SPIEGEL-RELASKOP®

METRIC STANDARD and METRIC CP

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MANUAL

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THE SPIEGEL-RELASKOP®

By Walter Bitterlich

Introduction

The Spiegel-Relaskop, essentially unchanged in design since it was introduced in 1955, fulfills 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 meters per hectare either at breast height (1.3 m above the ground) or any other height. For this reason, the Relaskops are principally known in connection with angle-count samp-ling. 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 hectare 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 pages 28 to 30).

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.

These are:

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.

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 the measurements are given in the American forestry dimensions of **feet and inches.**

A comparison between the possibilities of the different scales see Table 1 (page 4).

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

At the end of this manual is added a description of optically measuring **distance** with the use of a **wedge prism, field glasses** and a **vertical base target** and that of a special **scale light** for use in **bad light conditions.**

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

obtained from RELASKOP-TECHNIK VERTRIEBSGes.m.b.H., Salzburg, Austria.

Table 1: The SPIEGEL-RELASKOP® by Dr. Bitterlich and its different scales

The SPIEGEL-RELASKOP by Dr. Bitterlich
and its different scales

Common to all Relascope Scales:

All readings automatically slope-corrected
Diameter measurement within ½% of distance to tree

Differences between Relascope Scales:

	AMERICAN	WIDE	METRIC STANDARD	METRIC CP
Vertical Degree Scale (-60 to +70 degrees) Vertical Percent Scales (-170 to +270 percent	yes	yes	no	yes
Topographic Scales	yes	no	no	no
Range of BAFs	5-90 ft²/ac ~ 1-21 m²/ha	1-144 m²/ha ~ 4-625 ft²/ac	1-4 m²/ha ~ 4-17 ft²/ac	1-81 m²/ha ~ 4-350 ft²/ac
Even BAFs on scale	5,10,20,40,90 ft²/ac	1,4,9,16,25, etc m²/ha	1,2,4 m²/ha	1,2,3,4,9,16,25 etc m²/ha
Range of DBH measurable	½% - 9%	½% - 24%	½% - 4%	½% - 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 *0	9 standard distances 4 -20 m *1	15,20,25,30 meters *2	direct reading with attachment *3

*0 smaller values are possible with the quarter bars
*1 with use of vertical or horizontal target, resp. Wedge Prism Attachment with vertical base
*2 using RELASKOP distance scale and a vertical 2 m-target
*3 with use of horizontal staff of known length or percent scale with vertical 2 m-target or Wedge Prism Attachment with vertical base

Fundamentals of Angle-count Sampling (ACS)

1.0 Establishing the Tree Count

Angle-count sampling (ACS) provides a direct measurement of the forest basal-area density at a particular sample point (in square meters per hectare or other appropriate units) by simply counting all the trees which have a **diameter exceeding a given "critical angle"**. The use of an angle is just a simple optical way of determining a proportion between the tree diameter and the tree distance from the sample point. The tree diameter **d** will exceed the critical angle only if the distance to the tree is less than a proportional "critical distance" **R**, which is just a multiple of the tree diameter. If we use, for example, a critical angle of the proportion d : R = 1 : 50 , it implies that any tree counted by the ACS method lies within a "marginal circle", the diameter of which is 2R = 100d , and its area is therefore 10,000 times larger than the tree cross-section itself. Each tree cross-section counted in this way will therefore represent 1/10,000 basal-area density, or 1 m²/ha. The number of trees **z** counted in a full sweep by **ACS** gives the basal area **G** in square meters per hectare. When using critical angles with other proportions of d : R the tree count **z** must be multiplied by a "basal-area factor" **k** to give **G** in m²/ha. When using ACS, the general formula is

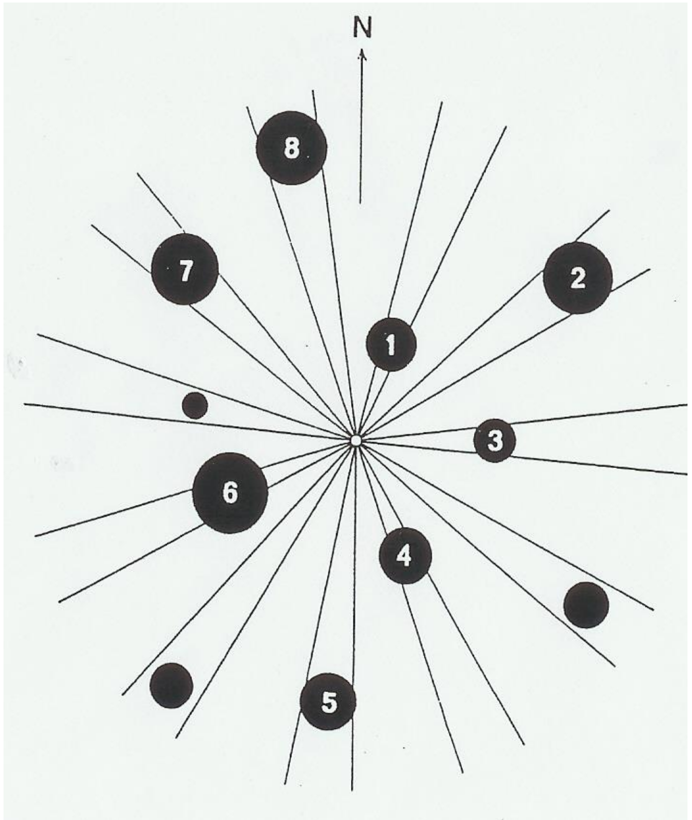
$$G \text{ (in m}^2\text{/ha)} = z \times k \qquad (1)$$

