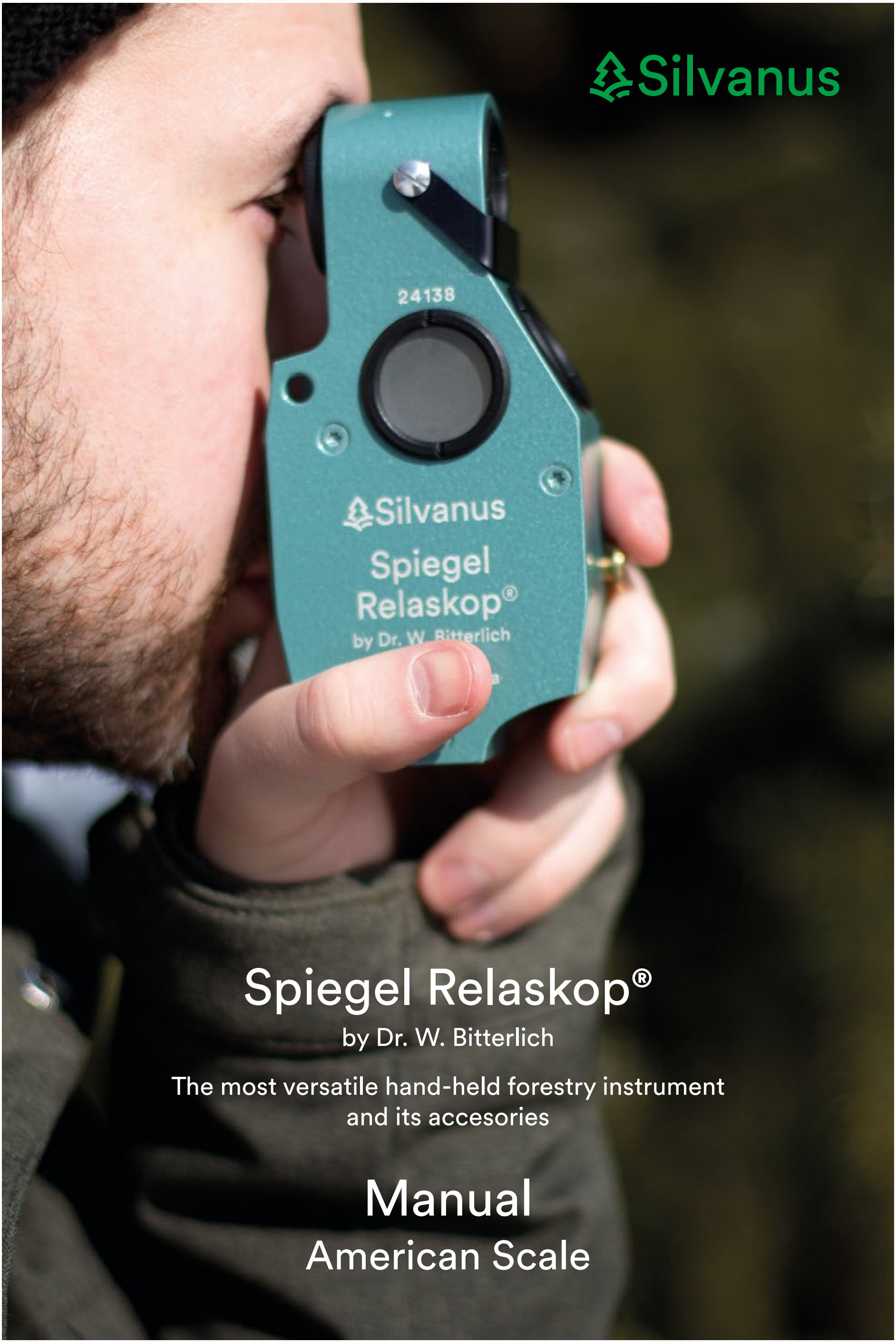


Silvanus

Spiegel Relaskop®

by Dr. W. Bitterlich

The most versatile hand-held forestry instrument
and its accesories

Manual

American Scale

Content

Spiegel Relaskop® – American Scale

Introduction

The Spiegel Relaskop, essentially unchanged in design since it has been introduced in 1955, fulfils all principle forestry measurement requirements throughout the world, as might be expected from a universal forestry instrument.

The construction of the Relaskop was initiated by the discovery of **angle-count sampling (ACS)** in 1947, a **method which determines basal area density in forests by a simple counting method.** The Relaskop automatically corrects for any inclination in the line of sight, making it possible to easily find the stand basal area in square feet per acre (or square meters per hectare) either at **breast height or any other height.**

For this reason, the Relaskops are principally known in connection with angle-count sampling.

In addition, however, the Relaskops offer quite a few other measurement applications in practical and scientific forestry. For example:

- Determining the horizontal distance, with automatic correction for the angle of inclination
- Measurement of total tree height, or heights to particular upper stem diameters
- Measurement of upper stem diameters at particular heights
- Quick determination of the "slenderness" (height/diameter ratio) of standing trees
- Determination of form heights, and the volumes of standing trees by Pressler's formula
- Determination of slope angles

Of special interest for practical work:

- Relaskops are the principle instrument of **"variable plot sampling"**, which has the special advantage of selecting a basal-area weighted distribution (and which has recently been used more generally for the selection of trees to assess forest damage). In addition, the appropriate stem numbers per acre can be derived from the ACS selection sample.

In scientific work and research, there are also the following special applications:

- Hirata's determination of the average stand height
- Strand's line sampling
  The sampling methods of Minowa-Strand, Minowa and Ueno

In order to utilize the precision of diameter and height measurements inherent in the Relaskops a **micro attachment** was constructed, which can be attached to a tripod with a special **tilting head**. These accessories in combination with the Spiegel Relaskop Metric CP are suitable for **precision measurements**, which previously required the Tele-Relaskop, under the assumption that the

power of the naked eye is sufficient and that special techniques are used (see separate booklet "Precision Measurements"). While the optical-mechanical functions of all Spiegel Relaskops are the same, they are made with four different types of scale, according to their principal use.

