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NIINISALO CALIBRATION BASE LINE

by

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Abstract

A base line of 22.2 km has been established for calibration of electronic distance measurement instruments at Niinisalo in central Finland. The base line was measured with 12 invar wires, calibrated at Nummela standard base line. The standard error of the length of the Niinisalo calibration base line is ± 1.73 mm.

The differences in ground elevations do not exceed 50 m. There are 25 m high towers at the terminals for instrument calibration. The measuring beam runs at least 10 m above the tree tops. The terrain is typical for the distance measurements general in Finland. Two 40 m high towers were built beside the line, making meteorological observations possible directly in the measuring beam.

Foreword

For calibration of the electronic distance measurement equipment the Finnish Geodetic Institute had measured a 6.0 km long invar wire base line and its extension net with ten sides of 6.8—29.1 km near the Nummela standard base line with special care. The standard error of the invar wire base line is ± 0.49 mm, but errors in the extension sides are considerably greater, the standard error of the longest side being ± 57.3 mm. For purposes of calibration the accuracy of the invar wire base line is sufficient, but its length does not correspond to that of the regular trilateration net. The lengths of the extension net sides are proper, but the accuracy does not exceed that of the instruments to be calibrated.

In order to provide better opportunities for calibration of the electronic distance measurement equipment the Finnish Geodetic Institute decided to measure, with invar wires, a calibration base line similar to the regular trilateration sides in Finland and to make arrangements for observation of meteorological factors along the line. Leading of the work was entrusted to the author. He and Mr. JUSSI KÄÄRIÄINEN carried out the invar wire observations. The building of the invar wire line and the auxiliary observations were made by Mr. PENTTI GRÖHN with the exception of precise levelling, which was entrusted to Mr. KÄÄRIÄINEN. The mathematical treatment was made by the author and Messrs. KÄÄRIÄINEN and GRÖHN. The three triangulation towers, the ground markers, the stakes for the invar wire measurement and the two towers for meteorological observations were built by the Survey and Ranging Battalion (Mittauspatteristo) at Niinisalo.

Niinisalo calibration base line

It was planned to establish a calibration base line for electronic distance measurement equipment 20—30 km long, with moderately high towers, mutually visible, at both ends of the line, and so that it would be possible to measure this line with invar wires. Finding a line like this in Finland proved very difficult, especially in view of the demands of invar wire measurement. From the few possibilities available the line running close to the road from Kankaanpää to Parkano was chosen. It was here possible to make the invar wire measurement mainly on the edge of the roadway or verge, and the terrain in question further corresponds very well to the typical Finnish terrain in which distance measurements are usually performed.

The SW end of the calibration base line, *Niinisalo* ($\varphi = 61°51'.8$ N, $\lambda = 22°28'.5$ E and $h = 135.948$ m. The abbreviation *Nii* is used.) is in the village of Niinisalo in the rural district of Kankaanpää, on an extensive sand ridge and 7.5 km from Kankaanpää church in the direction of 26°. A wooden 25.68 m high tower was built here for observations. This is composed of a tower for the observers and another tower for the instrument, one inside the other but not touching. The observation tower was built sufficiently steady for it to be used in observations of the first order triangulation. Because the bedrock is not visible at this point, the marker of the end point of the invar wire measurement and two reference end markers were fastened to concrete blocks. These blocks were cast in

autumn 1967. They are cylinders with a diameter of 1 m and reach a depth of 3 m. The ground is of gravel, and previous experience has shown that markers of this kind can be considered sufficiently immovable. The end marker of the invar wire measurement was located under the observation tower and one of the reference end markers lies on the invar wire measurement line at a distance of 24 m and the other on the extension of the invar wire measurement line and at a distance of 24 m. The markers are brass bolts, *i.e.* cylinders with a diameter of 22 mm and a length of 150 mm. On the level top of the bolt is a round hole with a diameter of 4 mm, this hole being the definitive measurement mark. There is also a marker perpendicular to the calibration base line for projecting the ground marker to the instrument table of the tower. The mutual locations of these 4 markers are described in Table 1.

The NE end of the calibration base line, *Pihnari* ($\varphi = 61°57'.3$ N, $\lambda = 22°51'.0$ E and $h = 156.484$ m. The abbreviation *Pri* is used.) is

Fig. 1. The Niinisalo triangulation tower.

in the village of Riitiala in the parish of Ikaalinen, on Pihnari hill and 11.2 km from Parkano church in the direction of 235°. A 24.82 m high observation tower was built here similar to the tower at Niinisalo. The end marker of the invar wire measurement line lies in the bedrock under the observation tower. The two reference end markers are similar to those at Niinisalo and are on the invar wire measurement line at distances of 24 and 48 m from the end marker. A marker for projecting was also set. The mutual locations of these 4 markers are shown in Table 1.

In order to get in usage *more calibration distances with different lengths* a third observation tower was built at *Naurisjoki* ($\varphi = 61°52'.9$ N, $\lambda = 22°32'.9$ E and $h = 127.967$ m. The abbreviation *Nau* is used.), 4.5 km from Niinisalo. In this way a calibration base line 22.2 km long and with sections of 4.5 and 17.7 km long were created. The observation tower at Naurisjoki is 16.23 m high and of the same construction as the tower at Niinisalo and Pihnari. The end mark of the invar wire measure-

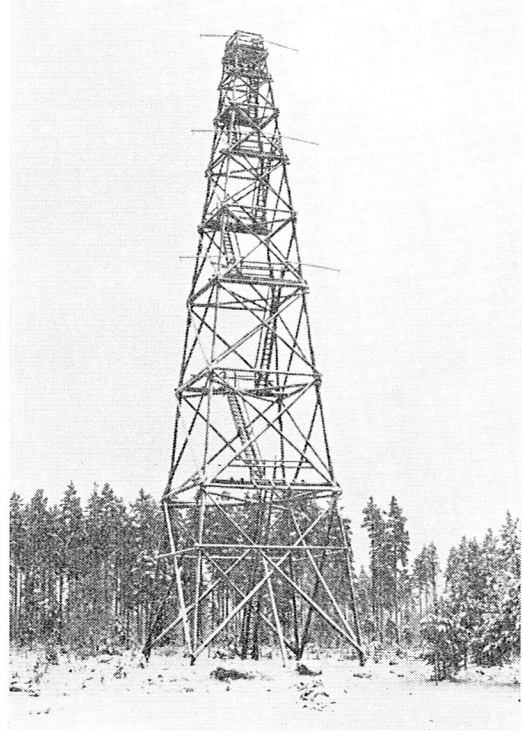

Fig. 2. The Peurala tower for meteorological observations.

ment is a marker in the bedrock and there are two reference end markers in the bedrock in the direction of the invar wire measurement line at distances of 24 and 48 m from the end marker toward Pihnari. Since the observation tower was built beside the invar wire measurement line the fourth marker was set in the bedrock under the observation tower. For projecting this marker to the instrument table a fifth marker and further an auxiliary sixth marker were set. The mutual locations of these six markers are described in Fig. 6 and in Table 1.

When instruments to be calibrated are placed on top of the towers the radiation beam runs from Niinisalo to Pihnari at least 10 m above the tree tops and from Naurisjoki to Niinisalo and Pihnari at least 4 m above the tree tops, as the heights of the trees were in 1969. In order for it to be possible to observe meteorological factors directly in the measuring beams, two 40 m high wooden single towers were built. The first, *Peurala*, is 10.7 km and the second, *Luojus*, 16.8 km from Niinisalo. Their locations and the course of the measuring rays are shown in the appended sketch of the calibration base line.

For *meteorological observations* four Theodor Friedrichs electrical aspiration psychrometers, model 3 X 101 are available, and these instruments are equipped with reading devices built by Dr. S. HUOVILA at the Finnish Meteorological Institute. For observations at different elevations and outside the influence of the tower, the towers were equipped with 2.4 m long wooden bars for suspending the psychrometers. The elevations of the bars from the ground are:

Niinisalo	25.2	18.2	—	m
Naurisjoki	15.6	—	—	»
Peurala	40.3	33.5	25.0	»
Luojus	41.5	35.0	26.4	»
Pihnari	24.3	16.8	—	»

As the Kankaanpää—Parkano road is not quite straight, 5 angles of break were made in the invar wire measurement:

No.	Distance from Niinisalo	Angle of break
1	3 527.6 m	179°51′38″.8 ± 1″.5
2	4 510.8 » (Naurisjoki)	180°24′31″.4
3	8 782.5 »	179°59′53″.8 ± 0″.7
4	11 231.1 »	180°09′07″.2 ± 1″.0
5 [1])	17 206.3 »	180°15′04″.6

[1]) Simultaneously a transfer of 8 881.3 mm sideways.

These angles of break were made so small that they do not increase significantly the total error in the effective length of the calibration base line and its sections. Due to the angles of break the Niinisalo—Pihnari sight line mostly runs 30—40 m southeast of the asphalt road, and 55 % of the terrain is here forest and 45 % open field or swamp. This is typical Finnish terrain. Since the Naurisjoki tower is 30 m southeast of the invar wire line and 12 cm southeast of the straight Niinisalo—Pihnari line, the two shorter lines Niinisalo—Naurisjoki and Naurisjoki—Pihnari thus run the same way as the line Niinisalo—Pihnari. In the sketch appendix the invar wire measurement line and the straight line Niinisalo—Pihnari are shown with regard to the terrain, roads and settlement.

The *building of the invar wire measurement line* was planned and led by Mr. GRÖHN. The construction was by Sergeant HANNU RAJAHALME from the Mittauspatteristo with the help of 10—20 soldiers on May 15—August 15, 1968. The line is 926 wire lengths long. For the invar wire measurement 916 wooden stakes, steadied from three sides, were built. They were of the same construction as those used earlier by the Finnish Geodetic Institute. The plumbing bars were used on 13 bolt markers on the invar wire measurement line ([3], pp. 13—25). In order to avoid too great height differences and to make the height differences continuous, 148 stakes essentially higher, and 75 stakes essentially lower than usual, were built, so that the greatest height difference was 163 cm. The remaining 693 stakes were of normal height, 90 cm.