The requirement for "counting a tree" is as follows. If **a** is the horizontal distance between the center of the tree cross-section observed and the observation point, then:

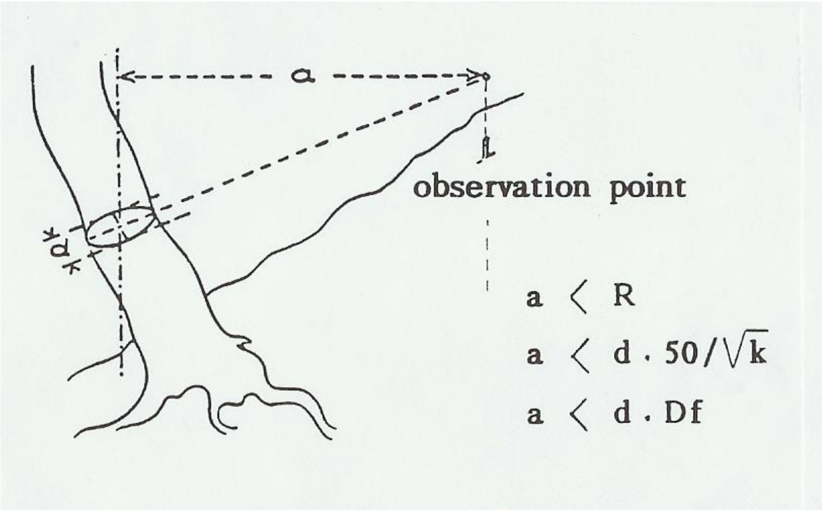
$$a < R \qquad (2)$$

where **R** is a constant multiple of tree diameter.

The following diagram may serve as an example of a complete ACS process at a sample point. Starting from the north, and turning clockwise, we would count 8 cross-sections which exceed the given angle. In this diagram the angle proportion is d:R = 1:50 (for better visualization the diameters and angles are increased tenfold). Each black cross-section would correspond to its marginal circle by the proportion (1/100)², and this single observation point would imply a basal-area density of 8/10,000 or 8 m²/ha.



The technique for counting a leaning tree at its breast height cross-section is illustated below:



Note that in the case of checking a so-called "borderline" tree (one which is questionable without more careful or additional measurement), the correct horizontal distance **a** is **from the observation point to the center of the tree cross-section observed**, not to the base of the tree. The correct diameter **d** is the one viewed from the observation point.

2.0. Basal-area Factor (k), RU-Width, Relaskop-Unit (RU), Distance Factor (Df)

In a **full 360 degree sweep**, the basal-area factor **k** is the ratio of the basal area of each tree to its marginal circle in hectares:

$$k \text{ (in m}^2\text{/ha)} = (\pi d^2/4) / (\pi R^2/10^4) = (50\, d/R)^2 \qquad (3)$$

where **d** and **R** are measured in the same units, e.g. in meters.

The **width of band 1** is called a **Relaskop-Unit (RU)**, because for any number **n** of such RU-widths we have the simple formula:

$$k \text{ (in m}^2\text{/ha)} = n^2 \qquad (4)$$

where **n** can also be any fraction you decide to use.

- Note:

The square of the number of Relaskop-Units n used for angle count sampling is the basal area factor k in m²/ha.

Examples:

n = 2.5	k = 6.25 m²/ha	n = 3	k = 9 m²/ha
n = 3.25	k = 10.5625 m²/ha	n = 4	k = 16 m²/ha
n = 0.75	k = 0.5625 m²/ha	etc.	

Where the bands of the Relaskop scales are marked with such basal-area factors, they assume the use of full sweeps. If an angle-count sample is made using only half circles (a 180 degree sweep, e.g. on steep slopes), then the usual values must be multiplied by 2 (the "plot factor").

Using formula (3), the critical distance **R**, given a particular tree diameter **d**, and basal-area factor **k** is:

$$R = d \times 50/\sqrt{k} = d \times Df \qquad (5)$$

where **Df = 50/√k** is called the distance factor.

In regard to k=1 (band 1 on the scale), we have the special case already mentioned, where Df = 50. In this case 1 RU corresponds to a critical angle with a width of 2% of the horizontal distance, that is:

A width of 1 RU corresponds to 2% of the horizontal distance to the measured object.

3.0. Treatment of Borderline Trees

Generally speaking, **"borderline trees"** are trees whose breast height diameter (d.b.h.) appears neither larger nor smaller than the RU-width as seen through the Relaskop. For **quick basal-area estimation**, such doubtful trees may be counted as **0.5 ("half-trees")** in each case, or for simplicity they may be counted as a 1.0 ("full-trees") every second time a borderline tree occurs. For careful work, however, it is necessary to determine if these trees qualify for selection by making an additional distance measurement (either by tape or optically) whenever there is a doubt. The multiple of the d.b.h., which depends upon the RU-width, must be larger than the horizontal distance to the tree to verify that the tree should be counted. For example: with RU-width 4, Df 25, and d.b.h. 36 cm the critical distance R = 36 x 25 = 900 cm. The measured horizontal distance is 897 cm, and the tree would therefore be counted.