Different Scales

MS - Metric Standard
WS - Wide Scale
CP - Metric CP
AS - American Scale

Metric Standard, in previous years called "Metric Scale", is especially suitable for forestry conditions of temperate climates with tree diameters of up to 80 centimeters, and is especially marked for measuring heights from the standard distances of 15, 20, 25 or 30 meters as introduced in general practice in certain regions.

Wide Scale, also called "virgin forest scale", is a special scale developed for the measurement of large tree diameters at different heights, for angle-count sampling with large basal-area factors, and for simple surveying purposes. It may be used for the measurement in the metric system as well as in the English system of feet and inches.

Metric CP combines the functions of the MS and WS scales. For this reason, it is a very versatile choice.

The American Scale has functions analogous to MS, but was specially designed for Northern America. The measurements are given in the American forestry dimensions of feet and inches.

Those who use English units of measure should not automatically select the American Scale Relaskop. They might find that Wide or Metric CP Scales are more versatile, even for use with English Measurements.

A comparison between the possibilities of the different scales see Table 1 (page 5).

In this manual the optical-mechanical functions and the field use of the Spiegel Relaskop are described in detail and particularly the AS scale. Detailed descriptions for the MS, CP and WS scales can be obtained by request. The appropriate manual is, of course, delivered with each instrument.

At the end of this manual a description of a special **scale light** for use in **bad light conditions** is added.

For further details of development, theory, methods, etc., see the book **"The Relascope Idea"** by Dr. W. Bitterlich (in English).

The book **"A Sampler of Inventory Topics** – a practical discussion for resource samplers, concentrating on forest inventory techniques." by Kim Iles, biometrician and consultant on Forest Inventory in British Columbia, Canada, gives a very good and detailed description of the methods of relative measurements as well as of the Spiegel Relaskop. It is obtainable from Kim Iles (www.island.net/~kiles/).

Common to all Scales

- All readings automatically slope-corrected
- Diameter measurement within 0,5 % of distance to tree

Differences between Scales

	AS	WS	MS	CP
Vertical Degree Scale (-60° – +70°) Percent Scale (-170 – +270 %)	yes	yes	no	yes
Topographic Scales	yes	no	no	no
Range of BAFs for bars	5-90 ft^2/ac ~1-21 m^2/ha	1-144 m^2/ha ~4-625 ft^2/ac	1-4 m^2/ha ~4-17 ft^2/ac	1-81 m^2/ha ~4-350 ft^2/ac
Even BAFs on Scale	5, 10, 20, 40, 90 ft^2/ac	1, 4, 9, 16, 25 etc. m^2/ha	1, 2, 4 m^2/ha	1, 2, 3, 4, 9, 16, 25 etc. m^2/ha
Range of DBH measurable	0,5 % - 9%	0,5% - 24%	0,5% - 4%	0,5% - 18%
Direct Height readings from these distances	66 units	4, 6, 8, ..., 20 units	20, 25, 30 units	100 units
CP Correction Scale for rangefinding	no	no	no	yes
Rangefinding Distances determined	66 & 99 feet [1]	9 standard distances 4-20 m [2]	15, 20, 25, 30 meters [3]	direct reading with attachment [4]

[1] smaller values are possible with quarter bars

[2] with use of vertical or horizontal target, resp. Wedge Prism Attachment with vertical base

[3] using Relaskop Distance Scale and a verticale 2 m-target

[4] with use of horizontal staff of known length or percent scale with vertical 2 m-target or Wedge Prism Attachment with vertical base

Fig. 1: Hand-held use

1	Eyepiece	5	Sun Shade
2	Clear window	6	Tripod Socket
3	Locking Brake Release	7	Neckstrap Attachment
4	Light Windows		

Description and Handling

Description of the Spiegel Relaskop and its Handling

The Spiegel Relaskop is a compact, ruggedly constructed instrument (see Fig. 1), that weighs approximately 14 ounces. For measurements it can be held by hand, using the other hand or a staff for additional support, but it can also be used with the aid of a breast support, or preferably with a tripod, Jacob staff or similar device.

During **hand-held use (Fig. 1)** you should take care to keep the light gathering windows (4) free of obstruction. The tip of the index finger rests upon the locking break release (3). The eyepiece (1) is kept close to the eye, and the other eye is kept open to give depth perception on the object being measured.

More exact measurements than by hand-held use are possible by the **use of a tripod**, which should be equipped with lockable ball joints (Fig. 2). In either case, the eye of the observer can be brought into the elongated axis of the tripod regardless of the inclination of the Spiegel Relaskop. This is necessary because the angle of view measured by the bands have their vertex in the eye of the observer, and because the horizontal distance a from the eye to the observer is the distance from a hypothetical vertical line through the eye to the center of the tree cross-section observed.

Inside the instrument there is a freely rotating wheel, which bears **scales consisting of alternating black and white bars (bands)**, used for the measurement of widths, and with **scales calibrated for the measurement of heights** (see Figures 3 to 5). Sighting through the eyepiece (1) of the Spiegel Relaskop shows a circular field of view, which is divided horizontally by a sharp line - **the measuring edge** - into an upper and lower part (Fig. 5). For better illustration, the measuring edge is marked **M-M** in Figure 5 (but not on the actual Relaskop scale!).