Measuring knobs of a new model were used in the invar wire measurement (Fig. 3). They are brass and nickelled conical markers, fastened to the tops of the stakes with a 17 mm long spike. A straight line was

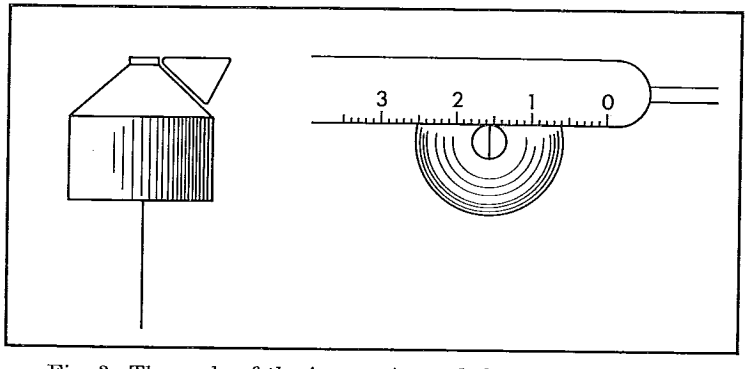

Fig. 3. The scale of the invar wire and the measuring knob.

engraved on the top surface of the knobs. When the knobs were aligned they were turned so that the reading lines on the tops of the knobs were perpendicular to the base line. As the reading lines of the knobs and the scales of the invar wires are on the same level no parallax appears and reading is convenient.

Reductions in the invar wire measurement

The distances between two successive measuring knobs are observed in the way used in earlier base line measurements of the Finnish Geodetic Institute ([3], pp. 13—25), *i.e.* the knob distance is read three times, the arithmetical mean of which is the observation result for the knob distance in question. The sum of the knob distances is the observed length of the line to be measured. This raw result is then reduced due to several factors.

The factors influencing the result of the wire measurement are considered in the same way as in the earlier base line measurements of the Finnish Geodetic Institute ([5], pp. 71—74). The corrections used are as follows.

a) The correction on the lengths of wires caused by *temperature*, k_t, was computed using the following formulas:

$$l = l_0 (1 + 0.000\,000\,094\, t - 0.000\,000\,0030\, t^2), \text{ for wires } 634—637$$

$$l = l_0 (1 - 0.000\,000\,323\, t + 0.000\,000\,0057\, t^2), \text{ for wires } 1042—1045$$

$$l = l_0 (1 + 0.000\,000\,391\, t - 0.000\,000\,0004\, t^2), \text{ for wires } 1115—1118$$

and then the total correction $k_t = n\,(l - l_0)$ for n stake intervals. The temperature was first measured using the special thermometer constructed by Dr. TAUNO HONKASALO, and when the thermometer broke in the measurement of 3/V (see p. 10) a mercury thermometer was used, ([1], pp. 39—41). All measurements are reduced to 15°C.

b) The correction caused by the *inclination* of the stake distances, k_h in mm, was computed using the following formula:

$$\begin{aligned} k_h = & - 20.830\,30\, \Sigma h^2 + 0.000\,868\, \lambda \Sigma h^2 - 0.009\,042\, \Sigma h^4 - 0.000\,0078\, \Sigma h^6 \\ & - 0.000\,241\, \Sigma B + 0.000\,8681\, \Sigma h^2 B + 0.000\,001\,13\, \Sigma h^4 B \\ & - 0.000\,000\,01\, \Sigma B^2 - 0.000\,000\,036\, \Sigma h^2 B^2 + 0.000\,000\,38\, \Sigma hB \\ & + 0.012\,77\, \Sigma h, \end{aligned}$$

where

h = the difference in elevation in metres between two successive stakes

$\lambda = l - 24\,000$ mm, where l is the length of the wire when the wire is stretched with a force of 10 kg and the wire is horizontal and

B = the difference of the scale readings in mm.

c) The effect of the *graduation* errors of the scales of the invar wires, k_s, was considered using the following formula:

$$k_s = s\Sigma B \text{ mm},$$

where s for different wires is, according to HONKASALO, as follows:

Wire	s	Wire	s	Wire	s
634	+ 0.000 23	1042	+ 0.000 17	1115	+ 0.000 47
635	+ 0.000 38	1043	+ 0.000 03	1116	+ 0.000 34
636	+ 0.000 19	1044	+ 0.000 00	1117	+ 0.000 39
637	+ 0.000 12	1045	+ 0.000 07	1118	+ 0.000 40

d) The effect of the difference between the *gravity value* at Nummela g_0 (981.950 cm/s²) and the values at Niinisalo g (982.020 — 982.027 cm/s²), k_g, was computed using the following formula:

$$k_g = 6.98\, n \cdot \frac{g - g_0}{g_0} \text{ mm},$$

where n is the number of stake intervals.

e) The correction caused by the *wire constant*, k_λ, was computed using the following formula:

$$k_\lambda = n\lambda \text{ mm}.$$

In the formula n is the number of stake intervals, and λ the wire constant (see p. 8).

f) The measuring knobs, which were fastened to the tops of the stakes for invar wire measurement, were *aligned* so accurately between the points of break that no deviations, which would cause reduction corrections, appear, with the exception of one case caused by an accident (see Table 3, note 3).

g) When the measuring group moves near a stake, the stake may *incline* in soft ground. Any doubtful stakes were specially tested with the theodolite. If moving was found, the stake was made immovable, so that no reduction correction of this kind has been necessary.

The corrections caused by the factors explained before are at the Niinisalo calibration base line at most:

k_t	k_h	k_s	k_g	k_λ	
40	4200	0.4	0.5	1200	mm

Calibrations of the invar wires at the Nummela standard base line

The invar wires used in the measurement of the Niinisalo calibration base line were calibrated using the Nummela standard base line ([2], p. 64). The calibrations were made by Mr. KÄÄRIÄINEN and the author. Mr. JORMA SAVOLAINEN was the record keeper. For the Nummela standard base line and its halves at the elevation of the 0 marker the following lengths were used:

$$N_I = 432 \text{ m} + 95.18 \text{ mm}$$
$$N_{II} = 432 \text{ m} + 27.18 \text{ mm}$$
$$N = 864 \text{ m} + 122.36 \pm 0.027 \text{ mm}$$

At the elevation of the invar wire measurement the lengths were:

$$N_I = 432 \text{ m} + 95.21 \text{ mm}$$
$$N_{II} = 432 \text{ m} + 27.05 \text{ mm}$$
$$N = 864 \text{ m} + 122.26 \pm 0.027 \text{ mm}$$

12 invar wires were used in the measurements. They were divided into three four-wire groups: a, b and c as follows:

a: Nos. 635, 1042, 1044 and 1115
b: Nos. 637, 1045, 1117 and 1118
c: Nos. 634, 636, 1043 and 1116

In the calibration measurements the same underground markers were used as those to which the interference measurements were projected. In order to plumb the measurement marks in the measurement elevation the symmetrical plumbing bars were used.

Measurements at Nummela and Niinisalo were made as follows:

Groups of wires		Time
at Nummela	at Niinisalo	1968
a, b		25.5.—29.5. and 11.6.
	a,b	4.—10.6. and 13.6.
a, b, c, a, b		11.—25.6.
	b, c	29.6.—4.7.
b, c, b, c		8.—13.7.
	a, c	15.—19.7.
a, c, a, c		22.—26.7.
	a, b	30.7.—6.8.
a, b, b		7.—9.8.
	b, c	15.—21.8.
b, c		26.—28.8.

Altogether wire measurement of 138 km was made at Nummela and 177 km at Niinisalo.

The results of the calibrations are presented in Table 2.

As the calibrations at Nummela showed that no systematic changes in the wire lengths appeared, for each wire one and the same wire constant, the arithmetical mean of all calibrations was used on the whole calibration base line measurement.

Measurement of the Niinisalo calibration base line

For the invar wire measurement the calibration base line was divided into five parts of almost equal length. The brass bolts in the blocks of concrete or in the bedrock were used as the end markers of every part. The markers at Niinisalo, Naurisjoki and Pihnari are fastened so that they remain unmovable over the years. The other markers at the limits of the parts may move due to winter frost, but they were built sufficiently stable for the whole period of the invar wire measurement. Here the parts are called the fifths and the following numbering is used: 1/V, 2/V, 3/V, 4/V and 5/V. Every fifth was measured as an independent base line. The invar wire measurement on the calibration base line was made by the same persons as on the standard base line. Every fifth was measured with two groups of wires *i.e.* with 8 invar wires. The calibrations of the invar wires were made both before and after the measurement of every fifth as is shown in the foregoing table. In this way continuous control of the possible variations in the lengths of the invar wires was attained. The results of the invar wire measurements at Niinisalo are presented in Table 3.

For computation of the correction for the *inclination of the stake distances*, k_h (see p. 7), the calibration base line was levelled three times except for 1/V, which was levelled four times. The elevation differences, which were below 80 cm, were levelled with a Zeiss Ni 025 automatic levelling instrument and with a wooden rod equipped with cm graduation. The levellings were made by Messrs. GRÖHN, RAJAHALME, HENDRIK SCHOK (from the Netherlands) and EGBERT KOLK (from the Netherlands). If the elevation difference was over 80 cm, precise levelling was made using a precise levelling instrument Zeiss Ni A and an invar rod. The end markers at Niinisalo and Pihnari were tied with the high precision levelling line. The precise levelling was made by Mr. KÄÄRIÄINEN with the assistance of Messrs. GRÖHN and SCHOK on 4/V. The numbers

of differences in elevation below and above 80 cm at different fifths were as follows:

	Above 80 cm	Below 80 cm
1/V	12	176 stake intervals
2/V	8	170 »
3/V	0	159 »
4/V	33	159 »
5/V	37	172 »

The first levelling of 1/V was made on May 31 — June 1, 1968 and the second on June 10, 1968. The levelled differences in elevation between stakes Nos. 70—182 did not agree, despite the fact that both levellings between the markers at Niinisalo and Naurisjoki were in agreement. The greatest variations in elevation per stake distance were 40 mm. It was apparent that the winter frost had not yet thawed completely and was moving the stakes. As at 1/V the differences in elevation were small, and as the moving of the individual stakes mostly causes opposite corrections eliminating each other in successive stake distances, the total correction k_h was not effected much by this movement. The correction was assumed as changing regularly and the correction for differences in elevation was interpolated for each invar wire measurement. The variation of this correction is represented in Fig. 4. The list of differences in elevation and the sum terms for computing of k_h are given in Table 4.

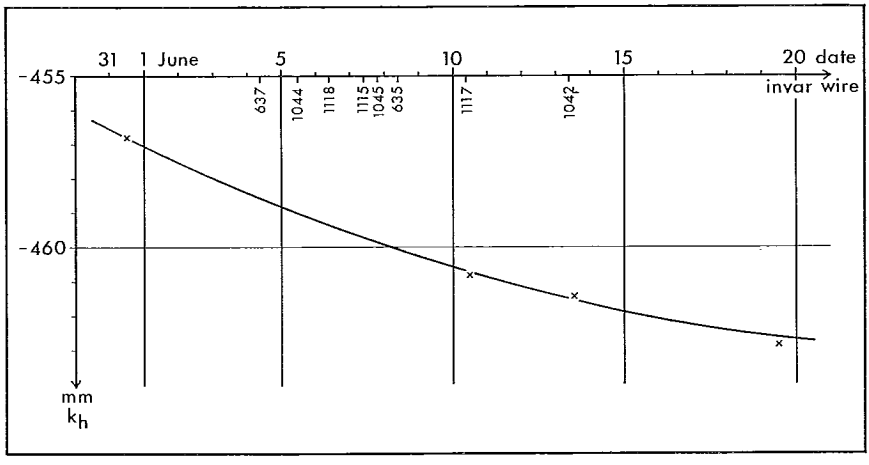

Fig. 4. The variation of k_h between stakes Nos. 70—182 on 1/V. The points represent the values computed using the levellings.

