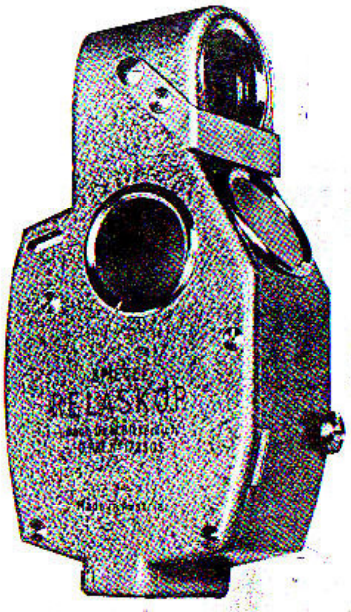
SPIEGEL - RELASKOP

SHA004



Inventor: DR. W. BITTERLICH

These Instructions prepared by
Dr. John P. Bell
School of Forestry
Oregon State University
Corvallis, Oregon, U.S.A.

SPIEGEL - RELASKOP

Inventor: W. W. Bitterlich

These instructions prepared by Dr. John F. Bell, School of Forestry, Oregon State University, Corvallis, Oregon, U.S.A.

INTRODUCTION:

The Spiegel-Relaskop is an instrument designed for use as an angle gauge in the Bitterlich angle method of forest sampling (also known as horizontal point sampling and variable plot sampling) for determining basal area in square feet per acre. The Spiegel-Relaskop can also be used to directly measure tree diameters to any height that stem visibility permits: to measure tree heights, to read slope in percent, topographic, and degree scales and to directly measure horizontal distances.

Three scale arrangements — American, Metric and Wide — are offered to fit different conditions and usages.

The Spiegel-Relaskop is a compact, ruggedly-constructed instrument. Weight 14 ounces.

Throughout the remainder of these instructions, the instrument is referred to as RELASKOP.

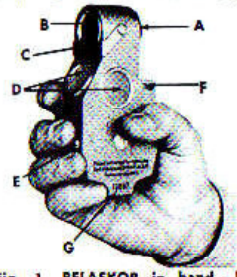


Fig. 1 RELASKOP in hand - held operating position.

OPERATION:

If hand-held, the RELASKOP should be positioned as per Fig. 1. For more precise work, mount it on a tripod (Fig. 2). One person, unassisted, can make accurate measurements with RELASKOP.

Looking through the small window "A" gives a clear, wide angle view through "B" in which is visible a series of black and white scales. A shade "C" is provided to permit use when facing bright light. In use, the 3 circular windows "D", beneath A and B should remain free of obstruction as they provide light to the scales. The button "E" releases the brake which holds the scale wheel in position between readings. The scale wheel operates on the pendulum principle but dampens very fast and brakes easily. There are 2 eyes "F" on which a strap is attached for carrying the instrument suspended from the neck, if desired.

The field of vision through A-B is divided into 2 halves, upper and lower, by a horizontal line which is the measuring "edge." No other point of reading is accurate. Through the upper half the RELASKOP user views the terrain and the trees. In the lower one-half the RELASKOP user will see against a dark background a series of bars and black and white bars and scales extending up to the measuring edge.

To take a reading, the user presses brake release button "E" and the scale automatically rotates to the angle the instrument is tilted when sighting at the point of measurement. Partial release of button "E" helps to bring the pendulum to a fast stop. The scales for the American (Standard) scale RELASKOP are illustrated in Fig. 3 and 3a and they are identified at the base of the scales when the instrument is tilted down 60°.

Fig. 2 RELASKOP on tripod mounting; shake-free for greater accuracy. Distance "a" is always measured from the eye of the observer.

INSTRUCTIONS FOR AMERICAN SCALE RELASKOP

HOW TO MEASURE BASAL AREA WITH AMERICAN SCALE RELASKOP

In the Bitterlich angle method, a tree whose diameter is larger than the fixed critical angle of the Relaskop is a count tree (Fig. 4). The American Scale RELASKOP offers a choice of 4 angles — the choice of which is dependent upon the average size of the trees in the sample area. The 4 angles are illustrated in Figure 3. The edge marked "O" is the common side of all the angles. The angle "0 - 5" has a factor of 5; "0 - 10" a factor of 10; "0 - 20" a factor of 20; and "0 - a" a factor of 40. In application, you select a sampling point, project the chosen angle to each tree at D.B.H. (or any other point of observation), and count the number of trees greater in diameter than the angle used.

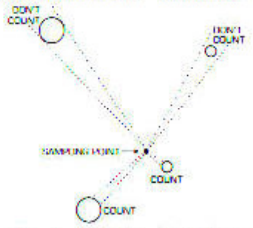


Fig. 4 Diagram illustrating how point sampling works.

If a stem is obscured by intervening trees, it is necessary to move to one side, but maintaining the same distance from the tree, to view it. The number of trees counted multiplied by the angle's factor (BAF) equals the basal area in square feet per acre at the sampling point. The effect of terrain slope is automatically compensated for by the curve in the scales. Figure 3 illustrates how the instrument corrects for slope by varying the width of the scale.

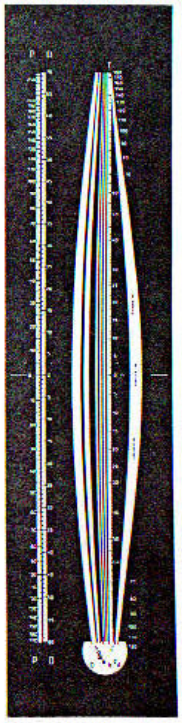


Fig. 3 American Scales, full view.

