TIMBER CRUISING HANDBOOK

CHAPTER 10 - PRINCIPLES OF MEASURING TREES

Contents

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Timber cruising is the determination of the gross and net product volume and value (timber quality) for a tract of timber. It involves measuring tree diameters and heights, estimating defects, and making other determinations, such as grade and form class, that may be specified by the cruise plan. This chapter deals with the technical aspects of making tree measurements and the tools required.

11 - SPECIES IDENTIFICATION. Each timber cruiser must properly identify tree species. Stumpage rates, merchantability specifications, and many product volume references are species related. Species may be identified by bark characteristics, form, type of fruit, cones, needles, leaves, and other features.

12 - TREE MERCHANTABILITY SPECIFICATIONS. Develop the minimum tree and piece merchantability specifications in the cruise design phase and document in the cruise plan. These specifications will be included in the Timber Sale Contract to identify material to be removed. Knowledge of the minimum piece and tree specifications for each end product category is required. The cruiser must recognize and record the end product potential for cruised materials. End products are subdivided into three categories:

1. Material suitable for the manufacture into lumber or veneer.
2. Material suitable for conversion into chips.
3. Material suitable for conversion into other products such as poles, pilings, rails, ties, and house logs.

The minimum piece specifications are described by:

1. Length.
2. Diameter inside bark at the small end.
3. Net product volume as a percent of gross product volume.
4. Other timber sale specifications.

The minimum tree specifications are described by:

1. Minimum number of pieces a tree must contain to be merchantable.
2. Minimum diameter breast height.
3. Piece net volume.

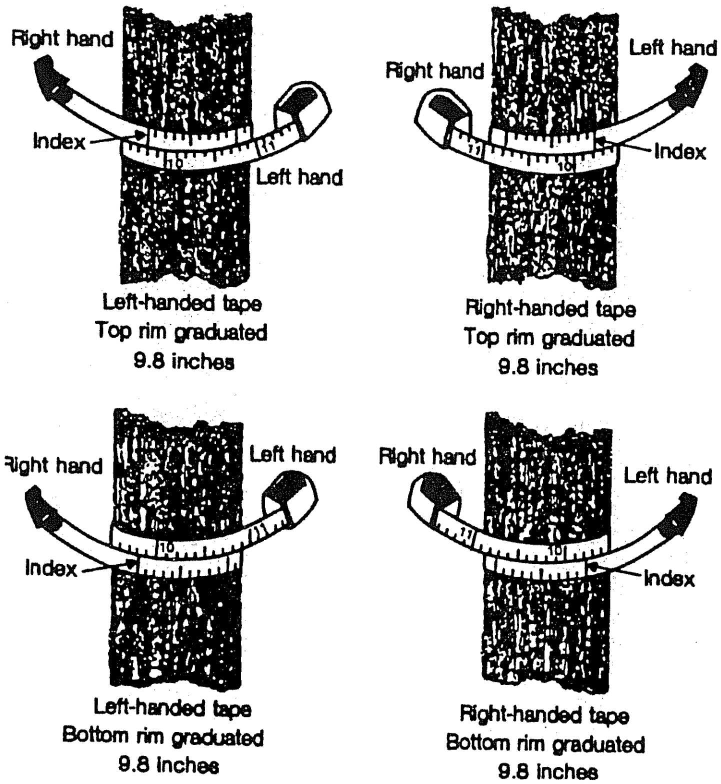
13 - TREE MEASURING INSTRUMENTS.

13.1 - Diameter Measuring Instruments.

13.11 - Diameter Tape. The diameter tape is the most common device used in measuring tree diameters. Tapes are either 20-feet or 50-feet long, are made of steel, usually have a bark hook on the zero end, and are graduated on the outside surface in inches and tenths of inches of diameter equivalents (3.1416 inches) of circumference. Tapes may also have linear graduation in feet or meters on the inside surface. Many logger's tapes are graduated, on the backside, in diameter equivalents of circumference.

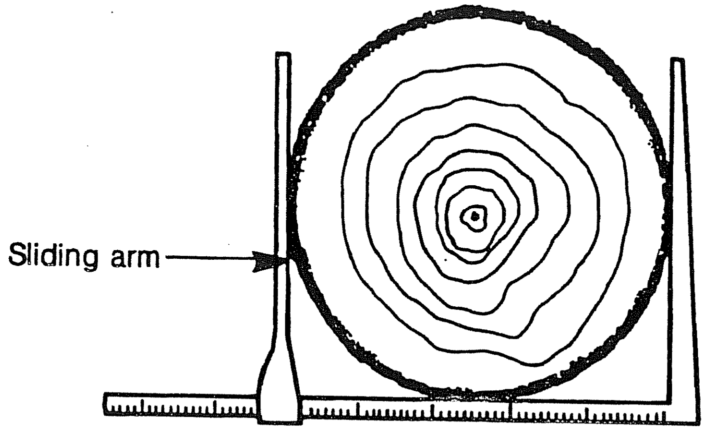
Diameter tapes come in right-handed and left-handed models. This refers to the hand in which the tape case must be held so, with the tape around a tree, the numbers are reading right side up.

In correct use, the diameter tape numbers are right side up and the tape is crossed on the face of the tree, so the index or zero mark lays along the graduated edge of the tape. Tapes may be graduated on either the upper or lower edge. Figure 01 illustrates the correct use of left-handed and right-handed tapes.



13.11 - Figure 01
Correct use of left-handed and right-handed tapes

13.12 - Tree Calipers. Tree calipers, available in either wood or metal and graduated in English or metric graduations, may be used for measuring tree diameters. English graduations are in tenth inches and metric graduations are in centimeters. Caliper sizes range from 18 to 60 inches, and the arm is attached at right angles to the beam. When using tree calipers, take two measurements at right angles and average the readings.



13.12 - Figure 01
Tree Calipers

13.13 - Dendrometers. Dendrometers are classified as optical forks, optical calipers, or short-base rangefinders, depending on the trigonometric principles of their design. Three dendrometers, two optical forks, and one optical caliper are commercially available. The most common optical fork is the Spiegel-Relaskop. A more sophisticated version, the telerelaskop is basically a Spiegel-Relaskop with magnification. The only optical caliper, the Wheeler penta prism caliper, has no magnification.

13.13a - Optical Fork (Relaskop, Telerelaskop). The optical fork measures stem diameter with a fork angle formed by two intersecting lines of sight with the apex at the observer. Optical forks depend on the observer to measure the distance (baseline) to the tree. Optical forks are further classified as fixed and variable. In use, the fixed fork is aligned with the tree, varying the distance (baseline) from the tree. With variable forks, of which the two relaskops are examples, the fork is aligned with the tree by varying the fork angle. These devices have the added advantage of having the fork-angle linked to the vertical angle by means of cylindrical cosine graphs. This enables a given diameter to be located at any height for a given distance from the tree. For example, the width of one vertical stripe on the relaskop drum defines a 4-inch diameter at 66 feet from the tree, regardless of its height, and a 2-inch diameter at 33 feet from the tree, regardless of its height.

When measuring diameters of a swaying tree, move the device with the sway of the bole to keep the fork angle in alignment with the bole. Failure to do this results in biased diameter estimates. If a tree is leaning either toward or away from the observer, erroneous readings will result. Readings on a tree leaning toward the observer will be high and readings on a tree leaning away from the observer will be low.

