 943	5.68	.398 412	32.72	.922 986	1.85	22
.385 101	4.47	.417 284	5.70	.396 449	32.67	.922 875	1.88	21
0.385 369	4.48	0.417 626	5.68	2.394 489	32.62	0.922 762	1.87	20
.385 638	4.47	.417 967	5.70	.392 532	32.58	.922 650	1.87	19
.385 906	4.47	.418 309	5.70	.390 577	32.53	.922 538	1.87	18
.386 174	4.48	.418 651	5.70	.388 625	32.48	.922 426	1.88	17
.386 443	4.47	.418 993	5.70	.386 676	32.45	.922 313	1.87	16
.386 711	4.47	.419 335	5.70	.384 726	32.38	.922 201	1.88	15
.386 979	4.47	.419 677	5.70	.382 786	32.37	.922 088	1.87	14
.387 247	4.48	.420 019	5.70	.380 844	32.30	.921 976	1.88	13
.387 516	4.47	.420 361	5.72	.378 906	32.27	.921 863	1.88	12
.387 784	4.47	.420 704	5.70	.376 970	32.22	.921 750	1.87	11
0.388 052	4.47	0.421 046	5.72	2.375 037	32.17	0.921 638	1.88	10
.388 320	4.47	.421 389	5.70	.373 107	32.13	.921 525	1.88	09
.388 588	4.47	.421 731	5.72	.371 179	32.08	.921 412	1.88	08
.388 856	4.47	.422 074	5.72	.369 254	32.03	.921 299	1.90	07
.389 124	4.47	.422 417	5.70	.367 332	32.00	.921 185	1.88	06
.389 392	4.47	.422 759	5.72	.365 412	31.95	.921 072	1.88	05
.389 660	4.47	.423 102	5.72	.363 495	31.92	.920 959	1.90	04
.389 928	4.47	.423 445	5.72	.361 580	31.87	.920 845	1.88	03
.390 196	4.45	.423 788	5.73	.359 668	31.82	.920 732	1.90	02
.390 463	4.47	.424 132	5.72	.357 759	31.78	.920 618	1.88	01
0.390 731		0.424 475		2.355 852		0.920 505		00
Cos	d."	Cot	d."	Tan	d."	Sin	d."	

Table A-1. Natural trigonometric functions (continued)

23°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.390 731	4.47	0.424 475	5.72	2.355 852	31.73	0.920 505	1.90	60′
01	.390 999	4.47	.424 818	5.73	.353 495	31.68	.920 391	1.90	59
02	.391 267	4.45	.425 162	5.72	.352 047	31.65	.920 277	1.88	58
03	.391 534	4.47	.425 505	5.73	.350 148	31.60	.920 164	1.90	57
04	.391 802	4.47	.425 849	5.72	.348 252	31.57	.920 050	1.90	56
05	.392 070	4.45	.426 192	5.73	.346 192	31.52	.919 936	1.92	55
06	.392 337	4.47	.426 536	5.73	.344 467	31.47	.919 821	1.90	54
07	.392 605	4.45	.426 880	5.73	.342 579	31.43	.919 707	1.90	53
08	.392 872	4.47	.427 224	5.73	.340 693	31.40	.919 593	1.90	52
09	.393 140	4.45	.427 568	5.73	.338 809	31.33	.919 479	1.92	51
10	0.393 407	4.47	0.427 912	5.73	2.336 929	31.32	0.919 364	1.90	50
11	.393 675	4.45	.428 256	5.75	.335 050	31.25	.919 250	1.92	49
12	.393 942	4.45	.428 601	5.73	.333 175	31.22	.919 135	1.90	48
13	.394 209	4.47	.428 945	5.73	.331 302	31.18	.919 021	1.92	47
14	.394 477	4.45	.429 289	5.75	.329 431	31.13	.918 906	1.92	46
15	.394 744	4.45	.429 634	5.75	.327 563	31.08	.918 791	1.92	45
16	.395 011	4.45	.429 979	5.73	.325 698	31.05	.918 676	1.92	44
17	.395 278	4.47	.430 323	5.75	.323 835	31.02	.918 561	1.92	43
18	.395 546	4.45	.430 668	5.75	.321 974	30.97	.918 446	1.92	42
19	.395 813	4.45	.431 013	5.75	.320 116	30.92	.918 331	1.92	41
20	0.396 080	4.45	0.431 358	5.75	2.318 261	30.88	0.918 216	1.92	40
21	.396 347	4.45	.431 703	5.75	.316 408	30.85	.918 101	1.92	39
22	.396 614	4.45	.432 048	5.75	.314 557	30.80	.917 986	1.93	38
23	.396 881	4.45	.432 393	5.77	.312 709	30.75	.917 870	1.92	37
24	.397 148	4.45	.432 739	5.75	.310 864	30.72	.917 755	1.93	36
25	.397 415	4.45	.433 084	5.77	.309 021	30.68	.917 639	1.93	35
26	.397 682	4.45	.433 430	5.75	.307 180	30.63	.917 523	1.92	34
27	.397 949	4.43	.433 775	5.77	.305 342	30.60	.917 408	1.93	33
28	.398 215	4.45	.434 121	5.77	.303 506	30.55	.917 292	1.93	32
29	.398 482	4.45	.434 467	5.75	.301 673	30.50	.917 176	1.93	31
30	0.398 749	4.45	0.434 812	5.77	2.299 843	30.48	0.917 060	1.93	30
31	.399 016	4.45	.435 158	5.77	.298 014	30.43	.916 944	1.93	29
32	.399 283	4.43	.435 504	5.77	.296 188	30.38	.916 828	1.93	28
33	.393 549	4.45	.435 850	5.78	.294 365	30.35	.916 712	1.95	27
34	.399 816	4.43	.436 197	5.77	.292 544	30.30	.916 595	1.93	26
35	.400 082	4.45	.436 543	5.77	.290 726	30.27	.916 479	1.93	25
36	.400 349	4.45	.436 889	5.78	.288 910	30.23	.916 363	1.95	24
37	.400 616	4.43	.437 236	5.77	.287 096	30.18	.916 246	1.93	23
38	.400 882	4.45	.437 582	5.78	.285 285	30.15	.916 130	1.95	22
39	.401 149	4.43	.437 929	5.78	.283 476	30.12	.916 013	1.95	21
40	0.401 415	4.43	0.438 276	5.77	2.281 669	30.07	0.915 896	1.95	20
41	.401 681	4.45	.438 622	5.78	.279 865	30.02	.915 779	1.93	19
42	.401 948	4.43	.438 969	5.78	.278 064	30.00	.915 663	1.95	18
43	.402 214	4.43	.439 316	5.78	.276 264	29.95	.915 546	1.95	17
44	.402 480	4.45	.439 663	5.80	.274 467	29.90	.915 429	1.97	16
45	.402 747	4.43	.440 011	5.78	.272 673	29.87	.915 311	1.95	15
46	.403 013	4.43	.440 358	5.78	.270 881	29.83	.915 194	1.95	14
47	.403 279	4.43	.440 705	5.80	.269 091	29.78	.915 077	1.95	13
48	.403 545	4.43	.441 053	5.78	.267 304	29.77	.914 960	1.97	12
49	.403 811	4.45	.441 400	5.80	.265 518	29.70	.914 842	1.95	11
50	0.404 078	4.43	.441 748	5.78	2.263 736	29.68	0.914 725	1.97	10
51	.404 344	4.43	.442 095	5.80	.261 955	29.63	.914 607	1.95	09
52	.404 610	4.43	.442 443	5.80	.260 177	29.58	.914 490	1.97	08
53	.404 876	4.43	.442 791	5.80	.258 402	29.57	.914 372	1.97	07
54	.405 142	4.43	.443 139	5.80	.256 628	29.52	.914 254	1.97	06
55	.405 408	4.42	.443 487	5.80	.254 857	29.47	.914 136	1.97	05
56	.405 673	4.43	.443 835	5.80	.253 089	29.45	.914 018	1.97	04
57	.405 939	4.43	.444 183	5.82	.251 322	29.40	.913 900	1.97	03
58	.406 205	4.43	.444 532	5.80	.249 558	29.37	.913 782	1.97	02
59	.406 471	4.43	.444 880	5.82	.247 796	29.32	.913 664	1.98	01
60	0.406 737		0.445 229		2.246 037		0.913 545		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

24°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.406 737	4.42	0.445 229	5.80	2.246 037	29.28	0.913 545	1.97	60′
01	.407 002	4.43	.445 577	5.82	.244 280	29.25	.913 427	1.97	59
02	.407 268	4.43	.445 926	5.82	.242 525	29.22	.913 309	1.98	58
03	.407 534	4.42	.446 275	5.82	.240 772	29.17	.913 190	1.97	57
04	.407 799	4.43	.446 624	5.82	.239 022	29.13	.913 072	1.98	56
05	.408 065	4.42	.446 973	5.82	.237 274	29.10	.912 953	1.98	55
06	.408 330	4.43	.447 322	5.82	.235 528	29.05	.912 834	1.98	54
07	.408 596	4.42	.447 671	5.82	.233 785	29.03	.912 715	1.98	53
08	.408 861	4.43	.448 020	5.82	.232 043	28.98	.912 596	1.98	52
09	.409 127	4.42	.448 369	5.83	.230 304	28.93	.912 477	1.98	51
10	0.409 392	4.43	0.448 719	5.82	2.228 568	28.92	0.912 358	1.98	50
11	.409 658	4.42	.449 068	5.83	.226 833	28.87	.912 239	1.98	49
12	.409 923	4.42	.449 418	5.83	.225 101	28.83	.912 120	1.98	48
13	.410 188	4.43	.449 768	5.82	.223 371	28.80	.912 001	2.00	47
14	.410 454	4.42	.450 117	5.83	.221 643	28.75	.911 881	1.98	46
15	.410 719	4.42	.450 467	5.83	.219 918	28.73	.911 762	1.98	48
16	.410 984	4.42	.450 817	5.83	.218 194	28.68	.911 643	2.00	44
17	.411 249	4.42	.451 167	5.83	.216 473	28.65	.911 523	2.00	43
18	.411 514	4.42	.451 517	5.85	.214 754	28.60	.911 403	1.98	42
19	.411 779	4.43	.451 868	5.83	.213 038	28.58	.911 284	2.00	41
20	0.412 045	4.42	0.452 218	5.83	2.211 323	28.53	0.911 164	2.00	40
21	.412 310	4.42	.452 568	5.85	.209 611	28.50	.911 044	2.00	39
22	.412 575	4.42	.452 919	5.83	.207 901	28.47	.910 924	2.00	38
23	.412 840	4.40	.453 269	5.85	.206 193	28.42	.910 804	2.00	37
24	.413 104	4.42	.453 620	5.85	.204 488	28.40	.910 684	2.02	36
25	.413 369	4.42	.453 971	5.85	.202 784	28.35	.910 563	2.00	35
26	.413 634	4.42	.454 322	5.85	.201 083	28.32	.910 443	2.00	34
27	.413 899	4.42	.454 673	5.85	.199 384	28.28	.910 323	2.02	33
28	.414 164	4.42	.455 024	5.85	.197 687	28.25	.910 202	2.00	32
29	.414 429	4.40	.455 375	5.85	.195 992	28.20	.910 082	2.02	31
30	0.414 693	4.42	0.455 726	5.87	2.194 300	28.18	0.909 961	2.00	30
31	.414 958	4.42	.456 078	5.85	.192 609	28.13	.909 841	2.02	29
32	.415 223	4.40	.456 429	5.87	.190 921	28.10	.909 720	2.02	28
33	.415 487	4.42	.456 781	5.85	.189 235	28.07	.909 599	2.02	27
34	.415 752	4.40	.457 132	5.87	.187 551	28.03	.909 478	2.02	26
35	.416 016	4.42	.457 484	5.87	.185 869	28.00	.909 357	2.02	25
36	.416 281	4.40	.457 836	5.87	.184 189	27.95	.909 236	2.02	24
37	.416 545	4.42	.458 188	5.87	.182 512	27.93	.909 115	2.02	23
38	.416 810	4.40	.458 540	5.87	.180 836	27.88	.908 994	2.03	22
39	.417 074	4.40	.458 892	5.87	.179 163	27.85	.908 872	2.02	21
40	0.417 338	4.42	0.459 244	5.87	2.177 492	27.82	0.908 751	2.02	20
41	.417 603	4.40	.459 596	5.88	.175 823	27.78	.908 630	2.03	19
42	.417 867	4.40	.459 949	5.87	.174 156	27.75	.908 508	2.02	18
43	.418 131	4.42	.460 301	5.88	.172 491	27.72	.908 387	2.03	17
44	.418 396	4.40	.460 654	5.87	.170 828	27.67	.908 265	2.03	16
45	.418 660	4.40	.461 006	5.88	.169 168	27.65	.908 143	2.03	15
46	.418 924	4.40	.461 359	5.88	.167 509	27.60	.908 021	2.03	14
47	.419 188	4.40	.461 712	5.88	.165 853	27.58	.907 899	2.03	13
48	.419 452	4.40	.462 065	5.88	.164 198	27.53	.907 777	2.03	12
49	.419 716	4.40	.462 418	5.88	.162 546	27.50	.907 655	2.03	11
50	0.419 980	4.40	0.462 771	5.88	2.160 896	27.47	.907 533	2.03	10
51	.420 244	4.40	.463 124	5.90	.159 248	27.43	.907 411	2.03	09
52	.420 508	4.40	.463 478	5.88	.157 602	27.40	.907 289	2.05	08
53	.420 772	4.40	.463 831	5.90	.155 958	27.37	.907 166	2.03	07
54	.421 036	4.40	.464 185	5.88	.154 316	27.33	.907 044	2.03	06
55	.421 300	4.38	.464 538	5.90	.152 676	27.30	.906 922	2.05	05
56	.421 563	4.40	.464 892	5.90	.151 038	27.27	.906 799	2.05	04
57	.421 827	4.40	.465 246	5.90	.149 402	27.43	.906 676	2.03	03
58	.422 091	4.40	.465 600	5.90	.147 768	27.18	.906 554	2.05	02
59	.422 355	4.38	.465 954	5.90	.146 402	27.17	.906 431	2.05	01
60	0.422 618		0.466 308		2.144 507		0.906 308		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

25°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.422 618	4.40	0.466 308	5.90	2.144 507	27.13	0.906 308	2.05	60′
0.	.422 882	4.38	.466 662	5.90	.142 879	27.08	.906 185	2.05	59
02	.423 145	4.40	.467 016	5.92	.141 254	27.07	.906 062	2.05	58
03	.423 409	4.40	.467 371	5.90	.139 630	27.02	.905 939	2.07	57
04	.423 673	4.38	.467 725	5.92	.138 009	27.00	.905 815	2.05	56
05	.423 936	4.38	.468 080	5.90	.136 389	26.97	.905 692	2.05	55
06	.424 199	4.40	.468 434	5.92	.134 771	26.92	.905 569	2.07	54
07	.424 463	4.38	.468 789	5.92	.133 156	26.90	.905 445	2.05	53
08	.424 726	4.40	.469 144	5.92	.131 542	26.85	.905 322	2.07	52
09	.424 990	4.38	.469 499	5.92	.129 931	26.83	.905 198	2.05	51
10	0.425 253	4.38	0.469 854	5.92	2.128 321	26.78	0.905 075	2.07	50
11	.425 516	4.38	.470 209	5.92	.126 714	26.77	.904 951	2.07	49
12	.425 779	4.38	.470 564	5.93	.125 108	26.72	.904 827	2.07	48
13	.426 042	4.40	.470 920	5.92	.123 505	26.70	.904 703	2.07	47
14	.426 306	4.38	.471 275	5.93	.121 903	26.67	.904 579	2.07	46
15	.426 569	4.38	.471 631	5.92	.120 303	26.62	.904 455	2.07	45
16	.426 832	4.38	.471 986	5.93	.118 706	26.60	.904 331	2.07	44
17	.427 095	4.38	.472 342	5.93	.117 110	26.57	.904 207	2.07	43
18	.427 358	4.38	.472 698	5.93	.115 516	26.52	.904 083	2.08	42
19	.427 621	4.38	.473 054	5.93	.113 925	26.50	.903 958	2.07	41
20	0.427 884	4.38	0.473 410	5.93	2.112 335	26.47	0.903 834	2.08	40
21	.428 147	4.38	.473 766	5.93	.110 747	26.43	.903 709	2.07	39
22	.428 410	4.37	.474 122	5.93	.109 161	26.40	.903 585	2.08	38
23	.428 672	4.38	.474 478	5.95	.107 577	26.37	.903 460	2.08	37
24	.428 935	4.38	.474 835	5.93	.105 995	26.33	.903 335	2.08	36
25	.429 198	4.38	.475 191	5.95	.104 415	26.30	.903 210	2.07	35
26	.429 461	4.37	.475 548	5.95	.102 837	26.27	.903 086	2.08	34
27	.429 723	4.38	.475 905	5.95	.101 261	26.25	.902 961	2.08	33
28	.429 986	4.38	.476 262	5.95	.099 686	26.20	.902 836	2.10	32
29	.430 249	4.37	.476 619	5.95	.098 114	26.17	.902 710	2.08	31
30	0.430 511	4.38	0.476 976	5.95	2.096 544	26.15	0.902 585	2.08	30
31	.430 774	4.37	.477 333	5.95	.094 975	26.12	.902 460	2.08	29
32	.431 036	4.38	.477 690	5.95	.093 408	26.07	.902 335	2.10	28
33	.431 299	4.37	.478 047	5.97	.091 844	26.05	.902 209	2.08	27
34	.431 561	4.37	.478 405	5.95	.090 281	26.02	.902 084	2.10	26
35	.431 823	4.38	.478 762	5.97	.088 720	25.98	.901 958	2.08	25
36	.432 086	4.37	.479 120	5.95	.087 161	25.95	.901 833	2.10	24
37	.432 348	4.37	.479 477	5.97	.085 604	25.92	.901 707	2.10	23
38	.432 610	4.38	.479 835	5.97	.084 049	25.90	.901 581	2.10	22
39	.432 873	4.37	.480 193	5.97	.082 495	25.85	.901 455	2.10	21
40	0.433 135	4.37	.480 551	5.97	2.080 944	25.83	.901 329	2.10	20
41	.433 397	4.37	.480 909	5.97	.079 394	25.78	.901 203	2.10	19
42	.433 659	4.37	.481 267	5.98	.077 847	25.77	.901 077	2.10	19
43	.433 921	4.37	.481 626	5.97	.076 301	25.73	.900 951	2.10	17
44	.434 183	4.37	.481 984	5.98	.074 757	25.70	.900 825	2.12	16
45	.434 445	4.37	.482 343	5.97	.073 215	25.68	.900 698	2.10	15
46	.434 707	4.37	.482 701	5.98	.071 674	25.63	.900 572	2.12	14
47	.434 969	4.37	.483 060	5.98	.070 136	25.62	.900 445	2.10	13
48	.435 231	4.37	.483 419	5.98	.068 599	25.57	.900 319	2.12	12
49	.435 493	4.37	.483 778	5.98	.067 065	25.55	.900 192	2.12	11
50	0.435 755	4.37	0.484 137	5.98	2.065 532	25.52	0.900 065	2.10	10
51	.436 017	4.35	.484 496	5.98	.064 001	25.48	.899 939	2.12	09
52	.436 278	4.37	.484 855	5.98	.062 472	25.47	.899 812	2.12	08
53	.436 540	4.37	.485 214	6.00	.060 944	25.42	.899 685	2.12	07
54	.436 802	4.35	.485 574	5.98	.059 419	25.40	.899 558	2.12	06
55	.437 063	4.37	.485 933	6.00	.057 895	25.37	.899 431	2.12	05
56	.437 325	4.37	.486 293	6.00	.056 373	25.33	.899 304	2.13	04
57	.437 587	4.35	.486 653	6.00	.054 853	25.30	.899 176	2.12	03
58	.437 848	4.37	.487 013	6.00	.053 335	25.28	.899 049	2.12	02
59	.438 110	4.35	.487 373	6.00	.051 818	25.23	.899 922	2.13	01
60	0.438 371		0.487 733		2.050 304		0.898 794		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

26°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.438 371	4.37	0.487 733	6.00	2.050 304	25.22	0.898 794	2.13	60'
01	.438 633	4.35	.488 093	6.00	.048 791	25.18	.898 666	2.12	59
02	.438 894	4.35	.488 453	6.00	.047 280	25.15	.898 539	2.13	58
03	.439 155	4.37	.488 813	6.02	.045 771	25.13	.898 411	2.13	57
04	.439 417	4.35	.489 174	6.00	.044 263	25.08	.898 283	2.12	56
05	.439 678	4.35	.489 534	6.02	.042 758	25.07	.898 156	2.13	55
06	.439 939	4.35	.489 895	6.02	.041 254	25.03	.898 028	2.13	54
07	.440 200	4.37	.490 256	6.02	.039 752	25.00	.897 900	2.15	53
08	.440 462	4.35	.490 617	6.02	.038 252	24.98	.897 771	2.13	52
09	.440 723	4.35	.490 978	6.02	.036 753	24.95	.897 643	2.13	51
10	0.440 984	4.35	0.491 339	6.02	2.035 256	24.90	.897 515	2.13	50
11	.441 245	4.35	.491 700	6.02	.033 762	24.90	.897 387	2.15	49
12	.441 506	4.35	.492 061	6.02	.032 268	24.85	.897 258	2.13	48
13	.441 767	4.35	.492 422	6.03	.030 777	24.83	.897 130	2.15	47
14	.442 028	4.35	.492 784	6.02	.029 287	24.80	.897 001	2.13	46
15	.442 289	4.35	.493 145	6.03	.027 799	24.77	.896 873	2.15	45
16	.442 550	4.33	.493 507	6.03	.026 313	24.73	.896 744	2.15	44
17	.442 810	4.35	.493 869	6.03	.024 829	24.72	.896 615	2.15	43
18	.443 071	4.35	.494 231	6.03	.023 346	24.68	.896 486	2.13	42
19	.443 332	4.35	.494 593	6.03	.021 865	24.65	.896 358	2.15	41
20	0.443 593	4.33	0.494 955	6.03	2.020 386	24.62	0.896 229	2.17	40
21	.443 853	4.35	.495 317	6.03	.018 909	24.60	.896 099	2.15	39
22	.444 114	4.35	.495 679	6.05	.017 433	24.57	.895 970	2.15	38
23	.444 375	4.33	.496 042	6.03	.015 959	24.53	.895 841	2.15	37
24	.444 635	4.35	.495 404	6.05	.014 487	24.52	.895 712	2.17	36
25	.444 896	4.33	.496 767	6.05	.013 016	24.47	.895 582	2.15	35
26	.445 156	4.35	.497 130	6.03	.011 548	24.45	.895 453	2.17	34
27	.445 417	4.33	.497 492	6.05	.010 081	24.43	.895 323	2.15	33
28	.445 677	4.33	.497 855	6.05	.008 615	24.38	.895 194	2.17	32
29	.445 937	4.35	.498 218	6.07	.007 152	24.37	.895 064	2.17	31
30	0.446 198	4.33	0.498 582	6.05	2.005 690	24.35	0.894 934	2.15	30
31	.446 458	4.33	.498 945	6.05	.004 229	24.30	.894 805	2.17	29
32	.446 718	4.35	.499 308	6.07	.002 771	24.28	.894 675	2.17	28
33	.446 979	4.33	.499 672	6.05	2.001 314	24.25	.894 545	2.17	27
34	.447 239	4.33	.500 035	6.07	1.999 859	24.22	.894 415	2.18	26
35	.447 499	4.33	.500 399	6.07	.998 406	24.20	.894 284	2.17	25
36	.447 759	4.33	.500 763	6.07	.996 954	24.17	.894 154	2.17	24
37	.448 019	4.33	.501 127	6.07	.995 504	24.15	.894 024	2.17	23
38	.448 279	4.33	.501 491	6.07	.994 055	24.10	.894 894	2.18	22
39	.448 539	4.33	.501 855	6.07	.992 609	24.08	.893 763	2.17	21
40	0.448 799	4.33	0.502 219	6.07	1.991 164	24.07	0.893 633	2.18	20
41	.449 059	4.33	.502 583	6.08	.989 720	24.02	.893 502	2.18	19
42	.449 319	4.33	.502 948	6.07	.988 279	24.00	.893 371	2.17	18
43	.449 579	4.33	.503 312	6.08	.986 839	23.98	.893 241	2.18	17
44	.449 839	4.32	.503 677	6.07	.985 400	23.93	.893 110	2.18	16
45	.450 098	4.33	.504 041	6.08	.983 964	23.92	.892 979	2.18	15
46	.450 358	4.33	.504 406	6.08	.982 529	23.90	.892 848	2.18	14
47	.450 618	4.33	.504 771	6.08	.981 095	23.85	.892 717	2.18	13
48	.450 878	4.32	.505 136	6.10	.979 664	23.85	.892 586	2.18	12
49	.451 137	4.33	.505 502	6.08	.978 233	23.80	.892 455	2.20	11
50	0.451 397	4.32	0.505 867	6.08	1.976 805	23.78	0.892 323	2.18	10
51	.451 656	4.33	.506 232	6.10	.975 378	23.75	.892 192	2.18	09
52	.451 916	4.32	.506 598	6.08	.973 953	23.72	.892 061	2.20	08
53	.452 175	4.33	.506 963	6.10	.972 530	23.70	.891 929	2.18	07
54	.452 435	4.32	.507 329	6.10	.971 108	23.68	.891 798	2.20	06
55	.452 694	4.32	.507 695	6.10	.969 687	23.63	.891 666	2.20	05
56	.452 953	4.33	.508 061	6.10	.968 269	23.62	.891 534	2.20	04
57	.453 213	4.32	.508 427	6.10	.966 852	23.60	.891 402	2.20	03
58	.453 472	4.32	.508 793	6.10	.965 436	23.55	.891 270	2.18	02
59	.453 731	4.32	.509 159	6.10	.964 023	23.53	.891 139	2.20	01
60	0.453 990		0.509 525		1.962 611		0.891 007		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

27°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.453 990	4.35	0.509 525	6.12	1.962 611	23.52	0.891 007	2.22	60′
01	.454 250	4.32	.509 892	6.10	.961 200	23.48	.890 874	2.20	59
02	.454 509	4.32	.510 258	6.12	.959 791	23.45	.890 742	2.20	58
03	.454 768	4.32	.510 625	6.12	.958 384	23.43	.890 610	2.20	57
04	.455 027	4.32	.510 992	6.12	.956 978	23.40	.890 478	2.22	56
05	.455 286	4.32	.511 359	6.12	.955 574	23.38	.890 345	2.20	56
06	.455 545	4.32	.511 726	6.12	.954 171	23.35	.890 213	2.22	54
07	.455 804	4.32	.512 093	6.12	.952 770	23.32	.890 080	2.20	53
08	.456 063	4.32	.512 460	6.13	.951 371	23.30	.889 948	2.22	52
09	.456 322	4.30	.512 828	6.12	.949 973	23.27	.889 815	2.22	51
10	9.456 580	4.32	0.513 195	6.13	1.948 577	23.23	9.889 682	2.22	50
11	.456 839	4.32	.513 563	6.12	.947 183	23.22	.889 549	2.22	49
12	.457 098	4.32	.513 930	6.13	.945 790	23.20	.889 416	2.22	48
13	.457 357	4.30	.514 298	6.13	.944 398	23.17	.889 283	2.22	47
14	.457 615	4.32	.514 666	6.13	.943 008	23.13	.889 150	2.22	46
15	.457 874	4.32	.515 034	6.13	.941 620	23.12	.889 017	2.22	45
16	.458 133	4.30	.515 402	6.13	.940 233	23.08	.888 884	2.22	44
17	.458 391	4.32	.515 770	6.13	.938 848	23.05	.888 751	2.23	43
18	.458 650	4.30	.516 138	6.15	.937 465	23.05	.888 617	2.22	42
19	.458 908	4.30	.516 507	6.13	.936 082	23.00	.888 484	2.23	41
20	0.459 166	4.32	0.516 875	6.15	1.934 702	22.98	0.888 350	2.22	40
21	.459 525	4.30	.517 244	6.15	.933 323	22.95	.888 217	2.23	39
22	.459 683	4.32	.517 613	6.15	.931 946	22.93	.888 083	2.23	38
23	.459 942	4.30	.517 982	6.15	.930 570	22.90	.887 949	2.23	37
24	.460 200	4.30	.518 351	6.15	.929 196	22.88	.887 815	2.23	36
25	.460 200	4.30	.518 351	6.15	.927 823	22.85	.987 681	2.22	35
26	.460 716	4.30	.519 089	6.15	.926 452	22.83	.887 548	2.25	34
27	.460 974	4.30	.519 458	6.17	.925 082	22.80	.887 413	2.23	33
28	.461 232	4.32	.519 828	6.15	.923 714	22.78	.887 279	2.23	32
29	.461 491	4.30	.520 197	6.17	.922 347	22.75	.887 145	2.23	31
30	0.461 749	4.30	0.520 567	6.17	1.920 982	22.72	0.887 011	2.25	30
31	.462 007	4.30	.520 937	6.17	.919 619	22.70	.886 876	2.23	29
32	.462 265	4.30	.521 307	6.17	.918 257	22.68	.886 742	2.23	28
33	.462 523	4.28	.521 677	6.17	.916 896	22.65	.886 608	2.25	27
34	.462 780	4.30	.522 047	6.17	.915 537	22.62	.886 473	2.25	26
35	.463 038	4.30	.522 417	6.17	.914 180	22.60	.886 338	2.23	25
36	.463 296	4.30	.522 787	6.18	.912 824	22.58	.886 204	2.25	24
37	.463 554	4.30	.523 158	6.17	.911 469	22.55	.886 069	2.25	23
38	.463 812	4.28	.523 528	6.18	.910 116	22.52	.885 934	2.25	22
39	.464 069	4.30	.523 899	6.18	.908 765	22.50	.885 799	2.25	21
40	0.464 327	4.28	0.524 270	6.18	1.907 415	22.48	0.885 664	2.25	20
41	.464 584	4.30	.524 641	6.18	.906 066	22.45	.885 529	2.25	19
42	.464 842	4.30	.525 012	6.18	.904 719	22.42	.885 394	2.27	18
43	.465 100	4.28	.525 383	6.18	.903 374	22.40	.885 258	2.25	17
44	.465 357	4.30	.525 754	6.18	.902 030	22.38	.885 123	2.25	16
45	.465 615	4.28	.526 125	6.20	.900 687	22.35	.884 988	2.27	15
46	.465 872	4.28	.526 497	6.18	.899 346	22.32	.884 852	2.25	14
47	.466 129	4.30	4.26 868	6.20	.898 007	22.30	.884 717	2.27	13
48	.466 387	4.28	.527 240	6.20	.896 669	22.28	.884 581	2.27	12
49	.466 644	4.28	.527 612	6.20	.895 332	22.25	.884 445	2.27	11
50	0.466 901	4.28	0.527 984	6.20	1.893 997	22.23	0.884 309	2.25	10
51	.467 158	4.30	.528 356	6.20	.892 663	22.20	.884 174	2.27	09
52	.467 416	4.28	.528 728	6.20	.891 331	22.17	.884 038	2.27	08
53	.467 673	4.28	.529 100	6.22	.890 001	22.17	.883 902	2.27	07
54	.467 930	4.28	.529 473	6.20	.888 671	22.12	.883 766	2.28	06
55	.468 187	4.28	.529 845	6.22	.887 344	22.12	.883 629	2.27	05
56	.468 444	4.28	.530 218	6.22	.886 017	22.08	.883 493	2.27	04
57	.468 701	4.28	.530 591	6.20	.884 692	22.05	.883 357	2.27	03
58	.468 958	4.28	.530 963	6.22	.883 369	22.03	.883 221	2.28	02
59	.469 215	4.28	.531 336	6.22	.882 047	22.02	.883 084	2.27	01
60	0.469 472		0.531 709		1.880 726		0.882 948		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

28°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.469 472	4.27	0.531 709	6.23	1.880 726	21.98	0.882 948	2.28	60′
01	.469 728	4.28	.532 083	6.22	.879 407	21.95	.882 811	2.28	59
02	.469 985	4.28	.532 456	6.22	.878 090	21.93	.882 674	2.27	58
03	.470 242	4.28	.532 829	6.23	.876 774	21.92	.882 538	2.28	57
04	.470 499	4.27	.533 203	6.23	.875 459	21.90	.882 401	2.28	56
05	.470 755	4.28	.533 577	6.22	.874 145	21.85	.882 264	2.28	55
06	.471 012	4.27	.533 950	6.23	.872 834	21.85	.882 127	2.28	54
07	.471 268	4.28	.534 324	6.23	.871 523	21.82	.881 990	2.28	53
08	.471 525	4.28	.534 698	6.23	.870 214	21.80	.881 853	2.30	52
09	.471 782	4.27	.535 072	6.23	.868 906	21.77	.881 715	2.28	51
10	0.472 038	4.27	0.535 446	6.25	1.867 600	21.75	0.881 578	2.28	50
11	.472 294	4.28	.535 821	6.23	.866 295	21.72	.881 441	2.30	49
12	.472 551	4.27	.536 195	6.25	.864 992	21.70	.881 303	2.28	48
13	.472 807	4.27	.536 570	6.25	.863 690	21.67	.881 166	2.30	47
14	.473 063	4.28	.536 945	6.23	.862 390	21.65	.881 028	2.28	46
15	.473 320	4.27	.537 319	6.25	.861 091	21.63	.880 891	2.30	45
16	.473 576	4.27	.537 694	6.25	.859 793	21.62	.880 753	2.30	44
17	.473 832	4.27	.538 069	6.27	.858 496	21.57	.880 615	2.30	43
18	.474 088	4.27	.538 445	6.25	.857 202	21.57	.880 477	2.30	42
19	.474 344	4.27	.538 820	6.25	.855 908	21.53	.880 339	2.30	41
20	0.474 600	4.27	0.539 195	6.27	1.854 616	21.52	0.880 201	2.30	40
21	.474 856	4.27	.539 571	6.25	.853 325	21.48	.880 063	2.30	39
22	.475 112	4.27	.539 946	6.27	.852 036	21.47	.879 925	2.30	43
23	.475 368	4.27	.540 322	6.27	.850 748	21.45	.879 787	2.30	37
24	.475 624	4.27	.540 698	6.27	.849 461	21.42	.879 649	2.32	36
25	.475 880	4.27	.541 074	6.27	.848 176	21.40	.879 510	2.30	35
26	.476 136	4.27	.541 450	6.27	.846 892	21.37	.879 372	2.32	34
27	.476 392	4.25	.541 826	6.28	.845 610	21.35	.879 233	2.30	33
28	.476 647	4.27	.542 203	6.27	.844 329	21.33	.879 095	2.32	32
29	.476 903	4.27	.542 579	6.28	.843 049	21.30	.878 956	2.32	31
30	0.477 159	4.25	0.542 956	6.27	1.841 771	21.28	0.878 817	2.32	30
31	.477 414	4.27	.543 332	6.28	.840 494	21.27	.878 678	2.32	29
32	.477 670	4.25	.543 709	6.28	.839 218	21.23	.878 539	2.32	28
33	.477 925	4.27	.544 086	6.28	.837 944	21.22	.878 400	2.32	27
34	.478 181	4.25	.544 463	6.28	.836 671	21.18	.878 261	2.32	26
35	.478 436	4.27	.544 840	6.30	.835 400	21.17	.878 122	2.32	25
36	.478 692	4.25	.545 218	6.28	.834 130	21.15	.877 983	2.32	24
37	.478 947	4.27	.545 595	6.30	.832 861	21.12	.877 844	2.33	23
38	.479 203	4.25	.545 973	6.28	.831 594	21.12	.877 704	2.32	22
39	.479 458	4.25	.546 350	6.30	.830 327	21.07	.877 565	2.33	21
40	0.479 713	4.25	0.546 728	6.30	1.829 063	21.07	0.877 425	2.32	20
41	.479 968	4.25	.547 106	6.30	.827 799	21.03	.877 286	2.33	19
42	.480 223	4.27	.547 484	6.30	.826 537	21.00	.877 146	2.33	18
43	.480 479	4.25	.547 862	6.30	.825 277	21.00	.877 006	2.32	17
44	.480 734	4.25	.548 240	6.32	.824 017	20.97	.876 867	2.33	16
45	.480 989	4.25	.548 619	6.30	.822 759	20.93	.876 727	2.33	15
46	.481 244	4.25	.548 997	6.32	.821 503	20.93	.876 587	2.33	14
47	.481 499	4.25	.549 376	6.32	.820 247	20.90	.876 447	2.33	13
48	.481 754	4.25	.549 755	6.32	.818 993	20.87	.876 307	2.33	12
49	.482 009	4.23	.550 134	6.32	.817 741	20.87	.876 167	2.35	11
50	0.482 263	4.25	0.550 513	6.32	1.816 489	20.83	0.876 026	2.33	10
51	.482 518	4.25	.550 892	6.32	.815 239	20.82	.875 886	2.33	09
52	.482 773	4.25	.551 271	6.32	.813 990	20.78	.875 746	2.35	08
53	.483 028	4.23	.551 650	6.33	.812 743	20.77	.875 605	2.33	07
54	.483 282	4.25	.552 030	6.32	.811 497	20.75	.875 465	2.35	06
55	.483 537	4.25	.552 409	6.33	.810 252	20.72	.875 324	2.35	05
56	.483 792	4.23	.552 789	6.33	.809 009	20.72	.875 183	2.35	04
57	.484 046	4.25	.553 169	6.33	.807 766	20.67	.875 042	2.33	03
58	.484 301	4.23	.553 549	6.33	.806 526	20.67	.874 902	2.35	02
59	.484 555	4.25	.553 929	6.33	.805 285	20.63	.874 761	2.35	01
60	0.484 810		0.554 309		1.804 048		0.874 620		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

29°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.484 810	4.23	0.554 309	6.33	1.804 048	20.62	.874 620	2.35	60′
01	.485 064	4.23	.554 689	6.35	.802 811	20.60	.874 479	2.35	59
02	.485 318	4.25	.555 070	6.33	.801 575	20.57	.874 338	2.37	58
03	.485 573	4.23	.555 450	6.35	.800 341	20.55	.874 196	2.35	57
04	.485 827	4.23	.555 831	6.35	.799 108	20.53	.874 055	2.35	56
05	.486 081	4.23	.556 212	6.35	.797 876	20.52	.873 914	2.37	55
06	.486 335	4.25	.556 593	6.35	.796 645	20.48	.874 772	2.35	54
07	.486 590	4.23	.556 974	6.35	.795 416	20.47	.873 631	2.37	53
08	.486 844	4.23	.557 355	6.35	.794 188	20.43	.873 489	2.37	52
09	.487 098	4.23	.557 736	6.37	.792 962	20.43	.873 347	2.35	51
10	0.487 352	4.23	0.558 118	6.35	1.791 736	20.40	0.873 206	2.37	50
11	.487 606	4.23	.558 499	6.37	.790 512	20.38	.873 064	2.37	49
12	.487 860	4.23	.558 881	6.37	.789 289	20.35	.872 922	2.37	48
13	.488 114	4.22	.559 263	6.37	.788 068	20.35	.872 780	2.37	47
14	.488 367	4.23	.559 645	6.37	.786 847	20.32	.872 638	2.37	46
15	.488 621	4.23	.560 027	6.37	.785 628	20.28	.872 496	2.37	45
16	.488 875	4.23	.560 409	6.37	.784 411	20.28	.872 354	2.37	44
17	.489 129	4.22	.560 791	6.38	.783 194	20.25	.872 212	2.38	43
18	.489 382	4.23	.561 174	6.37	.781 979	20.23	.872 069	2.37	42
19	.489 636	4.23	.561 556	6.38	.780 765	20.22	.871 927	2.38	41
20	0.489 890	4.22	0.561 939	6.38	1.779 552	20.18	0.871 784	2.37	40
21	.490 143	4.23	.562 322	6.38	.778 341	20.17	.871 642	2.38	39
22	.490 397	4.22	.562 705	6.38	.777 131	20.15	.871 499	2.37	38
23	.490 650	4.23	.563 088	6.38	.775 922	20.13	.871 357	2.38	37
24	.490 904	4.22	.563 471	6.38	.774 714	20.10	.871 214	2.38	36
25	.491 157	4.23	.563 854	6.40	.773 508	20.10	.871 071	2.38	35
26	.491 411	4.22	.564 238	6.38	.772 302	20.07	.870 928	2.38	34
27	.491 664	4.22	.564 621	6.40	.771 098	20.03	.870 785	2.38	33
28	.491 917	4.22	.565 005	6.40	.769 896	20.03	.870 642	2.38	32
29	.492 170	4.23	.565 389	6.40	.768 694	20.00	.870 499	2.38	31
30	0.492 424	4.22	0.565 773	6.40	1.767 494	19.98	0.870 356	2.40	30
31	.492 677	4.22	.566 157	6.40	.766 295	19.97	.870 212	2.38	29
32	.492 930	4.22	.566 541	6.40	.765 097	19.93	.870 069	2.38	28
33	.493 183	4.22	.566 925	6.42	.763 901	19.93	.869 926	2.40	27
34	.493 436	4.22	.567 310	6.40	.762 705	19.90	.869 782	2.38	26
35	.493 689	4.22	.567 694	6.42	.761 511	19.88	.869 639	2.40	25
36	.493 942	4.22	.568 079	6.42	.760 318	19.85	.869 495	2.40	24
37	.494 195	4.22	.568 464	6.42	.759 127	19.85	.869 351	2.40	23
38	.494 448	4.20	.568 849	6.42	.757 936	19.82	.869 207	2.38	22
39	.494 700	4.22	.569 234	6.42	.756 747	19.80	.869 064	2.40	21
40	0.494 953	4.22	0.569 619	6.42	1.755 559	19.78	0.868 920	2.40	20
41	.495 206	4.22	.570 004	6.43	.754 372	19.75	.868 776	2.40	19
42	.495 459	4.20	.570 390	6.43	.753 187	19.75	.868 632	2.42	18
43	.495 711	4.22	.570 776	6.42	.752 002	19.72	.868 487	2.40	17
44	.495 964	4.22	.571 161	6.43	.750 819	19.70	.868 343	2.40	16
45	.496 217	4.20	.571 547	6.43	.749 637	19.68	.868 199	2.42	15
46	.496 469	4.22	.571 933	6.43	.748 456	19.65	.868 054	2.40	14
47	.496 722	4.20	.572 319	6.43	.747 277	19.65	.867 910	2.42	13
48	.496 974	4.20	.572 705	6.45	.746 098	19.62	.867 765	2.40	12
49	.497 226	4.22	.573 092	6.43	.744 921	19.60	.867 621	2.42	11
50	0.497 479	4.20	0.573 478	6.45	1.743 745	19.57	0.867 476	2.42	10
51	.497 731	4.20	.573 865	6.45	.742 571	19.57	.867 331	2.40	09
52	.497 983	4.22	.574 252	6.43	.741 397	19.53	.867 187	2.42	08
53	.498 236	4.20	.574 638	6.47	.740 225	19.53	.867 042	2.42	07
54	.498 488	4.20	.575 026	6.45	.739 053	19.50	.866 897	2.42	06
55	.498 740	4.20	.575 413	6.45	.737 883	19.48	.866 752	2.42	05
56	.498 992	4.20	.575 800	6.45	.736 714	19.45	.866 607	2.43	04
57	.499 244	4.20	.576 187	6.47	.735 547	19.45	.866 461	2.42	03
58	.499 496	4.20	.576 575	6.45	.734 380	19.42	.866 316	2.42	02
59	.499 748	4.20	.576 962	6.47	.733 215	19.40	.866 171	2.43	01
60	0.500 000		0.577 350		1.732 051		0.866 025		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

30°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.500 000	4.20	0.577 350	6.47	1.732 051	19.38	0.866 025	2.42	60'
01	.500 252	4.20	.577 738	6.47	.730 888	19.37	.865 880	2.43	59
02	.500 504	4.20	.578 126	6.47	.729 726	19.35	.865 734	2.42	58
03	.500 756	4.18	.578 514	6.48	.728 565	19.32	.865 589	2.43	57
04	.501 007	4.20	.578 903	6.47	.727 406	19.30	.865 443	2.42	56
05	.501 259	4.20	.579 291	6.48	.726 248	19.28	.865 297	2.43	55
06	.501 511	4.18	.579 680	6.47	.725 091	19.27	.865 151	2.42	54
07	.501 762	4.20	.580 068	6.48	.723 935	19.25	.865 006	2.43	53
08	.502 014	4.20	.580 457	6.48	.722 780	19.23	.864 860	2.45	52
09	.502 266	4.18	.580 846	6.48	.721 626	19.20	.864 713	2.43	51
10	0.502 517	4.20	0.581 235	6.50	1.720 474	19.20	0.864 567	2.43	50
11	.502 769	4.18	.581 625	6.48	.719 322	19.17	.864 421	2.43	49
12	.503 020	4.18	.582 014	6.48	.718 172	19.15	.864 275	2.45	48
13	.503 271	4.20	.582 403	6.50	.717 023	19.13	.864 128	2.43	47
14	.503 523	4.18	.582 793	6.50	.715 875	19.12	.863 982	2.43	46
15	.503 774	4.18	.583 183	6.50	.714 728	19.08	.863 836	2.45	45
16	.504 025	4.18	.583 573	6.50	.713 583	19.08	.863 689	2.45	44
17	.504 276	4.20	.583 963	6.50	.712 438	19.05	.863 542	2.43	43
18	.504 528	4.18	.584 353	6.50	.711 295	19.03	.863 396	2.45	42
19	.504 779	4.18	.584 743	6.52	.710 153	19.02	.863 249	2.45	41
20	0.505 030	4.18	0.585 134	6.50	1.709 012	19.00	0.863 102	2.45	40
21	.505 281	4.18	.585 524	6.52	.707 872	18.98	.862 955	2.45	39
22	.505 532	4.18	.585 915	6.52	.706 733	18.97	.862 808	2.45	38
23	.505 783	4.18	.586 306	6.52	.705 595	18.93	.862 661	2.45	37
24	.506 034	4.18	.586 697	6.52	.704 459	18.93	.862 514	2.47	36
25	.506 285	4.17	.587 088	6.52	.703 323	18.90	.862 366	2.45	35
26	.506 535	4.18	.587 479	6.52	.702 189	18.88	.862 219	2.45	34
27	.506 786	4.18	.587 870	6.53	.701 056	18.87	.862 072	2.47	33
28	.507 037	4.18	.588 262	6.52	.699 924	18.85	.861 924	2.45	32
29	.507 288	4.17	.588 653	6.53	.698 793	18.83	.861 777	2.47	31
30	0.507 538	4.18	0.589 045	6.53	1.697 663	18.82	0.861 629	2.47	30
31	.507 789	4.18	.589 437	6.53	.696 534	18.78	.861 481	2.45	29
32	.508 040	4.17	.589 829	6.53	.695 407	18.78	.861 334	2.47	28
33	.508 290	4.18	.590 221	6.53	.694 280	18.75	.861 186	2.47	27
34	.508 541	4.17	.590 613	6.55	.693 155	18.73	.861 038	2.47	26
35	.508 791	4.17	.591 006	6.53	.692 031	18.72	.860 890	2.47	25
36	.509 041	4.18	.591 398	6.55	.690 908	18.70	.860 742	2.47	24
37	.509 292	4.17	.591 791	6.55	.689 786	18.68	.860 594	2.47	23
38	.509 542	4.17	.592 184	6.55	.688 665	18.67	.860 446	2.48	22
39	.509 792	4.18	.592 577	6.55	.687 545	18.65	.860 297	2.47	21
40	0.510 043	4.17	0.592 970	6.55	1.686 426	18.63	0.860 149	2.47	20
41	.510 293	4.17	.593 363	6.57	.685 308	18.60	.860 001	2.48	19
42	.510 543	4.17	.593 757	6.55	.684 192	18.58	.859 852	2.47	18
43	.510 793	4.17	.594 150	6.57	.683 077	18.58	.859 704	2.48	17
44	.511 043	4.17	.594 544	6.55	.681 962	18.55	.859 555	2.48	16
45	.511 293	4.17	.594 937	6.57	.680 849	18.53	.859 406	2.47	15
46	.511 543	4.17	.595 331	6.57	.679 737	18.52	.859 258	2.48	14
47	.511 793	4.17	.595 725	6.58	.678 626	18.50	.859 109	2.48	13
48	.512 043	4.17	.596 120	6.57	.677 516	18.48	.858 960	2.48	12
49	.512 293	4.17	.596 514	6.57	.676 407	18.47	.858 811	2.48	11
50	0.512 543	4.15	0.596 908	6.58	1.675 299	18.45	0.858 662	2.48	10
51	.512 792	4.17	.597 303	6.58	.674 192	18.43	0.858 513	2.48	09
52	.513 042	4.17	.597 698	6.58	.673 086	18.40	.858 364	2.50	08
53	.513 292	4.15	.598 093	6.58	.671 982	18.40	.858 214	2.48	07
54	.513 541	4.17	.598 488	6.58	.670 878	18.37	.858 065	2.50	06
55	.513 791	4.15	.598 883	6.58	.669 776	18.37	.857 915	2.48	05
56	.514 040	4.17	.599 278	6.60	.668 674	18.32	.857 766	2.50	04
57	.514 290	4.15	.599 674	6.58	.667 574	18.32	.857 616	2.48	03
58	.514 539	4.17	.600 069	6.60	.666 475	18.30	.857 467	2.50	02
59	.514 789	4.15	.600 465	6.60	.665 377	18.30	.857 317	2.50	01
60	0.515 038		0.600 861		1.664 279		0.857 167		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

31°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.515 038	4.15	0.600 861	6.60	1.664 279	18.27	0.857 167	2.50	60'
01	.515 287	4.17	.601 257	6.60	.663 183	18.25	.857 017	2.48	59
02	.515 537	4.15	.601 653	6.60	.662 088	18.23	.856 868	2.50	58
03	.515 786	4.15	.602 049	6.60	.660 994	18.20	.856 718	2.52	57
04	.516 035	4.15	.602 445	6.62	.659 902	18.20	.856 567	2.50	56
05	.516 284	4.15	.602 842	6.62	.658 810	18.18	.856 417	2.50	55
06	.516 533	4.15	.603 239	6.60	.657 719	18.17	.856 267	2.50	54
07	.516 782	4.15	.603 635	6.62	.656 629	18.13	.856 117	2.52	53
08	.517 031	4.15	.604 032	6.62	.655 541	18.13	.855 966	2.50	52
09	.517 280	4.15	.604 429	6.63	.654 453	18.12	.855 816	2.52	51
10	0.517 529	4.15	0.604 827	6.62	1.653 366	18.08	0.855 665	2.50	50
11	.517 778	4.15	.605 224	6.63	.652 281	18.08	.855 515	2.52	49
12	.518 027	4.15	.605 622	6.62	.651 196	18.05	.855 364	2.50	48
13	.518 276	4.15	.606 019	6.63	.650 113	18.05	.855 214	2.52	47
14	.518 525	4.13	.606 417	6.63	.649 030	18.02	.855 063	2.52	46
15	.518 773	4.15	.606 815	6.63	.647 949	18.00	.854 912	2.52	45
16	.519 022	4.15	.607 213	6.63	.646 869	18.00	.854 761	2.52	44
17	.519 271	4.13	.607 611	6.65	.645 789	17.97	.854 610	2.52	43
18	.519 519	4.15	.608 010	6.63	.644 711	17.95	.854 459	2.52	42
19	.519 768	4.13	.608 408	6.65	.643 634	17.93	.854 308	2.53	41
20	0.520 016	4.15	0.608 807	6.63	1.642 558	17.93	0.854 156	2.52	40
21	.520 265	4.13	.609 205	6.65	.641 482	17.90	.854 005	2.52	39
22	.520 513	4.13	.609 604	6.65	.640 408	17.88	.853 854	2.53	38
23	.520 761	4.15	.610 003	6.67	.639 335	17.87	.853 702	2.52	37
24	.521 010	4.13	.610 403	6.65	.638 263	17.85	.853 551	2.53	36
25	.521 258	4.13	.610 802	6.65	.637 192	17.83	.853 399	2.52	35
26	.521 506	4.13	.611 201	6.67	.636 122	17.82	.853 248	2.53	34
27	.521 754	4.13	.611 601	6.67	.635 053	17.80	.853 096	2.53	33
28	.522 002	4.15	.612 001	6.67	.633 985	17.78	.852 944	2.53	32
29	.522 251	4.13	.612 401	6.67	.632 918	17.77	.852 792	2.53	31
30	0.522 499	4.13	0.612 801	6.67	1.631 852	17.75	0.852 640	2.53	30
31	.522 747	4.13	.613 201	6.67	.630 787	17.73	.852 488	2.53	29
32	.522 995	4.12	.613 601	6.68	.629 723	17.72	.852 336	2.53	28
33	.523 242	4.13	.614 002	6.67	.628 660	17.70	.852 184	2.53	27
34	.523 490	4.13	.614 402	6.68	.627 598	17.68	.852 032	2.55	26
35	.523 738	4.13	.614 803	6.68	.626 537	17.67	.851 879	2.53	25
36	.523 986	4.13	.615 204	6.68	.625 477	17.65	.851 727	2.55	24
37	.524 234	4.12	.615 605	6.68	.624 418	17.63	.851 574	2.53	23
38	.524 481	4.13	.616 006	6.70	.623 360	17.62	.851 422	2.55	22
39	.524 729	4.13	.616 408	6.68	.622 303	17.60	.851 269	2.53	21
40	0.524 977	4.12	0.616 809	6.70	1.621 247	17.58	0.851 117	2.55	20
41	.525 224	4.13	.617 211	6.70	.620 192	17.57	.850 964	2.55	19
42	.525 472	4.12	.617 613	6.70	.619 138	17.55	.850 811	2.55	18
43	.525 719	4.13	.618 015	6.70	.618 085	17.53	.850 658	2.55	17
44	.525 967	4.12	.618 417	6.70	.617 033	17.52	.850 505	2.55	16
45	.526 214	4.12	.618 819	6.70	.615 982	17.50	.850 352	2.55	15
46	.526 461	4.13	.619 221	6.72	.614 932	17.48	.850 199	2.55	14
47	.526 709	4.12	.619 624	6.70	.613 883	17.47	.850 046	2.55	13
48	.526 956	4.12	.620 026	6.72	.612 835	17.45	.849 893	2.57	12
49	.527 203	4.12	.620 429	6.72	.611 788	17.43	.849 739	2.55	11
50	0.527 450	4.12	0.620 832	6.72	1.610 742	17.42	0.849 586	2.55	10
51	.527 697	4.12	.621 235	6.72	.609 697	17.40	.849 433	2.57	09
52	.527 944	4.12	.621 638	6.73	.608 653	17.40	.849 279	2.57	08
53	.528 191	4.12	.622 042	6.72	.607 609	17.37	.849 125	2.55	07
54	.528 438	4.12	.622 445	6.73	.606 567	17.35	.848 972	2.57	06
55	.528 685	4.12	.622 849	6.73	.605 526	17.33	.848 818	2.57	05
56	.528 932	4.12	.623 253	6.73	.604 486	17.33	.848 664	2.57	04
57	.529 179	4.12	.623 657	6.73	.603 446	17.30	.848 510	2.57	03
58	.529 426	4.12	.624 061	6.73	.602 408	17.28	.848 356	2.57	02
59	.529 673	4.10	.624 465	6.73	.601 371	17.27	.848 202	2.57	01
60	0.529 919		0.624 869		1.600 335		0.848 048		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

32°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.529 919	4.12	0.624 869	6.75	1.600 335	17.27	0.848 048	2.57	60'
01	.530 166	4.12	.625 274	6.75	.599 299	17.23	.847 894	2.57	59
02	.530 413	4.10	.625 679	6.73	.598 265	17.23	.847 740	2.58	58
03	.530 659	4.12	.626 083	6.75	.597 231	17.20	.847 585	2.57	57
04	.530 906	4.10	.626 488	6.77	.596 199	17.20	.847 431	2.58	56
05	.531 152	4.12	.626 894	6.75	.595 167	17.17	.847 276	2.57	55
06	.531 399	4.10	.627 299	6.75	.594 137	17.17	.847 122	2.58	54
07	.531 645	4.10	.627 704	6.77	.593 107	17.15	.846 967	2.57	53
08	.531 891	4.12	.628 110	6.77	.592 078	17.12	.846 813	2.58	52
09	.532 138	4.10	.628 516	6.75	.591 051	17.12	.846 658	2.58	51
10	0.532 384	4.10	0.628 921	6.77	1.590 024	17.10	0.846 503	2.58	49
11	.532 630	4.10	.629 327	6.78	.588 998	17.08	.846 348	2.58	49
12	.532 876	4.10	.629 734	6.77	.587 973	17.07	.846 193	2.58	48
13	.533 122	4.10	.630 140	6.77	.586 949	17.05	.846 038	2.58	47
14	.533 368	4.12	.630 546	6.78	.585 926	17.03	.845 883	2.58	46
15	.533 615	4.10	.630 953	6.78	.584 904	17.02	.845 728	2.58	45
16	.533 861	4.08	.631 360	6.78	.583 883	17.00	.845 573	2.60	44
17	.534 106	4.10	.631 767	6.78	.582 863	16.98	.845 417	2.58	43
18	.534 352	4.10	.632 174	6.78	.581 844	16.98	.845 262	2.60	42
19	.534 598	4.10	.632 581	6.78	.580 825	16.95	.845 106	2.58	41
20	0.534 844	4.10	0.632 988	6.80	1.579 808	16.93	0.844 951	2.60	40
21	.535 090	4.08	.633 396	6.80	.578 792	16.93	.844 795	2.58	39
22	.535 335	4.10	.633 804	6.78	.577 776	16.92	.844 640	2.60	38
23	.535 581	4.10	.634 211	6.80	.576 761	16.88	.844 484	2.60	37
24	.535 827	4.08	.634 619	6.80	.575 748	16.88	.844 328	2.60	36
25	.536 072	4.10	.635 027	6.82	.574 735	16.87	.844 172	2.60	35
26	.536 318	4.08	.635 436	6.80	.573 723	16.83	.844 016	2.60	34
27	.536 563	4.10	.635 844	6.82	.572 713	16.83	.843 860	2.60	33
28	.536 809	4.08	.636 253	6.80	.571 703	16.82	.843 704	2.60	32
29	.537 054	4.10	.636 661	6.82	.570 694	16.80	.843 548	2.62	31
30	0.537 300	4.08	0.637 070	6.82	1.569 686	16.80	0.843 391	2.60	30
31	.537 545	4.08	.637 479	6.82	.568 678	16.77	.843 235	2.60	29
32	.537 790	4.08	.637 888	6.83	.567 672	16.75	.843 079	2.62	28
33	.538 035	4.10	.638 298	6.82	.566 667	16.75	.842 922	2.60	27
34	.538 281	4.08	.638 707	6.83	.565 662	16.72	.842 766	2.62	26
35	.538 526	4.08	.639 117	6.83	.564 659	16.72	.842 609	2.62	25
36	.538 771	4.08	.639 527	6.83	.563 656	16.68	.842 452	2.60	24
37	.539 016	4.08	.639 937	6.83	.562 655	16.68	.842 296	2.62	23
38	.539 261	4.08	.640 347	6.83	.561 654	16.67	.842 139	2.62	22
39	.539 506	4.08	.640 757	6.83	.560 654	16.65	.841 982	2.62	21
40	0.539 751	4.08	0.641 167	6.85	1.559 655	16.63	0.841 825	2.62	20
41	.539 996	4.07	.641 578	6.85	.558 657	16.62	.841 668	2.62	19
42	.540 240	4.08	.641 989	6.83	.557 660	16.60	.841 511	2.62	18
43	.540 485	4.08	.642 399	6.85	.556 664	16.58	.841 354	2.63	17
44	.540 730	4.07	.642 810	6.87	.555 669	16.58	.841 196	2.62	16
45	.540 974	4.08	.643 222	6.85	.554 674	16.55	.841 039	2.62	15
46	.541 219	4.08	.643 633	6.85	.553 681	16.55	.840 882	2.63	14
47	.541 464	4.07	.644 044	6.87	.552 688	16.53	.840 724	2.62	13
48	.541 708	4.08	.644 456	6.87	.551 696	16.52	.840 567	2.63	12
49	.541 953	4.07	.644 868	6.87	.550 705	16.50	.840 409	2.63	11
50	0.542 197	4.08	0.645 280	6.87	1.549 715	16.48	0.840 251	2.62	10
51	.542 442	4.07	.645 692	6.87	.548 726	16.47	.840 094	2.63	09
52	.542 686	4.07	.646 104	6.87	.547 738	16.45	.839 936	2.63	08
53	.542 930	4.07	.646 516	6.88	.546 751	16.43	.839 778	2.63	07
54	.543 174	4.08	.646 929	6.88	.545 765	16.43	.839 620	2.63	06
55	.543 419	4.07	.647 342	6.88	.544 779	16.40	.839 462	2.63	05
56	.543 663	4.07	.647 755	6.88	.543 795	16.40	.839 304	2.63	04
57	.543 907	4.07	.648 168	6.88	.542 811	16.38	.839 146	2.65	03
58	.544 151	4.07	.648 581	6.88	.541 828	16.37	.838 987	2.63	02
59	.544 395	4.07	.648 994	6.90	.540 846	16.35	.838 829	2.63	01
60	0.544 639		0.649 408		1.539 865		0.838 671		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

33°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.544 639	4.07	0.649 408	6.88	1.539 865	16.33	0.836 671	2.65	60′
01	.544 883	4.07	.649 821	6.90	.538 885	16.33	.838 512	2.63	59
02	.545 127	4.07	.650 235	6.90	.537 905	16.30	.838 354	2.65	58
03	.545 371	4.07	.650 649	6.90	.536 927	16.30	.838 195	2.65	57
04	.545 615	4.05	.651 063	6.90	.535 949	16.27	.838 036	2.63	56
05	.545 858	4.07	.651 477	6.92	.534 973	16.27	.837 878	2.65	55
06	.546 102	4.07	.651 892	6.90	.533 997	16.25	.837 719	2.65	54
07	.546 346	4.05	.652 306	6.92	.533 022	16.23	.837 560	2.65	53
08	.546 589	4.07	.652 721	6.92	.532 048	16.22	.837 401	2.65	52
09	.546 833	4.05	.653 136	6.92	.531 075	16.22	.837 242	2.65	51
10	0.547 076	4.07	0.653 551	6.92	1.530 102	16.18	0.837 083	2.65	50
11	.547 320	4.05	.653 966	6.93	.529 131	16.18	.836 924	2.67	49
12	.547 563	4.07	.654 382	6.92	.528 160	16.17	.836 764	2.65	48
13	.547 807	4.05	.654 797	6.93	.527 190	16.13	.836 605	2.65	47
14	.548 050	4.05	.655 213	6.93	.526 222	16.15	.836 446	2.67	46
15	.548 293	4.05	.655 629	6.93	.525 253	16.12	.836 286	2.65	45
16	.548 536	4.07	.656 045	6.93	.524 286	16.10	.836 127	2.67	44
17	.548 780	4.05	.656 461	6.93	.523 320	16.08	.835 967	2.67	43
18	.549 023	4.05	.656 877	6.95	.522 355	16.08	.835 807	2.65	42
19	.549 266	4.05	.657 294	6.93	.521 390	16.07	.835 648	2.67	41
20	0.549 509	4.05	0.657 710	6.95	1.520 426	16.05	0.835 488	2.67	40
21	.549 752	4.05	.658 127	6.95	.519 463	16.03	.835 328	2.67	39
22	.549 995	4.05	.658 544	6.95	.518 501	16.02	.835 168	2.67	38
23	.550 238	4.05	.658 961	6.97	.517 540	16.00	.835 008	2.67	37
24	.550 481	4.05	.659 379	6.95	.516 580	16.00	.834 848	2.67	36
25	.550 724	4.03	.659 796	6.97	.515 620	15.98	.834 688	2.68	35
26	.550 966	4.05	.660 214	6.95	.514 661	15.95	.834 527	2.67	34
27	.551 209	4.05	.660 631	6.97	.513 704	15.95	.834 367	2.67	33
28	.551 452	4.03	.661 049	6.97	.512 747	15.95	.834 207	2.68	32
29	.551 694	4.05	.661 467	6.98	.511 790	15.92	.834 046	2.67	31
30	0.551 937	4.05	0.661 886	6.97	1.510 835	15.90	0.833 886	2.68	30
31	.552 180	4.03	.662 304	6.98	.509 881	15.90	.833 725	2.67	29
32	.552 422	4.03	.662 723	6.97	.508 927	15.88	.833 565	2.68	28
33	.552 664	4.05	.663 141	6.98	.507 974	15.87	.833 404	2.68	27
34	.552 907	4.03	.663 560	6.98	.507 022	15.85	.833 243	2.68	26
35	.553 149	4.05	.663 979	6.98	.506 071	15.83	.833 082	2.68	25
36	.553 392	4.03	.664 398	7.00	.505 121	15.82	.832 921	2.68	24
37	.553 634	4.03	.664 818	6.98	.504 172	15.82	.832 760	2.68	23
38	.553 876	4.03	.665 237	7.00	.503 223	15.80	.832 599	2.68	22
39	.554 118	4.03	.665 657	7.00	.502 275	15.78	.832 438	2.68	21
40	0.554 360	4.03	0.666 077	7.00	1.501 328	15.77	0.832 277	2.70	20
41	.554 602	4.03	.666 497	7.00	.500 382	15.75	.832 115	2.68	19
42	.554 844	4.03	.666 917	7.00	.499 437	15.75	.831 954	2.68	18
43	.555 086	4.03	.667 337	7.02	.499 492	15.72	.831 793	2.70	17
44	.555 328	4.03	.667 758	7.02	.497 549	15.72	.831 631	2.68	16
45	.555 570	4.03	.668 179	7.00	.496 606	15.70	.831 470	2.70	15
46	.555 812	4.03	.668 599	7.02	.495 664	15.68	.831 308	2.70	14
47	.556 054	4.03	.669 020	7.03	.494 723	15.68	.831 146	2.70	13
48	.556 296	4.02	.669 442	7.02	.493 782	15.65	.830 984	2.68	12
49	.556 537	4.03	.669 863	7.02	.492 843	15.65	.830 823	2.70	11
50	0.556 779	4.03	0.670 284	7.03	1.491 904	15.63	0.830 661	2.70	10
51	.557 021	4.02	.670 706	7.03	.490 966	15.62	.830 499	2.70	09
52	.557 262	4.03	.671 128	7.03	.490 029	15.62	.830 337	2.72	08
53	.557 504	4.02	.671 550	7.03	.489 092	15.58	.830 174	2.70	07
54	.557 745	4.03	.671 972	7.03	.488 157	15.58	.830 012	2.70	06
55	.557 987	4.02	.672 394	7.05	.487 222	15.57	.829 850	2.70	05
56	.558 228	4.02	.672 817	7.05	.486 288	15.55	.829 688	2.72	04
57	.558 469	4.02	.673 240	7.03	.485 355	15.53	.829 525	2.70	03
58	.558 710	4.03	.673 662	7.05	.484 423	15.52	.829 363	2.72	02
59	.558 952	4.02	.674 085	7.07	.483 492	15.52	.829 200	2.70	01
60	0.559 193		0.674 509		1.482 561		0.829 038		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