In this way the stake distances were measured with the invar wires on the *straight lines between the points of break,* and these sloping stake distances were reduced to the horizontal stake distances, each of which is in the direction of the tangent of the niveau surface at the mean elevation of the reading knobs. Thus the total sum of these individual stake distances is the distance between two successive points of break along the niveau surfaces in the average measuring elevations and between the plumb lines through the points of break. In the following these distances are called measured lengths (L).

The *projecting of the measured lengths* to the straight lines between the towers was performed by Mr. GRÖHN. Angles of break were measured with a Kern DKM 3 theodolite. Angle of break No. 1 was measured sighting at the targets at Niinisalo and Naurisjoki, centred at the end markers. Angle of break No. 2 was measured eccentrically from the Naurisjoki tower. Observations were made in five series sighting to lamps in the Niinisalo and Pihnari towers. Angle of break No. 3 was measured by sighting to the centred targets at Naurisjoki and to the point of break

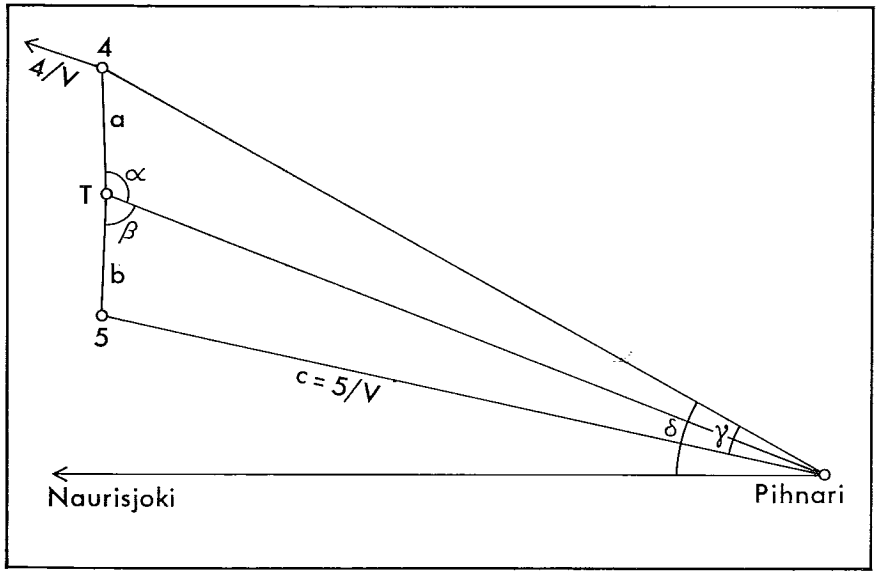

Fig. 5. Projection of the end point of 4/V and of the starting point of 5/V to the straight Pihnari—Naurisjoki line. T = auxiliary point, 4 = the end marker of 4/V, 5 = the starting marker of 5/V, a = 4436.3 mm, b = 4445.0 mm, c = 5 013 571.81 mm, $\alpha = 90°08'06'' \pm 5''$, $\beta = 89°52'39'' \pm 5''$, $\gamma = 6'05''.08 \pm 0''.5$, $\delta = 19'55''.21 \pm 0''.5$.

No. 4. Angle of break No. 4 was measured by sighting to the centred targets at the end points of 3/V. It was not possible to observe angle of break No. 5 directly, and it is derived from the other measurements. The end point of 4/V and the starting point of 5/V were projected to the straight Pihnari-Naurisjoki line with the measurements represented in Fig. 5. The angles γ and δ were measured sighting to the lamps at Naurisjoki and points 4 and 5. The angles α and β were measured with a theodolite Wild T2.

The following angles were further measured with Kern DKM 3 theodolite sighting to the lamps:

Pihnari—Niinisalo—Naurisjoki	5″.78 ± 0″.5
Niinisalo—Pihnari—Naurisjoki	1″.36 ± 0″.5
Niinisalo—Naurisjoki—Pihnari	179°59′52″.57 ± 0″.5

Finally the end marker of the invar wire measurement at Naurisjoki and the marker under the Naurisjoki tower were projected to the straight Niinisalo—Pihnari line. The observations for this projection are presented in Fig. 6.

In this way the measured lengths (L) were *projected* to the straight lines along the niveau surfaces between the towers in the average measuring elevation. The measured lengths, these projected lengths (S), and the average measuring elevations (H) are:

	L	S	H
Niinisalo—Pihnari	22 219 867.79 mm	22 219 696.59 mm	127.209 m
Niinisalo—Naurisjoki	4 510 781.49 »	4 510 651.49 »	126.234 »
Naurisjoki—Pihnari	17 709 086.30 »	17 709 045.08 »	127.457 »

The distance needed for calibration of electronic distance measurement equipment is a *sloping straight line* between the definitive measurement points on the instrument tables of the observation towers. As this measuring point it is practical to use the point on each instrument table which is on the plumb line running through the end marker on the ground. This point can be determined through projection with the aid of theodolite. The projecting must be repeated as soon as any significant movement of the instrument table *i.e.* of the tower is suspected.

The *reduction of the projected length* (S) from the average invar wire measurement niveau to the sloping straight line between the measurement points on the instrument tables, k_A, is made on the basis of the Earth's ellipsoidal radius 6 393 499 m in the azimuth of the calibration base line and of the above-mentioned levellings and heights of the towers.

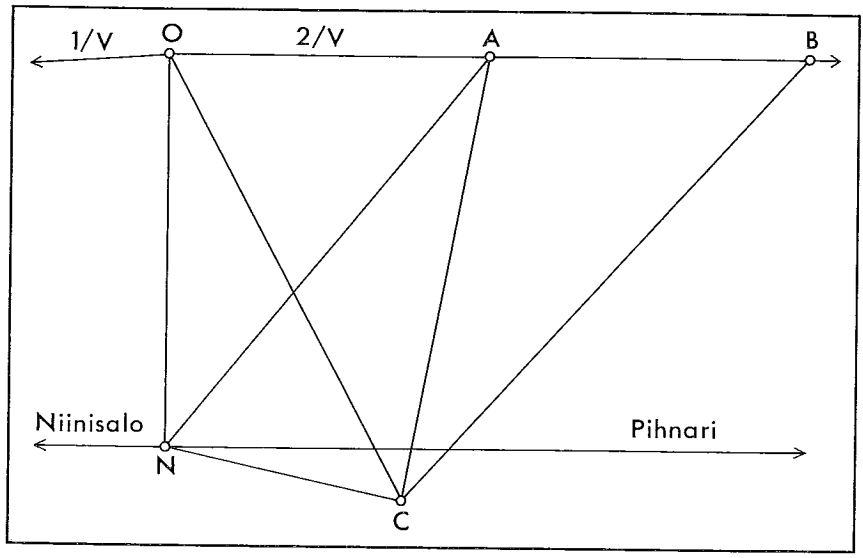

Fig. 6. Projection of the invar wire measurement at Naurisjoki and of the Naurisjoki tower to the straight Niinisalo—Pihnari line. N = the marker under the Naurisjoki tower, O = the end marker of 1/V (and starting marker of 2/V), A, B = the reference markers of O, C = auxiliary marker, a = 24 006.89 ± 0.03 mm, b = 23 992.40 ± 0.03 mm (a and b are measured with invar wires). The angles measured are:

BOC =	61°52′25.2 ± 2.7	OCN =	50°04′23.4 ± 2.7
OBC =	47 17 54.5 ± 2.7	NOA =	90 08 41.7 ± 2.7
BCO =	70 49 46.7 ± 2.7	OAN =	50 31 43.2 ± 2.7
CAB =	100 59 58.2 ± 2.7	ONA =	39 19 39.0 ± 2.7
ABC =	47 17 53.6 ± 2.7	ANC =	62 19 45.8 ± 2.7
ACB =	31 42 12.3 ± 2.7	NAC =	28 28 20.3 ± 2.7
COA =	61 52 21.4 ± 2.7	NCA =	89 11 57.8 ± 2.7
OAC =	79 00 03.5 ± 2.7	BOA =	3.8 ± 2.7
ACO =	39 07 34.4 ± 2.7	OBA =	0.9 ± 2.7
CON =	28 16 20.3 ± 2.7	OAB =	179 59 58.3 ± 2.7
ONC =	101 39 24.8 ± 2.7	PriNO =	89 56 00.2 ± 1.9

As the differences in the deflection of the vertical between the different towers influences the sloping straight line distances, the components of the deflection of the vertical in the direction Niinisalo—Pihnari were interpolated from the astro-geodetic results ([4], pp. 33—106). The Niinisalo—Pihnari direction is regarded as positive. k_A, the differences in the components of the deflection of the vertical (Θ), the height differences from the average measuring elevations to the average elevations

of the towers (ΔH) and the corrections computed using those values (k_Θ) are:

	k_A	Θ	ΔH	k_Θ
Niinisalo—Pihnari	+ 151.55 mm	+ 0".9 ± 1"	44.3 m	+ 0.19 mm
Niinisalo—Naurisjoki	+ 52.44 »	+ 0".2 ± 0".5	26.7 »	+ 0.03 »
Naurisjoki—Pihnari	+ 131.12 »	+ 0".7 ± 1"	35.3 »	+ 0.12 »

The *sloping straight line distances* ($S + k_A + k_\Theta$) between the measurement points on the instrument tables, which are on the plumb line running through the end markers on the ground, are:

Niinisalo—Pihnari	**22 219 848.3 mm**
Niinisalo—Naurisjoki	**4 510 704.0 »**
Naurisjoki—Pihnari	**17 709 176.3 »**

Errors in the lengths of the Niinisalo calibration base line and its sections

In computing errors in the lengths of the calibration base line and its sections the following sources of error are considered:

m_w, the standard error of the *invar wire measurement.* To determine this error, unlike in the computation of the lengths, an individual wire constant, the arithmetical mean of the two calibrations performed before and after the measurement of every fifth was computed. Using these individual wire constants the length of each fifth was computed and m_w is the standard error computed for each fifth from discrepancies in the results of the different wires:

	m_w
1/V	± 0.76 mm
2/V	0.46 »
3/V	0.48 »
4/V	0.69 »
5/V	0.88 »