HOW TO MEASURE DIAMETER WITH AMERICAN SCALE RELASKOP

The scale between "a" and "b" on Figure 3 is divided into 6 equal width bars (3 light and 3 dark).

The projection of the distance "a" to "b" is equal to
1 foot (each bar 2 inches) at a horizontal distance of 33 ft.
2 feet (each bar 4 inches) at a horizontal distance of 66 ft.
3 feet (each bar 6 inches) at a horizontal distance of 99 ft.
4 feet (each bar 8 inches) at a horizontal distance of 132 ft.

The distance between "0" and "10" on the scale equals the distance between "a" and "b". Similarly, the distance between "10" and "a" equals the distance between "a" and "b". At 33 feet, "a" to "b" intercepts 12 diameter inches.

Thus, to measure the diameter of a tree with a DBH of 34 inches, position the RELASKOP 33 feet from the tree and set the "0" edge of the scale on the left bark edge of the tree. Distance "0" to "10" will intercept 12 diameter inches; "10" to "a" will intercept another 12 diameter inches and the right bark edge will align with the right edge of the fifth bar between "a" and "b" for 10 more diameter inches. Total 12 + 12 + 10 = 34 inches DBH. In this case the diameter can be read to the nearest 2 inches (and estimated to the nearest 1 inch).

By positioning the RELASKOP at other distances, such as 66, 99 or 132 feet, different values apply. At 132 feet distance, a tree with a DBH of 144 inches could be measured.

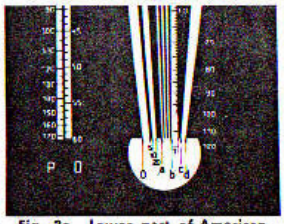


Fig. 3a Lower part of American scale, enlarged to show identification of graduations.

Since the instrument is self-adjusting for changes in slope, it follows that the diameter at any height above the ground may be determined without correcting for slope.

HOW TO MEASURE HEIGHT WITH AMERICAN SCALE RELASKOP

Scale "T" reads height in feet at a horizontal distance of 66 feet from the tree with a range of +180 feet to −120 feet. Figure 3 shows how the height is read by 1 foot intervals to plus 100 feet or minus 100 feet by five foot intervals from plus 100 feet to plus 180 feet and from minus 100 feet to minus 120 feet. The height scale may be changed by varying the distance: at 33 feet horizontal distance the 120 reading equals 60 feet, at 99 feet the 120 reading equals 180 feet.

COMBINING DIAMETER AND HEIGHT MEASUREMENTS WITH AMERICAN SCALE RELASKOP

By combining height (T) and diameter scale readings, it is possible to read the outside top diameter of each log length until the stem is obscured by the crown.

It is best to choose for distance "a" multiples of one inch divisable by 200, since full RELASKOP units (RU) are equivalent to 1/50, and quarter units (RU/4) are equivalent to 1/200 of distance "b":

The tables below will be helpful.

Distance "a"					1 RU			1 RU/4		
In.		Ft.	In.	Meters	In.		Cm	In.		Cm
200	=	16	8	= 5.08	4	=	10.16	1	=	2.54
400	=	33	4	= 10.16	8	=	20.32	2	=	5.08
600	=	50	0	= 15.24	12	=	30.48	3	=	7.62
800	=	66	8	= 20.32	16	=	40.64	4	=	10.16
1000	=	83	4	= 25.40	20	=	50.80	5	=	12.70

These distances are also well-suited for rapid determination of measuring heights which, in North America — aside from breast height — are at 16 feet above ground. With a distance in inches of

200, 16 feet above ground is at 96 percent ("P" scale)

400, 16 feet above ground is at 48 percent ("P" scale)

600, 16 feet above ground is at 32 percent ("P" scale)

800, 16 feet above ground is at 24 percent ("P" scale)

1000, 16 feet above ground is at 19.2 percent ("P" scale)

The measuring height of 32 feet is found through doubled percentage values, the measuring height of 48 feet is found through tripled percentage values, and so on.

TO MAKE GIRARD FORM CLASS MEASUREMENTS WITH AMERICAN SCALE RELASKOP

Rotated angle method

1. Find point on the ground where D.B.H. of sample tree is tangent to the critical angle of the prism (point P Fig. 5).
2. From P determine the vertical angle to the top of the first log (point B).
3. Sight from P to point B and rotate the prism at right angles to the line of sight until the stem images become "line." Measure the angle of rotation (abney or clinometer).

$$\text{Form class o.b.} = \frac{\text{Cosine rotated angle}}{\text{Cosine vertical angle}}$$

Form class i.b. = Form class o.b. x bark thickness ratio.

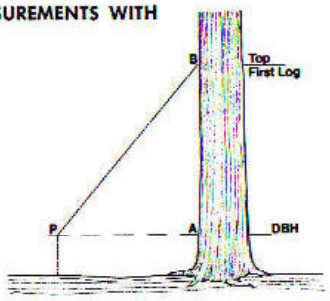


Fig. 5 Diagram to explain determination of Girard Form Class.

Cosines of Slopes

2° - .999	14° - .970	26° - .899	38° - .788
4° - .998	16° - .961	28° - .883	40° - .766
6° - .994	18° - .951	30° - .866	42° - .743
8° - .990	20° - .940	32° - .848	44° - .719
10° - .985	22° - .927	34° - .829	46° - .694
12° - .978	24° - .914	36° - .809	48° - .669

If Girard and Bruce form class tables are being used, form class can be eliminated by observing the trees at the top of the first 16-foot log — see Dilworth and Bell (Reference No. 3) for procedure to use.