34°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.559 193	4.02	0.674 509	7.05	1.482 561	15.50	0.829 038	2.72	60′
01	.559 434	4.02	.674 932	7.05	.481 631	15.48	.828 875	2.72	59
02	.559 675	4.02	.675 355	7.07	.480 702	15.47	.828 712	2.72	58
03	.559 916	4.02	.675 779	7.07	.479 774	15.47	.828 549	2.72	57
04	.560 157	4.02	.676 203	7.07	.478 846	15.43	.828 386	2.72	56
05	.560 398	4.02	.676 627	7.07	.477 926	15.43	.828 223	2.72	55
06	.560 639	4.02	.677 051	7.07	.476 994	15.42	.828 060	2.72	54
07	.560 880	4.02	.677 475	7.08	.476 069	15.42	.827 897	2.72	53
08	.561 121	4.00	.677 900	7.07	.475 144	15.38	.827 734	2.72	52
09	.561 361	4.02	.678 324	7.08	.474 221	15.38	.827 571	2.73	51
10	0.561 602	4.02	0.678 749	7.08	1.473 298	15.37	0.827 407	2.72	50
11	.561 843	4.00	.676 174	7.08	.472 376	15.35	.827 244	2.72	49
12	.562 083	4.02	.679 599	7.10	.471 455	15.33	.827 081	2.73	48
13	.562 324	4.00	.680 025	7.08	.470 535	15.33	.826 917	2.73	47
14	.562 564	4.02	.680 450	7.10	.469 615	15.30	.826 753	2.72	46
15	.562 805	4.00	.680 876	7.10	.468 697	15.30	.826 590	2.73	45
16	.563 045	4.02	.681 302	7.10	.467 779	15.28	.826 426	2.73	44
17	.563 286	4.00	.681 728	7.10	.466 862	15.28	.826 262	2.73	43
18	.563 526	4.00	.682 154	7.10	.465 945	15.25	.826 098	2.73	42
19	.563 766	4.02	.682 580	7.12	.465 030	15.25	.825 934	2.73	41
20	0.564 007	4.00	0.683 007	7.10	1.464 115	15.23	0.825 770	2.73	40
21	.564 247	4.00	.683 433	7.12	.463 201	15.23	.825 606	2.73	39
22	.564 487	4.00	.683 860	7.12	.462 287	15.20	.825 442	2.73	38
23	.564 727	4.00	.684 287	7.12	.461 375	15.20	.825 278	2.75	37
24	.564 967	4.00	.684 714	7.13	.460 463	15.18	.825 113	2.73	36
25	.565 207	4.00	.685 142	7.12	.459 552	15.17	.824 949	2.73	35
26	.565 447	4.00	.685 569	7.13	.458 642	15.15	.824 785	2.75	34
27	.565 687	4.00	.685 997	7.13	.457 733	15.15	.824 620	2.73	33
28	.565 927	3.98	.686 425	7.13	.456 824	15.13	.824 456	2.75	32
29	.566 166	4.00	.686 853	7.13	.455 916	15.12	.824 291	2.75	31
30	0.566 406	4.00	0.687 281	7.13	1.455 009	15.10	0.824 126	2.75	30
31	.566 646	4.00	.687 709	7.15	.454 103	15.10	.823 961	2.73	29
32	.566 886	3.98	.688 138	7.15	.453 197	15.08	.823 797	2.75	28
33	.567 125	4.00	.688 567	7.13	.452 292	15.07	.823 632	2.75	27
34	.567 365	3.98	.688 995	7.17	.451 388	15.05	.823 467	2.75	26
35	.567 604	4.00	.689 425	7.15	.450 485	15.03	.823 302	2.77	25
36	.567 844	3.98	.689 854	7.15	.449 583	15.03	.823 136	2.75	24
37	.568 083	4.00	.690 283	7.17	.448 681	15.02	.822 971	2.75	23
38	.568 323	3.98	.690 713	7.17	.447 780	15.00	.822 806	2.75	22
39	.568 562	3.98	.691 143	7.15	.446 880	15.00	.822 641	2.77	21
40	0.568 801	3.98	0.691 572	7.18	1.445 980	14.98	0.822 475	2.75	20
41	.569 040	4.00	.692 003	7.17	.445 081	14.97	.882 310	2.77	19
42	.569 280	3.98	.692 433	7.17	.444 183	14.95	.882 144	2.77	18
43	.569 519	3.98	.692 863	7.18	.443 286	14.93	.821 978	2.75	17
44	.569 758	3.98	.693 294	7.18	.442 390	14.93	.821 813	2.77	16
45	.569 997	3.98	.693 725	7.18	.441 494	14.92	.821 647	2.77	15
46	.570 236	3.98	.694 156	7.18	.440 599	14.90	.821 481	2.77	14
47	.570 475	3.98	.694 587	7.18	.439 705	14.90	.821 315	2.77	13
48	.570 714	3.97	.695 018	7.20	.438 811	14.87	.821 149	2.77	12
49	.570 952	3.98	.695 450	7.18	.437 919	14.87	.820 983	2.77	11
50	0.571 191	3.98	0.695 881	7.20	1.437 027	14.85	0.820 817	2.77	10
51	.571 430	3.98	.696 313	7.20	.436 136	14.85	.820 651	2.77	09
52	.571 669	3.97	.696 745	7.20	.435 245	14.83	.820 485	2.78	08
53	.571 907	3.98	.697 177	7.22	.434 355	14.82	.820 318	2.77	07
54	.572 146	3.97	.697 610	7.20	.433 466	14.80	.820 152	2.78	06
55	.572 384	3.98	.698 042	7.22	.432 578	14.78	.819 985	2.77	05
56	.572 623	3.97	.698 475	7.22	.431 691	14.78	.819 819	2.78	04
57	.572 861	3.98	.698 908	7.22	.430 804	14.77	.819 652	2.77	03
58	.573 100	3.97	.699 341	7.22	.429 918	14.75	.819 486	2.78	02
59	.573 338	3.97	.699 774	7.23	.429 033	14.75	.819 319	2.78	01
60	0.573 576		0.700 208		1.428 148		0.819 152		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

35°

	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	
00′	0.573 576	3.98	0.700 208	7.22	1.428 148	14.73	0.819 152	2.78	60′
01	.573 815	3.97	.700 641	7.23	.427 264	14.72	.818 985	2.78	59
02	.574 053	3.97	.701 075	7.23	.426 381	14.70	.818 818	2.78	58
03	.574 291	3.97	.701 509	7.23	.425 499	14.70	.818 651	2.78	57
04	.574 529	3.97	.701 943	7.23	.424 617	14.68	.818 484	2.78	56
05	.574 767	3.97	.702 377	7.25	.423 736	14.67	.818 317	2.78	55
06	.575 005	3.97	.702 812	7.23	.422 856	14.65	.818 150	2.80	54
07	.575 243	3.97	.703 246	7.25	.421 977	14.65	.817 982	2.78	53
08	.575 481	3.97	.703 681	7.25	.421 098	14.63	.817 815	2.78	52
09	.575 719	3.97	.704 116	7.25	.420 220	14.62	.817 648	2.80	51
10	0.575 957	3.97	0.704 551	7.27	1.419 343	14.62	0.817 480	2.78	50
11	.576 195	3.95	.704 987	7.25	.418 466	14.60	.817 313	2.80	49
12	.576 432	3.97	.705 422	7.27	.417 590	14.58	.817 145	2.80	48
13	.576 670	3.97	.705 858	7.27	.416 715	14.57	.816 977	2.80	47
14	.576 908	3.95	.706 294	7.27	.415 841	14.57	.816 809	2.78	46
15	.577 145	3.97	.706 730	7.27	.414 967	14.55	.816 642	2.80	45
16	.577 383	3.95	.707 166	7.28	.414 094	14.53	.816 474	2.80	44
17	.577 620	3.97	.707 603	7.27	.413 222	14.52	.816 306	2.80	43
18	.577 858	3.95	.708 039	7.28	.412 351	14.52	.816 138	2.82	42
19	.578 095	3.95	.708 476	7.28	.411 480	14.50	.815 969	2.80	41
20	0.578 332	3.97	0.708 913	7.28	1.410 610	14.50	0.815 801	2.80	40
21	.578 570	3.95	.709 350	7.30	.409 740	14.47	.815 633	2.80	39
22	.578 807	3.95	.709 788	7.28	.408 872	14.47	.815 465	2.82	38
23	.579 044	3.95	.710 225	7.30	.408 004	14.45	.815 296	2.80	37
24	.579 281	3.95	.710 663	7.30	.407 137	14.45	.815 128	2.82	36
25	.579 518	3.95	.711 101	7.30	.406 270	14.43	.814 959	2.80	35
26	.579 755	3.95	.711 539	7.30	.405 404	14.42	.814 791	2.82	34
27	.579 992	3.95	.711 977	7.32	.404 539	14.40	.814 622	2.82	33
28	.580 229	3.95	.712 416	7.30	.403 675	14.40	.814 453	2.82	32
29	.580 466	3.95	.712 854	7.32	.402 811	14.38	.814 284	2.80	31
30	0.580 703	3.95	0.713 293	7.32	1.401 948	14.37	0.814 116	2.82	30
31	.580 940	3.93	.713 732	7.32	.401 086	14.37	.813 947	2.82	29
32	.581 176	3.95	.714 171	7.33	.400 224	14.35	.813 778	2.83	28
33	.581 413	3.95	.714 611	7.32	.399 364	14.35	.813 608	2.82	27
34	.581 650	3.93	.715 050	7.33	.398 503	14.32	.813 439	2.82	26
35	.581 886	3.95	.715 490	7.33	.397 644	14.32	.813 270	2.82	25
36	.582 123	3.93	.715 930	7.33	.396 785	14.30	.813 101	2.83	24
37	.582 359	3.95	.716 370	7.33	.395 927	14.28	.812 931	2.82	23
38	.582 596	3.93	.716 810	7.33	.395 070	14.28	.812 762	2.83	22
39	.582 832	3.95	.717 250	7.35	.394 213	14.27	.812 592	2.82	21
40	0.583 069	3.93	0.717 691	7.35	1.393 357	14.25	0.812 423	2.83	20
41	.583 305	3.93	.718 132	7.35	.392 502	14.25	.812 253	2.82	19
42	.583 541	3.93	.718 573	7.35	.391 647	14.23	.812 084	2.83	18
43	.583 777	3.95	.719 014	7.35	.390 793	14.22	.811 914	2.83	17
44	.584 014	3.93	.719 455	7.37	.389 940	14.20	.811 744	2.83	16
45	.584 250	3.93	.719 897	7.37	.389 088	14.20	.811 574	2.83	15
46	.584 486	3.93	.720 339	7.37	.388 236	14.18	.811 404	2.83	14
47	.584 722	3.93	.720 781	7.37	.387 385	14.18	.811 234	2.83	13
48	.584 958	3.93	.721 223	7.37	.386 534	14.17	.811 064	2.83	12
49	.585 194	3.92	.721 665	7.38	.385 684	14.15	.810 894	2.85	11
50	0.585 429	3.93	0.722 108	7.37	1.384 835	14.13	0.810 723	2.83	10
51	.585 665	3.93	.722 550	7.38	.383 987	14.13	.810 553	2.83	09
52	.585 901	3.93	.722 993	7.38	.383 139	14.12	.810 383	2.85	08
53	.586 137	3.92	.723 436	7.38	.382 292	14.10	.810 212	2.83	07
54	.586 372	3.93	.723 879	7.40	.381 446	14.10	.810 042	2.85	06
55	.586 608	3.93	.724 323	7.38	.380 600	14.08	.809 871	2.85	05
56	.586 844	3.92	.724 766	7.40	.379 755	14.07	.809 700	2.83	04
57	.587 079	3.92	.725 210	7.40	.378 911	14.07	.809 530	2.85	03
58	.587 314	3.93	.725 654	7.40	.378 067	14.05	.809 359	2.85	02
59	.587 550	3.92	.726 098	7.42	.377 224	14.03	.809 188	2.85	01
60	0.587 785		0.726 543		1.376 382		0.809 017		00
	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	

Table A-1. Natural trigonometric functions (continued)

36°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.587 785	3.93	0.726 543	7.40	1.376 382	14.03	0.809 017	2.85	60′
01	.588 021	3.92	.726 987	7.42	.375 540	14.02	.808 846	2.85	59
02	.588 256	3.92	.727 432	7.42	.374 699	14.00	.808 675	2.85	58
03	.588 491	3.92	.727 877	7.42	.373 859	14.00	.808 504	2.85	57
04	.588 726	3.92	.728 322	7.42	.373 019	13.97	.808 333	2.87	56
05	.588 961	3.92	.728 767	7.43	.372 181	13.98	.808 161	2.85	55
06	.589 196	3.92	.729 213	7.42	.371 342	13.95	.807 990	2.87	54
07	.589 431	3.92	.729 658	7.43	.370 505	13.95	.807 818	2.85	53
08	.589 666	3.92	.730 104	7.43	.369 668	13.93	.807 647	2.87	52
09	.589 901	3.92	.730 550	7.43	.368 832	13.93	.807 475	2.85	51
10	0.590 136	3.92	0.730 996	7.45	1.367 996	13.92	0.807 304	2.87	50
11	.590 371	3.92	.731 443	7.43	.367 161	13.90	.807 132	2.87	49
12	.590 606	3.90	.731 889	7.45	.366 327	13.90	.806 960	2.87	48
13	.590 840	3.92	.732 443	7.45	.365 493	13.88	.806 788	2.85	47
14	.591 075	3.92	.732 783	7.45	.364 660	13.87	.806 617	2.87	47
15	.591 310	3.90	.733 230	7.47	.363 828	13.87	.806 445	2.87	45
16	.591 544	3.92	.733 678	7.45	.362 996	13.85	.806 273	2.88	44
17	.591 779	3.90	.734 125	7.47	.362 165	13.83	.806 100	2.87	43
18	.592 013	3.92	.734 573	7.47	.361 335	13.83	.805 928	2.87	42
19	.592 248	3.90	.735 021	7.47	.360 505	13.82	.805 756	2.87	41
20	0.592 482	3.90	0.735 469	7.47	1.359 676	13.80	0.805 584	2.88	40
21	.592 716	3.92	.735 917	7.48	.358 848	13.80	.805 411	2.87	39
22	.592 951	3.90	.736 366	7.48	.358 020	13.78	.805 239	2.88	38
23	.593 185	3.90	.736 815	7.48	.357 193	13.77	.805 066	2.87	37
24	.593 419	3.90	.737 264	7.48	.356 367	13.77	.804 894	2.88	36
25	.593 653	3.90	.737 713	7.48	.355 541	13.75	.804 721	2.88	35
26	.593 887	3.90	.738 162	7.48	.354 716	13.73	.804 548	2.87	34
27	.594 121	3.90	.738 611	7.50	.353 892	13.73	.804 376	2.88	33
28	.594 355	3.90	.739 061	7.50	.353 068	13.72	.804 203	2.88	32
29	.594 589	3.90	.739 511	7.50	.352 245	13.72	.804 030	2.88	31
30	0.594 823	3.90	.739 961	7.50	1.351 422	13.68	0.803 857	2.88	30
31	.595 057	3.88	.740 411	7.52	.350 601	13.70	.803 684	2.88	29
32	.595 290	3.90	.740 862	7.50	.349 779	13.67	.803 511	2.90	28
33	.595 524	3.90	.741 312	7.52	.348 959	13.67	.803 337	2.88	27
34	.595 758	3.88	.741 763	7.52	.348 139	13.65	.803 164	2.88	26
35	.595 991	3.90	.742 214	7.53	.347 320	13.65	.802 991	2.90	25
36	.596 225	3.88	.742 666	7.52	.346 501	13.63	.802 817	2.88	24
37	.596 458	3.90	.743 117	7.53	.345 683	13.62	.902 644	2.90	23
38	.596 692	3.88	.743 569	7.52	.344 866	13.62	.802 470	2.88	22
39	.596 925	3.90	.744 020	7.53	.344 049	13.60	.802 297	2.90	21
40	0.597 159	3.88	0.744 472	7.55	1.343 233	13.58	0.802 123	2.90	20
41	.597 392	3.88	.744 925	7.53	.342 418	13.58	.801 949	2.88	19
42	.597 625	3.88	.745 377	7.55	.341 603	13.57	.801 776	2.90	18
43	.597 858	3.88	.745 830	7.53	.340 789	13.57	.801 602	2.90	17
44	.598 091	3.90	.746 282	7.55	.339 975	13.55	.801 428	2.90	16
45	.598 325	3.88	.746 735	7.57	.339 162	13.53	.801 254	2.90	15
46	.598 558	3.88	.747 189	7.55	.338 350	13.52	.801 080	2.90	14
47	.598 791	3.88	.747 642	7.57	.337 539	13.52	.800 906	2.92	13
48	.599 024	3.87	.748 096	7.55	.336 728	13.52	.800 731	2.90	12
49	.599 256	3.88	.748 549	7.57	.335 917	13.48	.800 557	2.90	11
50	0.599 489	3.88	0.749 003	7.58	1.335 108	13.50	0.800 383	2.92	10
51	.599 722	3.88	.749 458	7.57	.334 298	13.47	.800 208	2.90	09
52	.599 955	3.88	.749 912	7.57	.333 490	13.47	.800 034	2.92	08
53	.600 188	3.87	.750 366	7.58	.332 682	13.45	.799 859	2.90	07
54	.600 653	3.87	.751 276	7.58	.331 068	13.43	.799 510	2.92	06
55	.600 420	3.88	.750 821	7.58	.311 875	13.45	.799 685	2.92	05
56	.600 885	3.88	.751 731	7.60	.330 262	13.42	.799 335	2.92	04
57	.601 118	3.87	.752 187	7.58	.329 457	13.42	.799 160	2.92	03
58	.601 350	3.88	.752 642	7.60	.328 652	13.40	.798 985	2.90	02
59	.601 583	3.87	.753 098	7.60	.327 848	13.38	.798 811	2.92	01
60	0.601 815		0.753 554		1.327 045		0.798 636		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

37°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.601 815	3.87	0.753 554	7.60	1.327 045	13.38	0.798 636	2.93	60′
01	.602 047	3.88	.754 010	7.62	.326 242	13.37	.798 460	2.92	59
02	.602 280	3.87	.754 467	7.60	.325 440	13.37	.798 285	2.92	58
03	.602 512	3.87	.754 923	7.62	.324 638	13.35	.798 110	2.92	57
04	.602 744	3.87	.755 380	7.62	.323 837	13.33	.797 935	2.93	56
05	.602 976	3.87	.755 837	7.62	.323 037	13.33	.797 759	2.92	55
06	.603 208	3.87	.756 294	7.62	.322 237	13.32	.797 584	2.93	54
07	.603 440	3.87	.756 751	7.63	.321 438	13.32	.797 408	2.92	53
08	.603 672	3.87	.757 209	7.63	.320 639	13.30	.797 233	2.93	52
09	.603 904	3.87	.757 667	7.63	.319 841	13.28	.797 057	2.92	51
10	0.604 136	3.85	0.758 125	7.63	1.319 044	13.28	0.796 882	2.93	50
11	.604 367	3.87	.758 583	7.63	.318 247	13.27	.796 706	2.93	49
12	.604 599	3.87	.759 041	7.65	.317 451	13.25	.796 530	2.93	48
13	.604 831	3.85	.759 500	7.65	.316 656	13.25	.796 354	2.93	47
14	.605 062	3.87	.759 959	7.65	.315 861	13.23	.796 178	2.93	46
15	.605 294	3.87	.760 418	7.65	.315 067	13.23	.796 002	2.93	45
16	.605 526	3.85	.760 877	7.65	.314 273	13.22	.795 826	2.93	44
17	.605 757	3.85	.761 336	7.67	.313 480	13.20	.795 650	2.95	43
18	.605 988	3.87	.761 796	7.67	.312 688	13.20	.795 473	2.93	42
19	.606 220	3.85	.762 256	7.67	.311 896	13.18	.795 297	2.93	41
20	0.606 451	3.85	0.762 716	7.67	1.311 105	13.18	0.795 121	2.95	40
21	.606 682	3.87	.763 176	7.67	.310 314	13.17	.794 944	2.93	39
22	.606 914	3.85	.763 636	7.68	.309 524	13.15	.794 768	2.95	38
23	.607 145	3.85	.764 097	7.68	.308 735	13.15	.794 591	2.93	37
24	.607 376	3.85	.764 558	7.68	.307 946	13.15	.794 415	2.95	36
25	.607 607	3.85	.765 019	7.68	.307 157	13.12	.794 238	2.95	35
26	.607 838	3.85	.765 480	7.68	.306 370	13.12	.794 061	2.95	34
27	.608 069	3.85	.765 941	7.70	.305 583	13.12	.793 884	2.95	33
28	.608 300	3.85	.766 403	7.70	.304 796	13.08	.793 707	2.95	32
29	.608 531	3.83	.766 865	7.70	.304 011	13.10	.793 530	2.95	31
30	0.608 761	3.85	0.767 327	7.70	1.303 225	13.07	0.793 353	2.95	30
31	.608 992	3.85	.767 789	7.72	.302 441	13.07	.793 176	2.95	29
32	.609 223	3.85	.768 252	7.70	.301 657	13.07	.792 999	2.95	28
33	.609 454	3.83	.768 714	7.72	.300 873	13.05	.792 822	2.97	27
34	.609 684	3.85	.769 177	7.72	.300 090	13.03	.792 644	2.95	26
35	.609 915	3.83	.769 640	7.73	.299 308	13.03	.792 467	2.95	25
36	.610 145	3.85	.770 104	7.72	.298 526	13.02	.792 290	2.97	24
37	.610 376	3.83	.770 567	7.73	.297 745	13.00	.792 112	2.95	23
38	.610 606	3.83	.771 031	7.73	.296 965	13.00	.791 935	2.97	22
39	.610 836	3.85	.771 495	7.73	.296 185	12.98	.791 757	2.97	21
40	0.611 067	3.83	0.771 959	7.73	1.295 406	12.98	0.791 579	2.97	20
41	.611 297	3.83	.772 423	7.75	.294 627	12.97	.791 401	2.95	19
42	.611 527	3.83	.772 888	7.75	.293 849	12.97	.791 224	2.97	18
43	.611 757	3.83	.773 353	7.75	.293 071	12.95	.791 046	2.97	17
44	.611 987	3.83	.773 818	7.75	.292 294	12.93	.790 868	2.97	16
45	.612 217	3.83	.774 283	7.75	.291 518	12.93	.790 690	2.97	15
46	.612 447	3.83	.774 748	7.77	.290 742	12.92	.790 511	2.97	14
47	.612 677	3.83	.775 214	7.77	.289 967	12.92	.790 333	2.97	13
48	.612 907	3.83	.775 680	7.77	.289 192	12.90	.790 155	2.97	12
49	.613 137	3.83	.776 146	7.77	.288 418	12.88	.789 977	2.98	11
50	0.613 367	3.82	0.776 612	7.77	1.287 645	12.88	0.789 798	2.97	10
51	.613 598	3.83	.777 078	7.78	.286 872	12.88	.789 620	2.98	09
52	.613 826	3.83	.777 545	7.78	.286 099	12.85	.789 441	2.98	08
53	.614 056	3.82	.778 012	7.78	.285 328	12.85	.789 263	2.98	07
54	.614 285	3.83	.778 479	7.78	.284 557	12.85	.789 084	2.98	06
55	.614 515	3.82	.778 946	7.80	.283 786	12.83	.788 905	2.97	05
56	.614 744	3.83	.779 414	7.78	.283 016	12.82	.788 727	2.98	04
57	.614 974	3.82	.779 881	7.80	.282 247	12.82	.788 548	2.98	03
58	.615 203	3.82	.780 349	7.80	.281 478	12.82	.788 369	2.98	02
59	.615 432	3.82	.780 817	7.82	.280 709	12.78	.788 190	2.98	01
60	0.615 661		0.781 286		1.279 942		0.788 011		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

38°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.615 661	3.83	0.781 286	7.80	1.279 942	12.78	0.788 011	2.98	60'
01	.615 891	3.82	.781 754	7.82	.279 174	12.77	.787 832	3.00	59
02	.616 120	3.82	.782 223	7.82	.278 408	12.77	.787 652	2.98	58
03	.616 349	3.82	.782 692	7.82	.277 642	12.77	.787 473	2.98	57
04	.616 578	3.82	.783 161	7.83	.276 876	12.73	.787 294	3.00	56
05	.616 807	3.82	.783 631	7.82	.276 112	12.75	.787 114	2.98	55
06	.617 036	3.82	.784 100	7.83	.275 347	12.72	.786 935	2.98	54
07	.617 265	3.82	.784 570	7.83	.274 584	12.73	.785 756	3.00	53
08	.617 494	3.80	.785 040	7.83	.273 820	12.70	.786 576	3.00	52
09	.617 722	3.82	.785 510	7.85	.273 058	12.70	.786 296	2.98	51
10	0.617 951	3.82	0.785 981	7.83	1.272 296	12.70	0.786 217	3.00	50
11	.618 180	3.80	.786 451	7.85	.271 534	12.68	.786 037	3.00	49
12	.618 408	3.82	.786 922	7.87	.270 773	12.67	.785 857	3.00	48
13	.618 637	3.80	.787 394	7.85	.270 013	12.67	.785 677	3.00	47
14	.618 865	3.82	.787 865	7.85	.269 253	12.65	.785 497	3.00	46
15	.619 094	3.80	.788 336	7.87	.268 494	12.65	.785 317	3.00	45
16	.619 322	3.82	.788 808	7.87	.267 735	12.63	.785 137	3.00	44
17	.619 551	3.80	.789 280	7.87	.266 977	12.62	.784 957	3.02	43
18	.619 779	3.80	.789 752	7.88	.266 220	12.62	.784 776	3.00	42
19	.620 007	3.80	.790 225	7.87	.265 463	12.62	.784 596	3.00	41
20	0.620 235	3.82	0.790 697	7.88	1.264 706	12.60	0.784 416	3.02	40
21	.620 464	3.80	.791 170	7.88	.263 950	12.58	.784 235	3.00	39
22	.620 692	3.80	.791 643	7.90	.263 195	12.58	.784 055	3.02	38
23	.620 920	3.80	.792 117	7.88	.262 440	12.57	.783 874	3.02	37
24	.621 148	3.80	.792 590	7.90	.261 686	12.57	.783 693	3.00	36
25	.621 376	3.80	.793 064	7.90	.260 932	12.55	.783 513	3.02	35
26	.621 604	3.78	.793 538	7.90	.260 179	12.53	.783 332	3.02	34
27	.621 831	3.80	.794 012	7.90	.259 427	12.53	.783 151	3.02	33
28	.622 059	3.80	.794 486	7.92	.258 675	12.53	.782 970	3.02	32
29	.622 287	3.80	.794 961	7.92	.257 923	12.52	.782 789	3.02	31
30	0.622 515	3.78	0.795 436	7.92	1.257 172	12.50	0.782 608	3.02	30
31	.622 742	3.80	.795 911	7.92	.256 422	12.50	.782 427	3.02	29
32	.622 970	3.78	.796 386	7.93	.255 672	12.48	.782 246	3.02	28
33	.623 197	3.80	.796 862	7.92	.254 923	12.48	.782 065	3.03	27
34	.623 425	3.78	.797 337	7.93	.254 174	12.47	.781 883	3.02	26
35	.623 652	3.80	.797 813	7.95	.253 426	12.47	.781 702	3.03	25
36	.623 880	3.78	.798 290	7.93	.252 678	12.45	.781 520	3.02	24
37	.624 107	3.78	.798 766	7.93	.251 931	12.43	.781 339	3.03	23
38	.624 334	3.78	.799 242	7.95	.251 185	12.43	.781 157	3.02	22
39	.624 561	3.80	.799 719	7.95	.250 439	12.43	.780 976	3.03	21
40	0.624 789	3.78	0.800 196	7.97	1.249 693	12.42	0.780 794	3.03	20
41	.625 016	3.78	.800 674	7.95	.248 948	12.40	.780 612	3.03	19
42	.625 243	3.78	.801 151	7.97	.248 204	12.40	.780 430	3.03	18
43	.625 470	3.78	.801 629	7.97	.247 460	12.38	.780 248	3.02	17
44	.625 697	3.77	.802 107	7.97	.246 717	12.38	.780 067	3.05	16
45	.625 923	3.78	.802 585	7.97	.245 974	12.37	.779 884	3.03	15
46	.626 150	3.78	.803 063	7.98	.245 232	12.37	.779 702	3.03	14
47	.626 377	3.78	.803 542	7.98	.244 490	12.35	.779 520	3.03	13
48	.626 604	3.77	.804 021	7.98	.243 749	12.33	.779 338	3.03	12
49	.626 830	3.78	.804 500	7.98	.243 009	12.35	.779 156	3.05	11
50	0.627 057	3.78	0.804 979	7.98	1.242 268	12.32	0.778 973	3.03	10
51	.627 284	3.77	.805 458	8.00	.241 529	12.32	.778 791	3.05	09
52	.627 510	3.78	.805 938	8.00	.240 790	12.30	.778 608	3.03	08
53	.627 737	3.77	.806 418	8.00	.240 052	12.30	.778 426	3.05	07
54	.627 963	3.77	.806 898	8.02	.239 314	12.30	.778 243	3.05	06
55	.628 189	3.78	.807 379	8.00	.238 576	12.28	.778 060	3.03	05
56	.628 416	3.77	.807 859	8.02	.237 839	12.27	.777 878	3.05	04
57	.628 642	3.77	.808 340	8.02	.237 103	12.27	.777 695	3.05	03
58	.628 868	3.77	.808 821	8.03	.236 367	12.25	.777 512	3.05	02
59	.629 094	3.77	.809 303	8.02	.235 632	12.25	.777 329	3.05	01
60	0.629 320		0.809 784		1.234 897		0.777 146		00
	Cos	d."	Cot		d."	Tan	d."	Sin	d."

Table A-1. Natural trigonometric functions (continued)

39°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.629 320	3.77	0.809 784	8.03	1.234 897	12.23	0.777 146	3.05	60'
01	.629 546	3.77	.810 266	8.03	.234 163	12.23	.776 963	3.05	59
02	.629 772	3.77	.810 748	8.03	.233 429	12.22	.776 780	3.07	58
03	.629 998	3.77	.811 230	8.03	.232 696	12.22	.776 596	3.05	57
04	.630 224	3.77	.811 712	8.05	.231 963	12.20	.776 413	3.95	56
05	.630 450	3.77	.812 195	8.05	.231 231	12.18	.776 230	3.07	55
06	.630 676	3.77	.812 678	8.05	.230 500	12.18	.776 046	3.05	54
07	.630 902	3.75	.813 161	8.05	.229 769	12.18	.775 863	3.07	53
08	.631 127	3.77	.813 644	8.07	.229 038	12.17	.775 679	3.05	52
09	.631 353	3.75	.814 128	8.07	.228 308	12.15	.775 496	3.07	51
10	0.631 578	3.77	0.814 612	8.07	1.227 579	12.15	0.775 312	3.07	50
11	.631 804	3.75	.815 096	8.07	.226 850	12.15	.775 128	3.07	49
12	.632 029	3.77	.815 580	8.08	.226 121	12.13	.774 944	3.05	48
13	.632 255	3.75	.816 065	8.07	.225 393	12.12	.774 761	3.07	47
14	.632 480	3.75	.816 549	8.08	.224 666	12.12	.774 577	3.07	46
15	.632 705	3.77	.817 034	8.08	.223 939	12.12	.774 393	3.07	45
16	.632 931	3.75	.817 519	8.10	.223 212	12.08	.774 209	3.08	44
17	.633 156	3.75	.818 005	8.10	.222 487	12.10	.774 024	3.07	43
18	.633 381	3.75	.818 491	8.08	.221 761	12.08	.773 840	3.07	42
19	.633 606	3.75	.818 976	8.12	.221 036	12.07	.773 656	3.07	41
20	0.633 831	3.75	0.819 463	8.10	1.220 312	12.07	0.773 472	3.08	40
21	.634 056	3.75	.819 949	8.10	.219 588	12.05	.773 287	3.07	39
22	.634 281	3.75	.820 435	8.12	.218 865	12.05	.773 103	3.08	38
23	.634 506	3.75	.820 922	8.12	.218 142	12.03	.772 918	3.07	37
24	.634 731	3.73	.821 409	8.13	.217 420	12.03	.772 734	3.08	36
25	.634 955	3.75	.821 897	8.12	.216 698	12.02	.772 549	3.08	35
26	.635 180	3.75	.822 384	8.13	.215 977	12.02	.772 364	3.08	34
27	.635 405	3.73	.822 872	8.13	.215 256	12.00	.772 179	3.07	33
28	.635 629	3.75	.823 360	8.13	.214 536	12.00	.771 995	3.08	32
29	.635 854	3.73	.823 848	8.13	.213 816	11.98	.771 810	3.08	31
30	0.636 078	3.75	0.824 336	8.15	1.213 097	11.98	0.771 625	3.08	30
31	.636 303	3.73	.824 825	8.15	.212 378	11.97	.771 440	3.10	29
32	.636 527	3.73	.825 314	8.15	.211 660	11.97	.771 254	3.08	28
33	.636 751	3.75	.825 803	8.15	.210 942	11.95	.771 069	3.08	27
34	.636 976	3.73	.826 292	8.17	.210 225	11.93	.770 884	3.08	26
35	.637 200	3.73	.826 782	8.17	.209 509	11.95	.770 699	3.10	25
36	.637 424	3.73	.827 272	8.17	.208 792	11.92	.770 513	3.08	24
37	.637 648	3.73	.827 762	8.17	.208 077	11.92	.770 328	3.10	23
38	.637 872	3.73	.828 252	8.18	.207 362	11.92	.770 142	3.08	22
39	.638 096	3.73	.828 743	8.18	.206 647	11.90	.769 957	3.10	21
40	0.638 320	3.73	0.829 234	8.18	1.205 933	11.90	0.769 771	3.10	20
41	.638 544	3.73	.829 725	8.18	.205 219	11.88	.769 585	3.08	19
42	.638 768	3.73	.830 216	8.18	.204 506	11.88	.769 400	3.10	18
43	.638 992	3.72	.830 707	8.20	.203 793	11.87	.769 214	3.10	17
44	.639 215	3.73	.831 199	8.20	.203 081	11.87	.769 028	3.10	16
45	.639 439	3.73	.831 691	8.20	.202 369	11.85	.768 842	3.10	15
46	.639 663	3.72	.832 183	8.22	.201 658	11.85	.768 656	3.10	14
47	.639 886	3.73	.832 676	8.22	.200 947	11.83	.768 470	3.10	13
48	.640 110	3.72	.833 169	8.22	.200 237	11.82	.768 284	3.12	12
49	.640 333	3.73	.833 662	8.22	.199 528	11.83	.768 097	3.10	11
50	0.640 557	3.72	0.834 155	8.22	1.198 818	11.80	0.767 911	3.10	10
51	.640 780	3.72	.834 648	8.23	.198 110	11.80	.767 725	3.12	09
52	.641 003	3.72	.835 142	8.23	.197 402	11.80	.767 538	3.10	08
53	.641 226	3.73	.835 636	8.23	.196 694	11.78	.767 352	3.12	07
54	.641 450	3.72	.836 130	8.23	.195 987	11.78	.767 165	3.10	06
55	.641 673	3.72	.836 624	8.25	.195 280	11.77	.766 979	3.12	05
56	.641 896	3.72	.837 119	8.25	.194 574	11.77	.766 792	3.12	04
57	.642 119	3.72	.837 614	8.25	.193 868	11.75	.766 605	3.12	03
58	.642 342	3.72	.838 109	8.25	.193 163	11.75	.766 418	3.12	02
59	.642 565	3.72	.838 604	8.27	.192 458	11.73	.766 231	3.12	01
60	0.642 788		0.839 100		1.191 754		0.766 044		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

40°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00'	0.642 788	3.70	0.839 100	8.25	1.191 754	11.73	0.766 044	3.12	60'
01	.643 010	3.72	.839 595	8.28	.191 050	11.72	.765 857	3.12	59
02	.643 233	3.72	.840 092	8.27	.190 347	11.72	.765 670	3.12	58
03	.643 456	3.72	.840 588	8.27	.189 644	11.72	.765 483	3.12	57
04	.643 679	3.70	.841 084	8.28	.188 941	11.68	.765 296	3.12	56
05	.643 901	3.72	.841 581	8.28	.188 240	11.70	.765 109	3.13	55
06	.644 124	3.70	.842 078	8.28	.187 538	11.68	.764 921	3.12	54
07	.644 346	3.72	.842 575	8.30	.186 837	11.67	.764 734	3.12	53
08	.644 569	3.70	.843 073	8.30	.186 137	11.67	.764 547	3.13	52
09	.644 791	3.70	.843 571	8.30	.185 437	11.65	.764 359	3.13	51
10	0.645 013	3.70	0.844 069	8.30	.184 738	11.65	0.764 171	3.12	50
11	.645 235	3.72	.844 567	8.32	.184 039	11.65	.763 984	3.13	49
12	.645 458	3.70	.845 066	8.30	.183 340	11.63	.763 796	3.13	48
13	.645 680	3.70	.845 680	8.32	.182 642	11.62	.763 608	3.13	47
14	.645 902	3.70	.846 063	8.32	.181 945	11.62	.763 420	3.13	46
15	.646 124	3.70	.846 562	8.33	.181 248	11.62	.763 232	3.13	45
16	.646 346	3.70	.847 062	8.33	.180 551	11.60	.763 044	3.13	44
17	.646 568	3.70	.847 562	8.33	.179 855	11.58	.762 856	3.13	43
18	.646 790	3.70	.848 062	8.33	.179 160	11.60	.762 668	3.13	42
19	.647 012	3.68	.848 562	8.33	.178 464	11.57	.762 480	3.13	41
20	0.647 233	3.70	0.849 062	8.35	1.177 770	11.57	0.762 292	3.13	40
21	.647 455	3.70	.849 563	8.35	.177 076	11.57	.762 104	3.15	39
22	.647 677	3.68	.850 064	8.35	.176 382	11.55	.761 915	3.13	38
23	.647 898	3.70	.850 565	8.37	.175 689	11.55	.761 727	3.15	37
24	.648 120	3.68	.851 067	8.35	.174 996	11.53	.761 538	3.13	36
25	.648 341	3.70	.851 568	8.37	.174 304	11.53	.761 350	3.15	35
26	.648 563	3.68	.852 070	8.38	.173 612	11.52	.761 161	3.15	34
27	.648 784	3.70	.852 573	8.37	.172 921	11.52	.760 972	3.13	33
28	.649 006	3.68	.853 075	8.38	.172 230	11.52	.760 784	3.15	32
29	.649 227	3.68	.853 578	8.38	.171 539	11.48	.760 595	3.15	31
30	0.649 448	3.68	0.854 081	8.38	1.170 850	11.50	0.760 406	3.15	30
31	.649 669	3.68	.854 584	8.38	.170 160	11.48	.760 217	3.15	29
32	.649 890	3.68	.855 087	8.40	.169 471	11.47	.760 028	3.15	28
33	.650 111	3.68	.855 591	8.40	.168 783	11.47	.759 839	3.15	27
34	.650 332	3.68	.856 095	8.40	.168 095	11.47	.759 650	3.15	26
35	.650 553	3.68	.856 599	8.42	.167 407	11.45	.759 461	3.17	25
36	.650 774	3.68	.857 104	8.40	.166 720	11.45	.759 271	3.15	24
37	.650 995	3.68	.857 608	8.42	.166 033	11.43	.759 082	3.15	23
38	.651 216	3.68	.858 113	8.43	.165 347	11.42	.758 893	3.17	22
39	.651 437	3.67	.858 619	8.42	.164 662	11.43	.758 703	3.15	21
40	0.651 657	3.68	0.859 124	8.43	1.163 976	11.40	0.758 514	3.17	20
41	.651 878	3.67	.859 630	8.43	.163 292	11.42	.758 324	3.17	19
42	.652 098	3.68	.860 136	8.43	.162 607	11.40	.758 134	3.15	18
43	.652 319	3.67	.860 642	8.43	.161 923	11.38	.757 945	3.17	17
44	.652 539	3.68	.861 148	8.45	.161 240	11.38	.757 755	3.17	16
45	.652 760	3.67	.861 655	8.45	.160 557	11.37	.757 565	3.17	15
46	.652 980	3.67	.862 162	8.45	.159 875	11.37	.757 375	3.17	14
47	.653 200	3.68	.862 669	8.47	.159 193	11.37	.757 185	3.17	13
48	.653 421	3.67	.863 177	8.47	.158 511	11.35	.756 995	3.17	12
49	.653 641	3.67	.863 685	8.47	.157 830	11.35	.756 805	3.17	11
50	0.653 861	3.67	0.864 193	8.47	1.157 149	11.33	0.756 615	3.17	10
51	.654 081	3.67	.864 701	8.47	.156 469	11.32	.756 425	3.18	09
52	.654 301	3.67	.865 209	8.48	.155 790	11.33	.756 234	3.17	08
53	.654 521	3.67	.865 718	8.48	.155 110	11.28	.756 044	3.18	07
54	.654 741	3.67	.866 227	8.48	.154 432	11.32	.755 853	3.17	06
55	.654 961	3.65	.866 736	8.50	.153 753	11.30	.755 663	3.18	05
56	.655 180	3.67	.867 246	8.50	.153 075	11.28	.755 472	3.17	04
57	.655 400	3.67	.867 756	8.50	.152 398	11.28	.755 282	3.18	03
58	.655 620	3.65	.868 266	8.50	.151 721	11.28	.755 091	3.18	02
59	.655 839	3.67	.868 776	8.52	.151 044	11.27	.754 900	3.17	01
60	0.656 059		0.869 287		1.150 368		0.754 710		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

41°

	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	
00′	0.656 059	3.67	0.869 287	8.52	1.150 368	11.25	0.754 710	3.18	60′
01	.656 279	3.65	.869 798	8.52	.149 693	11.25	.754 519	3.18	59
02	.656 498	3.65	.870 309	8.52	.149 018	11.25	.754 328	3.18	58
03	.656 717	3.67	.870 820	8.53	.148 343	11.23	.754 137	3.18	57
04	.656 937	3.65	.871 332	8.52	.147 669	11.23	.753 946	3.18	56
05	.657 156	3.65	.871 843	8.55	.146 995	11.22	.753 755	3.20	55
06	.657 375	3.65	.872 356	8.53	.146 322	11.22	.753 563	3.18	54
07	.657 594	3.67	.872 868	8.55	.145 649	11.22	.753 372	3.18	53
08	.657 814	3.65	.873 381	8.55	.144 976	11.20	.753 181	3.20	52
09	.658 033	3.65	.873 894	8.55	.144 304	11.18	.752 989	3.18	51
10	0.658 252	3.65	0.874 407	8.55	1.143 633	11.20	0.752 798	3.20	50
11	.658 471	3.63	.874 920	8.57	.142 961	11.17	.752 606	3.18	49
12	.658 689	3.65	.875 434	8.57	.142 291	11.17	.752 415	3.20	48
13	.658 908	3.65	.875 948	8.57	.141 621	11.17	.752 223	3.18	47
14	.659 127	3.65	.876 462	8.57	.140 951	11.17	.752 032	3.20	46
15	.659 346	3.63	.876 976	8.58	.140 281	11.13	.751 840	3.20	45
16	.659 564	3.65	.877 491	8.58	.139 613	11.15	.751 648	3.20	44
17	.659 783	3.65	.878 006	8.58	.138 944	11.13	.751 456	3.20	43
18	.660 002	3.63	.878 521	8.60	.138 276	11.12	.751 264	3.20	42
19	.660 220	3.65	.879 037	8.60	.137 609	11.13	.751 072	3.20	41
20	0.660 439	3.63	0.879 553	8.60	1.136 941	11.10	0.750 880	3.20	40
21	.660 657	3.63	.880 069	8.60	.136 275	11.10	.750 688	3.20	39
22	.660 875	3.65	.880 585	8.62	.135 609	11.10	.750 496	3.22	38
23	.661 094	3.63	.881 102	8.62	.134 943	11.10	.750 303	3.20	37
24	.661 312	3.63	.881 619	8.62	.134 277	11.08	.750 111	3.20	36
25	.661 530	3.63	.882 136	8.62	.133 612	11.07	.749 919	3.22	35
26	.661 748	3.63	.882 653	8.63	.132 948	11.07	.749 726	3.20	34
27	.661 966	3.63	.883 171	8.63	.132 284	11.07	.749 534	3.22	33
28	.662 184	3.63	.883 689	8.63	.131 620	11.05	.749 341	3.22	32
29	.662 402	3.63	.884 207	8.63	.130 957	11.05	.749 148	3.20	31
30	0.662 620	3.63	0.884 725	8.65	1.130 294	11.03	0.748 956	3.22	30
31	.662 838	3.63	.885 244	8.65	.129 632	11.03	.748 763	3.22	29
32	.663 056	3.62	.885 763	8.65	.128 970	11.02	.748 570	3.22	28
33	.663 273	3.63	.886 282	8.67	.128 309	11.02	.748 377	3.22	27
34	.663 491	3.63	.886 802	8.65	.127 648	11.02	.748 184	3.22	26
35	.663 709	3.62	.887 321	8.68	.126 987	11.00	.747 991	3.22	25
36	.663 926	3.63	.887 842	8.67	.126 327	11.00	.747 798	3.22	24
37	.664 144	3.62	.888 362	8.67	.125 667	10.98	.747 605	3.22	23
38	.664 361	3.63	.888 882	8.68	.125 008	10.98	.747 412	3.23	22
39	.664 579	3.62	.889 403	8.68	.124 349	10.97	.747 218	3.22	21
40	0.664 796	3.62	0.889 924	8.70	1.123 691	10.97	0.747 025	3.22	20
41	.665 013	3.62	.890 446	8.68	.123 033	10.97	.746 832	3.23	19
42	.665 230	3.63	.890 967	8.70	.122 375	10.95	.746 638	3.22	18
43	.665 448	3.62	.891 489	8.72	.121 718	10.93	.746 445	3.23	17
44	.665 665	3.62	.892 012	8.70	.121 062	10.95	.746 251	3.23	16
45	.665 882	3.62	.892 534	8.72	.120 405	10.92	.746 057	3.22	15
46	.666 099	3.62	.893 057	8.72	.119 750	10.93	.745 864	3.23	14
47	.666 316	3.60	.893 580	8.72	.119 094	10.92	.745 670	3.23	13
48	.666 532	3.62	.894 103	8.73	.118 439	10.90	.745 476	3.23	12
49	.666 749	3.62	.894 627	8.73	.117 785	10.92	.745 282	3.23	11
50	0.666 966	3.62	0.895 151	8.73	1.117 130	10.88	0.745 088	3.23	10
51	.667 183	3.60	.895 675	8.73	.116 477	10.90	.744 894	3.23	09
52	.667 399	3.62	.896 199	8.75	.115 823	10.87	.744 700	3.23	08
53	.667 616	3.62	.896 724	8.75	.115 171	10.88	.744 506	3.23	07
54	.667 833	3.60	.897 249	8.75	.114 518	10.87	.744 312	3.25	06
55	.668 049	3.60	.897 774	8.75	.113 866	10.85	.744 117	3.23	05
56	.668 265	3.62	.898 299	8.77	.113 215	10.87	.743 923	3.25	04
57	.668 482	3.60	.898 825	8.77	.112 563	10.83	.743 728	3.23	03
58	.668 698	3.60	.899 351	8.77	.111 913	10.85	.743 534	3.25	02
59	.668 914	3.62	.899 877	8.78	.111 262	10.82	.743 339	3.23	01
60	0.669 131		0.900 404		1.110 613		0.743 145		00
	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	

Table A-1. Natural trigonometric functions (continued)

42°

	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	
00′	0.669 131	3.60	0.900 404	8.78	1.110 613	10.83	0.743 145	3.25	60′
01	.669 347	3.60	.900 931	8.78	.109 963	10.82	.742 950	3.25	59
02	.669 563	3.60	.901 458	8.78	.109 314	10.82	.742 755	3.23	58
03	.669 779	3.60	.901 985	8.80	.108 665	10.80	.742 561	3.25	57
04	.669 995	3.60	.902 513	8.80	.108 017	10.80	.742 366	3.25	56
05	.670 211	3.60	.903 041	8.80	.107 369	10.78	.742 171	3.25	55
06	.670 427	3.58	.903 569	8.82	.106 722	10.78	.741 976	3.25	54
07	.670 642	3.60	.904 098	8.82	.106 075	10.78	.741 781	3.25	53
08	.670 858	3.60	.904 627	8.82	.105 428	10.77	.741 586	3.25	52
09	.671 074	3.58	.905 156	8.82	.104 782	10.75	.741 391	3.27	51
10	.671 289	3.60	0.905 685	8.83	1.104 137	10.77	0.741 195	3.25	50
11	.671 505	3.60	.906 215	8.83	.103 491	10.75	.741 000	3.25	49
12	.671 721	3.58	.906 745	8.83	.102 846	10.73	.740 805	3.27	48
13	.671 936	3.58	.907 275	8.83	.102 202	10.73	.740 609	3.25	47
14	.672 151	3.60	.907 805	8.85	.101 558	10.73	.740 414	3.27	46
15	.672 367	3.58	.908 336	8.85	.100 914	10.72	.740 218	3.25	45
16	.672 582	3.58	.908 867	8.85	.100 271	10.72	.740 023	3.27	44
17	.672 797	3.60	.909 398	8.87	.099 628	10.70	.739 827	3.27	43
18	.673 013	3.58	.909 930	8.87	.098 986	10.70	.739 631	3.27	42
19	.673 228	3.58	.910 462	8.87	.098 344	10.70	.739 435	3.27	41
20	0.673 443	3.58	0.910 994	8.87	1.097 702	10.68	0.739 239	3.27	40
21	.673 658	3.58	.911 526	8.88	.097 061	10.68	.739 043	3.25	39
22	.673 873	3.58	.912 059	8.88	.096 420	10.67	.738 848	3.28	38
23	.674 088	3.57	.912 592	8.88	.095 780	10.67	.738 651	3.27	37
24	.674 302	3.58	.913 125	8.90	.095 140	10.67	.738 455	3.27	36
25	.674 517	3.58	.913 659	8.90	.094 500	10.65	.738 259	3.27	35
26	.674 732	3.58	.914 193	8.90	.093 861	10.65	.738 063	3.27	34
27	.674 947	3.57	.914 727	8.90	.093 222	10.63	.737 867	3.28	33
28	.675 161	3.58	.915 261	8.92	.092 584	10.63	.737 670	3.27	32
29	.675 376	3.57	.915 796	8.92	.091 946	10.62	.737 474	3.28	31
30	0.675 590	3.58	0.916 331	8.92	1.091 309	10.63	0.737 277	3.27	30
31	.675 805	3.57	.916 866	8.93	.090 671	10.60	.737 081	3.28	29
32	.676 019	3.57	.917 402	8.93	.090 035	10.62	.736 884	3.28	28
33	.676 233	3.58	.917 938	8.93	.089 398	10.60	.736 687	3.27	27
34	.676 448	3.57	.918 474	8.93	.088 762	10.58	.736 491	3.28	26
35	.676 662	3.57	.919 010	8.95	.088 127	10.58	.736 294	3.28	25
36	.676 876	3.57	.919 547	8.95	.087 492	10.58	.736 097	3.28	24
37	.677 090	3.57	.920 084	8.95	.086 857	10.57	.735 900	3.28	23
38	.677 304	3.57	.920 621	8.97	.086 223	10.57	.735 703	3.28	22
39	.677 518	3.57	.921 159	8.97	.085 589	10.57	.735 506	3.28	21
40	0.677 732	3.57	0.921 697	8.97	1.084 955	10.55	0.735 309	3.28	20
41	.677 946	3.57	.922 235	8.97	.084 322	10.53	.735 112	3.28	19
42	.678 160	3.55	.922 773	8.98	.083 690	10.55	.734 915	3.30	18
43	.678 373	3.57	.923 312	8.98	.083 057	10.53	.734 717	3.28	17
44	.678 587	3.57	.923 851	8.98	.082 425	10.52	.734 520	3.28	16
45	.678 801	3.55	.924 390	9.00	.081 794	10.52	.734 323	3.30	15
46	.679 014	3.57	.924 930	9.00	.081 163	10.52	.734 125	3.30	14
47	.679 228	3.55	.925 470	9.00	.080 532	10.50	.733 927	3.28	13
48	.679 441	3.57	.926 010	9.02	.079 902	10.50	.733 720	3.30	12
49	.679 655	3.55	.926 551	9.00	.079 272	10.50	.733 530	3.30	11
50	0.679 868	3.55	0.927 091	9.02	1.078 642	10.48	0.733 334	3.28	10
51	.680 081	3.57	.927 632	9.03	.078 013	10.48	.733 137	3.30	09
52	.680 295	3.55	.928 174	9.02	.077 384	10.47	.732 939	3.30	08
53	.680 508	3.55	.928 715	9.03	.076 756	10.47	.732 741	3.30	07
54	.680 721	3.55	.929 257	9.05	.076 128	10.45	.732 543	3.30	06
55	.680 934	3.55	.929 800	9.03	.075 501	10.47	.732 345	3.30	05
56	.681 147	3.55	.930 342	9.05	.074 873	10.43	.732 147	3.30	04
57	.681 360	3.55	.930 885	9.05	.074 247	10.45	.731 949	3.32	03
58	.681 573	3.55	.931 428	9.05	.073 620	10.43	.731 750	3.30	02
59	.681 786	3.53	.931 971	9.07	.072 994	10.42	.731 552	3.30	01
60	0.681 998		0.932 515		1.072 369		0.731 354		00
	Sin	d.″	Tan	d.″	Cot	d.″	Cos	d.″	

Table A-1. Natural trigonometric functions (continued)

43°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.681 998	3.55	0.932 515	9.07	1.072 369	10.42	0.731 354	3.32	60′
01	.682 211	3.55	.933 059	9.07	.071 744	10.42	.731 155	3.30	59
02	.682 424	3.53	.933 603	9.08	.071 119	10.42	.730 957	3.32	58
03	.682 636	3.55	.934 148	9.08	.070 494	10.40	.730 758	3.30	57
04	.682 849	3.53	.934 693	9.08	.069 870	10.37	.730 560	3.32	56
05	.683 061	3.55	.935 238	9.08	.069 247	10.40	.730 361	3.32	55
06	.683 274	3.53	.935 783	9.10	.068 623	10.38	.730 162	3.32	54
07	.683 486	3.53	.936 329	9.10	.068 000	10.37	.729 963	3.30	53
08	.683 698	3.55	.936 875	9.12	.067 378	10.37	.729 765	3.32	52
09	.683 911	3.53	.937 422	9.10	.066 756	10.37	.729 566	3.32	51
10	0.684 123	3.53	0.937 968	9.12	1.066 134	10.35	0.729 367	3.32	50
11	.684 335	3.53	.938 515	9.13	.065 513	10.35	.729 168	3.32	49
12	.684 547	3.53	.939 063	9.12	.064 892	10.35	.728 969	3.33	48
13	.684 759	3.53	.939 610	9.13	.064 271	10.33	.728 769	3.32	47
14	.684 971	3.53	.940 158	9.13	.063 651	10.33	.728 570	3.32	46
15	.685 183	3.53	.940 706	9.15	.063 031	10.32	.728 371	3.32	45
16	.685 395	3.53	.941 255	9.13	.062 412	10.32	.728 172	3.33	44
17	.685 607	3.52	.941 803	9.15	.061 793	10.32	.727 972	3.32	43
18	.685 818	3.53	.942 352	9.17	.061 174	10.30	.727 773	3.33	42
19	.686 030	3.53	.942 902	9.15	.060 556	10.30	.727 573	3.32	41
20	0.686 242	3.52	0.943 451	9.17	1.059 938	10.28	0.727 374	3.33	40
21	.686 453	3.53	.944 001	9.18	.059 321	10.30	.727 174	3.33	39
22	.686 665	3.52	.944 552	9.17	.058 703	10.27	.726 974	3.32	38
23	.686 876	3.53	.945 102	9.18	.058 087	10.28	.726 775	3.33	37
24	.687 088	3.52	.945 653	9.18	.057 470	10.27	.726 575	3.33	36
25	.687 299	3.52	.946 204	9.20	.056 854	10.25	.726 375	3.33	35
26	.687 510	3.52	.946 756	9.18	.056 239	10.25	.726 175	3.33	34
27	.687 721	3.52	.947 307	9.20	.055 624	10.25	.725 975	3.33	33
28	.687 932	3.53	.947 859	9.22	.055 009	10.25	.725 775	3.33	32
29	.688 144	3.52	.948 412	9.22	.054 394	10.23	.725 575	3.35	31
30	0.688 355	3.52	0.948 965	9.22	1.053 780	10.23	0.725 374	3.33	30
31	.688 566	3.50	.949 518	9.22	.053 166	10.22	.725 174	3.33	29
32	.688 776	3.52	.950 071	9.22	.052 553	10.22	.724 974	3.35	28
33	.688 987	3.52	.950 624	9.23	.051 940	10.20	.724 773	3.33	27
34	.689 198	3.52	.951 178	9.25	.051 328	10.22	.724 573	3.35	26
35	.689 409	3.55	.951 733	9.23	.050 715	10.20	.724 372	3.33	25
36	.689 620	3.50	.952 287	9.25	.050 103	10.18	.724 172	3.35	24
37	.689 830	3.52	.952 842	9.25	.049 492	10.18	.723 971	3.33	23
38	.690 041	3.50	.953 397	9.27	.048 881	10.18	.723 771	3.35	22
39	.690 251	3.52	.953 953	9.25	.048 270	10.17	.723 570	3.35	21
40	0.690 462	3.50	0.954 508	9.27	1.047 660	10.17	0.723 369	3.35	20
41	.690 672	3.50	.955 064	9.28	.047 050	10.17	.723 168	3.35	19
42	.690 882	3.52	.955 621	9.27	.046 440	10.15	.722 967	3.35	18
43	.691 093	3.50	.956 177	9.28	.045 831	10.15	.722 766	3.35	17
44	.691 303	3.50	.956 734	9.30	.045 222	10.13	.722 565	3.35	16
45	.691 513	3.50	.957 292	9.28	.044 614	10.13	.722 364	3.35	15
46	.691 723	3.50	.957 849	9.30	.044 006	10.13	.722 163	3.35	14
47	.691 933	3.50	.958 407	9.32	.043 398	10.13	.721 962	3.37	13
48	.692 143	3.50	.958 966	9.30	.042 790	10.12	.721 760	3.35	12
49	.692 353	3.50	.959 524	9.32	.042 183	10.10	.721 559	3.37	11
50	0.692 563	3.50	0.960 083	9.32	1.041 577	10.12	0.721 357	3.35	10
51	.692 773	3.50	.960 642	9.33	.040 970	10.10	.721 156	3.37	09
52	.692 983	3.48	.961 202	9.32	.040 364	10.08	.720 954	3.35	08
53	.693 192	3.50	.961 761	9.35	.039 759	10.08	.720 753	3.37	07
54	.693 402	3.48	.962 322	9.33	.039 154	10.08	.720 551	3.37	06
55	.693 611	3.50	.962 882	9.35	.038 549	10.08	.720 349	3.35	05
56	.693 821	3.48	.963 443	9.35	.037 944	10.07	.720 148	3.37	04
57	.694 030	3.50	.964 004	9.35	.037 340	10.05	.719 946	3.37	03
58	.694 240	3.48	.964 565	9.37	.036 737	10.07	.719 744	3.37	02
59	.694 449	3.48	.965 127	9.37	.036 133	10.05	.719 542	3.37	01
60	0.694 658		0.965 689		1.035 530		0.719 340		00
	Sin	d."	Tan	d."	Cot	d."	Cos	d."	

Table A-1. Natural trigonometric functions (continued)

44°

	Sin	d."	Tan	d."	Cot	d."	Cos	d."	
00′	0.694 658	3.50	0.965 689	9.37	1.035 530	10.03	0.719 340	3.37	60′
01	.694 868	3.48	.966 251	9.38	.034 928	10.05	.719 138	3.37	59
02	.695 077	3.48	.966 814	9.38	.034 325	10.02	.718 936	3.38	58
03	.695 286	3.48	.967 377	9.38	.033 724	10.03	.718 733	3.37	57
04	.695 495	3.48	.967 940	9.40	.033 122	10.02	.718 531	3.37	56
05	.695 704	3.48	.968 504	9.38	.032 521	10.02	.718 329	3.38	55
06	.695 913	3.48	.969 067	9.42	.031 920	10.02	.718 126	3.37	54
07	.696 122	3.47	.969 632	9.40	.031 319	10.00	.717 924	3.38	53
08	.696 330	3.48	.970 196	9.42	.030 719	9.98	.717 721	3.37	52
09	.696 539	3.48	.970 761	9.42	.030 120	10.00	.717 519	3.38	51
10	0.696 748	3.48	0.971 326	9.43	1.029 520	9.98	0.717 316	3.38	50
11	.696 957	3.47	.971 892	9.43	.028 921	9.97	.717 113	3.37	49
12	.697 165	3.48	.972 458	9.43	.028 323	9.98	.716 911	3.38	48
13	.697 374	3.47	.973 024	9.43	.027 724	9.97	.716 708	3.38	47
14	.697 582	3.47	.973 590	9.45	.027 126	9.95	.716 505	3.38	46
15	.697 790	3.48	.974 157	9.45	.026 529	9.97	.716 302	3.38	45
16	.697 999	3.47	.974 724	9.45	.025 931	9.93	.716 099	3.38	44
17	.698 207	3.47	.975 291	9.47	.025 335	9.95	.715 896	3.38	43
18	.698 415	3.47	.975 859	9.47	.024 738	9.93	.715 693	3.38	42
19	.698 623	3.48	.976 427	9.48	.024 142	9.93	.715 490	3.40	41
20	0.698 832	3.47	0.976 996	9.47	1.023 546	9.92	0.715 286	3.38	40
21	.699 040	3.47	.977 564	9.48	.022 951	9.92	.715 083	3.38	39
22	.699 248	3.45	.978 133	9.50	.022 356	9.92	.714 880	3.40	38
23	.699 455	3.47	.978 703	9.48	.021 761	9.92	.714 676	3.38	37
24	.699 663	3.47	.979 272	9.50	.021 166	9.90	.714 473	3.40	36
25	.699 871	3.47	.979 842	9.52	.020 572	9.88	.714 269	3.38	35
26	.700 079	3.47	.980 413	9.50	.019 979	9.90	.714 066	3.40	34
27	.700 287	3.45	.980 983	9.52	.019 385	9.88	.713 862	3.40	33
28	.700 494	3.47	.981 554	9.53	.018 792	9.87	.713 658	3.40	32
29	.700 702	3.45	.982 126	9.52	.018 200	9.88	.713 454	3 40	31
30	0.700 909	3.47	0.982 697	9.53	1.017 607	9.87	0.713 250	3.38	30
31	.701 117	3.45	.983 269	9.55	.017 015	9.85	.713 047	3.40	29
32	.701 324	3.45	.983 842	9.53	.016 424	9.85	.712 843	3.40	28
33	.701 531	3.47	.984 414	9.55	.015 833	9.85	.712 639	3.42	27
34	.701 739	3.45	.984 987	9.55	.015 242	9.85	.712 434	3.40	26
35	.701 946	3.45	.985 560	9.57	.014 651	9.83	.712 230	3.40	25
36	.702 153	3.45	.986 134	9.57	.014 061	9.83	.712 026	3.40	24
37	.702 360	3.45	.986 708	9.57	.013 471	9.82	.711 822	3.42	23
38	.702 567	3.45	.987 282	9.58	.012 882	9.82	.711 617	3.40	22
39	.702 774	3.45	.987 857	9.58	.012 293	9.82	.711 413	3.40	21
40	0.702 981	3.45	0.988 432	9.58	1.011 704	9.82	0.711 209	3.42	20
41	.703 188	3.45	.988 007	9.58	.011 115	9.80	.711 004	3.42	19
42	.703 395	3.43	.989 582	9.60	.010 527	9.80	.710 799	3.40	18
43	.703 601	3.45	.990 158	9.62	.009 939	9.78	.710 595	3.42	17
44	.703 808	3.45	.990 735	9.60	.009 352	9.78	.710 390	3.42	16
45	.704 015	3.43	.991 311	9.62	.008 765	9.78	.710 185	3.40	15
46	.704 221	3.45	.991 888	9.62	.008 178	9.77	.709 981	3.42	14
47	.704 428	3.43	.992 465	9.63	.007 592	9.77	.709 776	3.42	13
48	.704 634	3.45	.993 043	9.63	.007 006	9.77	.709 571	3.42	12
49	.704 841	3.43	.993 621	9.63	.006 420	9.75	.709 366	3.42	11
50	0.705 047	3.43	0.994 199	9.65	1.005 835	9.75	0.709 161	3.42	10
51	.705 253	3.43	.994 778	9.65	.005 250	9.75	.708 956	3.43	09
52	.705 459	3.43	.995 357	9.65	.004 665	9.73	.708 750	3.43	08
53	.705 665	3.45	.995 936	9.65	.004 081	9.73	.708 545	3.42	07
54	.705 872	3.43	.996 515	9.67	.003 497	9.73	.708 340	3.43	06
55	.706 078	3.43	.997 095	9.68	.002 913	9.72	.708 134	3.42	05
56	.706 284	3.42	.997 676	9.67	.002 330	9.72	.707 929	3.42	04
57	.706 489	3.43	.998 256	9.68	.001 747	9.72	.707 724	3.43	03
58	.706 695	3.43	.998 837	9.68	.001 164	9.70	.707 518	3.43	02
59	.706 901	3.43	.999 418	9.70	.000 582	9.70	.707 312	3.42	01
60	0.707 107		1.000 000		1.000 000		0.707 107		00
	Cos	d."	Cot	d."	Tan	d."	Sin	d."	

Table A-2. Stadia reduction

Stadia work involves observing—

- The angle by which the line of sight departs from a horizontal line. This reading is the argument for entering the table.
- The rod interval intercepted by the stadia wires, which are usually adjusted so that the distance to the rod is exactly 100 times the reading on the rod when the telescope is level.

The table gives horizontal distances and differences of elevation for unit readings on the rod and for angle of elevation from 0° to 30°.

Example. Rod reading is 3.25 feet and angle of inclination is 5° 35′.

Horizontal Distance = 99.05 x 3.25 = 321.91 ft

Difference of Elevation = 9.68 x 3.25 = 31.46 ft

Stadia Reduction Formulas. The following formulas are used in computing stadia reductions.

Horizontal Distance = (Rod Interval x 100) $\mathrm{Cos}^2 a$

Vertical Distance = (Rod Interval x 100) ½ $\mathrm{Sin}^2 a$

a = Angle of inclination

Table A-2. Stadia reduction (continued)

Minutes	0°		1°		2°		3°	
	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	100.00	0.00	99.97	1.74	99.88	3.49	99.73	5.23
2	100.00	0.06	99.97	1.80	99.87	3.55	99.72	5.28
4	100.00	0.12	99.97	1.86	99.87	3.60	99.71	5.34
6	100.00	0.17	99.96	1.92	99.87	3.66	99.71	5.40
8	100.00	0.23	99.96	1.98	99.86	3.72	99.70	5.46
10	100.00	0.29	99.96	2.04	99.86	3.78	99.69	5.52
12	100.00	0.35	99.96	2.09	99.85	3.84	99.69	5.57
14	100.00	0.41	99.95	2.15	99.85	3.90	99.68	5.63
16	100.00	0.47	99.95	2.21	99.84	3.95	99.68	5.69
18	100.00	0.52	99.95	2.27	99.84	4.01	99.67	5.75
20	100.00	0.58	99.95	2.33	99.83	4.07	99.66	5.80
22	100.00	0.64	99.94	2.38	99.83	4.13	99.66	5.86
24	100.00	0.70	99.94	2.44	99.82	4.18	99.65	5.92
26	99.99	0.76	99.94	2.50	99.82	4.24	99.64	5.98
28	99.99	0.81	99.93	2.56	99.81	4.30	99.63	6.04
30	99.99	0.87	99.93	2.62	99.81	4.36	99.63	6.09
32	99.99	0.93	99.93	2.67	99.80	4.42	99.62	6.15
34	99.99	0.99	99.93	2.73	99.80	4.48	99.62	6.21
36	99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38	99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.33
40	99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
42	99.99	1.22	99.91	2.97	99.78	4.71	99.59	6.44
44	99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
46	99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
48	99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
50	99.98	1.45	99.90	3.20	99.76	4.94	99.56	6.67
52	99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.73
54	99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.78
56	99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
58	99.97	1.69	99.88	3.43	99.73	5.17	99.52	6.90
60	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96

*These tables are adequate for use in both feet and meters.