Fig. 2: The Spiegel Relaskop mounted on a tripod with lockable ball joints
a – horizontal distance from the eye to the center of the tree
Cross-section

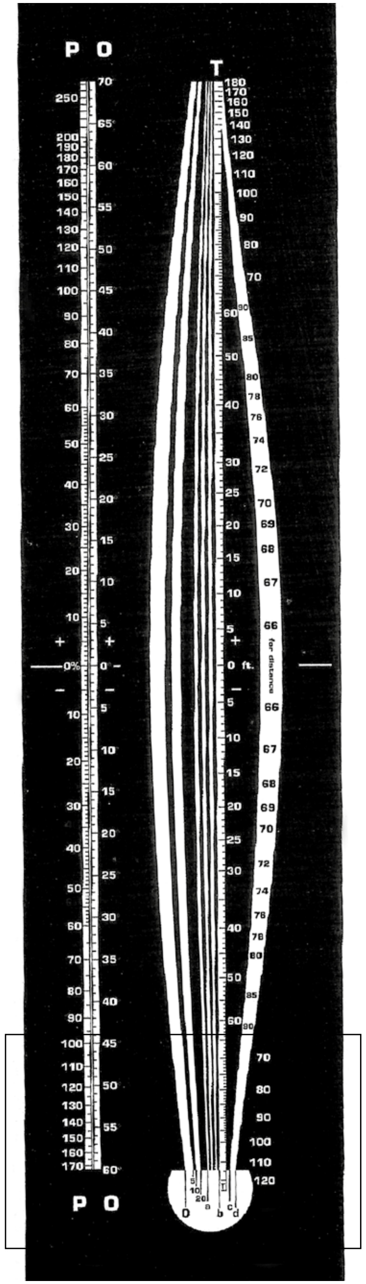
Description and Handling

The upper part allows a clear view into the surrounding terrain, and the lower part shows the scales, which are reflected upward by a mirror into the field of view from their position on the rotating wheel. While measuring work is done, the pendulum is released by depressing the locking break release (3) and the scale adjusts itself at the measuring edge according to the inclination of the line of sight. Partial release of the brake will help to quickly dampen the sensitive swinging pendulum to its final resting position. The full length of the AS scale of the Spiegel Relaskop is shown in Figure 3. The scales may be identified at the base of the scales when the instrument is tilted down 60° (see Fig. 4).

Note:
All readings (for measurements of either diameters or heights) are only correct when read directly at the measuring edge!

Moving the instrument slightly upward and downward in front of the observing eye a very good accordance between the border of darkening (which is not sharp) and the measuring edge can be achieved. For observations against a bright background, e.g. against the sky, the sun shade (5) can be brought into position so that the scale is darkened without obscuring the view of the tree.

Fig. 3: American Scales, full view



Description of the American Scale

The American Scale reads directly in English units: **basal area in square feet/acre, diameter in inches, and height in feet.** For this reason it has some special considerations for the English system of feet and inches. This Relaskop uses for horizontal scales the **RU** (relation of diameter to horizontal distance) measurements in a special ration of **1 : 33.** There are 3 RU's on this scale. The two following RU's are the white and black bars (0-10 and 10-"a"). One additional RU is broken into 6 parts (between "a" and "b" on the scale). At a horizontal distance of **33 feet, one RU equals 12 inches of diameter**. Each of the small bars therefore represents 2 inches. At other distances, other relationships apply (see Table 3, page 22).

The scales are designed for convenient use from a horizontal distance of 66 feet (one "chain"). The **T (Topographic)** scale provides height directly from a horizontal distance of 66 feet (which can be halved from 33 feet for shorter trees, or doubled from 132 feet for taller trees). The scales **"b"-"d"** and **"b"-"c"** intercept a 6 foot range-finding target at horizontal distances of 66 and 99 feet respectively. This makes finding these standard distances simple in the field, since the Relaskop corrects for slope automatically.

Vertical angles can be read in **percent (P)** and **degree (D)** on the left side of the scale (Fig. 3).

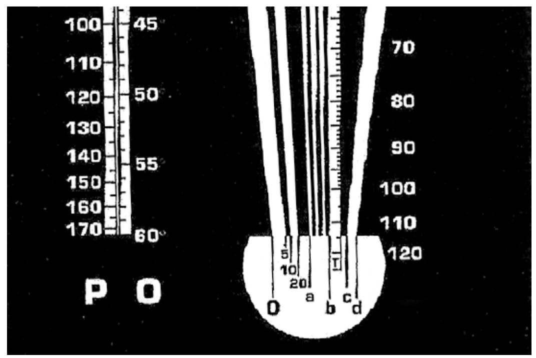


Fig. 4: Lower part of American Scale, enlarged to show identification of graduation

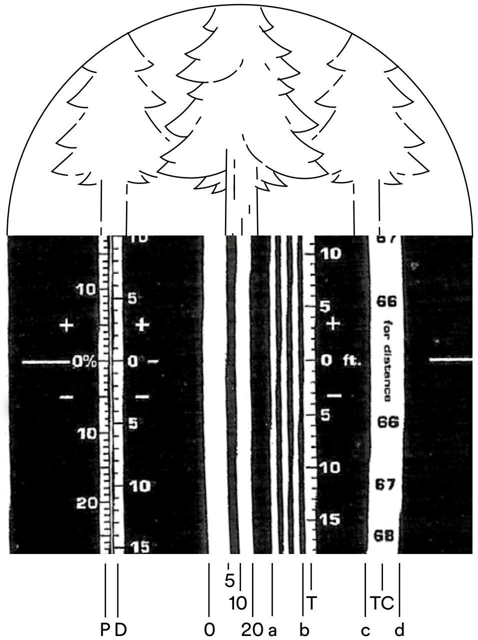


Fig. 5: American Relaskop Scale

P Percentage Scale

D Degree Scale

0 Common Side for BAF angles as follows:
0 – 5 = BAF 5 ft²/acre
0 – 10 = BAF 10 ft²/acre
0 – 20 = BAF 20 ft²/acre
0 – "a" = BAF 40 ft²/acre
0 – "b" = BAF 90 ft²/acre
"a" – "b" : 6 small bands for accurate diameter measurements

T Topographic Scale (direct readings from 66 feet)
Rangefinding:
"b" – "c" : intercepts 6 feet at 99 foot distance
"a" – "b" : intercepts 6 feet at 66 foot distance

TC Tape Correction
Scale for determining slope distances equivalent to a horizontal distance of 66 feet

Measurement Techniques and their Use

The name **"Relaskop"** stems from the notion of **"Relative"** optical measurements, where all horizontal (diameter and basal area factor) and vertical (height) measurements are made as a percent of the horizontal distance to the tree. Almost all functions of the Relaskop can be seen in this light. It is true that some of the scales are **direct reading** from certain distances, but these readings are always best understood as relative measurements first, which are then converted into units of measure by comparison to some actual horizontal distance.