For large scale inventories, the examination of borderline trees is often extended to the consideration of **non-circularity of the stems**. The caliper-type measurement with reference to the direction of the sample point is used, rather than just the average diameter as measured with a diameter tape. The **Spiegel-Relaskop Metric CP** can help with this procedure by the use of **"tolerance margins"** around the critical angle. For more on that topic, see Booklet 19 of the FOB publication series or refer to the book "The Relascope Idea".

4.0. Number of Stems per Hectare (St/ha)

Since each stem included in an ACS represents the same basal area (as specified by the **k** factor) the stems must exist in a number sufficient to add up to that basal area. We can therefore calculate the number of stems per hectare ($\mathbf{n_i}$) by dividing the **k** factor by the stem basal area

for that tree ($\mathbf{g_i}$):

$$n_i = k/g_i$$

If there are a total of **z** stems counted at a sample point, the combined number of stems per hectare is calculated as follows:

$$St/ha = k/g_1 + ... + k/g_i + ... + k/g_z \qquad (6)$$

It should be mentioned, in regard to the volume sampling methods of **Kitamura** and **Kim Iles**, that the number of stems per hectare can also be derived from summing all **n** , where $n = k \times h_{ci}/v_i$, with $\mathbf{h_{ci}}$ being the critical height of each tree, and where $\mathbf{v_i}$ is its volume – both values are usually found indirectly by calculation and stem form measurements (see pages 19 to 21).

Description of the Spiegel – Relaskop and of its Handling

For Figures 1 to 22, see Manual – second part.

The instrument (see Fig. 1) is small, and weighs approximately 350 grams. 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 or similar device (see Fig. 2, 3 and 4).

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.

The use of a breast support is illustrated in Figure 2. More exact measurements are possible by the use of a tripod, which should be equipped with a movable center-column (Fig. 4a) or with lockable balljoints (Fig. 4b). 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 from the tree to the observer **a** is the distance from a hypothetical vertical line through the eye to the center of the tree cross-section observed.

Even more exact measurements – especially necessary for the increment measurements with permanent observation points - are obtained by using a tripod equipped with tilting head and micro attachment (see Fig. 19).

Inside the instrument there is a freely rotating wheel, which bears **scales consisting of black and white bands,** used **for the measurement of widths**, and with **scales calibrated for the measurement of heights** (see Figures 5 to 8). 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. 7 and 8). For better illustration, the measuring edge is marked **M-M** in Figures 7 and 8 (but not on the actual Relaskop scales!). 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 ist final resting position. The full length of the MS and CP scales of the Spiegel-Relaskops are shown in Figures 5 and 6.

- 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.

Description of the Scales

1.0. Spiegel-Relaskop Metric Standard

As an aid to understanding this section, the details of this scale are labeled in Figure 7. The tangent scales labeled Ts20, Ts25 and Ts30 are used for the direct measurement of tree heights from distances of 20, 25 and 30 meters respectively. At 15 meters, half the readings of the 30-meter height band can be used. The height bands (tangent scales) have direct height readings in meters for use at the appropriate horizontal distances. At other distances they at least define equal vertical sections. The readings on the Ts scales frequently must be estimated in fractions of the smallest units, and it is therefore essential to keep the instrument as steady as possible (this applies to all other measurements as well), and to brake the swinging pendulum skillfully with the use of the brake release (3) shown in Figure 1.

To the right of Ts20 there is band 1, with a basal-area factor k = 1, which is frequently labeled along the length of the scale. Next to it is the “quarters field”, with two black and two white “quarter bands”. The combination of band 1 plus the quarters field corresponds to a basal-area factor of 4, also frequently used. This arrangement was chosen because of the proportion 1:25 represented by basal-area factor 4, which is the same proportion used in the Ts25 scale next to it. This facilitates the rapid determination of the **"slenderness" of trees** (similar to the **height : diameter ratio** often seen in North American forestry literature) and the use of "Pressler's form height" in d.b.h. units (see pages 27 and 28 and "The Relascope Idea", pages 106-111).

Next to the double scale Ts25 and Ts30, there is band 2 (its width corresponding to a basal-area factor of 2). Band 1, the quarters field and band 2 are all reduced automatically by the cosine of the angle of inclination whenever the brake is released, which causes the rotating wheel to adjust to the angle of inclination toward the object being measured. The **results of all measurements are therefore adjusted to a horizontal projection**, as is customary with map information.

Far to the right of the scales (Fig. 7) there are two white bands of different widths - the **rangefinder bands** - which are used for range-finding in conjunction with the **vertical 2-meter target** (see Fig. 11 and 12). Their use is connected with the left edge of band 2. The word "unten" is marking the lower edge of the rangefinding scales, and can be read when the instruments is turned 90 degrees and used in a horizontal mode (see Fig. 11). The upper edges are marked with the numbers 15, 20, 25 and 30, repeated at intervals (for use, see pages 22 and 23). In these bands, the angles of inclination are reduced by the squared cosine, therefore resulting in a kind of "Reichenbach's distance measurement" and producing results directly corrected for the cartographic projection of the terrain.