Table A-2. Stadia reduction (continued)

	4°		5°		6°		7°	
Minutes	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	99.51	6.69	99.24	8.68	98.91	10.40	98.51	12.10
2	99.51	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21
6	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.26
8	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32
10	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14	99.46	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55
18	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66
22	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77
26	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94
32	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00
34	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28
44	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33
46	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39
48	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50
52	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56
54	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56	99.26	8.57	99.93	10.28	98.54	11.98	98.10	13.67
58	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.73
60	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78

Table A-2. Stadia reduction (continued)

	8°		9°		10°		11°	
Minutes	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
2	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.32
24	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28	97.83	14.56	97.29	16.22	96.70	17.86	96.05	19.48
30	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.64
36	97.76	14.79	97.22	16.44	96.62	18.08	95.96	19.70
38	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40	97.73	14.90	97.18	16.55	96.57	18.19	95.91	19.80
42	97.71	14.95	97.16	16.61	96.55	18.24	95.89	19.86
44	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54	97.61	15.28	97.04	16.94	96.42	18.57	95.75	20.18
56	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60	97.55	15.45	96.98	17.10	96.36	18.73	95.68	20.34

Table A-2. Stadia reduction (continued)

Minutes	12°		13°		14°		15°	
	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00
2	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05
4	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20
50	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60	94.94	21.92	94.15	23.47	93.90	25.00	92.40	26.50

Table A-2. Stadia reduction (continued)

Minutes	16°		17°		18°		19°	
	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
2	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
4	92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87
6	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
8	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
10	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
12	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
14	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10
16	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
18	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
20	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24
22	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
24	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33
26	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
28	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
30	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
32	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
34	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56
36	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
38	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
40	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
42	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
44	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
46	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
48	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
50	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
52	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
54	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01
56	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
58	91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09
60	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14

Table A-2. Stadia reduction (continued)

	20°		21°		22°		23°	
Minutes	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	88.30	32.14	87.16	33.46	85.97	34.73	84.73	35.97
2	88.26	32.18	87.12	33.50	85.93	34.77	84.69	36.01
4	88.23	32.23	87.08	33.54	85.89	34.82	84.65	36.05
6	88.19	32.27	87.04	33.59	85.85	34.86	84.61	36.09
8	88.15	32.32	87.00	33.63	85.80	34.90	84.57	36.13
10	88.11	32.36	86.96	33.67	85.76	34.94	84.52	36.17
12	88.08	32.41	86.92	33.72	85.72	34.98	84.48	36.21
14	88.04	32.45	86.88	33.76	85.68	35.02	84.44	36.25
16	88.00	32.49	86.84	33.80	85.64	35.07	84.40	36.29
18	87.96	32.54	86.80	33.84	85.60	35.11	84.35	36.33
20	87.93	32.58	86.77	33.89	85.56	35.15	84.31	36.37
22	87.89	32.63	86.73	33.93	85.52	35.19	84.27	36.41
24	87.85	32.67	86.69	33.97	85.48	35.23	84.23	36.45
26	87.81	32.72	86.65	34.01	85.44	35.27	84.18	36.49
28	87.77	32.76	86.61	34.06	85.40	35.31	84.14	36.53
30	87.74	32.80	86.57	34.10	85.36	35.36	84.10	36.57
32	87.70	32.85	86.53	34.14	85.31	35.40	84.06	36.61
34	87.66	32.89	86.49	34.18	85.27	35.44	84.01	36.65
36	87.62	32.93	86.45	34.23	85.23	35.48	83.97	36.69
38	87.58	32.98	86.41	34.27	85.19	35.52	83.93	36.73
40	87.54	33.02	86.37	34.31	85.15	35.56	83.89	36.77
42	87.51	33.07	86.33	34.35	85.11	35.60	83.84	36.80
44	87.47	33.11	86.29	34.40	85.07	35.64	83.80	36.84
46	87.43	33.15	86.25	34.44	85.02	35.68	83.76	36.88
48	87.39	33.20	86.21	34.48	84.98	35.72	83.72	36.92
50	87.35	33.24	86.17	34.52	84.94	35.76	83.67	36.96
52	87.31	33.28	86.13	34.57	84.90	35.80	83.63	37.00
54	87.27	33.33	86.09	34.61	84.86	35.85	83.59	37.04
56	87.24	33.37	86.05	34.65	84.82	35.89	83.54	37.08
58	87.20	33.41	86.01	34.69	84.77	35.93	83.50	37.12
60	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16

Table A-2. Stadia reduction (continued)

Minutes	24°		25°		26°		27°	
	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45
2	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49
4	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52
6	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55
8	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59
10	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62
12	83.20	37.39	81.87	38.53	80.51	39.61	79.11	40.66
14	83.15	37.43	81.83	38.56	80.46	39.65	79.06	40.69
16	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72
18	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76
20	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79
22	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82
24	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86
26	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89
28	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92
30	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96
32	82.76	37.77	81.42	38.89	80.04	39.97	78.63	40.99
34	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02
36	82.67	37.85	81.33	38.97	79.95	40.04	78.54	41.06
38	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09
40	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12
42	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16
44	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19
46	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22
48	82.41	38.08	81.06	39.18	79.67	40.24	78.25	41.26
50	82.36	38.11	81.01	39.22	79.62	40.28	78.20	41.29
52	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32
54	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35
56	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39
58	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42
60	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45

Table A-2. Stadia reduction (continued)

Minutes	28°		29°		30°	
	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.	Hor. dist.	Diff. elev.
0	77.96	41.45	76.50	42.40	75.00	43.30
2	77.91	41.48	76.45	42.43	74.95	43.33
4	77.86	41.52	76.40	42.46	74.90	43.36
6	77.81	41.55	76.35	42.49	74.85	43.39
8	77.77	41.58	76.30	42.53	74.80	43.42
10	77.72	41.61	76.25	42.56	74.75	43.45
12	77.67	41.65	76.20	42.59	74.70	43.47
14	77.62	41.68	76.15	42.62	74.65	43.50
16	77.57	41.71	76.10	42.65	74.60	43.53
18	77.52	41.74	76.05	42.68	74.55	43.56
20	77.48	41.77	76.00	42.71	74.49	43.59
22	77.42	41.81	75.95	42.74	74.44	43.62
24	77.38	41.84	75.90	42.77	74.39	43.65
26	77.33	41.87	75.85	42.80	74.34	43.67
28	77.28	41.90	75.80	42.83	74.29	43.70
30	77.23	41.93	75.75	42.86	74.24	43.73
32	77.18	41.97	75.70	42.89	74.19	43.76
34	77.13	42.00	75.65	42.92	74.14	43.79
36	77.09	42.03	75.60	42.95	74.09	43.82
38	77.04	42.06	75.55	42.98	74.04	43.84
40	76.99	42.09	75.50	43.01	73.99	46.87
42	76.94	42.12	75.45	43.04	73.93	43.90
44	76.89	42.15	75.40	43.07	73.88	43.93
46	76.84	42.19	75.35	43.10	73.83	43.95
48	76.79	42.22	75.30	43.13	73.78	43.98
50	76.74	42.25	75.25	43.16	73.73	44.01
52	76.69	42.28	75.20	43.18	73.68	44.04
54	76.64	42.31	75.15	43.21	73.63	44.07
56	76.59	42.34	75.10	43.24	73.58	44.09
58	76.55	42.37	75.05	43.27	73.52	44.12
60	76.50	42.40	75.00	43.30	73.47	44.15

Table A-3. Conversion of minutes into decimals of a degree

	0″	10″	15″	20″	30″	40″	45″	50″	
0	.00000	.00278	.00417	.00556	.00833	.01111	.01250	.01389	0
1	.01667	.01944	.02083	.02222	.02500	.02778	.02917	.03056	1
2	.03333	.03611	.03750	.03889	.04167	.04444	.04583	.04722	2
3	.05000	.05278	.05417	.05556	.05833	.06111	.06250	.06389	3
4	.06667	.06944	.07083	.07222	.07500	.07778	.07917	.08056	4
5	.08333	.08611	.08750	.08889	.09167	.09444	.09583	.09722	5
6	.10000	.10278	.10417	.10556	.10833	.11111	.11250	.11389	6
7	.11667	.11944	.12083	.12222	.12500	.12778	.12917	.13056	7
8	.13333	.13611	.13750	.13889	.14167	.14444	.14583	.14722	8
9	.15000	.15278	.15417	.15556	.15833	.16111	.16250	.16389	9
10	.16667	.16944	.17083	.17222	.17500	.17778	.17917	.18056	10
11	.18333	.18611	.18750	.18889	.19167	.19444	.19583	.19722	11
12	.20000	.20278	.20417	.20556	.20833	.21111	.21250	.21389	12
13	.21667	.21944	.22083	.22222	.22500	.22778	.22917	.23056	13
14	.23333	.23611	.23750	.23889	.24167	.24444	.24583	.24722	14
15	.25000	.25278	.25417	.25556	.25833	.26111	.26250	.26389	15
16	.26667	.26944	.27083	.27222	.27500	.27778	.27917	.28056	16
17	.28333	.28611	.28750	.28889	.29167	.29444	.29583	.29722	17
18	.30000	.30278	.30417	.30556	.30833	.31111	.31250	.31389	18
19	.31667	.31944	.32083	.32222	.32500	.32778	.32917	.33056	19
20	.33333	.33611	.33750	.33889	.34167	.34444	.34583	.34722	20
21	.35000	.35278	.35417	.35556	.35833	.36111	.36250	.36389	21
22	.36667	.36944	.37083	.37222	.37500	.37778	.37917	.38056	22
23	.38333	.38611	.38750	.38889	.39167	.39444	.39583	.39722	23
24	.40000	.40278	.40417	.40556	.40833	.41111	.41250	.41389	24
25	.41667	.41944	.42083	.42222	.42500	.42778	.42917	.43056	25
26	.43333	.43611	.43750	.43889	.44167	.44444	.44583	.44722	26
27	.45000	.45278	.45417	.45556	.45883	.46111	.46250	.46389	27
28	.46667	.46944	.47083	.47222	.47500	.47778	.47917	.48056	28
29	.48333	.48611	.48750	.48889	.49167	.49444	.49583	.49722	29
30	.50000	.50278	.50417	.50556	.50833	.51111	.51250	.51389	30

Table A-3. Conversion of minutes into decimals of a degree (continued)

	0"	10"	15"	20"	30"	40"	45"	50"	
31	.51667	.51944	.52083	.52222	.52500	.52778	.52917	.53056	31
32	.53333	.53611	.53750	.53889	.54167	.54444	.54583	.54722	32
33	.55000	.55278	.55417	.55556	.55833	.56111	.56250	.56389	33
34	.56667	.56944	.57083	.57222	.57500	.57778	.57917	.58056	34
35	.58333	.58611	.58750	.58889	.59167	.59444	.59583	.59722	35
36	.60000	.60278	.60417	.60556	.60833	.61111	.61250	.61389	36
37	.61667	.61944	.62083	.62222	.62500	.62778	.62917	.63056	37
38	.63333	.63611	.63750	.63889	.64167	.64444	.64583	.64722	38
39	.65000	.65278	.65417	.65556	.65833	.66111	.66250	.66389	39
40	.66667	.66944	.67083	.67222	.67500	.67778	.67917	.68056	40
41	.68333	.68611	.68750	.68889	.69167	.69444	.69583	.69722	41
42	.70000	.70278	.70417	.70556	.70883	.71111	.71250	.71389	42
43	.71667	.71944	.72083	.72222	.72500	.72778	.72917	.73056	43
44	.73333	.73611	.73750	.73889	.74167	.74444	.74583	.74722	44
45	.75000	.75278	.75417	.75556	.75833	.76111	.76250	.76389	45
46	.76667	.76944	.77083	.77222	.77500	.77778	.77917	.78056	46
47	.78333	.78611	.78750	.78889	.79167	.79444	.79583	.79722	47
48	.80000	.80278	.80417	.80556	.80833	.81111	.81250	.81389	48
49	.81667	.81944	.82083	.82222	.82500	.82778	.82917	.83056	49
50	.83333	.83611	.83750	.83889	.84167	.84444	.84583	.84722	50
51	.85000	.85278	.85417	.85556	.85833	.86111	.86250	.86389	51
52	.86667	.86944	.87088	.87222	.87500	.87778	.87917	.88056	52
53	.83333	.88611	.88750	.88889	.89167	.89444	.89583	.89722	53
54	.90000	.90278	.90417	.90556	.90833	.91111	.91250	.91389	54
55	.91667	.91944	.92083	.92222	.92500	.92778	.92917	.93056	55
56	.93333	.93611	.93750	.93889	.94167	.94444	.94583	.94722	56
57	.95000	.95278	.95417	.95556	.95833	.96111	.96250	.96389	57
58	.96667	.96944	.97083	.97222	.97500	.97778	.97917	.98056	58
59	.98333	.98611	.98750	.98889	.99167	.99444	.99583	.99722	59

Table A-4. Useful constants and formulas

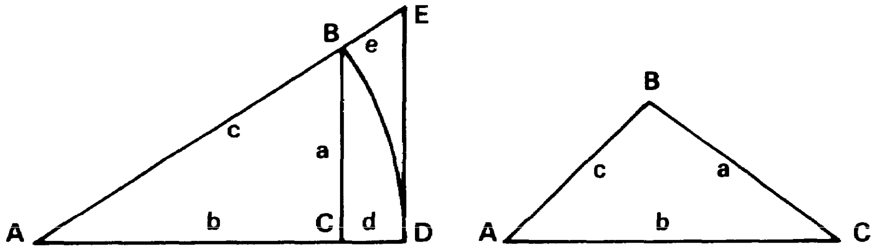


Figure A-1. Solution of triangles

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. $\sec A = \frac{c}{b} = \operatorname{cosec} B$

6. $\operatorname{cosec} A = \frac{c}{a} = \sec B$

7. $\operatorname{vers} A = \frac{c-b}{c} = \frac{d}{c}$

8. $\operatorname{exsec} A = \frac{e}{c}$

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. $d = c \operatorname{vers} A$

12. $e = c \operatorname{exsec} A$

13. $c = \frac{a}{\cos B} = \frac{b}{\sin B} = \frac{a}{\sin A} = \frac{b}{\cos A} = \frac{d}{\operatorname{vers} A} = \frac{e}{\operatorname{exsec} A}$

Table A-4. Useful constants and formulas (continued)

SOLUTION OF OBLIQUE TRIANGLES

Given	Sought	
14. A, B, a	b, c	$b = \frac{a}{\sin A} \sin B$ $\quad c = \frac{a}{\sin A} \sin (A + B)$
15. A, a, b	B, c	$\sin B = \frac{\sin A}{a} b$ $\quad c = \frac{a}{\sin a} \sin C$
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	$\text{area} = \frac{a^2 \sin B \,.\, \sin C}{2 \sin A}$
23., C, a, b	area	$\text{area} = \frac{1}{2} a b \sin C.$

Table A-4. Useful constants and formulas (continued)

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 relationships 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.

Table A-4. Useful constants and formulas (continued)

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.

$$\sin \frac{A}{2} = \pm \sqrt{\frac{1 - \cos A}{2}} \qquad \cos \frac{A}{2} = \pm \sqrt{\frac{1 + \cos A}{2}}$$

$$\tan \frac{A}{2} = \pm \frac{1 - \cos A}{\sin A} = \frac{\sin A}{1 + \cos A} = \pm \sqrt{\frac{1 - \cos A}{1 + \cos A}}$$

e. Powers of functions.

$\sin^2 A = \tfrac{1}{2}(1 - \cos 2A);\qquad \cos^2 A = \tfrac{1}{2}(1 + \cos 2A)$
$\sin^3 A = \tfrac{1}{4}(3 \sin A - \sin 3A);\ A = \tfrac{1}{4}(\cos 3A + 3 \cos A)$

f. Sum and difference of angles.

$\sin (A \pm B) = \sin A \cos B \pm \cos A \sin B$
$\cos (A \pm) = \cos A \cos B \pm \sin A \sin B$

$$\tan (A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

g. Sums, differences, and products of functions.

$\sin A \pm \sin B = 2 \sin \tfrac{1}{2}(A \pm B) \cos \tfrac{1}{2}(A \pm B)$
$\cos A + \cos B = 2 \cos \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$
$\cos A - \cos B = -2 \sin \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$

$$\tan A \pm \tan B = \frac{\sin (A \pm B)}{\cos A \cos B}$$

Table A-4. Useful constants and formulas (continued)

$\sin^2 A - \sin^2 B = \sin(A + B) \sin(A - B)$
$\cos^2 A - \cos^2 B = - \sin(A + B) ;\sin(A - B)$
$\cos^2 A - \sin^2 B = \cos(A + B) \cos(A - B)$
$\sin A \sin B = ½ \cos(A - B) - ½ \cos(A + B)$
$\cos A \cos B = ½ \cos(A - B) + ½ \cos(A + B)$
$\sin A \cos B = ½ \sin(A + B) + ½ \sin(A - B)$

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

GENERAL FORMULAS

24. $\sin A = 2 \sin ½ A \cos ½ A = \sqrt{1 - \cos^2 A} = \tan A \cos A$

25. $\cos A = 2 \cos^2 ½ A - 1 = 2 \sin^2 ½ A = \cos^2 ½ A - \sin^2 ½ A$

26. $\tan A = \dfrac{\sin A}{\cos A} = \dfrac{\sin 2 A}{1 + \cos 2 A}$

27. $\cot A = \dfrac{\cos A}{\sin A} = \dfrac{\sin 2 A}{1 - \cos 2 A} = \dfrac{\sin 2 A}{\text{vers } 2 A}$

28. $\text{vers } A = 1 - \cos A = \sin A \tan ½ A = 2 \sin^2 ½ A$

29. $\text{exsec } A = \sec A - 1 = \tan A \tan ½ A = \dfrac{\text{vers } A}{\cos A}$

30. $\sin 2 A = 2 \sin A \cos A$

31. $\cos 2 A = 2 \cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2 \sin^2 A$

32. $\tan 2 A = \dfrac{2 \tan A}{1 - \tan^2 A}$

33. $\cot 2 A = \dfrac{\cot^2 A - 1}{2 \cot A}$

34. $\text{vers } 2 A = 2 \sin^2 A = 2 \sin A \cos A \tan A$

35. $\text{exsec } 2 A = \dfrac{2 \tan^2 A}{1 - \tan^2 A}$

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. $\sin A + \sin B = 2 \sin ½ (A + B) \cos ½ (A - B)$

40. $\sin A - \sin B = 2 \cos ½ (A + B) \sin ½ (A - B)$

41. $\cos A + \cos B = 2 \cos ½ (A + B) \cos ½ (A - B)$

42. $\cos B - \cos A = 2 \sin ½ (A + B) \sin ½ (A - B)$

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. $\sin 3 A = 3 \sin A - 4 \sin^2 A$

48. $\cos 3 A = 4 \cos^2 A - 3 \cos A$

49. $\sin \dfrac{A}{2} = \pm \sqrt{\dfrac{1 - \cos A}{2}}$

Table A-4. Useful constants and formulas (continued)

50. $\cos\frac{A}{2} = \pm\sqrt{\frac{1 + \cos A}{2}}$

51. $\tan\frac{A}{2} = \pm\ \frac{1 - \cos A}{\sin A} = \frac{\sin A}{1 + \cos A} = \pm\sqrt{\frac{1 - \cos A}{1 + \cos A}}$

52. $\sin^2 A = ½\,(1 - \cos 2A)$

53. $\cos^2 A = ½\,(1 + \cos 2A)$

54. $\sin^2 A = ¼\,(3 \sin A - \sin 3A)$

55. $\cos^2 A = ¼\,(\cos 3A + 3 \cos A)$

56. $\sin A \sin B = ½ \cos (A - B) - ½ \cos (A + B)$

57. $\cos A \cos B = ½ \cos (A - B) + ½ \cos (A + B)$

58. $\sin A \cos B = ½ \sin (A + B) + ½ \sin A - B$

	0°	30°	45°	60°	90°	120°	135°	150°	180°	270
Sine	0	1/2	1/2 $\sqrt{2}$	1/2 $\sqrt{3}$	1	1/2 $\sqrt{3}$	1/2 $\sqrt{2}$	1/2	0	-1
Cosine	1	1/2 $\sqrt{3}$	1/2 $\sqrt{2}$	1/2	0	-1/2	-1/2 $\sqrt{2}$	-1/2 $\sqrt{3}$	-1	0
Tangent ...	0	1/3 $\sqrt{3}$	1	$\sqrt{3}$	± ∞	- $\sqrt{3}$	-1	-1/3 $\sqrt{3}$	0	± ∞
Cotangent .	± ∞	$\sqrt{3}$	1	1/3 $\sqrt{3}$	0	-1/3 $\sqrt{3}$	-1	- $\sqrt{3}$	± ∞	0
Secant	1	2/3 $\sqrt{3}$	$\sqrt{2}$	2	± ∞	-2	- $\sqrt{2}$	-2/3 $\sqrt{3}$	-1	± ∞
Cosecant ..	± ∞	2	$\sqrt{2}$	2/3 $\sqrt{3}$	1	2/3 $\sqrt{3}$	$\sqrt{2}$	2	± ∞	-1

Lineal feet	x .00019	= miles
Lineal yards	x .006	= miles
Square inches	x .007	= square feet
Square feet	x .111	= square yards
Square yards	x .0002067	= acres
Acres	x 4840.0	= square yards
Cubic inches	x .00058	= cubic feet
Cubic feet	x .03704	= cubic yards
Links	x .22	= yards
Links	x .66	= feet
Feet	x .15	= links

360° = 21600′ = 1296000″

Circumference of circle (r = radius) = $2\pi r$, or πd

Radius = arc of 57.2957790°

Arc of 1° (radius = 1) = .017453292

Arc of 1′ (radius = 1) = .000290888

Arc of 1″ (radius = 1) = .000004848

1 radian	= $\frac{180°}{\pi}$ = 57.2957790° = 57°17′44.8″ (nearly)
1 radian	= 1018.6 mile
1 degree	= 0.0174533 radians
1 minute	= 0.0002909 radians
1 mil	= 0.0009817 radians
π radians	= 180°
$\frac{\pi}{2}$ radians	= 90°

Area of circle (r = radius)	πr^2
Area of sector of circle (length of arc = L; r = radius)	1/2 Lr
Area of segment of parabola (c = chord; m = mid. ord.)	2/3 cm
Area of segment of circle (ap)	2/3 cm

Table A-4. Useful constants and formulas (continued)

$\pi = 3.141592654.$

$\frac{\pi}{4} = 0.785398163.$

$\frac{\pi}{6} = 0.523598776.$

$\sqrt{\frac{4}{\pi}} = 1.128379167.$

$\frac{4\pi}{3} = 4.188790205.$

$\sqrt[3]{\frac{6}{\pi}} = 1.240700982.$

$\pi^2 = 9.869604401.$

$\frac{1}{\pi^2} = 0.101321184.$

$\sqrt{\pi} = 1.772453851.$

$\frac{1}{\pi} = 0.3183099.$

Curvature of Earth's surface = about 0.7 foot in 1 mile.
Curvature in feet = 0.667 (dist. in miles)^2
Difference between arc and chord length, 0.02 foot in 11½ miles.

Table A-5. Functions of 1° curves

Functions of a 1° Curve. The long chords, mid-ordinates, externals, and tangent distances of this table are for a curve of 5730 feet radius. To find the corresponding functions of any other curve, divide the tabular values by the degree of curve. Values obtained from this table can be converted to the metric system by multiplying by 0.3048.

Table A-5. Functions of 1° curves (continued)

	0°				1°				
	LC	M	E	T	LC	M	E	T	
0	0.00	0.000	0.000	0.00	100.00	0.218	0.218	50.00	0
2	3.33	0.000	0.000	1.67	103.33	0.233	0.233	51.67	2
4	6.67	0.001	0.001	3.33	106.66	0.248	0.248	53.33	4
6	10.00	0.002	0.002	5.00	110.00	0.264	0.264	55.00	6
8	13.33	0.004	0.004	6.67	113.33	0.280	0.280	56.67	8
10	16.67	0.006	0.006	8.33	116.66	0.297	0.297	58.33	10
12	20.00	0.009	0.009	10.00	120.00	0.314	0.314	60.00	12
14	23.33	0.012	0.012	11.67	123.33	0.332	0.332	61.67	14
16	26.67	0.015	0.015	13.33	126.66	0.350	0.350	63.33	16
18	30.00	0.019	0.019	15.00	130.00	0.368	0.368	65.00	18
20	33.33	0.024	0.024	16.67	133.33	0.388	0.388	66.67	20
22	36.67	0.029	0.029	18.33	136.66	0.407	0.407	68.33	22
24	40.00	0.035	0.035	20.00	140.00	0.427	0.427	70.00	24
26	43.33	0.041	0.041	21.67	143.33	0.448	0.448	71.67	26
28	46.67	0.048	0.048	23.33	146.66	0.469	0.469	73.33	28
30	50.00	0.054	0.054	25.00	150.00	0.491	0.491	75.00	30
32	53.33	0.062	0.062	26.67	153.33	0.513	0.513	76.67	32
34	56.67	0.070	0.070	28.33	156.66	0.536	0.536	78.33	34
36	60.00	0.079	0.079	30.00	160.00	0.559	0.559	80.00	36
38	63.33	0.088	0.088	31.67	163.33	0.582	0.582	81.67	38
40	66.67	0.097	0.097	33.33	166.66	0.606	0.606	83.33	40
42	70.00	0.107	0.107	35.00	170.00	0.630	0.630	85.00	42
44	73.33	0.117	0.117	36.67	173.33	0.655	0.655	86.67	44
46	76.67	0.128	0.128	38.33	176.66	0.681	0.681	88.33	46
48	80.00	0.140	0.140	40.00	180.00	0.706	0.706	90.00	48
50	83.33	0.151	0.151	41.67	183.33	0.733	0.733	91.67	50
52	86.67	0.164	0.164	43.33	186.66	0.760	0.760	93.33	52
54	90.00	0.176	0.176	45.00	190.00	0.788	0.788	95.00	54
56	93.33	0.190	0.190	46.67	193.33	0.815	0.815	96.67	56
58	96.67	0.204	0.204	48.33	196.66	0.844	0.844	98.33	58
60	100.00	0.218	0.218	50.00	199.98	0.873	0.873	100.00	60

	2°				3°				
	LC	M	E	T	LC	M	E	T	
0	199.98	0.873	0.873	100.00	299.96	1.964	1.964	150.07	0
2	203.31	0.902	0.902	101.67	303.29	2.008	2.009	151.74	2
4	206.64	0.932	0.932	103.34	306.62	2.053	2.054	153.41	4
6	209.97	0.962	0.962	105.01	309.95	2.098	2.099	155.08	6
8	213.31	0.993	0.993	106.68	313.29	2.143	2.144	156.75	8
10	216.64	1.024	1.024	108.35	316.62	2.188	2.189	158.42	10
12	219.97	1.056	1.056	110.02	319.95	2.225	2.236	160.09	12
14	223.30	1.088	1.088	111.69	323.28	2.282	2.283	161.76	14
16	226.64	1.121	1.121	113.36	326.62	2.329	2.330	163.43	16
18	229.97	1.154	1.154	115.02	329.95	2.376	2.377	165.09	18
20	233.30	1.188	1.188	116.69	333.28	2.424	2.425	166.76	20
22	236.63	1.222	1.222	118.36	336.61	2.473	2.474	168.43	22
24	239.97	1.256	1.256	120.03	339.95	2.523	2.523	170.10	24
26	243.30	1.292	1.292	121.70	343.28	2.572	2.573	171.77	26
28	246.63	1.328	1.328	123.37	346.61	2.622	2.623	173.44	28
30	249.96	1.364	1.364	125.03	349.94	2.672	2.673	175.10	30
32	253.29	1.399	1.399	126.70	353.27	2.724	2.725	176.72	32
34	256.62	1.437	1.437	128.37	356.60	2.776	2.777	178.39	34
36	259.96	1.475	1.475	130.04	359.94	2.828	2.829	180.06	36
38	263.29	1.513	1.513	131.71	363.27	2.880	2.881	181.73	38
40	266.62	1.552	1.552	133.38	366.60	2.933	2.934	183.40	40
42	269.96	1.592	1.592	135.05	369.94	2.987	2.988	185.07	42
44	273.29	1.632	1.632	136.72	373.27	3.042	3.043	186.74	44
46	276.62	1.672	1.672	138.38	376.60	3.096	3.097	188.40	46
48	279.96	1.712	1.712	140.05	379.94	3.151	3.152	190.07	48
50	283.29	1.752	1.752	141.72	383.27	3.206	3.207	191.74	50
52	286.62	1.794	1.794	143.39	386.60	3.263	3.264	193.41	52
54	289.96	1.836	1.836	145.06	389.94	3.320	3.321	195.08	54
56	293.29	1.878	1.878	146.73	393.27	3.377	3.378	196.75	56
58	296.62	1.921	1.921	148.40	396.60	3.434	3.435	198.42	58
60	299.96	1.964	1.964	150.07	399.94	3.491	3.942	200.09	60

Table A-5. Functions of 1° curves (continued)

	4°				5°				
	LC	M	E	T	LC	M	E	T	
0	399.94	3.491	3.492	200.09	499.88	5.454	5.459	250.17	0
2	403.27	3.550	3.551	201.76	503.21	5.527	5.533	251.84	2
4	406.60	3.609	3.610	203.43	506.54	5.601	5.607	253.51	4
6	409.93	3.668	3.670	205.10	509.87	5.675	5.681	255.18	6
8	413.26	3.727	3.730	206.77	513.20	5.749	5.755	256.85	8
10	416.59	3.787	3.790	208.44	516.53	5.823	5.829	258.52	10
12	419.92	3.848	3.851	210.11	519.86	5.899	5.905	260.20	12
14	423.26	3.910	3.913	211.77	523.19	5.975	5.981	261.86	14
16	426.59	3.972	3.975	213.45	526.52	6.052	6.058	263.54	16
18	429.92	4.034	4.037	215.11	529.85	6.129	6.135	265.20	18
20	433.25	4.096	4.099	216.78	533.18	6.206	6.212	266.87	20
22	436.58	4.160	4.163	218.45	536.51	6.284	6.290	268.54	22
24	439.91	4.224	4.227	220.12	539.84	6.362	6.369	270.21	24
26	443.24	4.288	4.291	221.79	543.17	6.441	6.448	271.88	26
28	446.58	4.353	4.356	223.46	546.50	6.520	6.527	273.54	28
30	449.91	4.418	4.421	225.13	549.83	6.599	6.606	275.21	30
32	453.24	4.484	4.487	226.80	553.17	6.680	6.687	276.88	32
34	456.57	4.550	4.554	228.47	556.50	6.761	6.768	278.55	34
36	459.90	4.617	4.621	230.14	559.83	6.842	6.849	280.23	36
38	463.23	4.684	4.688	231.81	563.16	6.923	6.931	281.90	38
40	466.56	4.751	4.755	233.48	566.49	7.005	7.013	283.57	40
42	469.89	4.820	4.824	235.15	569.82	7.088	7.096	285.24	42
44	473.23	4.889	4.893	236.82	573.15	7.171	7.180	286.91	44
46	476.56	4.958	4.962	238.48	576.48	7.255	7.264	288.59	46
48	479.89	5.027	5.031	240.15	579.81	7.339	7.348	290.26	48
50	483.22	5.096	5.100	241.82	583.14	7.423	7.432	291.93	50
52	486.55	5.167	5.171	243.49	586.47	7.508	7.517	293.60	52
54	489.88	5.238	5.243	245.16	589.80	7.593	7.603	295.27	54
56	493.21	5.310	5.315	246.83	593.13	7.678	7.689	296.95	56
58	496.54	5.382	5.387	248.50	596.46	7.764	7.775	298.62	58
60	499.88	5.454	5.459	250.17	599.80	7.850	7.861	300.30	60

	6°				7°				
	LC	M	E	T	LC	M	E	T	
0	599.80	7.850	7.861	300.30	699.90	10.69	10.71	350.44	0
2	603.13	7.940	7.951	301.97	702.93	10.79	10.81	352.11	2
4	606.46	8.030	8.041	303.64	706.26	10.90	10.92	353.79	4
6	609.78	8.120	8.131	305.31	709.58	11.00	11.02	355.46	6
8	613.11	8.210	8.221	306.98	712.91	11.11	11.13	357.13	8
10	616.44	8.300	8.311	308.65	716.24	11.21	11.23	358.81	10
12	619.76	8.390	8.401	310.32	719.56	11.31	11.33	360.48	12
14	623.09	8.480	8.491	311.99	722.89	11.42	11.44	362.15	14
16	626.42	8.570	8.581	313.66	726.21	11.52	11.54	363.83	16
18	629.74	8.660	8.671	315.33	729.53	11.63	11.65	365.50	18
20	633.07	8.750	8.761	317.00	732.86	11.73	11.75	367.17	20
22	636.40	8.844	8.856	318.67	736.19	11.84	11.86	368.85	22
24	639.72	8.939	8.951	320.34	739.51	11.95	11.97	370.52	24
26	643.05	9.033	9.046	322.01	742.84	12.06	12.08	372.19	26
28	646.38	9.128	9.141	323.68	746.17	12.17	12.19	373.86	28
30	649.70	9.222	9.236	325.35	749.49	12.27	12.30	375.54	30
32	653.03	9.317	9.331	327.02	752.82	12.38	12.41	377.22	32
34	656.36	9.411	9.426	328.69	756.15	12.49	12.52	378.89	34
36	659.69	9.506	9.521	330.37	759.47	12.60	12.63	380.57	36
38	663.02	9.600	9.616	332.04	762.80	12.71	12.74	382.24	38
40	666.34	9.695	9.712	333.71	766.13	12.82	12.85	383.92	40
42	669.67	9.794	9.812	335.38	769.45	12.93	12.96	385.60	42
44	673.00	9.894	9.912	337.05	772.78	13.04	13.08	387.27	44
46	676.32	9.993	10.01	338.73	776.11	13.15	13.19	388.95	46
48	679.65	10.09	10.11	340.40	779.43	13.26	13.31	390.62	48
50	682.98	10.19	10.21	342.07	782.76	13.37	13.42	392.30	50
52	686.30	10.29	10.31	343.74	786.09	13.48	13.53	393.98	52
54	689.63	10.39	10.41	345.41	789.41	13.59	13.65	395.65	54
56	692.96	10.49	10.51	347.08	792.74	13.70	13.76	397.33	56
58	696.28	10.59	10.61	348.76	796.07	13.81	13.88	399.01	58
60	699.60	10.69	10.71	350.44	799.40	13.96	13.99	400.70	60

Table A-5. Functions of 1° curves (continued)

	8°				9°				
	LC	M	E	T	LC	M	E	T	
0	799.40	13.96	13.99	400.70	899.10	17.66	17.71	450.95	0
2	802.72	14.07	14.10	402.37	902.42	17.79	17.84	452.63	2
4	806.04	14.19	14.22	404.05	905.74	17.92	17.98	454.31	4
6	809.37	14.31	14.34	405.72	909.07	18.06	18.11	455.98	6
8	812.69	14.43	14.46	407.39	912.39	18.19	18.25	457.66	8
10	816.01	14.55	14.58	409.06	915.71	18.32	18.38	459.34	10
12	819.34	14.66	14.70	410.74	919.04	18.46	18.52	461.02	12
14	822.66	14.78	14.82	412.41	922.36	18.59	18.65	462.70	14
16	825.98	14.90	14.94	414.08	925.68	18.72	18.79	464.37	16
18	829.31	15.02	15.06	415.75	929.01	18.86	18.92	466.05	18
20	832.63	15.14	15.18	417.43	932.33	18.99	19.06	467.73	20
22	835.95	15.26	15.30	419.10	935.65	19.12	19.19	469.41	22
24	839.28	15.38	15.43	420.77	938.98	19.26	19.33	471.08	24
26	842.60	15.51	15.55	422.45	942.30	19.40	19.47	472.76	26
28	845.92	15.63	15.68	424.12	945.62	19.54	19.61	474.43	28
30	849.25	15.75	15.80	425.79	948.95	19.68	19.75	476.10	30
32	852.57	15.88	15.93	427.47	952.27	19.82	19.89	477.78	32
34	855.89	16.00	16.05	429.15	955.59	19.96	20.03	479.46	34
36	859.22	16.12	16.18	430.82	958.92	20.10	20.17	481.14	36
38	862.54	16.25	16.30	432.50	962.24	20.24	20.31	482.83	38
40	865.86	16.38	16.43	434.18	965.56	20.38	20.45	484.51	40
42	869.19	16.50	16.55	435.86	968.89	20.52	20.59	486.19	42
44	872.51	16.63	16.68	437.54	972.21	20.66	20.74	487.87	44
46	875.83	16.76	16.81	439.21	975.53	20.80	20.88	489.56	46
48	879.16	16.89	16.94	440.89	978.86	20.94	21.03	491.24	48
50	882.48	17.02	17.07	442.57	982.18	21.09	21.17	492.92	50
52	885.80	17.14	17.19	444.45	985.50	21.23	21.31	494.60	52
54	889.13	17.27	17.32	445.93	988.83	21.37	21.46	496.28	54
56	892.45	17.40	17.45	447.60	992.15	21.51	21.60	497.96	56
58	895.77	17.53	17.58	449.28	995.47	21.65	21.75	499.65	58
60	899.10	17.66	17.71	450.95	998.80	21.80	21.89	501.32	60

	10°				11°				
	LC	M	E	T	LC	M	E	T	
0	998.8	21.80	21.89	501.32	1098.4	26.38	26.50	551.74	0
2	1002.1	21.94	22.03	503.00	1101.7	26.54	26.66	553.42	2
4	1005.4	22.09	22.18	504.68	1105.0	26.70	26.83	555.10	4
6	1008.8	22.24	22.33	506.36	1108.3	26.86	26.99	556.78	6
8	1012.1	22.39	22.48	508.04	1111.7	27.02	27.16	558.46	8
10	1015.4	22.54	22.63	509.72	1115.0	27.19	27.32	560.14	10
12	1018.7	22.68	22.78	511.40	1118.3	27.35	17.48	561.82	12
14	1022.0	22.83	22.93	513.08	1121.6	27.51	27.65	563.50	14
16	1025.4	22.98	23.08	514.76	1124.9	27.67	27.81	565.18	16
18	1028.7	23.13	23.23	516.44	1128.2	27.83	27.98	566.86	18
20	1032.0	23.28	23.38	518.12	1131.6	28.00	28.14	568.54	20
22	1035.3	23.43	23.53	519.80	1134.9	28.17	28.30	570.22	22
24	1038.6	25.58	23.68	521.48	1138.2	28.34	28.47	571.90	24
26	1042.0	23.73	23.84	523.16	1141.5	28.50	28.64	573.58	26
28	1045.3	23.88	23.99	524.85	1144.8	28.67	28.81	575.27	28
30	1048.6	24.04	24.14	526.53	1148.1	28.84	28.98	576.95	30
32	1051.9	24.19	24.30	528.21	1151.5	29.00	29.14	578.63	32
34	1055.2	24.34	24.45	529.89	1154.8	29.17	29.31	580.32	34
36	1058.6	24.49	24.60	531.57	1158.1	29.34	29.48	582.00	36
38	1061.9	24.64	24.76	533.25	1161.4	29.50	29.65	583.69	38
40	1065.2	24.80	24.91	534.93	1164.7	29.67	29.82	585.37	40
42	1068.5	24.95	25.06	536.61	1168.0	29.84	29.99	587.05	42
44	1071.8	25.11	25.22	538.29	1171.4	30.01	30.17	588.74	44
46	1075.2	25.27	25.38	539.97	1174.7	30.18	30.34	590.42	46
48	1078.5	25.43	25.54	541.65	1178.0	30.35	30.52	592.11	48
50	1081.8	25.59	25.70	543.33	1181.3	30.53	30.69	593.79	50
52	1085.1	25.74	25.86	545.01	1184.6	30.70	30.86	595.47	52
54	1088.4	25.90	26.02	546.69	1187.9	30.87	31.04	597.16	54
56	1091.8	26.06	26.18	548.37	1191.3	31.04	31.21	598.84	56
58	1095.1	26.22	26.34	550.06	1194.6	31.21	31.39	600.53	58
60	1098.4	26.38	26.50	551.74	1197.9	31.39	31.56	602.22	60

Table A-5. Functions of 1° curves (continued)

	12°				13°				
	LC	M	E	T	LC	M	E	T	
0	1197.9	31.39	31.56	602.22	1297.3	36.83	37.07	652.87	0
2	1201.2	31.57	31.73	603.91	1300.6	37.02	37.26	654.56	2
4	1204.5	31.74	31.91	605.60	1303.9	37.21	37.46	656.25	4
6	1207.8	31.92	32.09	607.28	1307.2	37.40	37.65	657.93	6
8	1211.1	32.09	32.37	608.97	1310.5	37.59	37.85	659.62	8
10	1214.5	32.27	32.45	610.66	1313.8	37.79	38.04	661.31	10
12	1217.8	32.45	32.63	612.35	1317.2	37.98	38.23	663.00	12
14	1221.1	32.62	32.81	614.04	1320.5	38.17	38.43	664.69	14
16	1224.4	32.80	32.99	615.72	1323.8	38.36	38.62	666.37	16
18	1227.7	32.97	33.17	617.41	1327.1	38.55	38.82	668.06	18
20	1231.0	33.15	33.35	619.10	1330.4	38.75	39.01	669.75	20
22	1234.3	33.33	33.53	620.79	1333.7	38.95	39.20	671.44	22
24	1237.7	33.51	33.72	622.48	1337.0	39.15	39.40	673.13	24
26	1241.0	33.69	33.90	624.16	1340.3	39.35	39.60	674.81	26
28	1244.3	33.87	34.09	625.85	1343.6	39.54	39.80	676.51	28
30	1247.6	34.06	34.27	627.55	1346.9	39.74	40.00	678.20	30
32	1250.9	34.24	34.45	629.24	1350.3	39.94	40.19	679.89	32
34	1254.2	34.42	34.64	630.93	1353.6	40.13	40.39	681.58	34
36	1257.5	34.60	34.82	632.61	1356.9	40.23	40.59	683.26	36
38	1260.8	34.78	35.01	634.30	1360.2	40.52	40.79	684.95	38
40	1264.2	34.97	35.19	635.99	1363.5	40.71	40.99	686.64	40
42	1267.5	35.16	35.37	637.68	1366.8	40.91	41.19	688.33	42
44	1270.8	35.34	35.56	639.37	1370.1	41.11	41.40	690.02	44
46	1274.1	35.53	35.75	641.05	1373.4	41.31	41.60	691.70	46
48	1277.4	35.71	35.94	642.74	1376.7	41.51	41.81	693.39	48
50	1280.7	35.90	36.13	644.43	1380.0	41.71	42.01	695.08	50
52	1284.0	36.09	36.31	646.12	1383.4	41.91	42.21	696.77	52
54	1287.4	36.27	36.50	647.81	1386.7	42.11	42.42	698.46	54
56	1290.7	36.46	36.69	649.49	1390.0	42.31	42.62	700.14	56
58	1294.0	36.64	36.88	651.18	1393.3	42.51	42.83	701.83	58
60	1297.3	36.83	37.07	652.87	1396.6	42.71	43.03	703.53	60

	14°				15°				
	LC	M	E	T	LC	M	E	T	
0	1396.6	42.71	43.03	703.53	1495.9	49.02	49.44	754.35	0
2	1399.9	42.92	43.23	705.23	1499.2	49.24	49.66	756.05	2
4	1403.2	43.12	43.44	706.92	1502.5	49.46	49.89	757.74	4
6	1406.5	43.33	43.65	708.62	1505.8	49.68	50.11	759.44	6
8	1409.8	43.53	43.86	710.31	1509.1	49.90	50.34	761.13	8
10	1413.1	43.74	44.07	712.01	1512.4	50.12	50.56	762.83	10
12	1416.5	43.94	44.28	713.71	1515.7	50.34	50.78	764.53	12
14	1419.8	44.15	44.49	715.40	1519.0	50.56	51.01	766.22	14
16	1423.1	44.35	44.70	717.10	1522.3	50.78	51.23	767.92	16
18	1426.4	44.56	44.91	718.79	1525.6	51.00	51.46	769.61	18
20	1429.7	44.77	45.12	720.49	1528.9	51.22	51.68	771.31	20
22	1433.0	44.98	45.33	722.20	1532.2	51.44	51.90	773.01	22
24	1436.3	45.19	45.54	723.89	1535.5	51.67	52.13	774.70	24
26	1439.6	45.40	45.76	725.59	1538.8	51.89	52.36	776.40	26
28	1442.9	45.61	45.97	727.28	1542.1	52.12	52.59	778.09	28
30	1446.2	45.82	46.18	728.97	1545.4	52.34	52.82	779.79	30
32	1449.6	46.03	46.60	730.66	1548.7	52.57	53.05	781.49	32
34	1452.9	46.24	46.61	732.35	1552.0	52.79	53.28	783.19	34
36	1456.2	46.45	46.82	734.05	1555.3	53.02	53.51	784.89	36
38	1459.5	46.66	47.04	735.74	1558.6	53.24	53.74	786.59	38
40	1462.8	46.87	47.25	737.43	1561.9	53.47	53.97	788.29	40
42	1466.1	47.08	47.46	739.12	1565.2	53.69	54.20	789.99	42
44	1469.4	47.30	47.68	740.81	1568.5	53.92	54.44	791.69	44
46	1472.7	47.51	47.90	742.51	1571.8	54.15	54.67	793.39	46
48	1476.0	47.73	48.12	744.20	1575.1	54.38	54.91	795.09	48
50	1479.3	47.94	48.34	745.89	1578.4	54.61	55.14	796.79	50
52	1482.7	48.16	48.56	747.58	1581.7	54.84	55.37	798.49	52
54	1486.0	48.37	48.78	749.27	1585.0	55.07	55.61	800.19	54
56	1489.3	48.59	49.00	750.97	1588.3	55.30	55.84	801.89	56
58	1492.6	48.80	49.22	752.66	1591.6	55.53	56.08	803.59	58
60	1495.9	49.02	49.44	754.35	1594.9	55.76	56.31	805.29	60

Table A-5. Functions of 1° curves (continued)

	16°				17°				
	LC	M	E	T	LC	M	E	T	
0	1594.9	55.76	56.31	805.29	1693.9	62.94	63.64	856.35	0
2	1598.2	55.99	56.54	806.99	1697.2	63.18	63.89	858.05	2
4	1601.5	56.23	56.78	808.64	1700.5	63.43	64.15	859.76	4
6	1604.8	56.46	57.02	810.39	1703.8	63.68	64.40	861.46	6
8	1608.1	56.70	57.26	812.09	1707.1	63.93	64.66	863.16	8
10	1611.4	56.93	57.50	813.79	1710.4	64.18	64.91	864.87	10
12	1614.7	57.17	57.74	815.49	1713.7	64.42	65.16	866.57	12
14	1618.0	57.40	57.98	817.19	1716.9	64.67	65.42	868.27	14
16	1621.3	57.64	58.22	818.89	1720.2	64.92	65.67	869.98	16
18	1624.6	57.87	58.46	820.59	1723.5	65.17	65.93	871.68	18
20	1627.9	58.11	58.70	822.29	1726.8	65.42	66.18	873.38	20
22	1631.2	58.34	58.94	823.99	1730.1	65.67	66.43	875.09	22
24	1634.5	58.58	59.19	825.69	1733.4	65.93	66.69	876.79	24
26	1637.8	58.82	59.43	827.39	1736.7	66.18	66.95	878.49	26
28	1641.1	59.06	59.68	829.09	1740.0	66.44	67.21	880.20	28
30	1644.4	59.30	59.92	830.79	1743.3	66.69	67.47	881.90	30
32	1647.7	59.54	60.16	832.49	1746.6	66.94	67.72	883.61	32
34	1651.0	59.78	60.41	834.20	1749.9	67.20	67.98	885.32	34
36	1654.3	60.02	60.65	835.00	1753.2	67.45	68.24	887.02	36
38	1657.6	60.26	60.90	837.61	1756.5	67.71	68.50	888.73	38
40	1660.9	60.50	61.14	839.31	1759.8	67.96	68.76	890.44	40
42	1664.2	60.74	61.39	841.01	1763.1	68.21	69.03	892.15	42
44	1667.5	60.99	61.64	842.72	1766.3	68.47	69.29	893.86	44
46	1670.8	61.23	61.89	844.42	1769.6	68.73	69.56	895.56	46
48	1674.1	61.48	62.14	846.13	1772.9	68.99	69.82	897.27	48
50	1677.4	61.72	62.39	847.83	1776.2	69.25	70.09	898.98	50
52	1680.7	61.96	62.64	849.53	1779.5	69.50	70.36	900.69	52
54	1684.0	62.21	62.89	851.24	1782.8	69.76	70.62	902.40	54
56	1687.3	62.45	63.14	852.94	1786.1	70.02	70.89	904.10	56
58	1690.6	62.70	63.39	854.65	1789.4	70.28	71.17	905.81	58
60	1693.9	62.94	63.64	856.35	1792.7	70.54	71.42	907.52	60

	18°				19°				
	LC	M	E	T	LC	M	E	T	
0	1792.7	70.54	71.42	907.52	1891.5	78.58	79.65	958.86	0
2	1796.0	70.80	71.69	909.23	1894.8	78.86	79.94	960.57	2
4	1799.3	71.06	71.96	910.94	1898.1	79.13	80.22	962.30	4
6	1802.6	71.33	72.23	912.65	1901.3	79.41	80.51	964.00	6
8	1805.9	71.59	72.50	914.36	1904.6	79.68	80.79	965.72	8
10	1809.2	71.85	72.77	916.07	1907.9	79.96	81.08	967.43	10
12	1812.5	72.12	73.04	917.78	1911.2	80.24	81.37	969.15	12
14	1815.7	72.38	73.31	919.49	1914.5	80.51	81.65	970.86	14
16	1819.0	72.64	73.58	921.20	1917.8	80.79	81.94	972.58	16
18	1822.3	72.91	73.85	922.91	1921.0	81.07	82.22	974.29	18
20	1825.6	73.17	74.12	924.63	1924.3	81.35	82.51	976.01	20
22	1828.9	73.43	74.39	926.34	1927.6	81.63	82.80	977.72	22
24	1832.2	73.70	74.67	928.05	1930.9	81.91	83.09	979.44	24
26	1835.5	73.97	74.94	929.76	1934.2	82.20	83.38	981.15	26
28	1838.8	74.24	75.22	931.47	1937.5	82.48	83.67	982.86	28
30	1842.1	74.51	75.49	933.18	1940.7	82.76	83.97	984.58	30
32	1845.4	74.77	75.77	934.89	1944.0	83.05	84.26	986.30	32
34	1848.7	75.04	76.04	936.60	1947.3	83.33	84.55	988.02	34
36	1852.0	75.31	76.32	938.32	1950.6	83.61	84.84	989.74	36
38	1855.3	75.58	76.59	940.03	1953.9	83.90	85.13	991.46	38
40	1858.6	75.85	76.87	941.74	1957.2	84.18	85.43	993.18	40
42	1861.9	76.12	77.14	943.45	1960.4	84.47	85.73	994.90	42
44	1865.1	76.39	77.42	945.16	1963.7	84.75	86.02	996.62	44
46	1868.4	76.67	77.70	946.88	1967.0	85.04	86.32	998.34	46
48	1871.1	76.94	77.98	948.59	1970.3	85.32	86.61	1000.0	48
50	1875.0	77.21	78.26	950.30	1973.6	85.61	86.91	1001.8	50
52	1878.3	77.49	78.53	952.01	1976.9	85.90	87.21	1003.5	52
54	1881.6	77.76	78.81	953.72	1980.1	86.19	87.50	1005.2	54
56	1884.9	78.03	79.09	955.44	1983.4	86.47	87.80	1006.9	56
58	1888.2	78.31	79.37	957.15	1986.7	86.76	88.09	1008.6	58
60	1891.5	78.58	79.65	958.86	1990.0	87.05	88.39	1010.4	60

Table A-5. Functions of 1° curves (continued)

	20°				21°				
	LC	M	E	T	LC	M	E	T	
0	1990.0	87.50	88.39	1010.4	2088.5	95.95	97.58	1062.0	0
2	1993.3	87.34	88.69	1012.1	2091.8	96.26	97.90	1063.7	2
4	1996.6	87.63	88.99	1013.8	2095.0	96.56	98.21	1065.4	4
6	1999.8	87.92	89.29	1015.5	2098.3	96.87	98.53	1067.2	6
8	2003.1	88.21	89.59	1017.2	2101.6	97.17	98.84	1068.9	8
10	2006.4	88.50	89.89	1019.0	2104.9	97.48	99.16	1070.6	10
12	2009.7	88.79	90.19	1020.7	2108.1	97.79	99.48	1072.4	12
14	2013.0	89.08	90.49	1022.4	2111.4	98.09	99.79	1074.1	14
16	2016.3	89.37	90.79	1024.1	2114.7	98.40	100.1	1075.8	16
18	2019.5	89.66	91.09	1025.8	2118.0	98.70	100.4	1077.5	18
20	2022.8	89.96	91.40	1027.6	2121.2	99.00	100.7	1079.3	20
22	2026.1	90.25	91.71	1029.3	2124.5	99.39	101.1	1081.0	22
24	2029.4	90.55	92.01	1031.0	2127.8	99.60	101.4	1082.7	24
26	2032.7	90.85	92.32	1032.7	2131.0	99.90	101.7	1084.4	26
28	2036.0	91.15	92.62	1034.4	2134.3	100.2	102.0	1086.2	28
30	2039.2	91.45	92.93	1036.1	2137.6	100.5	102.3	1087.9	30
32	2042.5	91.74	93.24	1037.9	2140.9	100.8	102.7	1089.6	32
34	2045.8	92.04	93.54	1039.6	2144.1	101.1	103.0	1091.3	34
36	2049.1	92.34	93.85	1041.3	2147.4	101.4	103.3	1093.1	36
38	2052.4	92.64	94.15	1043.0	2150.7	101.7	103.6	1094.8	38
40	2055.7	92.94	94.46	1044.8	2154.0	102.1	104.0	1096.5	40
42	2058.9	93.24	94.78	1046.5	2157.2	102.4	104.3	1098.3	42
44	2062.2	93.54	95.09	1048.2	2160.5	102.7	104.6	1100.0	44
46	2065.5	93.84	95.40	1049.9	2163.8	103.0	104.9	1101.7	46
48	2068.8	94.14	95.71	1051.7	2167.1	103.3	105.3	1103.4	48
50	2072.1	94.44	96.03	1053.4	2170.3	103.6	105.6	1105.2	50
52	2075.4	94.74	96.34	1055.1	2173.6	103.9	105.9	1106.9	52
54	2078.6	95.04	96.65	1056.8	2176.9	104.2	106.3	1108.6	54
56	2081.9	95.34	96.96	1058.6	2180.1	104.5	106.6	1110.3	56
58	2085.2	95.64	97.27	1060.3	2183.4	104.8	106.9	1112.1	58
60	2088.5	95.95	97.58	1062.0	2186.7	105.2	107.2	1113.8	60

	22°				23°				
	LC	M	E	T	LC	M	E	T	
0	2186.7	105.2	107.2	1113.8	2284.8	115.0	117.4	1165.8	0
2	2190.0	105.6	107.6	1115.5	2288.1	115.3	117.7	1167.5	2
4	2193.2	105.9	107.9	1117.3	2291.3	115.7	118.1	1169.2	4
6	2196.5	106.2	108.2	1119.0	2294.6	116.0	118.4	1171.0	6
8	2199.8	106.5	108.6	1120.7	2297.8	116.4	118.8	1172.7	8
10	2203.0	106.8	108.9	1122.4	2301.1	116.7	119.1	1174.4	10
12	2206.3	107.1	109.2	1124.2	2304.4	117.0	119.5	1176.5	12
14	2209.6	107.4	109.6	1125.9	2307.6	117.4	119.8	1177.9	14
16	2212.9	107.7	109.9	1127.6	2310.9	117.7	120.4	1179.7	16
18	2216.1	108.0	110.2	1129.4	2314.1	118.1	120.5	1181.4	18
20	2219.4	108.4	110.6	1131.1	2317.4	118.4	120.9	1183.1	20
22	2222.7	108.7	110.9	1132.8	2320.7	118.7	121.2	1184.9	22
24	2225.9	109.0	111.2	1134.6	2323.9	119.1	121.6	1186.6	24
26	2229.2	109.4	111.6	1136.3	2327.2	119.4	121.9	1188.4	26
28	2232.5	109.7	111.9	1138.0	2330.4	119.8	122.3	1190.1	28
30	2235.7	110.0	112.3	1139.7	2333.7	120.1	122.6	1191.8	30
32	2239.0	110.4	112.6	1141.5	2337.0	120.4	123.0	1193.6	32
34	2242.3	110.7	112.9	1143.2	2340.2	120.8	123.3	1195.3	34
36	2245.6	111.0	113.3	1144.9	2343.5	121.1	123.7	1197.1	36
38	2248.8	111.4	113.6	1146.7	2346.7	121.5	124.1	1198.8	38
40	2252.1	111.7	113.9	1148.4	2350.0	121.8	124.4	1200.5	40
42	2255.4	112.0	114.3	1150.1	2353.3	122.1	124.8	1202.3	42
44	2258.6	112.3	114.6	1151.9	2356.5	122.5	125.1	1204.0	44
46	2261.9	112.7	115.0	1153.6	2359.8	122.8	125.5	1205.8	46
48	2265.2	113.0	115.3	1155.4	2363.0	123.2	125.8	1207.5	48
50	2268.4	113.3	115.7	1157.1	2366.3	123.5	126.2	1209.2	50
52	2271.7	113.7	116.0	1158.8	2369.6	123.8	126.6	1211.0	52
54	2275.0	114.0	116.3	1160.6	2372.8	124.2	126.9	1212.7	54
56	2278.3	114.3	116.7	1162.3	2376.1	124.5	127.3	1214.5	56
58	2281.5	114.7	117.0	1164.0	2379.3	124.9	127.6	1216.2	58
60	2284.8	115.0	117.4	1165.8	2382.6	125.2	128.0	1218.0	60

Table A-5. Functions of 1° curves (continued)

	24°				25°				
	LC	M	E	T	LC	M	E	T	
0	2382.6	125.2	128.0	1218.0	2480.4	135.8	139.1	1270.3	0
2	2385.9	125.5	128.4	1219.7	2483.6	136.2	139.5	1272.0	2
4	2389.1	125.9	128.7	1221.4	2486.9	136.5	139.9	1273.8	4
6	2392.4	126.2	129.1	1223.2	2490.1	136.9	140.3	1275.5	6
8	2395.6	126.6	129.5	1224.9	2493.4	137.2	140.6	1277.3	8
10	2398.9	126.9	129.8	1226.7	2496.6	137.6	121.0	1279.0	10
12	2402.2	127.3	130.2	1228.4	2499.9	138.0	121.4	1280.8	12
14	2405.4	127.6	130.6	1230.2	2503.1	138.3	121.8	1282.5	14
16	2408.7	128.0	130.9	1231.9	2506.4	138.7	142.2	1284.3	16
18	2411.9	128.3	131.3	1233.6	2509.6	139.0	142.5	1286.1	18
20	2415.2	128.7	131.7	1235.4	2512.9	139.4	142.9	1287.8	20
22	2418.5	129.0	132.0	1237.1	2516.1	139.8	143.3	1289.6	22
24	2421.7	129.4	132.4	1238.9	2519.4	140.1	143.7	1291.3	24
26	2425.0	129.7	132.8	1240.6	2522.6	140.5	144.1	1293.1	26
28	2428.2	130.1	133.1	1242.4	2525.9	140.8	144.5	1294.8	28
30	2431.5	130.4	133.5	1244.1	2529.1	141.2	144.9	1296.6	30
32	2434.8	130.8	133.9	1245.8	2532.4	141.6	145.3	1298.3	32
34	2438.0	131.1	134.2	1247.6	2535.6	142.0	145.6	1300.1	34
36	2441.3	131.5	134.6	1249.3	2538.9	142.3	146.0	1301.8	36
38	2444.5	131.8	135.0	1251.1	2542.1	142.7	146.4	1303.6	38
40	2447.8	132.2	135.4	1252.8	2545.4	143.1	146.8	1305.3	40
42	2451.1	132.6	135.7	1254.6	2548.6	143.5	147.2	1307.1	42
44	2454.3	132.9	136.1	1256.3	2551.9	143.8	147.6	1308.8	44
46	2457.6	133.3	136.5	1258.1	2555.1	144.2	148.0	1310.6	46
48	2460.8	133.6	136.9	1259.8	2558.4	144.5	148.4	1312.4	48
50	2464.1	134.0	137.2	1261.5	2561.6	144.9	148.8	1314.1	50
52	2467.4	134.4	137.6	1263.3	2564.9	145.3	149.2	1315.9	52
54	2470.6	134.7	138.0	1265.0	2568.1	145.7	149.5	1317.6	54
56	2473.9	135.1	138.4	1266.8	2571.4	146.0	149.9	1319.4	56
58	2477.1	135.4	138.7	1268.5	2574.6	146.4	150.3	1321.1	58
60	2480.4	135.8	139.1	1270.3	2577.9	146.8	150.7	1322.9	60

	26°				27°				
	LC	M	E	T	LC	M	E	T	
0	2577.9	146.8	150.7	1322.9	2675.3	158.3	162.8	1375.6	0
2	2581.1	147.1	151.1	1324.6	2678.5	158.6	163.2	1377.4	2
4	2584.4	147.5	151.5	1326.4	2681.8	159.0	163.7	1379.2	4
6	2587.6	147.9	151.9	1328.1	2685.0	159.4	164.1	1380.9	6
8	2590.9	148.3	152.3	1329.9	2688.2	159.8	164.5	1382.7	8
10	2594.1	148.7	152.7	1331.6	2691.5	160.2	164.9	1384.5	10
12	2597.4	149.1	153.1	1333.4	2694.7	160.6	165.3	1386.2	12
14	2600.6	149.4	153.5	1335.2	2698.0	161.0	165.7	1388.0	14
16	2603.9	149.8	153.9	1336.9	2701.2	161.4	166.1	1389.8	16
18	2607.1	150.2	154.3	1338.7	2704.4	161.8	166.5	1391.5	18
20	2610.4	150.6	154.7	1340.4	2707.7	162.2	167.0	1393.3	20
22	2613.6	151.0	155.1	1342.2	2710.9	162.6	167.4	1395.0	22
24	2616.9	151.4	155.5	1343.9	2714.1	163.0	167.8	1396.8	24
26	2620.1	151.7	155.9	1345.7	2717.4	163.4	168.2	1398.6	26
28	2623.4	152.1	156.3	1347.4	2720.6	163.8	168.6	1400.3	28
30	2626.6	152.5	156.7	1349.2	2723.8	164.2	169.1	1402.1	30
32	2629.8	152.9	157.1	1351.0	2727.1	164.6	169.5	1403.9	32
34	2633.1	153.3	157.5	1352.7	2730.3	165.0	169.9	1405.6	34
36	2636.3	153.7	157.9	1354.5	2733.6	165.4	170.3	1407.4	36
38	2639.6	154.0	158.3	1356.2	2736.8	165.8	170.8	1409.2	38
40	2642.8	154.4	158.7	1358.0	2740.0	166.2	171.2	1410.9	40
42	2646.1	154.8	159.1	1359.8	2743.3	166.6	171.6	1412.7	42
44	2649.3	155.2	159.5	1361.5	2746.5	167.0	172.0	1414.5	44
46	2652.6	155.6	160.0	1363.3	2749.7	167.4	172.5	1416.3	46
48	2655.8	156.0	160.4	1365.1	2753.0	167.8	172.9	1418.0	48
50	2659.1	156.3	160.8	1366.8	2756.2	168.2	173.3	1419.8	50
52	2662.3	156.7	161.2	1368.6	2759.5	168.6	173.7	1421.6	52
54	2665.6	157.1	161.6	1370.4	2762.7	169.0	174.1	1423.3	54
56	2668.8	157.5	162.0	1372.1	2765.9	169.4	174.6	1425.1	56
58	2672.1	157.9	162.4	1373.9	2769.2	169.8	175.0	1426.9	58
60	2675.3	158.3	162.8	1375.6	2772.4	170.2	175.4	1428.6	60

Table A-5. Functions of 1° curves (continued)

	28°				29°				
	LC	M	E	T	LC	M	E	T	
0	2772.4	170.2	175.4	1428.6	2869.4	182.5	188.5	1481.9	0
2	2775.6	170.6	175.8	1430.4	2872.6	182.9	189.0	1483.7	2
4	2778.9	171.0	176.3	1432.2	2875.8	183.3	189.4	1485.4	4
6	2782.1	171.4	176.7	1434.0	2879.1	183.7	189.9	1487.2	6
8	2785.3	171.8	177.1	1435.7	2882.3	184.2	190.3	1489.0	8
10	2788.6	172.2	177.6	1437.5	2885.5	184.6	190.8	1490.8	10
12	2791.8	172.6	178.0	1439.3	2888.7	185.0	191.2	1492.6	12
14	2795.0	173.0	178.4	1441.1	2892.0	185.4	191.7	1494.3	14
16	2798.3	173.4	178.9	1442.8	2895.2	185.8	192.1	1496.1	16
18	2801.5	173.8	179.3	1444.6	2898.4	186.3	192.5	1497.9	18
20	2804.7	174.3	179.7	1446.4	2901.6	186.7	193.0	1499.7	20
22	2808.0	174.7	180.2	1448.2	2904.8	187.1	193.5	1501.5	22
24	2811.2	175.1	180.6	1449.9	2908.1	187.5	193.9	1503.2	24
26	2814.4	175.5	181.0	1451.7	2911.3	188.0	194.4	1505.0	26
28	2817.7	175.9	181.5	1453.5	2914.5	188.4	194.8	1506.8	28
30	2820.9	176.3	181.9	1455.2	2917.7	188.8	195.3	1508.6	30
32	2824.1	176.7	182.3	1457.0	2921.0	189.2	195.7	1510.4	32
34	2827.4	177.1	182.8	1458.8	2924.2	189.7	196.2	1512.1	34
36	2830.6	177.5	183.2	1460.6	2927.4	190.1	196.7	1513.9	36
38	2833.8	177.9	183.6	1462.3	2930.6	190.5	197.1	1515.7	38
40	2837.1	178.4	184.1	1464.1	2933.9	190.9	197.6	1517.5	40
42	2840.3	178.8	184.5	1465.9	2937.1	191.4	198.0	1519.3	42
44	2843.5	179.2	185.0	1467.7	2940.3	191.9	198.5	1521.0	44
46	2846.8	179.6	185.4	1469.5	2943.5	192.4	198.9	1522.8	46
48	2850.0	180.0	185.9	1471.2	2946.8	192.8	199.4	1524.6	48
50	2853.2	180.4	186.3	1473.0	2950.0	193.2	199.8	1526.4	50
52	2856.5	180.8	186.8	1474.8	2953.2	193.6	200.3	1528.2	52
54	2859.7	181.2	187.2	1476.6	2956.4	194.0	200.8	1530.0	54
56	2862.9	181.6	187.6	1478.3	2959.6	194.4	201.2	1531.7	56
58	2866.2	182.0	188.1	1480.1	2962.9	194.8	201.7	1533.5	58
60	2869.4	182.5	188.5	1481.9	2966.1	195.2	202.1	1535.3	60