Therefore, when measuring stem diameters of leaning trees, make all sightings at right angles to the lean.

The instruments mentioned here should be mounted on a tripod or staff to facilitate accurate measurements. Failure to do so may increase measurement variation and increase the number of measurements necessary to attain the desired precision.

To avoid bias from the revolving drum of the relaskop being out of alignment, periodically check the device against a target of known width.

13.13b - Optical Calipers (Wheeler penta-prism caliper). The optical caliper measures stem diameter with two parallel lines of sight separated by a sliding measurement scale at the observer. It is an optical analog of the conventional mechanical tree caliper. There is currently no commercial optical caliper equipped with magnification. The commonly used Wheeler model is, however, equipped with a clinometer to measure height. This instrument requires a measured baseline from the observer to the tree when used with the clinometer to measure height. If only used for measuring diameters anywhere on the stem, the distance to the tree (baseline distance) does not have to be known.

The chief advantage of this instrument is that while tree lean in the line of sight affects height measurement, it does not affect diameter measurement. This is an advantage over all other dendrometers. Tree lean at right angles to the line of sight, however, does not affect either height or diameter measurement if the instrument is properly tilted and sight lines are parallel to the lean.

Use of the penta-prism caliper requires focusing simultaneously on the halving line of the prism and on the distant tree stem. This tends to make the halving line appear fuzzy instead of sharp, making accurate alignment of the two vertical images difficult. Since the instrument is in one-to-one correspondence with the diameter being measured, the baseline of the instrument must be wide enough to accommodate the working range of tree diameters. A 36-inch diameter seems to be the practical limit for a hand-held device; use a support staff or tripod for anything larger.

To avoid bias from the prism being out of alignment, periodically check the instrument against a target of known width.

13.13c - Short-Base Rangefinder Dendrometer. This type of device is represented by Barr and Stroud Dendrometers, Models FP-12, FP-15. These are precision instruments but their manufacture has been discontinued. They are self-contained instruments producing coincident images of tree stems by means of counter-rotating circular wedge prisms. The coincident image retains the same relation to the tree stem whether the tree is motionless or swaying in the breeze. The instrument setting in the coincident position is used to compute the distance (range), as well as the diameter outside bark (DOB), by means of complex trigonometric relationships applicable to the specific instrument. The dendrometer is equipped with 8X magnification, enabling precise definition of coincidence by providing a sharp halving line. An inclinometer with micrometric head is used for readings of elevation and depression that are translated into vertical height. The instrument weights about 5 pounds.

The Barr and Stroud is not a direct-reading device. The user records instrument readings in units that must be processed by a computer program like STX (Grosenbaugh, 1967). Mesavage (1964, 1968) devised a slide rule-like field calculator to convert instrument readings to standard units.

13.2 - Height Measuring Instruments.

13.21 - Telescoping Measuring Rod. Telescoping measuring rods consist of a number of progressively smaller sections which telescope inside each other. One or multiple sections may be pulled out since each section is locked in place independently. Rods are available in extended lengths of 17 to 50 feet. Rods are made of sturdy fiberglass and come graduated in either feet, inches, half inches; feet, tenths foot, hundredths foot; or meters, decimeters, centimeters. The height rod is an extremely useful instrument in timber less than 50 feet tall. It is also an excellent instrument to use as a standard when checking the calibrations of other height measuring instruments such as Relaskops and clinometers.

13.22 - Haga Altimeter. The Haga altimeter is a hand-held instrument used to measure vertical heights. The instrument has six different scales. Its scale values indicate height directly for various known base length distances. The first four scales (15, 20, 25, and 30) may be used with base length distances in feet, meters, or yards. The fifth scale (%) indicates height as a percent of the baseline distance. The sixth scale (topographic) indicates height directly in feet for a base length distance of 66 feet.

13.23 - Blume-Leiss Altimeter. The Blume-Leiss altimeter is a hand-held instrument used to measure vertical heights. The instrument has four different scales, each of which corresponds to a specific baseline distance of 45, 60, 90 and 120 feet. All readings are directly in feet. Height measurement range is up to 180 feet.

13.24 - Clinometer. The clinometer is a light, compact, and rugged hand-held instrument. Its primary function is to measure vertical angles above and below the horizontal. The instrument is available in either topographic or percent scales. Height measurements are easily made with this instrument. Because of its relatively low cost, it is probably the most common height instrument used by the Forest Service timber cruiser.

13.25 - Abney Level. The Abney is a light, compact hand-held instrument. Its primary function is to measure vertical angles above and below the horizontal. The instrument has both topographic or percent scales.

13.26 - Spiegel-Relaskop. The Spiegel-Relaskop described in 13.13a, is a versatile instrument. It is used to measure tree and limb diameters, tree height, slope and horizontal distances, and as an angle gauge in point sampling. Used as a height measuring instrument, the Relaskop indicates height in feet for known horizontal distances.

13.27 - Telerelaskop and Barr and Stroud Dendrometers. The Telerelaskop and Barr and Stroud dendrometers described in section 13.13 are used for making height measurements.

13.28 - Laser Measuring Devices. Laser measuring devices are being developed to measure heights and other characteristics of the trees as needed for timber cruising. Maintain awareness of the potential and limitations of this equipment for improving accuracy and reducing costs.

14 - MEASURING THE TREE. Measuring individual tree variables in a consistent and prescribed manner is essential. All volume estimation procedures require some or all of the following measurements:

1. Diameter breast height (DBH).

2. Reference height (measured to a specific diameter inside bark (DIB) or diameter outside bark (DOB)).

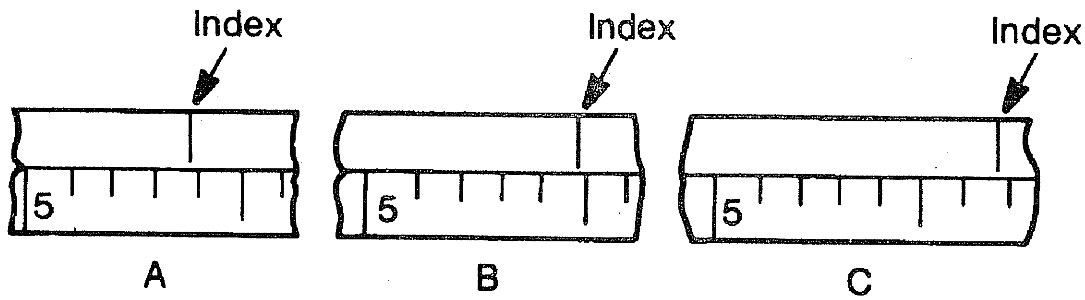
3. Total height.

4. Stump height.

5. Tree form class.

14.1 - Measuring Tree Diameter.

14.11 - Reading the Diameter Tape. If the diameter reading is not exactly on a tenth, take diameter tape readings to the next lower one-tenth inch. This compensates for the positive bias incurred by measuring out-of-round trees with a tape. Figure 01, example A is read as 5.3, example B as 5.4, and example C as 5.6.