Example:
The Relaskop might measure the fact that the diameter of the stem at the base of the tree is 2.5 % (of the horizontal distance to the tree), the height is 126 % of that distance, and the crown is 45 % of the total height. These are all simply relative measurements, but they tell us a great deal already. We know that the "height-to-diameter ratio" of the tree is 50.4 to 1 (126 % : 2.5 %). We know that if the tree falls toward us, it will hit us. We might guess that the crown is long enough to indicate a healthy and responsive tree.
These things are all known without knowing the distance to the tree. They can be converted to any unit of measurement we may later choose to use.

Example:
If we find that the distance to the tree is 60 feet, we can compute that the tree is (60 x 1.26) = 75.6 feet tall, the crown (60 x 0.45) = 27 feet long, and the diameter is (60 x 0.025) = 1.5 feet, which is 18 inches.

All uses of the Spiegel Relaskop can be viewed in this same way. A horizontal or vertical relative measurement is taken, and later converted into units (if necessary) by making a direct or indirect measurement of horizontal distance.

This is an important point, since many of the measurements in forestry are themselves ratio measurements. As we have just seen, the **Height-to-Diameter Ratio** (sometimes called "slenderness ratio") and **"Percent Crown"** can be obtained without knowing the distance to the tree, but many field crews still take time consuming and tedious measurements by routine, without thinking about how to do it strictly by **relative measurements**.

Because relative measurements are simpler questions, they generally have simpler answers and **simpler field work**. In many applications, this translates to real savings in effort of greater precision in measurement. Often, when field measurements (particularly in height) seem difficult, the tendency is to make estimates instead. Crown percent is an example of this. A field crew which does not know how to efficiently use their instrument may end up getting a biased set of **estimates** when they could just as easily have had a precise set of **measurements**.

Worse yet, the field crew may be told to obtain "height to the crown base", when in fact the organization is just using this to calculate percent crown. The field crew could get that relative measurement much more easily. Whenever a measurement is made you should be asking **"Is there some relative measurement which would do as well?** ".

Important hint:
Whenever the height or distance measurements are made in sloping terrain, the automatic correction of the Relaskops for an inclined angle of view is of special advantage!

Measurement Techniques

1. Determination of Basal-areas Using Angle-count Sampling (b-Measurement)

Decades of practical experience with **angle-count sampling (ACS)**, in **North America** often known as **"Variable Plot Sampling"** or **"Point Sampling"** ("Prism Cruising", when a prism is used as the angle gauge) under very different conditions throughout the world, have produced not only a large number of publications in the international forestry literature but a number of improvements in the Spiegel Relaskop as well. The authors book "The Relascope Idea" gives a survey of the development of the methods of Relaskop techniques. In this manual only the most important practical procedures will be discussed.

In the Bitterlich angle method, a tree whose diameter is larger than the fixed critical angle of the Relaskop is a count tree (Fig. 7). The Spiegel Relaskop with American Scale offers directly 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 5. The edge marked "0" is the common side of all the angles and the alternating white and black bars provide the **basal area factors of 5, 10, 20, 40, and 90 feet²/acre**. A more complete set of basal-area factors is available by using combinations of bars (see Table 2 and Fig.6).

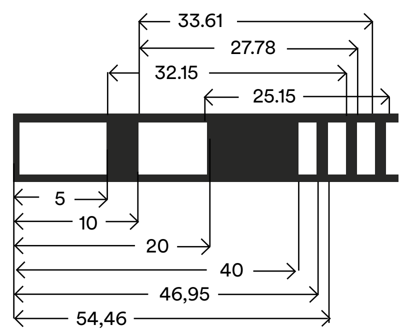


Fig. 6: BAF's as seen in the Relaskop

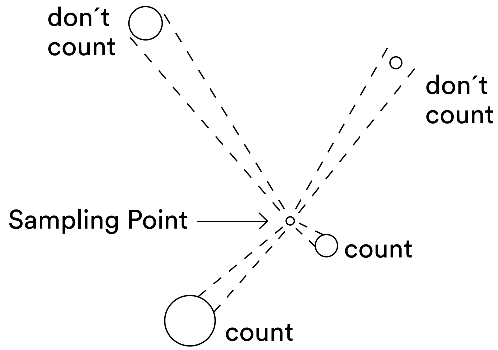


Fig. 7: Diagram illustrating how Point Sampling works

Table 2: **Basal area factors (BAF)** available in the American scale:

from	to	give BAF
0	5	5
0	10	10
10	"a"	10
"a"	"b"	10
10	"a"	10
10	"a" plus 1 bar	13.61
10	"a" plus 2 bars	17.78
10	"a" plus 3 bars	22.50
10	"a" plus 4 bars	27.78
10	"a" plus 5 bars	33.61
10	"a" plus 6 bars	40.00
0	"a" plus 1 bar	46.94
0	"a" plus 2 bars	54.44
0	"a" plus 3 bars	62.50
0	"a" plus 4 bars	71.11
0	"a" plus 5 bars	80.28
0	"a" plus 6 bars	90.00

In application, you select a sampling point, project the chosen angle to each tree at dbh (or any other point of observation), 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 on the 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.

1.1. Relative Basal Area

The Relaskop will select any type of tree proportional to its basal area in the stand. If 30 % of the selected trees are forked, then 30 % of the basal area in the stand is in forked trees. If 47 % of the trees selected are too small to be harvested, then 47 % of the basal area in the stand is in trees too small to be harvested. Each tree, once selected, represents the same amount of basal area – regardless of its size. The ability of the Spiegel Relaskop to **automatically weigh the values of trees by their basal area** is a major advantage of the Bitterlich ACS sampling method.