	30°				31°				
	LC	M	E	T	LC	M	E	T	
0	2966.1	195.2	202.1	1535.3	3062.6	208.4	216.3	1589.0	0
2	2969.3	195.6	202.6	1537.1	3065.8	208.8	216.8	1590.8	2
4	2972.5	196.1	203.1	1538.9	3069.0	209.3	217.2	1592.6	4
6	2975.7	196.5	203.5	1540.7	3072.2	209.7	217.7	1594.4	6
8	2979.0	197.0	204.0	1542.5	3075.4	210.2	218.2	1596.2	8
10	2982.2	197.4	204.5	1544.3	3078.6	210.6	218.7	1598.0	10
12	2985.4	197.8	204.9	1546.0	3081.8	211.1	219.2	1599.8	12
14	2988.6	198.2	205.4	1547.8	3085.0	211.5	219.6	1601.6	14
16	2991.8	198.6	205.9	1549.6	3088.3	212.0	220.1	1603.4	16
18	2995.0	199.1	206.3	1551.4	3091.5	212.4	220.6	1605.2	18
20	2998.3	199.5	206.8	1553.2	3094.7	212.9	221.1	1607.0	20
22	3001.5	199.9	207.3	1555.0	3097.9	213.3	221.6	1608.8	22
24	3004.7	200.4	207.7	1556.8	3101.1	213.8	222.1	1610.6	24
26	3007.9	200.8	208.2	1558.6	3104.3	214.2	222.6	1612.4	26
28	3011.1	201.3	208.7	1560.4	3107.5	214.7	223.0	1614.2	28
30	3014.3	201.7	209.1	1562.2	3110.7	215.1	223.5	1616.0	30
32	3017.6	202.1	209.6	1564.0	3113.9	215.6	224.0	1617.8	32
34	3020.8	202.6	210.1	1565.7	3117.1	216.0	224.5	1619.6	34
36	3024.0	203.0	210.5	1567.5	3120.3	216.5	225.0	1621.4	36
38	3027.2	203.5	211.0	1569.3	3123.5	216.9	225.5	1623.2	38
40	3030.4	203.9	211.5	1571.1	3126.7	217.4	226.0	1625.0	40
42	3033.6	204.3	212.0	1572.9	3129.9	217.8	226.5	1626.8	42
44	3036.9	204.8	212.4	1574.7	3133.1	218.3	227.0	1628.6	44
46	3040.1	205.2	212.9	1576.5	3136.4	218.7	227.5	1630.5	46
48	3043.3	205.7	213.4	1578.3	3139.6	219.2	228.0	1632.3	48
50	3046.5	206.1	213.9	1580.1	3142.8	219.6	228.4	1634.1	50
52	3049.7	206.5	214.4	1581.9	3146.0	220.1	228.9	1635.9	52
54	3052.9	207.0	214.8	1583.7	3149.2	220.5	229.4	1637.7	54
56	3056.2	207.4	215.3	1585.5	3152.4	221.0	229.9	1639.5	56
58	3059.4	207.9	215.8	1587.2	3155.6	221.5	230.4	1641.3	58
60	3062.6	208.4	216.3	1589.0	3158.8	222.0	230.9	1643.1	60

Table A-5. Functions of 1° curves (continued)

	32°				33°				
	LC	M	E	T	LC	M	E	T	
0	3158.8	222.0	230.9	1643.1	3245.9	236.0	246.1	1697.3	0
2	3162.0	222.5	231.4	1644.9	3258.1	236.4	246.6	1699.1	2
4	3165.2	222.9	231.9	1646.7	3261.3	236.9	247.1	1700.9	4
6	3168.4	223.4	232.4	1648.5	3264.5	237.4	247.7	1702.7	6
8	3171.6	223.8	232.9	1650.3	3267.7	237.9	248.2	1704.5	8
10	3174.8	224.3	233.4	1652.1	3270.8	238.4	248.7	1706.4	10
12	3178.0	224.8	233.9	1653.9	3274.0	238.9	249.2	1708.2	12
14	3181.2	225.2	234.4	1655.7	3277.2	239.3	249.7	1710.0	14
16	3184.4	225.7	234.9	1657.5	3280.4	239.8	250.2	1711.8	16
18	3187.6	226.1	235.4	1659.3	3283.6	240.3	250.8	1713.6	18
20	3190.8	226.6	235.9	1661.1	3286.8	240.8	251.3	1715.5	20
22	3194.0	227.1	236.4	1662.9	3290.0	241.2	251.8	1717.3	22
24	3197.2	227.5	236.9	1664.7	3293.2	241.7	252.3	1719.1	24
26	3200.4	228.0	237.4	1666.5	3296.4	242.2	252.9	1720.9	26
28	3203.6	228.4	237.9	1668.3	3299.6	242.7	253.4	1722.7	28
30	3206.8	228.9	238.4	1670.1	3302.7	243.2	253.9	1724.6	30
32	3210.0	229.4	239.0	1671.9	3305.9	243.6	254.4	1726.4	32
34	3213.2	229.8	239.5	1673.7	3309.1	244.1	255.0	1728.2	34
36	3216.5	230.3	240.0	1675.5	3312.3	244.6	255.5	1730.0	36
38	3219.7	230.7	240.5	1677.4	3315.5	245.1	256.0	1731.8	38
40	3222.9	231.2	241.0	1679.2	3318.7	245.6	256.5	1733.6	40
42	3226.1	231.7	241.5	1681.0	3321.9	246.0	257.1	1735.5	42
44	3229.3	232.2	242.0	1682.8	3325.1	246.5	257.6	1737.3	44
46	3232.5	232.6	242.5	1684.6	3328.3	247.0	258.1	1739.1	46
48	3235.7	233.1	243.0	1686.4	3331.5	247.5	258.6	1740.9	48
50	3238.9	233.5	243.5	1688.2	3334.6	248.0	259.2	1742.7	50
52	3242.1	234.0	244.1	1690.0	3337.8	248.4	259.7	1744.6	52
54	3245.3	234.5	244.6	1691.8	3341.0	248.9	260.2	1746.4	54
56	3248.5	235.0	245.1	1693.7	3344.2	249.4	260.8	1748.2	56
58	3251.7	235.5	245.6	1695.5	3347.4	249.9	261.3	1750.0	58
60	3254.9	236.0	246.1	1697.3	3350.6	250.4	261.8	1751.8	60

	34°				35°				
	LC	M	E	T	LC	M	E	T	
0	3350.6	250.4	261.8	1751.8	3446.1	265.2	278.1	1806.7	0
2	3353.8	250.8	262.3	1753.7	3449.3	265.7	278.6	1808.5	2
4	3357.0	251.2	262.9	1755.5	3452.5	266.2	279.2	1810.3	4
6	3360.1	251.7	263.4	1757.3	3455.6	266.7	279.7	1812.2	6
8	3363.3	252.2	264.0	1759.1	3458.8	267.2	280.3	1814.0	8
10	3366.5	252.7	264.5	1761.0	3462.0	267.7	280.8	1815.8	10
12	3369.7	253.2	265.0	1762.8	3465.2	268.2	281.4	1817.7	12
14	3372.9	253.7	265.6	1764.6	3468.3	268.7	281.9	1819.5	14
16	3376.1	254.2	266.1	1766.4	3471.5	269.2	282.5	1821.3	16
18	3379.2	254.7	266.7	1768.3	3474.7	269.7	283.0	1823.2	18
20	3382.4	255.2	267.2	1770.1	3477.9	270.2	283.6	1825.0	20
22	3385.6	255.7	267.7	1771.9	3481.0	270.7	284.2	1826.8	22
24	3388.8	256.2	268.3	1773.7	3484.2	271.2	284.7	1828.7	24
26	3392.0	256.7	268.8	1775.6	3487.4	271.7	285.3	1830.5	26
28	3395.2	257.2	269.3	1777.4	3490.6	272.2	285.9	1832.3	28
30	3398.3	257.7	269.9	1779.2	3493.7	272.7	286.4	1834.2	30
32	3401.5	258.2	270.4	1781.0	3496.9	273.2	287.0	1836.0	32
34	3404.7	258.7	271.0	1782.9	3500.1	273.7	287.5	1837.8	34
36	3407.9	259.2	271.5	1784.7	3503.3	274.2	288.1	1839.7	36
38	3411.1	259.7	272.0	1786.5	3506.5	274.7	288.7	1841.5	38
40	3414.3	260.2	272.6	1788.4	3509.6	275.2	289.2	1843.4	40
42	3417.4	260.7	273.1	1790.2	3512.8	275.7	289.8	1845.2	42
44	3420.6	261.2	273.7	1792.0	3516.0	276.2	290.4	1847.1	44
46	3423.8	261.7	274.2	1793.9	3519.2	276.7	290.9	1848.9	46
48	3427.0	262.2	274.8	1795.7	3522.3	277.2	291.5	1850.7	48
50	3430.2	262.7	275.3	1797.5	3525.5	277.7	292.0	1852.6	50
52	3433.4	263.2	275.9	1799.3	3528.7	278.2	292.6	1854.4	52
54	3436.5	263.7	276.4	1801.2	3531.9	278.7	293.2	1856.3	54
56	3439.7	264.2	277.0	1803.0	3535.0	279.2	293.7	1858.1	56
58	3442.9	264.7	277.5	1804.8	3538.2	279.8	294.3	1859.9	58
60	3446.1	265.2	278.1	1806.7	3241.4	280.4	294.9	1861.8	60

Table A-5. Functions of 1° curves (continued)

	36°				37°				
	LC	M	E	T	LC	M	E	T	
0	3541.4	280.4	294.9	1861.8	3636.3	296.1	312.3	1917.3	0
2	3544.6	280.9	295.4	1863.6	3639.5	296.6	312.8	1919.1	2
4	3547.7	281.4	296.0	1865.5	3642.6	297.1	313.4	1921.0	4
6	3550.9	281.9	296.6	1867.3	3645.8	297.7	314.0	1922.8	6
8	3554.0	282.5	297.2	1869.2	3648.9	298.2	314.6	1924.7	8
10	3557.2	283.0	297.7	1871.0	3652.1	298.7	315.2	1926.5	10
12	3560.4	283.5	298.3	1872.9	3655.2	299.3	315.8	1928.4	12
14	3563.5	284.0	298.9	1874.7	3658.4	299.8	316.4	1930.2	14
16	3566.7	284.6	299.5	1876.5	3661.6	300.3	317.0	1932.1	16
18	3569.9	285.1	300.0	1878.4	3664.7	300.9	317.5	1933.9	18
20	3573.0	285.6	300.6	1880.2	3667.9	301.4	318.1	1935.8	20
22	3576.2	286.1	301.2	1882.1	3671.0	301.9	318.7	1937.6	22
24	3579.4	286.7	301.8	1883.9	3674.2	302.5	319.3	1939.5	24
26	3582.5	287.2	302.3	1885.8	3677.3	303.0	319.9	1941.3	26
28	3585.7	287.7	302.9	1887.6	3680.5	303.5	320.5	1943.2	28
30	3588.8	288.2	303.5	1889.5	3683.6	304.1	321.1	1945.0	30
32	3592.0	288.8	304.1	1891.3	3686.8	304.6	321.7	1946.9	32
34	3595.2	289.3	304.6	1893.2	3690.0	305.1	322.3	1948.8	34
36	3598.3	289.8	305.2	1895.0	3693.1	305.7	322.9	1950.6	36
38	3601.5	290.3	305.8	1896.9	3696.3	306.2	323.5	1952.5	38
40	3604.7	290.9	306.4	1898.7	3699.4	306.7	324.2	1954.4	40
42	3607.8	291.4	307.0	1900.6	3702.6	307.3	324.8	1956.2	42
44	3611.0	291.9	307.5	1902.4	3705.7	307.8	325.4	1958.1	44
46	3614.1	292.4	308.1	1904.3	3708.9	308.3	326.0	1960.0	46
48	3617.3	293.0	308.7	1906.1	3712.1	308.9	326.6	1961.8	48
50	3620.5	293.5	309.3	1908.0	3715.2	309.4	327.2	1963.7	50
52	3623.6	294.0	309.9	1909.8	3718.4	309.9	327.8	1965.5	52
54	3626.8	294.5	310.5	1911.7	3721.5	310.5	328.4	1967.4	54
56	3630.0	295.1	311.1	1913.5	3724.7	311.0	329.0	1969.3	56
58	3633.1	295.6	311.7	1915.4	3727.8	311.6	329.6	1971.1	58
60	3636.3	296.1	312.3	1917.3	3731.0	312.2	330.2	1973.0	60

	38°				39°				
	LC	M	E	T	LC	M	E	T	
0	3731.0	312.2	330.2	1973.0	3825.5	328.7	348.7	2029.1	0
2	3734.1	312.7	330.8	1974.9	3828.6	329.2	349.3	2031.0	2
4	3737.3	313.3	331.4	1976.7	3831.8	329.8	349.9	2032.9	4
6	3740.4	313.8	332.0	1978.6	3834.9	330.3	350.6	2034.7	6
8	3743.6	314.4	332.6	1980.5	3838.0	330.9	351.2	2036.6	8
10	3746.7	314.9	333.2	1982.3	3841.2	331.5	351.8	2038.5	10
12	3749.9	315.5	333.8	1984.2	3844.3	332.0	352.4	2040.4	12
14	3753.0	316.0	334.5	1986.1	3847.4	332.6	353.1	2042.3	14
16	3756.2	316.6	335.1	1987.9	3850.6	333.2	353.7	2044.1	16
18	3759.3	317.1	335.7	1989.8	3853.7	333.7	354.3	2046.0	18
20	3762.5	317.7	336.3	1991.7	3856.8	334.3	354.0	2047.9	20
22	3765.6	318.2	336.9	1993.6	3860.0	334.9	355.6	2049.8	22
24	3768.8	318.8	337.5	1995.4	3863.1	335.4	356.2	2051.7	24
26	3771.9	319.3	338.1	1997.3	3866.2	336.0	356.9	2053.5	26
28	3775.1	319.9	338.7	1999.2	3869.4	336.6	357.5	2055.4	28
30	3778.2	320.4	339.4	2001.0	3872.5	337.1	358.1	2057.3	30
32	3781.4	321.0	340.0	2002.9	3875.6	337.7	358.8	2059.2	32
34	3784.5	321.5	340.6	2004.8	3878.8	338.3	359.4	2061.1	34
36	3787.7	322.1	341.2	2006.6	3881.9	338.8	360.1	2063.0	36
38	3790.8	322.6	341.8	2008.5	3885.0	339.4	360.7	2064.8	38
40	3794.0	323.2	342.4	2010.4	3888.2	340.0	361.3	2066.7	40
42	3797.1	323.7	343.1	2012.3	3891.3	340.5	362.0	2068.6	42
44	3800.3	324.3	343.7	2014.1	3894.4	341.1	362.6	2070.5	44
46	3803.4	324.8	344.3	2016.0	3897.6	341.7	363.3	2072.4	46
48	3806.6	325.4	344.9	2017.9	3900.7	342.2	363.9	2074.2	48
50	3809.7	325.9	345.6	2019.7	3903.8	342.8	364.5	2076.1	50
52	3812.9	326.5	346.2	2021.6	3907.0	343.4	365.2	2078.0	52
54	3816.0	327.0	346.8	2023.5	3910.1	343.9	365.8	2079.9	54
56	3819.2	327.6	347.4	2025.4	3913.2	344.5	366.5	2081.8	56
58	3822.3	328.1	348.1	2027.2	3916.4	345.1	367.1	2083.7	58
60	3825.5	328.7	348.7	2029.1	3919.5	345.6	367.7	2085.5	60

Table A-5. Functions of 1° curves (continued)

	40°				41°				
	LC	M	E	T	LC	M	E	T	
0	3919.5	345.6	367.7	2085.5	4013.4	362.9	387.4	2142.3	0
2	3922.6	346.1	368.4	2087.4	4016.5	363.4	388.1	2144.2	2
4	3925.8	346.7	369.0	2089.3	4019.6	364.0	388.8	2146.1	4
6	3928.9	347.2	369.7	2091.2	4022.7	364.5	389.4	2148.0	6
8	3932.0	347.8	370.3	2093.1	4025.9	365.1	390.1	2149.9	8
10	3935.1	348.4	371.0	2095.0	4029.0	365.6	390.7	2151.9	10
12	3938.3	348.9	371.6	2096.9	4032.1	366.2	391.4	2153.8	12
14	3941.4	349.5	372.3	2098.8	4035.2	366.8	392.1	2155.7	14
16	3944.5	350.1	372.9	2100.7	4038.3	367.4	392.7	2157.6	16
18	3947.7	350.7	373.6	2102.6	4041.4	368.0	393.4	2159.5	18
20	3950.8	351.3	374.3	2104.5	4044.6	368.6	394.1	2161.4	20
22	3953.9	351.8	374.9	2106.3	4047.7	369.2	394.7	2163.3	22
24	3957.1	352.4	375.6	2108.2	4050.8	369.8	395.4	2165.2	24
26	3960.2	353.0	376.2	2110.1	4053.9	370.4	396.1	2167.1	26
28	3963.3	353.6	376.9	2112.0	4057.0	371.0	396.8	2169.0	28
30	3966.4	354.2	377.5	2113.9	4060.1	371.6	397.5	2170.9	30
32	3969.6	354.7	378.2	2115.8	4063.3	372.2	398.1	2172.8	32
34	3972.7	355.3	378.8	2117.7	4066.4	372.8	398.8	2174.7	34
36	3975.8	355.9	379.5	2119.6	4069.5	373.4	399.5	2176.6	36
38	3979.0	356.5	380.1	2121.5	4072.6	374.0	400.2	2178.5	38
40	3982.1	357.1	380.8	2123.4	4075.7	374.6	400.9	2180.4	40
42	3985.2	357.6	381.4	2125.3	4078.8	375.2	401.5	2182.4	42
44	3988.4	358.2	382.1	2127.2	4082.0	375.8	402.2	2184.3	44
46	3991.5	358.8	382.8	2129.1	4085.1	376.4	402.9	2186.2	46
48	3994.6	359.4	383.4	2131.0	4088.2	377.0	403.6	2188.1	48
50	3997.7	360.0	384.1	2132.9	4091.3	377.6	404.3	2190.0	50
52	4000.9	360.5	384.8	2134.7	4094.4	378.2	404.9	2191.9	52
54	4004.0	361.1	385.4	2136.6	4097.5	378.8	405.6	2193.8	54
56	4007.1	361.7	386.1	2138.5	4100.7	379.4	406.3	2195.7	56
58	4010.3	362.3	386.8	2140.4	4103.8	380.0	407.0	2197.6	58
60	4013.4	362.9	387.4	2142.3	4106.9	380.6	407.7	2199.5	60

	42°				43°				
	LC	M	E	T	LC	M	E	T	
0	4106.9	380.6	407.7	2199.5	4200.1	398.7	428.6	2257.1	0
2	4110.0	381.2	408.3	2201.4	4203.2	399.3	429.3	2259.0	2
4	4113.1	381.8	409.0	2203.3	4206.3	399.9	430.0	2261.0	4
6	4116.2	382.4	409.7	2205.3	4209.4	400.5	430.7	2262.9	6
8	4119.3	383.0	410.4	2207.2	4212.5	401.1	431.4	2264.8	8
10	4122.4	383.6	411.1	2209.1	4215.6	401.7	432.1	2266.7	10
12	4125.5	384.2	411.8	2211.0	4218.7	402.4	432.8	2268.7	12
14	4128.6	384.8	412.5	2212.9	4221.8	403.0	433.5	2270.6	14
16	4131.8	385.4	413.2	2214.9	4224.9	403.6	434.2	2272.5	16
18	4134.9	386.0	413.9	2216.8	4228.0	404.2	434.9	2274.5	18
20	4138.0	386.6	414.6	2218.7	4231.0	404.8	435.6	2276.4	20
22	4141.1	387.2	415.3	2220.6	4234.2	405.4	436.3	2278.3	22
24	4144.2	387.8	416.0	2222.5	4237.3	406.1	437.0	2280.2	24
26	4147.3	388.4	416.6	2224.4	4240.4	406.7	437.8	2282.2	26
28	4150.4	389.0	417.3	2226.4	4243.5	407.3	438.5	2284.1	28
30	4153.5	389.6	418.0	2228.3	4246.5	407.9	439.2	2286.0	30
32	4156.6	390.2	418.7	2230.2	4249.6	408.5	439.9	2288.0	32
34	4159.7	390.8	419.4	2232.1	4252.7	409.1	440.6	2289.9	34
36	4162.8	391.4	420.1	2234.0	4255.8	409.8	441.4	2291.8	36
38	4165.9	392.0	420.8	2236.0	4258.9	410.4	442.1	2293.8	38
40	4169.0	392.6	421.5	2237.9	4262.0	411.0	442.8	2295.7	40
42	4172.1	393.2	422.2	2239.8	4265.1	411.6	443.5	2297.7	42
44	4175.2	393.8	422.9	2241.7	4268.2	412.2	444.2	2299.6	44
46	4178.4	394.4	423.6	2243.6	4271.3	412.8	445.0	2301.5	46
48	4181.5	395.0	424.3	2245.6	4274.4	413.5	445.7	2303.5	48
50	4184.6	395.6	425.0	2247.5	4277.5	414.1	446.4	2305.4	50
52	4187.7	396.2	425.7	2249.4	4280.6	414.7	447.1	2307.3	52
54	4190.8	396.8	426.4	2251.3	4283.7	415.3	447.8	2309.3	54
56	4193.9	397.4	427.1	2253.3	4286.8	415.9	448.6	2311.2	56
58	4197.0	398.0	427.8	2255.2	4289.9	416.5	449.3	2313.1	58
60	4200.1	398.7	428.6	2257.1	4293.0	417.2	450.0	2315.1	60

Table A-5. Functions of 1° curves (continued)

	44°				45°				
	LC	M	E	T	LC	M	E	T	
0	4293.0	417.2	450.0	2315.1	4385.5	436.2	472.1	2373.4	0
2	4296.1	417.8	450.7	2317.0	4388.6	436.8	472.9	2375.4	2
4	4299.2	418.4	451.5	2319.0	4391.7	437.5	473.6	2377.3	4
6	4302.2	419.1	452.2	2320.9	4394.7	438.1	474.4	2379.3	6
8	4305.3	419.7	452.9	2322.8	4397.8	438.8	475.1	2381.2	8
10	4308.4	420.3	453.7	2324.8	4400.9	439.4	475.9	2383.2	10
12	4311.5	421.0	454.4	2326.7	4404.0	440.0	476.6	2385.2	12
14	4314.6	421.6	455.1	2328.7	4407.0	440.7	477.4	2387.1	14
16	4317.7	422.2	455.9	2330.6	4410.1	441.3	478.1	2389.1	16
18	4320.7	422.9	456.6	2332.6	4413.2	442.0	478.9	2391.0	18
20	4323.8	423.5	457.3	2334.5	4416.3	442.6	479.6	2393.0	20
22	4326.9	424.1	458.1	2336.4	4419.3	443.2	480.4	2394.9	22
24	4330.0	424.8	458.8	2338.4	4422.4	443.9	481.1	2396.9	24
26	4333.1	425.4	459.5	2340.3	4425.5	444.5	481.9	2398.8	26
28	4336.2	426.0	460.3	2342.3	4428.6	445.2	482.6	2400.8	28
30	4339.2	426.7	461.0	2344.2	4431.6	445.8	483.4	2402.8	30
32	4342.3	427.3	461.7	2346.1	4434.7	446.4	484.2	2404.7	32
34	4345.4	427.9	462.5	2348.1	4437.8	447.1	484.9	2406.7	34
36	4348.5	428.6	463.2	2350.0	4440.9	447.7	485.7	2408.6	36
38	4351.6	429.2	463.9	2352.0	4444.0	448.3	486.5	2410.6	38
40	4354.7	429.8	464.7	2353.9	4447.0	448.9	487.2	2412.6	40
42	4357.7	430.5	465.4	2355.9	4450.1	449.5	488.0	2414.5	42
44	4360.8	431.1	466.2	2357.8	4453.2	450.2	488.7	2416.5	44
46	4363.9	431.7	466.9	2359.8	4456.3	450.8	489.5	2418.5	46
48	4367.0	432.4	467.7	2361.7	4459.3	451.5	490.3	2420.4	48
50	4370.1	433.0	468.4	2363.7	4462.4	452.1	491.0	2422.4	50
52	4373.2	433.6	469.1	2365.5	4465.5	452.7	491.8	2424.4	52
54	4376.2	434.3	469.9	2367.6	4468.6	453.4	492.5	2426.3	54
56	4379.3	434.9	470.6	2369.5	4471.6	454.1	493.3	2428.3	56
58	4382.4	435.6	471.4	2371.5	4474.7	454.8	494.1	2430.2	58
60	4385.5	436.2	472.1	2373.4	4477.8	455.5	494.8	2432.2	60

	46°				47°				
	LC	M	E	T	LC	M	E	T	
0	4477.8	455.5	494.8	2432.2	4569.7	475.2	518.3	2491.5	0
2	4480.9	456.1	495.6	2434.2	4572.7	475.9	519.0	2493.4	2
4	4483.9	456.8	496.5	2436.1	4575.8	476.5	519.8	2495.4	4
6	4487.0	457.4	497.2	2438.1	4578.8	477.2	520.6	2497.4	6
8	4490.0	458.1	497.9	2440.1	4581.9	477.8	521.4	2499.4	8
10	4493.1	458.7	498.7	2442.1	4584.9	478.5	522.2	2501.4	10
12	4496.2	459.4	499.5	2444.0	4588.0	479.2	523.0	2503.4	12
14	4499.2	460.0	500.3	2446.0	4591.0	479.8	523.8	2505.4	14
16	4502.3	460.7	501.0	2448.0	4594.1	480.5	524.6	2507.3	16
18	4505.4	461.3	501.8	2449.9	4597.1	481.1	525.4	2509.3	18
20	4508.4	462.0	502.6	2451.9	4600.2	481.7	526.2	2511.3	20
22	4511.5	462.7	503.4	2453.9	4603.2	482.3	527.0	2513.3	22
24	4514.6	463.3	504.1	2455.9	4606.3	483.0	527.8	2515.3	24
26	4517.6	464.0	504.9	2457.8	4609.3	483.7	528.6	2517.3	26
28	4520.7	464.6	505.7	2459.8	4612.4	484.3	529.4	2519.3	28
30	4523.7	465.3	506.5	2461.8	4615.4	485.0	530.2	2521.2	30
32	4526.8	466.0	507.3	2463.8	4618.5	485.7	531.0	2523.2	32
34	4529.9	466.6	508.0	2465.7	4621.5	486.3	531.8	2525.2	34
36	4532.9	467.3	508.8	2467.7	4624.6	487.0	532.6	2527.2	36
38	4536.0	467.9	509.6	2469.7	4627.6	487.7	533.4	2529.2	38
40	4539.1	468.6	510.4	2471.7	4630.7	488.4	534.2	2531.2	40
42	4542.1	469.3	511.1	2473.6	4633.7	489.1	535.0	2533.2	42
44	4545.2	469.9	511.9	2475.6	4636.8	489.8	535.8	2535.2	44
46	4548.2	470.6	512.7	2477.6	4639.8	490.5	536.6	2537.2	46
48	4551.3	471.2	513.5	2479.6	4642.9	491.2	537.4	2539.2	48
50	4554.4	471.9	514.3	2481.6	4645.9	491.9	538.2	2541.2	50
52	4557.4	472.6	515.1	2483.5	4649.0	492.6	539.0	2543.1	52
54	4566.5	473.2	515.9	2485.5	4652.0	493.3	539.8	2545.1	54
56	4563.6	473.9	516.7	2487.5	4655.1	494.0	540.6	2547.1	56
58	4566.6	474.5	517.5	2489.5	4658.1	494.7	541.4	2549.1	58
60	4569.7	475.2	518.3	2491.5	4661.2	495.4	542.3	2551.1	60

Table A-5. Functions of 1° curves (continued)

	48°				49°				
	LC	M	E	T	LC	M	E	T	
0	4661.2	495.4	542.3	2551.1	4752.3	515.9	567.0	2611.3	0
2	4664.2	496.0	543.1	2553.1	4755.3	516.5	567.8	2613.3	2
4	4667.3	496.7	543.9	2555.1	4758.4	517.2	568.7	2615.3	4
6	4670.3	497.4	544.7	2557.1	4761.4	517.9	569.5	2617.3	6
8	4673.3	498.1	545.5	2559.1	4764.4	518.6	570.3	2619.3	8
10	4676.4	498.8	546.4	2561.1	4767.4	519.3	571.2	2621.4	10
12	4679.4	499.4	547.2	2563.1	4770.5	520.0	572.0	2623.4	12
14	4682.5	500.1	548.0	2565.1	4773.5	520.7	572.8	2625.4	14
16	4685.5	500.8	548.8	2567.1	4776.5	521.4	573.7	2627.4	16
18	4688.5	501.5	549.6	2569.1	4779.6	522.1	574.5	2629.4	18
20	4691.6	502.2	550.5	2571.1	4782.6	522.8	575.3	2631.4	20
22	4694.6	502.8	551.3	2573.1	4785.6	523.5	576.2	2633.5	22
24	4697.6	503.5	552.1	2575.1	4788.7	524.2	577.0	2635.5	24
26	4700.7	504.2	552.9	2577.1	4791.7	524.9	577.9	2637.5	26
28	4703.7	504.9	553.7	2579.1	4794.7	525.6	578.7	2639.5	28
30	4706.7	505.6	554.6	2581.1	4797.7	526.3	579.6	2641.5	30
32	4709.8	506.2	555.4	2583.1	4800.8	527.0	580.4	2543.5	32
34	4712.8	506.9	556.2	2585.1	4803.8	527.7	581.3	2645.6	34
36	4715.9	507.6	557.0	2587.2	4806.8	528.4	582.1	2647.6	36
38	4718.9	508.3	557.8	2589.2	4809.9	529.1	583.0	2549.6	38
40	4721.9	509.0	558.7	2591.2	4812.9	529.8	583.8	2651.6	40
42	4725.0	509.6	559.5	2593.2	4815.9	530.5	584.7	2653.7	42
44	4728.0	510.3	560.3	2595.2	4819.0	531.2	585.5	2655.7	44
46	4731.0	511.0	561.2	2597.2	4822.0	531.9	586.4	2657.7	46
48	4734.1	511.7	562.0	2599.2	4825.0	532.6	587.2	2659.7	48
50	4737.1	512.4	562.8	2601.2	4828.0	533.3	588.1	2661.8	50
52	4740.2	513.1	563.7	2603.2	4831.1	534.0	588.9	2663.8	52
54	4743.2	513.8	564.5	2605.2	4834.1	534.7	589.8	2665.8	54
56	4746.2	514.5	565.3	2607.2	4837.1	535.4	590.6	2667.8	56
58	4749.3	515.2	566.2	2609.3	4840.2	536.1	591.5	2669.9	58
60	4752.3	515.9	567.0	2611.3	4843.2	536.8	592.4	2671.9	60

	50°				51°				
	LC	M	E	T	LC	M	E	T	
0	4843.2	536.8	592.4	2671.9	4933.6	558.2	618.5	2733.0	0
2	4846.2	537.5	593.2	2673.9	4936.6	558.9	619.3	2735.1	2
4	4849.2	538.2	594.1	2676.0	4939.6	559.7	620.2	2737.1	4
6	4852.2	538.9	594.9	2678.0	4942.6	560.4	621.1	2739.2	6
8	4855.2	539.6	595.8	2680.0	4945.6	561.1	622.0	2741.2	8
10	4858.3	540.3	596.7	2682.1	4948.6	561.8	622.9	2743.3	10
12	4861.3	541.0	597.5	2684.1	4951.6	562.5	623.7	2745.3	12
14	4864.3	541.7	598.4	2686.1	4954.6	563.3	624.6	2747.4	14
16	4867.3	542.4	599.3	2688.2	4957.6	564.0	625.5	2749.4	16
18	4870.3	543.1	600.1	2690.2	4960.6	564.7	626.4	2751.5	18
20	4873.3	543.9	601.0	2692.3	4963.6	565.4	627.3	2753.5	20
22	4876.3	544.6	601.9	2694.3	4966.6	566.2	628.2	2755.6	22
24	4879.4	545.3	602.7	2696.3	4969.6	566.9	629.9	2757.7	24
26	4882.4	546.0	603.6	2698.4	4972.6	567.6	630.0	2759.7	26
28	4885.4	546.7	604.5	2700.4	4975.6	568.3	630.9	2761.8	28
30	4888.4	547.4	605.3	2702.4	4978.6	569.1	631.8	2763.8	30
32	4891.4	548.1	606.2	2704.5	4981.8	569.8	632.7	2765.9	32
34	4894.4	548.8	607.0	2706.5	4984.6	570.5	633.6	2767.9	34
36	4897.4	549.5	607.9	2708.6	4987.7	571.2	634.5	2770.0	36
38	4900.4	550.2	608.8	2710.6	4990.7	572.0	635.3	2772.0	38
40	4903.5	551.0	609.7	2712.6	4993.7	572.7	636.2	2774.1	40
42	4906.5	551.7	610.5	2714.7	4996.7	573.4	637.1	2776.2	42
44	4909.5	552.4	611.4	2716.7	4999.7	574.1	638.0	2778.2	44
46	4912.5	553.1	612.3	2718.8	5002.7	574.9	638.9	2780.3	46
48	4915.5	553.8	613.2	2720.8	5005.7	575.6	639.8	2782.3	48
50	4918.5	554.5	614.1	2722.8	5008.7	576.3	640.7	2784.4	50
52	4921.5	555.2	614.9	2724.9	5011.7	577.0	641.6	2786.4	52
54	4924.6	555.9	615.8	2726.9	5014.7	577.8	642.5	2788.5	54
56	4927.6	556.6	616.7	2729.0	5017.7	578.5	643.4	2790.6	56
58	4930.6	557.4	617.6	2731.0	5020.7	579.2	644.3	2792.6	58
60	4933.6	558.2	618.5	2733.0	5023.7	579.9	645.2	2794.7	60

Table A-5. Functions of 1° curves (continued)

	52°				53°				
	LC	M	E	T	LC	M	E	T	
0	5023.7	579.9	645.2	2794.7	5113.5	602.0	672.7	2856.9	0
2	5026.7	580.6	646.1	2796.8	5116.5	602.8	673.7	2858.9	2
4	5029.7	581.3	647.0	2798.8	5119.4	603.5	674.6	2861.0	4
6	5032.7	582.1	647.9	2800.9	5122.4	604.3	675.5	2863.1	6
8	5035.7	582.8	648.9	2803.0	5125.4	605.0	676.4	2865.2	8
10	5038.7	583.5	649.8	2805.0	5128.4	605.8	677.4	2867.3	10
12	5041.7	584.3	650.7	2807.1	5131.3	606.5	678.3	2869.4	12
14	5044.7	585.0	651.6	2809.2	5134.3	607.3	679.2	2871.5	14
16	5047.7	585.7	652.5	2811.2	5137.3	608.0	680.2	2873.5	16
18	5050.7	586.5	653.4	2813.3	5140.3	608.8	681.1	2875.6	18
20	5053.6	587.2	654.3	2815.4	5143.2	609.5	682.0	2877.7	20
22	5056.6	587.9	655.2	2817.4	5146.2	610.3	683.0	2879.8	22
24	5059.6	588.7	656.2	2819.5	5149.2	611.0	683.9	2881.9	24
26	5062.6	589.4	657.1	2821.6	5152.1	611.8	684.9	2884.0	26
28	5065.6	590.1	658.0	2823.6	5155.1	612.5	685.8	2886.1	28
30	5068.6	590.9	658.9	2825.7	5158.1	613.3	686.7	2888.1	30
32	5071.6	591.6	659.8	2827.8	5161.1	614.0	687.7	2890.2	32
34	5074.6	592.3	660.7	2829.8	5164.0	614.8	688.6	2892.3	34
36	5077.6	593.1	661.6	2831.9	5167.0	615.5	689.6	2894.4	36
38	5080.6	593.8	662.5	2834.0	5170.0	616.3	690.5	2896.5	38
40	5083.6	594.5	663.5	2836.1	5173.0	617.0	691.5	2898.6	40
42	5086.6	595.3	664.4	2838.2	5175.9	617.8	692.4	2900.7	42
44	5089.6	596.0	665.3	2840.2	5178.9	618.5	693.4	2902.8	44
46	5092.6	596.7	666.2	2842.3	5181.9	619.3	694.3	2904.9	46
48	5095.6	597.5	667.2	2844.4	5184.9	620.1	695.3	2907.0	48
50	5098.6	598.2	668.1	2846.5	5187.8	620.8	696.2	2909.1	50
52	5101.6	598.9	669.0	2848.5	5190.8	621.5	697.1	2911.2	52
54	5104.6	599.7	699.9	2850.6	5193.8	622.3	698.1	2913.3	54
56	5107.6	600.4	670.9	2852.7	5196.7	623.0	699.0	2915.4	56
58	5110.6	601.2	671.8	2854.8	5199.7	623.8	700.0	2917.5	58
60	5113.5	602.0	672.7	2856.9	5202.7	624.6	700.9	2919.5	60

	54°				55°				
	LC	M	E	T	LC	M	E	T	
0	5202.7	624.6	700.9	2919.5	5291.7	647.4	729.9	2982.8	0
2	5205.7	625.4	701.9	2921.6	5294.6	648.1	730.9	2984.9	2
4	5208.6	626.1	702.8	2923.8	5297.6	648.9	731.9	2987.1	4
6	5211.6	626.9	703.8	2925.9	5300.5	649.6	732.9	2989.2	6
8	5214.6	627.6	704.8	2928.0	5303.5	650.4	733.8	2991.3	8
10	5217.5	628.4	705.7	2930.1	5306.4	651.2	734.8	2993.4	10
12	5220.5	629.2	706.7	2932.2	5309.4	652.0	735.8	2995.5	12
14	5223.5	629.9	707.7	2934.3	5312.3	652.7	736.8	2097.7	14
16	5226.4	630.7	708.6	2936.4	5315.3	653.5	737.8	2999.8	16
18	5229.4	631.4	709.6	2938.5	5318.2	654.3	738.7	3001.9	18
20	5232.4	632.2	710.5	2940.6	5321.2	655.1	739.7	3004.0	20
22	5235.3	633.0	711.5	2942.7	5324.1	655.8	740.7	3006.2	22
24	5238.3	633.7	712.5	2944.8	5327.1	656.6	741.7	3008.3	24
26	5241.3	634.5	713.4	2946.9	5330.0	657.4	742.7	3010.4	26
28	5244.2	635.2	714.4	2949.0	5333.0	658.2	743.7	3012.5	28
30	5247.2	636.0	715.3	2951.1	5335.9	658.9	744.7	3014.7	30
32	5250.2	636.8	716.3	2953.2	5338.8	659.7	745.7	3016.8	32
34	5253.1	637.5	717.3	2955.3	5341.8	660.5	746.7	3018.9	34
36	5256.1	638.3	718.2	2957.5	5344.7	661.3	747.7	3021.1	36
38	5259.1	639.0	719.2	2959.6	5347.7	662.0	748.7	3023.2	38
40	5262.0	639.8	720.7	2961.7	5350.6	662.8	749.7	3025.3	40
42	5265.0	640.6	721.1	2963.8	5353.6	663.6	750.7	3027.5	42
44	5268.0	641.3	722.1	2965.0	5356.5	664.4	751.7	3029.6	44
46	5270.9	642.1	723.1	2968.0	5359.5	665.1	752.6	3031.7	46
48	5273.9	642.8	724.1	2970.1	5362.4	665.9	753.6	3033.8	48
50	5276.9	643.6	725.0	2972.2	5365.4	666.7	754.6	3036.0	50
52	5279.8	644.4	726.0	2974.4	5368.3	667.5	755.6	3038.1	52
54	5282.8	645.1	727.0	2976.5	5371.3	668.3	756.6	3040.2	54
56	5285.8	645.9	728.0	2978.6	5374.2	669.1	757.6	3042.4	56
58	5288.7	646.6	729.0	2980.7	5377.2	669.9	758.6	3044.5	58
60	5291.7	647.4	729.9	2982.8	5380.1	670.7	759.6	3046.6	60

Table A-5. Functions of 1° curves (continued)

	56°				57°				
	LC	M	E	T	LC	M	E	T	
0	5380.1	670.7	759.6	3046.6	5468.2	694.4	790.2	3111.1	0
2	5383.0	671.4	760.6	3048.8	5471.1	695.2	791.2	3113.3	2
4	5386.0	672.2	761.6	3050.9	5474.0	696.0	792.2	3115.4	4
6	5388.9	672.9	762.7	3053.1	5477.0	696.8	793.3	3117.6	6
8	5391.8	673.7	763.7	3055.2	5479.9	697.6	794.3	3119.7	8
10	5394.8	674.4	764.7	3057.4	5482.8	698.4	795.3	3121.9	10
12	5397.7	675.2	765.7	3059.5	5485.7	699.2	796.3	3124.1	12
14	5400.7	676.0	766.7	3061.6	5488.7	700.0	797.4	3126.2	14
16	5403.6	676.8	767.7	3063.8	5491.6	700.8	798.4	3128.4	16
18	5406.5	677.6	768.7	3065.9	5494.5	701.6	799.4	3130.6	18
20	5409.5	678.4	769.7	3068.1	5497.4	702.4	800.5	3132.7	20
22	5412.4	679.2	770.8	3070.2	5500.3	703.2	801.2	3134.9	22
24	5415.3	680.0	771.8	3072.4	5503.3	704.0	802.6	3137.0	24
26	5418.3	680.8	772.8	3074.5	5506.2	704.8	803.6	3139.2	26
28	5421.2	681.6	773.8	3076.6	5509.1	705.6	804.7	3141.4	28
30	5424.1	682.4	774.8	3078.8	5512.0	706.4	805.7	3143.5	30
32	5427.1	683.2	775.8	3080.9	5515.0	707.2	806.8	3145.7	32
34	5430.0	684.0	776.8	3083.1	5517.9	708.0	807.8	3147.9	34
36	5433.0	684.8	777.8	3085.2	5520.8	708.8	808.8	3150.0	36
38	5435.9	685.6	778.9	3087.4	5523.7	709.6	809.9	3152.2	38
40	5438.8	686.4	779.9	3089.6	5526.7	710.4	810.9	3154.4	40
42	5441.8	687.2	780.9	3091.7	5529.6	711.2	812.0	3156.6	42
44	5444.7	688.0	781.9	3093.9	5532.5	712.0	813.0	3158.7	44
46	5447.6	688.8	783.0	3096.0	5535.4	712.8	814.1	3160.9	46
48	5450.6	689.6	784.0	3098.2	5538.2	713.6	815.1	3163.1	48
50	5453.5	690.4	785.0	3100.3	5541.3	714.4	816.2	3165.3	50
52	5456.5	691.2	786.0	3102.5	5544.2	715.2	817.2	3167.4	52
54	5459.4	692.0	787.1	3104.6	5547.1	716.0	818.3	3169.6	54
56	5462.3	692.8	788.1	3106.8	5550.0	716.8	819.3	3171.8	56
58	5465.3	693.6	789.1	3108.9	5553.0	717.6	820.4	3174.0	58
60	5468.2	694.4	790.2	3111.1	5555.9	718.4	821.4	3176.1	60

	58°				59°				
	LC	M	E	T	LC	M	E	T	
0	5555.9	718.4	821.4	3176.1	5643.1	742.8	853.5	3241.9	0
2	5558.8	719.2	822.5	3178.3	5646.0	743.6	854.6	3244.1	2
4	5561.7	720.0	823.5	3180.5	5648.9	744.4	855.7	3246.3	4
6	5564.6	720.8	824.6	3182.7	5651.8	745.3	856.8	3248.5	6
8	5567.5	721.6	825.7	3184.9	5654.7	746.1	857.9	3250.7	8
10	5570.4	722.4	826.7	3187.1	5657.6	746.9	859.0	3252.9	10
12	5573.3	723.2	827.8	3189.2	5660.5	747.7	860.0	3255.1	12
14	5576.2	724.0	828.9	3191.4	5663.4	748.6	861.1	3257.3	14
16	5579.2	724.8	829.9	3193.6	5666.3	749.4	862.2	3259.5	16
18	5582.1	725.6	831.0	3195.8	5669.2	750.2	863.3	3261.7	18
20	5585.0	726.5	832.1	3198.0	5672.1	751.1	864.4	3263.9	20
22	5587.9	727.3	833.1	3200.2	5675.0	751.9	865.5	3266.1	22
24	5590.8	728.1	834.2	3202.4	5677.9	752.7	866.6	3268.3	24
26	5593.7	728.9	835.3	3204.5	5680.8	753.5	867.7	3270.5	26
28	5596.6	729.7	836.3	3206.7	5683.7	754.4	868.8	3272.7	28
30	5599.5	730.5	837.4	3208.9	5686.5	755.2	869.9	3274.9	30
32	5602.4	731.3	838.4	3211.1	5689.4	756.0	871.0	3277.1	32
34	5605.3	732.1	839.5	3213.3	5692.3	756.9	872.1	3279.4	34
36	5608.2	732.9	840.6	3215.5	5695.2	757.7	873.2	3281.6	36
38	5611.1	733.7	841.6	3217.7	5698.1	758.5	874.3	3283.8	38
40	5614.0	734.6	842.7	3219.9	5701.0	759.4	875.4	3286.0	40
42	5616.9	735.4	843.8	3222.1	5703.9	760.2	876.5	3288.2	42
44	5619.8	736.2	844.9	3224.3	5706.8	761.0	877.6	3290.5	44
46	5622.8	737.0	846.0	3226.5	5709.7	761.9	878.7	3292.7	46
48	5625.7	737.8	847.0	3228.7	5712.6	762.7	879.8	3294.9	48
50	5628.6	738.6	848.1	3230.9	5715.5	763.5	880.9	3297.1	50
52	5631.5	739.4	849.2	3233.1	5718.4	764.4	882.0	3299.3	52
54	5634.4	740.2	850.3	3235.3	5721.3	765.2	883.1	3301.5	54
56	5637.3	741.0	851.4	3237.5	5724.2	766.0	884.2	3303.8	56
58	5640.2	741.9	852.5	3239.7	5727.1	766.8	885.3	3306.0	58
60	5643.1	742.8	853.5	3241.9	5730.0	767.7	886.4	3308.2	60

Table A-5. Functions of 1° curves (continued)

	60°				61°				
	LC	M	E	T	LC	M	E	T	
0	5730.0	767.7	886.4	3308.2	5816.4	792.9	920.2	3375.2	0
2	5732.9	768.5	887.5	3310.4	5819.3	793.7	921.4	3377.4	2
4	5735.8	769.4	888.7	3312.7	5822.1	794.6	922.5	3379.7	4
6	5738.6	770.2	889.8	3314.9	5825.0	795.4	923.6	3381.9	6
8	5741.5	771.1	890.9	3317.1	5827.9	796.3	924.8	3384.2	8
10	5744.4	771.9	892.0	3319.3	5830.7	797.1	925.9	3386.4	10
12	5747.3	772.7	893.1	3321.6	5833.6	798.0	927.1	3388.7	12
14	5750.2	773.6	894.3	3323.8	5836.5	798.8	928.2	3390.9	14
16	5753.0	774.4	895.4	3326.0	5839.3	799.7	929.3	3393.2	16
18	5755.9	775.3	896.5	3328.3	5842.2	800.5	930.5	3395.4	18
20	5758.8	776.1	897.6	3330.5	5845.1	801.4	931.6	3397.7	20
22	5761.7	776.9	898.8	3332.7	5847.9	802.2	932.8	3399.9	22
24	5764.6	777.8	899.9	3334.9	5850.8	803.1	933.9	3402.2	24
26	5767.4	778.6	901.0	3337.2	5853.7	803.9	935.1	3404.4	26
28	5770.3	779.5	902.1	3339.4	5856.5	804.8	936.3	3406.7	28
30	5773.2	780.3	903.2	3341.6	5859.4	805.6	937.4	3408.9	30
32	5776.1	781.1	904.4	3343.9	5862.3	806.5	938.6	3411.2	32
34	5779.0	782.0	905.5	3346.1	5865.1	807.3	939.7	3413.5	34
36	5781.8	782.8	906.6	3348.3	5868.0	808.2	940.9	3415.7	36
38	5784.7	783.7	907.7	3350.6	5870.9	809.0	942.1	3418.0	38
40	5787.6	784.5	908.8	3352.8	5873.7	809.9	943.2	3420.3	40
42	5790.5	785.3	910.0	3355.0	5876.6	810.7	944.4	3422.5	42
44	5793.4	786.2	911.1	3357.3	5879.5	811.6	945.5	3424.8	44
46	5796.6	787.0	918.8	3359.5	5882.3	812.4	946.7	3427.1	46
48	5799.1	787.9	913.4	3361.8	5885.2	813.3	947.8	3429.3	48
50	5802.0	788.7	914.5	3364.0	5888.1	814.1	949.0	3431.6	50
52	5804.9	789.5	915.7	3366.2	5890.9	815.0	950.2	3433.9	52
54	5807.8	790.4	916.8	3368.5	5893.8	815.8	951.3	3436.1	54
56	5810.6	791.2	918.0	3370.7	5896.7	816.7	952.5	3438.4	56
58	5813.5	792.1	919.1	3373.0	5899.5	817.5	953.6	3440.7	58
60	5816.4	792.9	920.2	3375.2	5902.4	818.4	954.8	3442.9	60

	62°				63°				
	LC	M	E	T	LC	M	E	T	
0	5902.4	818.4	954.8	3442.9	5987.8	844.4	990.3	3511.3	0
2	5905.2	819.3	956.0	3445.2	5990.6	845.3	991.5	3513.6	2
4	5908.1	820.1	957.2	3447.5	5993.5	846.2	992.7	3515.9	4
6	5910.9	821.0	958.3	3449.7	5996.3	847.1	993.9	3518.2	6
8	5913.8	821.8	959.5	3452.0	5999.1	847.9	995.1	3520.5	8
10	5916.6	822.7	960.7	3454.3	6002.0	848.8	996.3	3522.8	10
12	5919.5	823.6	961.9	3456.6	6004.8	849.7	997.5	3525.1	12
14	5922.3	824.4	963.0	3458.8	6007.7	850.6	988.7	3527.4	14
16	5925.2	825.3	964.2	3461.1	6010.5	851.4	999.9	3529.7	16
18	5928.0	826.1	965.4	3463.4	6013.3	852.3	1001.1	3532.0	18
20	5930.9	827.0	966.6	3465.7	6016.2	853.2	1002.3	3534.3	20
22	5933.7	827.9	967.8	3467.9	6019.0	854.1	1003.5	3536.6	22
24	5936.6	828.7	968.9	3470.2	6021.8	854.9	1004.7	3538.9	24
26	5939.4	829.6	970.1	3472.5	6024.7	855.8	1005.9	3541.2	26
28	5942.3	830.4	971.3	3474.7	6027.5	856.7	1007.1	3543.5	28
30	5945.1	831.3	972.5	3477.0	6030.3	857.6	1008.4	3545.8	30
32	5847.9	832.2	973.6	3479.3	6033.2	858.4	1009.6	3548.1	32
34	5950.8	833.0	974.8	3481.6	6036.0	859.3	1010.8	3550.4	34
36	5953.6	833.9	976.0	3483.9	6038.9	860.2	1012.0	3552.7	36
38	5956.5	834.7	977.2	3486.2	6041.7	861.1	1013.2	3555.0	38
40	5959.3	835.6	978.4	3488.5	6044.5	861.9	1014.5	3557.3	40
42	5962.2	836.5	979.6	3490.7	6047.4	862.8	1015.7	3559.0	42
44	5965.0	837.4	980.8	3493.0	6050.2	863.7	1016.9	3562.0	44
46	5967.9	838.3	982.0	3495.3	6053.0	864.6	1018.1	3564.3	46
48	5970.7	839.1	983.2	3497.6	6055.9	865.4	1019.3	3566.6	48
50	5973.6	840.0	984.4	3499.9	6058.7	866.3	1020.6	3568.9	50
52	5976.4	840.9	985.5	3502.2	6061.6	867.2	1021.8	3571.2	52
54	5979.3	841.7	986.7	3504.5	6064.4	868.1	1023.0	3573.5	54
56	5982.1	842.6	987.9	3506.8	6067.2	868.9	1024.2	3575.8	56
58	5985.0	843.5	989.1	3509.0	6070.1	869.8	1025.4	3578.1	58
60	5987.8	844.4	990.3	3511.3	6072.9	870.7	1026.7	3580.4	60

Table A-5. Functions of 1° curves (continued)

	64°				65°				
	LC	M	E	T	LC	M	E	T	
0	6072.9	870.7	1026.7	3580.4	6157.5	897.3	1064.0	3650.4	0
2	6075.7	871.5	1027.9	3582.8	6160.3	898.2	1065.2	3652.8	2
4	6078.5	872.4	1029.2	3585.1	6163.1	899.1	1066.5	3655.1	4
6	6081.4	873.3	1030.4	3587.4	6165.9	900.0	1067.7	3657.5	6
8	6084.2	874.2	1031.7	3589.7	6168.7	900.9	1069.0	3659.8	8
10	6087.0	875.1	1032.9	3592.1	6171.5	901.8	1070.2	3662.2	10
12	6089.8	875.9	1034.1	3594.4	6174.3	902.7	1071.5	3664.5	12
14	6092.6	876.8	1035.4	3596.7	6177.1	903.6	1072.7	3666.9	14
16	6095.5	877.7	1036.6	3599.1	6179.9	904.5	1074.0	3669.2	16
18	6098.3	878.6	1037.9	3601.4	6182.7	905.4	1075.2	3671.6	18
20	6101.1	879.5	1039.1	3603.7	6185.5	906.3	1076.6	3673.9	20
22	6103.9	880.3	1040.3	3606.0	6188.3	907.2	1077.8	3676.2	22
24	6106.7	881.2	1041.6	3608.4	6191.1	908.1	1079.1	3678.6	24
26	6109.6	882.1	1042.8	3610.7	6193.9	909.0	1080.4	3680.9	26
28	6112.4	883.0	1044.1	3613.0	6196.7	909.9	1081.7	3683.3	28
30	6115.2	883.9	1045.3	3615.3	6199.5	910.8	1083.0	3685.6	30
32	6118.0	884.7	1046.5	3617.7	6202.3	911.7	1084.2	3688.0	32
34	6120.8	885.6	1047.8	3620.0	6205.1	912.6	1085.5	3690.4	34
36	6123.7	886.5	1049.0	3622.3	6208.0	913.5	1086.8	3692.7	36
38	6126.5	887.4	1050.3	3624.7	6210.8	914.4	1088.1	3695.1	38
40	6129.3	888.3	1051.5	3627.0	6213.6	915.3	1089.4	3697.4	40
42	6132.1	889.2	1052.7	3629.4	6216.4	916.2	1090.6	3699.8	42
44	6134.9	890.1	1054.0	3631.7	6219.2	917.1	1091.9	3702.2	44
46	6137.8	891.0	1055.2	3634.0	6222.0	918.0	1093.2	3704.5	46
48	6140.6	891.9	1056.5	3636.4	6224.8	918.9	1094.5	3706.9	48
50	6143.4	892.8	1057.7	3638.7	6227.6	919.8	1095.8	3709.3	50
52	6146.2	893.7	1059.0	3641.1	6230.4	920.7	1097.0	3711.6	52
54	6149.0	894.6	1060.2	3643.4	6233.2	921.6	1098.3	3714.0	54
56	6151.9	895.5	1061.5	3645.7	6236.0	922.5	1099.6	3716.3	56
58	6154.7	896.4	1062.7	3648.1	6238.8	923.4	1100.9	3718.7	58
60	6157.5	897.3	1064.0	3650.4	6241.6	924.3	1102.2	3721.1	60

	66°				67°				
	LC	M	E	T	LC	M	E	T	
0	6241.6	924.3	1102.2	3721.1	6325.2	951.8	1141.5	3792.6	0
2	6244.4	925.2	1103.5	3723.4	6328.0	952.7	1142.8	3795.0	2
4	6247.2	926.1	1104.8	3725.8	6330.7	953.6	1144.1	3797.4	4
6	6250.0	927.0	1106.1	3728.2	6333.5	954.5	1145.4	3799.8	6
8	6252.7	927.9	1107.4	3730.6	6336.3	955.5	1146.7	3802.2	8
10	6255.5	928.8	1108.7	3732.9	6339.0	956.4	1148.1	3804.6	10
12	6258.3	929.8	1110.0	3735.3	6341.8	957.3	1149.4	3807.0	12
14	6261.1	930.7	1111.3	3737.7	6344.6	958.2	1150.7	3809.4	14
16	6263.9	931.6	1112.6	3740.1	6347.4	959.2	1152.0	3811.8	16
18	6266.7	932.5	1113.9	3742.4	6350.1	960.1	1153.3	3814.2	18
20	6269.5	933.4	1115.2	3744.8	6352.9	961.0	1154.7	3816.6	20
22	6272.3	934.3	1116.5	3747.2	6355.7	961.9	1156.0	3819.0	22
24	6275.0	935.3	1117.8	3749.6	6358.4	962.9	1157.4	3821.4	24
26	6277.8	936.2	1119.1	3751.9	6361.2	963.8	1158.7	3823.8	26
28	6280.6	937.1	1120.4	3754.3	6364.0	964.7	1160.1	3826.2	28
30	6283.4	938.0	1121.7	3756.7	6366.7	965.6	1161.4	3828.6	30
32	6286.2	938.9	1123.0	3759.1	6369.5	966.6	1162.8	3831.0	32
34	6289.0	939.8	1124.3	3761.5	6372.3	967.5	1164.1	3833.4	34
36	6291.8	940.8	1125.6	3763.9	6375.1	968.4	1165.5	3835.9	36
38	6294.5	941.7	1126.9	3766.3	6377.8	969.3	1166.8	3838.3	38
40	6297.3	942.6	1128.3	3768.7	6380.6	970.3	1168.2	3840.7	40
42	6300.1	943.5	1129.6	3771.0	6388.4	971.2	1169.5	3843.1	42
44	6302.9	944.4	1130.9	3773.4	6386.1	972.1	1170.9	3845.5	44
46	6305.7	945.3	1132.2	3775.8	6388.9	973.0	1172.2	3847.9	46
48	6308.5	946.3	1133.5	3778.2	6391.7	974.0	1173.6	3850.4	48
50	6311.3	947.2	1134.9	3780.6	6394.4	974.9	1174.9	3852.8	50
52	6314.1	948.1	1136.2	3783.0	6397.2	975.8	1176.3	3855.2	52
54	6316.8	949.0	1137.5	3785.4	6400.0	976.8	1177.6	3857.6	54
56	6319.6	949.9	1138.8	3787.8	6402.8	977.7	1179.0	3860.0	56
58	6322.4	950.8	1140.1	3790.2	6405.5	978.6	1180.3	3862.5	58
60	6325.2	951.8	1141.5	3792.6	6408.3	979.6	1181.6	3864.9	60

Table A-5. Functions of 1° curves (continued)

	68°				69°				
	LC	M	E	T	LC	M	E	T	
0	6408.3	979.6	1181.6	3864.9	6491.1	1007.7	1222.9	3938.1	0
2	6411.1	980.5	1183.0	3867.3	6493.8	1008.7	1224.3	3940.6	2
4	6413.8	981.4	1184.4	3869.7	6496.6	1009.6	1225.7	3943.0	4
6	6416.6	982.4	1185.7	3872.2	6499.3	1010.6	1227.1	3945.5	6
8	6419.3	983.3	1187.1	3874.6	6502.1	1011.5	1228.5	3947.9	8
10	6422.1	984.2	1188.5	3877.0	6504.8	1012.5	1229.0	3950.4	10
12	6424.9	985.2	1189.8	3879.5	6507.5	1013.4	1231.2	3952.9	12
14	6427.6	986.1	1191.2	3881.9	6510.3	1014.4	1232.7	3955.3	14
16	6430.4	987.0	1192.6	3884.3	6513.0	1015.3	1234.1	3957.8	16
18	6433.1	988.0	1193.9	3886.8	6515.8	1016.3	1235.5	3960.2	18
20	6435.9	988.9	1195.3	3889.2	6518.5	1017.2	1236.9	3962.7	20
22	6438.7	989.8	1196.7	3891.6	6521.2	1018.2	1238.3	3965.2	22
24	6441.4	990.8	1198.0	3894.1	6524.0	1019.1	1239.7	3967.6	24
26	6444.2	991.7	1199.4	3896.5	6526.7	1020.1	1241.1	3970.1	26
28	6446.9	992.6	1200.8	3898.9	6529.5	1021.0	1242.5	3972.5	28
30	6449.7	993.6	1202.1	3901.4	6532.2	1022.0	1243.9	3975.0	30
32	6452.5	994.5	1203.5	3903.8	6534.9	1022.9	1245.3	3977.5	32
34	6455.2	995.4	1204.9	3906.3	6537.7	1023.9	1246.7	3980.0	34
36	6458.0	996.4	1206.2	3908.7	6540.4	1024.8	1248.1	3982.4	36
38	6460.7	997.3	1207.6	3911.2	6543.2	1025.8	1249.5	3984.9	38
40	6463.7	998.2	1209.0	3913.6	6545.9	1026.7	1250.9	3987.4	40
42	6466.3	999.2	1210.3	3916.1	6548.6	1027.7	1252.3	3989.9	42
44	6469.0	1000.1	1211.7	3918.5	6551.4	1028.6	1253.7	3992.3	44
46	6471.8	1001.0	1213.1	3921.0	6554.1	1029.6	1255.1	3994.8	46
48	6474.5	1002.0	1214.5	3923.4	6556.9	1030.9	1256.5	3997.3	48
50	6477.3	1002.9	1215.9	3925.9	6559.6	1031.5	1257.9	3999.8	50
52	6480.1	1003.8	1217.3	3928.3	6562.3	1032.4	1259.3	4002.2	52
54	6482.8	1004.8	1218.7	3930.8	6565.1	1033.4	1260.7	4004.7	54
56	6485.6	1005.7	1220.1	3933.2	6567.8	1034.3	1262.1	4007.2	56
58	6488.3	1006.7	1221.5	3935.7	6570.6	1035.3	1263.5	4009.7	58
60	6491.1	1007.7	1222.9	3938.1	6573.3	1036.3	1265.0	4012.1	60

	70°				71°				
	LC	M	E	T	LC	M	E	T	
0	6573.3	1036.3	1265.0	4012.1	6654.9	1065.1	1308.4	4087.1	0
2	6576.0	1037.3	1266.4	4014.6	6657.6	1066.1	1309.9	4089.7	2
4	6578.7	1038.2	1267.9	4017.1	6660.3	1067.0	1311.3	4092.2	4
6	6581.5	1039.2	1269.3	4019.6	6663.0	1068.0	1312.8	4094.7	6
8	6584.2	1040.1	1270.8	4022.1	6665.7	1068.9	1314.2	4097.2	8
10	6586.9	1041.1	1272.2	4024.6	6668.4	1069.9	1315.7	4099.8	10
12	6589.6	1042.1	1273.6	4027.1	6671.1	1070.9	1317.2	4102.3	12
14	6592.3	1043.0	1275.1	4029.6	6673.8	1071.9	1318.6	4104.8	14
16	6595.1	1044.0	1276.5	4032.1	6676.6	1072.9	1320.1	4107.3	16
18	6597.8	1044.9	1278.0	4034.6	6679.3	1073.8	1321.5	4109.8	18
20	6600.5	1045.9	1279.4	4037.1	6682.0	1074.8	1323.0	4112.4	20
22	6603.2	1046.9	1280.8	4039.6	6684.7	1075.8	1324.4	4114.9	22
24	6605.9	1047.8	1282.3	4042.1	6687.4	1076.8	1325.9	4117.4	24
26	6608.7	1048.8	1283.7	4044.6	6690.1	1077.7	1327.4	4119.9	26
28	6611.4	1049.7	1285.2	4047.1	6692.8	1078.7	1328.9	4122.4	28
30	6614.1	1050.7	1286.6	4049.6	6695.5	1079.7	1330.4	4125.0	30
32	6616.8	1051.7	1288.0	4052.1	6698.2	1080.7	1331.8	4127.5	32
34	6619.5	1052.6	1289.5	4054.6	6700.9	1081.6	1333.3	4130.1	34
36	6622.3	1053.6	1290.9	4057.1	6703.6	1082.6	1334.8	4132.6	36
38	6625.0	1054.5	1292.4	4059.6	6706.3	1083.6	1336.3	4135.1	38
40	6627.7	1055.5	1293.8	4062.1	6709.0	1084.5	1337.8	4137.7	40
42	6630.4	1056.5	1295.3	4064.6	6711.7	1085.5	1339.2	4140.2	42
44	6633.1	1057.4	1296.7	4067.1	6714.4	1086.5	1340.7	4142.7	44
46	6635.9	1058.4	1298.2	4069.6	6717.2	1087.5	1342.2	4145.3	46
48	6638.6	1059.3	1299.6	4072.1	6719.9	1088.4	1343.7	4147.8	48
50	6641.3	1060.3	1301.1	4074.6	6722.6	1089.4	1345.2	4150.4	50
52	6644.0	1061.3	1302.6	4077.1	6725.3	1090.4	1346.7	4152.9	52
54	6646.7	1062.2	1304.0	4079.6	6728.0	1091.3	1348.2	4155.4	54
56	6649.5	1063.2	1305.5	4082.1	6730.7	1092.3	1349.7	4158.0	56
58	6652.2	1064.1	1306.9	4084.6	6733.4	1093.3	1351.2	4160.5	58
60	6654.9	1065.1	1308.4	4087.1	6736.1	1094.3	1352.7	4163.1	60

Table A-5. Functions of 1° curves (continued)

	72°				73°				
	LC	M	E	T	LC	M	E	T	
0	6736.1	1094.3	1352.7	4163.1	6816.6	1123.9	1398.1	4240.0	0
2	6738.8	1095.2	1354.2	4165.6	6819.3	1124.8	1399.6	4242.6	2
4	6741.5	1096.2	1355.7	4168.2	6821.9	1125.8	1401.2	4245.1	4
6	6744.1	1097.2	1357.2	4170.7	6824.6	1126.8	1402.7	4247.7	6
8	6746.8	1098.2	1358.7	4173.3	6827.3	1127.8	1404.2	4250.3	8
10	6749.5	1099.2	1360.2	4175.8	6830.0	1128.8	1405.8	4252.9	10
12	6752.2	1100.1	1361.7	4178.4	6832.6	1129.8	1407.3	4255.5	12
14	6754.9	1101.1	1363.2	4181.0	6835.3	1130.8	1408.8	4258.1	14
16	6757.6	1102.1	1364.7	4183.5	6838.0	1131.8	1410.4	4260.7	16
18	6760.2	1103.1	1366.2	4186.1	6840.7	1132.8	1411.9	4263.2	18
20	6762.9	1104.1	1367.7	4188.6	6843.3	1133.8	1413.5	4265.8	20
22	6765.6	1105.1	1369.2	4191.2	6846.0	1134.8	1415.1	4268.4	22
24	6768.3	1106.0	1370.7	4193.7	6848.7	1135.8	1416.6	4271.0	24
26	6771.0	1107.0	1372.2	4196.3	6851.3	1136.8	1418.2	4273.6	26
28	6773.7	1108.0	1373.7	4198.8	6854.0	1137.8	1419.7	4276.2	28
30	6776.3	1109.0	1375.2	4201.4	6856.7	1138.8	1421.3	4278.8	30
32	6779.0	1109.9	1376.7	4204.0	6859.4	1139.8	1422.9	4281.4	32
34	6781.7	1110.9	1378.2	4206.5	6862.0	1140.8	1424.4	4284.0	34
36	6784.4	1111.9	1379.7	4209.1	6864.7	1141.8	1426.0	4286.6	36
38	6787.1	1112.9	1381.2	4211.7	6867.4	1142.8	1427.5	4289.2	38
40	6789.8	1113.9	1382.8	4214.3	6870.1	1143.8	1429.1	4291.8	40
42	6792.4	1114.9	1384.3	4216.8	6872.7	1144.8	1430.7	4294.4	42
44	6795.1	1115.9	1385.8	4219.4	6875.4	1145.8	1432.2	4297.0	44
46	6797.8	1116.9	1387.4	4222.0	6878.1	1146.8	1433.8	4299.6	46
48	6800.5	1117.9	1388.9	4224.5	6880.8	1147.8	1435.3	4302.2	48
50	6803.2	1118.9	1390.4	4227.1	6883.4	1148.8	1436.9	4304.8	50
52	6805.9	1119.9	1392.0	4229.7	6886.1	1149.8	1438.5	4307.4	52
54	6808.5	1120.9	1393.5	4232.3	6888.8	1150.8	1440.0	4310.0	54
56	6811.2	1121.9	1395.0	4234.8	6891.4	1151.8	1441.6	4312.6	56
58	6813.9	1122.9	1396.6	4237.4	6894.1	1152.8	1443.1	4315.2	58
60	6816.6	1123.9	1398.1	4240.0	6896.8	1153.8	1444.7	4317.8	60