14.11 - Figure 01
Diameter Tape Measurement Readings

There are situations where diameter measurements are made and recorded to the nearest 1- or 2-inch diameter class. This may occur when the precision of the measuring instrument can only be to the closest 1 or 2 inches or specified product volume estimation procedures are based on 1- or 2-inch DBH classes. Standard 1- and 2-inch classes are:

1. Examples of 1-inch diameter class are: 5-inch class = 4.6 - 5.5 inches; 9-inch class = 8.6 - 9.5 inches, and so on.

2. Examples of 2-inch diameter class are: 12-inch class = 11.0 - 12.9 inches; 14-inch class = 13.0 - 14.9 inches, and so on.

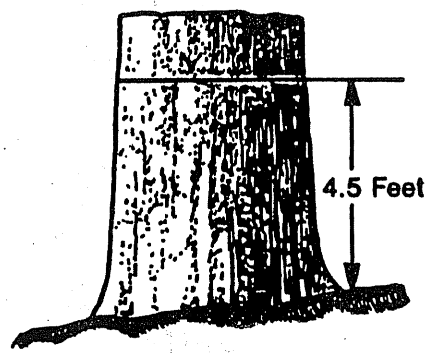
There are situations where diameter measurements are not rounded. This situation occurs when absolute measurements are specified. Timber sale contract minimum tree DBH and minimum piece specifications are absolute.

Example:

1. Minimum tree DBH specification = 7.0 inches. This means 6.95 would not be rounded to 7.0 inches.

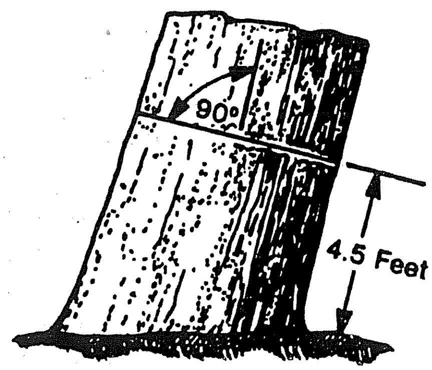
2. Minimum piece specification = 7.6 inches DIB. This means 7.55 would not be rounded up to 7.6 inches.

14.12 - Measuring Tree Diameter at Breast Height (DBH). Measure DBH from the high ground side of the tree at 4.5 feet above the forest floor (fig. 01). If tree diameter cannot be measured at 4.5 feet because of abnormalities, measure as described in section 14.12d.



14.12 - Figure 01
Measuring DBH - Normal Case

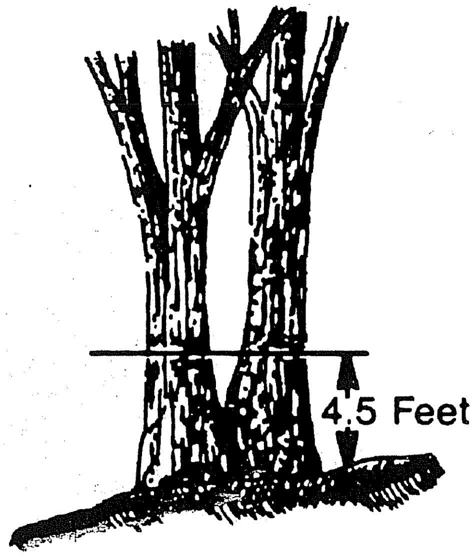
14.12a - Leaning Trees. Measure DBH on leaning trees at a right angle to the center line of the tree as shown in figure 01.



14.12a - Figure 01
Measuring DBH - Leaning Trees

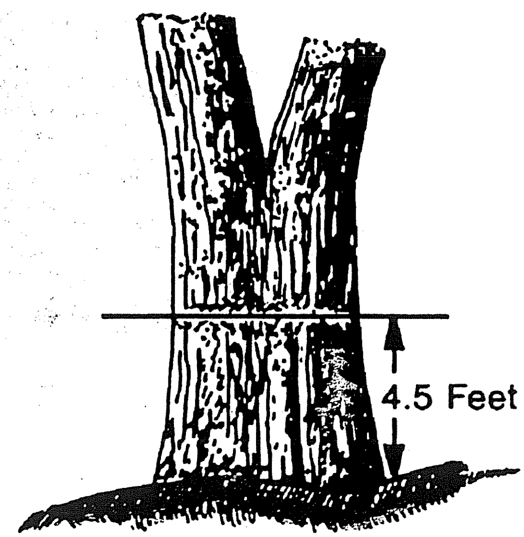
14.12b - Forked Trees. A forked tree is a tree with two or more stems originating from one stump. Consider forking to start at the point where daylight is seen.

When a tree forks below 4.5 feet, consider as two trees and measure DBH on each stem at 4.5 feet above the ground on the high side (fig. 01). If either stem at this point is abnormal, measure as described in section 14.12d.



14.12b - Figure 01
Fork Occurs Below 4.5 Feet

When a tree forks at or above 4.5 feet, consider as one tree and record the smallest diameter at 4.5 feet or below (fig. 02).

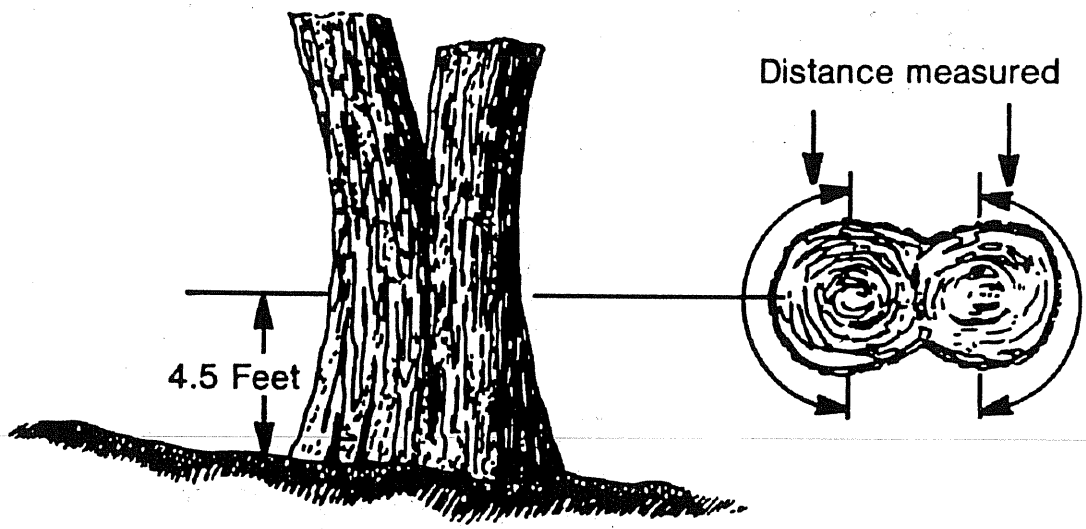


14.12b - Figure 02
Fork Occurs Above 4.5 Feet

<u>14.12c</u> - <u>Trees Growing Together</u>. Two methods may be used to determine DBH on trees growing together.