TO USE AMERICAN SCALE RELASKOP AS A RANGEFINDER

To find ranges of 33, 66 and 99 feet proceed as follows:
Hold the RELASKOP flat with scales locked as per Fig. 6.

3 feet are intercepted by "b" to "d" at a horiz. distance of 33 ft.
6 feet are intercepted by "b" to "d" at a horiz. distance of 66 ft.
6 feet are intercepted by "b" to "c" at a horiz. distance of 99 ft.
8 feet are intercepted by "b" to "c" at a horiz. distance of 132 ft.

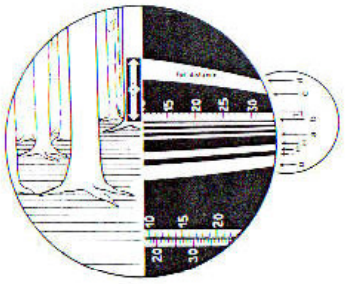


Fig. 6 Illustrating determination of distance (or range) with American Scale RELASKOP.

In using the instrument to establish horizontal distances from the tree to be measured, a staff exactly 6 feet long is held vertically (or leaned against the tree) at its central axis. From an estimated horizontal distance of 66 feet from the tree the slope is measured with the instrument and the scale fixed in position at this slope by setting the brake. The instrument is turned 90° and the staff should intercept the distance along the "measuring edge" from "b" to "d" if the 66 feet is estimated accurately. (Fig. 6) By moving forward or backwards the accurate point can be established. You can do the same with a staff 3 feet long and a horizontal distance of 33 feet.

TO MAKE SLOPE MEASUREMENTS WITH AMERICAN SCALE RELASKOP

DEGREE SCALE

Scale "D" to the left of "0" is graduated in degrees. See Fig. 3a. The range is from plus 70° to minus 60°.

PERCENT SCALE

Scale "P" to the left of Scale "D" is graduated in percent. See Fig. 3a. The range is from plus 270 percent to minus 170 percent.

TOPOGRAPHIC SCALE

Scale "T" to the right of "b" gives the topographic corrections to be applied in using the 2-chain tape with trailer. See Fig. 3a. The readings are the number of feet difference elevation per 1 chain horizontal distance. Range is between plus 180 feet and minus 120 feet.

The plus and minus direction of the instrument for scales "T", "D" and "P" are indicated only at the zero point.

INSTRUCTIONS FOR METRIC SCALE RELASKOP

HOW TO MEASURE BASAL AREA WITH METRIC SCALE RELASKOP

In the Bitterlich method, a tree whose diameter is larger than the fixed critical angle of the Relaskop is a count tree (Fig. 4).

The angles with the counting factor 1 and 2 are the ones most frequently used. Both angles are illustrated by white stripes showing the continuous numbers 1 and 2 respectively (Fig. 8). In application, select a plot center, project the chosen angle (strip) of the scale to each tree at DBH that can be seen from the point, and count the number of trees greater in diameter than the angle used. If a stem is obscured by intervening trees, it is necessary to move to one side but maintaining the same distance from the tree, to view it. The number of trees counted times the angle's basal area factor equals the basal area in square meters per hectare in the plot. The effect of the slope of the terrain is automatically adjusted by the instrument when the brake is released and the scale comes to rest on a particular tree's DBH.

To the right of strip 1, the same width is divided into 4 bars (two dark and two light ones). Added to strip 1, they give an angle with the basal area factor 4, which is also used frequently.

Trees which seem to be of the same width in diameter as the angle used, have to be checked by measuring. In order to be counted, the tree diameter multiplied by the Plot radius factor must give an answer larger than the distance from the plot center to the stem. (Example: Basal Area Angle factor 4, having the Plot radius factor 1 :25; tree with measured DBH 36cm; the critical radius is 36 x 25 = 900 cm; tape measurement gives a distance of 897 cm. Tree has to be counted).

Basal area may be determined at any desired height. Measurements at different height give valuable information about the shape-factor of a particular stand. Using a colored 4 meter staff, it is easy to find the height where the diameter is of the same width as the angle used. (This point is called "Deckpunkt"). This staff, for example, is from 1,3 m blue, from 3,0-3,5m white, and from 3,5-4,0m red. If the "Deckpunkt" falls into the blue section, the stem has to be counted up to a height of 2,5 meters, but not at a height of 3,0 meters.

Fig. 7 Scales of the Metric RELASKOP in their full length. The varying width of the stripes illustrates how the instrument corrects for changes in slope. From left to right: tangent scale for horizontal distance of 20 meters, strip 1 with the following dark and two light bars, tangent scales for horizontal distances of 25 and 30 meters, strip 2, and two stripes of different width used as range finder.

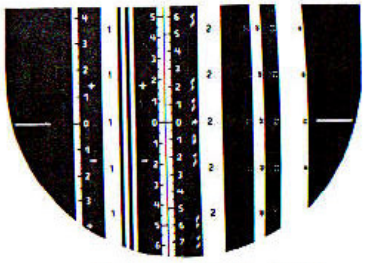


Fig. 8 Metric scales, close-up.