Using these values the following standard errors in the calibration base line and its sections are obtained:

Niinisalo—Pihnari	± 1.51 mm
Niinisalo—Naurisjoki	0.76 »
Naurisjoki—Pihnari	1.30 »

This error caused by the invar wire measurement can also be computed in the following way. The standard errors in the results of every wire group computed from the discrepancies in the results of the different wires, are:

	a-group	
539 stake distances,	Niinisalo—Pihnari	± 1.87 mm
188 stake distances,	Niinisalo—Naurisjoki	1.07 »
351 stake distances,	Naurisjoki—Pihnari	0.82 »
	b-group	
767 stake distances,	Niinisalo—Pihnari	± 0.87 mm
188 stake distances,	Niinisalo—Naurisjoki	0.48 »
579 stake distances,	Naurisjoki—Pihnari	0.57 »
	c-group	
546 stake distances,	Niinisalo—Pihnari	± 2.39 mm
546 stake distances,	Naurisjoki—Pihnari	2.39 »

As each fifth was measured with two wire groups, the errors, m_w, for the calibration base line and its sections are:

$$\text{Niinisalo—Pihnari} \quad \pm \frac{\sqrt{1.87^2 + 0.87^2 + 2.39^2}}{\sqrt{2} \quad \sqrt{2}} = \pm 1.58 \text{ mm}$$

$$\text{Niinisalo—Naurisjoki} \quad \pm \frac{\sqrt{1.0\,?^2 + 0.48^2}}{\sqrt{2} \quad \sqrt{2}} = \pm 0.59 \text{ mm}$$

$$\text{Naurisjoki—Pihnari} \quad \pm \frac{\sqrt{0.82^2 + 0.57^2 + 2.39^2}}{\sqrt{2} \quad \sqrt{2}} = \pm 1.30 \text{ mm}$$

In the table at the end of this chapter the arithmetical mean of these two results is used as the standard error of invar wire measurement m_w.

m_h, standard error caused by the *differences in elevation between successive stakes*. The error in the levelling is ± 0.5 mm and in the precise levelling ± 0.3 mm per stake interval. The above-mentioned movement of the stakes on 1/V causes the error. Using the adjustment of the curve in Fig. 4 the standard error caused by the moving of the stakes is estimated to be equal to ± 0.15 mm. This error is added to the error of 1/V. The following standard errors, m_h, are obtained:

Niinisalo—Pihnari	± 0.27 mm
Niinisalo—Naurisjoki	0.17 »
Naurisjoki—Pihnari	0.22 »

m_t, standard error caused by the *differences between the temperatures* at Nummela and Niinisalo. This error was computed using the following formula:

$$m_t = \pm (t - t_0) \sqrt{0.222 - 0.0160 (t + t_0) + 0.00037 (t + t_0)^2},$$

where t_0 is the average temperature in the calibration measurement at Nummela and t the average temperature in measurement on the calibration base line ([5], p. 38). As $t_0 = 19°.50$ C and $t = 19°.11$ C the following standard errors are obtained:

Niinisalo—Pihnari	± 0.14 mm
Niinisalo—Naurisjoki	0.03 »
Naurisjoki—Pihnari	0.11 »

m_N, standard error caused by the *error of the length of the Nummela standard base line*. When the value of standard error ± 0.027 mm ([3], p. 64) for the Nummela standard base line is used the following standard errors for the Niinisalo calibration base line and its sections are obtained:

Niinisalo—Pihnari	± 0.69 mm
Niinisalo—Naurisjoki	0.14 »
Naurisjoki—Pihnari	0.55 »

m_g, the standard error, which is caused by the *errors in the angles of break* and by the errors in the *projection observations* at Naurisjoki and at the limit between 4/V and 5/V. The error is computed on the basis of the errors given on pages 12—14 and in Figs. 5 and 6. The following standard errors for the Niinisalo base line and its sections are obtained:

Niinisalo—Pihnari	± 0.07 mm
Niinisalo—Naurisjoki	0.14 »
Naurisjoki—Pihnari	0.16 »

m_s, standard error caused by the *projection of the wire measurement* to straight line distances between the instrument tables. Inaccuracies in the deflections of the vertical (see p. 15) give:

Niinisalo—Pihnari	± 0.2 mm
Niinisalo—Naurisjoki	0.1 »
Naurisjoki—Pihnari	0.2 »

The errors caused by the different sources of the errors are combined as

$$M = \pm \sqrt{m_w^2 + m_h^2 + m_t^2 + m_N^2 + m_g^2 + m_s^2}$$

The standard errors in the sloping straight line distances between the measurement marks on the instrument tables (M) are:

	m_w	m_h	m_t	m_N	m_g	m_s	M	
Niinisalo—Pihnari	± 1.54	0.27	0.14	0.69	0.07	0.2	**1.73**	mm
Niinisalo—Naurisjoki	± 0.68	0.17	0.03	0.14	0.14	0.1	**0.74**	»
Naurisjoki—Pihnari	± 1.30	0.22	0.11	0.55	0.16	0.2	**1.46**	»

The observations at the Nummela standard base line and at the Niinisalo calibration base line are made symmetrically and directly above the end markers, and so they refer to the actual lengths of these base lines without any projection errors. Further, the observations at Nummela and Niinisalo are carried out with the same equipment, by the same personnel and with the identical method and procedures. On the basis of these facts the total standard error M can be considered a real error without significant systematic errors.

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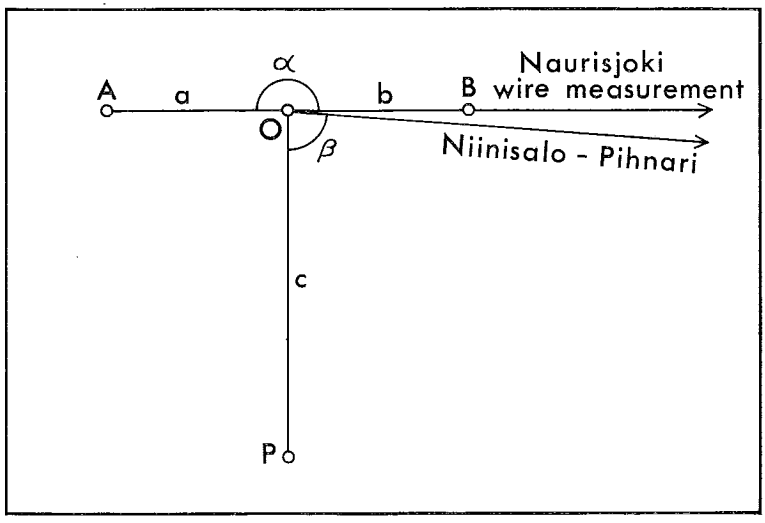
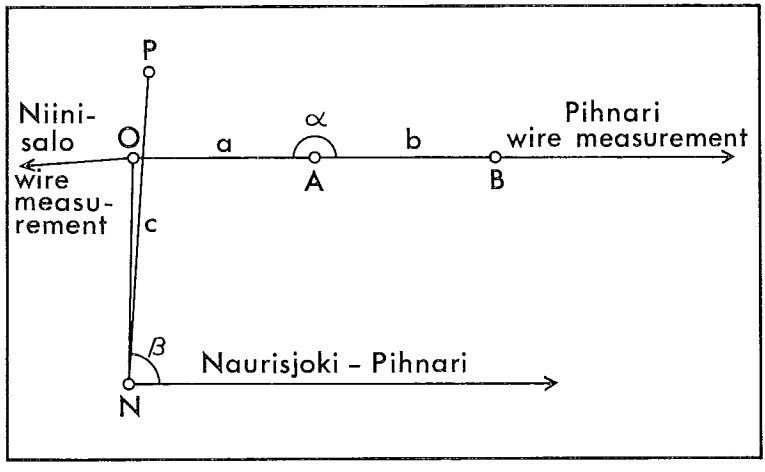
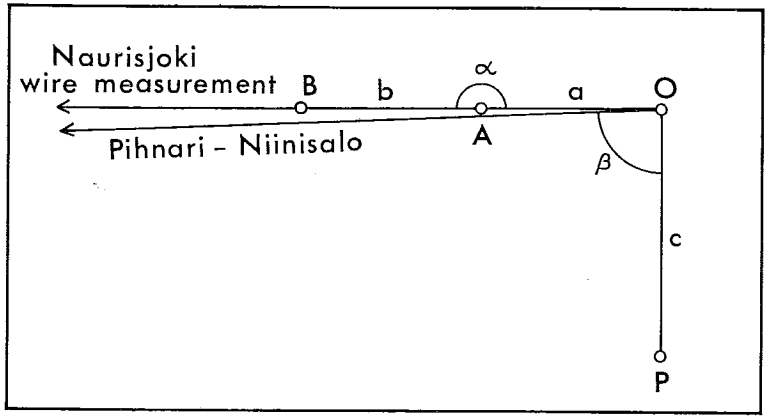
Table 1. Mutual location of the markers at towers.



Niinisalo



Naurisjoki



Pihnari

In the figures:

O = end markers of the invar wire measurement
N = marker of the Naurisjoki tower
A, B = reference end markers of the invar wire measurement
P = markers for projecting the markers lying under the towers to the instrument tables
a,b,c = horizontal distances
α, β = angles

	Niinisalo[1])	Naurisjoki	Pihnari	
a	23 983.64 ± 0.03	24 006.89 ± 0.03	23 982.97 ± 0.03	mm
b	23 976.94 ± 0.03	23 992.40 ± 0.03	23 989.98 ± 0.03	»
c	45 732	41 356	32 546	»
α	180°00′24″.1 ± 2″.7	179°59′57″.3 ± 2″.7	179°59′49″.6 ± 2″.7	
β	89°50′12″	89°53′30″	89°50′42″	

The levelled differences in elevation are:

	Niinisalo	Naurisjoki	Pihnari
O → A	− 1350.60 ± 0.04	+ 212.52 ± 0.04	− 1046.0 ± 1 mm
O → B	− 1500.67 ± 0.04		
A → B		+ 346.77 ± 0.04	+ 634.2 ± 1 »

The type of support for the markers:

	Niinisalo	Naurisjoki	Pihnari
A	concrete block	bedrock	concrete block
B	»	»	»
O	»	»	bedrock
P	»	»	concrete block

[1]) The distances a and b were remeasured June 10, 1970. The results are: a = 23 983.60 mm and b = 23 976.88 mm. They show, that the markers at Niinisalo are immovable enough.

Table 2. Calibrations at Nummela.