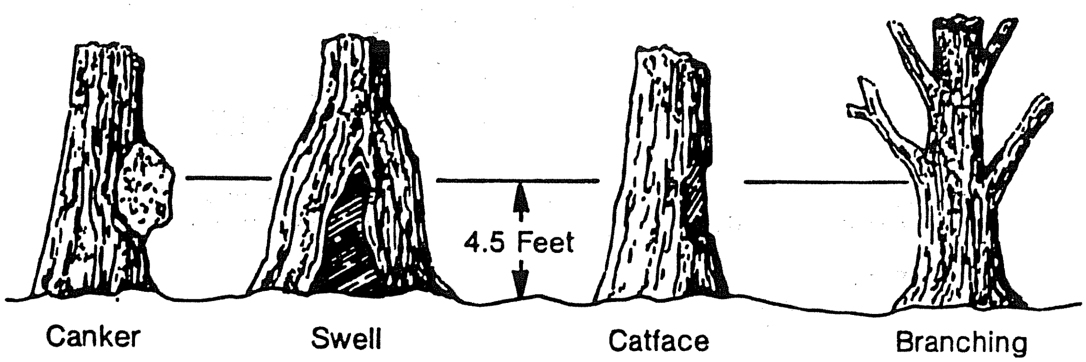
1. If calipers are available, measure each tree at normal DBH point, 4.5 feet above high ground side.

2. To use one-half diameter method, make two marks opposite each other on the stem at 4.5 feet. Measure the distance between the marks with a diameter tape; double the measurement to determine DBH.



<u>14.12c</u> - <u>Figure 01</u>
<u>Measuring DBH on Trees Growing Together</u>

<u>14.12d</u> - <u>Trees With Abnormalities at 4.5 Feet</u>. Figure 01 illustrates examples of trees with abnormalities such as canker, swell, catface, or excessive branching.



<u>14.12d</u> - <u>Figure 01</u>
<u>Abnormalities at 4.5 Feet</u>

Use one of the following procedures when DBH measurement cannot be taken at 4.5 feet:

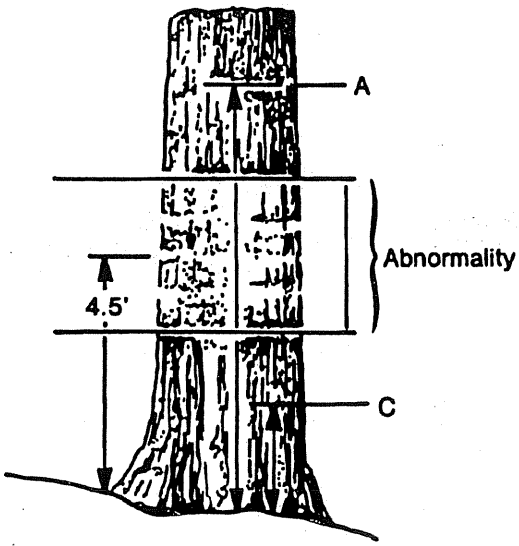
1. If the tree can be measured at normally formed points above and below the abnormality, take measurements for "A" and "C" where tree exhibits normal taper and is free from influences of abnormality. (figure 02).

a. Measure diameter above DBH, point "A."
b. Measure diameter below DBH, point "C."

If these measurements are at equal distances from 4.5 feet, average A and C to arrive at DBH measurement.

Example:
Diameter "A" = 16 inches
Diameter "C" = 18 inches

$$DBH = \frac{16 + 18}{2} = 17 \text{ inches}$$



14.12d - Figure 02
Techniques for Determining DBH
with Abnormalities at 4.5 Feet

If point A and point C are at unequal distances from 4.5 feet, interpolate the distances to arrive at DBH measurement.

Example:
Diameter "A" = 16 inches
Diameter "C" = 22 inches
Height of "A" above ground = 12 feet
Height of "C" above ground = 2 feet

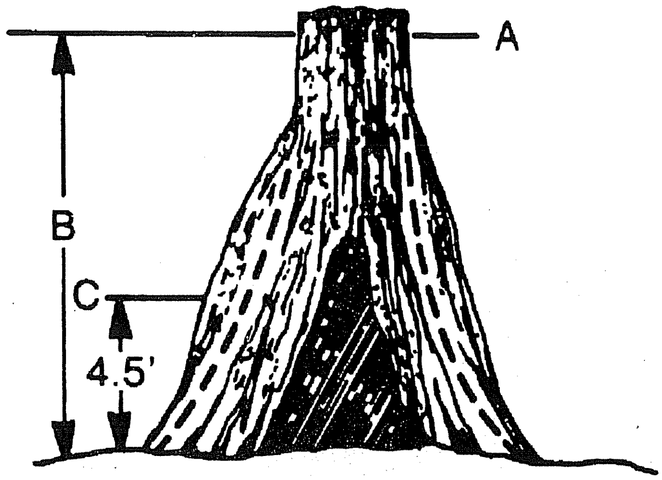
$$\text{Normal taper} = \frac{22'' - 16''}{12' - 2'} = 0.6 \text{ inches/foot}$$

$$DBH = 22'' - [(4.5' - 2') \times 0.6''/\text{ft.}] = 20.5 \text{ inches}$$

or

$$DBH = 16'' + [(12' - 4.5') \times 0.6''/\text{ft.}] = 20.5 \text{ inches}$$

2. If the tree cannot be measured at normal points above and below the abnormality, measure above the abnormality and apply taper from comparable trees of the same species (figure 03).



14.12d - Figure 03
Abnormal Butt Swell

a. Measure diameter above DBH where shape is normal, point "A."

b. Measure height to point "A," length "B."

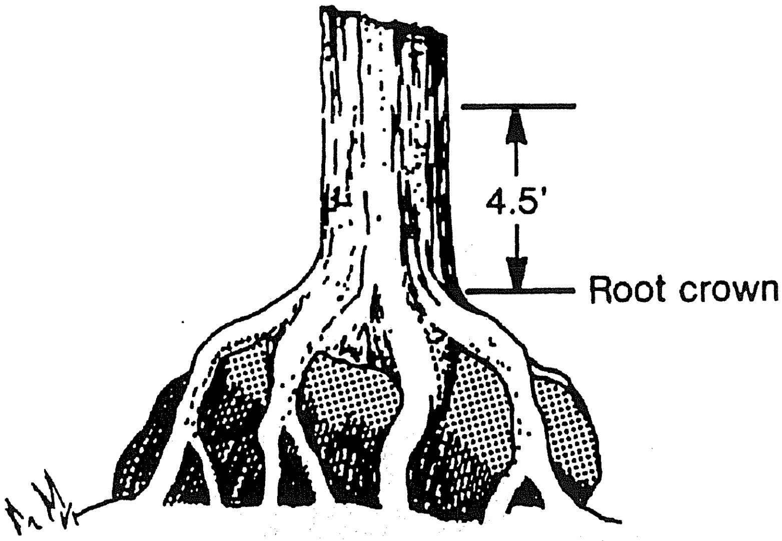
c. Determine average taper from comparable trees of the same species in immediate area.

d. Interpolate DBH measurement "C" based on diameter measurement "A," the estimated average taper, and length "B."

Example:

Diameter "A" = 18.0 inches
Length "B" = 12 feet
Estimated taper = 2 inches in 8 feet or .25 inches per foot
DBH = 18 + ((12 - 4.5) x .25) = 19.88 inches or 19.9 inches

14.12e - Trees Growing on Objects. When trees are growing on objects, such as rocks or logs, measure at 4.5 feet above the root crown rather than above the forest floor.