2.0. Spiegel-Relaskop Metric CP

This scale (see Fig. 6 and 8) combines many of the advantages of MS and WS, it has basal-area factor 3 available as a separate white band, includes tolerance margins for borderline trees, and has the CP-

values for squared cosine corrections listed along the left side of the scale.

The details of the Metric CP scale are shown in Figure 8. "CP" is an abbreviation for "correction percentage". On the far left are the CP-values. During the optical measurement of distance using a wedge prism and the vertical base target (for details see pages 30 – 33 and Fig. 18) the CP-value, which corresponds to the angle of inclination at the measuring edge, will give the percentage for reducing the reading of the vertical base target in order to calculate the horizontal distance.

To the right of the CP-values are the white bands with the basal-area factors k = 3, 2 and 1 which are labeled at intervals along the white bands. Any bands labeled as 1 are also equal to one Relaskop-Unit (RU) in width, which corresponds to 2% of the horizontal distance (compare page 8).

Next to band 3 is a single RU band 1, then a black and white pair (which together are 2 RUs in width), then four more single RU bands. The left part of band 4 is also one RU in width. The right side of band 4 is divided into four quarter bands, comprising another RU in total. Band 4 is therefore 2 RU in total width.

To the right of the quarters field lies the "percentage scale" **P**, used for many kinds of height measurement (see page 23), and which measures height segments as a percentage of the horizontal distance to the tree. At the far right there is the final scale **D** which measures the sighting angle in degrees and can also be used to measure height.

The black and white dots along the edge of the bands for k = 3, 2, 1 and 4 are to facilitate the determination of borderline trees. Whenever a tree edge lies between these marks ("tolerance margins"), it should be checked accurately by using a diameter tape, or taken for a subsample to determine deviations of cross-sections from circularity (see page 9 and FOB publication, Volume 10 in German language).

Measurement Techniques and Their Use

1.0. Determination of Basal-areas Using Angle-count Sampling (B-Measurement)

Decades of practical experience with angle-count sampling (ACS), 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. Other publications, many of which are collected in consecutively numbered volumes of FOB publications (mostly in the German language), can be obtained from Relaskop-Technik free of charge. In this manual only the most important practical procedures will be discussed.

1.1. For Quick Basal-area and Volume Estimates

In this illustration we will use only band 1, found on the Relaskops described in this manual. Standing at a sampling point in the forest, the observer makes a sweep of the surrounding trees and compares the breast height diameter (d.b.h.) to band 1, always along the measuring edge. The brake must be released to insure automatic slope correction. The observer wishes to count each tree whose apparent width is larger than band 1. In Figure 7 you can see that the tree diameters marked by the numbers 1, 3, 4, 5 and 6 are larger than 1 RU-width, and should be counted. Tree number 2 (placed especially to show this effect) is exactly 1 RU-width, and is a genuine “borderline tree”. Therefore it will be counted as a “half tree” of 0.5 in the tree count. You can also see from Figure 7 that all the other trees are considerably smaller than 1 RU, and should not be counted. The result of the sample is a count of 5.5 trees.

All that is required is a simple count of trees l a r g e r at d.b.h. than band 1. The locking brake release (3 in Fig. 1) **must be pushed to insure an automatic slope correction.**

The number of stems counted at each sample point, separately by species, can simply be multiplied by the estimated form height (where **form height is V/G**) to get the volume per hectare for each tree. The sum of these gives the total volume per hectare. For example:

In a full sweep from one sampling point we find 12 spruce, 8 fir and 4 larch which are larger than band 1. The count also implies the basal-area density of all three species, namely:

12	m²/ha of spruce
8	m²/ha of fir
4	m²/ha of larch
24	m²/ha of basal-area in total

This gives the following approximate volume density per hectare:

a) As a fast approximation, if we estimate the height of all trees to be 30 meters, and the form height as half the total height (15 meters), we would get:

180	m³/ha of spruce
120	m³/ha of fir
60	m³/ha of larch
360	m³/ha of total volume

b) For a somewhat more exact result, if the average height is estimated (or measured) separately by species, we might get spruce at 31 meters, fir at 29 meters and larch at 30 meters. We can then multi-ply the assumed form factors of 0.5, 0.6 and 0.4 to convert these total heights to form height as follows:

Spruce:	31 x 0.5 = 15.5 meters (form height)
Fir:	29 x 0.6 = 17.4 m
Larch:	30 x 0.4 = 12.0 m

and therefore:

12 x 15.5 = 186.0 m³/ha of spruce
8 x 17.4 = 139.2 m³/ha of fir
4 x 12.0 = 48.0 m³/ha of larch
373.2 m³/ha of total volume

Such a result is only valid for a single point of observation. In a stand covering an area of about 2 hectares one estimate of this kind is not sufficient. It would be better to make the same measurements at approximately 4 sample points, distributed uniformly through the area, and then obtain an average for each tree species in this manner.