The **relative basal area by species** is given by the abundance of each species in the counted trees. If 20 % of the counted trees are maple, then 20 % of the basal area of the stand is maple (subject to sampling errors, of course). If the height of the sample trees in each species is approximately equal then roughly 20 % of the gross stand volume will also be in maple.

> Note:
> No measurements on counted trees are needed to get estimates of percentages by species.

1.2. Choosing a Basal Area Factor

The most efficient basal area factor for sampling chooses from 4 to 8 trees on the average during the sampling process. Other BAFs are not wrong, just less efficient. A few sample counts should tell you if the BAF is about right. In addition, if you know the approximate basal area of the stand beforehand, you can calculate the appropriate BAF by the formula:

Desired BAF = (stand BA ÷ desired tree count)

This, of course will be rounded off to an easily used scale for the instrument.

1.3. Stand Volume Determination

Many inventory needs are fulfilled by basal area alone. When actual volume is required, some tree measurements are needed. The usual procedure is to measure a valid sample of the counted trees for volume, using a **volume table** appropriate to that species. A ratio is then established between the volume and basal area of each sample tree. This is called the **"VBAR"** or "**Volume to Basal Area Ratio"**. The VBARs are averaged for the measured trees. The stand volume is the basal area of the stand multiplied by the average VBAR. For methods to make this sampling more efficient, see the book "Log Scaling and Timber Cruising" by John F. Bell.

When no volume tables are available, or when they cannot be reliably made because of the tree form, there is one direct estimate of tree VBAR: this is called **Critical Height Sampling** by **Kim Iles**.

For trees that are counted with the Relaskop, measure the distance from the stump to the point where the stem diameter is just "borderline"(or the merchantable point, whichever comes first). This distance is a direct sample for the VBAR of the tree. Average these measurements for the counted trees and you have a direct estimate of average VBAR (in this case you have outside bark volume).

1.4. Approximate Methods

1.4.1. Form Height and Volume Measurement Using Pressler's Formula

This technique for the simple determination of the volume of standing trees was introduced into forest mensuration by Pressler in the 19th century, and is a **particularly efficient application of the Spiegel Relaskop**.

The "Pressler Height (HP)" is the length up the stem to the point where the upper stem diameter is ½ the diameter at the base of a tree (B). "B" is often the stump, or sometimes dbh. The area at the base multiplied by Pressler Height is the volume of a cylinder. 2/3 of that cylinder volume is the volume of the tree. The final formula is:

$$\text{Volume} = 2/3\ [B \times H_P]$$

How to find Pressler's Point is a perfect example of how the Relaskop could be used effectively. You are looking for a point on the stem that is a **relative width** (1/2) compared with the base measurement (often dbh was used here). If the dbh appeared to be 4 bars wide, you simply look up to where the upper stem appears to be 2 bars wide and you are now looking at the point you want to locate.

> Note:
> It is not yet necessary to know the distance to the tree to locate the point. Once you are looking at the correct point, then the stem length to that point can be measured by whatever method you choose to use, perhaps from another location or with a laser device.

A detailed proof of the theory is found by Pressler himself and is contained in "The Relaskop Idea". The publication can be obtained from Silvanus Forstbedarf GmbH. More details you find also in the chapter on "Variable Plot Sampling" by Kim Iles p. 543 and pp. 546 of the book "A Sampler of Inventory Topics".

This method of measurement also gives a **good approximation of stem volume even on abnormally crooked tree stems**, and is therefore a "**lifejacket" when all other methods fail:** A measurement connected to an estimate is still better than no measurement at all!

1.4.2. Rough Approximation

There are also other ways to get the volume with less precision, but perhaps adequate to the task at hand. Many inventory needs are only for approximate volumes. The Spiegel Relaskop makes the tree counting procedure for basal area quite simple already. Only average VBAR is still needed. An approximate average VBAR can be retrieved from **past samples** and used directly. In this case no measurements are needed except the tree count. This will be particularly appropriate if the stand heights were approximately the same as in the past cruises, since VBAR usually varies directly with tree height.

There is a second, more reliable rough approximation. From old cruises, or special studies, you can determine **the ratio of VBAR to total or merchantable tree height.** This ratio will be fairly stable within a conifer species, especially for gross volume. Net volume will be more variable. With this ratio known, only a random sample of counted trees needs to be measured, and only for height.

If you need just a rough estimate of volume, use 1/3 of the stand height as an estimate of VBAR. Once you have an actual sample available, calculate average VBAR by dividing stand volume by stand basal area. Compare this to average stand height to get a more appropriate value for the ratio of VBAR to stand height.

Measurement Techniques

1.5. Number of Trees

The number of trees counted with the Spiegel Relaskop does not translate directly into numbers of trees per acre. To do this you must know how many trees each counted tree "represents", and that depends upon its size. This relationship is called the **"Tree Factor" (TF)** or in some literature the **"Stand Table Factor"**. Each tree counted with the Relaskop represents a number of other trees of the same size, and together they add up to a basal area given by the BAF used. The basal area of the tree (in the same units as the BAF uses) must be calculated. Next, the "Tree Factor" is determined by dividing the BAF by that tree basal area:

$$\text{TF} = \text{BAF} \div (\text{basal area of tree in feet}^2)$$

[TF is in trees by acre]

The basal area in square feet of a tree diameter in inches is calculated as follows:

$$\text{Basal area in feet}^2 = 0.005454154 \times (\text{diameter in inches})^2$$

[constant is pi ÷ (4 x 144)]

With BAF 20 ft^2/acre, for a 16 inch tree:

$$\text{TF} = (20 \div 1.396) = 14.3 \text{ trees/acre}$$

After this calculation is done for each of the trees on the sample point, add them up to get the number of trees per acre. For many sample points, average the results. If the numbers of trees are kept for each diameter class, a stand table can be formed showing the numbers of trees in each diameter class.