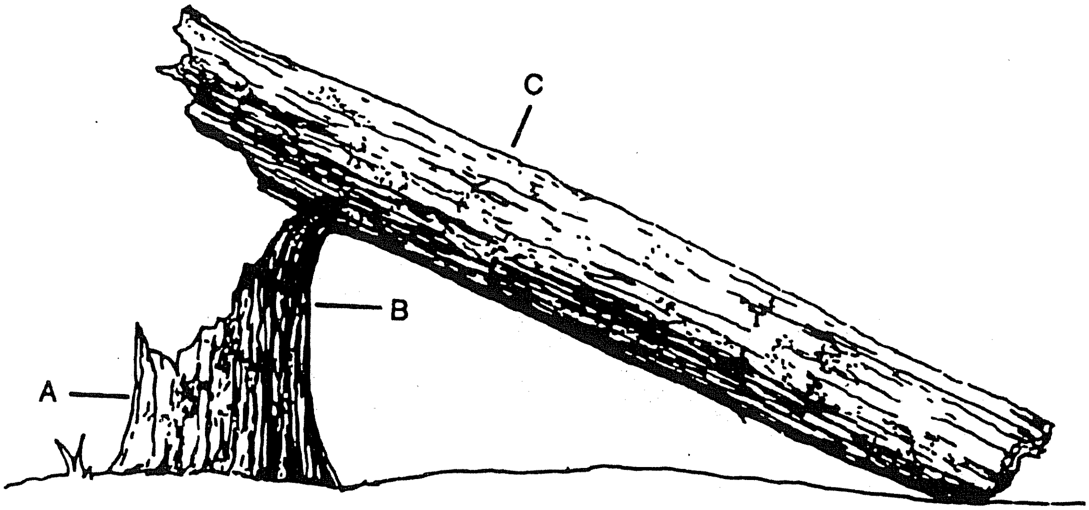
14.12e - Figure 01
Measuring DBH on Trees Growing on Objects
(Rocks, Logs)

14.12f - Coppice Growth. To measure DBH on coppice growth or on trees growing in clumps, follow the procedures described in section 14.12b - 14.12c.

14.12g - Broken Trees. Use one of the following procedures to determine DBH on broken trees:

1. If DBH occurs either below the break (A) or above the break (C), measure normally using calipers or diameter tape (fig. 01).

2. If DBH occurs at the break (B) as shown in figure 01, use procedures outlined in section 14.12d.



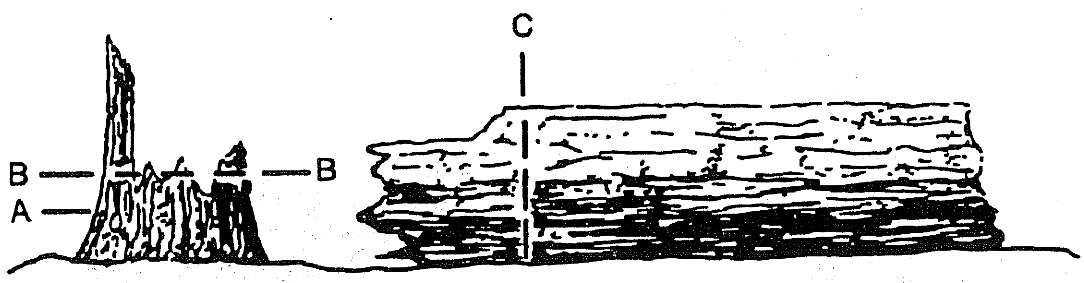
14.12g - Figure 01
Measuring DBH on Broken Tree

14.12h - Broken Off Trees. Use one of the following procedures for determining DBH on broken off trees. Figure 01 illustrates these procedures.

1. If DBH occurs below the break (A), measure normally using calipers or diameter tape.

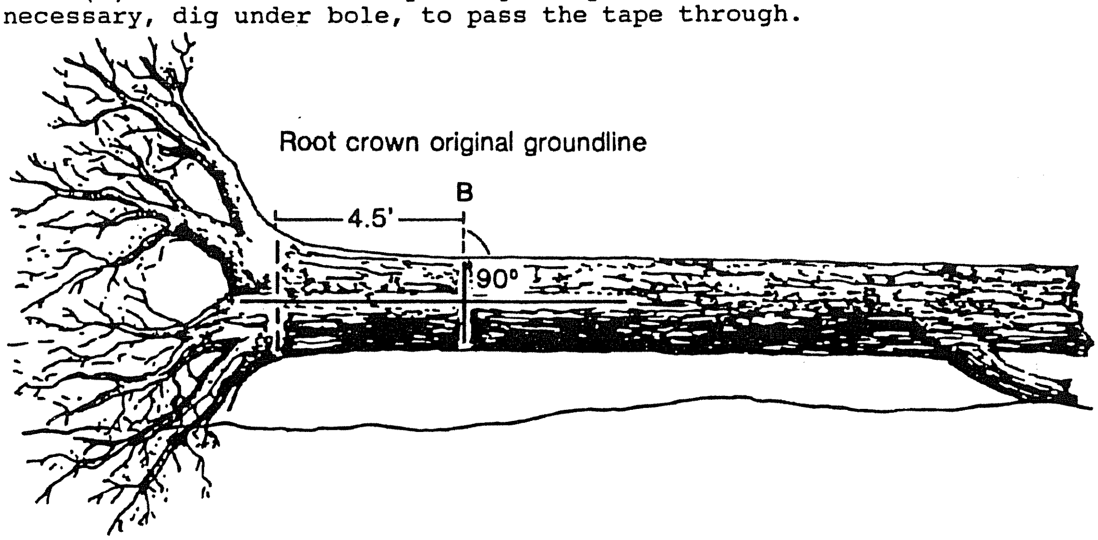
2. If DBH occurs at the break (B), and if bole is not shattered badly, make the DBH measurement at the break point. If bole is shattered, use procedures in section 14.12d.

3. If DBH occurs above the break (C), measure normally using calipers or diameter tape. If necessary, dig under bole, to pass the tape through.



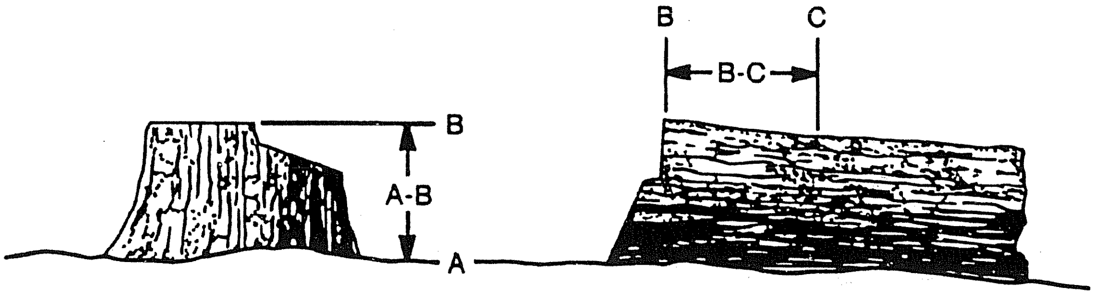
14.12h - Figure 01
Measuring DBH on Broken Off Tree

14.12i - Down Trees. On down trees measure DBH at 4.5 feet above original high side ground line at right angles to the center line of the bole (B). Measure normally using calipers or diameter tape. If necessary, dig under bole, to pass the tape through.