1.2. B-measurement for Well Controlled Samples

1.2.1. Choice of Basal-area Factor

The angle-count could be carried out exactly as described in Section 1.1 by using bands 2, 3 or 4. If, for example, band 2 was chosen as the critical angle for the tree count, then approximately half the number of trees would be expected. This tree count would be multiplied by the basal-area factor of 2 in order to get the basal-area density per hectare. The same reasoning would apply to band 3 or 4.

In rare cases, one or more of the **quarter bands** may be used for angle-count sampling. The basal-area factors would be: with one quarter band 1/16, with two 4/16, with three 9/16, four quarters is the same as band 1, with 5 quarters (1 RU plus 1 quarter) 25/16, with six 36/16, and with seven 49/16.

The distance within which a tree will be counted depends, as seen in formula 5, partly on the tree diameter **d** (usually d.b.h.) and partly on the distance factor (**Df**). The combination of the two items determines the radius of the marginal circle **R**. The **Df**, in turn, is a direct function of the basal-area factor **k**. Using a diameter of 30 centimeter for tree diameter (**d**) see table 2:

At basal-area factor **k** =	1	2	3	4	9	16	m^2/ha
RU-width	1.00	1.41	1.73	2.00	3.00	4.00	
Distance factor **Df**	50.00	35.36	28.87	25.00	16.67	12.50	
Critical distance **R**	15.00	10.61	8.66	7.55	5.00	3.75	in m

The choice of the basal-area factor depends first upon visibility in the field, and secondly upon the purpose of the tree count. If the ACS stems serve not only for the determination of basal-area density, but also are sample trees for more general purposes in a large scale inventory, there must be strict demands on the accuracy of the selection. This can only be achieved by the use of small marginary circles and large basal-area factors.

There are also statistical considerations, which indicate that average stem counts between 7 and 14 are best. This also may influence the choice of the basal-area factor (see e.g. “The Relascope Idea”, page 13).

1.2.2. Arrangement of the Sampling Points

This is best done by a systematic sampling grid. A fixed grid of squares, rectangles or equilateral triangles is placed over the sampling area and a sample point is installed at each node of the grid (chosen on the map and transferred to the field, of course). The density of the sampling points will depend upon the variability of the sampling unit, the tree diameters found, and the sampling accuracy desired. For older stands, using a basal-area factor of 4 and full sweeps, the following can be recommended:

Number of sample points per hectare	Spacing of the square grid	Size of sample area (in ha)
4.0	50.00	up to 4
3.8	51.30	from 4 to 8
3.5	53.45	8 16
3.1	56.80	16 32
2.6	62.02	32 64
2.0	70.71	more than 64

This recommendation is not in accordance with statistical calculations of sample size for large inventory areas, but is based on practical experience in forestry reported in "Vollaufnahmen durch Stichproben" (Full enumerations by sampling) in "Allgemeine Forstzeitung", Nr. 6, 1968. The accuracy can be further improved by using basal-area factor 3, or even 2, at the same density of measurement points.

1.3 Critical Height Sampling

Good theories have an effect on the future, and are forerunners of practical work – as can be seen in this case. **Kim Iles** has found that using **Kitamura's** formula, which samples critical height as a measurement, is an ideal solution for a **smoothly increasing growth sample with continuous forest inventory**. After some initial measurements using the Tele-Relaskop, the subsequent field work can be done using the Spiegel-Relaskops with Metric CP or Wide Scale.

The critical height is defined as the height of the stem below the point where the critical angle used in ACS exactly matches the

cross-sectional diameter. According to the formula derived by Kitamura, the sum of all critical heights (of one sweep) times the basal-area factor k gives the volume density in m³/ha directly.

In respect to measurements using permanent observation points in the forest, it is desirable that the size of the area sampled grows proportional to the tree cross-sections and the larger distances between them, a requirement that ACS sampling fulfills very well in general.

Unfortunately, this growing is discontinuous when the d.b.h. represents an equal density in m²/hectare (as determined by the basal-area factor **k**) as it does with the usual methods. For example, if a tree grows enough to become a "borderline tree" it **suddenly "jumps"** into the sample with the full weight of its basal area and number of trees per hectare. This has a large effect upon the results, especially with large basal-area factors.

For the sampling of forest growth as suggested by **Kim Iles**, the sampled elements are the **critical heights h_c**. When multiplied by **k** they represent the volume density in m³/ha, and have the special advantage that the **change in the sampled area is not discontinuous** (in leaps and bounds) **but will change smoothly. New sample trees "creep" unnoticeably into the sample with the small weight of their initial critical height, and later gain steadily in importance.**

The practical measurement of critical heights in the forest can not be made directly, but must be made indirectly using the advantages of taper functions (see FOB publications 7/1978 and 17/1983; as well as "The Relascope Idea", pages 113 and 123 – 125). The necessary values must usually be obtained by 3-point or 4-point measurements on single trees or parts of stems using the Tele-Relaskop (see the manual "Tele-Relaskop", Fig. 7). However, with the use of the tilting head and micro attachment described at the end of this manual, the Spiegel-Relaskop Metric CP can also master this task (see page 29 - 31 and Fig. 22).