Date, Number of wire	Direction of wire[1])	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
24. VI	Ki −	+26.13	+97.37	−0.14	−10.71	+0.02	−8.67	
	Kä−	+25.68	+27.34	−0.13	− 8.81	+0.01	−8.64	
634	Kä+	+25.77	+26.83	−0.13	− 8.76	+0.01	−9.10	
	Ki +	+26.87	+96.41	−0.16	−10.65	+0.02	−9.59	+0.5000
10. VII	Ki −	+15.64	+96.88	0.00	−10.66	+0.02	−8.97	
	Kä−	+15.90	+27.37	0.00	− 8.81	+0.01	−8.48	
634	Kä+	+16.33	+27.30	0.00	− 8.77	+0.01	−8.51	
	Ki +	+16.38	+96.71	0.00	−10.60	+0.02	−9.08	+0.4867
13. VII	Ki −	+15.03	+96.98	0.00	−10.66	+0.02	−8.87	
	Kä−	+16.11	+27.48	0.00	− 8.81	+0.01	−8.37	
634	Kä+	+16.31	+26.75	0.00	− 8.77	+0.01	−9.06	
	Ki +	+15.84	+97.32	0.00	−10.60	+0.02	−8.47	+0.4829
23. VII	Ki −	+14.32	+98.07	0.00	−10.70	+0.02	−7.82	
	Kä−	+13.81	+27.08	0.00	− 8.81	+0.01	−8.77	
634	Kä+	+15.48	+27.07	0.00	− 8.76	+0.01	−8.73	
	Ki +	+15.61	+96.90	0.00	−10.64	+0.02	−8.93	+0.4757
26. VII	Ki −	+20.00	+97.77	−0.02	−10.70	+0.02	−8.14	
	Kä−	+20.38	+27.37	−0.03	− 8.81	+0.01	−8.51	
634	Kä+	+21.04	+27.71	−0.04	− 8.76	+0.01	−8.13	
	Ki +	+21.16	+96.86	−0.04	−10.64	+0.02	−9.01	+0.4693
27.VIII	Ki −	+18.05	+96.81	−0.01	−10.70	+0.02	−9.09	
	Kä−	+17.92	+26.49	−0.01	− 8.81	+0.01	−9.37	
634	Kä+	+17.92	+27.48	−0.01	− 8.76	+0.01	−8.33	
	Ki +	+17.82	+96.61	−0.01	−10.65	+0.02	−9.24	+0.5004
							mean	+0.4858
							standard error of mean	±0.0052
29. V	Kä+	+18.12	+81.68	−0.01	−10.71	+0.03	−24.22	
	Ki +	+21.62	+11.02	−0.04	− 8.81	0.00	−24.88	
635	Ki −	+19.41	+12.42	−0.02	− 8.76	0.00	−23.41	
	Kä−	+18.41	+81.63	−0.01	−10.65	+0.03	−24.21	+1.3433
15. VI	Kä+	+25.59	+81.87	−0.13	−10.71	+0.03	−24.15	
	Ki +	+26.69	+12.24	−0.16	− 8.81	0.00	−23.78	
635	Ki −	+26.42	+12.51	−0.15	− 8.76	0.00	−23.45	
	Kä−	+26.17	+82.14	−0.14	−10.65	+0.03	−23.83	+1.3224
20. VI	Kä+	+23.59	+82.02	−0.08	−10.71	+0.03	−23.95	
	Ki +	+23.84	+12.75	−0.08	− 8.81	0.00	−23.19	
635	Ki −	+24.44	+13.10	−0.10	− 8.76	0.00	−22.81	
	Kä−	+25.03	+82.11	−0.11	−10.65	+0.03	−23.83	+1.3025

[1]) Ki = Kiviniemi is going in front
Kä = Kääriäinen » » »
\+ = scale of invar wire on right side
− = » » » » » left »

$\Sigma = \Sigma B + k_t + k_n + k_s - N_I$ (or N_{II})

Table 2. (Continued)

Date, Number of wire	Direction of wire	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
24. VII	Kä+	+12.50	+81.60	−0.01	−10.70	+0.03	−24.29	
	Ki +	+12.73	+12.41	−0.01	− 8.81	0.00	−23.46	
635	Ki −	+12.78	+12.73	−0.01	− 8.76	0.00	−23.09	
	Kä−	+13.27	+82.17	−0.01	−10.64	+0.03	−23.66	+1.3125
25. VII	Kä+	+14.71	+81.97	0.00	−10.70	+0.03	−23.91	
	Ki +	+14.63	+12.38	0.00	− 8.81	0.00	−23.48	
635	Ki −	+15.33	+12.56	0.00	− 8.76	0.00	−23.25	
	Kä−	+16.36	+82.45	0.00	−10.64	+0.03	−23.37	+1.3057
8.VIII	Kä+	+21.63	+82.25	−0.05	−10.70	+0.03	−23.68	
	Ki +	+19.53	+12.07	−0.02	− 8.81	0.00	−23.81	
635	Ki −	+19.81	+12.61	−0.02	− 8.76	0.00	−23.22	
	Kä−	+23.12	+81.89	−0.07	−10.65	+0.03	−24.01	+1.3156
							mean	+1.3170
							standard error of mean	±0.0060
24. VI	Ki +	+25.80	+85.91	−0.13	−10.71	+0.02	−20.12	
	Kä+	+26.27	+16.06	−0.14	− 8.81	0.00	−19.94	
636	Kä−	+26.38	+16.49	−0.15	− 8.76	0.00	−19.47	
	Ki −	+26.39	+85.65	−0.15	−10.65	+0.02	−20.34	+1.1093
10. VII	Ki +	+15.08	+86.03	0.00	−10.66	+0.02	−19.82	
	Kä+	+15.82	+15.81	0.00	− 8.81	0.00	−20.05	
636	Kä−	+16.57	+16.36	0.00	− 8.77	0.00	−19.46	
	Ki −	+17.26	+86.70	0.00	−10.60	+0.02	−19.09	+1.0892
11. VII	Ki +	+16.35	+86.70	0.00	−10.66	+0.02	−19.15	
	Kä+	+14.70	+16.17	0.00	− 8.81	0.00	−19.69	
636	Kä−	+16.94	+16.27	0.00	− 8.77	0.00	−19.55	
	Ki −	+14.79	+86.27	0.00	−10.60	+0.02	−19.52	+1.0821
24. VII	Ki +	+14.73	+85.91	0.00	−10.70	+0.02	−19.98	
	Kä+	+14.83	+16.30	0.00	− 8.81	0.00	−19.56	
636	Kä−	+15.51	+16.08	0.00	− 8.76	0.00	−19.73	
	Ki −	+15.81	+86.21	0.00	−10.64	+0.02	−19.62	+1.0957
25. VII	Ki +	+17.30	+86.03	0.00	−10.70	+0.02	−19.86	
	Kä+	+18.06	+15.97	−0.01	− 8.81	0.00	−19.90	
636	Kä−	+17.91	+16.28	−0.01	− 8.76	0.00	−19.54	
	Ki −	+17.96	+86.38	−0.01	−10.64	+0.02	−19.46	+1.0939
28.VIII	Ki +	+17.85	+86.32	−0.01	−10.70	+0.02	−19.58	
	Kä+	+17.99	+16.12	−0.01	− 8.81	0.00	−19.75	
636	Kä−	+18.07	+16.41	−0.01	− 8.76	0.00	−19.41	
	Ki −	+18.21	+86.27	−0.01	−10.65	+0.02	−19.58	+1.0878
							mean	+1.0930
							standard error of mean	±0.0038
29. V	Kä−	+21.08	+95.63	−0.04	−10.71	+0.01	−10.32	
	Ki −	+19.06	+26.34	−0.01	− 8.81	0.00	− 9.53	
637	Ki +	+19.10	+24.98	−0.02	− 8.76	0.00	−10.85	
	Kä+	+19.09	+94.93	−0.01	−10.65	+0.01	−10.93	+0.5782

Table 2 (Continued)

Date, Number of wire	Direction of wire	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
11. VI	Kä−	+20.82	+95.05	−0.03	−10.71	+0.01	−10.89	
	Ki −	+19.21	+26.95	−0.02	− 8.81	0.00	− 8.93	
637	Ki +	+20.19	+25.70	−0.03	− 8.76	0.00	−10.14	
	Kä+	+19.67	+95.75	−0.02	−10.65	+0.01	−10.12	+0.5567
18. VI	Kä−	+26.64	+95.45	−0.15	−10.71	+0.01	−10.61	
	Ki −	+26.23	+25.67	−0.14	− 8.81	0.00	−10.33	
637	Ki +	+27.60	+25.48	−0.18	− 8.76	0.00	−10.51	
	Kä+	+27.70	+95.63	−0.19	−10.65	+0.01	−10.41	+0.5814
8. VII	Kä−	+15.99	+95.38	0.00	−10.71	+0.01	−10.53	
	Ki −	+16.72	+25.81	0.00	− 8.81	0.00	−10.05	
637	Ki +	+16.57	+25.99	0.00	− 8.77	0.00	− 9.83	
	Kä+	+17.08	+95.32	0.00	−10.65	+0.01	−10.53	+0.5686
11. VII	Kä−	+16.88	+95.16	0.00	−10.66	+0.01	−10.70	
	Ki −	+16.93	+25.97	0.00	− 8.81	0.00	− 9.89	
637	Ki +	+17.15	+25.46	0.00	− 8.77	0.00	−10.36	
	Kä+	+16.58	+95.50	0.00	−10.60	+0.01	−10.30	+0.5729
8.VIII	Kä−	+14.91	+95.57	0.00	−10.70	+0.01	−10.33	
	Ki −	+15.27	+25.42	0.00	− 8.81	0.00	−10.44	
637	Ki +	+15.70	+25.47	0.00	− 8.76	0.00	−10.34	
	Kä+	+16.46	+95.66	0.00	−10.65	+0.01	−10.19	+0.5736
9.VIII	Kä−	+21.22	+94.95	−0.04	−10.70	+0.01	−10.99	
	Ki −	+21.46	+25.88	−0.04	− 8.81	0.00	−10.02	
637	Ki +	+22.98	+25.19	−0.06	− 8.76	0.00	−10.68	
	Kä+	+22.92	+94.98	−0.06	−10.65	+0.01	−10.93	+0.5919
27.VIII	Kä−	+17.99	+95.12	−0.01	−10.70	+0.01	−10.79	
	Ki −	+17.76	+25.47	−0.01	− 8.81	0.00	−10.40	
637	Ki +	+18.13	+25.76	−0.01	− 8.76	0.00	−10.06	
	Kä+	+17.83	+94.95	−0.01	−10.65	+0.01	−10.91	+0.5856
							mean	+0.5761
							standard error of mean	±0.0038
11. VI	Ki −	+19.45	+87.46	−0.24	−10.71	+0.01	−18.69	
	Kä−	+19.65	+17.38	−0.25	− 8.81	0.00	−18.73	
1042	Kä+	+22.03	+17.58	−0.33	− 8.76	0.00	−18.56	
	Ki +	+21.35	+86.67	−0.31	−10.65	+0.01	−19.49	+1.0482
15. VI	Ki −	+22.13	+87.12	−0.34	−10.71	+0.01	−19.13	
	Kä−	+22.37	+18.03	−0.34	− 8.81	0.00	−18.17	
1042	Kä+	+22.89	+17.97	−0.36	− 8.76	0.00	−18.20	
	Ki +	+24.08	+86.50	−0.38	−10.65	+0.01	−19.73	+1.0449
19. VI	Ki −	+29.86	+87.76	−0.42	−10.71	+0.01	−18.57	
	Kä−	+29.91	+17.30	−0.42	− 8.81	0.00	−18.98	
1042	Kä+	+29.71	+17.67	−0.42	− 8.76	0.00	−18.56	
	Ki +	+28.86	+87.03	−0.42	−10.65	+0.01	−19.24	+1.0465