You can also combine numbers of trees in other ways. For instance, you can accumulate the number of trees below merchantable size or the number of trees which were diseased.

When trees are selected with an angle gauge like the Spiegel Relaskop, with its automatic weighting by area, but you want to get simple average of the trees (such as would be derived from a simple fixed plot) the number of trees is used to "weight the sample".

2. Diameter Measurement (d-measurement)

To measure diameter, align the left edge of the tree with the left edge of the **RU (white or black band)** that is closest to but less than the diameter of the tree. Allow the part of the tree that is less than a full RU to fall over into the small bands. Add the total RU's represented by diameter of the tree (see also Fig. 5).

The scale between **a and b (1 RU)** on Figure 4 is divided into 6 equal width bars (3 light and 3 dark).

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 **a and b** (see Fig. 4 and 5). At 33 feet, **a to b** intercepts 12 diameter inches.

Example 1:
To measure the diameter of a tree with a dbh of 34 inches, position the Spiegel 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 Spiegel 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 (see Table 3).

Horizontal Distance in feet	Diameter of 1 RU in inches	Diameter of small bar (1/6 RU) in inches
33	12	2
66	24	4
99	36	6
132	48	8

Example 2:
You wish to locate the 16 inch diameter along the stem. Position yourself 33 feet from the tree center. You need to find a point which measures 12 inches plus an extra 4 inches, which is the same as 1 RU plus 2 small bars. Place the left side of the tree **at the 10** mark and release the Relaskop brake. Sight up the tree until the tree spans the distance from **10 - a** plus the first 2 small bars. This will be the 16-inch point on the stem (outside bark, of course) (see Fig. 5).

Using this procedure, you would find the 9-inch point spanning 4 ½ small bars. This is a **useful way to find critical grade changes and merchantable diameters.**

Note:
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.

At other distances than the 33-foot units, you can still determine diameter. At any distance, one RU is (1/33 = 3.03 %) of the horizontal distance to the tree. One small bar is .505 % (or 3 % and .5 % for practical purposes):
Example: From a distance of 39.4 feet the diameter would be read:

1 (full) plus one "sixth bar"
(1 + 1/6) = 1.17 RU
1.17 RU x 3.03 % each = 3.53 %
(39.4 feet x .035) = 1.39 ft or 16.7 inches

Note:
The average diameter of the trees counted with the Relaskop as an angle gauge will not be the average for the stand. To get this average have to calculate the number of trees represented by each tree counted. See "Number of Trees" to do this (see p. 20).

3. Height Measurement (h-measurement)

Height is another important measurement which the Spiegel Relaskop can measure quite accurately. There are two vertical measurement scales. The **D (= degree)** and the **P (= percent)** scales (see Fig. 3) as well as the **topographic scale T.**

The topographic scale **T** reads **height in feet at a horizontal distance of 66** feet (= 1 chain) 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 + 100 feet or - 100 feet by 5 foot intervals from + 100 feet to + 180 feet and from - 100 feet to - 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.

3.1. Measurement of Relative and Actual Height

The appropriate scale to get the relative height of a tree is the **"percent" scale P**, which is also common to many other forestry instruments. This scale is actually the tangent of the angle. An angle with a tangent of 0.24 is said to be "a 24 % angle" on the P scale. For tree height two measurements are taken, one to the base of the tree (usually the stump) and another to the "top" measurement. The two segments are subtracted to get the length along the stem **as a percent of the horizontal distance to the tree**.

Example: The illustration in Fig. 8 shows two typical situations taken from the same distance but different elevations:

+ 60 % - (- 25 %) = 85 %
or: + 100 % - 15 % = 85 %

Any set of measurements taken along the vertical line (v) will have the same **result**, since the tree height is always in the same proportion to the constant horizontal distance between the tree and the **vertical line "v".**

Note:
It is important to check carefully when one of the sightings is near zero, because it is very easy to reverse the positive and negative reading or to interpolate in the wrong direction.

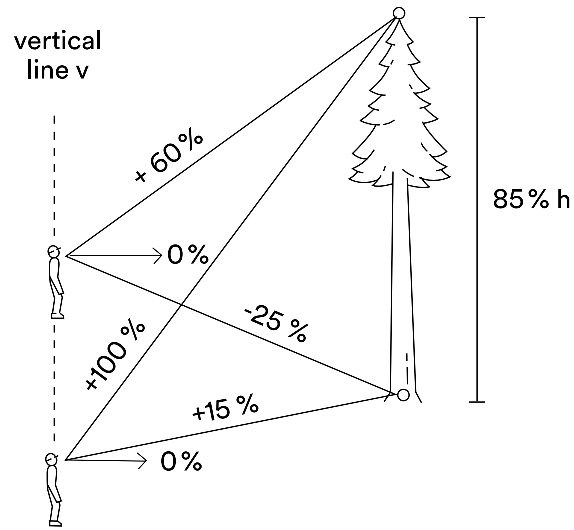


Fig. 8: Measuring Relative Height from 2 Elevations

Once you have the **relative height**, the **actual height** is obtained by multiplying this percentage by the horizontal distance to the tree. In most cases, the slope distance is measured, then converted to horizontal distance using the cosine of the angle of slope.

Example: 36 units of distance (ft.) measured along a slope angle of ± 15 degrees is:

36 ft. x 0.9659 = 34.77 ft.
[cos (15 degrees) = 0.9659]

If tree height is measured at 85 % with the Relaskop, then the actual height is:

0.85 x 34.77 ft. = 29.55 ft.

3.2. Other Height Measurements

3.2.1. Defect Position

The position of defects on the tree can be quickly noted on a tree using the percent scale. These can be converted to distance if the tree height is later measured.