Sampling for increment measurements from permanent sample points requires much more work for the initial installation than for the remeasurements. For instance, it is possible to make tables of the locally appropriate r-values (or other parameters for taper functions) of tree species and parts of stems (e.g. lower, middle and upper part) and to use these without change over a considerable period. The constant distance between the sample point and the tree is determined exactly at the first measurement and is unchanged for all subsequent measurements. The appropriate measurements at a later time require only the Spiegel-Relaskop (Metric CP or Wide Scale) to obtain the measurement of every diameter in RUs, as well as to obtain a careful measurement of tree height on all sample trees.

Concerning the installation of permanent observation points with firmly fixed plastic tubes, see FOB publication 21/1988.

2.0. Distance Measurement (a-Measurement) with the Spiegel-Relaskop

2.1. Horizontal Target

For this purpose the **Spiegel-Relaskop Metric Standard** makes exclusively use of the basal-area factor 4. If the band width (with the pendulum swinging freely) exactly matches the width of the horizontal target, then the horizontal distance is 25 times the width of the horizontal target. For example: with a horizontal target of 80 cm, the distance at which this will exactly match the factor 4 band will be 80 x 25 = 2000 cm = 20 meters (see also pages 12 and 13).

By using a horizontal target with a graduated scale, the width matching basal-area factor 4 can be read off in centimeters, then multiplied by 25 to calculate horizontal distance. Scale graduations of 4 cm correspond in this case to horizontal steps of 1 meter.

Using the **Spiegel-Relaskop Metric CP** the constant width of a horizontal target can be read off in **distance percentages** (see Fig. 8). The size of the target, divided by the number of distance percentages, indicates the distance. The scale also relates **each 1% of the horizontal distance in centimeters to one meter horizontal distance in meters.**

For example:
The horizontal staff of 120 cm gives a reading of 9.2%; therefore 1 % corresponds to a length of 120/9.2 = 13.04 cm, and the horizontal distance is equal to 13.04 m.

2.2. Vertical Target

For this purpose, a **2-meter target** is used (see Fig. 9 and 10), which can be obtained with the Spiegel-Relaskop. The unit is equipped with two highly visible marks on a handle at each end and a mark at its midpoint (1). Two spikes (2 and 3) are screwed in for transport, and then attached to the back of the target to fasten the target to the tree stem (see item 4 in Fig. 10).

The **Spiegel-Relaskop Metric Standard** makes it possible to locate the horizontal distances of 15, 20, 25 and 30 meters using the 2-meter target by following this procedure: Find the approximately correct distance from the tree axis without regard for slope and visibility. From this temporary point, press the brake release and view the midpoint of the 2-meter target (see Fig. 9). Lock the brake when the measuring edge is exactly on the mark at the midpoint of the target. Turn the instrument counter-clockwise by 90 degrees to a horizontal position, and again view the target with the right eye. It is an advantage if the left hand is holding the right one, and the index finger is supporting the instrument near the sun shade (see Fig. 11).

The usually horizontal measuring edge now stands vertically, and the bands are on the right side of the field of view (Fig. 12). All further measurements are made between the edge of band 2, labeled "unten"and the edges of the two white rangefinder bands in the upper part. Measurements are always made exactly along the measuring edge, which is now vertical. The measuring edge is matched with the 2-meter target so that the lower mark of the target matches the lower edge of band 2, and the upper mark of the target matches the other edge of the rangefinder band for the desired distance. Walking back and forth slightly will bring the marks into exact correspondence with the edges of the rangefinding bands. One can normally assume that the angle of inclination will not change considerably. Should this be the case, one should once more sight at the midpoint of the target with the pendulum released and repeat the procedure.

Figure 12 shows an illustration of the scale seen through the Spiegel-Relaskop when the distance from the stem is exactly 20 meters. In the same way, the horizontal distances of 15, 25 and 30 meters can be located.

When using the **Spiegel-Relaskop Metric CP** the height interval **i** of the vertical target (in this case 2 meters) (see Fig. 9) can be measured in percent from the observation point using the **P** scale and estimating to the nearest tenth of a percent. The length of the target **i** divided by the measured percentage **p** gives the height corresponding to 1%, and multiplying by 100 gives the horizontal distance.

For the example in Figure 13, the horizontal distance is calculated as follows:

i = 2 meters
p = +6.8 - (-3.6) = 10.4
a = (2/10.4) x 100 = 19.2 m

- Note:

Whenever the target is not situated on the side of the tree along the axis, but on the side facing the observer, this additional distance must be added to the horizontal distance!

3.0. Height Measurement (h-Measurement)

- 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!

Using the **Spiegel-Relaskop Metric Standard,** height measurements are made from the standard distances of 15, 20, 25 and 30 meters using the three height bands labeled Ts20, Ts25 and Ts30. The Ts30 band is also used at a distance of 15 meters, but the readings are divided by two. At the appropriate distances, the readings on these tangent scales give meters directly, with fractions being estimated.

The upper reading minus the lower reading gives the height. Since the base of the tree mostly lies below a level horizon, making the reading negative, the absolute values of the readings must be added.

With the **Spiegel-Relaskop Metric CP** all height measurements on standing trees, such as **total height, stem height at particular diameters, crown length** as well as the **determination of slenderness of Pressler's height**, etc., can be measured **from any distance using the P scale** (i.e. in percentages of the horizontal distance). If the percentage readings to the top and the base are designated $\mathbf{p_o}$ and $\mathbf{p_u}$, then the general formula for heights is:

$$\mathbf{h = a\,(p_o - p_u)\ /\ 100}$$

- Note:

All readings are correct only at the measuring edge! Since the parts of the scale above the measuring edge are not visible, one must observe the sequence of the numbers to interpolate properly.