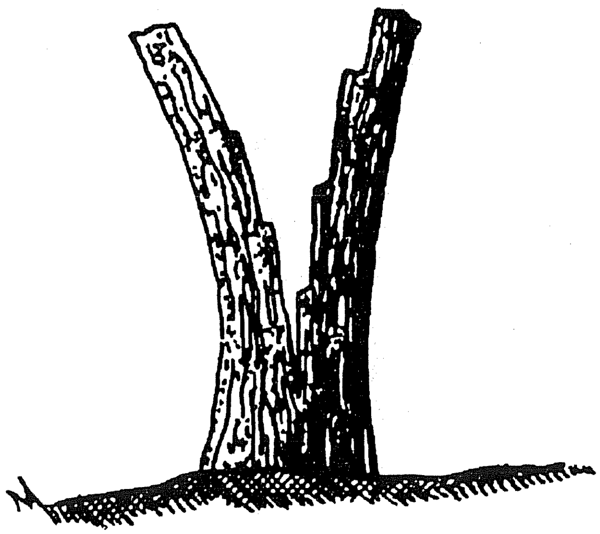
14.12i - Figure 01
Measuring DBH on Down Trees

14.12j - Severed, Down Trees. Measure from the ground on the high side to the saw cut on the stump (AB) and then from the saw cut on the end of the log up the bole (BC) to determine where 4.5 feet above the ground would be (fig. 01). Measure diameter at this point, normally using calipers or diameter tape. If necessary, dig under bole, to pass the tape through.



14.12j - Figure 01
Measuring DBH on Severed Trees

14.12k - Split Trees. Measure DBH with calipers or use the one-half diameter technique described in section 14.12c.



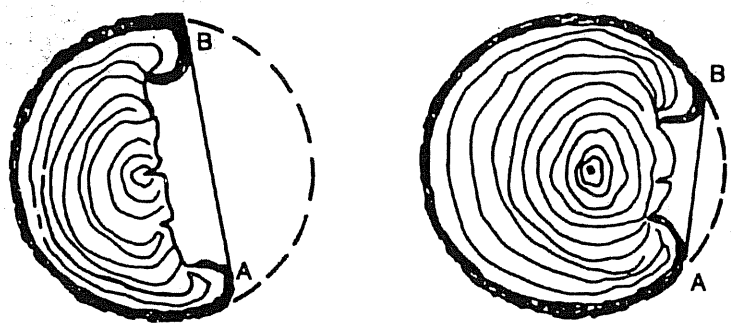
14.12k - Figure 01
Measuring DBH on Split Trees

14.121 - Trees Having a Large Catface. Use the most appropriate of the following procedures when measuring trees abnormally formed by a catface at 4.5 feet:

1. Use calipers. Measure DBH at right angle to catface.

2. Use a diameter tape. Adjust the tape to a normally rounded position to allow for the catface portion missing. If the tape is not adjusted but is pulled tight, the tape will be straight across the missing portion and the diameter read will be less than it should be (fig. 01).

3. Use the one-half diameter technique described in section 14.12c.



14.121 - Figure 01
Measuring DBH on Trees With Large Catface

14.12m - Trees Without Bark. Volume estimation procedures assume Diameter Breast Height (DBH) will be measured outside bark. The DBH measurement for trees with no bark or only partial bark at 4.5 feet must be increased to reflect the contribution of the missing bark.

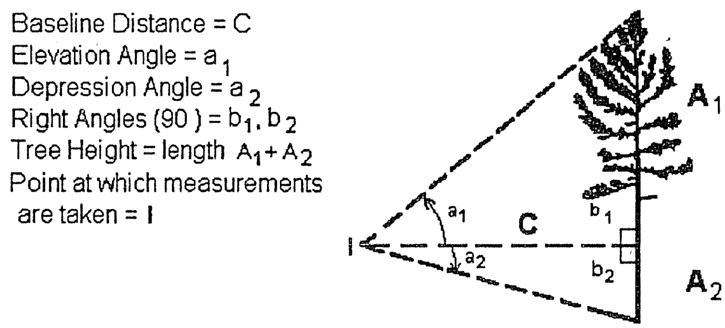
If a tree has no bark at 4.5 feet, add two times the average bark thickness (developed using data from trees with bark, of the same species, size, and geographic location) to the tree's DBH. If a tree has a partial bark covering at 4.5 feet, the individual making the measurement must use their best judgment in determining an accurate DBH.

<u>14.2</u> - <u>Measuring Tree Heights</u>. Most volume estimation procedures require accurate tree heights to provide an accurate estimate of tree volume. An error in tree height can result in an erroneous tree volume and by extension an erroneous sale volume.

The procedures described in this section apply to all height measuring instruments.

Heights of standing trees are calculated using measurements of baseline distance, elevation angle, and depression angle. An error in any one of these measurements will result in the calculation of an erroneous tree height.

The calculation of tree height is based on the "Law of Sines" which states, in part, for any triangle, if two angles and one side are known, then the remaining angle and two sides of the triangle may be found. The known side of the triangle is the baseline distance. The known angles are the right angle formed where the baseline intersects the tree bole and the measured elevation/depression, angle. Determine the length (height) on the tree bole from the baseline intersection to the sight point used for the elevation/depression angle (fig. 01).



<u>14.2</u> - <u>Figure 01</u>
<u>Measuring Tree Heights</u>

It is usually more accurate to measure height from a point uphill from the tree or on the same contour line as the tree. Avoid measuring height downhill from the tree whenever possible.

Measure tree height to the tip of the tree and/or to specified reference heights, such as total merchantable height, or sawlog height. Depending on the volume estimation procedures used, a standard stump height may or may not be considered as part of the total or reference height measurement.

1. Total tree height. Measure from the base of the tree on the high ground side to the tip of the tree leader. Record total tree height to the nearest foot.

2. Reference heights. Measure using one of the following:

   a. To a specified diameter. Measure from the base of the tree on the high ground side to a specific reference diameter (minimum DIB or DOB).

b. To a merchantability limit. Measure from the base of the tree on the high ground side to a point above which the bole is too small or defective to meet the specified product utilization standards.

14.21 - Baseline Distance. Baseline distance is the horizontal distance from the face of the tree to a manufacturer's specified point on the height (angle) measuring instruments. Many instruments used to measure tree height are calculated for specific baseline distances.

When using a tape to measure baseline distance, attach the tape at a convenient height on the tree and back off the required distance, pulling the tape tight. With a clinometer, find the percent slope of the tape going back to the tree. If the slope is over 10 percent, an adjustment to the measured slope distance is necessary to prevent a bias in the height calculation. Calculate the slope distance by multiplying the desired baseline distance by the slope correction factor (ex. 01). Back off the slope distance and measure the tree height from this distance, the desired baseline distance.

Example:

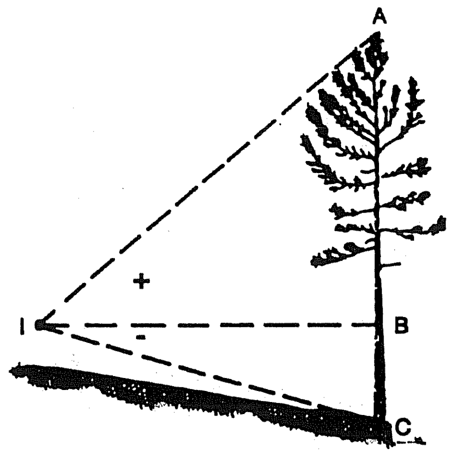
Initial measured base distance (desired horizontal distance) = 66 feet
Percent slope to tree = 25
Indicated slope distance for 66 feet = 68 feet (66 x 1.03)

This adjustment is necessary to ensure the desired horizontal distance is maintained.