Table 2 (Continued)

Date, Number of wire	Direction of wire	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
23. VII	Ki −	+14.04	+87.38	+0.07	−10.70	+0.01	−18.45	
	Kä−	+14.59	+17.37	+0.03	− 8.81	0.00	−18.46	
1042	Kä+	+14.99	+16.80	0.00	− 8.76	0.00	−19.01	
	Ki +	+14.21	+86.50	+0.05	−10.64	+0.01	−19.29	+1.0446
26. VII	Ki −	+16.39	+87.08	−0.08	−10.70	+0.01	−18.90	
	Kä−	+16.31	+17.90	−0.08	− 8.81	0.00	−18.04	
1042	Kä+	+17.88	+17.52	−0.17	− 8.76	0.00	−18.46	
	Ki +	+18.71	+86.54	−0.21	−10.64	+0.01	−19.51	+1.0404
7.VIII	Ki −	+29.82	+87.24	−0.42	−10.70	+0.01	−19.08	
	Kä−	+28.74	+17.02	−0.42	− 8.81	0.00	−19.26	
1042	Kä+	+23.74	+16.65	−0.38	− 8.76	0.00	−19.54	
	Ki +	+22.88	+86.28	−0.36	−10.65	+0.01	−19.93	+1.0807
							mean	+1.0509
							standard error of mean	±0.0061
25. VI	Kä−	+22.42	+95.33	−0.34	−10.71	0.00	−10.93	
	Ki −	+19.97	+25.33	−0.26	− 8.81	0.00	−10.79	
1043	Ki +	+19.88	+25.62	−0.26	− 8.76	0.00	−10.45	
	Kä+	+20.47	+94.98	−0.28	−10.65	0.00	−11.16	+0.6018
9. VII	Kä−	+15.22	+95.02	−0.01	−10.66	0.00	−10.86	
	Ki −	+14.93	+25.05	0.00	− 8.81	0.00	−10.81	
1043	Ki +	+15.06	+24.88	0.00	− 8.77	0.00	−10.94	
	Kä+	+15.72	+94.22	−0.04	−10.60	0.00	−11.63	+0.6144
11. VII	Kä−	+18.36	+95.27	−0.19	−10.66	0.00	−10.79	
	Ki −	+18.07	+25.13	−0.18	− 8.81	0.00	−10.91	
1043	Ki +	+17.99	+25.35	−0.17	− 8.77	0.00	−10.64	
	Kä+	+16.89	+94.53	−0.11	−10.60	0.00	−11.39	+0.6074
23. VII	Kä−	+16.26	+95.16	−0.08	−10.70	0.00	−10.83	
	Ki −	+17.46	+25.73	−0.14	− 8.81	0.00	−10.27	
1043	Ki +	+14.64	+25.34	+0.02	− 8.76	0.00	−10.45	
	Kä+	+16.77	+95.17	−0.11	−10.64	0.00	−10.79	+0.5881
25. VII	Kä−	+20.14	+95.41	−0.27	−10.70	0.00	−10.77	
	Ki −	+17.31	+25.55	−0.14	− 8.81	0.00	−10.45	
1043	Ki +	+17.58	+25.13	−0.15	− 8.76	0.00	−10.83	
	Kä+	+17.70	+94.77	−0.16	−10.64	0.00	−11.24	+0.6012
27.VIII	Kä−	+16.56	+94.40	−0.09	−10.70	0.00	−11.60	
	Ki −	+16.62	+24.90	−0.10	− 8.81	0.00	−11.06	
1043	Ki +	+16.41	+25.36	−0.09	− 8.76	0.00	−10.54	
	Kä+	+16.51	+94.79	−0.09	−10.65	0.00	−11.16	+0.6161
							mean	+0.6048
							standard error of mean	±0.0042
25. V	Ki +	+ 9.04	+95.95	+0.48	−10.71	0.00	−9.49	
	Kä+	+ 9.40	+26.24	+0.44	− 8.81	0.00	−9.18	
1044	Kä−	+11.12	+26.47	+0.29	− 8.76	0.00	−9.05	
	Ki −	+11.30	+96.73	+0.28	−10.65	0.00	−8.85	+0.5079

Table 2 (Continued)

Date, Number of wire	Direction of wire	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
17. VI	Ki +	+22.76	+97.33	−0.35	−10.71	0.00	−8.94	
	Kä+	+24.39	+27.75	−0.39	− 8.81	0.00	−8.50	
1044	Kä−	+25.14	+27.78	−0.40	− 8.76	0.00	−8.43	
	Ki −	+24.09	+97.52	−0.38	−10.65	0.00	−8.72	+0.4804
19. VI	Ki +	+25.62	+97.33	−0.41	−10.71	0.00	−9.00	
	Kä+	+26.66	+27.61	−0.42	− 8.81	0.00	−8.67	
1044	Kä−	+26.76	+28.17	−0.42	− 8.76	0.00	−8.06	
	Ki −	+27.22	+97.58	−0.42	−10.65	0.00	−8.70	+0.4782
23. VII	Ki +	+11.98	+97.01	+0.22	−10.70	0.00	−8.68	
	Kä+	+12.44	+27.18	+0.18	− 8.81	0.00	−8.50	
1044	Kä−	+12.52	+26.70	+0.18	− 8.76	0.00	−8.93	
	Ki −	+12.68	+97.35	+0.16	−10.64	0.00	−8.34	+0.4785
24. VII	Ki +	+15.89	+96.88	−0.06	−10.70	0.00	−9.09	
	Kä+	+16.41	+27.86	−0.09	− 8.81	0.00	−8.09	
1044	Kä−	+17.45	+27.84	−0.14	− 8.76	0.00	−8.11	
	Ki −	+18.44	+97.04	−0.19	−10.64	0.00	−9.00	+0.4762
8.VIII	Ki +	+17.79	+96.98	−0.16	−10.70	0.00	−9.09	
	Kä+	+18.21	+26.72	−0.18	− 8.81	0.00	−9.32	
1044	Kä−	+18.48	+27.85	−0.20	− 8.76	0.00	−8.16	
	Ki −	+19.62	+97.09	−0.25	−10.65	0.00	−9.02	+0.4943
							mean	+0.4859
							standard error of mean	±0.0051
28. V	Kä+	+16.72	+87.52	−0.10	−10.71	+0.01	−18.49	
	Ki +	+17.52	+16.53	−0.15	− 8.81	0.00	−19.48	
1045	Ki −	+17.95	+17.69	−0.17	− 8.76	0.00	−18.29	
	Kä−	+18.38	+87.24	−0.19	−10.65	+0.01	−18.80	+1.0425
18. VI	Kä+	+22.21	+86.57	−0.34	−10.71	+0.01	−19.68	
	Ki +	+23.44	+17.68	−0.37	− 8.81	0.00	−18.55	
1045	Ki −	+23.80	+17.71	−0.38	− 8.76	0.00	−18.48	
	Kä−	+25.77	+87.37	−0.41	−10.65	+0.01	−18.89	+1.0500
19. VI	Kä+	+28.40	+87.11	−0.42	−10.71	+0.01	−19.22	
	Ki +	+29.10	+16.88	−0.42	− 8.81	0.00	−19.40	
1045	Ki −	+30.01	+16.95	−0.42	− 8.76	0.00	−19.28	
	Kä−	+30.23	+87.33	−0.41	−10.65	+0.01	−18.93	+1.0671
10. VII	Kä+	+16.33	+86.77	−0.08	−10.66	+0.01	−19.17	
	Ki +	+15.73	+17.22	−0.05	− 8.81	0.00	−18.69	
1045	Ki −	+15.49	+17.19	−0.03	− 8.77	0.00	−18.66	
	Kä−	+18.59	+87.26	−0.20	−10.60	+0.01	−18.74	+1.0453
11. VII	Kä+	+17.59	+86.86	−0.15	−10.66	+0.01	−19.15	
	Ki +	+18.64	+16.83	−0.20	− 8.81	0.00	−19.23	
1045	Ki −	+16.84	+17.54	−0.11	− 8.77	0.00	−18.39	
	Kä−	+14.83	+86.99	+0.01	−10.60	+0.01	−18.80	+1.0496

Table 2 (Continued)