	74°				75°				
	LC	M	E	T	LC	M	E	T	
0	6896.8	1153.8	1444.7	4317.8	6976.4	1184.1	1492.5	4396.7	0
2	6899.4	1154.8	1446.2	4320.5	6979.0	1185.1	1494.1	4399.4	2
4	6902.1	1155.8	1447.8	4323.1	6981.7	1186.1	1495.7	4402.1	4
6	6904.8	1156.8	1449.4	4325.7	6984.3	1187.1	1497.3	4404.7	6
8	6907.4	1157.8	1451.0	4328.3	6986.9	1188.1	1499.0	4407.4	8
10	6910.1	1158.8	1452.6	4330.9	6989.6	1189.2	1500.6	4410.0	10
12	6912.7	1159.8	1454.1	4333.6	6992.2	1190.2	1502.2	4412.7	12
14	6915.4	1160.8	1455.7	4336.2	6994.9	1191.2	1503.8	4415.3	14
16	6918.0	1161.8	1457.3	4338.8	6997.5	1192.2	1505.4	4418.0	16
18	6920.7	1162.8	1458.9	4341.4	7000.1	1193.2	1507.0	4420.7	18
20	6923.3	1163.9	1460.5	4344.0	7002.8	1194.3	1508.7	4423.3	20
22	6926.0	1164.9	1462.0	4346.7	7005.4	1195.3	1510.3	4426.0	22
24	6928.6	1165.9	1463.6	4349.3	7008.0	1196.3	1512.0	4428.6	24
26	6931.3	1166.9	1465.2	4351.9	7010.7	1197.3	1513.6	4431.3	26
28	6933.9	1167.9	1466.8	4354.5	7013.3	1198.3	1515.3	4434.0	28
30	6936.6	1168.9	1468.4	4357.1	7015.9	1199.4	1516.9	4436.6	30
32	6939.2	1169.9	1469.9	4359.8	7018.6	1200.4	1518.5	4439.3	32
34	6941.9	1170.9	1471.5	4362.4	7021.2	1201.4	1520.2	4442.0	34
36	6944.6	1171.9	1473.1	4365.1	7023.9	1202.4	1521.8	4444.6	36
38	6947.2	1172.9	1474.7	4367.7	7026.5	1203.4	1523.5	4447.3	38
40	6949.9	1174.0	1476.4	4370.3	7029.1	1204.5	1525.1	4450.0	40
42	6952.5	1175.0	1478.0	4373.0	7031.8	1205.5	1526.7	4452.7	42
44	6955.2	1176.0	1479.6	4375.6	7034.4	1206.5	1528.4	4455.3	44
46	6957.8	1177.0	1481.2	4378.3	7037.0	1207.5	1530.0	4458.0	46
48	6960.5	1178.0	1482.8	4380.9	7039.7	1208.5	1531.7	4460.7	48
50	6963.1	1179.0	1484.4	4383.5	7042.3	1209.6	1533.3	4463.4	50
52	6965.8	1180.0	1486.0	4386.2	7045.0	1210.6	1534.9	4466.0	52
54	6968.4	1181.0	1487.7	4388.8	7047.6	1211.6	1536.6	4468.7	54
56	6971.1	1182.0	1489.3	4391.5	7050.2	1212.6	1538.2	4471.4	56
58	6973.7	1183.0	1490.9	4394.1	7052.9	1213.6	1539.9	4474.1	58
60	6976.4	1184.1	1492.5	4396.7	7055.5	1214.7	1541.5	4476.7	60

Table A-5. Functions of 1° curves (continued)

	76°				77°				
	LC	M	E	T	LC	M	E	T	
0	7055.5	1214.7	1541.5	4476.7	7134.0	1245.6	1591.7	4557.8	0
2	7058.1	1215.7	1543.2	4479.4	7136.6	1246.6	1593.4	4560.5	2
4	7060.7	1216.7	1544.9	4482.1	7139.2	1247.7	1595.1	4563.3	4
6	7063.3	1217.8	1546.5	4484.8	7141.8	1248.7	1596.8	4566.0	6
8	7066.0	1218.8	1548.2	4487.5	7144.4	1249.8	1598.5	4568.7	8
10	7068.6	1219.8	1549.9	4490.2	7147.0	1250.8	1600.2	4571.5	10
12	7071.2	1220.9	1551.5	4492.9	7149.6	1251.8	1601.9	4574.2	12
14	7073.8	1221.9	1553.2	4495.6	7152.2	1252.9	1603.6	4576.9	14
16	7076.4	1222.9	1554.9	4498.3	7154.8	1253.9	1605.3	4579.7	16
18	7079.0	1224.0	1556.5	4501.0	7157.4	1255.0	1607.0	4582.4	18
20	7081.7	1225.0	1558.2	4503.7	7160.0	1256.0	1608.7	4585.1	20
22	7084.3	1226.0	1559.9	4506.3	7162.6	1257.0	1610.4	4587.9	22
24	7086.9	1227.1	1561.5	4509.0	7165.2	1258.1	1612.1	4590.2	24
26	7089.5	1228.1	1563.2	4511.7	7167.8	1259.1	1613.8	4593.3	26
28	7092.1	1229.1	1564.9	4514.4	7170.4	1260.2	1615.5	4596.0	28
30	7094.7	1230.2	1566.5	4517.1	7173.0	1261.2	1617.3	4598.8	30
32	7097.4	1231.2	1568.2	4519.8	7175.6	1262.2	1619.0	4601.5	32
34	7100.0	1232.2	1569.9	4522.5	7178.2	1263.3	1620.7	4604.3	34
36	7102.6	1233.3	1571.5	4525.3	7180.8	1264.3	1622.4	4607.0	36
38	7105.2	1234.3	1573.2	4528.0	7183.4	1265.4	1624.1	4609.8	38
40	7107.8	1235.3	1574.8	4530.7	7186.0	1266.4	1625.9	4612.5	40
42	7110.4	1236.4	1576.4	4533.4	7188.6	1267.4	1627.6	4615.3	42
44	7113.1	1237.4	1578.1	4536.1	7191.2	1268.5	1629.3	4618.0	44
46	7115.7	1238.4	1579.8	4538.8	7193.8	1269.5	1631.0	4620.8	46
48	7118.3	1239.5	1581.5	4541.5	7196.4	1270.6	1632.7	4623.5	48
50	7120.9	1240.5	1583.2	4544.2	7199.0	1271.6	1634.5	4626.3	50
52	7123.5	1241.5	1584.9	4547.0	7201.6	1272.7	1636.2	4629.0	52
54	7126.1	1242.6	1586.6	4549.7	7204.2	1273.7	1637.9	4631.8	54
56	7128.8	1243.6	1588.3	4552.4	7206.8	1274.8	1639.6	4634.5	56
58	7131.4	1244.6	1590.0	4555.1	7209.4	1275.8	1641.3	4637.3	58
60	7134.0	1245.6	1591.7	4557.8	7212.0	1276.9	1643.1	4640.0	60

	78°				79°				
	LC	M	E	T	LC	M	E	T	
0	7212.0	1276.9	1643.1	4640.0	7289.5	1308.5	1696.0	4723.4	0
2	7214.6	1278.0	1644.8	4642.8	7292.1	1309.5	1697.7	4726.2	2
4	7217.2	1279.0	1646.6	4645.6	7294.6	1310.6	1699.5	4729.0	4
6	7219.7	1280.1	1648.3	4648.3	7297.2	1311.7	1701.3	4731.8	6
8	7222.3	1281.1	1650.1	4651.1	7299.7	1312.7	1703.1	4734.7	8
10	7224.9	1282.2	1651.8	4653.9	7302.3	1313.8	1704.9	4737.5	10
12	7227.5	1283.2	1653.6	4656.7	7304.9	1314.9	1706.6	4740.3	12
14	7230.1	1284.3	1655.3	4659.4	7307.4	1315.9	1708.4	4743.1	14
16	7232.7	1285.3	1657.1	4662.2	7310.0	1317.0	1710.2	4745.9	16
18	7235.2	1286.4	1658.8	4665.0	7312.6	1318.1	1712.0	4748.7	18
20	7237.8	1287.4	1660.6	4667.7	7315.1	1319.1	1713.8	4751.5	20
22	7240.4	1288.5	1662.3	4670.5	7317.7	1320.2	1715.6	4754.3	22
24	7243.0	1289.5	1664.1	4673.3	7320.3	1321.3	1717.4	4757.1	24
26	7245.6	1290.6	1665.8	4676.0	7322.8	1322.3	1719.2	4760.0	26
28	7248.2	1291.6	1667.6	4678.8	7325.4	1323.4	1721.0	4762.8	28
30	7250.7	1292.7	1669.3	4681.6	7327.9	1324.5	1722.8	4765.6	30
32	7253.3	1293.7	1671.1	4684.4	7330.5	1325.5	1724.6	4768.4	32
34	7255.9	1294.8	1672.8	4687.2	7333.1	1326.6	1726.4	4771.2	34
36	7258.5	1295.8	1674.6	4689.9	7335.6	1327.7	1728.2	4774.1	36
38	7261.1	1296.9	1676.3	4692.7	7338.2	1328.7	1730.0	4776.9	38
40	7263.7	1297.9	1678.2	4695.5	7340.8	1329.8	1731.9	4779.7	40
42	7266.2	1299.0	1679.9	4698.3	7343.3	1330.8	1733.7	4782.6	42
44	7268.8	1300.0	1681.7	4701.1	7345.9	1331.9	1735.5	4785.4	44
46	7271.4	1301.1	1683.5	4703.9	7348.4	1333.0	1737.3	4788.2	46
48	7274.0	1302.1	1685.3	4706.7	7351.0	1334.1	1739.1	4791.0	48
50	7276.6	1303.2	1687.1	4709.5	7353.6	1335.2	1740.9	4793.9	50
52	7279.2	1304.2	1688.8	4712.2	7356.1	1336.2	1742.7	4796.7	52
54	7281.7	1305.3	1690.6	4715.0	7358.7	1337.3	1744.5	4799.5	54
56	7284.3	1306.3	1692.4	4717.8	7361.3	1338.4	1746.3	4802.4	56
58	7286.9	1307.4	1694.2	4720.6	7363.8	1339.5	1748.1	4805.2	58
60	7289.5	1308.5	1696.0	4723.4	7366.4	1340.6	1750.0	4808.0	60

Table A-5. Functions of 1° curves (continued)

	80°				81°				
	LC	M	E	T	LC	M	E	T	
0	7366.4	1340.6	1750.0	4808.0	7442.7	1372.8	1805.5	4893.9	0
2	7368.9	1341.7	1751.8	4810.9	7445.2	1373.9	1807.3	4896.8	2
4	7371.5	1342.7	1753.7	4813.7	7447.7	1375.0	1809.2	4899.7	4
6	7374.0	1343.8	1755.5	4816.6	7450.3	1376.1	1811.1	4902.6	6
8	7376.6	1344.9	1757.4	4819.4	7452.8	1377.1	1813.0	4905.4	8
10	7379.1	1346.0	1759.2	4822.3	7455.3	1378.2	1814.9	4908.3	10
12	7381.7	1347.0	1761.0	4825.1	7457.8	1379.3	1816.8	4911.2	12
14	7384.2	1348.1	1762.9	4828.0	7460.4	1380.4	1818.6	4914.1	14
16	7386.7	1349.2	1764.7	4830.8	7462.9	1381.4	1820.5	4917.0	16
18	7389.3	1350.3	1766.6	4833.7	7465.4	1382.5	1822.4	4919.9	18
20	7391.8	1351.3	1768.4	4836.5	7467.9	1383.6	1824.2	4922.8	20
22	7394.4	1352.4	1770.2	4839.4	7470.4	1384.7	1826.1	4925.7	22
24	7396.9	1353.5	1772.1	4842.2	7473.0	1385.7	1828.0	4928.6	24
26	7399.5	1354.6	1773.9	4845.1	7475.5	1386.8	1829.9	4931.5	26
28	7402.0	1355.6	1775.8	4847.9	7478.0	1387.9	1831.8	4934.4	28
30	7404.5	1356.7	1777.6	4850.8	7480.5	1389.0	1833.7	4937.2	30
32	7407.1	1357.8	1779.4	4853.7	7483.1	1390.1	1835.6	4940.2	32
34	7409.6	1358.9	1781.3	4856.5	7485.6	1391.2	1837.5	4943.1	34
36	7412.2	1359.9	1783.1	4859.4	7488.1	1392.3	1839.4	4649.0	36
38	7414.7	1361.0	1785.0	4862.3	7490.6	1393.4	1841.3	4948.9	38
40	7417.3	1362.1	1786.8	4865.1	7493.2	1394.5	1843.2	4951.8	40
42	7419.8	1363.2	1788.6	4868.0	7495.7	1395.6	1845.1	4954.7	42
44	7422.3	1364.2	1790.5	4870.9	7498.2	1396.7	1847.0	4957.6	44
46	7424.9	1365.3	1792.4	4873.8	7500.7	1397.8	1848.9	4960.6	46
48	7427.4	1366.4	1794.3	4876.6	7503.3	1398.9	1850.8	4963.5	49
50	7430.0	1367.5	1796.2	4879.5	7505.8	1400.0	1852.7	4966.4	50
52	7432.5	1368.5	1798.0	4882.4	7508.3	1401.1	1854.6	4969.3	52
54	7435.1	1369.6	1799.9	4885.3	7510.8	1402.2	1856.5	4972.2	54
56	7437.6	1370.7	1801.8	4888.1	7513.3	1403.3	1858.4	4975.1	56
58	7440.1	1371.8	1803.7	4891.0	7515.9	1404.4	1860.3	4978.0	58
60	7442.7	1372.8	1805.5	4893.9	7518.4	1405.5	1862.3	4981.0	60

	82°				83°				
	LC	M	E	T	LC	M	E	T	
0	7518.4	1405.5	1862.3	4981.0	7593.6	1438.5	1920.6	5069.4	0
2	7520.9	1406.6	1864.2	4983.9	7596.1	1439.6	1922.6	5072.4	2
4	7523.4	1407.7	1866.1	4986.8	7598.6	1440.7	1924.6	5075.4	4
6	7525.9	1408.8	1868.1	4989.8	7601.1	1441.8	1920.5	5078.4	6
8	7528.4	1409.9	1870.0	4992.7	7603.6	1442.0	1928.5	5081.4	8
10	7530.9	1411.0	1871.9	4995.7	7606.0	1444.0	1930.5	5084.4	10
12	7533.4	1412.1	1873.9	4998.6	7608.5	1445.1	1932.4	5087.3	12
14	7535.9	1413.2	1875.8	5001.5	7611.0	1446.2	1934.4	5090.3	14
16	7538.5	1414.3	1877.7	5004.5	7613.5	1447.3	1936.4	5093.3	16
18	7541.0	1415.4	1879.7	5007.4	7616.0	1448.4	1938.4	5096.3	18
20	7543.5	1416.5	1881.6	5010.3	7618.5	1449.6	1940.4	5099.3	20
22	7546.0	1417.6	1883.5	5013.3	7621.0	1450.7	1942.4	5102.3	22
24	7548.5	1418.7	1885.5	5016.2	7623.5	1451.8	1944.4	5105.2	24
26	7551.0	1419.8	1887.4	5019.2	7626.0	1452.9	1946.4	5108.2	26
28	7553.5	1420.9	1889.3	5022.1	7628.5	1454.0	1948.4	5111.2	28
30	7556.0	1422.0	1891.3	5025.0	7630.9	1455.1	1950.4	5114.2	30
32	7558.5	1423.1	1893.2	5028.0	7633.4	1456.2	1952.4	5117.2	32
34	7561.0	1424.2	1895.1	5031.0	7635.9	1457.3	1954.4	5120.2	34
36	7563.5	1425.3	1897.1	5033.9	7638.4	1458.4	1956.4	5123.2	36
38	7566.0	1426.4	1899.0	5036.9	7640.9	1459.5	1958.4	5126.2	38
40	7568.5	1427.5	1901.0	5039.8	7643.4	1460.7	1960.4	5129.2	40
42	7571.0	1428.6	1902.9	5042.8	7645.9	1461.8	1962.4	5132.2	42
44	7573.5	1429.7	1904.9	5045.8	7648.4	1462.9	1964.4	5135.2	44
46	7576.1	1430.8	1906.9	5048.7	7650.9	1464.0	1966.4	5138.2	46
48	7578.6	1431.9	1908.8	5051.7	7653.4	1465.1	1968.4	5141.2	48
50	7581.1	1433.0	1910.8	5054.6	7655.8	1466.2	1970.4	5144.3	50
52	7583.6	1434.1	1912.8	5057.6	7658.3	1467.3	1972.4	5147.3	52
54	7586.1	1435.2	1914.7	5060.6	7660.8	1468.4	1974.4	5150.3	54
56	7588.6	1436.3	1916.7	5063.5	7663.3	1469.5	1976.4	5153.3	56
58	7591.1	1437.4	1918.7	5066.5	7665.8	1470.6	1978.4	5156.3	58
60	7593.6	1438.5	1920.6	5069.4	7668.3	1471.8	1980.5	5159.3	60

Table A-5. Functions of 1° curves (continued)

	84°				85°				
	LC	M	E	T	LC	M	E	T	
0	7668.3	1471.8	1980.5	5159.3	7742.4	1505.4	2041.8	5250.6	0
2	7670.8	1472.9	1982.5	5162.3	7744.8	1506.5	2043.9	5253.6	2
4	7673.2	1474.0	1984.5	5165.3	7747.3	1507.6	2046.0	5256.7	4
6	7675.7	1475.1	1986.6	5168.4	7749.7	1508.8	2048.0	5259.8	6
8	7678.2	1476.2	1988.6	5171.4	7752.2	1509.9	2050.1	5262.9	8
10	7680.6	1477.4	1990.6	5174.4	7754.6	1511.0	2052.2	5266.0	10
12	7683.1	1478.5	1992.7	5177.5	7757.1	1512.2	2054.2	5269.0	12
14	7685.6	1479.6	1994.7	5180.7	7759.5	1513.3	2056.3	5272.1	14
16	7688.1	1480.7	1996.7	5183.5	7762.0	1514.4	2058.4	5275.4	16
18	7690.5	1481.8	1998.8	5186.6	7764.4	1515.6	2060.5	5278.3	18
20	7693.0	1483.0	2000.8	5189.6	7766.9	1516.7	2062.6	5281.4	20
22	7695.5	1484.1	2002.8	5192.6	7769.3	1517.8	2064.7	5284.4	22
24	7697.9	1485.2	2004.9	5195.6	7771.8	1519.0	2066.8	5287.5	24
26	7700.4	1486.3	2006.9	5198.7	7774.2	1520.1	2068.9	5290.6	26
28	7702.9	1487.4	2008.9	5201.7	7776.7	1521.2	2071.0	5293.7	28
30	7705.3	1488.6	2011.0	5204.7	7779.1	1522.4	2073.1	5296.7	30
32	7707.8	1489.7	2013.0	5207.8	7781.5	1523.5	2075.2	5299.8	32
34	7710.3	1490.8	2015.0	5210.8	7784.0	1524.6	2077.3	5302.9	34
36	7712.8	1491.9	2017.0	5213.9	7786.4	1525.8	2079.4	5306.1	36
38	7715.2	1493.0	2019.1	5216.9	7788.9	1526.9	2081.5	5309.2	38
40	7717.7	1494.2	2021.2	5220.0	7791.3	1528.0	2083.7	5312.3	40
42	7720.2	1495.3	2023.2	5223.1	7793.8	1529.2	2085.8	5315.4	42
44	7722.6	1496.4	2025.3	5226.1	7796.2	1530.3	2087.9	5318.5	44
46	7725.1	1497.5	2027.4	5229.2	7798.7	1531.4	2090.0	5321.6	46
48	7727.6	1498.6	2029.4	5232.2	7801.1	1532.6	2092.1	5324.7	48
50	7730.0	1499.8	2031.5	5235.5	7803.6	1533.7	2094.2	5327.8	50
52	7732.5	1500.9	2033.6	5238.3	7806.0	1534.8	2096.3	5330.9	52
54	7735.0	1502.0	2035.6	5241.4	7808.5	1536.0	2098.4	5334.0	54
56	7737.5	1503.1	2037.7	5244.5	7810.9	1537.1	2100.6	5337.1	56
58	7739.9	1504.2	2039.8	5247.5	7813.4	1538.2	2102.7	5340.2	58
60	7742.4	1505.4	2041.8	5250.6	7815.8	1539.3	2104.8	5343.3	60

	86°				87°				
	LC	M	E	T	LC	M	E	T	
0	7815.8	1539.3	2104.8	5343.3	7888.5	1573.6	2169.5	5437.5	0
2	7818.2	1540.4	2106.9	5346.4	7890.9	1574.8	2171.6	5440.7	2
4	7820.6	1541.6	2109.1	5349.5	7893.3	1575.9	2173.8	5443.9	4
6	7823.1	1542.7	2111.2	5352.7	7895.7	1577.1	2176.0	5447.1	6
8	7825.5	1543.9	2113.4	5355.8	7898.1	1578.2	2178.2	5450.3	8
10	7827.9	1545.0	2115.5	5358.9	7900.5	1579.4	2180.4	5453.4	10
12	7830.3	1546.1	2117.6	5362.0	7903.0	1580.5	2182.5	5456.6	12
14	7832.8	1547.3	2119.8	5365.2	7905.4	1581.7	2184.7	5459.8	14
16	7835.2	1548.4	2121.9	5368.3	7907.8	1582.9	2186.9	5463.0	16
18	7837.6	1549.6	2124.1	5371.4	7910.2	1584.0	2189.1	5466.2	18
20	7840.0	1550.7	2126.2	5374.6	7912.6	1585.1	2191.3	5469.4	20
22	7842.4	1551.8	2128.3	5377.7	7915.0	1586.3	2193.5	5472.5	22
24	7844.9	1553.0	2130.5	5380.8	7917.4	1587.4	2195.7	5475.7	24
26	7847.3	1554.1	2132.6	5383.9	7919.8	1588.6	2197.9	5478.9	26
28	7849.7	1555.3	2134.8	5387.1	7922.2	1589.7	2200.1	5482.1	28
30	7852.1	1556.4	2136.9	5390.2	7924.6	1590.9	2202.3	5485.3	30
32	7854.6	1557.5	2139.0	5393.4	7927.1	1592.0	2204.5	5488.5	32
34	7857.0	1558.7	2141.2	5396.5	7929.5	1593.2	2206.8	5491.7	34
36	7859.4	1559.8	2143.3	5399.7	7931.9	1594.3	2209.0	5494.9	36
38	7861.8	1561.0	2145.5	5402.8	7934.3	1595.5	2211.2	5498.1	38
40	7864.3	1562.1	2147.7	5406.0	7936.7	1596.6	2213.4	5501.3	40
42	7866.7	1563.2	2149.8	5409.1	7939.1	1597.8	2215.6	5504.5	42
44	7869.1	1564.4	2152.0	5412.3	7941.5	1598.9	2217.8	5507.7	44
46	7871.5	1565.5	2154.2	5415.4	7943.9	1600.1	2220.0	5510.9	46
48	7874.0	1566.7	2156.4	5418.6	7946.3	1601.2	2222.3	5514.1	48
50	7876.4	1567.8	2158.6	5421.8	7948.7	1602.4	2224.5	5517.3	50
52	7878.8	1568.9	2160.7	5424.9	7951.2	1603.5	2226.7	5520.5	52
54	7881.2	1570.1	2162.9	5428.1	7953.6	1604.7	2228.9	5523.7	54
56	7883.6	1571.2	2165.1	5431.2	7956.0	1605.8	2231.1	5526.9	56
58	7886.1	1572.4	2167.3	5434.4	7958.4	1607.0	2233.3	5530.1	58
60	7888.5	1573.6	2169.5	5437.5	7960.8	1608.2	2235.6	5533.3	60

Table A-5. Functions of 1° curves (continued)

	88°				89°				
	LC	M	E	T	LC	M	E	T	
0	7960.8	1608.2	2235.6	5533.3	8032.4	1643.0	2303.6	5630.8	0
2	7963.2	1609.4	2237.8	5536.6	8034.8	1644.1	2305.9	5634.1	2
4	7965.6	1610.5	2240.1	5539.8	8037.1	1645.3	2308.2	5637.4	4
6	7968.0	1611.7	2242.3	5543.1	8039.5	1646.5	2310.5	5640.7	6
8	7970.3	1612.8	2244.6	5546.3	8041.9	1647.7	2312.8	5644.0	8
10	7972.7	1614.0	2246.8	5549.5	8044.2	1648.9	2315.1	5647.3	10
12	7975.1	1615.2	2249.1	5552.8	8046.6	1650.0	2317.4	5650.6	12
14	7977.5	1616.3	2251.3	5556.0	8049.0	1651.2	2319.7	5653.9	14
16	7979.9	1617.5	2253.6	5559.2	8051.4	1652.4	2322.0	5657.1	16
18	7982.3	1618.6	2255.8	5562.5	8053.7	1653.6	2324.3	5660.4	18
20	7984.7	1619.8	2258.1	5565.7	8056.1	1654.8	2326.7	5663.7	20
22	7987.1	1621.0	2260.4	5568.9	8058.5	1655.9	2329.0	5667.0	22
24	7989.4	1622.1	2262.7	5572.2	8060.8	1657.1	2331.3	5670.3	24
26	7991.8	1623.3	2264.9	5575.4	8063.2	1658.3	2333.7	5673.6	26
28	7994.2	1624.4	2267.2	5578.6	8065.6	1659.5	2336.0	5676.9	28
30	7996.6	1625.6	2269.5	5581.9	8067.9	1660.7	2338.3	5680.2	30
32	7999.0	1626.8	2271.7	5585.1	8070.3	1661.8	2340.7	5683.5	32
34	8001.4	1627.9	2273.9	5588.4	8073.7	1663.0	2343.0	5686.8	34
36	8003.8	1629.1	2276.2	5591.7	8075.1	1664.2	2345.3	5690.2	36
38	8006.1	1630.2	2278.5	5594.9	8077.4	1665.4	2347.7	5693.5	38
40	8008.5	1631.4	2280.8	5598.2	8079.8	1666.6	2350.0	5696.8	40
42	8010.9	1632.6	2283.0	5601.4	8082.2	1667.7	2352.3	5700.1	42
44	8013.3	1633.7	2285.3	5604.7	8084.5	1668.8	2354.7	5703.4	44
46	8015.7	1634.9	2287.6	5608.0	8086.9	1670.0	2357.0	5706.8	46
48	8018.1	1636.0	2289.9	5611.2	8089.3	1671.2	2359.3	5710.1	48
50	8020.5	1637.2	2292.2	5614.5	8091.6	1672.4	2361.7	5713.4	50
52	8022.9	1638.4	2294.4	5617.8	8094.0	1673.5	2364.0	5716.7	52
54	8025.2	1639.5	2296.7	5621.0	8096.4	1674.7	2366.3	5720.0	54
56	8027.6	1640.7	2299.0	5624.3	8098.8	1675.9	2368.7	5723.4	56
58	8030.0	1641.8	2301.3	5627.5	8101.1	1677.1	2371.0	5726.7	58
60	8032.4	1643.0	2303.6	5630.8	8103.5	1678.3	2373.4	5730.0	60

	90°				91°				
	LC	M	E	T	LC	M	E	T	
0	8103.5	1678.3	2373.4	5730.0	8173.9	1713.8	2445.1	5830.9	0
2	8105.8	1679.5	2375.8	5733.3	8176.2	1715.0	2447.5	5834.3	2
4	8108.2	1680.6	2378.2	5736.7	8178.5	1716.2	2450.0	5837.7	4
6	8110.5	1681.8	2380.5	5740.0	8180.9	1717.4	2452.4	5841.1	6
8	8112.9	1683.0	2382.9	5743.4	8183.2	1718.6	2454.8	5844.5	8
10	8115.2	1684.2	2385.3	5746.7	8185.5	1719.7	2457.2	5847.9	10
12	8117.6	1685.4	2387.6	5750.0	8187.9	1720.9	2459.7	5851.3	12
14	8119.9	1686.5	2390.0	5753.4	8190.2	1722.1	2462.1	5854.7	14
16	8122.3	1687.7	2392.4	5756.7	8192.5	1723.3	2464.5	5858.1	16
18	8124.6	1688.9	2394.7	5760.1	8194.8	1724.5	2467.0	5861.5	18
20	8127.0	1690.1	2397.1	5763.4	8197.2	1725.7	2469.4	4864.9	20
22	8129.3	1691.3	2399.5	5766.8	8199.5	1726.9	2471.9	5668.3	22
24	8131.7	1692.5	2401.9	5770.1	8201.8	1728.1	2474.3	5871.8	24
26	8134.0	1693.6	2404.3	5773.5	8204.2	1729.3	2476.7	5875.2	26
28	8136.4	1694.8	2406.6	5776.9	8206.5	1730.5	2479.2	5878.6	28
30	8138.7	1696.0	2409.0	5780.2	8208.8	1731.7	2481.6	5882.0	30
32	8141.1	1697.2	2411.4	5783.6	8211.1	1732.9	2484.1	5885.4	32
34	8143.4	1698.4	2413.8	5787.0	8213.5	1734.1	2486.5	5888.9	34
36	8145.8	1699.6	2416.2	5790.3	8215.8	1735.3	2489.0	5892.3	36
38	8148.1	1700.7	2418.6	5793.7	8218.1	1736.4	2491.5	5895.7	38
40	8150.4	1701.9	2421.0	5797.1	8220.4	1737.6	2493.9	5899.2	40
42	8152.8	1703.1	2423.4	5800.4	8222.8	1738.8	2496.4	5902.6	42
44	8155.1	1704.3	2425.8	5803.8	8225.1	1740.0	2498.9	5906.0	44
46	8157.5	1705.5	2428.2	5807.2	8227.4	1741.2	2501.3	5909.4	46
48	8159.8	1706.7	2430.6	5810.6	8229.7	1742.4	2503.8	5912.9	48
50	8162.2	1707.9	2433.0	5814.0	8232.0	1743.6	2506.3	5916.3	50
52	8164.5	1709.0	2435.4	5817.3	8234.3	1744.8	2508.7	5919.8	52
54	8166.8	1710.2	2437.9	5820.7	8236.7	1746.0	2511.2	5923.2	54
56	8169.2	1711.4	2440.3	5824.1	8239.0	1747.2	2513.7	5926.7	56
58	8171.5	1712.6	2442.7	5827.5	8241.3	1748.4	2516.2	5930.1	58
60	8173.9	1713.8	2445.1	5830.9	8243.6	1749.6	2518.7	5933.6	60

Table A-5. Functions of 1° curves (continued)

	92°				93°				
	LC	M	E	T	LC	M	E	T	
0	8243.6	1749.6	2518.7	5933.6	8312.8	1785.7	2594.2	6038.2	0
2	8245.9	1750.8	2521.2	5937.0	8315.1	1786.9	2596.8	6041.7	2
4	8248.2	1752.0	2523.6	5940.5	8317.4	1788.2	2599.3	6045.2	4
6	8250.6	1753.2	2526.1	5944.0	8319.7	1789.4	2601.9	6048.7	6
8	8252.9	1754.4	2528.6	5947.4	8322.0	1790.6	2604.4	6052.2	8
10	8255.2	1755.6	2531.1	5950.9	8324.3	1791.8	2607.0	6055.8	10
12	8257.5	1756.8	2533.6	5954.4	8326.6	1793.0	2609.6	6059.3	12
14	8259.8	1758.0	2536.1	5957.8	8328.8	1794.2	2612.1	6062.8	14
16	8262.2	1759.2	2338.6	5961.3	8331.1	1795.4	2614.7	6066.4	16
18	8264.5	1760.4	2541.1	5964.8	8333.3	1796.6	2617.3	6069.9	18
20	8266.8	1761.6	2543.6	5968.2	8335.6	1797.8	2619.8	6073.4	20
22	8269.1	1762.8	2546.1	5971.7	8337.9	1799.1	2622.4	6077.0	22
24	8271.4	1764.0	2548.6	5975.2	8340.2	1800.3	2625.0	6080.5	24
26	8273.7	1765.2	2551.2	5978.7	8342.5	1801.5	2627.6	6084.1	26
28	8276.0	1766.4	2553.7	5982.2	8344.8	1802.7	2630.2	6087.6	28
30	8278.3	1767.6	2556.2	5985.6	8347.1	1803.9	2632.7	6091.2	30
32	8280.6	1768.8	2558.7	5989.1	8349.4	1805.1	2635.3	6094.7	32
34	8282.9	1770.0	2561.2	5992.6	8351.7	1806.3	2637.9	6098.3	34
36	8285.2	1771.2	2563.8	5996.1	8354.0	1807.6	2640.5	6101.8	36
38	8287.5	1772.5	2566.3	5999.6	8356.3	1808.8	2643.1	6105.4	38
40	8289.8	1773.7	2568.8	6003.1	8358.5	1810.0	2645.7	6109.0	40
42	8292.1	1774.9	2571.3	6006.6	8360.8	1811.2	2648.3	6112.5	42
44	8294.4	1776.1	2573.9	6010.1	8363.1	1812.4	2650.9	6116.1	44
46	8296.7	1777.3	2576.4	6013.6	8365.4	1813.6	2653.5	6119.7	46
48	8299.0	1778.5	2578.9	6017.1	8367.7	1814.9	2656.1	6123.2	48
50	8301.3	1779.7	2581.5	6020.6	8369.9	1816.1	2658.7	6128.7	50
52	8303.6	1780.9	2584.0	6024.1	8372.2	1817.3	2661.3	6130.4	52
54	8305.9	1782.1	2586.6	6027.6	8374.5	1818.5	2663.9	6133.9	54
56	8308.2	1783.3	2589.1	6031.1	8376.8	1819.7	2666.6	6137.5	56
58	8310.5	1784.5	2591.7	6034.6	8379.1	1820.9	2669.2	6141.1	58
60	8312.8	1785.7	2594.2	6038.2	8381.3	1822.2	2671.8	6144.7	60

	94°				95°				
	LC	M	E	T	LC	M	E	T	
0	8381.3	1822.2	2671.8	6144.7	8449.2	1858.9	2751.5	6253.2	0
2	8383.6	1823.4	2674.4	6148.3	8451.5	1860.1	2754.2	6256.9	2
4	8385.9	1824.6	2677.0	6151.9	8453.7	1861.3	2756.9	6260.5	4
6	8388.1	1825.8	2679.7	6155.4	8456.0	1862.6	2759.0	6264.2	6
8	8390.4	1827.0	2682.3	6159.0	8458.2	1863.8	2762.3	6267.8	8
10	8392.7	1828.3	2684.9	6162.6	8460.4	1865.0	2765.0	6271.5	10
12	8395.0	1829.5	2687.6	6166.2	8462.7	1866.3	2767.7	6275.2	12
14	8397.2	1830.7	2690.2	6169.8	8464.9	1867.5	2770.4	6278.8	14
16	8399.5	1831.9	2692.8	6173.4	8467.2	1868.7	2773.1	6282.5	16
18	8401.7	1833.1	2695.6	6177.0	8469.4	1869.9	2775.8	6286.2	18
20	8404.0	1834.4	2698.1	6180.6	8471.7	1871.2	2778.5	6289.8	20
22	8406.3	1835.6	2700.8	6184.2	8473.9	1872.4	2781.2	6293.5	22
24	8408.5	1836.8	2703.4	6187.8	8476.2	1873.6	2784.0	6297.2	24
26	8410.8	1838.0	2706.1	6191.5	8478.4	1874.9	2786.7	6300.9	26
28	8413.1	1839.3	2708.7	6195.1	8480.7	1876.1	2789.4	6304.6	28
30	8415.3	1840.5	2711.4	6198.7	8482.9	1877.3	2792.1	6308.2	30
32	8417.6	1841.7	2714.0	6202.3	8485.1	1878.6	2794.9	6311.9	32
34	8419.9	1842.9	2716.7	6205.9	8487.4	1879.8	2797.6	6315.6	34
36	8422.1	1844.2	2719.3	6209.5	8489.6	1881.0	2800.3	6319.3	36
38	8424.4	1845.4	2722.0	6213.2	8491.9	1882.3	2803.1	6323.0	38
40	8426.6	1846.6	2724.7	6216.8	8494.1	1883.5	2805.8	6326.7	40
42	8428.9	1847.8	2727.3	6220.4	8496.3	1884.8	2808.6	6330.4	42
44	8431.2	1849.1	2730.0	6224.1	8498.6	1886.0	2811.3	6334.1	44
46	8433.4	1850.3	2732.7	6227.7	8500.8	1887.2	2814.1	6337.8	46
48	8435.7	1851.5	2735.4	6231.3	8503.0	1888.5	2816.8	6341.5	48
50	8437.9	1852.7	2738.0	6235.0	8505.3	1889.7	2819.6	6345.2	50
52	8440.2	1854.0	2470.7	6238.6	8507.5	1890.9	2822.3	6349.0	52
54	8442.4	1855.2	2743.4	6242.3	8509.8	1892.2	2825.1	6352.7	54
56	8444.7	1856.4	2746.1	6245.9	8512.0	1893.4	2827.8	6356.4	56
58	8447.0	1857.6	2748.8	6249.6	8514.2	1894.6	2830.6	6360.1	58
60	8449.2	1858.9	2751.5	6253.2	8516.4	1895.9	2833.4	6363.8	60

Table A-5. Functions of 1° curves (continued)

	96°				97°				
	LC	M	E	T	LC	M	E	T	
0	8516.4	1895.9	2833.4	6363.8	8583.0	1933.2	2917.5	6476.6	0
2	8518.7	1897.1	2836.1	6367.5	8585.2	1934.4	2920.3	6480.4	2
4	8520.9	1898.4	2838.9	6371.3	8587.5	1935.7	2923.2	6484.2	4
6	8523.1	1899.6	2841.7	6375.0	8589.7	1936.9	2926.0	6488.0	6
8	8525.4	1900.8	2844.5	6378.7	8591.9	1938.2	2928.9	6491.8	8
10	8527.6	1902.1	2847.2	6382.5	8594.1	1939.4	2931.7	6495.6	10
12	8529.8	1903.3	2850.0	6386.2	8596.3	1940.7	2934.6	6499.4	12
14	8532.0	1904.6	2852.8	6389.9	8598.5	1941.9	2937.5	6503.2	14
16	8534.3	1905.8	2855.6	6393.7	8600.7	1943.2	2940.3	6507.1	16
18	8536.5	1907.0	2858.4	6397.4	8602.9	1944.4	2943.2	6510.9	18
20	8538.7	1908.3	2861.2	6401.2	8605.1	1945.7	2946.7	6514.7	20
22	8540.9	1909.5	2864.0	6404.9	8607.3	1946.9	2948.9	6518.5	22
24	8543.2	1910.8	2866.7	6408.7	8609.5	1948.2	2951.8	6522.3	24
26	8545.4	1912.0	2869.5	6412.4	8611.7	1949.4	2954.7	6526.2	26
28	8547.6	1913.3	2872.3	6416.2	8613.9	1950.7	2957.6	6530.0	28
30	8549.8	1914.5	2875.1	6419.9	8616.1	1952.0	2960.4	6533.8	30
32	8552.0	1915.7	2877.9	6423.7	8618.3	1953.2	2963.3	6537.7	32
34	8554.3	1917.0	2880.8	6427.5	8620.5	1954.5	2966.2	6541.5	34
36	8556.5	1918.2	2883.6	6431.2	8622.7	1955.7	2969.1	6545.3	36
38	8558.7	1919.5	2886.4	6435.0	8624.9	1957.0	2972.0	6549.2	38
40	8560.9	1920.7	2889.2	6438.8	8627.1	1958.2	2974.9	6553.0	40
42	8563.1	1922.0	2892.0	6442.5	8629.3	1959.5	2977.8	6556.9	42
44	8565.3	1923.2	2894.8	6446.3	8631.5	1960.7	2980.7	6560.7	44
46	8567.6	1924.5	2897.7	6450.1	8633.7	1962.0	2983.6	6564.6	46
48	8569.8	1925.7	2900.5	6453.9	8635.8	1963.2	2986.5	6568.4	48
50	8572.0	1927.0	2903.3	6457.6	8638.0	1964.5	2989.4	6572.3	50
52	8574.2	1928.2	2906.1	6461.4	8640.2	1965.8	2992.3	6576.2	52
54	8576.4	1929.4	2909.0	6465.2	8642.4	1967.0	2995.2	6580.0	54
56	8578.6	1930.7	2911.8	6469.0	8644.6	1968.3	2998.1	6583.9	56
58	8580.8	1931.9	2914.7	6472.8	8646.8	1969.5	3001.1	6587.7	58
60	8583.0	1933.2	2917.5	6476.6	8649.0	1970.8	3004.0	6591.6	60

	98°				99°				
	LC	M	E	T	LC	M	E	T	
0	8649.0	1970.8	3004.0	6591.6	8714.3	2008.7	3092.9	6709.0	0
2	8651.2	1972.0	3006.9	6595.5	8716.4	2009.9	3095.9	6712.9	2
4	8653.3	1973.3	3009.8	6599.4	8718.6	2011.2	3098.9	6716.9	4
6	8655.5	1974.6	3012.8	6603.2	8720.7	2012.5	3101.9	6720.8	6
8	8657.7	1975.8	3015.7	6607.1	8722.9	2013.7	3104.9	6724.8	8
10	8659.9	1977.1	3018.6	6611.0	8725.1	2015.0	3107.9	6728.8	10
12	8662.1	1978.3	3021.6	6614.9	8727.2	2016.3	3111.0	6732.7	12
14	8664.3	1979.6	3024.5	6618.8	8729.4	2017.5	3114.0	6736.7	14
16	8666.4	1980.9	3027.5	6622.7	8731.5	2018.8	3117.0	6740.7	16
18	8668.6	1982.1	3030.4	6626.6	8733.7	2020.1	3120.0	6744.6	18
20	8670.8	1983.4	3033.3	6630.5	8735.9	2021.4	3123.1	6748.6	20
22	8673.0	1984.4	3036.3	6634.4	8738.0	2022.6	3126.1	6752.6	22
24	8675.2	1985.9	3039.3	6638.3	8740.2	2023.9	3129.1	6756.6	24
26	8677.3	1987.2	3042.2	6642.2	8742.3	2025.2	3132.2	6760.6	26
28	8679.5	1988.4	3045.2	6646.1	8744.5	2026.4	3135.2	6764.6	28
30	8681.7	1989.7	3048.1	6650.0	8746.6	2027.7	3138.3	6768.6	30
32	8683.9	1991.0	3051.1	6653.9	8748.8	2029.0	3141.3	6772.6	32
34	8686.0	1992.2	3054.1	6657.8	8750.9	2030.3	3144.4	6776.6	34
36	8688.2	1993.5	3057.0	6661.7	8753.1	2031.5	3147.4	6780.6	36
38	8690.4	1994.7	3060.0	6665.7	8755.3	2032.8	3150.5	6784.6	38
40	8692.6	1996.0	3063.0	6669.6	8757.4	2034.1	3153.5	6788.6	40
42	8694.7	1997.3	3066.0	6673.5	8759.5	2035.4	3156.6	6792.6	42
44	8696.9	1998.5	3068.9	6677.4	8761.7	2036.6	3159.7	6796.6	44
46	8699.1	1999.8	3071.9	6681.4	8763.8	2037.9	3162.7	6800.6	46
48	8701.2	2001.1	3074.9	6685.3	8766.0	2039.2	3165.8	6804.6	48
50	8703.4	2002.3	3077.9	6689.2	8768.1	2040.5	3168.9	6808.6	50
52	8705.6	2003.6	3080.9	6693.2	8770.3	2041.7	3172.0	6812.6	52
54	8707.8	2004.9	3083.9	6697.1	8772.4	2043.0	3175.1	6816.7	54
56	8709.9	2006.1	3086.9	6701.1	8774.6	2044.3	3178.1	6820.7	56
58	8712.1	2007.4	3089.9	6705.2	8776.7	2045.6	3181.2	6824.7	58
60	8714.3	2008.7	3092.9	6709.0	8778.9	2046.8	3184.3	6828.8	60

Table A-5. Functions of 1° curves (continued)

	100°				101°				
	LC	M	E	T	LC	M	E	T	
0	8778.9	2046.8	3184.3	6828.8	8842.8	2085.3	3278.3	6951.0	0
2	8781.0	2048.1	3187.4	6832.8	8844.9	2086.6	3281.5	6955.2	2
4	8783.1	2049.4	3190.5	6836.8	8847.0	2087.8	3284.7	6959.3	4
6	8785.3	2050.7	3193.6	6849.9	8849.2	2089.1	3287.9	6963.4	6
8	8787.4	2051.9	3196.7	6844.9	8851.3	2090.4	3291.1	6967.6	8
10	8789.6	2053.2	3199.8	6849.0	8853.4	2091.7	3294.3	6971.7	10
12	8791.7	2054.5	3202.9	6853.0	8855.5	2093.0	3297.5	6975.8	12
14	8793.9	2055.8	3206.0	6857.1	8857.6	2094.3	3300.7	6980.0	14
16	8796.0	2057.1	3209.1	6861.1	8859.8	2095.6	3303.9	6984.1	16
18	8798.9	2958.3	3212.2	6865.2	8861.9	2096.9	3307.1	6988.2	18
20	8800.3	2059.6	3215.4	6869.2	8864.0	2098.2	3310.3	6992.4	20
22	8802.4	2060.9	3218.5	6873.3	8866.1	2099.4	3313.5	6996.6	22
24	8804.5	2062.2	3221.6	6877.4	8868.2	2100.7	3316.7	7000.7	24
26	8806.7	2063.5	3224.7	6681.4	8870.3	2102.0	3319.9	6004.9	26
28	8808.8	2064.7	3227.9	6885.5	8872.4	2103.3	3323.1	7009.0	28
30	8810.9	2066.0	3231.0	6889.6	8874.5	2104.6	3326.4	7013.2	30
32	8813.1	2067.3	3234.1	6893.7	8876.7	2105.9	3329.6	7017.3	32
34	8815.2	2068.6	3237.3	6897.8	8878.8	2107.2	3332.8	7021.5	34
36	8817.3	2069.9	3240.4	6901.8	8880.9	2108.5	3336.0	7025.7	36
38	8819.5	2071.1	3243.5	6905.9	8883.0	2109.8	3339.3	7209.9	38
40	8821.6	2072.4	3246.7	6910.0	8885.1	2111.1	3342.5	7034.0	40
42	8823.7	2073.7	3249.8	6914.1	8887.2	2112.4	3345.8	7038.2	42
44	8825.8	2075.0	3253.0	6918.2	8889.3	2113.6	3349.0	7042.4	44
46	8828.0	2076.3	3256.2	6922.3	8891.4	2114.9	3352.3	7046.6	46
48	8830.1	2077.6	3259.3	6926.4	8893.5	2116.2	3355.5	7050.8	48
50	8832.2	2078.9	3262.5	6930.5	8895.6	2117.5	3358.8	7055.0	50
52	8834.3	2080.1	3265.7	6934.6	8897.7	2118.8	3362.0	7059.2	52
54	8836.4	2081.4	3268.8	6938.7	8899.8	2120.1	3365.5	7063.4	54
56	8838.6	2082.7	3272.0	6942.8	8901.9	2121.4	3368.7	7067.6	56
58	8840.7	2084.0	3275.2	6946.9	8904.0	2122.7	3372.0	7071.8	58
60	8842.8	2085.3	3278.3	6951.0	8906.1	2124.0	3375.1	7076.0	60

	102°				103°				
	LC	M	E	T	LC	M	E	T	
0	8906.1	2124.0	3375.1	7076.0	8968.7	2163.0	3474.6	7203.6	0
2	8908.2	2125.3	3378.3	7080.2	8970.8	2164.3	3478.0	7207.9	2
4	8910.3	2126.6	3381.6	7084.4	8972.9	2165.6	3481.4	7212.2	4
6	8912.4	2127.9	3384.9	7088.6	8974.9	2166.9	3484.7	7216.5	6
8	8914.5	2129.2	3388.2	7092.8	8977.0	2168.2	3488.1	7220.8	8
10	8916.6	2130.5	3391.5	7097.1	8979.1	2169.5	3491.5	7225.1	10
12	8918.7	2131.8	3394.7	7101.3	8981.1	2170.8	3494.9	7229.5	12
14	8920.8	2133.1	3398.0	7105.5	8983.2	2172.1	3498.3	7233.8	14
16	8922.9	2134.4	3401.3	7109.7	8985.3	2173.4	3501.6	7238.1	16
18	8925.0	2135.7	3404.6	7114.0	8987.3	2174.7	3505.3	7242.4	18
20	8927.0	2137.0	3407.9	7118.2	8989.4	2176.1	3508.4	7246.8	20
22	8929.1	2138.3	3411.2	7122.4	8991.5	2177.4	3511.8	7251.1	22
24	8931.2	2139.6	3414.5	7126.7	8993.5	2178.7	3515.2	7255.4	24
26	8933.3	2140.9	3417.9	7130.9	8995.6	2180.0	3518.7	7259.8	26
28	8935.4	2142.2	3421.2	7135.2	8997.7	2181.3	3522.1	7264.1	28
30	8937.5	2143.5	3424.5	7139.4	8999.7	2182.6	3525.5	7268.5	30
32	8939.6	2144.8	3427.8	7143.7	9001.8	2183.9	3528.9	7272.8	32
34	8941.6	2146.1	3431.1	7148.0	9003.9	2185.2	3532.3	7277.2	34
36	8943.7	2147.4	3434.5	7152.2	9005.9	2186.5	3535.7	7281.5	36
38	8945.8	2148.7	3437.8	7156.5	9008.0	2187.8	3539.2	7285.9	38
40	8947.9	2150.0	3441.1	7160.7	9010.0	2189.1	3542.6	7290.3	40
42	8950.0	2151.3	3444.4	7165.0	9012.1	2190.5	3546.0	7294.6	42
44	8952.1	2152.6	3447.8	7169.3	9014.2	2191.8	3549.5	7299.0	44
46	8954.1	2153.9	3451.1	7173.6	9016.2	2193.1	3552.9	7303.4	46
48	8956.2	2155.2	3454.5	7177.9	9018.3	2194.4	3556.3	7307.7	48
50	8958.3	2156.5	3457.8	7182.1	9020.3	2195.7	3559.8	7312.1	50
52	8960.4	2157.8	3461.2	7186.4	9022.4	2197.0	3563.2	7316.5	52
54	8962.5	2159.1	3464.5	7190.7	9024.5	2198.3	3566.7	7320.9	54
56	8964.5	2160.4	3467.9	7195.0	9026.5	2199.6	3570.2	7325.3	56
58	8966.6	2161.7	3471.2	7199.3	9028.6	2200.9	3573.6	7329.7	58
60	8968.7	2163.0	3474.6	7203.6	9030.6	2202.3	3577.1	7334.1	60

Table A-5. Functions of 1° curves (continued)

	104°				105°				
	LC	M	E	T	LC	M	E	T	
0	9030.6	2202.3	3577.1	7334.1	9091.8	2241.8	3682.6	7467.5	0
2	9032.7	2203.6	3580.5	7338.5	9093.9	2243.1	3686.1	7472.0	2
4	9034.7	2204.9	3584.0	7342.9	9095.9	2244.4	3689.7	7476.5	4
6	9036.8	2206.2	3587.5	7347.3	9097.9	2245.8	3693.3	7481.0	6
8	9038.8	2207.5	3591.0	7351.7	9099.9	2247.1	3696.9	7485.5	8
10	9040.9	2208.8	3594.4	7356.1	9102.0	2248.4	3700.4	7490.0	10
12	9042.9	2210.2	3597.9	7360.5	9104.0	2249.7	3704.0	7494.5	12
14	9045.0	2211.5	3601.4	7364.9	9106.0	2251.1	3707.6	7499.1	14
16	9047.0	2212.8	3604.9	7369.4	9108.0	2252.4	3711.2	7503.6	16
18	9049.1	2214.1	3608.4	7373.8	9110.1	2253.7	3714.8	7508.1	18
20	9051.1	2215.4	3611.9	7378.2	9112.1	2255.0	3718.4	7512.6	20
22	9053.1	2216.7	3615.4	7382.6	9114.1	2256.4	3722.0	7517.2	22
24	9055.2	2218.0	3618.9	7387.1	9116.1	2257.7	3725.6	7521.7	24
26	9057.2	2219.4	3622.4	7391.5	9118.1	2259.0	3729.3	7526.3	26
28	9059.3	2220.7	3625.9	7396.0	9120.2	2260.3	3732.9	7530.8	28
30	9061.3	2222.0	3629.4	7400.4	9122.2	2261.7	3736.5	7535.3	30
32	9063.3	2223.3	3633.0	7404.8	9124.2	2263.0	3740.1	7539.9	32
34	9065.4	2224.6	3636.5	7409.3	9126.2	2264.3	3743.7	7544.4	34
36	9067.4	2226.0	3640.0	7413.8	9128.2	2265.7	3747.4	7549.0	36
38	9069.5	2227.3	3643.5	7418.2	9130.2	2267.0	3751.0	7553.6	38
40	9071.5	2228.6	3647.1	7422.7	9132.3	2268.3	3754.6	7558.1	40
42	9073.5	2229.9	3650.6	7427.1	9134.3	2269.6	3758.3	7562.7	42
44	9075.6	2231.2	3654.1	7431.6	9136.3	2271.0	3761.9	7567.3	44
46	9077.6	2232.6	3657.7	7436.1	9138.3	2272.3	3765.6	7571.8	46
48	9079.6	2233.9	3661.2	7440.6	9140.3	2273.6	3769.2	7576.4	48
50	9081.7	2235.2	3664.8	7445.0	9142.3	2275.0	3772.9	7581.0	50
52	9083.7	2236.5	3668.3	7449.5	9144.3	2276.3	3776.5	7585.6	52
54	9085.7	2237.8	3671.9	7454.0	9146.3	2277.6	3780.2	7590.2	54
56	9087.8	2239.2	3675.4	7458.5	9148.3	2278.9	3783.9	7594.8	56
58	9089.8	2240.5	3679.0	7463.0	9150.4	2280.3	3787.5	7599.4	58
60	9091.8	2241.8	3682.6	7467.5	9152.4	2281.6	3791.2	7604.0	60

Table A-6. Corrections for tangent and external distances

(This table is to convert tabular values in table A-5 to the chord definition.)

Example

Required are the tangent, external distance, and length of curve for a curve of 18° 20′ and an I angle of 9° 46′.

$$\text{Tangent: } T = \frac{\text{Tabluar Entry}}{\text{Degree of Curve}} = \frac{489.56}{18.333} = 26.70$$

+ (correction to be added from table A-6 for 18° 20′ and 9° 46′) 0.12′ = 26.82′

$$\text{External Distance} = \frac{\text{Tabluar Entry}}{\text{Degree of Curve}} = \frac{20.88}{18.333} = 1.139$$

+ (correction to be added from table A-6 for 18° 20′ and 9° 46′) 0.005 = 1.14′

Table A-6. Corrections for tangent and external distance (continued)

Angle	Curve												
	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°
5°	.02	.03	.05	.06	.08	.10	.11	.13	.15	.16	.18	.20	.21
10°	.03	.06	.09	.13	.16	.19	.22	.25	.28	.31	.34	.38	.42
15°	.04	.10	.14	.19	.24	.29	.34	.39	.45	.51	.53	.58	.63
20°	.06	.13	.19	.26	.32	.39	.45	.51	.58	.65	.72	.79	.84
25°	.08	.16	.24	.33	.40	.49	.58	.67	.75	.83	.90	.99	1.06
30°	.10	.19	.29	.39	.49	.59	.69	.79	.89	.99	1.09	1.20	1.29
35°	.11	.22	.34	.47	.58	.69	.80	.93	1.05	1.17	1.29	1.42	1.54
40°	.13	.26	.40	.53	.67	.80	.93	1.06	1.20	1.34	1.49	1.64	1.79
45°	.15	.30	.44	.60	.76	.91	1.06	1.21	1.37	1.52	1.70	1.87	2.04
50°	.17	.34	.51	.68	.85	1.02	1.19	1.36	1.54	1.72	1.91	2.10	2.29
55°	.19	.38	.57	.76	.95	1.14	1.32	1.52	1.72	1.92	2.14	2.35	2.56
60°	.21	.42	.63	.84	1.05	1.27	1.49	1.71	1.92	2.17	2.38	2.60	2.83
65°	.23	.46	.69	.93	1.16	1.40	1.64	1.88	2.13	2.38	2.63	2.88	3.13
70°	.25	.51	.76	1.02	1.28	1.54	1.80	2.06	2.33	2.60	2.88	3.16	3.44
75°	.27	.56	.83	1.12	1.40	1.69	1.98	2.27	2.57	2.87	3.16	3.47	3.78
80°	.30	.61	.91	1.22	1.53	1.84	2.15	2.46	2.78	3.10	3.44	3.78	4.12
85°	.33	.66	1.00	1.33	1.68	2.02	2.36	2.70	3.05	3.40	3.77	4.14	4.55
90°	.36	.72	1.09	1.45	1.83	2.20	2.57	2.94	3.32	3.70	4.10	4.50	4.91
95°	.39	.79	1.19	1.55	2.00	2.40	2.80	3.20	3.61	4.02	4.49	4.98	5.38
100°	.43	.86	1.30	1.74	2.18	2.62	3.06	3.50	3.95	4.40	4.88	5.37	5.85
105°	.46	.94	1.42	1.90	2.38	2.87	3.34	3.84	4.35	4.84	5.35	5.87	6.40
110°	.50	1.03	1.55	2.08	2.60	3.14	3.66	4.21	4.76	5.31	5.86	6.43	7.01
115°	.54	1.13	1.70	2.29	2.86	3.45	4.03	4.63	5.23	5.83	6.44	7.07	7.70
120°	.61	1.25	1.89	2.52	3.16	3.81	4.44	5.11	5.78	6.44	7.11	7.80	8.51

Angle	Curve												
	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°
5°	.000	.000	.001	.001	.002	.002	.002	.003	.003	.004	.004	.004	.005
10°	.001	.003	.004	.006	.007	.008	.009	.011	.012	.014	.015	.017	.018
15°	.003	.007	.010	.014	.018	.023	.027	.029	.032	.035	.039	.043	.047
20°	.006	.011	.017	.022	.028	.034	.038	.045	.051	.057	.063	.070	.076
25°	.009	.018	.027	.036	.046	.056	.065	.074	.083	.093	.106	.120	.127
30°	.013	.025	.038	.051	.065	.078	.090	.103	.116	.129	.149	.170	.179
35°	.018	.035	.054	.072	.086	.109	.131	.153	.175	.197	.213	.230	.247
40°	.023	.046	.070	.093	.117	.141	.172	.203	.234	.265	.277	.290	.315
45°	.030	.060	.093	.119	.153	.184	.216	.254	.289	.325	.351	.378	.411
50°	.037	.075	.116	.151	.189	.227	.266	.305	.345	.384	.425	.467	.508
55°	.046	.093	.142	.188	.236	.283	.332	.381	.420	.479	.530	.582	.641
60°	.056	.112	.168	.225	.283	.340	.398	.457	.516	.575	.636	.697	.774
65°	.067	.135	.204	.273	.343	.412	.483	.554	.625	.697	.711	.845	.922
70°	.080	.159	.240	.321	.403	.485	.568	.652	.735	.819	.906	.994	1.08
75°	.095	.182	.286	.383	.480	.578	.678	.777	.877	.977	1.07	1.18	1.29
80°	.110	.220	.332	.445	.558	.671	.787	.903	1.02	1.13	1.25	1.38	1.50
85°	.128	2.59	.391	.524	.657	.790	.926	1.06	1.20	1.34	1.47	1.62	1.76
90°	.149	.299	.450	.603	.756	.910	1.07	1.22	1.38	1.54	1.70	1.87	2.03
95°	.174	.350	.522	.706	.985	1.06	1.25	1.43	1.62	1.80	1.99	2.18	2.38
100°	.200	.401	.604	.809	1.01	1.22	1.43	1.64	1.85	2.06	2.28	2.50	2.73
105°	.230	.470	.700	.938	1.17	1.42	1.65	1.90	2.14	2.39	2.64	2.90	3.16
110°	.260	.535	.808	1.08	1.36	1.63	1.91	2.19	2.49	2.61	3.05	3.35	3.65
115°	.307	.624	.939	1.26	1.57	1.89	2.21	2.54	2.87	3.20	3.53	3.88	4.23
120°	.339	.720	1.08	1.45	1.82	2.20	2.56	2.95	3.33	3.72	4.10	4.50	4.91

Table A-7. Deflections and chords for 25-, 50-, and 100-foot arcs

$$\text{Deflection} = \frac{1718.873}{R}\text{ arc length}$$

Chord = 2R sin definition

Radius	Deflection for arc length			Chord for arc length			Degree of curve. Arc definition
	25'	50'	100'	25'	50'	100'	
150	4° 46.48'	9° 32.96'	19° 05.92'	24.97'	49.77'	98.16'	38° 12'
200	3° 34.86'	7° 09.72'	14° 19.44'	24.98'	49.87'	98.96'	28° 39'
225	3° 10.99'	6° 21.97'	12° 43.94'	24.99'	49.90'	99.18'	25° 28'
250	2° 51.89'	5° 43.78'	11° 27.55'	24.99'	49.92'	99.34'	22° 55'
275	2° 36.36'	5° 12.52'	10° 25.04'	24.99'	49.93'	99.45'	20° 50'
300	2° 23.24'	4° 46.48'	9° 32.96'	24.99'	49.94'	99.54'	19° 06'
325	2° 12.22'	4° 24.44'	8° 48.88'	24.99'	49.95'	99.61'	17° 38'
350	2° 02.78'	4° 05.55'	8° 11.11'	25.00'	49.96'	99.66'	16° 22'
375	1° 54.59'	3° 49.18'	7° 38.37'	25.00'	49.96'	99.70'	15° 17'
400	1° 47.43'	3° 34.86'	7° 09.72'	25.00'	49.97'	99.74'	14° 19'
450	1° 35.49'	3° 10.99'	6° 21.97'	25.00'	49.97'	99.79'	12° 44'
500	1° 25.94'	2° 51.89'	5° 43.77'	25.00'	49.98'	99.83'	11° 28'
550	1° 18.13'	2° 36.26'	5° 12.52'	25.00'	49.98'	99.86'	10° 25'
600	1° 11.62'	2° 23.24'	4° 46.48'	25.00'	49.99'	99.89'	9° 33'
650	1° 06.11'	2° 12.22'	4° 24.44'	25.00'	49.99'	99.90'	8° 49'
700	1° 01.39'	2° 02.78'	4° 05.55'	25.00'	49.99'	99.92'	8° 11'
750	0° 57.30'	1° 54.59'	3° 49.18'	25.00'	50.00'	99.93'	7° 38'
800	0° 53.71'	1° 47.43'	3° 34.86'	25.00'	50.00'	99.93'	7° 10'
850	0° 50.56'	1° 41.11'	3° 22.22'	25.00'	50.00'	99.94'	6° 44'
900	0° 47.75'	1° 35.49'	3° 10.99'	25.00'	50.00'	99.95'	6° 22'
950	0° 45.23'	1° 30.47'	3° 00.93'	25.00'	50.00'	99.95'	6° 02'
1000	0° 42.97'	1° 25.94'	2° 51.89'	25.00'	50.00'	99.96'	5° 44'
1050	0° 40.93'	1° 21.85'	2°43.70'	25.00'	50.00'	99.96'	5° 27'
1100	0° 39.07'	1° 18.13'	2° 36.26'	25.00'	50.00'	99.96'	5° 13'
1150	0° 37.37'	1° 14.73'	2° 29.47'	25.00'	50.00'	99.97'	4° 59'
1200	0° 35.81'	1° 11.62'	2° 23.24'	25.00'	50.00'	99.97'	4° 46'
1300	0° 33.06'	1° 06.11'	2° 12.22'	25.00'	50.00'	99.97'	4° 24'
1400	0° 30.69'	1° 01.39'	2° 02.78'	25.00'	50.00'	99.98'	4° 06'
1500	0° 28.65'	0° 57.30'	1° 54.59'	25.00'	50.00'	99.98'	3° 49'
1600	0° 26.86'	0° 53.72'	1° 47.43'	25.00'	50.00'	99.98'	3° 35'
1700	0° 25.28'	0° 50.56'	1° 41.11'	25.00'	50.00'	99.99'	3° 22'
1800	0° 23.87'	0° 47.75'	1° 35.49'	25.00'	50.00'	99.99'	3° 11'
1900	0° 22.62'	0° 45.23'	1° 30.47'	25.00'	50.00'	100.00'	3° 01'
2000	0° 21.49'	0° 42.97'	1° 25.95'	25.00'	50.00'	100.00'	2° 52'
2100	0° 20.46'	0° 40.93'	1° 21.85'	25.00'	50.00'	100.00'	2° 44'
2200	0° 19.53'	0° 39.07'	1° 18.13'	25.00'	50.00'	100.00'	2° 36'
2300	0° 18.68'	0° 37.37'	1° 14.73'	25.00'	50.00'	100.00'	2° 29'
2400	0° 17.91'	0° 35.81'	1° 11.62'	25.00'	50.00'	100.00'	2° 23'
2500	0° 17.19'	0° 34.38'	1° 08.75'	25.00'	50.00'	100.00'	2° 18'
3000	0° 14.32'	0° 28.65'	0° 57.30'	25.00'	50.00'	100.00'	1° 55'
3500	0° 12.28'	0° 24.56'	0° 49.11'	25.00'	50.00'	100.00'	1° 38'
4000	0° 10.74'	0° 21.49'	0° 42.97'	25.00'	50.00'	100.00'	1° 26'
4500	0° 09.55'	0° 19.10'	0° 38.20'	25.00'	50.00'	100.00'	1° 16'
5000	0° 08.59'	0° 17.19'	0° 34.38'	25.00'	50.00'	100.00'	1° 09'
6000	0° 07.16'	0° 14.32'	0° 28.65'	25.00'	50.00'	100.00'	0° 57'
7000	0° 06.14'	0° 12.28'	0° 24.56'	25.00'	50.00'	100.00'	0° 49'
7500	0° 05.73'	0° 11.46'	0° 22.92'	25.00'	50.00'	100.00'	0°46'
8000	0° 05.37'	0° 10.74'	0° 21.49'	25.00'	50.00'	100.00'	0° 43'
9000	0° 04.77'	0° 09.55'	0° 19.10'	25.00'	50.00'	100.00'	0° 38'
10000	0° 04.30'	0° 08.59'	0° 17.19'	25.00'	50.00'	100.00'	0° 34'

Table A-8. Squares, cubes, square roots, and cube roots

Example: The square of 26 = 676; the cube of 26 = 17,576; the square root of 26 = 5.0990; the cube root of 26 = 2.9625.

To find the square root of a decimal or mixed number, first multiply the number by either 100 or 10,000 to eliminate as many of the decimals as possible. Round the result off to the nearest whole number. Locate this number in the *square column.* Determine the desired square root by taking the corresponding number from the *number column* and moving the decimal point. If the original number was multiplied by 100, move the decimal one place to the left; if it was multiplied by 10,000, move the decimal two places to the left.

Example:

Find the square root of 5.246 to the first decimal place. Multiply by 100. The result is 524. The nearest number in the column of squares is 529, which is opposite 23 in the column of numbers. Move the decimal point one place to the left. This gives 2.3 as the desired root to the first place of decimals.

Find the square root of 5.246 to the second decimal place. Multiply by 10,000. The result is 52,460. The nearest number in the column of squares is 52,441, which is opposite 229 in the column of numbers.

Move the decimal point two places to the left. The result is 2.29

To find the cube root of a similar number, multiply by 1,000 or by 1,000,000, and find the nearest number in the column of cubes. The corresponding number in the column of numbers with a decimal point one or two places to the left is the required root. Perform similarly to preceding example.

Table A-8. Squares, cubes, square roots, and cube roots (continued)

To find the square root or cube root of number greater than 1,000, find the nearest number in the column of squares or cubes and take the corresponding number in the first column. The number thus found is correct for the number of figures it contains.

To find various roots:

For the fourth root, take the square root of the square root.

For the sixth root, take the square root of the cube root or vice versa.

Higher roots, whose indices can be factored into 2s and 3s, maybe obtained in a similar manner.