14.21 - Exhibit 01
Slope Correction Factor
(Corrects Horizontal to Slope Distance)

Slope Correction Factor			
Percent of Slope	Slope Correction Factor	Percent of Slope	Slope Correction Factor
0 to 9	1.00	70	1.22
10 to 17	1.01	71 to 72	1.23
18 to 22	1.02	73 to 74	1.24
23 to 26	1.03	75	1.25
27 to 30	1.04	76 to 77	1.26
31 to 33	1.05	78 to 79	1.27
34 to 36	1.06	80	1.28
37 to 39	1.07	81 to 82	1.29
40 to 42	1.08	83	1.30
43 to 44	1.09	84 to 85	1.31
45 to 47	1.10	86	1.32
48 to 49	1.11	87 to 88	1.33
50 to 51	1.12	89	1.34
52 to 53	1.13	90 to 91	1.35
54 to 55	1.14	92	1.36
56 to 57	1.15	93 to 94	1.37
58 to 59	1.16	95	1.38
60 to 61	1.17	96 to 97	1.39
62 to 63	1.18	98	1.40
64 to 65	1.19	99 to 100	1.41
66 to 67	1.20	101	1.42
68 to 69	1.21		

<u>14.22</u> - <u>Vertical Trees</u>. Measure the height of a vertical tree whenever possible from either level ground or from the uphill side. Use elevation and depression angle measurements from horizontal to get the height. In figure 01, the elevation angle from the horizontal line to the tree top is shown by a (+); the depression angle from the horizontal to the ground by a (-).



<u>14.22</u> - <u>Figure 01</u>
<u>Measured on Level Ground or from the Uphill Side</u>

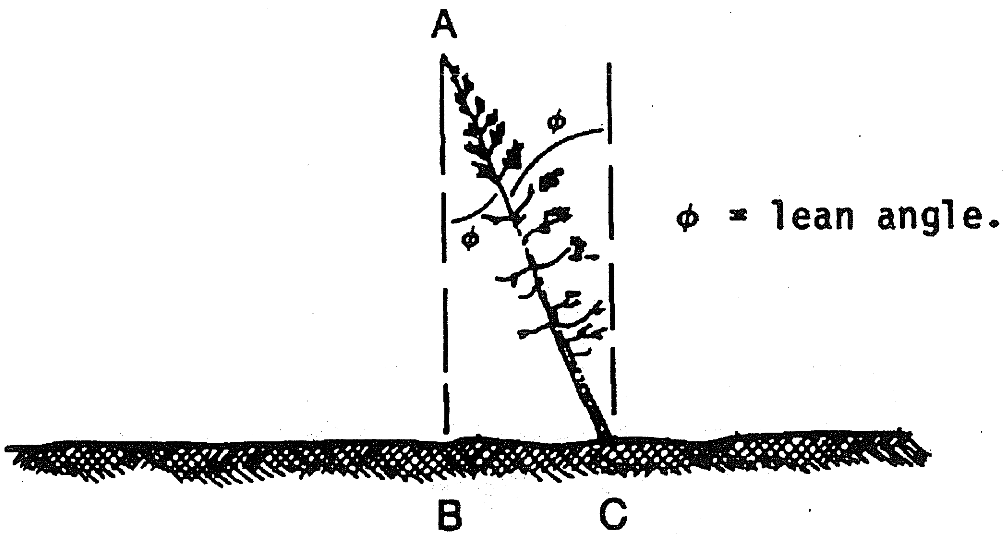
If the two angles from horizontal have different signs (if measured from level or up-slope position), add the absolute values of the two height measurements to determine tree height. If both angles from horizontal have the same sign (if measured from the down-slope position), take the absolute values of the heights and subtract the smaller height reading from the larger one to get tree height.

Examples:

1. Tree measured from up-slope position:
   Instrument elevation to tree top = +40 feet;
   Instrument elevation to ground = -10 feet.
   Tree height = 40 + 10 = 50 feet.

2. Tree measured from down-slope position:
   Instrument elevation to tree top = +65 feet;
   Instrument to ground = +15 feet.
   Tree height = 65 - 15 = 50 feet.

14.23 - Leaning Trees. Trees leaning 25 percent (about 15°) or more from vertical require the following special height measuring technique. See figure 01. The angle formed by the intersection of line AB and line BC must be a right (90°) angle.



14.23 - Figure 01
Measuring Height of Leaning Trees

1. Determine vertical distance from the ground to the tip of the tree (AB).

2. Determine horizontal distance by measuring from the tree bole to a point directly under the tip of the leaning tree (BC).

3. Determine length of the bole (actual tree height, AC) using the pythagorean theorem for right triangles where

$$\text{Tree Height (bole length)} = \sqrt{AB^2 + BC^2}$$

or use table 1 in chapter 90.

Example:
Vertical Distance, ground to tip (AB) = 65 feet.
Horizontal Distance, stump to point under tip (BC) = 26 feet.

$$\begin{aligned} \text{Tree Height} &= \sqrt{AB^2 + BC^2} \\ &= \sqrt{65^2 + 26^2} \\ &= \sqrt{4901} \\ &= 70 \text{ feet} \end{aligned}$$

Alternatively, use the angle-of-lean method:

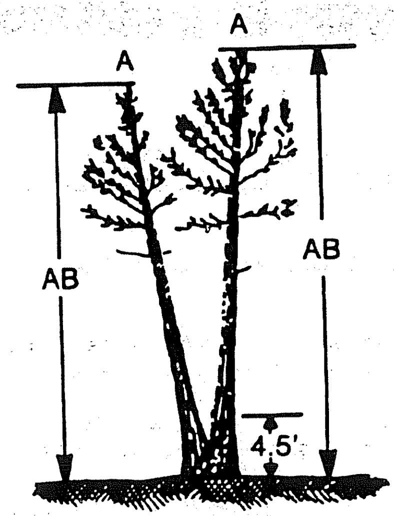
1. Measure Vertical Distance (AB)

2. Determine tree lean angle (ϕ in percent or degrees). The lean angle can be measured in degrees rather than percent, but then a trigonometric table is necessary to find the secant of the measured angle.

3. Multiply Vertical Distance by slope correction factor (sec. 14.21) to obtain bole length or the leaning tree height.

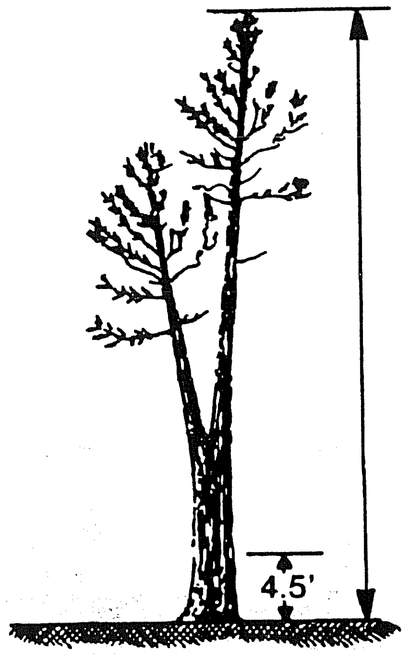
Example:
Lean percent = 40, Factor = 1.08
(Lean angle = 22° Secant = 1.08)
Vertical Distance = 65 feet
Leaning tree height = 65 x 1.08 = 70 feet.