4.0. Measurement of Upper Stem Diameters (d-Measurement)

The **Spiegel-Relaskop Metric Standard** uses band 1 (= 1 RU) and the quarter bands to the right of it. The width of the quarter field as a whole corresponds to 1/50 (= 2%) of the horizontal distance, half the field to 1/100 (= 1%), and a quarter to 1/200 (= 0.5%).

- Note:

Half of band 1 gives a width in centimeters which corresponds to the distance in meters. The relationship is therefore:

at a distance of 10 m, half of band 1 = 10 cm.

15 m	15 cm
20 m	20 cm
25 m	25 cm
30 m	30 cm

All other relationships for the total width of the measuring field corresponding to each tree distance follow this pattern, for example: At a distance of 20 meters, the width of band 1 represents 40 cm, each quarter to the right represents 10 cm, and fractions of 10 cm can be estimated. The combined measuring fields (band 1 + the quarters field) correspond to a width of 80 cm.

The **Spiegel-Relaskop Metric CP** has a **very wide measuring field for the determination of stem diameters**, as seen in Figure 8. Because of this, it is possible to be quite near to the stem when determining the

diameters, and there is **no requirement to use fixed distances.** The general formula for a stem diameter **d** is as follows:

d (in cm) = a (in meters) x b (in %)

In Figure 8 the scale of the distance percentages is shown having its zero point in the middle of the quarters field. During measurement, the left edge of the stem should match the edge of one of the bands with an even percentage value (e.g. 6%) so that the right edge of the stem falls within the quarters field (the right half of band 4) to obtain the best estimate of the fractional part of the percentage. In the example, the diameter width would be read as 7.7%, which is multiplied by the distance to the tree in meters to calculate the diameter in centimeters.

Usually, **5 RU** (= 10%) plus the quarters field will suffice for width measurements of this kind. Taking the small black band to the right of band 2 gives an additional **1.17 %**, and in combination with band 2, which is **2.83 %**, gives a **total of 4 %**. To utilize the widths fully in some special case, one can add to the standard 16 % of the scale an additional **3.46 %** with the use of band 3.

All measurements of width are made with the pendulum released!

5.0. "Slenderness" ("h/d" Measurement)

In forestry, the "slenderness" is the height of a tree in multiplies of the breast height diameter. This reference number is often used to judge the danger of snow damage to conifer forests. As a rule, the trees concerned are only examined, whether their "slenderness" exceeds a certain value (for example "70").

The useful parameter of tree "slenderness" is **easily determined with the Spiegel-Relaskop Metric Standard** in this way: Regardless of the viewing angle, release the pendulum and find the distance from the tree where the d.b.h. coincides with band 1 plus the quarters field. Then use the units of the tangent scale Ts25, which is just to the right of the quarters field, to measure the height from the top to the base of the tree. This measurement gives a direct reading of the “slenderness”.

When using the **Spiegel-Relaskop Metric CP**, follow the same procedure, but use the percentage scale to measure height and divide the result by four to calculate the slenderness.

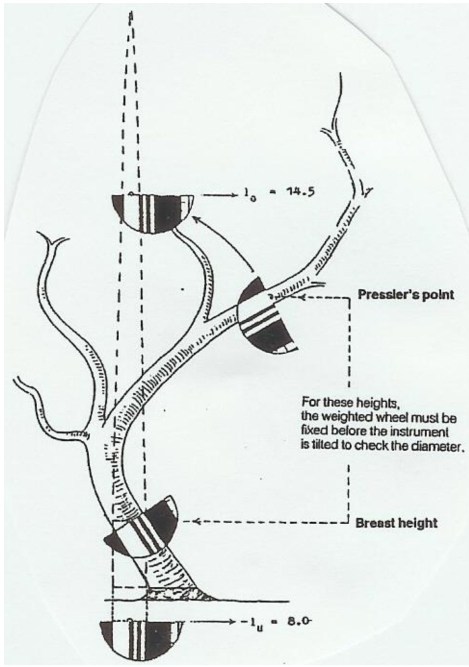
6.0. Form Height and Volume Measurement Using Pressler’s Formula (“fh/d” Measurement)

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**. Locate the point on the stem at which the diameter is exactly half as large as the diameter in breast height. The height to this point (Pressler’s height) above a point estimated to be 50 to 70 cm underneath the base of the tree **times 2/3** gives in best approximation the **form height (fh)** which we must multiply by the **basal-area in breast height (g)** in order to get the **stem volume (v)**. A detailed proof of the theory is found by Pressler himself and is contained in “The Relaskop Idea”.

For the use of the Spiegel-Relaskop in the practical application of this technique there are several publications by the author. These can be obtained for users of the instrument free of charge from RELASKOP-TECHNIK VERTRIEBSGes.m.b.H., Salzburg.