Date, Number of wire	Direction of wire	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
7.VIII	Kä+	+27.98	+87.16	−0.42	−10.70	+0.01	−19.16	
	Ki +	+28.26	+17.12	−0.42	− 8.81	0.00	−19.16	
1045	Ki −	+27.80	+17.24	−0.42	− 8.76	0.00	−18.99	
	Kä−	+28.98	+87.09	−0.42	−10.65	+0.01	−19.18	+1.0624
9.VIII	Kä+	+15.29	+87.51	−0.02	−10.70	+0.01	−18.41	
	Ki +	+15.91	+15.88	−0.06	− 8.81	0.00	−20.04	
1045	Ki −	+16.22	+17.06	−0.07	− 8.76	0.00	−18.82	
	Kä−	+17.16	+86.50	−0.13	−10.65	+0.01	−19.48	+1.0660
27.VIII	Kä+	+16.82	+87.18	−0.11	−10.70	+0.01	−18.83	
	Ki +	+16.84	+17.29	−0.11	− 8.81	0.00	−18.68	
1045	Ki −	+16.93	+16.82	−0.12	− 8.76	0.00	−19.11	
	Kä−	+17.43	+86.37	−0.14	−10.65	+0.01	−19.62	+1.0589
							mean	+1.0552
							standard error of mean	±0.0034
28. V	Kä−	+19.33	+118.84	+0.70	−10.71	+0.06	+13.68	
	Ki −	+19.26	+ 49.98	+0.69	− 8.81	+0.02	+14.83	
1115	Ki +	+19.00	+ 49.11	+0.65	− 8.76	+0.02	+13.97	
	Kä+	+19.68	+118.80	+0.76	−10.65	+0.06	+13.76	−0.7811
17. VI	Kä−	+19.84	+118.35	+0.79	−10.71	+0.06	+13.28	
	Ki −	+20.24	+ 49.57	+0.85	− 8.81	+0.02	+14.58	
1115	Ki +	+20.62	+ 48.32	+0.91	− 8.76	+0.02	+13.44	
	Kä+	+22.16	+118.95	+1.16	−10.65	+0.06	+14.31	−0.7724
18. VI	Kä−	+28.62	+117.74	+2.19	−10.71	+0.06	+14.07	
	Ki −	+27.52	+ 48.03	+2.02	− 8.81	+0.02	+14.21	
1115	Ki +	+27.44	+ 48.01	+2.01	− 8.76	+0.02	+14.23	
	Kä+	+27.89	+117.45	+2.08	−10.65	+0.06	+13.73	−0.7811
22. VII	Kä−	+12.10	+119.70	−0.48	−10.70	+0.06	+13.37	
	Ki −	+12.49	+ 50.48	−0.41	− 8.81	+0.02	+14.23	
1115	Ki +	+13.05	+ 49.52	−0.32	− 8.76	+0.02	+13.41	
	Kä+	+12.96	+119.46	−0.33	−10.64	+0.06	+13.34	−0.7549
25. VII	Kä−	+19.18	+119.85	+0.68	−10.70	+0.06	+14.68	
	Ki −	+18.80	+ 50.25	+0.62	− 8.81	+0.02	+15.03	
1115	Ki +	+18.43	+ 49.85	+0.56	− 8.76	+0.02	+14.62	
	Kä+	+20.09	+118.29	+0.83	−10.64	+0.06	+13.33	−0.8008
26. VII	Kä−	+20.94	+119.48	+0.97	−10.70	+0.06	+14.60	
	Ki −	+22.72	+ 49.80	+1.25	− 8.81	+0.02	+15.21	
1115	Ki +	+21.62	+ 49.36	+1.07	− 8.76	+0.02	+14.64	
	Kä+	+16.06	+119.05	+0.17	−10.64	+0.06	+13.43	−0.8039
7.VIII	Kä−	+25.36	+117.71	+1.68	−10.70	+0.06	+13.54	
	Ki −	+25.24	+ 48.56	+1.66	− 8.81	+0.02	+14.38	
1115	Ki +	+26.60	+ 47.20	+1.87	− 8.76	+0.02	+13.28	
	Kä+	+26.34	+117.58	+1.83	−10.65	+0.06	+13.61	−0.7612
							mean	−0.7755
							standard error of mean	±0.0069

Table 2 (Continued)

Date, Number of wire	Direction of wire	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
25. VI	Kä+	+19.02	+117.61	+0.65	−10.71	+0.04	+12.38	
	Ki +	+20.76	+47.20	+0.94	− 8.81	+0.02	+12.30	
1116	Ki −	+21.27	+ 47.26	+1.02	− 8.76	+0.02	+12.49	
	Kä−	+21.01	+117.75	+0.98	−10.65	+0.04	+12.91	−0.6956
8. VII	Kä+	+16.69	+117.54	+0.28	−10.71	+0.04	+11.94	
	Ki +	+16.09	+ 46.56	+0.18	− 8.81	+0.02	+10.90	
1116	Ki −	+16.56	+ 48.25	+0.25	− 8.77	+0.02	+12.70	
	Kä−	+16.78	+118.11	+0.29	−10.65	+0.04	+12.58	−0.6683
12. VII	Kä+	+12.51	+118.56	−0.41	−10.66	+0.04	+12.32	
	Ki +	+13.33	+ 48.57	−0.27	− 8.81	+0.02	+12.46	
1116	Ki −	+13.69	+ 48.78	−0.21	− 8.77	+0.02	+12.77	
	Kä−	+14.28	+117.94	−0.12	−10.60	+0.04	+12.05	−0.6889
22. VII	Kä+	+12.65	+118.08	−0.39	−10.70	+0.04	+11.82	
	Ki +	+13.21	+ 48.24	−0.29	− 8.81	+0.02	+12.11	
1116	Ki −	+13.64	+ 48.51	−0.22	− 8.76	+0.02	+12.50	
	Kä−	+12.94	+118.04	−0.34	−10.64	+0.04	+11.89	−0.6711
24. VII	Kä+	+18.02	+117.81	+0.49	−10.70	+0.04	+12.43	
	Ki +	+16.11	+ 47.61	+0.18	− 8.81	+0.02	+11.95	
1116	Ki −	+16.42	+ 48.58	+0.23	− 8.76	+0.02	+13.02	
	Kä−	+17.97	+117.15	+0.48	−10.64	+0.04	+11.82	−0.6836
26.VIII	Kä+	+22.21	+115.82	+1.17	−10.70	+0.04	+11.12	
	Ki +	+22.08	+ 46.36	+1.15	− 8.81	+0.02	+11.67	
1116	Ki −	+21.67	+ 45.76	+1.08	− 8.76	+0.02	+11.05	
	Kä−	+22.14	+115.68	+1.16	−10.65	+0.04	+11.02	−0.6231
							mean	−0.6718
							standard error of mean	±0.0106
29. V	Ki −	+16.67	+113.23	+0.27	−10.71	+0.04	+7.62	
	Kä−	+17.52	+ 42.67	+0.41	− 8.81	+0.02	+7.24	
1117	Kä+	+18.47	+ 43.58	+0.57	− 8.76	+0.02	+8.36	
	Ki +	+18.33	+112.71	+0.54	−10.65	+0.04	+7.43	−0.4257
17. VI	Ki −	+24.72	+111.78	+1.57	−10.71	+0.04	+7.47	
	Kä−	+24.93	+ 42.13	+1.61	− 8.81	+0.02	+7.90	
1117	Kä+	+26.09	+ 41.42	+1.79	− 8.76	+0.02	+7.42	
	Ki +	+26.71	+111.47	+1.89	−10.65	+0.04	+7.54	−0.4212
19. VI	Ki −	+31.77	+111.40	+2.69	−10.71	+0.04	+8.21	
	Kä−	+31.11	+ 40.98	+2.59	− 8.81	+0.02	+7.73	
1117	Kä+	+30.68	+ 41.42	+2.52	− 8.76	+0.02	+8.15	
	Ki +	+30.78	+110.72	+2.54	−10.65	+0.04	+7.44	−0.4379
9. VII	Ki −	+14.97	+113.24	0.00	−10.66	+0.04	+7.41	
	Kä−	+15.17	+ 43.54	+0.03	− 8.81	+0.02	+7.73	
1117	Kä+	+15.53	+ 43.98	+0.09	− 8.77	+0.02	+8.27	
	Ki +	+15.36	+113.06	+0.06	−10.60	+0.04	+7.35	−0.4272
10. VII	Ki −	+17.99	+112.87	+0.49	−10.66	+0.04	+7.53	
	Kä−	+17.86	+ 43.58	+0.47	− 8.81	+0.02	+8.21	
1117	Kä+	+17.79	+ 43.41	+0.45	− 8.77	+0.02	+8.06	
	Ki +	+17.46	+113.22	+0.40	−10.60	+0.04	+7.85	−0.4396

Table 2 (Continued)

Date, Number of wire	Direction of wire	t (°C)	ΣB mm	k_t mm	k_h mm	k_s mm	Σ mm	λ mm
8.VIII	Ki −	+21.37	+112.95	+1.03	−10.70	+0.04	+8.11	
	Kä−	+20.30	+ 42.79	+0.86	− 8.81	+0.02	+7.81	
1117	Kä+	+20.48	+ 42.71	+0.89	− 8.76	+0.02	+7.81	
	Ki +	+20.68	+112.39	+0.92	−10.65	+0.04	+7.49	−0.4336
9.VIII	Ki −	+20.11	+113.19	+0.83	−10.70	+0.04	+8.15	
	Kä−	+20.17	+ 42.31	+0.84	− 8.81	+0.02	+7.31	
1117	Kä+	+20.40	+ 43.51	+0.88	− 8.76	+0.02	+8.60	
	Ki +	+20.26	+112.39	+0.86	−10.65	+0.04	+7.43	−0.4374
26.VIII	Ki −	+22.04	+112.28	+1.14	−10.70	+0.04	+7.55	
	Kä−	+22.11	+ 42.58	+1.15	− 8.81	+0.02	+7.89	
1117	Kä+	+22.54	+ 42.58	+1.22	− 8.76	+0.02	+8.01	
	Ki +	+23.52	+112.53	+1.38	−10.65	+0.04	+8.09	−0.4381
							mean	−0.4326
							standard error of mean	±0.0025
29. V	Ki +	+20.89	+121.25	+0.96	−10.71	+0.05	+16.34	
	Kä+	+18.80	+ 51.74	+0.62	− 8.81	+0.02	+16.52	
1118	Kä−	+19.49	+ 51.87	+0.73	− 8.76	+0.02	+16.81	
	Ki −	+20.92	+122.11	+0.96	−10.65	+0.05	+17.26	−0.9296
18. VI	Ki +	+22.12	+121.46	+1.16	−10.71	+0.05	+16.75	
	Kä+	+20.16	+ 51.84	+0.84	− 8.81	+0.02	+16.84	
1118	Kä−	+20.16	+ 52.17	+0.84	− 8.76	+0.02	+17.22	
	Ki −	+20.52	+121.97	+0.90	−10.65	+0.05	+17.06	−0.9426
24. VI	Ki +	+22.45	+120.85	+1.21	−10.71	+0.05	+16.19	
	Kä+	+23.38	+ 51.01	+1.36	− 8.81	+0.02	+16.53	
1118	Kä−	+23.52	+ 51.04	+1.38	− 8.76	+0.02	+16.63	
	Ki −	+24.86	+120.82	+1.60	−10.65	+0.05	+16.61	−0.9161
9. VII	Ki +	+16.34	+122.42	+0.22	−10.66	+0.05	+16.82	
	Kä+	+16.58	+ 52.30	+0.26	− 8.81	+0.02	+16.72	
1118	Kä−	+15.82	+ 52.73	+0.13	− 8.77	+0.02	+17.06	
	Ki −	+15.28	+123.24	+0.05	−10.60	+0.05	+17.53	−0.9462
12. VII	Ki +	+13.16	+122.53	−0.30	−10.66	+0.05	+16.41	
	Kä+	+12.21	+ 53.60	−0.46	− 8.81	+0.02	+17.30	
1118	Kä−	+13.64	+ 53.23	−0.22	− 8.77	+0.02	+17.21	
	Ki −	+12.96	+123.42	−0.33	−10.60	+0.05	+17.33	−0.9479
8.VIII	Ki +	+20.98	+121.77	+0.97	−10.70	+0.05	+16.88	
	Kä+	+19.87	+ 52.26	+0.79	− 8.81	+0.02	+17.21	
1118	Kä−	+20.72	+ 51.66	+0.93	− 8.76	+0.02	+16.80	
	Ki −	+20.27	+122.53	+0.86	−10.65	+0.05	+17.58	−0.9510
9.VIII	Ki +	+17.86	+121.79	+0.47	−10.70	+0.05	+16.40	
	Kä+	+18.41	+ 52.62	+0.56	− 8.81	+0.02	+17.34	
1118	Kä−	+19.13	+ 51.64	+0.67	− 8.76	+0.02	+16.52	
	Ki −	+19.25	+122.74	+0.69	−10.65	+0.05	+17.62	−0.9428
26.VIII	Ki +	+21.38	+121.17	+1.04	−10.70	+0.05	+16.35	
	Kä+	+21.51	+ 51.25	+1.06	− 8.81	+0.02	+16.47	
1118	Kä−	+22.21	+ 51.48	+1.17	− 8.76	+0.02	+16.86	
	Ki −	+22.13	+121.44	+1.16	−10.65	+0.05	+16.79	−0.9232
							mean	−0.9374
							standard error of mean	±0.0045

Table 3. Measurements at Niinisalo

1/V. 188 stake distances.