Example:

One might note "conk at + 22 %". Along with "base at – 20 %, top at + 60 %, horizontal distance of 20 meters" you could calculate the exact position of the conk. Even without the horizontal distance you could specify the relative position on the stem: 3 sightings give the relative position, adding the horizontal distance gives the actual position (see Fig. 9).

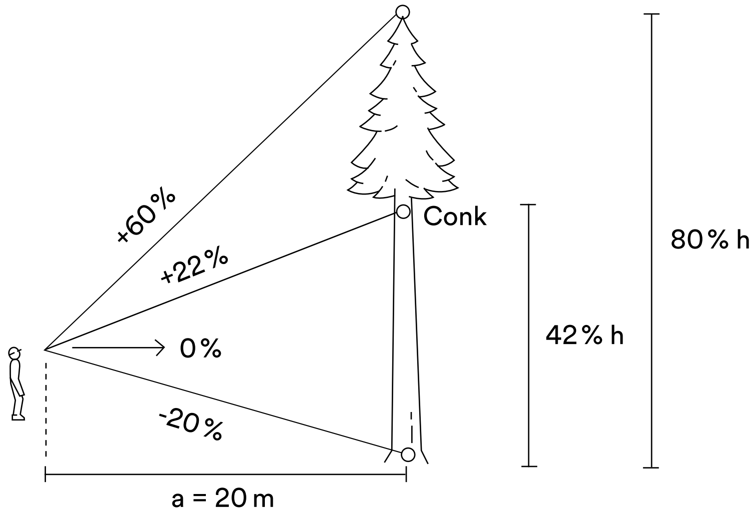


Fig. 9: Measuring the position of a defect
Relative position of conk: (42/80) = 52.5 % of tree height
Actual position of conk: 60 x 42 % = 25.2 ft. above tree base

Measurement Techniques

3.2.2. Crown Ratio

The crown ratio is often of interest in making silvicultural prescriptions. Crown ratio can be easily measured **without knowing the distance** to the tree by using the percent scale. The ratio of the percent between the top and bottom of the tree vs. the percent between the top and bottom of the crown is easy to observe. The actual height-to-live-crown, another measurement used in silvicultural research, can be calculated if distance a is measured (see Fig. 10).

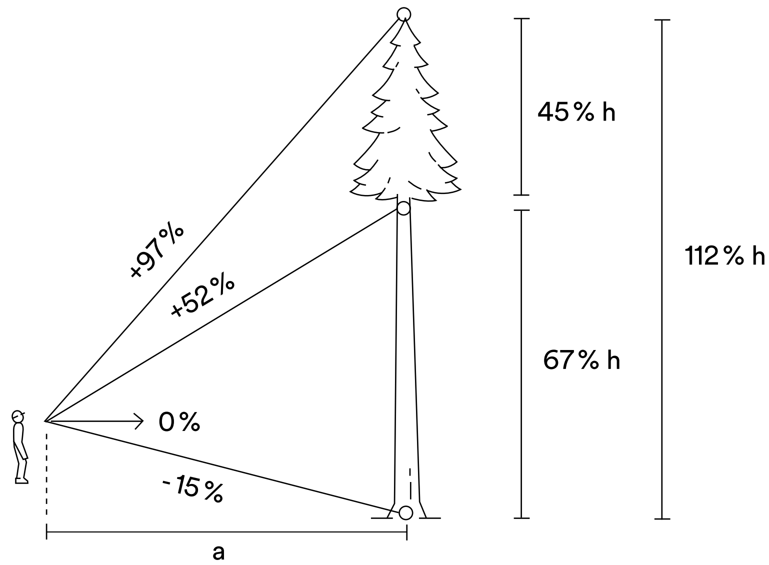


Fig. 10: Simple Calculation of Crown Ratio
Relative crown size ("percent Crown"): % Crown=(45/112) = 40.2 %
Height to crown: = (67 %) x a = (67/112) x tree height

3.2.3. Merchantable Point

3.2.3.1. Percent of Diameter

In some systems, the merchantable height of the tree is defined as a fixed percentage of diameter (at dbh or some other point). This point can be easily located using the Spiegel Relaskop.

Example:

Say, for instance, that the merchantable point is defined as 30 % of dbh. When sighting the dbh suppose that it is 2 RU's wide from where you are standing. The merchantable point will be

$$30\ \% \times 2\ \text{RU} = 0.6\ \text{RU}$$

in width. Scan up the tree until you locate this point (using the small bands). In order to locate this point, distance does not need to be known. To get the actual height, a distance must then be measured. For reasons of visibility, it may be more convenient to actually measure this height from another position once the correct point has been identified on the tree.

3.2.3.2. Fixed Diameter

Have an assistant stand beside the base of the tree and show the appropriate image for the merchantable top by using a target of that size. It is handy, if a piece of waterproof paper is kept for this purpose. Note the number of RU's the target covers (say 0.2 RU for example). Simply scan up the tree until you see the tree stem cover this same number of RU's. This will be the merchantable top (outside bark, of course). You do not need to know the distance to the tree to find the point. Convert Relaskop readings to actual distances as noted in the above example, if you need to do so.

Any bar or combination of bars can be used for this comparison. Simply match the known target with the tree stem covering the same apparent width and you will be looking at the same diameter (there is a small theoretical correction here, but for practical purposes it can be ignored).

Another technique is to measure a fixed distance where the Relaskop bars are equivalent to a convenient fixed width. You can then look for a number of bars corresponding to the merchantable top you are seeking (see page 22).

3.3. Average Height

When trees are chosen by an angle gauge they are selected with an automatic "weighting" by their basal area, so the average height of these larger trees is usually higher than the average of a set of trees on a fixed plot where each tree has an equal chance of being measured. If desired, the simple average height can be calculated by weighting the selected trees by the "tree factor", which tells how many trees each selected tree represents (see pp. 20, 21).