Basal area of a stand will be measured at random. The number of sample plots, which depends upon the homogenity of the particular stand, upon the size of the average stem diameter, and the accuracy desired, has to be determined by statistical means. The distribution of the plots will be done by the grid method, using either the rectangular system or the triangular system. In old stands, using the angle of factor 4, the following numbers of sample plots are recommended:

For areas smaller than 4 hectare	4,0 plots per hectare
For areas of 4 - 8 hectare	3,8 plots per hectare
For areas of 8 - 16 hectare	3,5 plots per hectare
For areas of 16 - 32 hectare	3,1 plots per hectare
For areas of 32 - 64 hectare	2,6 plots per hectare
For areas larger than 64 hectare	2,0 plots per hectare

Using the angle of factor 2, the number of plots per hectare can be reduced by roughly 40 percent, and by 60 percent when the angle of factor 1 is used. The number of plots must be enlarged when stands are heterogeneous, when the average diameter at breast height is smaller than 20 centimeters, or high accuracy is desired.

HOW TO DETERMINE AVERAGE STAND HEIGHT by HIRATA'S METHOD USING METRIC SCALE RELASKOP

Average stand height according to Hirata can also be determined by measuring sample plots. Using the 25 m tangent scale which appears on the right hand side of strip 1 and the four bars, the height of every tree seen from the plot center has to be measured. The sum of the readings at the approximate stump height and at the top of the tree (in case the stump height falls above the horizontal line the difference of both readings) has to be larger than the value of 63 (exactly 62,7) in order to be counted. Every tree of the value smaller than 63 "Z" and is employed in the following formula:

$$h_m = 100 \cdot \sqrt{2_Z / n}$$

In order to calculate the average stand height "h_m", the number of trees per hectare "n" must be found. This can be done by combining the H-Measurement with a B-Measurement at breast height, taken from the same plot center. In this measurement — similar to the determination of basal area — the angle of factor 4 is used. Every tree in question also has to be scaled at breast height by a basal area scaler reading whole square decimeter. One stem counted represents 4 square meters per hectare, or 400 square decimeters per hectare respectively. Hence, there must be so many trees per hectare as the scaled basal area of this particular tree (x dm²) is contained in 400 dm²:

$$n_1 = 400/x_1$$

Any counted tree represents a certain number of trees per hectare (n_1, n_2, n_3, ...), and the real number of trees per hectare "n" which we are looking for, is found by simple addition:

$$n = n_1 + n_2 = n_3 + \ldots .$$

An exact implementation of those measurements at random gives satisfactory values of the average stand height.

HOW TO MEASURE DIAMETER ON STANDING TREES AT ANY HEIGHT USING METRIC SCALE RELASKOP

Estimation of diameters is possible from a distance of either 15, 20, 25 or 30 meters. For this purpose, strip 1 and the four bars are applied. Strip 1 corresponds with the proportion stem diameter. :horizontal distance from the tree = 1 :50. One half of its width, therefore, corresponds with the proportion 1 :100, and one fourth of its width 1 :200.

Note: One half of strip 1 intercepts the same width in centimeter as the horizontal distance does amount in meter.

Hence:

at a horizontal distance of 15 m one half of strip 1 intercepts 15 cm

at a horizontal distance of 20 m one half of strip 1 intercepts 20 cm

at a horizontal distance of 25 m one half of strip 1 intercepts 25 cm

at a horizontal distance of 30 m one half of strip 1 intercepts 30 cm

From this, all other relations concerning horizontal distance and diameter scale readings may be derived.

For example: at a horizontal distance of 20 meters, strip 1 intercepts 40 centimeters, and one bar 10 centimeters. Parts of 10 cm have to be estimated. The entire width of strip 1 + all bars intercepts 80 centimeters. Or: at a horizontal distance of 25 meters, the entire width intercepts 100 centimeters, hence one bar 12½ centimeters and so on.

In such a way, diameter at any height may be estimated with acceptable accuracy. Care has to be taken that the brake is released, in order to adjust for changes in slope. The tripod socket permits setting up the instrument on a stable support for accurate readings.

By combining height and diameter scale readings from either one of the given distances, it is possible to read the outside top diameter of each log length until the stem is obscured by the crown. For this purpose, the applied scale — strip 1 + the four bars — was set between the tangent scale 20 and the scales 25 + 30.

HOW TO MEASURE HEIGHT USING METRIC SCALE RELASKOP

There are three different scales available, marked with 20m, 25m, and 30m (Fig. 7). These scales read height in meters at a horizontal distance of 20, 25, or 30 meters respectively. Scale 20 m ranges from −55 to −35 meters, scale 25 m from +70 to −45m, and scale 30 m from +80 to −52m. For height measurements at a horizontal distance of 15 meters from the tree the readings of the scale 30 m must be halved.

Fig. 7 Metric Scale, full view.

In order to obtain the height of a tree, two readings are necessary: one at the base and one at the top of the tree. If one reading is below the horizontal line and the other one above, the readings have to be added. If both readings are above or below the horizontal line, then the smaller reading has to be subtracted from the larger one.

HOW TO MAKE DIRECT MEASUREMENT OF FORM HEIGHT, USING METRIC SCALE RELASKOP

The form height depends upon Pressler's "Richtpunkt", the diameter on the upper part of the stem which is half as large as the diameter at breast height. This point may be found with either of three pairs of width of the diameter scale. Then, the readings of scale 25 have to be taken at this point and at the base of the tree. The sum of these readings has to be converted by the following key:

a). Using the entire width (strip 1 + 4 bars): Establish the distance from the tree where this width intercepts the diameter at breast height. Tilt the instrument upwards until the tapering stem will be covered by strip 1 only. Read scale 25 at this point and at the base of the tree, and multiply the sum of readings by 2/3. The result equals the value of "fh/d" which is the relative form height. Do not forget to release the brake while reading!

b). In the same way, strip 1 + 2 bars may be used. Here, the "Richtpunkt" is determined with aid of three bars. The reading sum of scale 25 has to be multiplied by 8/9, in order to get the relative form height.

c). In case only strip 1 is used, the "Richtpunkt" is found by 2 bars. Here, the conversion factor is 4/3.