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
1	1	1	1.0000	1.	21	441	9261	4.5826	2.7589
2	4	8	1.4142	1.2599	22	484	10648	4.6904	2.8020
3	9	27	1.7321	1.4422	23	529	12167	4.7958	2.8439
4	16	64	2.0000	1.5874	24	576	13824	4.8990	2.8845
5	25	125	2.2361	1.7100	25	625	15625	5.0000	2.9240
6	36	216	2.4495	1.8171	26	676	17576	5.0990	2.9625
7	49	343	2.6458	1.9129	27	729	19683	5.1962	3.0000
8	64	512	2.8284	2.0000	28	784	21952	5.2915	3.0366
9	81	729	3.0000	2.0801	29	841	24389	5.3852	3.0723
10	100	1000	3.1623	2.1544	30	900	27000	5.4772	3.1072
11	121	1331	3.3166	2.2240	31	961	29791	5.5678	3.1414
12	144	1728	3.4641	2.2894	32	1024	32768	5.6569	3.1748
13	169	2197	3.6056	2.3513	33	1089	35937	5.7446	3.2075
14	196	2744	3.7417	2.4101	34	1156	39304	5.8310	3.2396
15	225	3375	3.8730	2.4662	35	1225	42875	5.9161	3.2711
16	256	4096	4.0000	2.5198	36	1296	46656	6.0000	3.3019
17	289	4913	4.1231	2.5713	37	1369	50653	6.0828	3.3322
18	324	5832	4.2426	2.6207	38	1444	54872	6.1644	3.3620
19	361	6859	4.3589	2.6684	39	1521	59315	6.2450	3.3912
20	400	8000	4.4721	2.7144	40	1600	64000	6.3246	3.4200

Table A-8. Squares, cubes, square roots, and cube roots

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
41	1681	68921	6.4031	3.4482	91	8281	753571	9.5394	4.4979
42	1764	74088	6.4807	3.4760	92	8464	778688	9.5917	4.5144
43	1849	79507	6.5574	3.5034	93	8649	804357	9.6437	4.5307
44	1936	85184	6.6332	3.5303	94	8836	830584	9.6954	4.5468
45	2025	91125	6.7082	3.5569	95	9025	857375	9.7468	4.5629
46	2116	97336	6.7823	3.5830	96	9216	884736	9.7980	4.5789
47	2209	103823	6.8557	3.6088	97	9409	912673	9.8489	4.5947
48	2304	110592	6.9282	3.6342	98	9604	941192	9.8995	4.6104
49	2401	117649	7.0000	3.6593	99	9801	970299	9.9499	4.6261
50	2500	125000	7.0711	3.6840	100	10000	1000000	10.0000	4.6416
51	2601	132651	7.1414	3.7084	101	10201	1030301	10.0499	4.6570
52	2704	140608	7.2111	3.7325	102	10404	1061208	10.0995	4.6723
53	2809	148877	7.2801	3.7563	103	10609	1092727	10.1489	4.6875
54	2916	157464	7.3485	3.7798	104	10816	1124864	10.1980	4.7027
55	3025	166375	7.4162	3.8030	105	11025	1157625	10.2470	4.7177
56	3136	175616	7.4833	3.8259	106	11236	1191016	10.2956	4.7326
57	3249	185193	7.5498	3.8485	107	11449	1225043	10.3441	4.7475
58	3364	195112	7.6158	3.8709	108	11664	1259712	10.3923	4.7622
59	3481	205379	7.6811	3.8930	109	11881	1295029	10.4403	4.7769
60	3600	216000	7.7460	3.9149	110	12100	1331000	10.4881	4.7914
61	3721	226981	7.8102	3.9365	111	12321	1367631	10.5357	4.8059
62	3844	238328	7.8740	3.9579	112	12544	1404928	10.5830	4.8203
63	3969	250047	7.9373	3.9791	113	12769	1442896	10.6301	4.8346
64	4096	262144	8.0000	4.0000	114	12996	1481544	10.6771	4.8488
65	4225	274625	8.0623	4.0207	115	13225	1520875	10.7238	4.8629
66	4356	287496	8.1240	4.0412	116	13456	1560896	10.7703	4.8770
67	4489	300763	8.1854	4.0615	117	13689	1601613	10.8167	4.8910
68	4624	314432	8.2462	4.0817	118	13924	1643032	10.8628	4.9049
69	4761	328509	8.3066	4.1016	119	14161	1685159	10.9087	4.9187
70	4900	343000	8.3666	4.1213	120	14400	1728000	10.9545	4.9324
71	5041	357911	8.4261	4.1408	121	14641	1771561	11.0000	4.9461
72	5184	373248	8.4853	4.1602	122	14884	1815848	11.0454	4.9597
73	5329	389017	8.5440	4.1793	123	15129	1860867	11.0905	4.9732
74	5476	405224	8.6023	4.1983	124	15376	1906624	11.1355	4.9866
75	5625	421875	8.6603	4.2172	125	15625	1953125	11.1803	5.0000
76	5776	438976	8.7178	4.2358	126	15876	2000376	11.2250	5.0133
77	5929	456533	8.7750	4.2543	127	16129	2048383	11.2694	5.0265
78	6084	474552	8.8318	4.2727	128	16384	2097152	11.3137	5.0397
79	6241	493039	8.8882	4.2908	129	16641	2146689	11.3578	5.0528
80	6400	512000	8.9443	4.3089	130	16900	2197000	11.4018	5.0658
81	6561	531441	9.0000	4.3267	131	17161	2248091	11.4455	5.0788
82	6724	551368	9.0554	4.3445	132	17424	2299968	11.4891	5.0916
83	6889	571787	9.1104	4.3621	133	17689	2352637	11.5326	5.1045
84	7056	592704	9.1652	4.3795	134	17956	2406104	11.5758	5.1172
85	7225	614125	9.2195	4.3968	135	18225	2460375	11.6190	5.1299
86	7396	636056	9.2736	4.4140	136	18496	2515456	11.6619	5.1426
87	7569	658503	9.3274	4.4310	137	18769	2571353	11.7047	5.1551
88	7744	681472	9.3808	4.4480	138	19044	2628072	11.7473	5.1676
89	7921	704969	9.4340	4.4647	139	19321	2685619	11.7898	5.1801
90	8100	729000	9.4868	4.4814	140	19600	2744000	11.8322	5.1925

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
141	19881	2803221	11.8743	5.2048	191	36481	6967871	13.8203	5.7590
142	20164	2863288	11.9164	5.2171	192	36864	7077888	13.8564	5.7690
143	20449	2924207	11.9583	5.2293	193	37249	7189057	13.8924	5.7790
144	20736	2985984	12.0000	5.2415	194	37636	7301384	13.9284	5.7890
145	21025	3048625	12.0416	5.2536	195	38025	7414875	13.9642	5.7989
146	21316	3112136	12.0830	5.2656	196	38416	7529536	14.0000	5.8088
147	21609	3176523	12.1244	5.2776	197	38809	7645373	14.0357	5.8186
148	21904	3241792	12.1655	5.2896	198	39204	7762392	14.0712	5.8285
149	22201	3307949	12.2066	5.3015	199	39601	7880599	14.1067	5.8383
150	22500	3375000	12.2474	5.3133	200	40000	8000000	14.1421	5.8480
151	22801	3442951	12.2882	5.3251	201	40401	8120601	14.1774	5.8578
152	23104	3511808	12.3288	5.3368	202	40804	8242408	14.2127	5.8675
153	23409	3581577	12.3693	5.3485	203	41209	8365427	14.2478	5.8771
154	23716	3652264	12.4097	5.3601	204	41616	8489664	14.2829	5.8868
155	24025	3723875	12.4499	5.3717	205	42025	8615125	14.3178	5.8964
156	24336	3796416	12.4900	5.3832	206	42436	8741816	14.3527	5.9059
157	24649	3869893	12.5300	5.3947	207	42849	8869743	14.3875	5.9155
158	24964	3944312	12.5698	5.4061	208	43264	8998912	14.4222	5.9250
159	25281	4019679	12.6095	5.4175	209	43681	9129329	14.4568	5.9345
160	25600	4096000	12.6491	5.4288	210	44100	9261000	14.4914	5.9439
161	25921	4173281	12.6886	5.4401	211	44521	9393931	14.5258	5.9533
162	26244	4251528	12.7279	5.4514	212	44944	9528128	14.5602	5.9627
163	26569	4330747	12.7671	5.4626	213	45369	9663597	14.5945	5.9721
164	26896	4410944	12.8062	5.4737	214	45796	9800344	14.6287	5.9814
165	27225	4492125	12.8452	5.4848	215	46225	9938375	14.6629	5.9907
166	27556	4574296	12.8841	5.4959	216	46656	10077696	14.6969	6.0000
167	27889	4657463	12.9228	5.5069	217	47089	10218313	14.7309	6.0092
168	28224	4741631	12.9615	5.5178	218	47524	10360232	14.7648	6.0185
169	28561	4826809	13.0000	5.5288	219	47961	10503459	14.7986	6.0277
170	28900	4913000	13.0384	5.5397	220	48400	10648000	14.8324	6.0368
171	29241	5000211	13.0767	5.5505	221	48841	10793861	14.8661	6.0459
172	29584	5088448	13.1149	5.5613	222	49284	10941048	14.8997	6.0550
173	29929	5177717	13.1529	5.5721	223	49729	11089567	14.9332	6.0641
174	30276	5268024	13.1909	5.5828	224	50176	11239424	14.9666	6.0732
175	30625	5359375	13.2288	5.5934	225	50625	11390625	15.0000	6.0822
176	30976	5451776	13.2665	5.6041	226	51076	11543176	15.0333	6.0912
177	31329	5545233	13.3041	5.6147	227	51529	11697083	15.0665	6.1002
178	31684	5639752	13.3417	5.6252	228	51984	11852352	15.0997	6.1091
179	32041	5735339	13.3791	5.6357	229	52441	12008989	15.1327	6.1180
180	32400	5832000	13.4164	5.6462	230	52900	12167000	15.1658	6.1269
181	32761	5929741	13.4536	5.6567	231	53361	12326391	15.1987	6.1358
182	33124	6028568	13.4907	5.6671	232	53824	12487168	14.2315	6.1446
183	33489	6128487	13.5277	5.6774	233	54289	12649337	15.2643	6.1534
184	33856	6229504	13.5647	4.6877	234	54756	12812904	15.2971	6.1622
185	34225	6331625	13.6015	5.6980	235	55225	12977875	15.3297	6.1710
186	34596	6434856	13.6382	5.7083	236	55696	13144256	15.3623	6.1797
187	34969	6539203	13.6748	5.7185	237	56169	13312053	15.3948	6.1885
188	35344	6644672	13.7113	5.7287	238	56644	13481272	15.4272	6.1972
189	35721	6751269	13.7477	5.7388	239	57121	13651919	15.4596	6.2058
190	36100	6859000	13.7840	5.7489	240	57600	13824000	15.4919	6.2145

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
241	58081	13997521	15.5242	6.2231	291	84681	24642171	17.0587	6.6267
242	58564	14172488	15.5563	6.2317	292	85264	24897088	17.0880	6.6343
243	59049	14348907	15.5885	6.2403	293	85849	25153757	17.1172	6.6419
244	59536	14526784	15.6205	6.2488	294	86436	25412184	17.1464	6.6494
245	60025	14706125	15.6525	6.2573	295	87025	25672375	17.1756	6.6569
246	60516	14886936	15.6844	6.2658	296	87616	25934336	17.2047	6.6644
247	61099	15069223	15.7162	6.2743	297	88209	26198073	17.2337	6.6719
248	61504	15252992	15.7480	6.2828	298	88804	26463592	17.2627	6.6794
249	62001	15438249	15.7797	6.2912	299	89401	26730899	17.2916	6.6869
250	62500	15625000	15.8114	6.2996	300	90000	27000000	17.3205	6.6943
251	63001	15813251	15.8430	6.3080	301	90601	27270901	17.3494	6.7018
252	63504	16003008	15.8745	6.3164	302	91204	27543608	17.3781	6.7092
253	64009	16194277	15.9060	6.3247	303	91809	27818127	17.4069	6.7166
254	64516	16387064	15.9374	6.3330	304	92416	28094464	17.4356	6.7240
255	65025	16581375	15.9687	6.3413	305	93025	28372625	17.4642	6.7313
256	65536	16777216	16.0000	6.3496	306	93636	28652616	17.4929	6.7387
257	66049	16974593	16.0312	6.3579	307	94249	28934443	17.5214	6.7460
258	66564	17173512	16.0624	6.3661	308	94864	29218112	17.5499	6.7533
259	67081	17373979	16.0935	6.3743	309	95481	29503629	17.5784	6.7606
260	67600	17576000	16.1245	6.3825	310	96100	29791000	17.6068	6.7679
261	68121	17779581	16.1555	6.3907	311	96721	30080231	17.6352	6.7752
262	68644	17984728	16.1864	6.3988	312	97344	30371328	17.6635	6.7824
263	69169	18191447	16.2173	6.4070	313	97969	30664297	17.6918	6.7897
264	69696	18399744	16.2481	6.4151	314	98596	30959144	17.7200	6.7969
265	70225	18609625	16.2788	6.4232	315	99225	31255875	17.7482	6.8041
266	70756	18821096	16.3095	6.4312	316	99856	31554496	17.7764	6.8113
267	71289	19034163	16.3401	6.4393	317	100489	31855013	17.8045	6.8185
268	71824	19248832	16.3707	6.4473	318	101124	32157432	17.8326	6.8256
269	72361	19465109	16.4012	6.4553	319	101761	32461759	17.8606	6.8328
270	72900	19683000	16.4317	6.4633	320	102400	32768000	17.8885	6.8399
271	73441	19902511	16.4621	6.4713	321	103041	33076161	17.9165	6.8470
272	73984	20123648	16.4924	6.4792	322	103684	33386248	17.9444	6.8541
273	74529	20346417	16.5227	6.4872	323	104329	33698267	17.9722	6.8612
274	75076	20570824	16.5529	6.4951	324	104976	34012224	18.0000	6.8683
275	75625	20796875	16.5831	6.5030	325	105625	34328125	18.0278	6.8753
276	76176	21024576	16.6132	6.5108	326	106276	34645976	18.0555	6.8824
277	76729	21253933	16.6433	6.5187	327	106929	34965783	18.0831	6.8894
278	77284	21484952	16.6733	6.5265	328	107584	35287552	18.1108	6.8964
279	77841	21717639	16.7033	6.5343	329	108241	35611289	18.1384	6.9034
280	78400	21952000	16.7332	6.5421	330	108900	35937000	18.1659	6.9104
281	78961	22188041	16.7631	6.5499	331	109561	36264691	18.1934	6.9174
282	79524	22425768	16.7929	6.5577	332	110224	36594368	18.2209	6.9244
283	80089	22665187	16.8226	6.5654	333	110889	36926037	18.2483	6.9313
284	80656	22906304	16.8523	6.5731	334	111556	37259704	18.2757	6.9382
285	81225	23149125	16.8819	6.5808	335	112225	37595375	18.3030	6.9451
286	81796	23393656	16.9115	6.5885	336	112896	37933056	18.3303	6.9521
287	82369	23639903	16.9411	6.5962	337	113569	38272753	18.3576	6.9589
288	82944	23887872	16.9706	6.6039	338	114244	38614472	18.3848	6.9658
289	83521	24137569	17.0000	6.6115	339	114921	38958219	18.4120	6.9727
290	84100	24389000	17.0294	6.6191	340	115600	39304000	18.4391	6.9795

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
341	116281	39651821	18.4662	6.9864	391	152881	59776471	19.7737	7.3124
342	116964	40001688	18.4932	6.9932	392	153664	60236288	19.7990	7.3186
343	117649	40353607	18.5203	7.0000	393	154449	60698457	19.8242	7.3248
344	118336	40707584	18.5472	7.0068	394	155236	61162984	19.8494	7.3310
345	113025	41063625	18.5742	7.0136	395	156025	61629875	19.8746	7.3372
346	119716	41421736	18.6011	7.0203	396	156816	62099136	19.8997	7.3434
347	120409	41781923	18.6279	7.0271	397	157609	62570773	19.9249	7.3496
348	121104	42144192	18.6548	7.0338	398	158404	63044792	19.9499	7.3558
349	121801	42508549	18.6815	7.0406	399	159201	63521199	19.9750	7.3619
350	122500	42875000	18.7083	7.0473	400	160000	64000000	20.0000	7.3681
351	123201	43243551	18.7350	7.0540	401	160801	64481201	20.0250	7.3742
352	123904	43614208	18.7617	7.0607	402	161604	64964808	20.0499	7.3803
353	124609	43986977	18.7883	7.0674	403	162409	65450827	20.0749	7.3864
354	125316	44361864	18.8149	7.0740	404	163216	65939264	20.0998	7.3925
355	126025	44738875	18.8414	7.0807	405	164025	66430125	20.1246	7.3986
356	126736	45118016	18.8680	7.0873	406	164836	66923416	20.1494	7.4047
357	127449	45499293	18.8944	7.0940	407	165649	67410143	20.1742	7.4108
358	128164	45882712	18.9209	7.1006	408	166464	67917312	20.1990	7.4169
359	128881	46268279	18.9473	7.1072	409	167281	68417929	20.2237	7.4229
360	129600	46656000	18.9737	7.1138	410	168100	68921000	20.2485	7.4290
361	130321	47045881	19.0000	7.1204	411	168921	69426531	20.2731	7.4350
362	131044	47437928	19.0263	7.1269	412	169744	69934528	20.2978	7.4410
363	131769	47832147	19.0526	7.1335	413	170569	70444997	20.3224	7.4470
364	132496	48228544	19.0788	7.1400	414	171396	70957944	20.3470	7.4530
365	133225	48627125	19.1050	7.1466	415	172225	71473375	20.3715	7.4590
366	133956	49027896	19.1311	7.1531	416	173056	71991296	20.3961	7.4650
367	134689	49430863	19.1572	7.1596	417	173889	72511713	20.4206	7.4710
368	135424	49836032	19.1833	7.1661	418	174724	73034632	20.4450	7.4770
369	136161	50243409	19.2094	7.1726	419	175561	73560059	20.4695	7.4829
370	136900	50653000	19.2354	7.1791	420	176400	74088000	20.4939	7.4889
371	137641	51064811	19.2614	7.1855	421	177241	74618461	20.5183	7.4948
372	138384	51478848	19.2873	7.1920	422	178084	75151448	20.5426	7.5007
373	139129	51895117	19.3132	7.1984	423	178929	75686967	20.5670	7.5067
374	139786	52313624	19.3391	7.2048	424	179776	76225024	20.5913	7.5126
375	140625	52734375	19.3649	7.2112	425	180625	76765625	20.6155	7.5185
376	141376	53157376	19.3907	7.2177	426	181476	77308776	20.6398	7.5244
377	142129	53582633	19.4165	7.2240	427	182329	77854483	20.6640	7.5302
378	142884	54010152	19.4422	7.2304	428	183184	78402752	20.6882	7.5361
379	143641	54439939	19.4679	7.2368	429	184041	78953589	20.7123	7.5420
380	144400	54872000	19.4936	7.2432	430	184900	79507000	20.7364	7.5478
381	145161	55306341	19.5192	7.2495	431	185761	80062991	20.7605	7.5537
382	145924	55742968	19.5448	7.2558	432	186624	80621568	20.7846	7.5595
383	146689	56181887	19.5704	7.2622	433	187489	81182737	20.8087	7.5654
384	147456	56623104	19.5959	7.2685	434	188356	81746504	20.8327	7.5712
385	148225	57066625	19.6214	7.2748	435	189225	82312875	20.8567	7.5770
386	148996	57512456	19.6469	7.2811	436	190096	82881856	20.8806	7.5828
387	149769	57960603	19.6723	7.2874	437	190969	83453453	20.9045	7.5886
388	150544	58411072	19.6977	7.2936	438	191844	84027672	20.9284	7.5944
389	151321	58863869	19.7231	7.2999	439	192721	84604519	20.9523	7.6001
390	152100	59319000	19.7484	7.3061	440	193600	85184000	20.9762	7.6059

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
441	194481	85766121	21.0000	7.6117	491	241081	118370771	22.1585	7.8891
442	195364	86350888	21.0238	7.6174	492	242064	119895488	22.1811	7.8944
443	196249	86938307	21.0476	7.6232	493	243049	119823157	22.2036	7.8998
444	197136	87528384	21.0713	7.6289	494	244036	120553784	22.2261	7.9051
445	198025	88121125	21.0950	7.6346	495	245025	121287375	22.2486	7.9105
446	198916	88716536	21.1187	7.6403	496	246016	122023936	22.2711	7.9158
447	198809	89314623	21.1424	7.6460	497	247009	122763473	22.2935	7.9211
448	200704	89915392	21.1660	7.6517	498	248004	123505992	22.3159	7.9264
449	201601	90518849	21.1896	7.6574	499	249001	124251499	22.3383	7.9317
450	202500	91125000	21.2132	7.6631	500	250000	125000000	22.3607	7.9370
451	203401	91733851	21.2368	7.6688	501	251001	125751501	22.3830	7.9423
452	204304	92345408	21.2603	7.6744	502	252004	126506008	22.4054	7.9476
453	205209	92959677	21.2838	7.6801	503	253009	127263527	22.4277	7.9528
454	206116	93576664	21.3073	7.6857	504	254016	128024064	22.4499	7.9581
455	207025	94196375	21.3307	7.6914	505	255025	128787625	22.4722	7.9634
456	207936	94818816	21.3542	7.6970	506	256036	129554216	22.4944	7.9686
457	208849	95443993	21.3776	7.7026	507	257049	130323843	22.5167	7.9739
458	209764	96071912	21.4009	7.7082	508	258064	131096512	22.5389	7.9791
459	210681	96702579	21.4243	7.7138	509	259081	131872229	22.5610	7.9843
460	211600	97336000	21.4476	7.7194	510	260100	132651000	22.5832	7.9896
461	212521	97972181	21.4709	7.7250	511	261121	133432831	22.6053	7.9948
462	213444	98611128	21.4942	7.7306	512	262144	134217728	22.6274	8.0000
463	214369	99252847	21.5174	7.7362	513	263169	135005697	22.6495	8.0052
464	215296	99897344	21.5407	7.7418	514	264196	135796744	22.6716	8.0104
465	216225	100544625	21.5639	7.7473	515	265225	136590875	22.6936	8.0156
466	217156	101194696	21.5870	7.7529	516	266256	137388096	22.7156	8.0208
467	218089	101847563	21.6102	7.7584	517	267289	138188413	22.7376	8.0206
468	219024	102503232	21.6333	7.7639	518	268324	138991832	22.7596	8.0311
469	219961	103161709	21.6564	7.7695	519	269361	139798359	22.7816	8.0363
470	220900	103823000	21.6795	7.7750	520	270400	140608000	22.8035	8.0415
471	221841	104487111	21.7025	7.7805	521	271441	141420761	22.8254	8.0466
472	222784	105154048	21.7256	7.7860	522	272484	142236648	22.8473	8.0517
473	223729	105823817	21.7486	7.7915	523	273529	143055667	22.8692	8.0569
474	224676	106496424	21.7715	7.7970	524	274576	143877824	22.8910	8.0620
475	225625	107171875	21.7945	7.8025	525	275625	144703125	22.9129	8.0671
476	226576	107850176	21.8174	7.8079	526	276676	145531576	22.9347	8.0723
477	227529	108531333	21.8403	7.8134	527	277729	146363183	22.9565	8.0774
478	228484	109215352	21.8632	7.8188	528	278784	147197952	22.9783	8.0825
479	229441	109902239	21.8861	7.8243	529	279841	148035889	23.0000	8.0876
480	230400	110592000	21.9089	7.8297	530	280900	148877000	23.0217	8.0927
481	231361	111284641	21.9317	7.8352	531	281961	149721291	23.0434	8.0978
482	232324	111980168	21.9545	7.8406	532	283024	150568768	23.0651	8.1028
483	233289	112678587	21.9773	7.8460	533	284089	151419437	23.0868	8.1079
484	234256	113379904	22.0000	7.8514	534	285156	152273304	23.1084	8.1130
485	235225	114084125	22.0227	7.8568	535	286225	153130375	23.1301	8.1180
486	236196	114791256	22.0454	7.8622	536	287296	153990656	23.1517	8.1231
487	237169	115501303	22.0681	7.8676	537	288369	154854153	23.1733	8.1281
488	238144	116214272	22.0907	7.8730	538	289444	155720872	23.1948	8.1332
489	239121	116930169	22.1133	7.8784	539	290521	156590819	23.2164	8.1382
490	240100	177649000	22.1359	7.8837	540	291600	157464000	23.2379	8.1433

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
541	292681	138340421	23.2594	8.1483	591	349281	206425071	24.3105	8.3919
542	293764	149220088	23.2809	8.1533	592	350464	207474688	24.3311	8.3967
543	294849	160103007	23.3024	8.1583	593	351649	208527857	24.3516	8.4014
544	295936	160989184	23.3238	8.1633	594	352836	209584584	24.3721	8.4061
545	297025	161878625	23.3452	8.1683	595	354025	210644875	24.3926	8.4108
546	298116	162771336	23.3666	8.1733	596	355216	211708736	24.4131	8.4155
547	299209	163667323	23.3880	8.1783	597	356409	212776173	24.4336	8.4202
548	300304	164566592	23.4094	8.1833	598	357604	213847192	24.4540	8.4249
549	301401	165469149	23.4307	8.1882	599	358801	214921799	24.4745	8.4296
550	302500	166375000	23.4521	8.1932	600	360000	216000000	24.4949	8.4343
551	303601	167284151	23.4734	8.1982	601	361201	217081801	24.5153	8.4390
552	304704	168196608	23.4947	8.2031	602	362404	218167208	24.5357	8.4437
553	305809	169112377	23.5160	8.2081	603	363609	219256227	24.5561	8.4484
554	306916	170031464	23.5372	8.2130	604	364816	220348864	24.5764	8.4530
555	308025	170953875	23.5584	8.2180	605	366025	221445125	24.5967	8.4577
556	309136	171879616	23.5797	8.2229	606	367236	222545016	24.6171	8.4623
557	310249	172808693	23.6008	8.2278	607	368449	233648543	24.6374	8.4670
558	311364	173741112	23.6220	8.2327	608	369664	224755712	24.6577	8.4716
559	312481	174676879	23.6432	8.2377	609	370881	225866529	24.6779	8.4763
560	313600	175616000	23.6643	8.2426	610	372100	226981000	24.6982	8.4809
561	314721	176558481	23.6854	8.2475	611	373321	228099131	24.7184	8.4856
562	315844	177504328	23.7065	8.2524	612	374544	229220928	24.7386	8.4902
563	316969	178453547	23.7276	8.2573	613	375769	230346397	24.7588	8.4948
564	318096	179406144	23.7487	8.2621	614	376996	231475544	24.7790	8.4994
565	319225	180362125	23.7697	8.2670	615	378225	232608375	24.7992	8.5040
566	320356	181321496	23.7908	8.2719	616	379456	233744896	24.8193	8.5086
567	321489	182284263	23.8118	8.2768	617	380689	234885113	24.8395	8.5132
568	322624	183250432	23.8328	8.2816	618	381924	236029032	24.8596	8.5178
569	323761	184220009	23.8537	8.2865	619	383161	237176659	24.8797	8.5224
570	324900	185193000	23.8747	8.2913	620	384400	238328000	24.8998	8.5270
571	326041	186169411	23.8956	8.2962	621	385641	239483061	24.9199	8.5316
572	327184	187149248	23.9165	8.3010	622	386884	240641848	24.9399	8.5362
573	328329	188132517	23.9374	8.3059	623	388129	241804367	24.9600	8.5408
574	329476	189119224	23.9583	8.3107	624	389376	242970624	24.9800	8.5453
575	330625	190109375	23.9792	8.3155	625	390625	244140625	25.0000	8.5499
576	331776	191102976	24.0000	8.3203	626	391876	245314376	25.0200	8.5544
577	332929	192100033	24.0209	8.3251	627	393129	246491883	25.0400	8.5590
578	334084	193100552	24.0416	8.3300	628	394384	247673152	25.0599	8.5635
579	335241	194104539	24.0624	8.3348	629	395641	248858189	25.0799	8.5681
580	336400	195112000	24.0832	8.3396	630	396900	250047000	25.0998	8.5726
581	337561	196122941	24.1039	8.3443	613	398161	251239591	25.1197	8.5772
582	338724	197137368	24.1247	8.3491	632	399424	252435968	25.1396	8.5817
583	339889	198155287	24.1454	8.3539	633	400689	253636137	25.1595	8.5862
584	341056	199176704	24.1661	8.3587	634	401956	254840104	25.1794	8.5907
585	342225	200201625	24.1868	8.3634	635	403225	256047875	25.1992	8.5952
586	343396	201230056	24.2074	8.3682	636	404496	257259456	25.2190	8.5997
587	344569	202262003	24.2281	8.3730	637	405769	258474853	25.2389	8.6043
588	345744	203297472	24.2487	8.3777	638	407044	259694072	25.2587	8.6088
589	346921	204336469	24.2693	8.3825	639	408321	260917119	25.2784	8.6132
590	348100	205379000	24.2899	8.3872	640	409600	262144000	25.2982	8.6177

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
641	410881	263374721	25.3180	8.6222	691	477481	329939371	26.2869	8.8408
642	412164	264609288	25.3377	8.6267	692	478864	331373888	26.3059	8.8451
643	413449	265847707	25.3574	8.6312	693	490249	332812557	26.3249	8.8493
644	414736	267089984	25.3772	6.6357	694	481636	334255384	26.3439	8.8536
645	416025	268336125	25.3969	8.6401	695	483025	335702375	26.3629	8.8578
646	417316	269586136	25.4165	8.6446	696	484416	337153536	26.3818	8.8621
647	418609	270840023	25.4362	8.6490	697	485809	338608873	26.4008	8.8663
648	419904	272097792	25.4558	8.6535	698	487204	340068392	26.4197	8.8706
649	421201	273359449	25.4755	8.6579	699	488601	341532099	26.4386	8.8748
650	422500	274625000	25.4951	8.6624	700	490000	343000000	26.4575	8.8790
651	423801	275894451	25.5147	8.6668	701	491401	344472101	26.4764	8.8833
652	425104	277167808	25.5343	8.6713	702	492804	345948408	26.4953	8.8875
653	426409	278445077	25.5539	8.6757	703	494209	347428927	26.5141	8.8917
654	427716	279726264	25.5734	8.6801	704	495616	348913664	26.5330	8.8959
655	429025	281011375	25.5930	8.6845	705	497025	350402625	26.5518	8.9001
656	430336	282300416	25.6125	8.6890	706	498436	351895816	26.5707	8.9043
657	431649	283593393	25.6320	8.6934	707	499849	353393243	26.5895	8.9085
658	432964	284890312	25.6515	8.6978	708	501264	354894912	26.6083	8.9127
659	434281	286191179	25.6710	8.7022	709	502681	356400829	26.6271	8.9169
660	435600	287496000	25.6905	8.7066	710	504100	357911000	26.6458	8.9211
661	436921	288804781	25.7099	8.7110	711	505521	359425431	26.6646	8.9253
662	438244	290117528	25.7294	8.7154	712	506944	360944128	26.6833	8.9295
663	439569	291434247	25.7488	8.7198	713	508369	362467097	26.7021	8.9337
664	440896	292754944	25.7682	8.7241	714	509796	363994344	26.7208	8.9378
665	442225	294079625	25.7876	8.7285	715	511225	365525875	26.7395	8.9420
666	443556	295408296	25.8070	8.7329	716	512656	367061696	26.7582	8.9462
667	444889	296740963	25.8263	8.7373	717	514089	368601813	26.7769	8.9503
668	446224	298077632	25.8457	8.7416	718	515524	370146232	26.7955	8.9545
669	447561	299418309	25.8650	8.7460	719	516961	371694959	26.8142	8.9587
670	448900	300763000	25.8844	8.7503	720	518400	373248000	26.8328	8.9628
671	450241	302111711	25.9037	8.7547	721	519841	374805361	26.8514	8.9670
672	451584	303464448	25.9230	8.7590	722	521284	376367048	26.8701	8.9711
673	452929	304821217	25.9422	8.7634	723	522729	377933067	26.8887	8.9752
674	454276	306182024	25.9615	8.7677	724	524176	379503424	26.9072	8.9794
675	455625	307546875	25.9808	8.7721	725	525625	381078125	26.9258	8.9835
676	456976	308915776	26.0000	8.7764	726	527076	382657176	26.9444	8.9876
677	458329	310288733	26.0192	8.7807	727	528529	384240583	26.9629	8.9918
678	459684	311665752	26.0384	8.7850	728	529984	385828352	26.9815	8.9959
679	461041	313046839	26.0576	8.7893	729	531441	387420489	27.0000	9.0000
680	462400	314432000	26.0768	8.7937	730	532900	389017000	27.0185	9.0041
681	463761	315821241	26.0960	8.7980	731	534361	390617891	27.0370	9.0082
682	465124	317214568	26.1151	8.8023	732	535824	392223168	27.0555	9.0123
683	466489	318611987	26.1343	8,8066	733	537289	393832837	27.0740	9.0164
684	467856	320013504	26.1543	8.8109	734	538756	395446904	27.0924	9.0205
685	469225	321419125	26.1725	8.8152	735	540225	397065375	27.1109	9.0246
686	470596	322828856	26.1916	8.8194	736	541696	398688256	27.1293	9.0287
687	471969	324242703	26.2107	8.8237	737	543169	400315553	27.1477	9.0328
688	473344	325660673	26.2298	8.8280	738	544644	401947272	27.1662	9.0369
689	474721	327083769	26.2488	8.8323	739	546121	403583419	27.1846	9.0410
690	476100	328509000	26.2679	8.8366	740	547600	405224000	27.2029	9.0450

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
741	549081	406869021	27.2213	9.0491	791	625681	494913671	28.1247	9.2482
742	550564	408518488	27.2397	9.0532	792	626264	496793088	28.1425	9.2521
743	552049	410172407	27.2580	9.0572	793	628849	498677257	28.1603	9.2560
744	553536	411830784	27.2764	9.0613	794	630436	500566184	28.1780	9.2599
745	555025	413493625	27.2947	9.0654	795	632025	502459875	28.1957	9.2638
746	556516	415160936	27.3130	9.0694	796	633616	504358836	28.2135	9.2677
747	558009	416832723	27.3313	9.0735	797	635209	506261573	28.2312	9.2716
748	559504	418508992	27.3496	9.0775	798	636804	508169592	28.2489	9.2754
749	561001	420189749	27.3679	9.0816	799	638401	510082399	28.2666	9.2793
750	562500	421875000	27.3861	9.0856	800	640000	512000000	28.2843	9.2832
751	564001	423564751	27.4044	9.0896	801	641601	513922401	28.3019	9.2870
752	565504	425259008	27.4226	9.0937	802	643204	515849608	28.3196	9.2909
753	567009	426957777	27.4408	9.0977	803	644809	517781627	28.3373	9.2948
754	568516	428661064	27.4591	9.1017	804	646416	519718464	28.3549	9.2986
755	570025	430368875	27.4773	9.1057	805	648025	521660125	28.3725	9.3025
756	571536	432081216	27.4955	9.1098	806	649636	523606616	28.3901	9.3063
757	573049	433798093	27.5136	9.1138	807	651249	525557943	28.4077	9.3102
758	574564	435519512	27.5318	9.1178	808	652864	527414112	28.4253	9.3140
759	576081	437245479	27.5500	9.1218	809	654481	529475129	28.4429	9.3179
760	577600	438976000	27.5681	9.1258	810	656100	531441000	28.4605	9.3217
761	579121	440711081	27.5862	9.1298	811	657721	533411731	28.4781	9.3255
762	580644	442450728	27.6043	9.1338	812	659344	535387328	28.4956	9.3294
763	582169	444194947	27.6225	9.1378	813	660969	537367797	28.5132	9.3332
764	583696	445943744	27.6405	9.1418	814	662596	539351344	28.5307	9.3370
765	585225	447697125	27.6586	9.1458	815	664225	541343375	28.5482	9.3408
766	586756	449455096	27.6767	9.1498	816	665856	543338496	28.5657	9.3447
767	588289	451217663	27.6948	9.1537	817	667489	545338513	28.5832	9.3485
768	589824	452984832	27.7128	9.1577	818	669124	547343432	28.6007	9.3523
769	591361	454756609	27.7308	9.1617	819	670761	549353259	28.6182	9.3561
770	592900	456533000	27.7489	9.1657	820	672400	551368000	28.6356	9.3599
771	594441	458314011	27.7669	9.1696	821	674041	553387661	28.6531	9.3637
772	595984	460099648	27.7849	9.1736	822	675684	555412248	28,6705	9.3675
773	597529	461889917	27.8029	9.1775	823	677329	557441767	28.6880	9.3713
774	599076	463684824	27.8209	9.1815	824	678976	559476224	28.7054	9.3751
775	600625	465484375	27.8388	9.1855	825	680625	561515625	28.7228	9.3789
776	602176	467288576	27.8568	9.1894	826	682276	563559976	28.7402	9.3827
777	603729	469097433	27.8747	9.1933	827	683929	565609283	28.7576	9.3865
778	605284	470910952	27.8927	9.1973	828	685584	567663552	28.7750	9.3902
779	606841	472729139	27.9106	9.2012	829	687241	569722789	28.7924	9.3940
780	608400	474552000	27.9285	9.2052	830	688900	571787000	28.8097	9.3978
781	609961	476379541	27.9464	9.2091	831	690561	573856191	28.8271	9.4016
782	611524	478211768	27.9643	9.2130	832	692224	575930368	28.8444	9.4053
783	613089	480048687	27.9821	9.2170	833	693889	578009537	28.8617	9.4091
784	614656	481890304	28.0000	9.2209	834	695556	580093704	28.8791	9.4129
785	616225	483736625	28.0179	9.2248	835	697225	582182875	28.8964	9.4166
876	617796	485587656	28.0357	9.2287	836	698896	584277056	28.9137	9.4204
787	619369	487443403	28.0535	9.2326	837	700569	586376253	28.9310	9.4241
788	620944	489303872	28.0713	9.2365	838	702244	588480472	28.9482	9.4279
789	622521	491169069	28.0891	9.2404	839	703921	590589719	28.9655	9.4316
790	624100	493039000	28.1069	9.2443	840	705600	592704000	28.9828	9.4354

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
841	707281	594823321	29.0000	9.4391	891	793881	707347971	29.8496	9.6226
842	708964	596947688	29.0172	9.4429	892	795664	709732288	29.8664	9.6262
843	710649	599077107	29.0345	9.4466	893	797449	712121957	29.8831	9.6298
844	712336	601211584	29.0517	9.4503	894	799236	714516984	29.8998	9.6334
845	714025	603351125	29.0689	9.4541	895	801025	716917375	29.9166	9.6370
846	715716	605495736	29.0861	9.4578	896	802816	719323136	29.9333	9.6406
847	717409	607645423	29.1033	9.4615	897	804609	721734273	29.9500	9.6442
848	719104	609800192	29.1204	9.4652	898	806404	724150792	29.9666	9.6477
849	720801	611960049	29.1376	9.4690	899	808201	726572699	29.9833	9.6513
850	722500	614125000	29.1548	9.4727	900	810000	729000000	30.0000	9.6549
851	724201	616295051	29.1719	9.4764	901	811801	731432701	30.0167	9.6585
852	725904	618470208	29.1890	9.4801	902	813604	733870808	30.0333	9.6620
853	727609	620650477	29.2062	9.4838	903	815409	736314327	30.0500	9.6656
854	729316	622835864	29.2233	9.4875	904	817216	738763264	30.0666	9.6692
855	731025	625026375	29.2204	9.4912	905	819025	741217625	30.0832	9.6727
856	732736	627222016	29.2575	9.4949	906	820836	743677416	30.0998	9.6763
857	734449	629422793	29.2746	9.4986	907	822649	746142643	30.1164	9.6799
858	736164	631628712	29.2916	9.5023	908	824464	748613312	30.1330	9.6834
859	737881	633839779	29.3087	9.5060	909	826281	751089429	30.1496	9.6870
860	739600	636056000	29.3258	9.5097	910	828100	753571000	30.1662	9.6905
861	741321	638277381	29.3428	9.5134	911	829921	756058031	30.1828	9.6941
862	743044	640503928	29.3598	9.5171	912	831744	758550528	30.1993	9.6976
863	744769	642735647	29.3769	9.5207	913	833569	761048497	30.2159	9.7012
864	746496	644972544	29.3339	9.5244	914	835396	763551944	30.2324	9.7047
865	748225	647214625	29.4109	9.5281	915	837225	766060875	30.2490	9.7082
866	749956	649461896	29.4279	9.5317	916	839056	768575296	30.2655	9.7118
867	751689	651714363	29.4449	9.5354	917	840889	771095213	30.2820	9.7153
868	753424	653972032	29.4618	9.5291	918	842724	773620632	30.2985	9.7188
869	755161	656234909	29.4788	9.5427	919	844561	776151559	30.3150	9.7224
870	756900	658503000	29.4958	9.5464	920	846400	778688000	30.3315	9.7259
871	758641	660776311	29.5127	9.5501	921	848241	781229961	30.3480	9.7294
872	760384	663054848	29.5296	9.5537	922	850084	783777448	30.3645	9.7329
873	762129	665338617	29.5466	9.5574	923	851929	786330467	30.3809	9.7364
874	763876	667627624	29.5635	9.5610	924	853776	788889024	30.3974	9.7400
875	765625	669921875	29.5804	9.5647	925	855625	791453125	30.4138	9.7435
876	767376	672221376	29.5973	9.5683	926	857476	794022776	30.4302	9.7470
877	769129	674526133	29.6142	9.5719	927	859329	796597983	30.4467	9.7505
878	770884	676836152	29.6311	9.5756	928	861184	799178752	30.4631	9.7540
879	772641	679151439	29.6479	9.5792	929	863041	801765089	30.4795	9.7575
880	774400	681472000	29.6648	9.5828	930	864900	804357000	30.4959	9.7610
881	776161	683797841	29.6816	9.5865	931	866761	806954491	30.5123	9.7645
882	777924	686128968	29.6985	9.5901	932	868624	809557568	30.5287	9.7680
883	779689	688465387	29.7153	9.5937	933	870489	812166237	30.5450	9.7715
884	781456	690807104	29.7321	9.5973	934	872356	841780504	30.5614	9.7750
885	783225	693154125	29.7489	9.6010	935	874225	817400375	30.5778	9.7785
886	784996	695506456	29.7658	9.6046	936	876096	820025856	30.5941	9.7819
887	786769	697864103	29.7825	9.6082	937	877969	822656953	30.6105	9.7854
888	788544	700227072	29.7993	9.6118	938	879844	825293672	30.6268	9.7889
889	790321	702595369	29.8161	9.6154	939	881721	827936019	30.6431	9.7924
890	792100	704969000	29.8329	9.6190	940	883600	830584000	30.6594	9.7959

Table A-8. Squares, cubes, square roots, and cube roots (continued)

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
941	885481	833237621	30.6757	9.7993	971	942841	915498611	31.1609	9.9024
942	887364	835896888	30.6920	9.8028	972	944784	918330048	31.1769	9.9058
943	889249	838561807	30.7083	9.8063	973	946729	921167317	31.1929	9.9092
944	891136	841232384	30.7246	9.8097	974	948676	924010424	31.2090	9.9126
945	893025	843908625	30.7409	9.8132	975	950625	926859375	31.2250	9.9160
946	894916	846590536	30.7571	9.8167	976	952576	929714176	31.2410	9.9194
947	896809	849278123	30.7734	9.8201	977	954529	932574833	31.2570	9.9227
948	898704	851971392	30.7896	9.8236	978	956484	935441352	31.2730	0.9261
949	900601	854670349	30.8058	9.8270	979	958441	938313739	31.2890	9.9295
950	902500	857375000	30.8221	9.8305	980	960400	941192000	31.3050	9.9329
951	904401	860085351	30.8383	9.8339	981	962361	944076141	31.3209	9.9363
952	906304	862801408	30.8545	9.8374	982	964324	946966168	31.3369	9.9396
953	908209	865523177	30.8707	9.8408	983	966289	949862087	31.3528	9.9430
954	910116	868250664	30.8869	9.8443	984	968256	952763904	31.3688	9.9464
955	912025	870983875	30.9031	9.8477	985	970225	955671625	31.3847	9.9497
956	913936	873722816	30.9192	9.8511	986	972196	958585256	31.4006	9.9531
957	915849	876467493	30.9354	9.8546	987	974169	961504803	31.4166	9.9565
958	917764	879217912	30.9516	9.8580	988	976144	964439272	31.4325	9.9598
959	919681	881974079	30.9677	9.8614	989	978121	967361669	31.4484	9.9632
960	921600	884736000	30.9839	9.8648	990	980100	970299000	31.4643	9.9666
961	923521	887503681	31.0000	9.8683	991	982081	973242271	31.4802	9.9699
962	925444	890277128	31.0161	9.8717	992	984064	976191488	31.4960	9.9733
963	927369	893056347	31.0332	9.8751	993	986049	979146657	31.5119	9.9766
964	929296	895841344	31.0483	9.8785	994	988036	982107784	31.5278	9.9800
965	931225	898632125	31.0644	9.8819	995	990025	985074875	31.5436	9.9833
966	933156	901428696	31.0805	9.8854	996	992016	988047936	31.5595	9.9866
967	935089	904231063	31.0966	9.8888	997	994009	991026973	31.5753	9.9900
968	937024	907039232	31.1127	9.8922	998	996004	994011992	31.5911	9.9933
969	938961	909853209	31.1288	9.8956	999	998001	997002999	31.6070	9.9967
970	940900	912673000	31.1448	9.8990	1000	1000000	1000000000	31.6228	10.0000

Table A-9. Functions of the 10-chord spiral

(To use table, locate the angle in the left column.)

The valve for angle A is in the second column.

To compute the value of C, X or Y, multiply the appropriate value times the length of the spiral (L_s).

Table A-9. Functions of the 10-chord spiral (continued)

Δ	A	$\frac{C}{L.}$	$\frac{X}{L.}$	$\frac{Y}{L.}$	Δ	A	$\frac{C}{L.}$	$\frac{X}{L.}$	$\frac{Y}{L.}$
0.0°	0° 00′ 00″	1.000 000	1.000 000	0.000 000	5.0°	1° 40′ 00″	.999 666	.999 243	.029 073
0.1°	0° 02′ 00″	1.000 000	1.000 000	.000 582	5.1°	1° 42′ 00″	.999 652	.999 212	.029 654
0 2°	0° 04′ 00″	.999 999	.999 999	.001 164	5.2°	1° 44′ 00″	.999 639	.999 181	.030 235
0.3°	0° 06′ 00″	.999 999	.999 997	.001 745	5.3°	1° 46′ 00″	.999 625	.999 149	.030 816
0.4°	0° 08′ 00″	.999 998	.999 995	.002 327	5.4°	1° 48′ 00″	.999 610	.999 117	.031 396
0.5°	0° 10′ 00″	.999 997	.999 993	.002 909	5.5°	1° 50′ 00″	.999 596	.999 084	.031 977
0.6°	0° 12′ 00″	.999 995	.999 989	.003 491	5.6°	1° 51′ 59″	.999 581	.999 051	.032 558
0.7°	0° 14′ 00″	.999 993	.999 985	.004 072	5.7°	1° 53′ 59″	.999 566	.999 016	.033 138
0.8°	0° 16′ 00″	.999 991	.999 981	.004 654	5.8°	1° 55′ 59″	.999 550	.998 982	.033 719
0.9°	0° 18′ 00″	.999 989	.999 975	.005 236	5.9°	1° 57′ 59″	.999 535	.998 946	.034 299
1.0°	0° 20′ 00″	.999 987	.999 970	.005 818	6.0°	1° 59′ 59″	.999 519	.998 910	.034 880
1.1°	0° 22′ 00″	.999 984	.999 963	.006 399	6.1°	2° 01′ 59″	.999 503	.998 873	.035 460
1.2°	0° 24′ 00″	.999 981	.999 956	.006 981	6.2°	2° 03′ 59″	.999 486	.998 836	.036 040
1.3°	0° 26′ 00″	.999 977	.999 949	.007 563	6.3°	2° 05′ 59″	.999 470	.998 799	.036 621
1.4°	0° 28′ 00″	.999 974	.999 941	.008 145	6.4°	2° 07′ 59″	.999 453	.998 760	.037 201
1.5°	0° 30′ 00″	.999 970	.999 932	.008 726	6.5°	2° 09′ 59″	.999 435	.998 721	.037 781
1.6°	0° 32′ 00″	.999 966	.999 923	.009 308	6.6°	2° 11′ 59″	.999 418	.998 681	.038 361
1.7°	0° 34′ 00″	.999 961	.999 913	.009 890	6.7°	2° 13′ 59″	.999 400	.998 641	.038 941
1.8°	0° 36′ 00″	.999 957	.999 902	.010 471	6.8°	2° 15′ 59″	.999 382	.998 600	.039 522
1.9°	0° 38′ 00″	.999 952	.999 891	.011 053	6.9°	2° 17′ 59″	.999 364	.998 559	.040 102
2.0°	0° 40′ 00″	.999 947	.999 879	.011 635	7.0°	2° 19′ 59″	.999 345	.998 517	.040 681
2.1°	0° 42′ 00″	.999 941	.999 867	.012 216	7.1°	2° 21′ 59″	.999 326	.998 474	.041 261
2.2°	0° 44′ 00″	.999 935	.999 853	.012 798	7.2°	2° 23′ 59″	.999 307	.998 431	.041 841
2.3°	0° 46′ 00″	.999 930	.999 840	.013 379	7.3°	2° 25′ 59″	.999 288	.998 387	.042 421
2.4°	0° 48′ 00″	.999 923	.999 826	.013 961	7.4°	2° 27′ 59″	.999 268	.998 343	.043 001
2.5°	0° 50′ 00″	.999 916	.999 811	.014 542	7.5°	2° 29′ 59″	.999 248	.998 298	.043 581
2.6°	0° 52′ 00″	.999 910	.999 795	.015 124	7.6°	2° 31′ 59″	.999 228	.998 252	.044 160
2.7°	0° 54′ 00″	.999 903	.999 779	.015 706	7.7°	2° 33′ 59″	.999 208	.998 206	.044 740
2.8°	0° 56′ 00″	.999 895	.999 763	.016 287	7.8°	2° 35′ 59″	.999 187	.998 159	.045 319
2.9°	0° 58′ 00″	.999 888	.999 745	.016 868	7.9°	2° 37′ 59″	.999 166	.998 111	.045 899
3.0°	1° 00′ 00″	.999 880	.999 727	.017 450	8.0°	2° 39′ 58″	.999 145	.998 063	.046 478
3.1°	1° 02′ 00″	.999 872	.999 709	.018 031	8.1°	2° 41′ 58″	.999 123	.998 015	.047 058
3.2°	1° 04′ 00″	.999 863	.999 690	.018 613	8.2°	2° 43′ 58″	.999 102	.997 965	.047 637
3.3°	1° 06′ 00″	.999 854	.999 670	.019 194	8.3°	2° 45′ 58″	.999 080	.997 916	.048 216
3.4°	1° 08′ 00″	.999 845	.999 650	.019 776	8.4°	2° 47′ 58″	.999 057	.997 865	.048 795
3.5°	1° 10′ 00″	.999 836	.999 629	.020 357	8.5°	2° 49′ 58″	.999 035	.997 814	.049 374
3.6°	1° 12′ 00″	.999 827	.999 607	.020 938	8.6°	2° 51′ 58″	.999 012	.997 762	.049 953
3.7°	1° 14′ 00″	.999 817	.999 585	.021 519	8.7°	2° 53′ 58″	.998 989	.997 710	.050 532
3.8°	1° 16′ 00″	.999 807	.999 563	.022 101	8.8°	2° 55′ 58″	.998 965	.997 657	.051 111
3.9°	1° 18′ 00″	.999 797	.999 539	.022 682	8.9°	2° 57′ 58″	.998 942	.997 603	.051 690
4.0°	1° 20′ 00″	.999 786	.999 515	.023 263	9.0°	2° 59′ 58″	.998 918	.997 549	.052 269
4.1°	1° 22′ 00″	.999 775	.999 491	.023 844	9.1°	3° 01′ 58″	.998 894	.997 494	.052 848
4.2°	1° 24′ 00″	.999 764	.999 466	.024 425	9.2°	3° 03′ 58″	.998 869	.997 439	.053 426
4.3°	1° 26′ 00″	.999 753	.999 440	.025 006	9.3°	3° 05′ 58″	.998 844	.997 383	.054 005
4.4°	1° 28′ 00″	.999 741	.999 414	.025 588	9.4°	3° 07′ 58″	.998 819	.997 327	.054 583
4.5°	1° 30′ 00″	.999 729	.999 387	.026 169	9.5°	3° 09′ 57″	.998 794	.997 270	.055 162
4.6°	1° 32′ 00″	.999 717	.999 359	.026 750	9.6°	3° 11′ 57″	.998 769	.997 212	.055 740
4.7°	1° 34′ 00″	.999 705	.999 331	.027 330	9.7°	3° 13′ 57″	.998 743	.997 154	.056 318
4.8°	1° 36′ 00″	.999 692	.999 302	.027 911	9.8°	3° 15′ 57″	.998 717	.997 095	.056 897
4.9°	1° 38′ 00″	.999 679	.999 273	.028 492	9.9°	3° 17′ 57″	.998 691	.997 035	.057 475

Table A-9. Functions of the 10-chord spiral (continued)

Δ	A	$\frac{C}{L.}$	$\frac{X}{L.}$	$\frac{Y}{L.}$	Δ	A	$\frac{C}{L.}$	$\frac{X}{L.}$	$\frac{Y}{L.}$
10.0°	3° 19′ 57″	.998 664	.996 975	.058 053	15.0°	4° 59′ 50″	.996 996	.993 206	.086 846
10.1°	3° 21′ 57″	.998 637	.996 915	.058 631	15.1°	5° 01′ 50″	.996 956	.993 115	.087 419
10.2°	3° 23′ 57″	.998 610	.996 853	.059 209	15.2°	5° 03′ 50″	.996 915	.993 024	.087 992
10.3°	3° 25′ 57″	.998 583	.996 791	.059 787	15.3°	5° 05′ 49″	.996 874	.992 932	.088 565
10.4°	3° 27′ 57″	.998 555	.996 729	.060 364	15.4°	5° 07′ 49″	.996 833	.992 840	.089 138
10.5°	3° 29′ 57″	.998 527	.996 666	.060 942	15.5°	5° 09′ 49″	.996 792	.992 747	.089 711
10.6°	3° 31′ 56″	.998 499	.996 602	.061 520	15.6°	5° 11′ 49″	.996 751	.992 653	.090 284
10.7°	3° 33′ 56″	.998 471	.996 538	.062 097	15.7°	5° 13′ 49″	.996 709	.092 559	.090 857
10.8°	3° 35′ 56″	.998 442	.996 473	.062 675	15.8°	5° 15′ 48″	.996 667	.992 465	.091 429
10.9°	3° 37′ 56″	.998 413	.996 407	.063 252	15.9°	5° 17′ 48″	.996 625	.992 369	.092 001
11.0°	3° 39′ 56″	.998 384	.996 341	0.063 829	16.0°	5° 19′ 48″	.996 582	.992 273	.092 574
11.1°	3° 41′ 56″	.998 354	.996 274	.064 406	16.1°	5° 21′ 48″	.996 539	.992 177	.093 146
11.2°	3° 43′ 56″	.998 324	.996 207	.064 984	16.2°	5° 23′ 47″	.996 496	.992 080	.093 718
11.3°	3° 45′ 56″	.998 294	.996 139	.065 561	16.3°	5° 25′ 47″	.996 453	.991 982	.094 290
11.4°	3° 47′ 56″	.998 264	.996 071	.066 138	16.4°	5° 27′ 47″	.996 409	.991 884	.094 862
11.5°	3° 49′ 55″	.998 233	.996 002	.066 714	16.5°	5° 29′ 47″	.996 366	.991 785	.095 433
11.6°	3° 51′ 55″	.998 203	.995 932	.067 291	16.6°	5° 31′ 46″	.996 321	.991 685	.090 005
11.7°	3° 53′ 55″	.998 172	.995 862	.067 868	16.7°	5° 33′ 46″	.996 277	.991 585	.096 576
11.8°	3° 55′ 55″	.998 140	.995 791	.068 445	16.8°	5° 35′ 46″	.996 232	.991 484	.097 148
11.9°	3° 57′ 55″	.998 109	.995 719	.069 021	16.9°	5° 37′ 46″	.996 187	.991 383	.097 719
12.0°	3° 59′ 55″	.998 077	.995 647	.069 598	17.0°	5° 39′ 45″	.996 142	.991 281	.098 290
12.1°	4° 01′ 55″	.998 044	.995 574	.070 174	17.1°	5° 41′ 45″	.996 097	.991 179	.098 861
12.2°	4° 03′ 55″	.998 012	.995 501	.070 750	17.2°	5° 43′ 45″	.996 051	.991 076	.099 432
12.3°	4° 05′ 54″	.997 979	.995 427	.071 326	17.3°	5° 45′ 45″	.996 005	.990 972	.100 002
12.4°	4° 07′ 54″	.997 946	.995 353	.071 902	17.4°	5° 47′ 44″	.995 959	.990 868	.100 573
12.5°	4° 09′ 54″	.997 913	.995 278	.072 478	17.5°	5° 49′ 44″	.995 912	.990 763	.101 143
12.6°	4° 11′ 54″	.997 880	.995 202	.073 054	17.6°	5° 51′ 44″	.995 865	.990 657	.101 713
12.7°	4° 13′ 54″	.997 846	.995 126	.073 630	17.7°	5° 53′ 44″	.995 818	.990 551	.102 284
12.8°	4° 15′ 54″	.997 812	.995 049	.074 206	17.8°	5° 55′ 43″	.995 771	.990 445	.102 854
12.9°	4° 17′ 54″	.997 777	.994 971	.074 781	17.9°	5° 57′ 43″	.995 723	.990 338	.103 424
13.0°	4° 19′ 53″	.997 743	.994 893	.075 357	18.0°	5° 59′ 43″	.995 676	.990 230	.103 993
13.1°	4° 21′ 53″	.997 708	.994 814	.075 932	18.1°	6° 01′ 42″	.995 627	.990 122	.104 563
13.2°	4° 23′ 53″	.997 673	.994 735	.076 508	18.2°	6° 03′ 42″	.995 579	.990 013	.105 132
13.3°	4° 25′ 53″	.997 638	.994 655	.077 083	18.3°	6° 05′ 42″	.995 530	.989 903	.105 702
13.4°	4° 27′ 53″	.997 602	.994 575	.077 658	18.4°	6° 07′ 42″	.995 482	.989 793	.106 271
13.5°	4° 29′ 53″	.997 566	.994 494	.078 233	18.5°	6° 09′ 41″	.995 432	.989 682	.106 840
13.6°	4° 31′ 53″	.997 530	.994 412	.078 808	18.6°	6° 11′ 41″	.995 383	.989 571	.107 409
13.7°	4° 33′ 52″	.997 493	.994 330	.079 383	18.7°	6° 13′ 41″	.995 333	.989 459	.107 978
13.8°	4° 35′ 52″	.997 457	.994 247	.079 957	18.8°	6° 15′ 40″	.995 283	.989 346	.108 547
13.9°	4° 37′ 52″	.997 420	.994 163	.080 532	18.9°	6° 17′ 40″	.995 233	.989 233	.109 115
14.0°	4° 39′ 52″	.997 383	.994 079	.0[illegible]1 106	19.0°	6° 19′ 40″	.995 183	.989 120	.109 683
14.1°	4° 41′ 52″	.997 345	.993 995	.081 681	19.1°	6° 21′ 39″	.995 132	.989 005	.110 252
14.2°	4° 43′ 51″	.997 307	.993 909	.082 255	19.2°	6° 23′ 39″	.995 081	.988 891	.110 820
14.3°	4° 45′ 51″	.997 269	.993 823	.082 829	19.3°	6° 25′ 39″	.995 029	.988 775	.111 388
14.4°	4° 47′ 51″	.997 231	.993 737	.083 403	19.4°	6° 27′ 38″	.994 978	.988 659	.111 956
14.5°	4° 49′ 51″	.997 192	.993 650	.083 977	19.5°	6° 29′ 38″	.994 926	.988 543	.112 523
14.6°	4° 51′ 51″	.997 154	.993 562	.084 551	19.6°	6° 31′ 38″	.994 874	.988 425	.113 091
14.7°	4° 53′ 51″	.997 115	.993 474	.085 125	19.7°	6° 33′ 37″	.994 822	.988 308	.113 658
14.8°	4° 55′ 50″	.997 075	.993 385	.085 699	19.8°	6° 35′ 37″	.994 769	.988 189	.114 226
14.9°	4° 57′ 50″	.997 036	.993 296	.086 272	19.9°	6° 37′ 37″	.994 716	.988 070	.114 793

Table A-9. Functions of the 10-chord spiral (continued)

Δ	A	$\frac{C}{L.}$	$\frac{X}{L.}$	$\frac{Y}{L.}$
20.0°	6° 39′ 36″	.994 663	.987 951	.115 360
20.1°	6° 41′ 36″	.994 610	.987 830	.115 926
20.2°	6° 43′ 36″	.994 556	.987 710	.116 493
20.3°	6° 45′ 35″	.994 502	.987 589	.117 059
20.4°	6° 47′ 35″	.994 448	.987 467	.117 626
20.5°	6° 49′ 34″	.994 393	.987 344	.118 192
20.6°	6° 51′ 34″	.994 339	.987 221	.118 758
20.7°	6° 53′ 34″	.994 284	.987 097	.119 324
20.8°	6° 55′ 33″	.994 228	.986 973	.119 890
20.9°	6° 57′ 33″	.994 173	.986 849	.120 455
21.0°	6° 59′ 32″	.994 117	.986 723	.121 021
21.1°	7° 01′ 32″	.994 061	.986 597	.121 586
21.2°	7° 03′ 32″	.994 005	.986 471	.122 151
21.3°	7° 05′ 31″	.993 948	.986 343	.122 716
21.4°	7° 07′ 31″	.993 891	.986 216	.123 281
21.5°	7° 09′ 30″	.993 834	.986 088	.123 846
21.6°	7° 11′ 30″	.993 777	.985 959	.124 410
21.7°	7° 13′ 30″	.993 719	.985 829	.124 974
21.8°	7° 15′ 29″	.993 661	.985 699	.125 539
21.9°	7° 17′ 29″	.993 603	.985 568	.126 103
22.0°	7° 19′ 28″	.993 545	.985 437	.126 667
22.1°	7° 21′ 28″	.993 486	.985 305	.127 230
22.2°	7° 23′ 28″	.993 427	.985 173	.127 794
22.3°	7° 25′ 27″	.993 368	.985 040	.128 357
22.4°	7° 27′ 27″	.993 308	.984 906	.128 920
22.5°	7° 29′ 26″	.993 248	.984 772	.129 483
22.6°	7° 31′ 26″	.993 188	.984 638	.130 046
22.7°	7° 33′ 25″	.993 128	.984 502	.130 609
22.8°	7° 35′ 25″	.993 068	.984 366	.131 172
22.9°	7° 37′ 24″	.993 007	.984 230	.131 734
23.0°	7° 39′ 24″	.992 946	.984 093	.132 296
23.1°	7° 41′ 23″	.992 884	.983 955	.132 858
23.2°	7° 43′ 23″	.992 823	.983 817	.133 420
23.3°	7° 45′ 22″	.992 761	.983 678	.133 982
23.4°	7° 47′ 22″	.992 699	.983 539	.134 543
23.5°	7° 49′ 21″	.992 636	.983 399	.135 105
23.6°	7° 51′ 21″	.992 574	.983 258	.135 666
23.7°	7° 53′ 20″	.992 511	.983 117	.136 227
23.8°	7° 55′ 20″	.992 448	.982 976	.136 788
23.9°	7° 57′ 19″	.992 384	.982 834	.137 348
24.0°	7° 59′ 19″	.992 321	.982 691	.137 909
24.1°	8° 01′ 18″	.992 257	.982 547	.138 469
24.2°	8° 03′ 18″	.992 192	.982 403	.139 029
24.3°	8° 05′ 17″	.992 128	.982 259	.139 589
24.4°	8° 07′ 17″	.992 063	.982 114	.140 149
24.5°	8° 09′ 16″	.991 998	.981 968	.140 708
24.6°	8° 11′ 16″	.991 933	.981 822	.141 268
24.7°	8° 13′ 15″	.991 867	.981 675	.141 827
24.8°	8° 15′ 15″	.991 801	.981 528	.142 386
24.9°	8° 17′ 14″	.991 735	.981 380	.142 945
25.0°	8° 19′ 14″	.991 669	.981 231	.143 504
25.1°	8° 21′ 13″	.991 602	.981 082	.144 062
25.2°	8° 23′ 12″	.991 536	.980 932	.144 620
25.3°	8° 25′ 12″	.991 468	.980 782	.145 179
25.4°	8° 27′ 11″	.991 401	.980 631	.145 737
25.5°	8° 29′ 11″	.991 333	.980 479	.146 294
25.6°	8° 31′ 10″	.991 265	.980 327	.146 852
25.7°	8° 33′ 10″	.991 197	.980 175	.147 409
25.8°	8° 35′ 09″	.991 129	.980 022	.147 966
25.9°	8° 37′ 08″	.991 060	.979 868	.148 523
26.0°	8° 39′ 08″	.990 991	.979 714	.149 080
26.1°	8° 41′ 07″	.990 922	.979 559	.149 637
26.2°	8° 43′ 07″	.990 853	.979 403	.150 193
26.3°	8° 45′ 06″	.990 783	.979 247	.150 750
26.4°	8° 47′ 05″	.990 713	.979 090	.151 306
26.5°	8° 49′ 05″	.990 642	.978 933	.151 861
26.6°	8° 51′ 04″	.990 572	.978 776	.152 417
26.7°	8° 53′ 03″	.990 501	.978 617	.152 973
26.8°	8° 55′ 03″	.990 430	.978 459	.153 528
26.9°	8° 57′ 02″	.990 359	.978 299	.154 083
27.0°	8° 59′ 02″	.990 287	.978 139	.154 638
27.1°	9° 01′ 01″	.990 215	.977 978	.155 193
27.2°	9° 03′ 00″	.990 143	.977 817	.155 747
27.3°	9° 05′ 00″	.990 071	.977 655	.156 301
27.4°	9° 06′ 59″	.989 998	.977 493	.156 855
27.5°	9° 08′ 58″	.989 925	.977 330	.157 409
27.6°	9° 10′ 58″	.989 852	.977 167	.157 963
27.7°	9° 12′ 57″	.989 779	.977 003	.158 516
27.8°	9° 14′ 56″	.989 705	.976 838	.159 070
27.9°	9° 16′ 55″	.989 631	.976 673	.159 623
28.0°	9° 18′ 55″	.989 557	.976 508	.160 176
28.1°	9° 20′ 54″	.989 482	.976 341	.160 728
28.2°	9° 22′ 53″	.989 408	.976 174	.161 281
28.3°	9° 24′ 53″	.989 333	.976 007	.161 833
28.4°	9° 26′ 52″	.989 257	.975 839	.162 385
28.5°	9° 28′ 51″	.989 182	.975 670	.162 937
28.6°	9° 30′ 51″	.989 106	.975 500	.163 489
28.7°	9° 32′ 50″	.989 030	.975 331	.164 040
28.8°	9° 34′ 49″	.988 954	.975 161	.164 591
28.9°	9° 36′ 48″	.988 877	.974 990	.165 142
29.0°	9° 38′ 48″	.988 800	.974 819	.165 693
29.1°	9° 40′ 47″	.998 723	.974 647	.166 244
29.2°	9° 42′ 46″	.988 646	.974 475	.166 794
29.3°	9° 44′ 45″	.988 568	.974 301	.167 344
29.4°	9° 46′ 45″	.988 491	.974 128	.167 894
29.5°	9° 48′ 44″	.988 412	.973 954	.168 444
29.6°	9° 50′ 43″	.988 334	.973 779	.168 993