The simple average of tree heights (when selected with an angle gauge) produces an automatic weighting which gives the so-called **"Lorey Height"**. This is useful in many calculations in forestry. In most cases, the Lorey Height is preferred as an indication of stand height, since it gives a larger representation to larger trees. The stand basal area, multiplied by the Lorey Height (times a constant) equals stand volume.

4. Combining Diameter and Height Measurements

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 divisible 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** (see table 4).

Table 4: Relationship between **distance a** and **RU:**

Distance "a"			1 RU		1 RU / 4	
In.	**Ft.**	**In.**	**In.**	**Cm.**	**In.**	**Cm.**
200 =	16	8	4 =	10.16	1 =	2.54
400 =	33	4	8 =	20.32	2 =	5.08
600 =	50	0	12 =	30.48	3 =	7.62
800 =	66	8	16 =	40.46	4 =	10.16
1000 =	83	4	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)**

1.000, 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.

5. Determination of Girard Form-Class

Rotated angle method:

1. Find point on the ground where dbh of sample tree is tangent to the critical angle of the prism (**point P** Fig. 11).

2. From **P** determine the vertical angle to the top of the first log **(B).**

3. Sight from **P to 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.

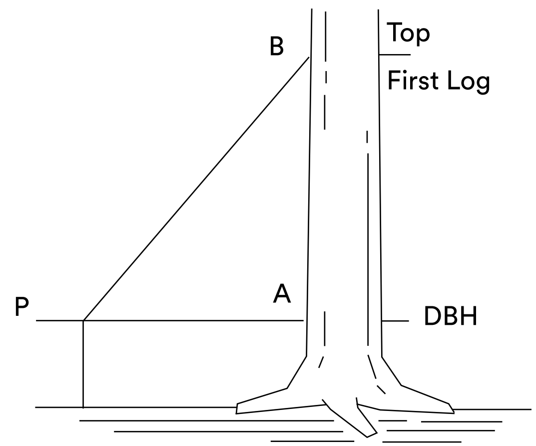


Fig. 11: Diagram to explain determination of Girard Form Class

Table 5: Relationship between **degree** and **cosine 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. 2) for procedure to use.

6. Use as a Rangefinder

To find ranges of 33, 66 and 99 feet proceed as follows: Hold the Spiegel Relaskop flat with scales locked as per Fig. 12

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.

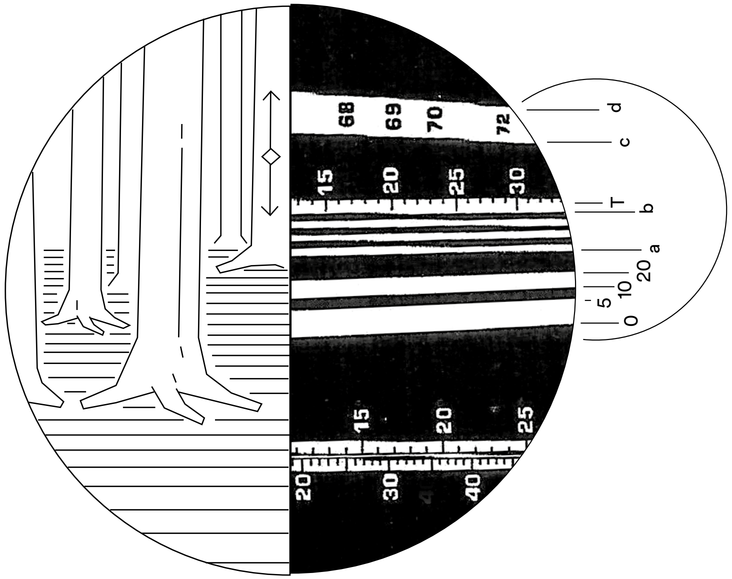


Fig. 12: Illustrating determination of distance (or range)

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. 4). 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.

7. Slope Measurements

Degree scale

Scale **D** to the **left of 0** is graduated in degrees. See Fig. 3. 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. 3. 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. 3. The readings are the number of feet difference elevation per 1 chain horizontal distance. Range is between plus 180 feet and minus 120 feet.

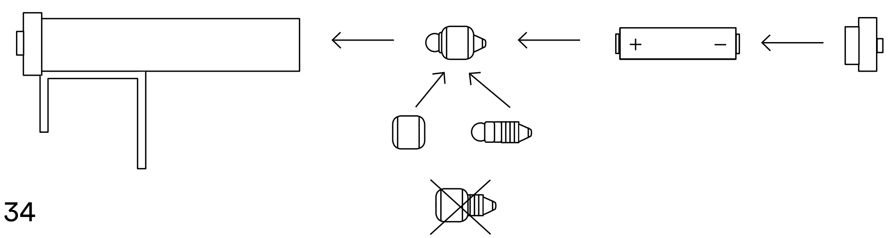
The plus and minus direction of the instrument for scales **T, D and P** are indicated only at the zero point.

Relaskop Light – Illumination for the Scale

The Relaskop Light is a clip-on instrument, easy to operate and fits on instruments even delivered decades ago.

Especially designed for use **in dense forests and in bad light conditions** the even illumination along the reading line gives an **excellent picture of all the stripes and figures of the Relaskop Scale.**

The Relaskop Light is clamped on in front of the instrument right over the front-window and is fixed instantaneously by a spring. The light is switched on and off by pushing the button on the cap. For permanent light change the caps and the light goes on and off by a short turn of the threaded cap. For electrical power a standard type of battery "Mignon 1.5 V" is used.



Conversion Factors

English Units ⟶ Metric Units

inches	x 2.540	= centimeters
feet	x 0.3048	= meters
acres	x 0.4047	= hectares
feet^2/acre	x 0.2296	= meters^2/hectare
feet^3/acre	x 0.06997	= meters^3/hectare

Metric Units ⟶ English Units

centimeters	x 0.3937	= inches
meters	x 3.2808	= feet
hectares	x 2.471	= acres
meters^2/hectare	x 4.3561	= feet^2/acre
meters^3/hectare	x 14.2918	= feet^3/acre

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