HOW TO MEASURE RANGE USING METRIC SCALE RELASKOP

The distances between the left edge of strip 2 and the following edges at the right side which are numbered continuously with 30, 25, 20, and 15 respectively in Fig. 7 and 8 intercept 2 meters at a horizontal distance of either 30, 25, 20, or 15 meters.
The numbers are readable when the instrument is turned 90 degrees; the common edge of strip 2 is inscribed with "unten".

In using the instrument to establish horizontal distances from the tree to be measured, a staff exactly 2 meters long is held (or leaned against the tree) at its central axis (See Fig. 9). Any staff should show a visible mark in its middle. From an estimated horizontal distance desired, the slope is measured by viewing the middle mark of the staff and the scale fixed in position at this slope by setting the brake. The instrument is turned 90 degrees, and the staff should intercept the distance along the "measuring edge" if the distance is estimated accurately. By moving forward and backward the accurate point can be established.

Fig. 9 Horizontal Distance Measurement with Metric Scales. Illustration of establishing horizontal distances: after a 2 meter staff is fixed on the tree vertically, the slope is measured from the estimated distance desired by viewing the mark at the middle of the staff. Then the scale is locked and the instrument turned 90°. By moving forward or backward, the accurate point was established. Here, the staff fits into the distance between the low edge of strip 2 (inscribed with "unten") and the edge marked with "20". The horizontal distance from the tree, therefore is 20 meters.

TO USE METRIC SCALE RELASKOP AS A CLINOMETER

There exists no special percent scale, but each of the three tangent scales may serve.

Just as "percent" means "of hundred" the values of the scale 20 may be called "of twenty", those of scale 25 "of twentyfive", and those of scale 30 "of thirty". The conversion of the readings into percent is easy:

"of twenty" times 5 gives "of hundred"
"of twentyfive" times 4 gives "of hundred" and
"of thirty" times 10/3 gives "of hundred."

So, the relaskop serves as a fine reading clinometer, too, very adaptable in forestry work.

INSTRUCTIONS FOR WIDE-SCALE RELASKOP

DESCRIPTION OF WIDE SCALE

The main area of the scale resembling the shape of a stave, consists of alternating white and black bars (Fig. 10). The width of this scale is referred to as a "field of measurement". The right margin of the field of measurement consists of 4 narrow bars, 2 white and 2 black. These 4 bars form the "quarter field", which has the same width as the large white bar adjoining to the left. This width is equivalent to one RELASKOP Unit (RU); i.e., to the basal area factor 1 (1 m²/ha in the metric system) in variable plot cruising. The width of the quarter field corresponds also to the plot radius factor 50, or to about 2 percent of the scale "p" (Fig. 10). Width of each of the 5 black and 5 white bars to the left may be assumed to be the same as that of the quarter field or the first large white bar.

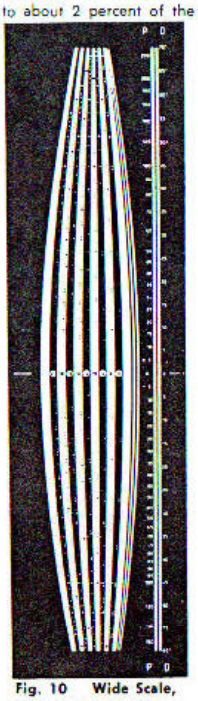


Fig. 10 Wide Scale, full view.

The stave-like taper of both ends of the group of bars corresponds to the reduction of width with the cosine of any angle of inclination in sighting at an object. The group of bars is being dissected horizontally by the measuring edge at a point that depends on the degree of tilt needed for sighting. Where the bars are being dissected by the measuring edge, a corrected measuring scale is formed as if the observed tree-diameters were projected vertically into the horizontal field of vision. The effect of all this is to automatically convert slope distance to horizontal distance.

To the right of the quarter field are two scales. The one marked "P" gives per cent slope and the other marked "D" gives degree of angle (Fig. 10).

The zero corner of the measuring field is formed by the boundary between the quarter field and the first white bar (Fig. 10). Full units are read from the right to left, while quarter units are read from the zero corner to the right. To facilitate counting full units from the zero point to the left, each bar carries a number. The number of each bar re-appears along the bar's left border at intervals that are equivalent to the distance of the 5-degree intervals on scale "D". These numbers are hatched and slightly smaller (e.g., numbers pointed at by the two lower pairs of arrows in Fig. 11) than the subsequently discussed "Ladder numbers" to avoid confusing these two different kinds of numbers.

Bars 2 to 10 contain tangent scales for measuring tree diameters at steps of one meter below and above the observer's horizon. These height scales, referred to as "ladders", appear as rows of points in the right portion of a bar. They are marked by numbers from 1 to 9, and by symbols from 10 on upward. The values 10, 20 and 30 are marked by squares that stand on one corner and have point in the center. The values 15 and 25 are represented by small rings. Intermediate values can be obtained quickly by counting from the nearest value of 5. Maximal height of each ladder is "30", or 70 degrees plus or 60 degrees minus, respectively.

Ladder values indicate meters above or below the horizon, if observations are made at the appropriate distance from the tree. The appropriate horizontal distances "a" from stem to eye of the observer (see Fig. 2 and 12) are given as even meters from 4 to 20. The numbers appear in circles at the zero point of the ladders (Fig. 12). The appropriate ladder can even be found without reference to the number at zero point. Doubling the position number of each bar indicates the appropriate base line for the respective bar-ladder. For instance, the ladder for a = 12 m can only be in the sixth bar, for a = 14 m in the seventh bar, and so on.