Here is an example, with an illustration, which shows that the **fh/d measurement gives a good approximation of stem volume even on abnormally crooked tree stems**, and is therefore **a “lifejacket” when all other methods fail:**

By changing the appropriate distance from the tree, the breast height diameter is made to match band 4, Pressler’s point is then found by matching the upper stem with band 1. The pendulum must be fixed before tilting the instrument. In order to measure Pressler’s height, one must imagine the crooked stem to be straight, as indicated in the illustration.



A measurement connected to an estimate is still better than no measurement at all!

7.0. 3-point Measurement with the Micro Attachment

The **micro attachment** in conjunction with the tilting head (see pages 33 and 34) greatly increases the value of the **Spiegel-Relakop CP** for measurements previously requiring the Tele-Relaskop, under the assumption that the power of the naked eye is sufficient and that the special technique illustrated in Figure 22 is used.

Unlike the Tele-Relaskop, where a minimum distance is necessary for the measurement of standing trees, the Spiegel-Relaskop should be used **as close to the stem as possible**. The following procedure is recommended:

After selecting a suitable observation point (preferably on the uphill side of the tree) take the readings for the inclination **p** to the diameter at breast height and for the width **b** at that point. Then take the readings for the inclination $\mathbf{p_2}$ and width $\mathbf{b_2}$ of a second point higher on the tree.

Each of the readings for **p** and **b** are taken with the instrument in the same position. In this example **p** = **-34** is read on the percentage scale. For measuring width, the left edge of the tree must be aligned with the left edge of one of the RU bands so that the right edge of the tree falls within the quarters field. Now count the full RUs to the left of 0 (Fig. 8) (1 RU = 2%), the quarter fields to the right of 0, and estimate to the nearest 1/10 RU. In this example the relative value of **b** is therefore equal to **11.6 %.** Multiplying by the distance **a** in meters will give the absolute value of the diameter in centimeters:

$$\mathbf{d\ (in\ cm) = a\ (in\ m) \cdot b\ (in\ \%)}$$

At the second point higher up the tree, follow the same procedure ($\mathbf{b_2 = 8.5\ \%}$). From this same point near the tree, if possible, measure the inclination $\mathbf{p_o}$ to the top of the tree and calculate the tree height **h** (see also page 24):

$$\mathbf{h = a \cdot (p_o - p) / 100}$$

If it is not possible to see the top of the tree from the current position (at distance **a**), or the angle of vision is too steep to read the percent scale, then follow this procedure: Select a new position where the distance **a** is doubled, but maintain the same angle of inclination **p″** to the d.b.h. which you had before (**p**). For this optical measurement look for equal CP values! One can get $\mathbf{p_o}$ by doubling $\mathbf{p_o'}$ and adding

p″. If **p″** was different from **p**, the procedure would also be correct as long as the reading was taken in the direction of the former position of the instrument (not the d.b.h.). Remember to take the different heights of the instrument into account!

If it is also necessary to make width measurements at the doubled distance, the calculation of **b** in the distance **a** is made by doubling the readings.

In the same way, this method can be extended to measurements from triple (or other) multiple distances of **a**, which may be an advantage in connection with continuous forest inventory for increment measurements (Critical Height Sampling by Kim Iles, see pages 19 to 21).

Tilting Head and Micro Attachment for Precision Measurements

In order to utilize **the precision of diameter and height measurements** inherent in the Relaskops (Tele-Relaskop and Spiegel-Relaskop) a micro attachment was constructed, which can be attached to a tripod or a single-pole staff which has a tilting head (Fig. 19, 20, and 21).

The micro attachment (Fig. 20) has at its center a large flat socket plate with a screw bolt (8) for attaching the Relaskop. At the side, a short lever (7) locks the socket plate to which the instrument is attached. In order to maintain a constant orientation of the instrument, it is necessary that the Spiegel-Relaskop lies close to the device for the permanent release of the brake (10 in Fig.3), as described below.

In order to release the brake of the Spiegel-Relaskop permanently, during precision measurement, the device for the permanent release of the brake (10) must be fitted over the stop pin (9 in Fig. 21). This device has a rectangular cross-section, a longitudinal borehole and at the upper end it has a right angle pin which can secure the locking brake release (6 in Fig. 19) when turned across it. When attaching the Relaskop, it should initially be turned to the right, away from the stop pin, and after attachment to the socket plate moved to the left until it lies close to the stop of the device for the permanent brake release (10) where it can be fixed in this position by the lever (7).

The use of the micro attachment is as follows (see Fig. 19): A rough adjustment of the height is made by the long handle (1) of the tilting head and can be read from the scale of the Spiegel-Relaskop after depressing the locking brake release (6). The device for permanent release of the brake (10) is moved therefore into position to keep the brake release depressed. The internal pendulum now swings freely and will continuously adjust for changes in inclination, which can be made using the adjusting knob (2). The locking screw (3) of the tilting head gives a rough horizontal adjustment, whereas the adjusting knob (4) allows a very precise adjustment needed for measuring widths. The locking screw (5) provides for sideways tilting of the tilting head, where there is no need for precise adjustment.

RELASKOP LIGHT -Illumination for the scale of the Spiegel-Relaskop®

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 electricity a standard type of battery "Mignon 1,5 V" is used.

The Relaskop Light ready to be clipped on

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English edition: **Kim Iles**