<u>14.24</u> - <u>Forked Trees</u>. If trees fork below DBH, treat as two trees and measure height of each stem from base of tree to tip of tree.



<u>14.24</u> - <u>Figure 01</u>
<u>Height of Trees Forked</u>
<u>Below DBH</u>

If the fork crotch occurs at or above 4.5 feet on high ground side, the tree is treated as a single tree. Measure height of the best fork.



14.24 - Figure 02
Height of Trees Forked Above DBH

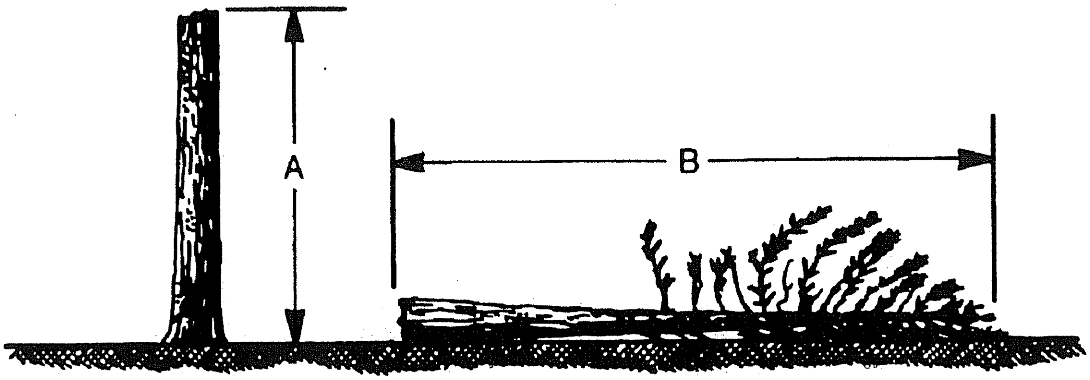
14.25 - Trees Having a Broken or Missing Top. Measure according to the following examples:

1. Total height of trees with broken top lying on the ground (fig. 01):

a. Measure height of the stub (A).

b. Measure length of the piece on the ground (B).

c. Add the two measurements to obtain total height (A + B).



14.25 - Figure 01
Height of Trees With Broken Top

2. Total height of trees with broken top attached (fig. 02). If distance to the break is short, measure tree height using procedures in paragraph 1. If distance to the break is great, measure tree height using the following procedures:

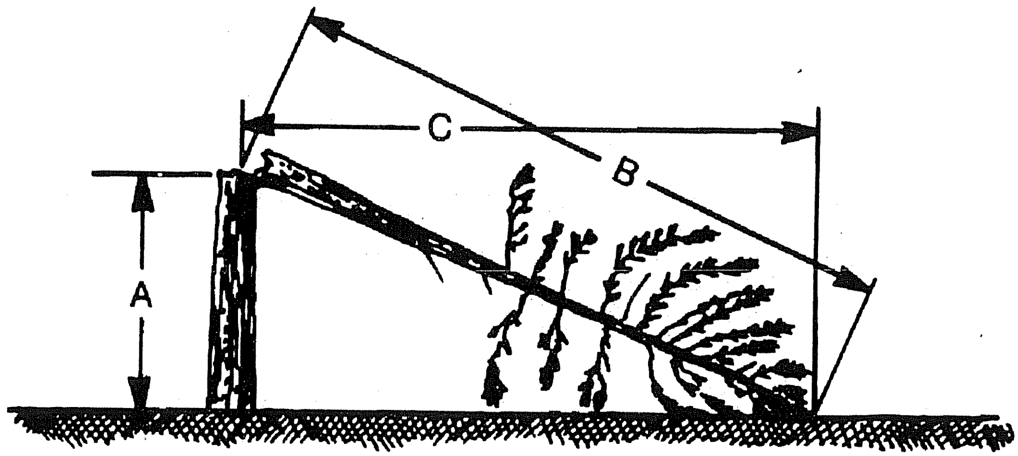
a. Measure height to break (A).

b. Measure ground distance from tip to stump (C).

c. Calculate length of the broken piece (B) using the pythagorean theorem for right triangles where:

$$Height\ B = \sqrt{A^2 + C^2}$$

d. Add the two height measurements to obtain total height (A + B).



14.25 - Figure 02
Height of Trees with Broken Top Attached

3. Total tree height when top is missing. Locate three trees of the same species, with similar DBH measurements and diameter measurements at a convenient point up the tree, such as 16 feet, 32 feet, or other height. Measure total height of the three comparison trees and use their average height as the total height measurement.

14.26 - When Measurement Point is Hidden. There are many instances where height to be measured such as merchantable height cannot be measured directly. Dense foliage or foliage from an adjacent tree may obscure the measurement point. In these instances, obtain an average height from three comparison trees.

Example of comparison tree method for merchantable height (reference height):

	Tree 1	Tree 2	Tree 3	Average	Tree being Measured
Total height	100 ft.	110 ft.	105 ft.	105	108
Merch. height	81 ft.	87 ft.	84 ft.	84	to be estimated
DBH	16	18	18	17.33	17

$$\text{Average height ratio} = \frac{84}{105} = .80$$

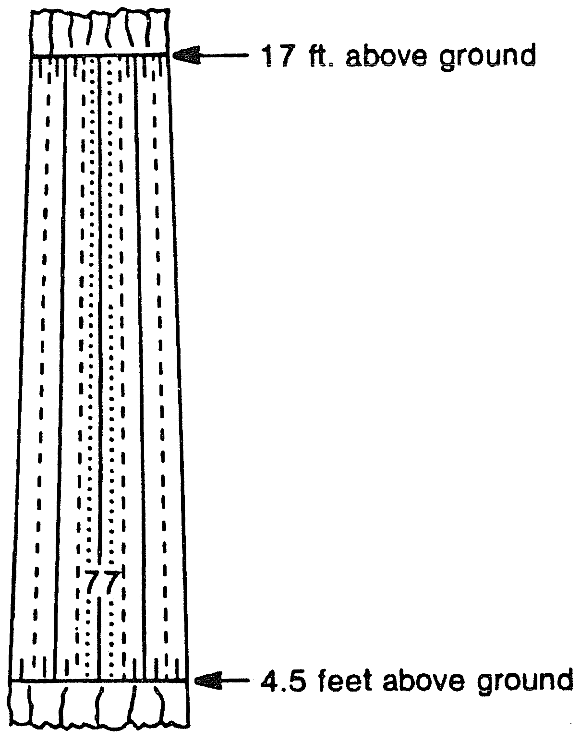
Reference height (tree being measured) = 108 feet x 0.80 = 86.4 = 86 feet.

14.3 - Tree Form Class. A measure commonly used as an independent variable along with DBH and height is Girard form class.

$$\textit{Girard form class} = \left(\frac{\textit{DIB at top of butt log}}{\textit{DBH}}\right) \times 100$$

Specify the length of the butt log used for this purpose since form class may be expressed for either a 16-foot or 32-foot butt log. (Normally the DIB of the butt log is recorded at 17 or 33 feet above the ground to allow for a 1-foot stump.)

An alternate method of determining Girard form class is to use the Wiant f-c wedge, available from forestry supply houses. Match the wedge to the form of the butt log.



14.3 - Figure 01
Wiant F-C Wedge (reduced size)