HOW TO MEASURE BASAL AREA WITH WIDE SCALE RELASKOP

Tree count in dense forests usually requires large factors for basal area. These are readily available in the Wide Scale RELASKOP.
The square of the number of RELASKOP units **u** used for tree count is the basal area factor **k** in m²/ha ($k = u^2$).

When measuring width 0 - 1, k = BAF 1; 0 - 2, k = BAF 4; 0 - 3, k = BAF 9; 0 - 4, k = BAF 16; 0 - 5, k = BAF 25; 0 - 6, k = BAF 36, and so forth.

The same rule applies for the quarter bands: for 1 RU/4, k = 1/16; for 2 RU/4, k = 4/16 = ¼; for 3 RU/4, k = 9/16 m²/ha. Likewise, this also applies for combinations of whole RU and quarters, as for instance: For (2 + ¼) RU = 9/4 RU, k = 81/16m²/ha. Since determination of diameter at breast height generally is of little value in old-growth or tropical timber, tree counts to obtain basal area will employ measuring heights from 4 to 10 meters above ground. Finding the desired height for measurement is accomplished most expediently by means of a bamboo pole placed vertically beside the tree. An even fraction of the measuring height, chosen as large as possible, should be indicated on the pole by two clearly visible marks (for instance, i = 4 m at measuring heights of 4, 8, 12, or 16 meters). The known rod-interval (in this example i = 4) is measured with the P scale as accurately as possible (for instance, with 23%) and then multiplied for the desired measuring height (for instance, 23 x 3 = 69%). The per cent value thus obtained (69 in this example) is used to measure from the foot point of the tree (either ground or stump) upwards and to indicate the desired measuring height (12 meters in this example). For sighting above and below the line of eye level, values of the P scale have to be added. However, if foot level and height measurement are within the same scale, the difference has to be calculated.

The rod interval obtained in p per cent (p = 23 in this example) also can be used directly for d-measurements. Since 1 RU = 2% and i/p gives the length that is equivalent to 1 per cent of the respective distance, then 1 RU = 2 i/p (800/23 cm in this example). With this method, there can be made from one point at a tree count as well as a determination of diameters at heights not accessible directly from the ground.

If horizontal distance to the point of observation is determined with a tape to obtain a highly accurate determination of diameter, the height of the measuring point is found at as many per cent units as per cent of the distance is contained in the measuring height.

ADDENDUM: Basal area is measured as square feet per acre in North America. One square foot/acre = 0.2296 square meters/hectare, or 1 m² /ha = 4.3561 sq. ft./acre. Because of the complicated relation to the metric system, counting widths with even basal-area factors cannot be used. For this reason, use the metric system for tree counts and then convert to the other measuring system. With the use of u RU for the tree count, the basal-area factor k is as follows:

$$k \text{ (in sq. ft/acre)} = 4.3561\ u^2$$

HOW TO MEASURE TREE DIAMETERS AT ANY HEIGHT USING WIDE SCALE RELASKOP

Measurement consists of two steps, finding the desired height of the stem and measuring the actual diameter. Angles are employed in both steps. Since angles give only relative values, they have to be supplemented by an absolute measure. The base line "a" is best suited as an absolute measure. An even value in meters from 4 to 20 is recommended because it allows use of the already described ladders and it simplifies computation of diameter. The length of the selected base line should be measured with a tape.

The closer the observer is to the diameter to be measured the greater will be the accuracy of measurement with the RELASKOP. However, too steep a sighting should be avoided. For instance, a diameter at 10 meters above the observer's horizontal eye line should not be measured from a distance of 4 meters, but from 10 or 12 meters.

The following rules apply to the determination of diameter. The left edge of the stem should coincide with the edge of one of the bars in such a fashion that the right edge of the stem falls into the quarter field. First the full RU to the left of zero are counted and then the remainder in the quarter bars (RU/4), or estimated fractions thereof to the right of zero.

RU and RU/4 are converted to centimeters by using the distance of the base line. If distance in meters is a, then 1 RU = a2cm (Conversion is simple, since suggested a-values are even and therefore result in even centimeters for 1 RU/4). See example in Figure 12: Base line is 18 meters; point of measurement is situated 5 meters above eye level. 1 RU = 36 cm, 1 RU/4 = 9 cm. The left edge of the stem coincides with the edge of bar 7, or 7 RU to the left of zero. From zero to the right edge of the stem one reads 1 RU/4 + 0.6 RU/4, 7 RU x 36 = 252 cm; 1 RU/4 = 9 cm; 0.6 RU/4 = 5.4 cm. Adding together these values shows that the diameter is 266.4 cm.