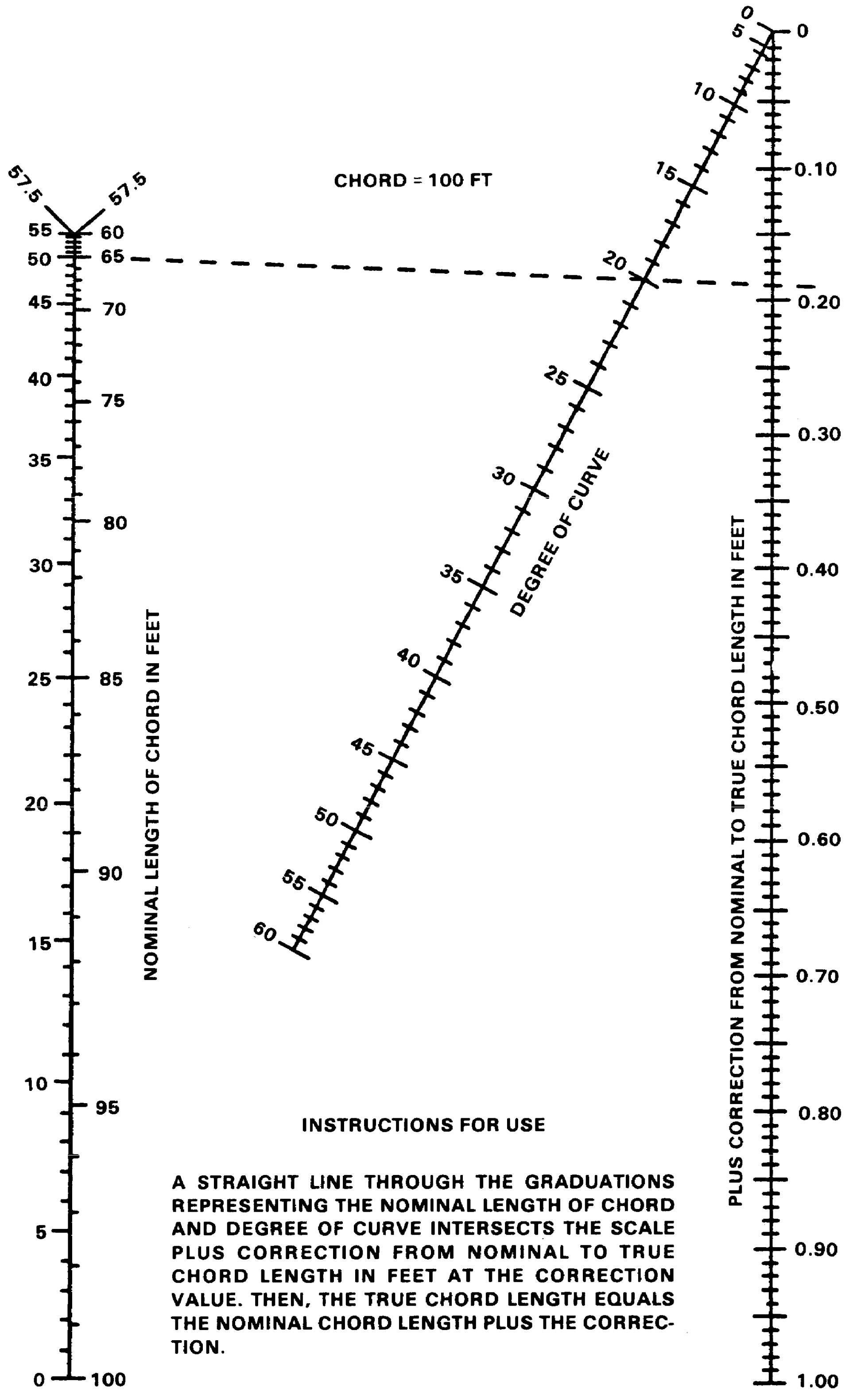
Table A-9. Functions of the 10-chord spiral (continued)

Δ	A	C/L.	X/L.	Y/L.
29.7°	9° 52′ 42″	.988 255	.973 604	.169 543
28.8°	9° 54′ 41″	.988 176	.973 428	.170 092
29.9°	9° 56′ 41″	.988 097	.973 251	.170 641
30.0°	9° 58′ 40″	.988 018	.973 074	.171 189
30.1°	10° 00′ 39″	.987 938	.972 897	.171 738
30.2°	10° 02′ 38″	.987 858	.972 719	.172 286
30.3°	10° 04′ 37″	.987 778	.972 540	.172 834
30.4°	10° 06′ 37″	.987 699	.972 361	.173 382
30.5°	10° 08′ 36″	.987 617	.972 181	.173 929
30.6°	10° 10′ 35″	.987 536	.972 000	.174 477
30.7°	10° 12′ 34″	.987 455	.971 820	.175 023
30.8°	10° 14′ 33″	.987 373	.971 638	.175 571
30.9°	10° 16′ 32″	.987 291	.971 456	.176 117
31.0°	10° 18′ 32″	.987 209	.971 273	.176 664
31.1°	10° 20′ 31″	.987 127	.971 090	.177 210
31.2°	10° 22′ 30″	.987 044	.970 907	.177 756
31.3°	10° 24′ 29″	.986 962	.970 722	.178 302
31.4°	10° 26′ 28″	.986 879	.970 537	.178 847
31.5°	10° 28′ 27″	.986 795	.970 352	.179 392
31.6°	10° 30′ 26″	.986 712	.970 166	.179 938
31.7°	10° 32′ 25″	.986 628	.969 980	.180 482
31.8°	10° 34′ 24″	.986 544	.969 792	.181 027
31.9°	10° 36′ 24″	.986 459	.969 605	.181 571
32.0°	10° 38′ 23″	.986 375	.969 417	.182 116
32.1°	10° 40′ 22″	.986 290	.969 228	.182 659
32.2°	10° 42′ 21″	.986 205	.969 039	.183 203
32.3°	10° 44′ 20″	.986 119	.968 849	.183 747
32.4°	10° 46′ 19″	.986 033	.968 658	.184 290
32.5°	10° 48′ 18″	.985 948	.968 468	.184 833
32.6°	10° 50′ 17″	.985 861	.968 276	.185 376
32.7°	10° 52′ 16″	.985 775	.968 084	.185 918
32.8°	10° 54′ 15″	.985 688	.967 891	.186 460
32.9°	10° 56′ 14″	.985 601	.967 698	.187 002
33.0°	10° 58′ 13″	.985 514	.967 504	.187 544
33.1°	11° 00′ 12″	.985 426	.967 310	.188 086
33.2°	11° 02′ 11″	.985 339	.967 115	.188 627
33.3°	11° 04′ 10″	.985 251	.966 920	.189 168
33.4°	11° 06′ 09″	.985 162	.966 724	.189 709
33.5°	11° 08′ 08″	.985 074	.966 528	.190 250
33.6°	11° 10′ 07″	.984 985	.966 331	.190 790
33.7°	11° 12′ 06″	.984 896	.966 133	.191 330
33.8°	11° 14′ 05″	.984 807	.965 935	.191 870
33.9°	11° 16′ 04″	.984 717	.965 736	.192 410
34.0°	11° 18′ 03″	.984 627	.965 537	.192 949
34.1°	11° 20′ 02″	.984 537	.965 337	.193 488
34.2°	11° 22′ 01″	.984 447	.965 137	.194 027
34.3°	11° 24′ 00″	.984 356	.964 936	.194 566
34.4°	11° 25′ 59″	.984 265	.964 734	.195 104
34.5°	11° 27′ 58″	.984 174	.964 532	.195 643
34.6°	11° 29′ 57″	.984 083	.964 330	.196 180
34.7°	11° 31′ 56″	.983 991	.964 127	.196 718
34.8°	11° 33′ 55″	.983 899	.963 923	.197 256
34.9°	11° 35′ 54″	.983 807	.963 719	.197 793
35.0°	11° 37′ 53″	.983 715	.963 515	.198 330
35.1°	11° 39′ 52″	.983 622	.963 300	.198 866
35.2°	11° 41′ 50″	.983 520	.963 103	.199 403
35.3°	11° 43′ 49″	.983 436	.962 897	.199 939
35.4°	11° 45′ 48″	.983 343	.962 690	.200 475
35.5°	11° 47′ 47″	.983 249	.962 483	.201 010
35.6°	11° 49′ 46″	.983 155	.962 275	.201 546
35.7°	11° 51′ 45″	.983 061	.962 066	.202 081
35.8°	11° 53′ 44″	.982 966	.961 857	.202 616
35.9°	11° 55′ 43″	.982 872	.961 648	.203 151
36.0°	11° 57′ 41″	.982 777	.961 438	.203 685
36.1°	11° 59′ 40″	.982 681	.961 227	.204 219
36.2°	12° 01″ 39″	.982 586	.961 016	.204 753
36.3°	12° 03′ 38″	.982 490	.960 804	.205 286
36.4°	12° 05′ 37″	.982 394	.960 592	.205 820
36.5°	12° 07′ 36″	.982 298	.960 379	.206 353
36.6°	12° 09′ 34″	.982 201	.960 165	.206 886
36.7°	12° 11′ 33″	.982 104	.959 951	.207 418
36.8°	12° 13′ 32″	.982 007	.959 737	.207 951
36.9°	12° 15′ 31″	.981 910	.959 522	.208 483
37.0°	12° 17′ 30″	.981 813	.959 306	.209 014
37.1°	12° 19′ 28″	.981 715	.959 090	.209 546
37.2°	12° 21′ 27″	.981 617	.958 874	.210 077
37.3°	12° 23′ 26″	.981 518	.958 657	.210 608
37.4°	12° 25′ 25″	.981 420	.958 439	.211 139
37.5°	12° 27′ 23″	.981 321	.958 221	.211 669
37.6°	12° 29′ 22″	.981 222	.958 002	.212 199
37.7°	12° 31′ 21″	.981 122	.957 783	.212 729
37.8°	12° 33′ 20″	.981 023	.957 563	.213 259
37.9°	12° 35′ 18″	.980 923	.957 342	.213 788
38.0°	12° 37′ 17″	.980 823	.957 121	.214 317
38.1°	12° 39′ 16″	.980 722	.956 900	.214 846
38.2°	12° 41′ 14″	.980 622	.956 678	.215 375
38.3°	12° 43′ 13″	.980 521	.956 456	.215 903
38.4°	12° 45′ 12″	.980 420	.956 232	.216 431
38.5°	12° 47′ 11″	.980 318	.956 009	.216 959
38.6°	12° 49′ 09″	.980 217	.955 785	.217 486
38.7°	12° 51′ 08″	.980 115	.955 560	.218 013
38.8°	12° 53′ 07″	.980 012	.955 335	.218 540
38.9°	12° 55′ 05″	.979 910	.955 109	.219 067
39.0°	12° 57′ 04″	.979 807	.954 883	.219 593
39.1°	12° 59′ 02″	.979 704	.954 656	.220 119
39.2°	13° 01′ 01″	.979 601	.954 429	.220 645
39.3°	13° 03′ 00″	.979 498	.954 201	.221 171
39.4°	13° 04′ 58″	.979 394	.953 973	.221 696
39.5°	13° 06′ 57″	.979 290	.953 744	.222 221

Table A-9. Functions of the 10-chord spiral (continued)

Δ	A	$\frac{C}{L.}$	$\frac{X}{L.}$	$\frac{Y}{L.}$
39.6°	13° 08′ 56″	.979 186	.953 514	.222 745
39.7°	13° 10′ 54″	.979 081	.953 284	.223 270
39.8°	13° 12′ 53″	.978 977	.953 054	.223 794
39.9°	13° 14′ 51″	.978 872	.952 823	.224 318
40.0°	13° 16′ 50″	.978 766	.952 591	.224 841
40.1°	13° 18′ 48″	.978 661	.952 359	.225 365
40.2°	13° 20′ 47″	.978 555	.952 127	.225 888
40.3°	13° 22′ 46″	.978 440	.951 893	.226 410
40.4°	13° 24′ 44″	.978 343	.951 660	.226 933
40.5°	13° 26′ 43″	.978 236	.951 426	.227 455
40.6°	13° 28′ 41″	.978 130	.951 191	.227 977
40.7°	13° 30′ 40″	.978 023	.950 956	.228 498
40.8°	13° 32′ 38″	.977 915	.950 720	.229 019
40.9°	13° 34′ 37″	.977 808	.950 484	.229 540
41.0°	13° 36′ 35″	.977 700	.950 247	.230 061
41.1°	13° 38′ 34″	.977 592	.950 010	.230 581
41.2°	13° 40′ 32″	.977 484	.949 772	.231 102
41.3°	13° 42′ 31″	.977 375	.949 533	.231 621
41.4°	13° 44′ 29″	.977 266	.949 294	.232 141
41.5°	13° 46′ 28″	.977 157	.949 055	.232 660
41.6°	13° 48′ 26″	.977 048	.948 815	.233 179
41.7°	13° 50′ 25″	.976 938	.948 575	.233 698
41.8°	13° 52′ 23″	.976 828	.948 334	.234 216
41.9°	13° 54′ 22″	.976 718	.948 092	.234 734
42.0°	13° 56′ 20″	.976 608	.947 850	.235 252
42.1°	13° 58′ 18″	.976 498	.947 608	.235 789
42.2°	14° 00′ 17″	.976 387	.947 365	.236 286
42.3°	14° 02′ 15″	.976 276	.947 121	.236 803
42.4°	14° 04′ 14″	.976 164	.946 877	.237 320
42.5°	14° 06′ 12″	.976 053	.946 632	.237 836
42.6°	14° 08′ 10″	.975 941	.946 387	.238 352
42.7°	14° 10′ 09″	.975 829	.946 142	.238 868
42.8°	14° 12′ 07″	.975 716	.945 895	.239 383
42.9°	14° 14′ 06″	.975 604	.945 649	.239 898
43.0°	14° 16′ 04″	.975 491	.945 402	.240 413
43.1°	14° 18′ 02″	.975 378	.945 154	.240 927
43.2°	14° 20′ 01″	.975 264	.944 906	.241 442
43.3°	14° 21′ 59″	.975 151	.944 657	.241 956
43.4°	14° 23′ 57″	.975 037	.944 408	.242 469
43.5°	14° 25′ 56″	.974 923	.944 158	.242 982
43.6°	14° 27′ 54″	.974 808	.943 908	.243 495
43.7°	14° 29′ 52″	.974 694	.943 657	.244 008
43.8°	14° 31′ 50″	.974 579	.943 405	.244 520
43.9°	14° 33′ 49″	.974 464	.943 154	.245 032
44.0°	14° 35′ 47″	.974 348	.942 901	.245 544
44.1°	14° 37′ 45″	.974 233	.942 648	.246 055
44.2°	14° 39′ 44″	.974 117	.942 395	.246 567
44.3°	14° 41′ 42″	.974 001	.942 141	.247 077
44.4°	14° 43′ 40″	.973 884	.941 887	.247 588
44.5°	14° 45′ 38″	.973 768	.941 632	.248 098
44.6°	14° 47′ 37″	.973 651	.941 377	.248 608
44.7°	14° 49′ 35″	.973 534	.941 121	.249 117
44.8°	14° 51′ 33″	.973 416	.940 864	.249 627
44.9°	14° 53′ 31″	.974 299	.940 608	.250 135
45.0°	14° 55′ 29″	.973 181	.940 350	.250 644

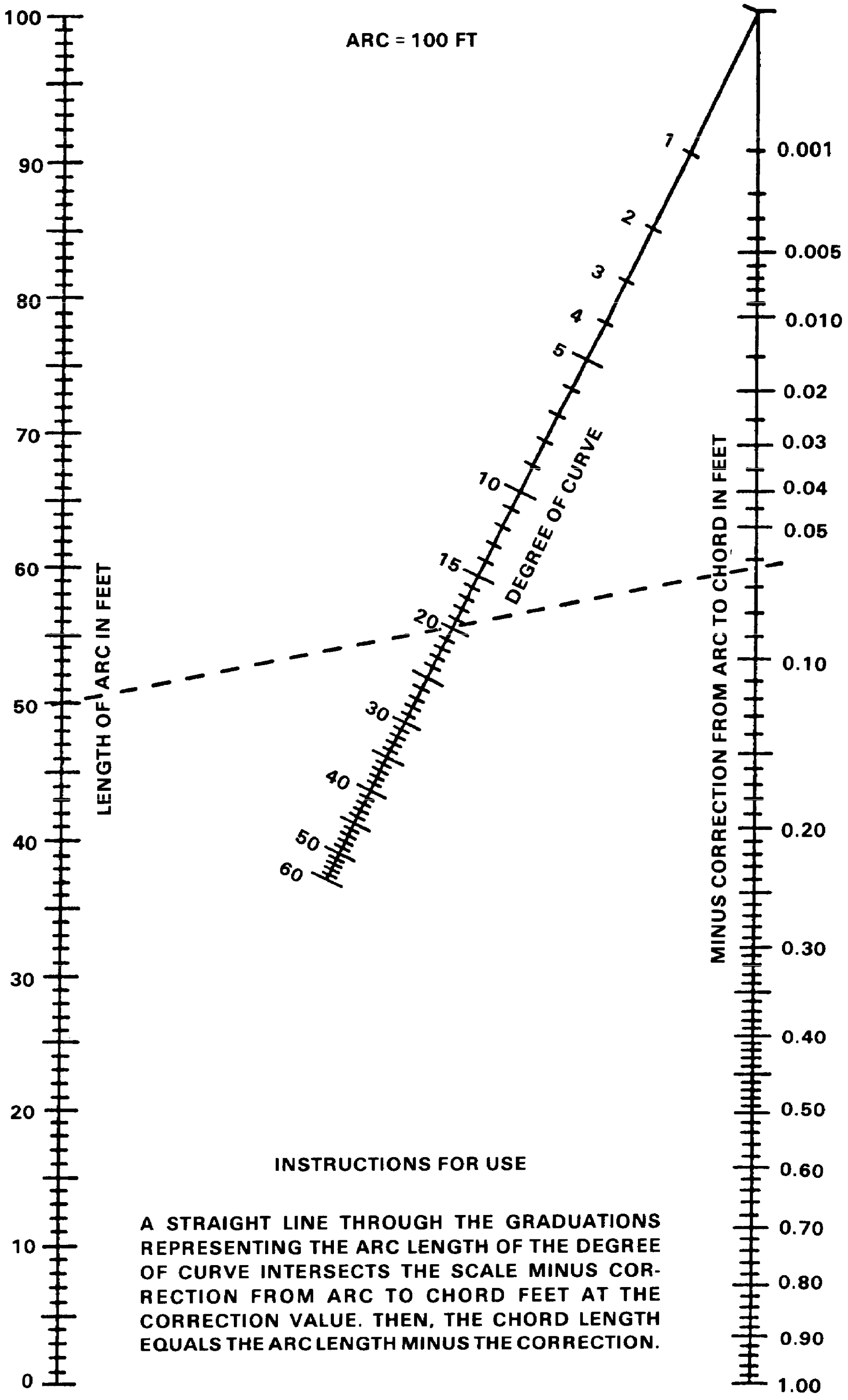
Table A-10. Subchord corrections (chord definition)



INSTRUCTIONS FOR USE

A STRAIGHT LINE THROUGH THE GRADUATIONS REPRESENTING THE NOMINAL LENGTH OF CHORD AND DEGREE OF CURVE INTERSECTS THE SCALE PLUS CORRECTION FROM NOMINAL TO TRUE CHORD LENGTH IN FEET AT THE CORRECTION VALUE. THEN, THE TRUE CHORD LENGTH EQUALS THE NOMINAL CHORD LENGTH PLUS THE CORRECTION.

Table A-11. Subchord corrections (arc definition)



INSTRUCTIONS FOR USE

A STRAIGHT LINE THROUGH THE GRADUATIONS REPRESENTING THE ARC LENGTH OF THE DEGREE OF CURVE INTERSECTS THE SCALE MINUS CORRECTION FROM ARC TO CHORD FEET AT THE CORRECTION VALUE. THEN, THE CHORD LENGTH EQUALS THE ARC LENGTH MINUS THE CORRECTION.

Table A-12. Temperature conversion table

To use the table, look in the middle column for the temperature reading you have. If the reading you have is in degrees Centigrade, read the Fahrenheit equivalent in the right-hand column. If the reading you have is in degrees Fahrenheit, read the Centigrade equivalent in the left-hand column.

FORMULAS. $C = 5/9 (F-32)$ or $F = 9/5 (C + 32)$

-80 to 34			35 to 77			78 to 290		
C		F	C		F	C		F
-62	-80	-112	1.7	35	95.0	25.6	78	172.4
-57	-70	-94	2.2	36	96.8	26.1	79	174.2
-51	-60	-76	2.8	37	98.6	26.7	80	176.0
-46	-50	-58	3.3	38	100.4	27.2	81	177.8
-40	-40	-40	3.9	39	102.4	27.8	82	179.6
-34	-30	-22	4.4	40	104.0	28.3	83	181.4
-29	-20	-4	5.0	41	105.8	28.9	84	183.2
-23	-10	14	5.6	42	107.6	29.4	85	185.0
-17.8	0	32	6.1	43	109.4	30.0	86	186.8
-17.2	1	33.8	6.7	44	111.2	30.6	87	188.6
-16.7	2	35.6	7.2	45	113.0	31.1	88	190.6
-16.1	3	37.4	7.8	46	114.8	31.7	89	192.2
-15.6	4	39.2	8.3	47	116.6	32.2	90	194.0
-15.0	5	41.0	8.9	48	118.4	32.8	91	195.8
-14.4	6	42.8	9.4	49	120.2	33.3	92	197.6
-13.9	7	44.6	10.0	50	122.0	33.9	93	199.4
-13.3	8	46.4	10.6	51	123.8	34.4	94	201.2
-12.8	9	48.2	11.1	52	125.6	35.0	95	203.0
-12.2	10	50.0	11.7	53	127.4	35.6	96	204.8
-11.7	11	51.8	12.2	54	129.2	36.1	97	206.6
-11.1	12	53.6	12.8	55	131.0	36.7	98	208.4
-10.6	13	55.4	13.3	56	132.8	37.2	99	210.2
-10.0	14	57.2	13.9	57	134.6	37.8	100	212.0
-9.4	15	59.0	14.4	58	136.4	43	110	230
-8.9	16	60.8	15.0	59	138.2	49	120	248
-8.3	17	62.6	15.6	60	140.0	54	130	260
-7.8	18	64.4	16.1	61	141.8	60	140	284
-7.2	19	66.2	16.7	62	143.6	66	150	302
-6.7	20	68.0	17.2	63	145.4	71	160	320
-6.1	21	69.8	17.8	64	147.2	77	170	338
-5.6	22	71.6	18.3	65	149.0	82	180	356
-5.0	23	73.4	18.9	66	150.8	88	190	374
-4.4	24	75.2	19.4	67	152.6	93	200	392
-3.9	25	77.0	20.0	68	154.4	99	210	410
-3.3	26	78.8	20.6	69	156.2	100	212	413.6
-2.8	27	80.6	21.1	70	158.0	104	220	428
-2.2	28	82.4	21.7	71	159.8	110	230	446
-1.7	29	84.2	22.2	72	161.6	116	240	464
-1.1	30	86.0	22.8	73	163.4	121	250	482
-0.6	31	87.8	23.3	74	165.2	127	260	500
0.0	32	89.6	23.9	75	167.0	132	270	518
0.6	33	91.4	24.4	76	168.8	138	280	536
1.1	34	93.2	25.0	77	170.6	143	290	554

Table A-13. Conversion of meters to feet

Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet
0		50	164.04167	100	328.08333	150	492.12500	200	656.16667
1	3.28083	1	167.32250	1	331.36417	1	495.40583	1	659.44750
2	6.56167	2	170.60333	2	334.64500	2	498.68667	2	662.72833
3	9.84250	3	173.88417	3	337.92583	3	501.96750	3	666.00917
4	13.12333	4	177.16500	4	341.20667	4	505.24833	4	669.2900
5	16.40417	5	180.44583	5	344.48750	5	508.52917	5	672.57083
6	19.68500	6	183.72667	6	347.76833	6	511.81000	6	675.85167
7	22.96583	7	187.00750	7	351.04917	7	515.09083	7	679.13250
8	26.24667	8	190.28833	8	354.33000	8	518.37167	8	682.41333
9	29.52750	9	193.56917	9	357.61083	9	521.65250	9	685.69417
10	32.80833	60	196.85000	110	360.89167	160	524.93333	210	688.97500
1	36.08917	1	200.13083	1	364.17250	1	528.21417	1	692.25583
2	39.37000	2	203.41167	2	367.45333	2	531.49500	2	695.53667
3	42.65083	3	206.69250	3	370.73417	3	534.77583	3	698.81750
4	45.93167	4	209.97333	4	374.01500	4	538.05667	4	702.09833
5	49.21250	5	213.25417	5	377.29583	5	541.33750	5	705.37917
6	52.49333	6	216.53500	6	380.57667	6	544.61833	6	708.66000
7	55.77417	7	219.81583	7	383.85750	7	547.89917	7	711.94083
8	59.05500	8	223.09667	8	387.13833	8	551.18000	8	715.22167
9	62.33583	9	226.37750	9	390.41917	9	554.46083	9	718.50250
20	65.61667	70	229.65833	120	393.70000	170	557.74167	220	721.78333
1	68.89750	1	232.93917	1	396.98083	1	561.02250	1	725.06417
2	72.17822	2	236.22000	2	400.26167	2	564.30333	2	728.34500
3	75.45917	3	239.50083	3	403.54250	3	567.58417	3	731.62583
4	78.74000	4	242.78167	4	406.82333	4	570.86500	4	734.90667
5	82.02083	5	246.06250	5	410.10417	5	574.14583	5	738.18750
6	85.30167	6	249.34333	6	413.38500	6	577.42667	6	741.46833
7	88.58250	7	252.62417	7	416.66583	7	580.70750	7	744.74917
8	91.86333	8	255.90500	8	419.94667	8	583.98833	8	748.03000
9	95.14417	9	259.18583	9	423.22750	9	587.26917	9	751.31083
30	98.42500	80	262.46667	130	426.50833	180	590.55000	230	754.59167
1	101.70583	1	265.74750	1	429.78917	1	593.83083	1	757.87250
2	104.98667	2	269.02833	2	433.07000	2	597.11167	2	761.15333
3	108.26750	3	272.30917	3	436.35083	3	600.39250	3	764.43417
4	111.54833	4	275.59000	4	439.63167	4	603.67333	4	767.71500
5	114.82917	5	278.87083	5	442.91250	5	606.95417	5	770.99583
6	118.11000	6	282.15167	6	446.19333	6	610.23500	6	774.27667
7	121.39083	7	285.43250	7	449.47417	7	613.51583	7	777.55750
8	124.67167	8	288.71333	8	452.75500	8	616.79667	8	780.83833
9	127.95250	9	291.99417	9	456.03583	9	620.07750	9	784.11917
40	131.23333	90	295.27500	140	459.31667	190	623.35833	240	787.40000
1	134.51417	1	298.55583	1	462.59750	1	626.63917	1	790.68083
2	137.79500	2	301.83667	2	465.87833	2	629.92000	2	793.96167
3	141.07583	3	305.11750	3	469.15917	3	633.20083	3	797.24250
4	144.35667	4	308.39833	4	472.44000	4	636.48167	4	800.52333
5	147.63750	5	311.67917	5	475.72083	5	639.76250	5	803.80417
6	150.91833	6	314.96000	6	479.00167	6	643.04333	6	807.08500
7	154.19917	7	318.24083	7	482.28250	7	646.32417	7	810.36583
8	157.48000	8	321.52167	8	485.56333	8	649.60500	8	813.64667
9	160.76083	9	324.80250	9	488.84417	9	652.88583	9	816.92750

Table A-13. Conversion of meters to feet (continued)

Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet
250	820.20833	300	984.25000	350	1,148.29167	400	1,312.33333	450	1,476.37500
1	823.48917	1	987.53083	1	1,151.57250	1	1,315.61417	1	1,479.65583
2	826.77000	2	990.81167	2	1,154.85333	2	1,318.89500	2	1,482.93667
3	830.05083	3	994.09250	3	1,158.13417	3	1,322.17583	3	1,486.21750
4	833.33167	4	997.37333	4	1,161.41500	4	1,325.45667	4	1,489.49833
5	836.61250	5	1,000.65417	5	1,164.69583	5	1,328.73750	5	1,492.77917
6	839.89333	6	1,003.93500	6	1,167.97667	6	1,332.01833	6	1,496.06000
7	843.17417	7	1,007.21583	7	1,171.25750	7	1,335.29917	7	1,499.34083
8	846.45500	8	1,010.49667	8	1,174.53833	8	1,338.58000	8	1,502.62167
9	849.73583	9	1,013.77750	9	1,177.81917	9	1,341.86083	9	1,505.90250
260	853.01667	310	1,017.05833	360	1,181.10000	410	1,345.14167	460	1,509.18333
1	856.29750	1	1,020.33917	1	1,184.38083	1	1,348.42250	1	1,512.46417
2	859.57833	2	1,023.62000	2	1,187.66167	2	1,351.70333	2	1,515.74500
3	862.85917	3	1,026.90083	3	1,190.94250	3	1,354.98417	3	1,519.02583
4	866.14000	4	1,030.18167	4	1,194.22333	4	1,358.26500	4	1,522.30667
5	869.42083	5	1,033.46250	5	1,197.50417	5	1,361.54583	5	1,525.58750
6	872.70167	6	1,036.74333	6	1,200.78500	6	1,364.82667	6	1,528.86833
7	875.98250	7	1,040.02417	7	1,204.06583	7	1,368.10750	7	1,532.14917
8	879.26333	8	1,043.30500	8	1,207.34667	8	1,371.38833	8	1,535.43000
9	882.54417	9	1,046.58583	9	1,210.62750	9	1,374.66917	9	1,538.71083
270	885.82500	320	1,049.86667	370	1,213.90833	420	1,377.95000	470	1,541.99167
1	889.10583	1	1,053.14750	1	1,217.18917	1	1,381.23083	1	1,545.27250
2	892.38667	2	1,056.42833	2	1,220.47000	2	1,384.51167	2	1,548.55333
3	895.66750	3	1,059.70917	3	1,223.75083	3	1,387.79250	3	1,551.83417
4	898.94833	4	1,062.99000	4	1,227.03167	4	1,391.07333	4	1,555.11500
5	902.22917	5	1,066.27083	5	1,230.31250	5	1,394.35417	5	1,558.39583
6	905.51000	6	1,069.55167	6	1,233.59333	6	1,397.63500	6	1,561.67667
7	908.79083	7	1,072.83250	7	1,236.87417	7	1,400.91583	7	1,564.95750
8	912.07167	8	1,076.11333	8	1,240.15500	8	1,404.19667	8	1,568.23833
9	915.35250	9	1,079.39417	9	1,243.43583	9	1,407.47750	9	1,571.51917
280	918.63333	330	1,082.67500	380	1,246.71667	430	1,410.75833	480	1,574.80000
1	921.91417	1	1,085.95583	1	1,249.99750	1	1,414.03917	1	1,578.08083
2	925.19500	2	1,089.23667	2	1,253.27833	2	1,417.32000	2	1,581.36167
3	928.47583	3	1,092.51750	3	1,256.55917	3	1,420.60083	3	1,584.64250
4	931.75667	4	1,095.79833	4	1,259.84000	4	1,423.88167	4	1,587.92333
5	935.03750	5	1.099.07917	5	1,263.12083	5	1,427.16250	5	1,591.20417
6	938.31833	6	1,012.36000	6	1,266.40167	6	1,430.44333	6	1,594.48500
7	941.59917	7	1,105.64083	7	1,269.68250	7	1,433.72417	7	1,597.76583
8	944.88000	8	1,108.92167	8	1,272.96333	8	1,437.00500	8	1,601.04667
9	948.16083	9	1,112.20250	9	1,276.24417	9	1,440.28583	9	1,604.32750
290	951.44167	340	1,115.48333	390	1,279.52500	440	1,443.56667	490	1,607.60833
1	954.72250	1	1,118.76417	1	1,282.80583	1	1,446.84750	1	1,610.88917
2	958.00333	2	1,122.04500	2	1,286.08667	2	1,450.12833	2	1,614.17000
3	961.28417	3	1,125.32583	3	1,289.36750	3	1,453.40917	3	1,617.45083
4	964.56500	4	1,128.60667	4	1,292.64833	4	1,456.69000	4	1,620.73167
5	967.84583	5	1,131.88750	5	1,295.92917	5	1,459.97083	5	1,624.01250
6	971.12667	6	1,135.16833	6	1,299.21000	6	1,463.25167	6	1,627.29333
7	974.40750	7	1,138.44917	7	1,302.49083	7	1,466.53250	7	1,630.57417
8	977.68833	8	1,141.73000	8	1,305.77167	8	1,469.81333	8	1,633.85500
9	980.96917	9	1,145.01083	9	1,309.05250	9	1,473.09417	9	1,637.13583

Table A-13. Conversion of meters to feet (continued)

Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet
500	1,640.41667	550	1,804.45833	600	1,968.50000	650	2,132.54167	700	2,296.58333
1	1,643.69750	1	1,807.73917	1	1,971.78083	1	2,135.82250	1	2,299.86417
2	1,646.97833	2	1,811.02000	2	1,975.06167	2	2,139.10333	2	2,303.14500
3	1,650.25917	3	1,814.30083	3	1,978.34250	3	2,142.38417	3	2,306.42583
4	1,653.54000	4	1,817.58167	4	1,981.62333	4	2,145.66500	4	2,309.70667
5	1,656.82083	5	1,820.86250	5	1,984.90417	5	2,148.94583	5	2,312.98750
6	1,660.10167	6	1,824.14333	6	1.988.18500	6	2,152.22667	6	2,316.26833
7	1,663.38250	7	1,827.42417	7	1.991.46583	7	2,155.50750	7	2,319.54917
8	1,666.66333	8	1,830.70500	8	1.994.74667	8	2,158.78833	8	2,322.83000
9	1,669.94417	9	1,833.98583	9	1,998.02750	9	2,162.06917	9	2,226.11083
510	1,673.22500	560	1,837.26667	610	2,001.30833	660	2,165.35000	710	2,329.39167
1	1,676.50583	1	1,840.54750	1	2,004.58917	1	2,168.63083	1	2,332.67250
2	1,679.78667	2	1,843.82833	2	2,007.87000	2	2,171.91167	2	2,335.95333
3	1,683.06750	3	1,847.10917	3	2,011.15083	3	2,175.19250	3	2,339.23417
4	1,686.34833	4	1,850.39000	4	2,014.43167	4	2,178.47333	4	2,342.51500
5	1,689.62917	5	1,853.67083	5	2,017.71250	5	2,181.75417	5	2,345.79583
6	1,692.91000	6	1,856.95167	6	2,020.99333	6	2,185.03500	6	2,349.07667
7	1,696.19083	7	1,860.23250	7	2,024.27417	7	2,188.31583	7	2,352.35750
8	1,699.47167	8	1,863.51333	8	2,027.55500	8	2,191.59667	8	2,355.63833
9	1,702.75250	9	1,866.79417	9	2,030.83583	9	2,194.87750	9	2,358.91917
520	1,706,03333	570	1,870.07500	620	2,034.11667	670	2,198.15833	720	2,362.20000
1	1,709.31417	1	1,873.35583	1	2,037.39750	1	2,201.43917	1	2,365.48083
2	1,712.59500	2	1,876.63667	2	2,040.67833	2	2,204.72000	2	2,368.76167
3	1,715.87583	3	1,879.91750	3	2,043.95917	3	2,208.00083	3	2,372.04250
4	1,719.15667	4	1,883.19833	4	2,047.24000	4	2,211.28167	4	2,375.32333
5	1,722.43750	5	1,886.47917	5	2,050.52083	5	2,214.56250	5	2,378.60417
6	1,725.71833	6	1,889.76000	6	2,053.80167	6	2,217.84333	6	2,381.88500
7	1,728.99917	7	1,893.04083	7	2,057.08250	7	2,221.12417	7	2,385.16583
8	1,732.28000	8	1,896.32167	8	2,060.36333	8	2,224.40500	8	2,388.44667
9	1,735,56083	9	1,899.60250	9	2,063.64417	9	2,227.68583	9	2,391.72750
530	1,738.84167	580	1,902.88333	630	2,066.92500	680	2,230.96667	730	2,395.00833
1	1,742.12250	1	1,906.16417	1	2,070.20583	1	2,234.24750	1	2,398.28917
2	1,745.40333	2	1,909.44500	2	2,073.48667	2	2,237.52833	2	2,401.57000
3	1,748.68417	3	1,912.72583	3	2,076.76750	3	2,240.80917	3	2,404.85083
4	1,751.96500	4	1,916.00667	4	2,080.04833	4	2,244.09000	4	2,408.13167
5	1,755.24583	5	1,919.28750	5	2,083.32917	5	2,247.37083	5	2,411.41250
6	1,758.52667	6	1,922.56833	6	2,086.61000	6	2,250.65167	6	2,414.69333
7	1,761.80750	7	1,925.84917	7	2,089.89083	7	2,253.93250	7	2,417.97417
8	1,765,08833	8	1,929.13000	8	2,093.17167	8	2,257.21333	8	2,421.25500
9	1,768.36917	9	1,932.41083	9	2,096.45250	9	2,260.49417	9	2,424.53583
540	1,771.65000	590	1,935.69167	640	2,099.73333	690	2,263.77500	740	2,427.81667
1	1,774.93083	1	1,938.97250	1	2,103.01417	1	2,267.05583	1	2,431.09750
2	1,778.21167	2	1,942.25333	2	2,106.29500	2	2,270.33667	2	2,434.37833
3	1,781.49250	3	1,945.53417	3	2,109.57583	3	2,273.61750	3	2,437.65917
4	1,784.77333	4	1,948.81500	4	2,112.85667	4	2,276.89833	4	2,440.94000
5	1,788.05417	5	1,952.09583	5	2,116.13750	5	2,280.17917	5	2,444.22083
6	1,791.33500	6	1,955.37667	6	2,119.41833	6	2,283.46000	6	2,447.50167
7	1,794.61583	7	1,958.65750	7	2,122.69917	7	2,286.74083	7	2,450.78250
8	1,797.89667	8	1,961.93833	8	2,125.98000	8	2,290.02167	8	2,454.06333
9	1,801.17750	9	1,965.21917	9	2,129.26083	9	2,293.30250	9	2,457.34417

Table A-13. Conversion of meters to feet (continued)

Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet
750	2,460.62500	800	2,624.66667	850	2,788.70833	900	2,952.75000	950	3,116.79167
1	2,463.90583	1	2,627.94750	1	2,791.98917	1	2,956.03083	1	3,120.07250
2	2,467.18667	2	2,631.22833	2	2,795.27000	2	2,959.31167	2	3,123.35333
3	2,470.46750	3	2,634.50917	3	2,798.55083	3	2,962.59250	3	3,126.63417
4	2,473.74833	4	2,637.79000	4	2,801.83167	4	2,965.87333	4	3,129.91500
5	2,477.02917	5	2,641.07083	5	2,805.11250	5	2,969.15417	5	3,133.19583
6	2,480.31000	6	2,644.35167	6	2,808.39333	6	2,972.43500	6	3,136.47667
7	2,483.59083	7	2,647.63250	7	2,811.67417	7	2,975.71583	7	3,139.75750
8	2,486.87167	8	2,650.91333	8	2,814.95500	8	2,978.99667	8	3,143.03833
9	2,490.15250	9	2,654.19417	9	2,818.23583	9	2,982.27750	9	3,146.31917
760	2,493.43333	810	2,657.47500	860	2,821.51667	910	2,985.55833	960	3,149.60000
1	2,496.71417	1	2,660.75583	1	2,824.79750	1	2,988.83917	1	3,152.88083
2	2,499.99500	2	2,664.03667	2	2,828.07833	2	2,992.12000	2	3,156.16167
3	2,503.27583	3	2,667.31750	3	2,831.35917	3	2,995.40083	3	3,159.44250
4	2,506.55667	4	2,670.59833	4	2,834.64000	4	2,998.68167	4	3,162.72333
5	2,509.83750	5	2,673.87917	5	2,837.92083	5	3,001.96250	5	3,166.00417
6	2,513.11833	6	2,677.16000	6	2,841.20167	6	3,005.24333	6	3,169.28500
7	2,516.39917	7	2,680.44083	7	2,844.48250	7	3,008.52417	7	3,172.56583
8	2,519.68000	8	2,683.72167	8	2,847.76333	8	3,011.80500	8	3,175.84667
9	2,522.96083	9	2,687.00250	9	2,851.04417	9	3,015.08583	9	3,179.12750
770	2,526.24167	820	2,690.28333	870	2,854.32500	920	3,018.36667	970	3,182.40833
1	2,529.52250	1	2,693.56417	1	2,857.60583	1	3,021.64750	1	3,185.68917
2	2,532.80333	2	2,696.84500	2	2,860.88667	2	3,024.92833	2	3,188.97000
3	2,536.08417	3	2,700.12583	3	2,864.16750	3	3,028.20917	3	3,192.25083
4	2,539.36500	4	2,703.40667	4	2,867.44833	4	3,031.49000	4	3,195.53167
5	2,542.64583	5	2,760.68750	5	2,870.72917	5	3,034.77083	5	3,198.81250
6	2,545.92667	6	2,709.96833	6	2,874.01000	6	3,038.05167	6	3,202.09333
7	2,549.20750	7	2,713.24917	7	2,877.29083	7	3,041.33250	7	3,205.37417
8	2,552.48833	8	2,716.53000	8	2,880.57167	8	3,044.61333	8	3,208.65500
9	2,555.76917	9	2,719.81083	9	2,883.85250	9	3,047.89417	9	3,211.93583
780	2,559.05000	830	2,723.09167	880	2,887.13333	930	3,051.17500	980	3,215.21667
1	2,562.33083	1	2,726.37250	1	2,890.41417	1	3,054.45583	1	3,218.49750
2	2,565.61167	2	2,729.65333	2	2,893.69500	2	3,057.73667	2	3,221.77833
3	2,568.89250	3	2,732.93417	3	2,896.97583	3	3,061.01750	3	3,225.05917
4	2,572.17333	4	2,736.21500	4	2,900.25667	4	3,064.29833	4	3,228.34000
5	2,575.45417	5	2,739.49583	5	2,903.53750	5	3,067.57917	5	3,231.62083
6	2,578.73500	6	2,742.77667	6	2,906.81833	6	3,070.86000	6	3,234.90167
7	2,582.01583	7	2,746.05750	7	2,910.09917	7	3,074.14083	7	3,238.18250
8	2,585.29667	8	2,749.33833	8	2,913.38000	8	3,077.42167	8	3,241.46333
9	2,588.57750	9	2,752.61917	9	2,916.66083	9	3,080.70250	9	3,244.74417
790	2,591.85833	840	2,755.90000	890	2,919.94167	940	3,083.98333	990	3,248.02500
1	2,595.13917	1	2,759.18083	1	2,923.22250	1	3,087.26417	1	3,251.30583
2	2,598.42000	2	2,762.46167	2	2,926.50333	2	3,090.54500	2	3,254.58667
3	2,601.70083	3	2,765.74250	3	2,929.78417	3	3,093.82583	3	3,257.86750
4	2,604.98167	4	2,769.02333	4	2,933.06500	4	3,097.10667	4	3,261.14833
5	2,608.26250	5	2,772.30417	5	2,936.34583	5	3,100.38750	5	3,264.42917
6	2,611.54333	6	2,775.58500	6	2,939.62667	6	3,103.66833	6	3,267.71000
7	2,614.82417	7	2,778.86583	7	2,942.90750	7	3,106.94917	7	3,270.99083
8	2,618.10500	8	2,782.14667	8	2,946.18833	8	3,110.23000	8	3,274.27167
9	2,621.38583	9	2,785.42750	9	2,949.46917	9	3,113.51083	9	3,277.55250

Table A-14. Conversion of feet to meters

Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
0	0.0	50	15.24003	100	30.48006	150	45.72009	200	60.96012
1	0.30480	1	15.54483	1	30.78486	1	46.02489	1	61.26492
2	0.60960	2	15.84963	2	31.08966	2	46.32969	2	61.56972
3	0.91440	3	16.15443	3	31.39446	3	46.63449	3	61.87452
4	1.21920	4	16.45923	4	31.69926	4	46.93929	4	62.17932
5	1.52400	5	16.76403	5	32.00406	5	47.24409	5	62.48412
6	1.82880	6	17.06883	6	32.30886	6	47.54890	6	62.78893
7	2.13360	7	17.37363	7	32.61367	7	47.85370	7	63.09373
8	2.43840	8	17.67844	8	32.91847	8	48.15850	8	63.39853
9	2.74321	9	17.98324	9	33.22327	9	48.46330	9	63.70333
10	3.04801	60	18.38804	110	33.52807	160	48.76810	210	64.00813
1	3.35281	1	18.59284	1	33.83287	1	49.07290	1	64.31293
2	3.65761	2	18.89764	2	34.13767	2	49.37770	2	64.61773
3	3.96241	3	19.20244	3	34.44247	3	49.68250	3	64.92253
4	4.26721	4	19.50724	4	34.74727	4	49.98730	4	65.22733
5	4.57201	5	19.81204	5	35.05207	5	50.29210	5	65.53213
6	4.87681	6	20.11684	6	35.35687	6	50.59690	6	65.83693
7	5.18161	7	20.42164	7	35.66167	7	50.90170	7	66.14173
8	5.48641	8	20.72644	8	35.96647	8	51.20650	8	66.44653
9	5.79121	9	21.03124	9	36.27127	9	51.51130	9	66.75133
20	6.09601	70	21.33604	120	36.57607	170	51.81610	220	67.05613
1	6.40081	1	21.64084	1	36.88087	1	52.12090	1	67.36093
2	6.70561	2	21.94564	2	37.18567	2	52.42570	2	67.66574
3	7.01041	3	22.25044	3	37.49047	3	52.73051	3	67.97054
4	7.31521	4	22.55525	4	37.79528	4	53.03531	4	68.27534
5	7.62002	5	22.86005	5	38.10008	5	53.34011	5	68.58014
6	7.92482	6	23.16485	6	38.40488	6	53.64491	6	68.88494
7	8.22962	7	23.46965	7	38.70968	7	53.94971	7	69.18974
8	8.53442	8	23.77445	8	39.01448	8	54.25451	8	69.49454
9	8.83922	9	24.07925	9	39.31928	9	54.55931	9	69.79934
30	9.14402	80	24.38405	130	39.62408	180	54.86411	230	70.10414
1	9.44882	1	24.68885	1	39.92888	1	55.16891	1	70.40894
2	9.75362	2	24.99365	2	40.23368	2	55.47371	2	70.71374
3	10.05842	3	25.29845	3	40.53848	3	55.77851	3	71.01854
4	10.36322	4	25.60325	4	40.84328	4	56.08331	4	71.32334
5	10.66802	5	25.90805	5	41.14808	5	56.38811	5	71.62814
6	10.97282	6	26.21285	6	41.45288	6	56.69291	6	71.93294
7	11.27762	7	26.51765	7	41.75768	7	56.99771	7	72.23774
8	11.58242	8	26.82245	8	42.06248	8	57.30251	7	72.54255
9	11.88722	9	27.12725	9	42.36728	9	57.60732	9	72.84735
40	12.19202	90	27.43205	140	42.67209	190	57.91212	240	73.15215
1	12.49682	1	27.73686	1	42.97689	1	58.21692	1	73.45695
2	12.80163	2	28.04166	2	43.28169	2	58.52172	2	73.76175
3	13.10643	3	28.34646	3	43.58649	3	58.82652	3	74.06655
4	13.41123	4	28.65126	4	43.89129	4	59.13132	4	74.37135
5	13.71603	5	28.95606	5	44.19609	5	59.43612	5	74.67615
6	14.02083	6	29.26086	6	44.50089	6	59.74092	6	74.98095
7	14.32563	7	29.56566	7	44.80569	7	60.04572	7	75.28575
8	14.63043	8	29.87046	8	45.11049	8	60.35052	8	75.59055
9	14.93523	9	30.17526	9	45.41529	9	60.65532	9	75.89535

Table A-14. Conversion of feet to meters (continued)

Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
250	76.20015	300	91.44018	350	106.68021	400	121.92024	450	137.16027
1	76.50495	1	91.74498	1	106.98501	1	122.22504	1	137.46507
2	76.80975	2	92.04978	2	107.28981	2	122.52985	2	137.76988
3	77.11455	3	92.35458	3	107.59462	3	122.83465	3	138.07468
4	77.41935	4	92.65939	4	107.89942	4	123.13945	4	138.37948
5	77.72416	5	92.96419	5	108.20422	5	123.44425	5	138.68428
6	78.02896	6	93.26899	6	108.50902	6	123.74905	6	138.98908
7	78.33376	7	93.57379	7	108.81382	7	124.05385	7	139.29388
8	78.63856	8	93.87859	8	109.11862	8	124.35865	8	139.59868
9	78.94336	9	94.18339	9	109.42342	9	124.66345	9	139.90348
260	79.24816	310	94.48819	360	109.72822	410	124.96825	460	140.20828
1	79.55296	1	94.79299	1	110.03302	1	125.27305	1	140.51308
2	79.85776	2	95.09779	2	110.33782	2	125.57785	2	140.81788
3	80.16256	3	95.40259	3	110.64262	3	125.88265	3	141.12268
4	80.46736	4	95.70739	4	110.94742	4	126.18745	4	141.42748
5	80.77216	5	96.01219	5	111.25222	5	126.49225	5	141.73228
6	81.07696	6	96.31699	6	111.55702	6	126.79705	6	142.03708
7	81.38176	7	96.62179	7	111.86182	7	127.10185	7	142.34188
8	81.68656	8	96.92659	8	112.16662	8	127.40665	8	142.64669
9	81.99136	9	97.23139	9	112.47142	9	127.71146	9	142.95149
270	82.29616	320	97.53620	370	112.77623	420	128.01626	470	143.25629
1	82.60097	1	97.84100	1	113.08103	1	128.32106	1	143.56109
2	82.90577	2	98.14580	2	113.38583	2	128.62586	2	143.86589
3	83.21057	3	98.45060	3	113.69063	3	128.93066	3	144.17069
4	83.51537	4	98.75540	4	113.99543	4	129.23546	4	144.47549
5	83.82017	5	99.06020	5	114.30023	5	129.54026	5	144.78029
6	84.12497	6	99.36500	6	114.60503	6	129.84506	6	145.08509
7	84.42977	7	99.66980	7	114.90983	7	130.14986	7	145.38989
8	84.73457	8	99.97460	8	115.21463	8	130.45466	8	145.69469
9	85.03927	9	100.27940	9	115.51943	9	130.75946	9	145.99949
280	85.34417	330	100.58420	380	115.82423	430	131.06426	480	146.30429
1	85.64897	1	100.88900	1	116.12903	1	131.36906	1	146.60909
2	85.95377	2	101.19380	2	116.43383	2	131.67386	2	146.91389
3	86.25857	3	101.49860	3	116.73863	3	131.97866	3	147.21869
4	86.56337	4	101.80340	4	117.04343	4	132.28346	4	147.52350
5	86.86817	5	102.10820	5	117.34823	5	132.58827	5	147.82830
6	87.17297	6	102.41300	6	117.65304	6	132.89307	6	148.13310
7	87.47777	7	102.71781	7	117.95784	7	133.19787	7	148.43790
8	87.78258	8	103.02261	8	118.26264	8	133.50267	8	148.74270
9	88.08738	9	103.32741	9	118.56744	9	133.80747	9	149.04750
290	88.39218	340	103.63221	390	118.87224	440	134.11227	490	149.35230
1	88.69698	1	103.93701	1	119.17704	1	134.41707	1	149.65710
2	89.00178	2	104.24181	2	119.48184	2	134.72187	2	149.96190
3	89.30658	3	104.54661	3	119.78664	3	135.02667	3	150.26670
4	89.61138	4	104.85141	4	120.09144	4	135.33147	4	150.57150
5	89.91618	5	105.15621	5	120.39624	5	135.63627	5	150.87630
6	90.22098	6	105.46101	6	120.70104	6	135.94107	6	151.18110
7	90.52578	7	105.76581	7	121.00584	7	136.24587	7	151.48590
8	90.83058	8	106.07061	8	121.31064	8	136.55067	8	151.79070
9	91.13538	9	106.37541	9	121.61544	9	136.85547	9	152.09550

Table A-14. Conversion of feet to meters (continued)

Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
500	152.40030	550	167.64034	600	182.88037	650	198.12040	700	213.36043
1	152.70511	1	167.94514	1	183.18517	1	198.42520	1	213.66523
2	153.00991	2	168.24994	2	183.48997	2	198.73000	2	213.97003
3	153.31471	3	168.55474	3	183.79477	3	199.03480	3	214.27483
4	153.61951	4	168.85954	4	184.09957	4	199.33960	4	214.57963
5	153.92431	5	169.16434	5	184.40437	5	199.64440	5	214.88443
6	154.22911	6	169.46914	6	184.70917	6	199.94920	6	215.18923
7	154.53391	7	169.77394	7	185.01397	7	200.25400	7	215.49403
8	154.83871	8	170.07874	8	185.31877	8	200.55880	8	215.79883
9	155.14351	9	170.38354	9	185.62357	9	200.86360	9	216.10363
510	155.44831	560	170.68834	610	185.92837	660	201.16840	710	216.40843
1	155.75311	1	170.99314	1	186.23317	1	201.47320	1	216.71323
2	156.05791	2	171.29794	2	186.53797	2	201.77800	2	217.01803
3	156.36271	3	171.60274	3	186.84277	3	202.08280	3	217.32283
4	156.66751	4	171.90754	4	187.14757	4	202.38760	4	217.62764
5	156.97231	5	172.21234	5	187.45237	5	202.69241	5	217.93244
6	157.27711	6	172.51715	6	187.75718	6	202.99721	6	218.23724
7	157.58192	7	172.82195	7	188.06198	7	203.30201	7	218.54204
8	157.88672	8	173.12675	8	188.36678	8	203.60681	8	218.84684
9	158.19152	9	173.43155	9	188.67158	9	203.91161	9	219.15164
520	158.49632	570	173.73635	620	188.97638	670	204.21641	720	219.45644
1	158.80112	1	174.04115	1	189.28118	1	204.52121	1	219.76124
2	159.10592	2	174.34595	2	189.58598	2	204.82601	2	220.06604
3	159.41072	3	174.65075	3	189.89078	3	205.13081	3	220.37084
4	159.71552	4	174.95555	4	190.19558	4	205.43561	4	220.67564
5	160.02032	5	175.26035	5	190.50038	5	205.74041	5	220.98044
6	160.32512	6	175.56515	6	190.80518	6	206.04521	6	221.28524
7	160.62992	7	175.86995	7	191.10998	7	206.35001	7	221.59004
8	160.93472	8	176.17475	8	191.41478	8	206.65481	8	221.89484
9	161.23952	9	176.47955	9	191.71958	9	206.95961	9	222.19964
530	161.54432	580	176.78435	630	192.02438	680	207.26441	730	222.50445
1	161.84912	1	177.08915	1	192.32918	1	207.56922	1	222.80925
2	162.15392	2	177.39395	2	192.63399	2	207.87402	2	223.11405
3	162.45872	3	177.69876	3	192.93879	3	208.17882	3	223.41885
4	162.76353	4	178.00356	4	193.24359	4	208.48362	4	223.72365
5	163.06833	5	178.30836	5	193.54839	5	208.78842	5	224.02845
6	163.37313	6	178.61316	6	193.85319	6	209.09322	6	224.33325
7	163.67793	7	178.91796	7	194.15799	7	209.39802	7	224.63805
8	163.98273	8	179.22276	8	194.46279	8	209.70282	8	224.94285
9	164.28753	9	179.52756	9	194.76759	9	210.00762	9	225.24765
540	164.59233	590	179.83236	640	195.07239	690	210.31242	740	225.55245
1	164.89713	1	180.13716	1	195.37719	1	210.61722	1	225.85725
2	165.20193	2	180.44196	2	195.68199	2	210.92202	2	226.16205
3	165.50673	3	180.74676	3	195.98679	3	211.22682	3	226.46685
4	165.81153	4	181.05156	4	196.29159	4	211.53162	4	226.77165
5	166.11633	5	181.35636	5	196.59639	5	211.83642	5	227.07645
6	166.42113	6	181.66116	6	196.90119	6	212.14122	6	227.38125
7	166.72593	7	181.96596	7	197.20599	7	212.44602	7	227.68606
8	167.03073	8	182.27076	8	197.51080	8	212.75083	8	227.99086
9	167.33553	9	182.57557	9	197.81560	9	213.05563	9	228.29566

Table A-14. Conversion of feet to meters (continued)

Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
750	228.60046	800	243.84049	850	259.08052	900	274.32055	950	289.56058
1	228.90526	1	244.14529	1	259.38532	1	274.62535	1	289.86538
2	229.21006	2	244.45009	2	259.69012	2	274.93015	2	290.17018
3	229.51486	3	244.75489	3	259.99492	3	275.23495	3	290.47498
4	229.81966	4	245.95969	4	260.29972	4	275.53975	4	290.77978
5	230.12446	5	245.36449	5	260.60452	5	275.84455	5	291.98458
6	230.42926	6	245.66929	6	260.90932	6	276.14935	6	291.38938
7	230.73406	7	245.97409	7	261.21412	7	276.45415	7	291.69418
8	231.03886	2	246.27889	8	261.51892	8	276.75895	8	291.99898
9	231.34366	9	246.58369	9	261.82372	9	277.06375	9	292.30378
760	231.64846	810	246.88849	860	262.12852	910	277.36855	960	292.60859
1	231.95326	1	247.19329	1	262.43332	1	277.67336	1	292.91339
2	232.25806	2	247.49809	2	262.73813	2	277.97816	2	293.21819
3	232.56287	3	247.80290	3	263.04293	3	278.28296	3	293.52299
4	232.86767	4	248.10770	4	263.34773	4	278.58776	4	293.82779
5	233.17247	5	248.41250	5	263.65253	5	278.89256	5	294.13259
6	233.47727	6	248.71730	6	263.95733	6	279.19736	6	294.43739
7	233.78207	7	249.02210	7	264.26213	7	279.50216	7	294.74219
8	234.08687	8	249.32690	8	264.56693	8	279.80696	8	295.04699
9	234.39167	9	249.63170	9	264.87173	9	280.11176	9	295.35179
770	234.69647	820	249.93650	870	265.17653	920	280.41656	970	295.65659
1	235.00127	1	250.24130	1	265.48133	1	280.72136	1	295.96139
2	235.30607	2	250.54610	2	265.78613	2	281.02616	2	296.26619
3	235.61087	3	250.85090	3	266.09092	3	281.33096	3	296.57099
4	235.91567	4	251.15570	4	266.39573	4	281.63576	4	296.87579
5	236.22047	5	251.46050	5	266.70053	5	281.94056	5	297.18059
6	236.52527	6	251.76530	6	267.00533	6	282.24536	6	297.48539
7	236.83007	7	252.07010	7	267.31013	7	282.55017	7	297.79020
8	237.13487	8	252.37490	8	267.61494	8	282.85497	8	298.09500
9	247.43967	9	252.67971	9	267.91974	9	283.15977	9	298.39980
780	237.74448	830	252.98451	880	268.22454	930	283.46457	980	298.70460
1	238.04928	1	253.28931	1	268.52934	1	283.76937	1	299.00940
2	238.35408	2	253.59411	2	268.83414	2	284.07417	2	299.31420
3	238.65888	3	253.89891	3	269.13894	3	284.37897	3	299.61900
4	238.96368	4	254.20371	4	269.44374	4	284.68377	4	299.92380
5	239.26848	5	254.50851	5	269.74854	5	284.98857	5	300.22860
6	239.57328	6	254.81331	6	270.05334	6	285.29337	6	300.53340
7	239.87808	7	255.11811	7	270.35814	7	285.59817	7	300.83820
8	240.18288	8	255.42291	8	270.66294	8	285.90297	8	301.14300
9	240.48768	9	255.72771	9	270.96774	9	286.20777	9	301.44780
790	240.79248	840	256.03251	890	271.27254	940	286.51257	990	301.75260
1	241.09728	1	256.33731	1	271.57734	1	286.81737	1	302.05740
2	241.40208	2	256.64211	2	271.88214	2	287.12217	2	302.36220
3	241.70688	3	256.94691	3	272.18694	3	287.42697	3	302.66701
4	242.01168	4	257.25171	4	272.49174	4	287.73178	4	302.97181
5	242.31648	5	257.55652	5	272.79655	5	288.03658	5	303.27661
6	242.62129	6	257.86132	6	273.10135	6	288.34138	6	303.58141
7	242.92609	7	258.16612	7	273.40615	7	288.64618	7	303.88621
8	243.23089	8	248.47092	8	273.71095	8	288.95098	8	304.19101
9	243.53569	9	258.77572	9	274.01575	9	289.25578	9	304.49581

APPENDIX B

SAMPLE NOTES (CONSTRUCTION SURVEY)

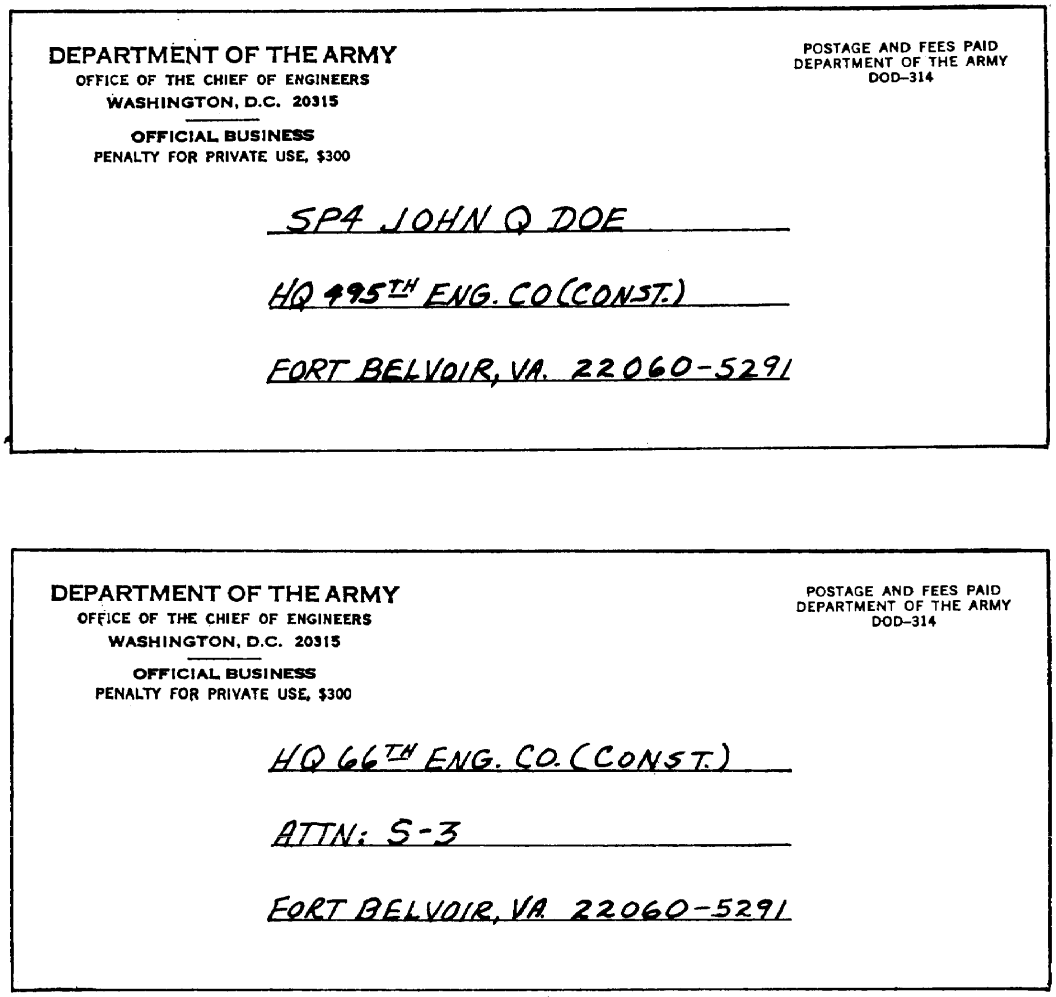
LIST OF FIGURES

INTRODUCTION

Keeping good notes is not only an art, it is a science as well. Notes must not only be legible, but also correct and 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 decide which 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, sketch, or remark is necessary and wil contribute to the completeness of the notes. On the following pages are samples of notes which the construction surveyor may be required to keep. They are only samples of how they may be kept, not of how they must be kept. When assigned to a unit in the field, you will determine what to record and how to do it. Most of the time, the chief of the party will prescribe how notes on the project are to be kept. Above all, decide on your notekeeping procedures and format before you go out on your survey. Your headings, members of party, instrument identification, and weatherman all be entered before you leave for the field.

LABELING AND MAILING PROCEDURES

The surveyor normally fills out the mailing label in front of the notebook to the unit conducting the project(s) (figure B-l).



DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20315

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE ARMY
DOD-314

SP4 JOHN Q DOE
HQ 495TH ENG. CO (CONST.)
FORT BELVOIR, VA. 22060-5291

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20315

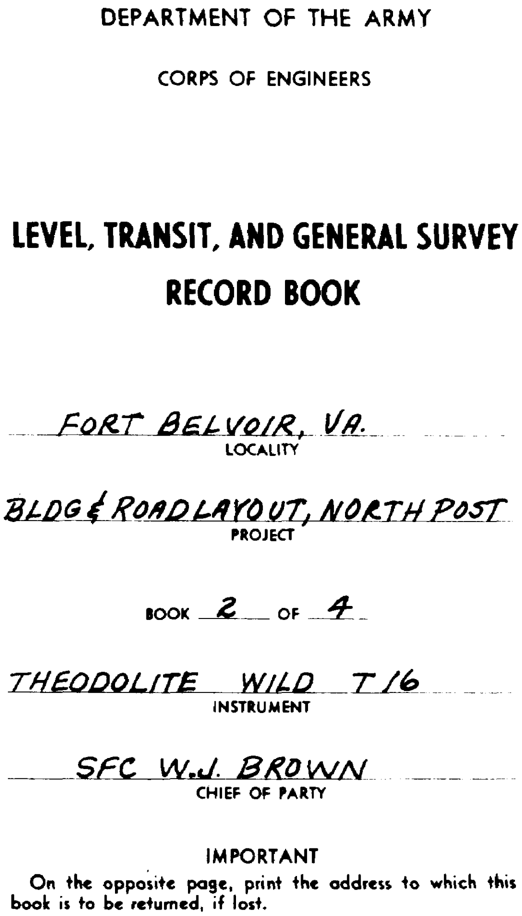
OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE ARMY
DOD-314

HQ 66TH ENG. CO. (CONST.)
ATTN: S-3
FORT BELVOIR, VA 22060-5291

Figure B-1. Mailing label

The front page is to be filled out as required by the unit (figure B-2).



DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

LEVEL, TRANSIT, AND GENERAL SURVEY
RECORD BOOK

FORT BELVOIR, VA.
LOCALITY

BLDG & ROAD LAYOUT, NORTH POST
PROJECT

BOOK 2 OF 4

THEODOLITE WILD T16
INSTRUMENT

SFC W.J. BROWN
CHIEF OF PARTY

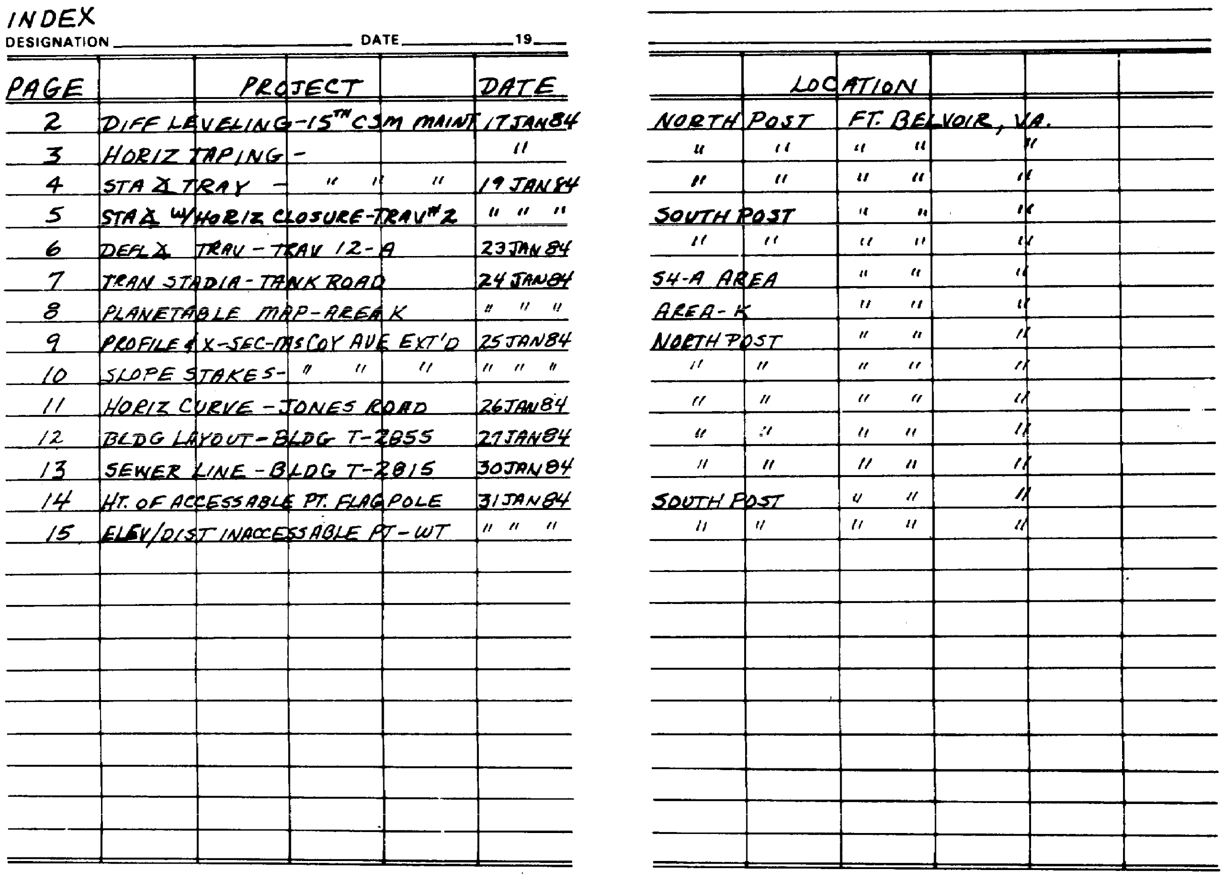
IMPORTANT

On the opposite page, print the address to which this book is to be returned, if lost.

Figure B-2. Front page of notebook

SURVEY NOTES

The backsight (BS) and foresight (FS) distances are determined by stadia and should be balanced. A page check (PC) is made (figure B-3) for each page. REMEMBER: Page checks only check the accuracy of your mathematics, not the accuracy of the survey.



INDEX

DESIGNATION ______ DATE ______ 19__

PAGE	PROJECT	DATE	LOCATION
2	DIFF LEVELING-15TH CSM MAINT	17JAN84	NORTH POST FT. BELVOIR, VA.
3	HORIZ TAPING -	"	" " " " "
4	STA ∡ TRAY - " " "	19 JAN 84	" " " " "
5	STA ∡ W/HORIZ CLOSURE-TRAV #2	" " "	SOUTH POST " " "
6	DEFL ∡ TRAV - TRAV 12-A	23JAN84	" " " " "
7	TRAN STADIA-TANK ROAD	24JAN84	54-A AREA " " "
8	PLANETABLE MAP-AREA K	" " "	AREA-K " " "
9	PROFILE & X-SEC-MSCOY AVE EXT'D	25JAN84	NORTH POST " " "
10	SLOPE STAKES- " " "	" " "	" " " " "
11	HORIZ CURVE - JONES ROAD	26JAN84	" " " " "
12	BLDG LAYOUT-BLDG T-2855	27JAN84	" " " " "
13	SEWER LINE - BLDG T-2815	30JAN84	" " " " "
14	HT. OF ACCESSABLE PT. FLAGPOLE	31JAN84	SOUTH POST " " "
15	ELEV/DIST INACCESSABLE PT - WT	" " "	" " " " "

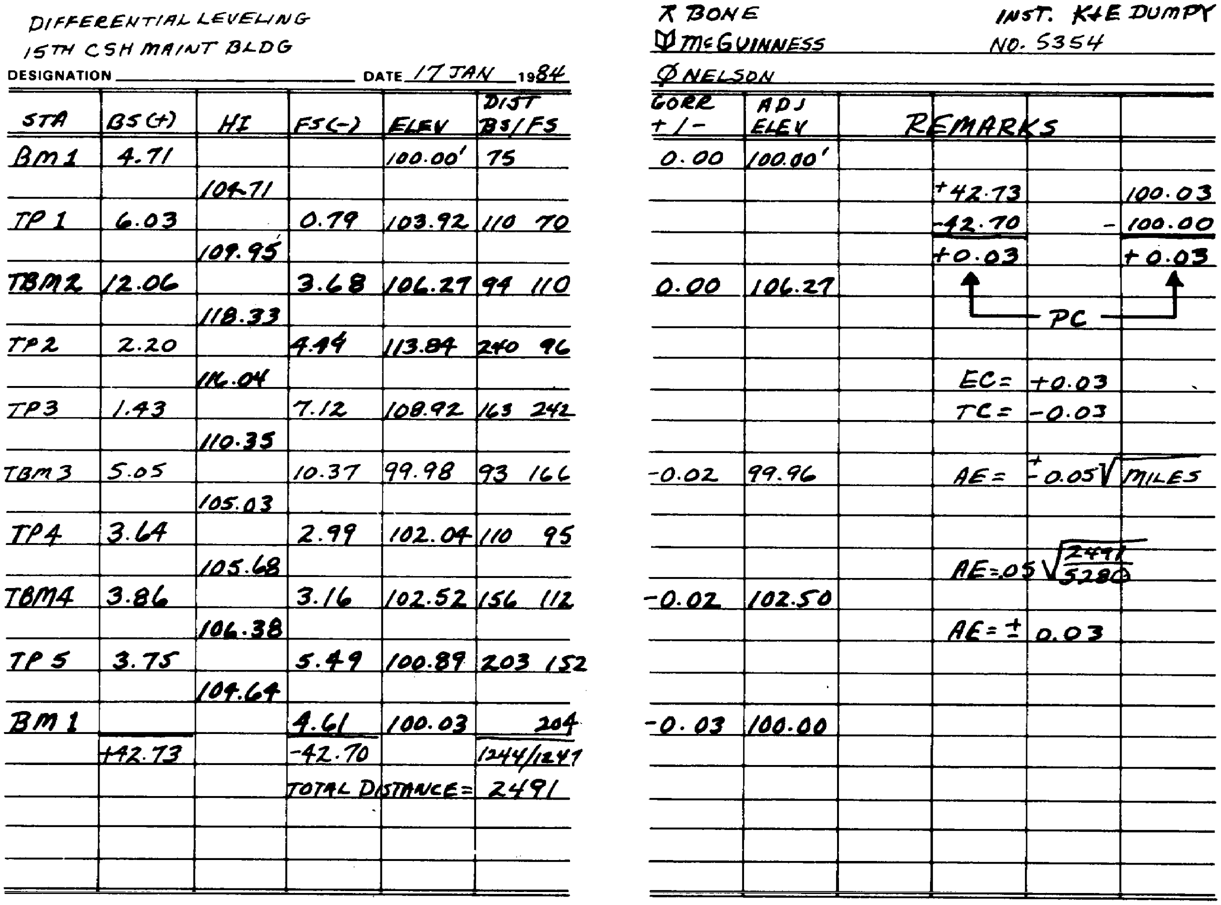
Figure B-3. Index

The error of closure (EC) is equal to the computed elevation minus the starting or fixed elevation. For total correction (TC), change the sign of the EC. The allowable error (AE) maybe given in the project specifications. The following formulas can be used when the BS and FS distances are balanced as near as possible.

For normal construction work — AE = ± 0.1 ft miles or ± 24mm kilometers

Third order (figure B-4) — AE = ± 0.05 ft miles or ± 12mm kilometers

Elevations for fixed points are adjusted by dividing the TC by the total distance and multiplying the result by the distance from the beginning station to the station being adjusted. This value is then algebraically added to the station's computed elevation.



DIFFERENTIAL LEVELING
15TH CSH MAINT BLDG
DESIGNATION ____ DATE 17 JAN 1984

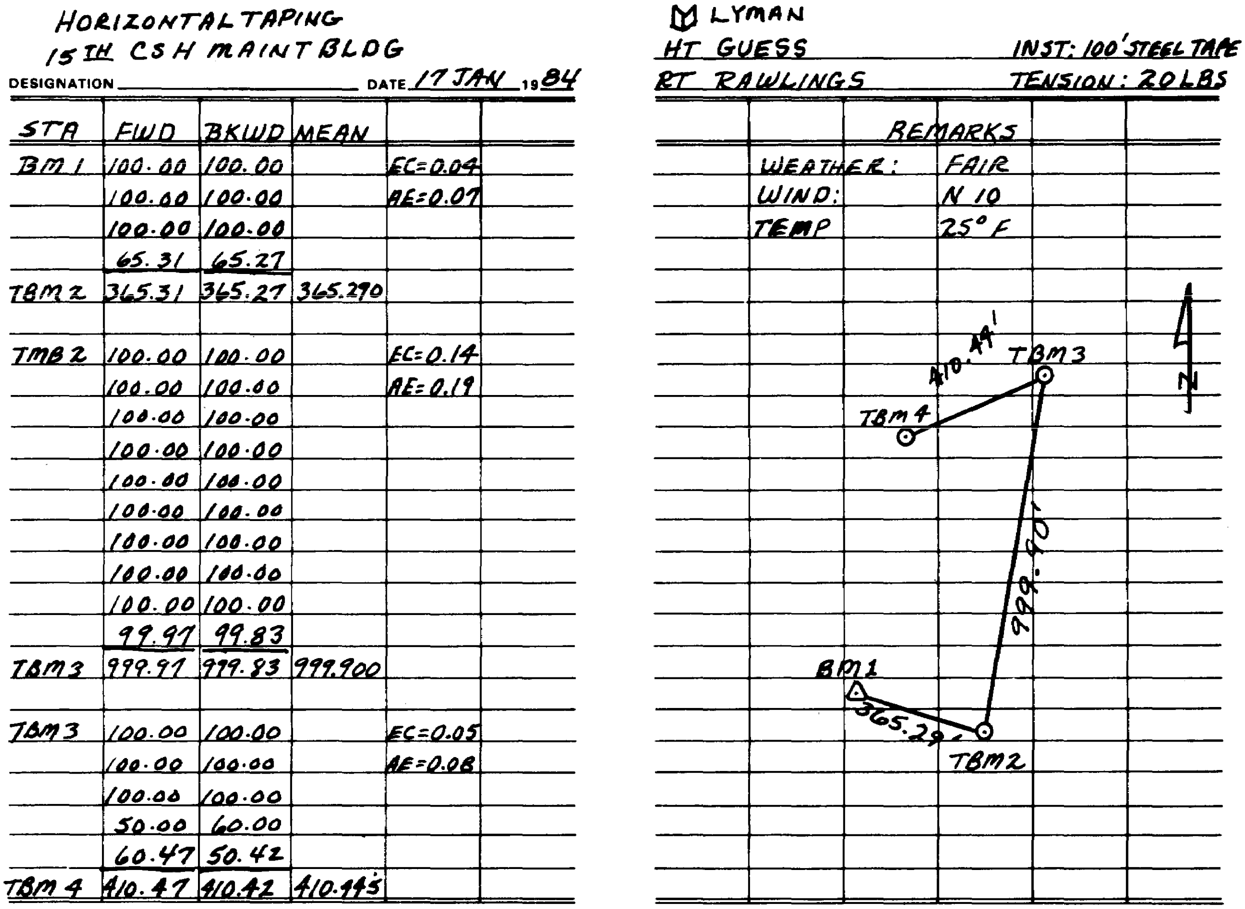
STA	BS (+)	HI	FS (-)	ELEV	DIST BS/FS
BM 1	4.71			100.00'	75
		104.71			
TP 1	6.03		0.79	103.92	110 70
		109.95			
TBM2	12.06		3.68	106.27	94 110
		118.33			
TP2	2.20		4.44	113.84	240 96
		116.04			
TP3	1.43		7.12	108.92	163 242
		110.35			
TBM3	5.05		10.37	99.98	93 166
		105.03			
TP4	3.64		2.99	102.04	110 95
		105.68			
TBM4	3.86		3.16	102.52	156 112
		106.38			
TP 5	3.75		5.49	100.89	203 152
		104.64			
BM 1			4.61	100.03	204
	+42.73		-42.70		1244/1247
			TOTAL DISTANCE=		2491

⊼ BONE INST. K+E DUMPY
Ψ McGUINNESS NO. 5354
Ø NELSON

CORR +/-	ADJ ELEV		REMARKS		
0.00	100.00'				
			+42.73		100.03
			-42.70	-	100.00
			+0.03		+0.03
0.00	106.27		↑		↑
				PC	
			EC=	+0.03	
			TC=	-0.03	
-0.02	99.96		AE=	$\pm 0.05\sqrt{MILES}$	
			AE=.05	$\sqrt{\frac{2491}{5280}}$	
-0.02	102.50				
			AE=±	0.03	
-0.03	100.00				

Figure B-4. Differential leveling

This set of horizontal taping notes (figure B-5) shows the proper way to record distances between points. The lines are taped in both the forward (FWD) and backward (BKWD) direction. The difference between the forward and backward total distances equals the error of closure (EC). The allowable error (AE) is computed by dividing the mean distance (MEAN) by 5,000. Do not round the AE up. This AE will give an accuracy ratio of 1 in 5,000 or third order accuracy. The AE must equal or exceed the EC for the taping to be acceptable.



HORIZONTAL TAPING
15TH CSH MAINT BLDG
DESIGNATION ______ DATE 17 JAN 1984

STA	FWD	BKWD	MEAN		
BM 1	100.00	100.00		EC=0.04	
	100.00	100.00		AE=0.07	
	100.00	100.00			
	65.31	65.27			
TBM 2	365.31	365.27	365.290		
TMB 2	100.00	100.00		EC=0.14	
	100.00	100.00		AE=0.19	
	100.00	100.00			
	100.00	100.00			
	100.00	100.00			
	100.00	100.00			
	100.00	100.00			
	100.00	100.00			
	100.00	100.00			
	99.97	99.83			
TBM 3	999.97	999.83	999.900		
TBM 3	100.00	100.00		EC=0.05	
	100.00	100.00		AE=0.08	
	100.00	100.00			
	50.00	60.00			
	60.47	50.42			
TBM 4	410.47	410.42	410.445		

LYMAN
HT GUESS INST: 100' STEEL TAPE
RT RAWLINGS TENSION: 20 LBS

		REMARKS			
	WEATHER:		FAIR		
	WIND:		N 10		
	TEMP		25° F		

Figure B-5. Horizontal taping

The station angles in figure B-6 were first measured with the instrument's telescope in the direct (D) position. The angle is then doubled by measuring it again with the telescope in the reverse (R) position. The mean angle (MEAN) is found by dividing the R value by 2. The mean angle must be within ± 30 seconds of the D value. The total of the mean angles should equal N-2(180 degrees); N is the number of station angles within the loop traverse. When using a one-minute instrument, an error of ± 30 seconds per station angle is acceptable. The distances recorded were obtained by a separate survey and copied here for completeness.

STATION ANGLE TRAVERSE
16TH CSH MAINT BLDG

DESIGNATION ______ DATE 19 JAN 1984

STA	TEL	STA	∡	MEAN	DIST
⊙4 ← △1	D	98°	03'		
				98°02'30"	365.29'
⊙2	R	196°	05'		
△1 ← ⊙2	D	80°	30'		
				80°30'00"	999.90'
⊙3	R	161°	00'		
⊙2 ← ⊙3	D	56°	58'		
				56°58'30"	410.44'
⊙4	R	113°	57'		
⊙3 ← ⊙4	D	124°	30'		
				124°29'30"	715.03'
△1	R	248°	59'		
			TOTAL	360'00'30"	

⊼ GLEASON
BLANTON INST: WILD T-16
Ø PATTON NO: 12683

REMARKS

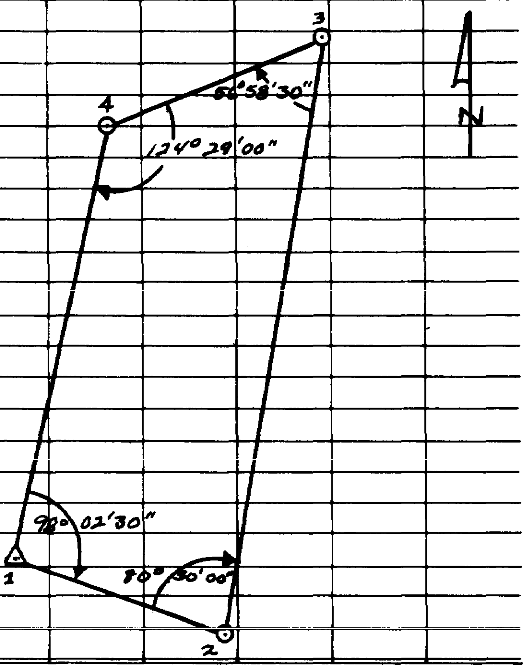
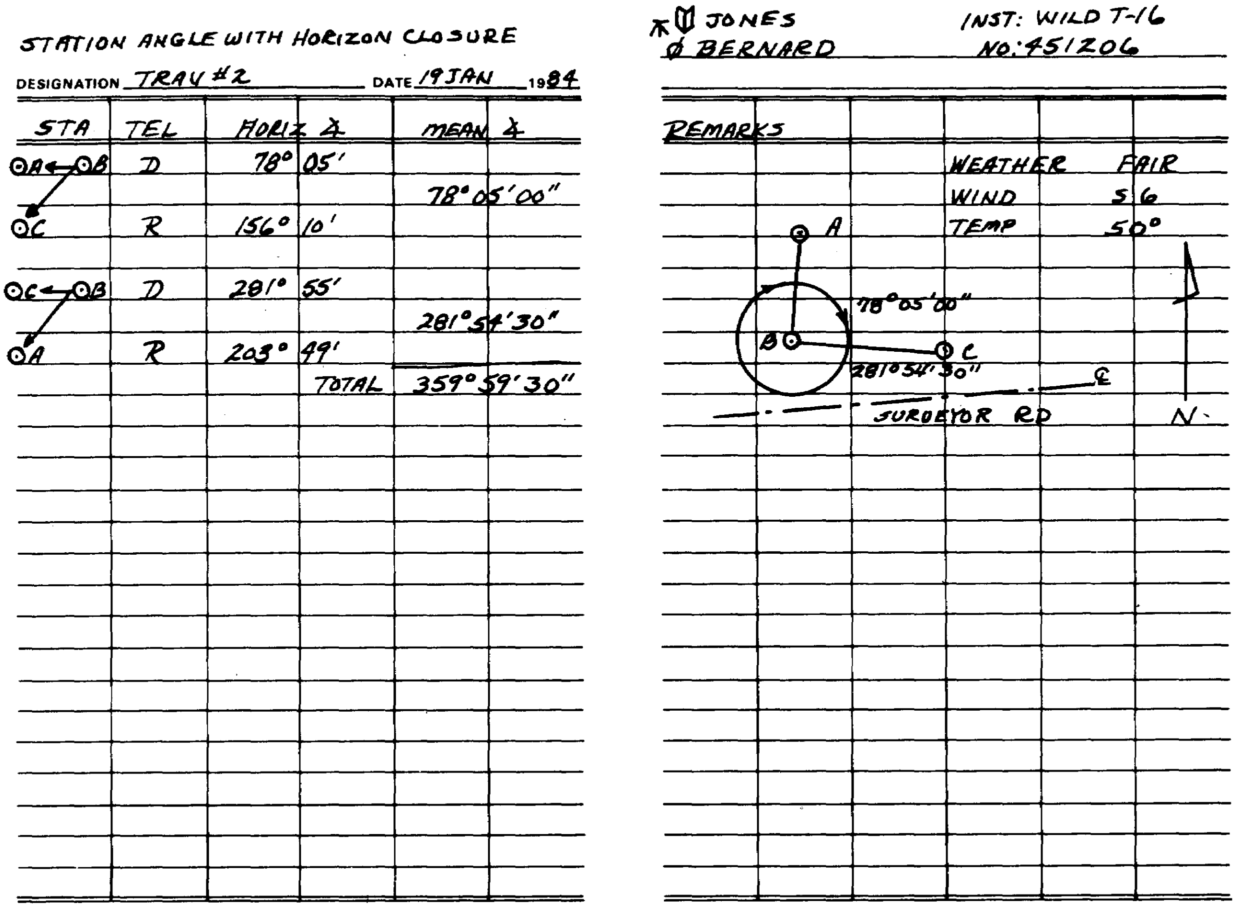


Figure B-6. Station angle traverse

The station angle in figure B-7 was measured as described on the preceding page. The explement angle is similarly measured and meaned, thus closing the horizon.

Note: When the explement angle was measured in direct (D), its value exceeded 180 degrees. To compute the MEAN first, add 360 degrees to the reverse (R) value and divide the result by 2.

Any mean angle must be within ± 30 seconds of its D value. The total of both MEAN angles for a station must be within ± 30 seconds of 360 degrees to be acceptable.



STATION ANGLE WITH HORIZON CLOSURE

DESIGNATION TRAV #2 DATE 19 JAN 1984

STA	TEL	HORIZ ∠		MEAN ∠
⊙A ← ⊙B	D	78°	05'	
				78°05'00"
⊙C	R	156°	10'	
⊙C ← ⊙B	D	281°	55'	
				281°54'30"
⊙A	R	203°	49'	
			TOTAL	359°59'30"

JONES
Ø BERNARD

INST: WILD T-16
NO: 451206

REMARKS

WEATHER	FAIR
WIND	S 6
TEMP	50°

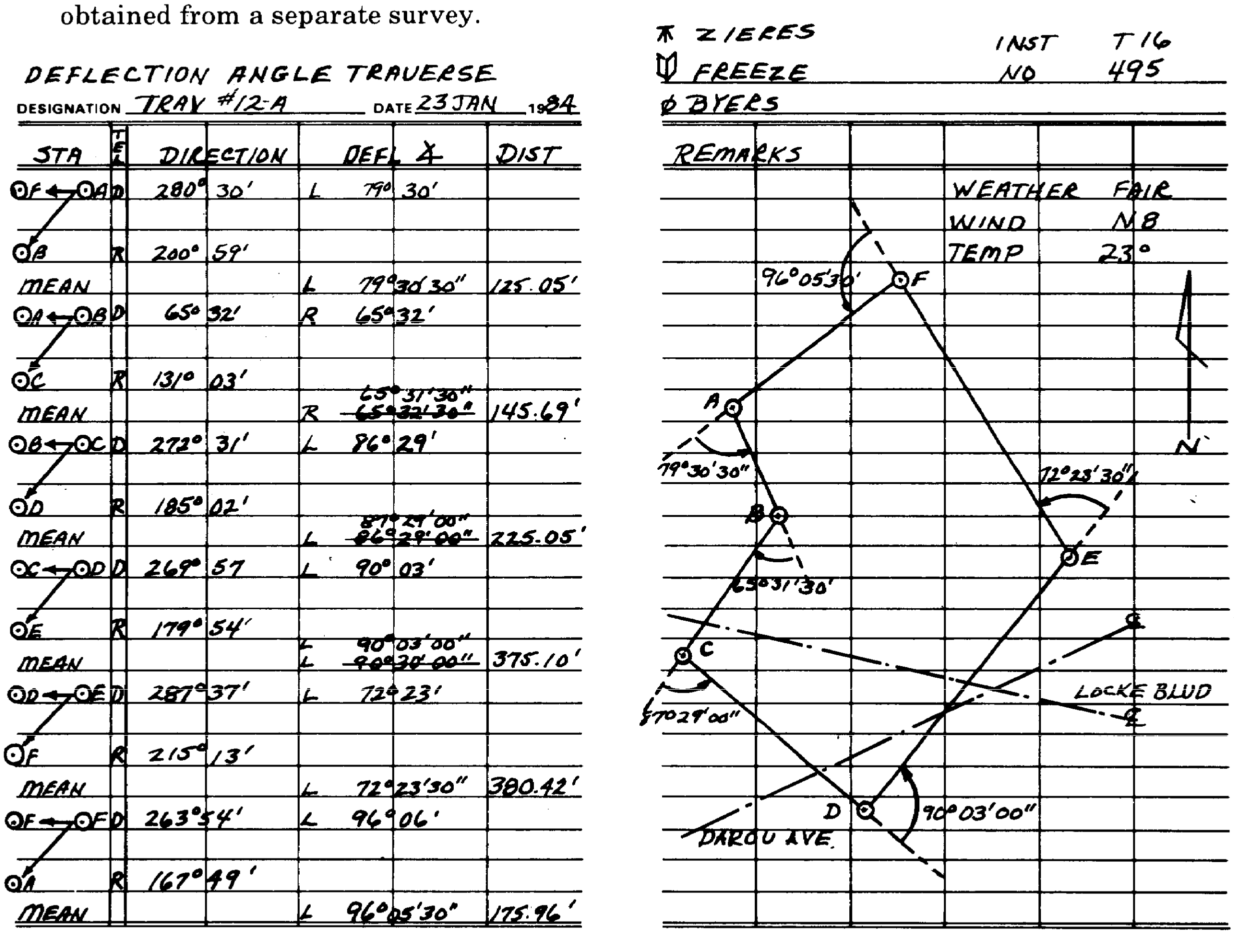
Figure B-7. Station angle with horizon closure

Figure B-8 shows deflection angles. When the direct (D) value for direction exceeds 180 degrees—

- The deflection angle is computed by subtracting the D value from 360 degrees. The difference is a left deflection angle and is preceded by the letter L.
- The mean deflection angle is computed by subtracting the reverse (R) value from 360 degrees and dividing the difference by 2. The mean deflection angle is also preceded by the letter L.

When the direct (D) value for direction is less than 180 degrees—

- The deflection angle is the same as the D value and is preceded by the R for right deflection angle.
- The mean deflection angle is computed by dividing the reverse (R) value by 2. The mean deflection angle is also preceded by the letter R. Deflection angles never exceed 180 degrees. Any mean deflection angle must be with ±30 seconds of its D value. The distances (DIST) were obtained from a separate survey.



DEFLECTION ANGLE TRAVERSE

DESIGNATION TRAV #12-A DATE 23 JAN 1984

STA	TEL	DIRECTION		DEFL ∡			DIST
⊙F ← ⊙A	D	280°	30'	L	79°	30'	
⊙B	R	200°	59'				
MEAN				L	79°	30'30"	125.05'
⊙A ← ⊙B	D	65°	32'	R	65°	32'	
⊙C	R	131°	03'				
MEAN				R	65°31'30" ~~65°32'30"~~		145.69'
⊙B ← ⊙C	D	272°	31'	L	86°	29'	
⊙D	R	185°	02'				
MEAN				L	87°29'00" ~~86°29'00"~~		225.05'
⊙C ← ⊙D	D	269°	57	L	90°	03'	
⊙E	R	179°	54'				
MEAN				L L	90°03'00" ~~90°30'00"~~		375.10'
⊙D ← ⊙E	D	287°	37'	L	72°	23'	
⊙F	R	215°	13'				
MEAN				L	72°	23'30"	380.42'
⊙F ← ⊙F	D	263°	54'	L	96°	06'	
⊙A	R	167°	49'				
MEAN				L	96°	05'30"	175.96'

⊼ ZIERES INST T16
Ѱ FREEZE NO 495
ϕ BYERS

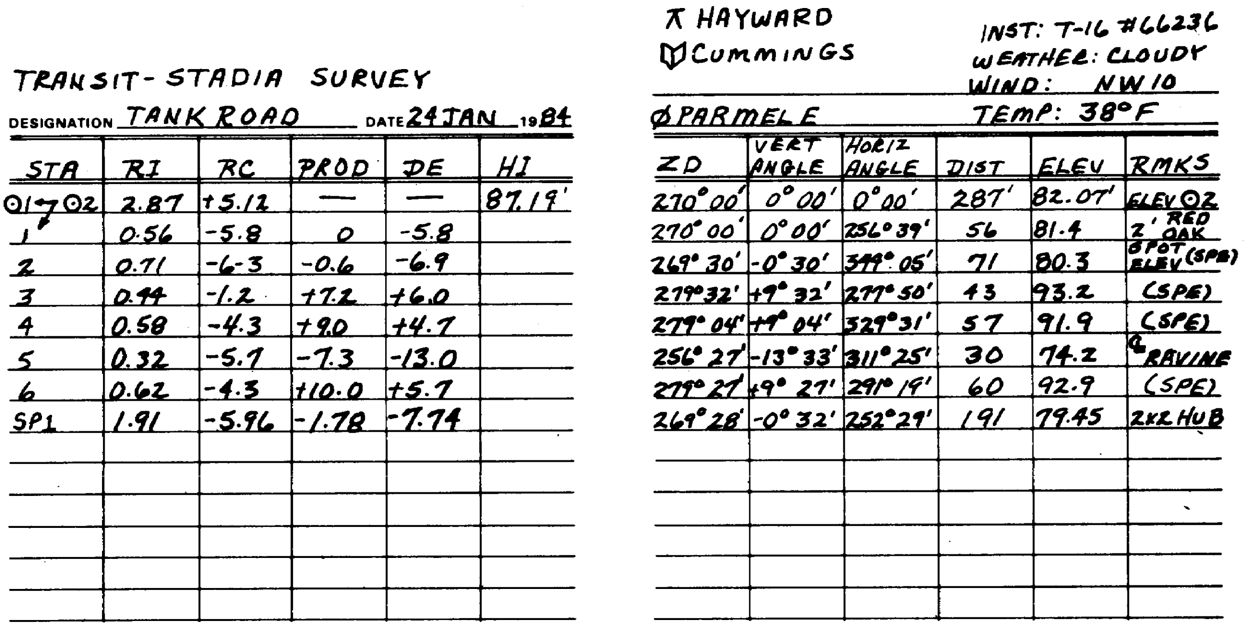
REMARKS

WEATHER FAIR
WIND N8
TEMP 23°

Figure B-8. Deflection angle traverse

The rod intercept (RI) is the difference between the top and bottom stadia crosshairs. The rod correction (RC) is the value of the center crosshair rod reading. Figure B-9 shows notes for RI and RC.

Product (PROD) is determined by multiplying the RI by the difference in elevation value extracted from table A-2 using the vertical angle as the argument. For level shots, the PROD is zero. The PROD can also be computed using the formula: PROD = (RI x 100) ½ Sin 2 Vertical Angle. The PROD has the opposite sign of the vertical angle when backlighting and the same sign when foresighting. Difference in elevation (DE) is determined by algebraically adding the RC to the PROD. Height of instrument is determined by making a level backsight to a point and adding the RC to the point's known elevation or by determining the vertical angle and the RC, computing the PROD and the DE, then algebraically adding the DE to the known elevation. Zenith distance (ZD) is the angular value between zenith and the RC. Vertical angle (VERT ANGLE) is the angular value between a level line of sight and the RC. Its value and sign are determined by subtracting 270 degrees from the ZD. Horizontal angle (HORIZ ANGLE) is the angle from a beginning reference point to the observed point. Horizontal distance (DIST) is determined for level shots by multiplying the RI by 100. For inclined shots, multiply the RI times the horizontal distance value from table A-2 using the vertical angle as the argument. The DIST can also be computed using the formula: Horizontal Distance = (RI x 100) Cos^2 Vertical Angle. ELEV is the elevation of the station. When not given, it is determined by algebraically adding the DE to the HI. Remarks (RMKS) is used to give a brief description of the occupied or observed station.



TRANSIT-STADIA SURVEY

DESIGNATION TANK ROAD DATE 24 JAN 19 84

STA	RI	RC	PROD	DE	HI
⊙1→⊙2	2.87	+5.12	—	—	87.19'
1	0.56	-5.8	0	-5.8	
2	0.71	-6.3	-0.6	-6.9	
3	0.44	-1.2	+7.2	+6.0	
4	0.58	-4.3	+9.0	+4.7	
5	0.32	-5.7	-7.3	-13.0	
6	0.62	-4.3	+10.0	+5.7	
SP1	1.91	-5.96	-1.78	-7.74	

⊼ HAYWARD
▽ CUMMINGS

INST: T-16 #66236
WEATHER: CLOUDY
WIND: NW 10

Ø PARMELE

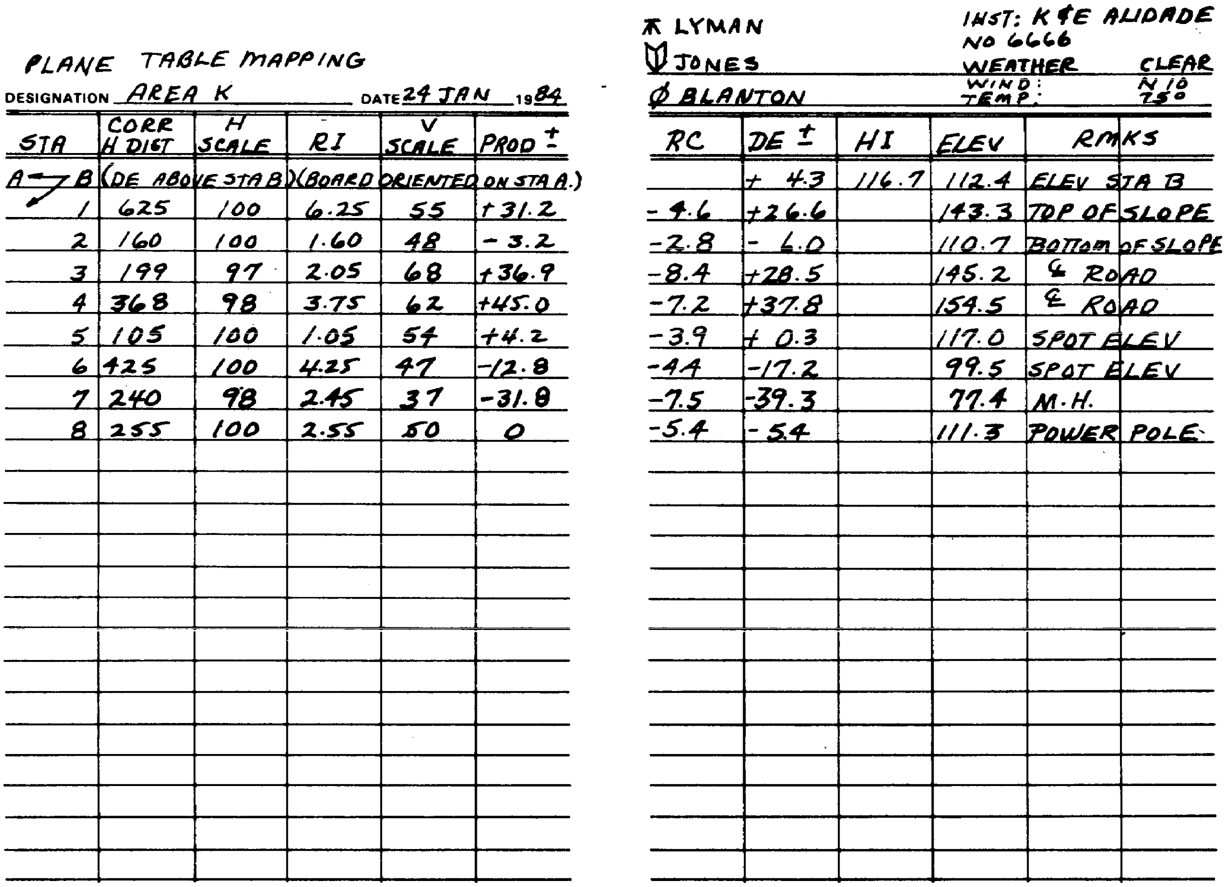
TEMP: 38°F

ZD	VERT ANGLE	HORIZ ANGLE	DIST	ELEV	RMKS
270° 00'	0° 00'	0° 00'	287'	82.07'	ELEV ⊙2
270° 00'	0° 00'	256° 39'	56	81.4	2' RED OAK
269° 30'	-0° 30'	349° 05'	71	80.3	SPOT ELEV (SPE)
279° 32'	+9° 32'	277° 50'	43	93.2	(SPE)
279° 04'	+9° 04'	329° 31'	57	91.9	(SPE)
256° 27'	-13° 33'	311° 25'	30	74.2	℄ RAVINE
279° 27'	+9° 27'	291° 19'	60	92.9	(SPE)
269° 28'	-0° 32'	252° 29'	191	79.45	2x2 HUB

Figure B-9. Transit-stadia survey

Correct horizontal distance (CORR H DIST) is determined by multiplying the H SCALE by the RI (figure B-10).

Horizontal scale (H SCALE) is read directly on the alidade. Rod intercept (RI) is the difference between the top and bottom crosshairs.
Vertical scale (V SCALE) is read directly on the alidade.
Product (PROD ±) is determined by subtracting 50 from the V-SCALE reading and multiplying the result by the RI.
Rod correction (RC) is the value of the center crosshair rod reading. The RC is always negative when foresighting.
Difference in elevation (DE) is determined by algebraically adding the (PROD ±) to the RC.
Height of instrument (HI) can be determined by measuring the DE above the occupied station or by making a level backsight to station of known elevation. The RC is positive when backlighting.
Elevation (ELEV) is the elevation of the station. When not given, it is determined by algebraically adding the DE to the HI.
Remarks (RMKS) is used to give a brief description of the occupied or observed station.



PLANE TABLE MAPPING

DESIGNATION AREA K DATE 24 JAN 1984

⊼ LYMAN
Ʊ JONES
Ø BLANTON

INST: K&E ALIDADE NO 6666
WEATHER CLEAR
WIND: N 10
TEMP: 75°

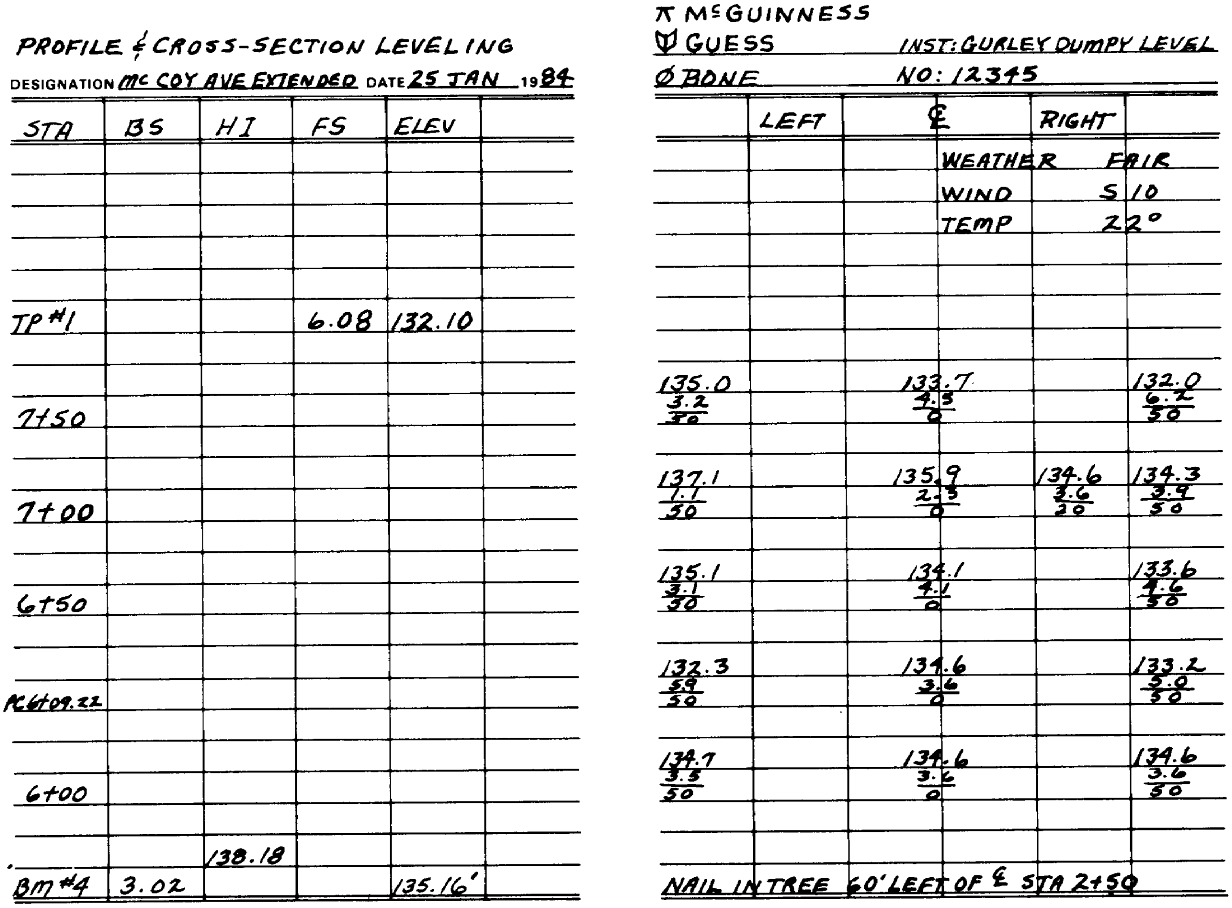
STA	CORR H DIST	H SCALE	$\overline{RI}$	V SCALE	PROD ±	RC	DE ±	HI	ELEV	RMKS
A → B	(DE ABOVE STA B)(BOARD ORIENTED ON STA A.)						+ 4.3	116.7	112.4	ELEV STA B
1	625	100	6.25	55	+31.2	-4.6	+26.6		143.3	TOP OF SLOPE
2	160	100	1.60	48	- 3.2	-2.8	- 6.0		110.7	BOTTOM OF SLOPE
3	199	97	2.05	68	+36.9	-8.4	+28.5		145.2	℄ ROAD
4	368	98	3.75	62	+45.0	-7.2	+37.8		154.5	℄ ROAD
5	105	100	1.05	54	+4.2	-3.9	+ 0.3		117.0	SPOT ELEV
6	425	100	4.25	47	-12.8	-4.4	-17.2		99.5	SPOT ELEV
7	240	98	2.45	37	-31.8	-7.5	-39.3		77.4	M.H.
8	255	100	2.55	50	0	-5.4	- 5.4		111.3	POWER POLE

Figure B-10. Plane table

Profile and cross-sectional level notes (figure B-11) are best recorded from the bottom of the page up. This method will align the direction of the survey with the notes. The right page shows the elevations of ground shots and their distance from the road centerline.

Ground Elevation	134.7
Rod Reading	3.5
Distance from Centerline	50

The ground elevation is determined by subtracting the rod reading from the HI. The distance from the centerline is measured with a tape.



PROFILE & CROSS-SECTION LEVELING

DESIGNATION MC COY AVE EXTENDED DATE 25 JAN 1984

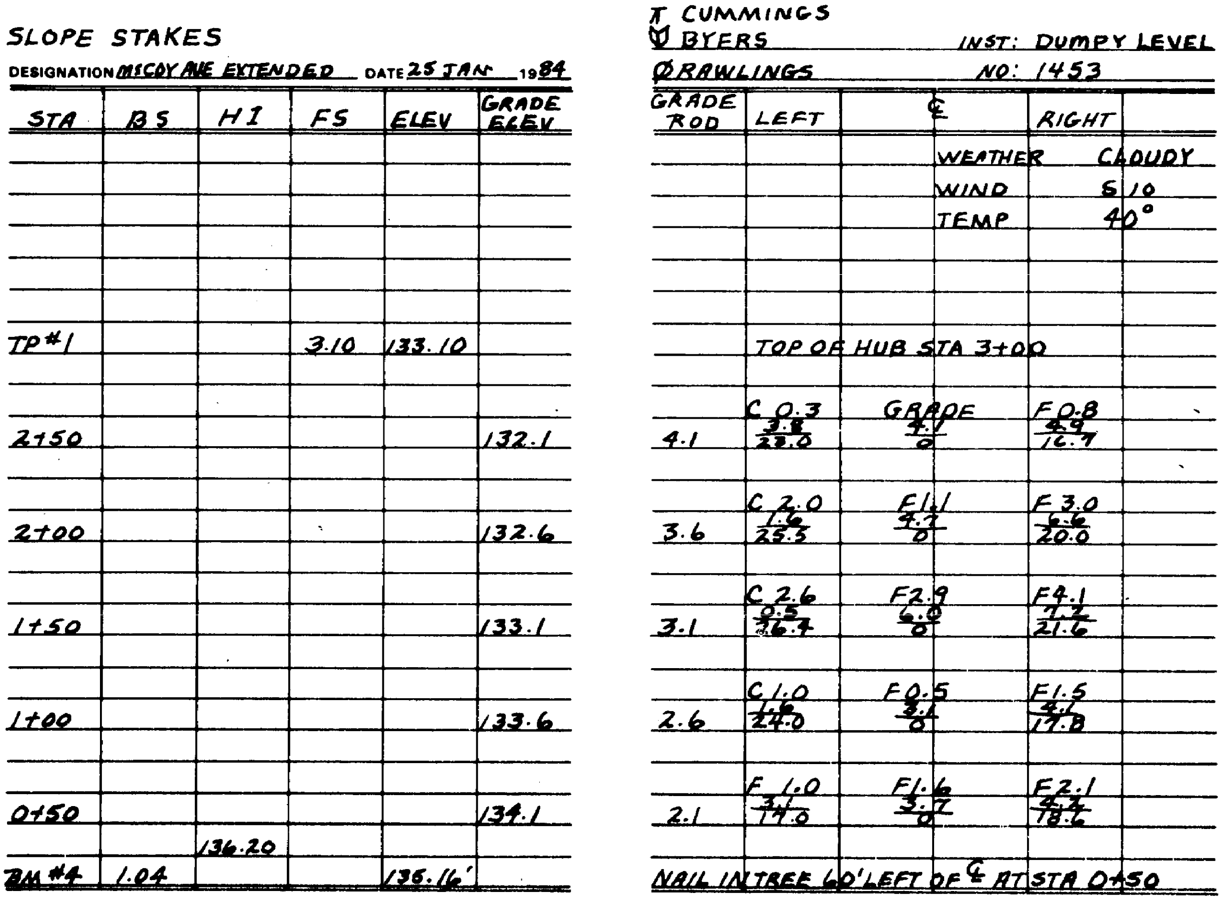
STA	BS	HI	FS	ELEV	
TP #1			6.08	132.10	
7+50					
7+00					
6+50					
PC 6+09.22					
6+00					
		138.18			
BM #4	3.02			135.16'	

π McGUINNESS
Ψ GUESS INST: GURLEY DUMPY LEVEL
Ø BONE NO: 12345

	LEFT	℄	RIGHT	
		WEATHER	FAIR	
		WIND	S 10	
		TEMP	22°	
135.0 3.2 50		133.7 4.5 0		132.0 6.2 50
137.1 1.1 50		135.9 2.3 0	134.6 3.6 20	134.3 3.9 50
135.1 3.1 50		134.1 4.1 0		133.6 4.6 50
132.3 5.9 50		134.6 3.6 0		133.2 5.0 50
134.7 3.5 50		134.6 3.6 0		134.6 3.6 50
NAIL IN TREE 60' LEFT OF ℄ STA 2+50				

Figure B-11. Profile and cross-section leveling

Slope stake notes (figure B-12) are best recorded from the bottom of the page up. This method aligns the direction of the survey with the notes. Grade elevations are normally given in the construction drawings. The grade rod values are determined by subtracting the grade elevation from the HI. The three-part entries on the right page show the amount of cut (C) or fill (F), the ground rod reading, and the distance of the slope stake from the road centerline. A detailed method of setting slope stakes can be found in chapter 2.



SLOPE STAKES

DESIGNATION McCOY AVE EXTENDED DATE 25 JAN 1984

STA	BS	HI	FS	ELEV	GRADE ELEV
TP#1			3.10	133.10	
2+50					132.1
2+00					132.6
1+50					133.1
1+00					133.6
0+50					134.1
		136.20			
BM#4	1.04			136.16'	

T CUMMINGS
Ψ BYERS INST: DUMPY LEVEL
Ø RAWLINGS NO: 1453

GRADE ROD	LEFT		℄	RIGHT	
			WEATHER		CLOUDY
			WIND		S 10
			TEMP		40°
	TOP OF HUB STA 3+00				
	C 0.3		GRADE	F 0.8	
4.1	$\frac{3.8}{23.0}$		$\frac{4.1}{0}$	$\frac{4.9}{16.7}$	
	C 2.0		F1.1	F 3.0	
3.6	$\frac{1.6}{25.5}$		$\frac{4.7}{0}$	$\frac{6.6}{20.0}$	
	C 2.6		F2.9	F4.1	
3.1	$\frac{0.5}{26.4}$		$\frac{6.0}{0}$	$\frac{7.2}{21.6}$	
	C 1.0		F 0.5	F1.5	
2.6	$\frac{1.6}{24.0}$		$\frac{3.1}{0}$	$\frac{4.1}{17.8}$	
	F 1.0		F1.6	F2.1	
2.1	$\frac{3.1}{17.0}$		$\frac{3.7}{0}$	$\frac{4.2}{18.6}$	
NAIL IN TREE 60' LEFT OF ℄ AT STA 0+50					

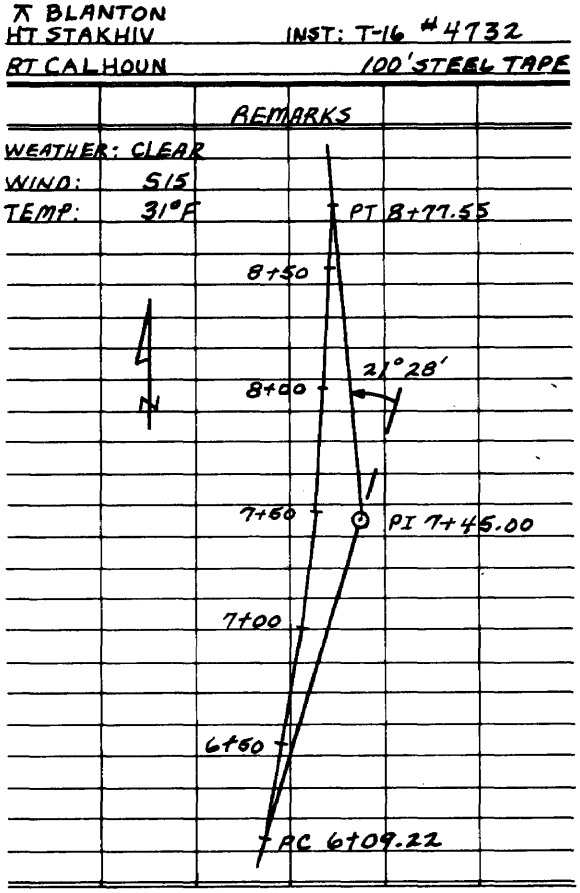
Figure B-12. Slope stakes

The right deflection angles (R DEFL) (figure B-13) were extracted from the curve computations (chapter 3). When a road curves to the left, the left deflection angles (L DEFL) are determined by subtracting the R DEFL from 360 degrees. The R DEFL are used to “back-in” a left curve from the point of tangency (PT). When a curve is to the right, the L DEFL need not be computed.

HORIZONTAL CURVE LAYOUT

DESIGNATION JONES ROAD DATE 26 JAN 1984

STA	CHORD	R DEFL	L DEFL	CURVE DATA	
8+77.55	27.55'	10° 44'	349° 16'	I =	21° 28'
				D =	8° 00'
8+50	50.00	9° 38'	350° 22'	PI =	7+45.00
				T =	135.78'
8+00	50.00	7° 38'	352° 22'	PC =	6+09.22
				L =	268.33'
7+50	50.00	5° 38'	354° 22'	PT =	8+77.55
				R =	716.25'
7+00	50.00	3° 38'	356° 22'	E =	12.75'
				M =	12.52'
6+50	48.78	1° 38'	358° 22'	C_1 =	40.78'
				C_2 =	27.55'
6+09.22	0.00	0° 00'	360° 00'	C_{STD} =	50.00'
				D_1 =	1° 38'
				D_2 =	1° 06'
				D_{STD} =	2° 00'



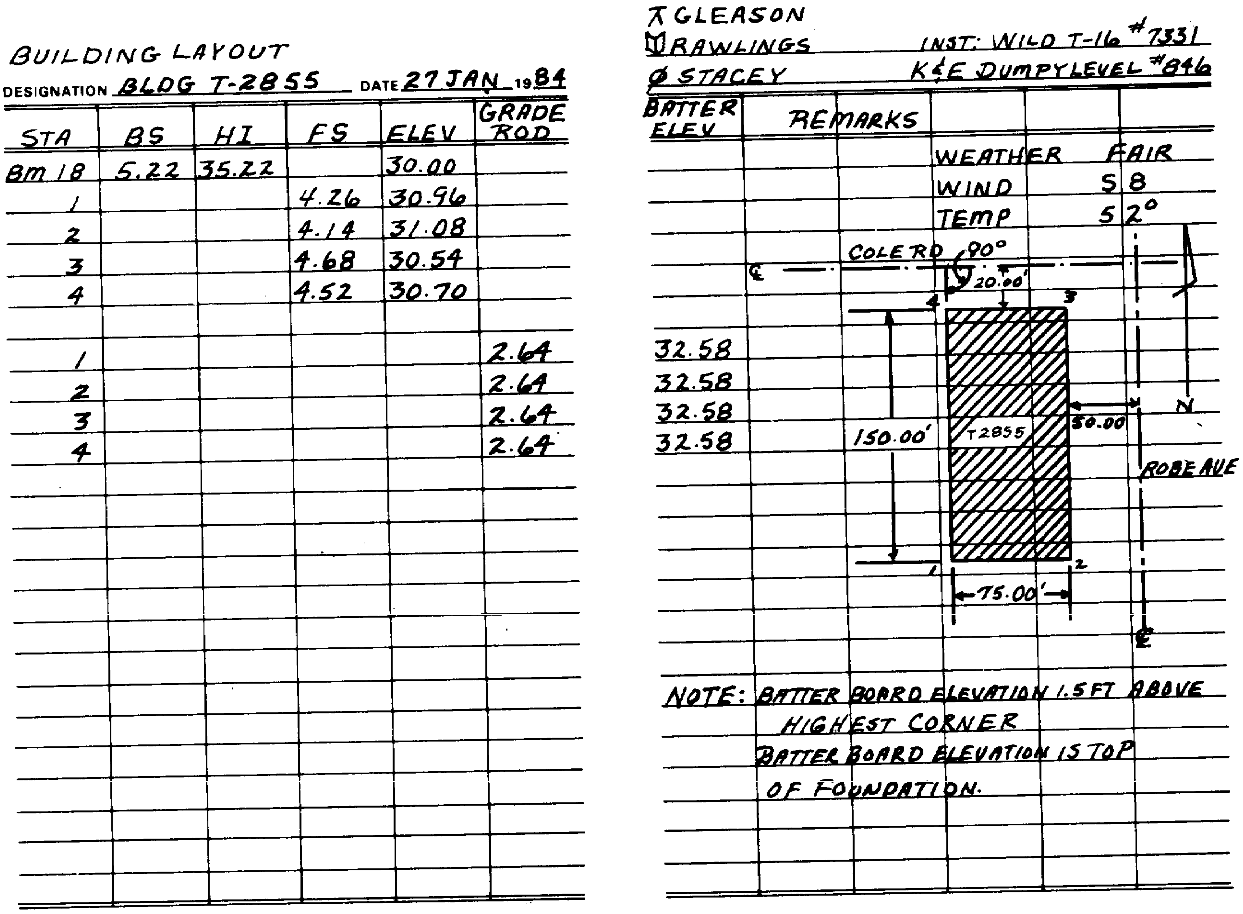
⊼ BLANTON
HT STAKHIV INST: T-16 #4732
RT CALHOUN 100' STEEL TAPE

REMARKS

WEATHER: CLEAR
WIND: S15
TEMP: 31°F

Figure B-13. Horizontal curve layout

The building corner numbers in the sketch must agree with the corner numbers on the left page. In this example, (figure B-14) the building foundation is required to be 1.5 feet above the ground at the highest corner. The batter board elevation (BATTER ELEV) is determined by adding 1.5 feet to the ground elevation (ELEV) of the highest corner. The difference between the BATTER ELEV and the HI equals the grade rod. When a batter board elevation is given, the ground shots are not necessary. The grade rod equals the HI minus the given batter board elevation.



BUILDING LAYOUT

DESIGNATION BLDG T-2855 DATE 27 JAN 1984

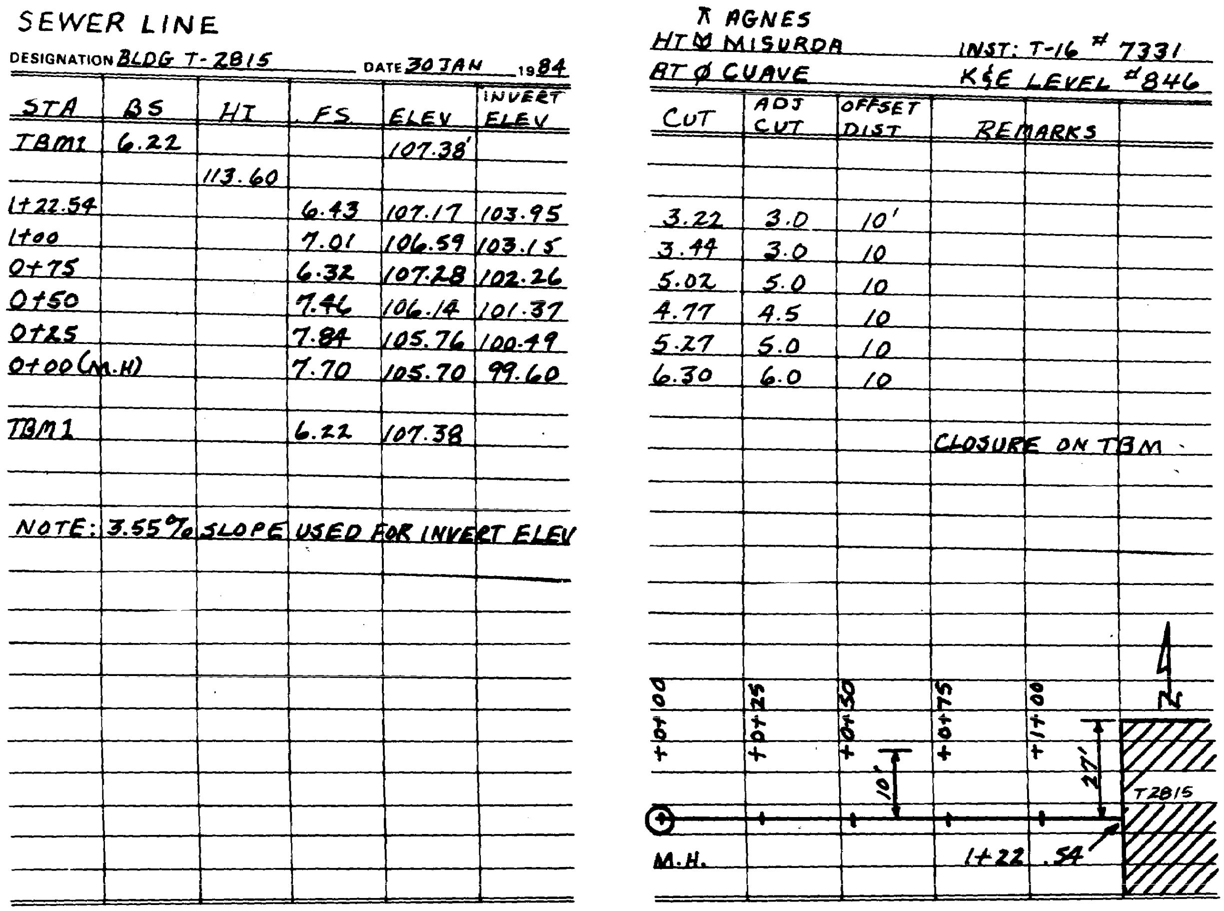
⊼ GLEASON
RAWLINGS INST: WILD T-16 #7331
ϕ STACEY K&E DUMPYLEVEL #846

STA	BS	HI	FS	ELEV	GRADE ROD	BATTER ELEV	REMARKS
Bm 18	5.22	35.22		30.00			WEATHER FAIR
1			4.26	30.96			WIND S 8
2			4.14	31.08			TEMP 52°
3			4.68	30.54			
4			4.52	30.70			
1					2.64	32.58	
2					2.64	32.58	
3					2.64	32.58	
4					2.64	32.58	

NOTE: BATTER BOARD ELEVATION 1.5 FT ABOVE HIGHEST CORNER
BATTER BOARD ELEVATION IS TOP OF FOUNDATION.

Figure B-14. Building layout

The stations in figure B-15 were foresighted on top of their offset stakes. The invert elevations (INVERT ELEV) were computed using the manhole (M.H.) invert elevation at 0+00 and the percent of the slope. The elevation (ELEV) of a station minus the INVERT ELEV equals the amount of CUT at the offset station. The CUT is rounded down to the nearest whole or half foot for the adjusted cut (ADJ CUT). The ADJ CUT assists the construction crew when digging the ditch. The difference between the CUT and ADJ CUT is the distance measured down and marked on the offset stakes. The ADJ CUT value and the offset distance (OFFSET DIST) is also marked on the offset stakes facing the sewer line. The station values are marked on the opposite side (figure B-16 and figure B-17 on page B-18).



SEWER LINE

DESIGNATION BLDG T-2815 DATE 30 JAN 1984

STA	BS	HI	FS	ELEV	INVERT ELEV
TBM1	6.22			107.38'	
		113.60			
1+22.54			6.43	107.17	103.95
1+00			7.01	106.59	103.15
0+75			6.32	107.28	102.26
0+50			7.46	106.14	101.37
0+25			7.84	105.76	100.49
0+00 (M.H)			7.70	105.70	99.60
TBM1			6.22	107.38	

NOTE: 3.55% SLOPE USED FOR INVERT ELEV

⊼ AGNES
HT ⊻ MISURDA INST: T-16 # 7331
RT Ø CUAVE K&E LEVEL #846

CUT	ADJ CUT	OFFSET DIST	REMARKS
3.22	3.0	10'	
3.44	3.0	10	
5.02	5.0	10	
4.77	4.5	10	
5.27	5.0	10	
6.30	6.0	10	
			CLOSURE ON TBM

Figure B-15. Sewer line

HEIGHT OF AN ACCESSIBLE POINT

DESIGNATION HEIGHT OF FLAG POLE DATE 31 JAN 19 84

STA	TEL	ZD	VERT ANGLE	DIST	
FP ← ⊙1	D	70°30'	+19°30'	100.000	
	R	289°29'	+19°29'	100.010	
MEAN			+19°29'30"	100.005'	METERS
FP ← ⊙1	D	91°25'	-01°25'		
	R	268°35'	-01°25'		
MEAN			-01°25'00"		
TAN	19°29'30	X 100.005 =		35.397	
TAN	1°25'	X 100.005 =		2.473	
			TOTAL =	37.870	METERS

⊼ HAYWARD
📖 PARMELE
HT CARL
RT CUMMINGS

INST: T16
NO: 2391

REMARKS

WEATHER	FAIR
WIND	N 8
TEMP	30°

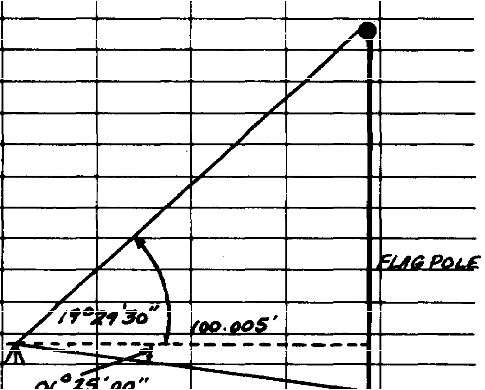
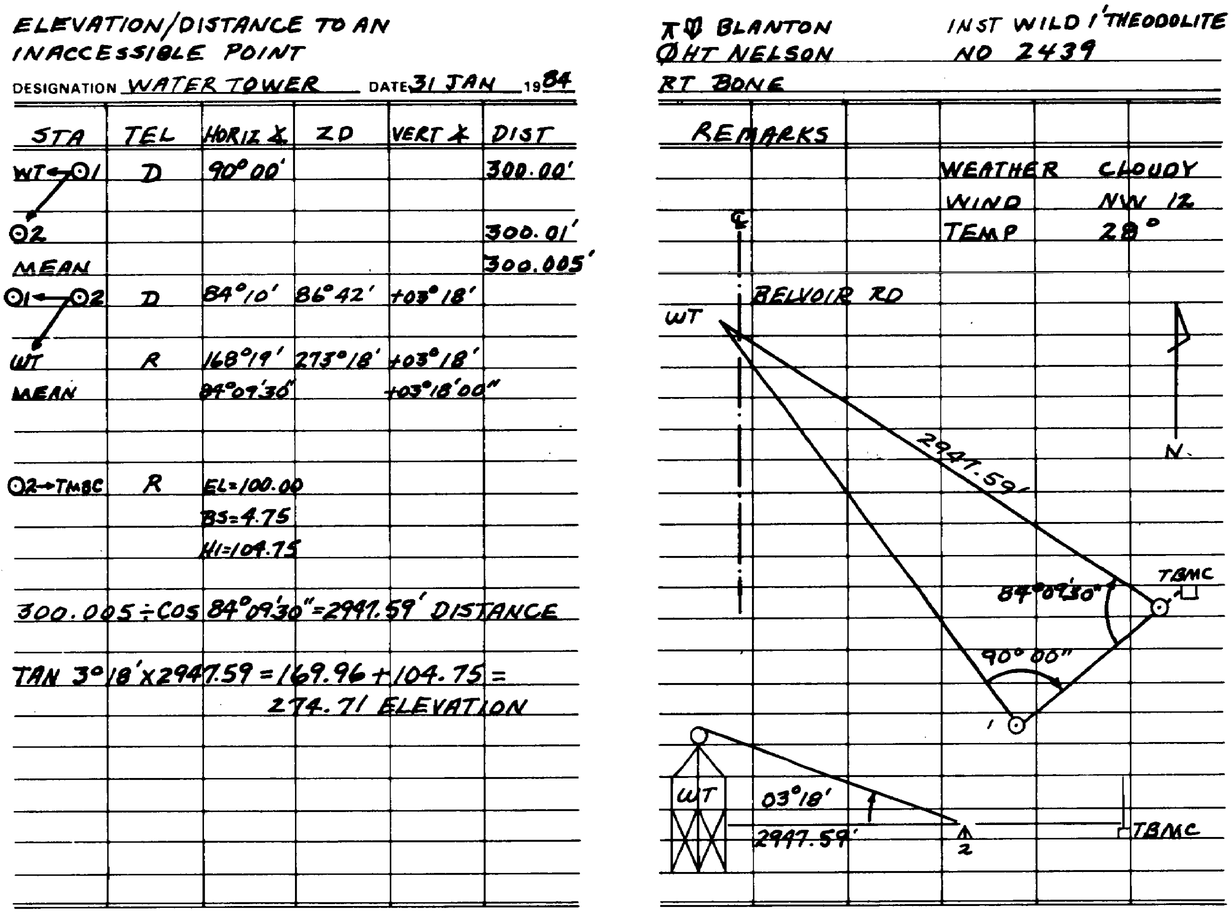


Figure B-16. Height of an accessible point



ELEVATION/DISTANCE TO AN
INACCESSIBLE POINT

DESIGNATION WATER TOWER DATE 31 JAN 1984

STA	TEL	HORIZ ∡	ZD	VERT ∡	DIST
WT ← ⊙1	D	90° 00′			300.00′
⊙2					300.01′
MEAN					300.005′
⊙1 ← ⊙2	D	84°10′	86°42′	+03°18′	
WT	R	168°19′	273°18′	+03°18′	
MEAN		84°09′30″		+03°18′00″	
⊙2 → TMBC	R	EL=100.00			
		BS=4.75			
		HI=104.75			

300.005 ÷ COS 84°09′30″ = 2947.59′ DISTANCE

TAN 3°18′ X 2947.59 = 169.96 + 104.75 =
274.71 ELEVATION

⊼⊕ BLANTON
ØHT NELSON
RT BONE

INST WILD 1′ THEODOLITE
NO 2439

REMARKS

WEATHER	CLOUDY
WIND	NW 12
TEMP	28°

Figure B-17. Elevation/distance to an inaccessible point