Double ladder distances can be employed for measurements of very tall trees. In this instance, the ladder units are equivalent to 2 meters instead of 1 meter. The per cent scale "P" has to be used to determine the height of the measuring point when difficult terrain or other circumstances do not permit working with any of the base lines (2 to 20 meters), indicated along the zero line. This scale indicates the desired height, below or above eye level, as a percentage of the length of the base line. For example: a = 25 m, 1% = 25 cm. If 7 meters above eye level is desired as a point of measurement, the sight has to be raised until 700 cm: 25 cm = 28 units of "P" are indicated by the measuring edge. Thus, 1 RU is equivalent to 50 cm, and 1 RU/4 = 12.5 cm. (What

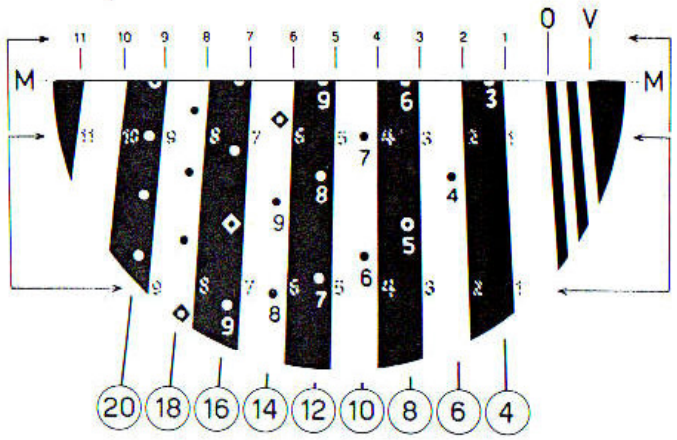


Fig. 11 Wide Scale Terms and Symbols. MM = measuring edge. 0 = zero point of the scale. From the zero point whole RELASKOP units (RU) are counted to the left, and quarter units (RU/4) are counted to the right. 1, 2, 3, ...11 = Numbering of bars and their left edges or corners (along M-M). Numbers to designate bars are hatched and are pointed at by the four lower horizontal arrows. V = the right limit of the quarter field. The encircled even numbers 4, 6, 8, ...20 indicate horizontal distances in meters that have to be used with the ladder scales in the bar above the encircled number. Each encircled number is double that of the number of the appropriate bar (e.g., bar 2 for a = 4, bar 3 for a = 6, and so on). The ladders consist of points, rings and diamonds. Ladders are numbered only from 1 to 9. The values 10, 20 and 30 are marked by the diamonds, the values 15 and 25 are marked by rings. In this illustration, the scale is so dissected by the measuring edge that for distance a = 4 the ladder value is h = 3. Consequently, one reads therefore h = 15 at a = 20. All values are in meters, but other units of length may be used instead.

falls into the quarter field is estimated best as tenths of an RU rather than as RU/4 or fractions thereof; c.f., 0.4 RU, instead of 1 RU/4 + 0.6 RU/4. Doing so simplifies conversion: 7.4 RU X 50 = 370 cm).

HOW TO DETERMINE GIRARD FORM-CLASS USING WIDE SCALE RELASKOP

The Girard form-class is a measure of the taper of trees. The form classes on which tree tapers are based are determined by the ratio (decimal) which the diameter inside bark at the top of the first 16-foot log bears to the diameter breast high outside bark. Precise determination of form class on standing trees is possible only by using ladders and measuring the thickness of the bark. For example: diameter inside bark at the top of the first 16-foot log = 21 inches, diameter breast high outside bark = 25 inches; 21 is 84% of 25, therefore form class is "84". Construction of volume tables in the United States is based on these form classes. This makes the tables usable for most commercial species, and eliminates necessity for separate tables for each species.

However, actual determination of form class usually is based on estimates and known figures for the respective species. Now, the Wide Scale RELASKOP permits rapid and accurate determination of Girard form class as follows:

That distance from the tree is sought at which 10 RU exactly cover dbh (diameter breast high) (when working on a slope, distance is determined on the up-slope face of the tree). Then the 10 RU are equivalent to 100 per cent. The next step is to sight at the top of the tree's first 16-foot log and to measure the (estimated) diameter inside bark in RU, whereby fractions of a RU should be estimated in tenths (for instance, 7.2 RU). Since one RU is equivalent to 10 per cent of the dbh (with bark), the obtained figure has to be multiplied by 10 to get the form class (in this example: 7.2 x 10% = 72% = form class 72). The measuring height of 16 feet should be indicated wherever possible by an assistant by means of a pole.

The distance from the axis of the tree is only 5 dbh in the procedure described above (dbh = 10 RU). This can lead to too steep a sighting to the upper measuring point when working in small timber. In such event, twice the distance should be used with dbh = 5 RU = 100 per cent. But then one must remember that 1 RU is equivalent to 20 per cent of the dbh.

HOW TO MEASURE DISTANCE USING WIDE SCALE RELASKOP

A. To Establish a Desired Distance

With horizontal base: Use distance factor 10 (Df 10) which is equivalent to 5 RU and given by the width 05 of the wide scale. Length of the rod should be 1/10 of the distance that is being measured. Horizontal distance is obtained with pendulum disengaged. Sloping distance is found when the pendulum is arrested at zero degrees.

With vertical base: Use Df 10 and rod as described above. For slopes up to 60 per cent, $\cos^2$ correction can be approximated closely enough to determine horizontal distance by the following procedure. Sight at the center of the rod positioned at a distance estimated to be approximate to the distance desired. Read on "P" the slope of sight. Add half of the value of the obtained reading. Tilt the instrument further until the new value can be read at "P" and arrest the pendulum. (E.g., First reading — 24 per cent, final positioning at — 36 per cent). Without touching button E, the RELASKOP is now turned counterclockwise along the axis of sight until it is in horizontal position. By this motion, the width of measurement to be employed is brought into a vertical position. The next step is to coincide measuring width 05 with the vertically positioned staff by either moving forward or backward.

B. To Determine An Unknown Horizontal Distance.

Use a large vertical base and use the P-scale, preferably employing a tripod. The height interval i (in meters), known through the vertical base, is being measured in per cent from the observer's position. Fractions of a per cent should be estimated to the nearest one-tenth. The per cent value obtained for i (difference resp. sum of both readings) is to be called p; as is i, the desired horizontal distance a is expressed in meters.

Since $i = a, \frac{P}{100,}$

then $a = \frac{100,i}{P}$ . . . . . (1)

To judge precision of the procedure more closely, function a — equation (1) — is differentiated to P:

$$\frac{da}{dp} = \frac{-100.i}{p^2} \quad \text{or, because} \quad P = \frac{100.i,}{a}$$

$$\frac{da}{dp} = -\frac{a^2}{100.i} \quad \text{or}$$

$$da = -\frac{a^2}{100.i} .dp \quad . \quad . \quad . \quad . \quad (2)$$

An error dp contained in the measured per cent value p will be less effective as distance error da the larger i is. At the same time, however, this error will increase with the square of the distance.

Fig. 12 Example of Diameter Measurement Using Wide Scale. Distance to the tree is 18 meters, and the measuring point selected is 5 meters above eye level. Edge 7 coincides with the left edge of the tree while the right edge of the tree falls into the quarter field. The reading gives: 07 = 7 whole relaskop units (RU); to this add another 1.6 quarter units (RU/4). 1 RU = 36cm, 1 RU/4 = 9 cm; d = 7 x 36 cm + 1.6 x 9 = 152 cm + 14.4cm = 266.4cm.

Example: a = 20, i = 4, da = —dp; if for instance, a plus error of 0.2 per cent is made in the measurement, it will show as a minus error of —0.2m for distance. But if for the same base length of i = 4, distance a is only a = 10, then da = —¼.dp, i.e., the distance error amounts to just —0.05m.

This example demonstrates the necessity for a long vertical base and the importance of progressive increase in the precision of measuring per cent with increasing distance. Greater precision can be obtained by use of a tripod and repetition of readings. To what maximal distance measurements can be made will depend on the requirements for accuracy of results.

GENERAL SURVEYING APPLICATIONS.

If the wide-scale RELASKOP is used on a tripod, it is suitable to a variety of surveying purposes within the range where the naked eye can resolve details.

A panoramic head on the tripod makes possible dividing the full turning cycle into 24 equal sectors of 15 degrees each. Within each of these sectors, individual degrees can be determined by means of the RELASKOP units. When sighting horizontally, the band width of an RU is equivalent to an angle of 1° 08' 55"; however, when the sight is lowered about 29° 20', or 56%, and the pendulum arrested in this position, then each RELASKOP unit equals one degree and thus may be used for measurements. Fractions of a degree have to be estimated. For such an estimate, the quarter field may be employed.

Vertical angles can be measured either with scale "D" within a range from —60° to +70° or with the percent scale "P". The "P" scale gives differences of elevation in per cent of distances, something that has been discussed already. Differences of elevation also may be determined with a level when markings on the rod can still be discerned with the naked eye. The "P" scale is particularly suitable for leveling and determining cross profiles.

It is also possible to perform rough topographic surveys measuring horizontal angles as described above, taking distances with help of a tape or by optical means and measuring elevations with the P- or D-scale.

Topographic description and orientation: It is better to use the units "RU" than your thumb. These units offer you a continuous scale of horizontal angles which quickly may be compared with the panorama of country. The same is true for vertical angles which may be measured or transmitted by means of the P- or D-scale.

To fix surveyed points if their marks, such as boundary stones or stakes, should be damaged, or to fix the place of pipe lines under ground, we can use tape measures from fixed objects, as buildings, and big stones. With help of the Wide Scale RELASKOP, we can substitute for these tape measures by reading the width of houses, of windows, or of big stones in RU, regarded from the point in question (It often is easier to use RU than tape measures for such purposes). It is also suitable to use diameters breast high of trees for such fixations of points, although it is necessary to consider the increment of diameters for longer intervals.

Example: In road construction, a boundary stone must be eliminated temporarily because its place must be dug off. Its later place will be a few meters deeper. Fixation by tape measure to neighboring trees is not accurate enough, as the slopes to the present point and to the future point are very different. So it is better to use the wide-scale relaskop combined with angle measuring over the boundary-stone before its elimination. Beginning from a given unobstructed direction, the horizontal angles to all neighboring trees should be measured and also the "relative width" of each tree diameter breast high in RU. Due to the automatic reduction of widths in function of slope by the relaskop, all data of measurement have to remain the same, regardless of the fact that the point in question to be fixed will be a few meters deeper than before.

REFERENCES

(1) Beers, T. W. and C. I. Miller. 1964. Point Sampling: research results and theory and applications. Research Bulletin No. 786. Purdue University, Agricultural and Experimental Station, Lafayette, Indiana.

(2) Bitterlich, W. 1948. Die Winkelzahlprobe. Allg. Forst-u. Holzw. stg. 59:4-5.

(3) Dilworth, J. R. and John F. Bell. Variable probability sampling — variable plot and Three P. OSU Cooperative Assoc., Corvallis, Oregon. 1971.

(4) Gockerell, L. C. 1957. Determination of form class of standing trees with an angle gauge. Jour. For. 55:656-659.

(5) Grosenbaugh, L. R. Plotless timber estimates — new, fast, easy. Jour. For. 50:32-37.

(6) Grosenbaugh, L. R. 1958. Point-sampling and line-sampling: probability theory, geometric implication, synthesis. South. For. Exp. Sta. Occ. Paper 160.

(7) Bitterlich, W. SPIEGEL RELASKOP: the modern instrument to measure the volume of forest stands optically. Booklet, undated.

(8) Bitterlich, W. RELASKOP with Wide Scale. Translated by Richard K. Hermann, State Forest Research Laboratory, Oregon State University, Corvallis, Oregon. 1962.