Wire[1])	Date	t (C°)	ΣB mm	k_t mm	k_h mm	k_s mm	k_g mm	k_λ mm	k_p mm	Σ mm
637 P	VI 4^d 9-13^h	+23.36	−655.02	−0.84	−670.45	−0.07	+0.10	+108.31	—	−1217.97
1044 N	5 10-14	+22.56	−635.70	−3.62	−670.44	−0.00	+0.10	+ 91.35	—	−1218.31
1118 P	6 8-12	+20.58	−377.64	+9.46	−671.33	−0.16	+0.10	−176.23	—	−1215.80
1115 N	7 9-12	+17.17	−408.35	+3.70	−671.07	−0.19	+0.10	−145.79	—	−1221.60
1045 P	7 14-18	+12.90	−746.75	+1.56	−670.80	−0.06	+0.10	+198.38	—	−1217.57
635 N	8 8-11	+17.72	−797.77	−0.05	−671.33	−0.30	+0.10	+247.60	—	−1221.75
1117 P	10 8-11	+14.62	−463.71	−0.65	−671.63	−0.18	+0.10	− 81.33	—	−1217.40
1042 N	13 8-12	+22.76	−738.72	−3.65	−672.84	−0.13	+0.10	+197.57	—	−1217.67
									mean	−1218.51
									standard error of mean ±	0.74

2/V. 178 stake distances.

637 N	VI 29 10-13	+12.42	−111.87	− 0.13	−324.41	−0.01	+0.09	+101.97	—	− 334.36
634 P	VII 1 8-11	+18.50	− 97.92	− 0.13	−324.20	−0.03	+0.09	+ 85.99	—	− 336.20
1045 N	1 12-15	+22.45	−192.19	− 3.40	−324.39	−0.02	+0.09	+186.77	—	− 333.14
1043 P	2 8-11	+23.05	−114.65	− 3.50	−324.37	−0.01	+0.09	+107.05	−0.27[3])	− 335.66
1118 N	2 17-20	+27.98	+137.85	+20.57	−324.64	+0.06	+0.09	−165.92	−0.27	− 332.26
636 P	3 8-11	+25.92	−201.37	− 1.36	−324.36	−0.03	+0.09	+193.46	−0.27	− 333.84
1117 N	3 16-19	+27.18	+ 48.91	+19.31	−324.63	+0.02	+0.09	− 76.57	−0.27	− 333.14
1116 P	4 8-11	+24.16	+ 96.94	+14.58	−324.43	+0.03	+0.09	−118.91	−0.27	− 331.97
									mean	− 333.82
									stake distance No. 1[2])	+ 6.89
										− 326.93
									standard error of mean ±	0.54

3/V. 159 stake distances.

1043 N	VII 15 14-16	+20.54	+ 920.37	−2.50	−61.36	+0.02	+0.08	+ 96.16	—	+ 952.77
1044 P	16 8-10	+14.67	+ 939.67	+0.24	−61.57	0.00	+0.08	+ 77.26	—	+ 955.68
1116 N	16 14-16	+18.32	+1119.11	+4.77	−61.40	+0.38	+0.08	−106.82	—	+ 956.12
1115 P	17 8-10	+15.22	+1137.38	+0.33	−61.59	+0.53	+0.08	−123.30	—	+ 953.43
636 N	17 14-17	+15.66	+ 840.99	0.00	−61.35	+0.15	+0.08	+173.79	—	+ 953.66
1042 P	18 8-11	+18.93	+ 851.06	−1.83	−61.56	+0.15	+0.08	+167.09	—	+ 954.99
634 N	18 14-17	+18.90	+ 936.25	−0.12	−61.36	+0.22	+0.08	+ 77.24	—	+ 952.31
635 P	19 8-11	+20.94	+ 806.62	−0.33	−61.56	+0.30	+0.08	+209.40	—	+ 954.51
									mean	+ 954.18
									standard error of mean ±	0.48

4/V. 192 stake distances.

Table 3 (Continued)

Wire[1])	Date	t (C°)	ΣB mm	k_t mm	k_h mm	k_s mm	k_g mm	k_λ mm	k_p mm	Σ mm
1042 N	VII 30^{d}13-18^h	+22.64	+208.70	− 3.72	−1519.23	+0.04	+0.10	+201.77	—	−1112.34
1045 P	31 8-12	+16.32	+205.02	− 0.81	−1519.23	+0.01	+0.10	+202.60	—	−1112.31
1115 N	VIII 1 8-12	+20.54	+545.35	+ 9.62	−1519.32	+0.26	+0.10	−148.90	—	−1110.90
637 P	2 9-13	+17.82	+297.81	− 0.07	−1519.38	+0.03	+0.10	+110.61	—	−1110.90
1044 N	3 8-12	+18.40	+315.61	− 1.96	−1519.40	0.00	+0.10	+ 93.29	—	−1112.36
1118 P	4 16-19	+17.58	+581.32	+ 4.48	−1519.46	+0.23	+0.10	−179.98	—	−1113.31
635 N	5 9-13	+20.57	+152.09	− 0.34	−1519.37	+0.05	+0.10	+252.86	—	−1114.61
1117 P	6 8-12	+20.98	+478.43	+10.37	−1519.42	+0.20	+0.10	− 83.06	—	−1113.38
									mean	−1112.76
									standard error of mean ±	0.38
				5/V. 209 stake distances.						
1116 P	VIII15 12-17	+19.51	−619.37	+ 8.49	−1659.62	−0.22	+0.10	−139.73	—	−2410.35
1118 N	16 8-11	+16.00	−557.89	+ 1.89	−1658.92	−0.22	+0.10	−194.98	—	−2410.02
636 P	16 13-16	+18.88	−980.46	− 0.15	−1659.54	−0.19	+0.10	+227.34	—	−2412.90
1045 N	19 8-12	+15.74	−969.45	− 0.54	−1658.84	−0.08	+0.10	+219.48	—	−2409.33
1043 P	19 13-18	+16.01	−877.45	− 0.67	−1659.56	−0.03	+0.10	+125.80	—	−2411.81
637 N	20 8-11	+14.16	−873.14	− 0.07	−1658.85	−0.11	+0.10	+119.83	—	−2412.24
634 P	20 13-16	+16.68	−854.86	− 0.02	−1659.57	−0.21	+0.10	+101.05	—	−2413.51
1117 N	21 8-11	+15.81	−661.62	+ 1.52	−1658.91	−0.26	+0.10	− 89.98	—	−2409.15
									mean	−2411.16
									stake distance No. 209[2])	− 17.03
										−2428.19
									standard error of mean ±	0.59

The measured lengths (L):

1/V	4 510 781.49	mm
2/V	4 271 673.07	»
3/V	3 816 954.18	»
4/V	4 606 887.24	»
5/V	5 013 571.81	»
Σ	22 219 867.79	»

[1]) P = measuring was started from the end nearer Pihnari
N = » » » » » » » Niinisalo

[2]) As the measuring group had only three pieces of equipment of plumbing bars at its disposal, it was not possible to measure stake distances No. 1 on 2/V and No. 209 on 5/V in connection with the regular invar wire measurement. These stake distances were measured with three invar wires after the regular invar wire measurement. Using the discrepancies in the observations the standard error of both stake distances is ±0.03 mm.

[3]) In the night between the measurement of invar wires Nos. 1045 and 1043 a vehicle ran into stake No. 115 and moved it. The transition of the stake from the invar wire line was measured and the correction in the measured length, k_p, was computed.

Table 4. The levelled differences in elevation h and the sum terms for computing k_h at Niinisalo

Stake interval No.	1/V h[1]) mm[2])	2/V h mm[2])	3/V h mm[2])	4/V h mm[2])	5/V h mm[2])
1	− 701.0	+ 265.0	+ 198.5	+ 343.0	− 163.3
2	− 394.0	+ 246.5	+ 197.0	+ 73.2	− 359.7
3	− 396.3	− 242.7	+ 249.5	− 138.8	− 490.7
4	− 32.5	− 772.0	+ 73.8	− 364.0	− 762.3
5	− 55.3	−1111.83	+ 44.5	− 143.7	− 754.8
6	+ 82.3	− 674.0	+ 119.0	− 13.2	− 815.75
7	+ 114.3	+ 327.0	+ 40.8	− 192.8	− 882.18
8	+ 132.5	+ 285.3	− 108.8	− 217.8	− 732.7
9	+ 440.5	− 57.3	− 8.8	− 78.5	− 534.6
10	− 357.5	− 882.59	+ 61.5	− 203.7	−1456.74
11	− 335.3	− 899.03	− 31.5	− 156.0	−1149.98
12	+ 135.0	− 342.0	− 100.0	+ 100.2	− 572.8
13	+ 107.7	− 247.0	− 1.5	+ 60.0	− 978.90
14	− 366.0	−1052.01	− 92.8	− 434.5	−1302.51
15	− 280.0	− 701.7	+ 188.3	− 285.0	−1489.50
16	+ 393.8	− 169.7	+ 384.7	− 248.7	−1468.59
17	− 247.7	− 118.3	− 615.7	− 241.5	−1411.02
18	− 586.0	− 56.0	− 184.7	− 278.3	−1463.75
19	− 761.25	+ 55.3	− 82.5	− 214.8	−1490.16
20	− 545.5	+ 88.5	− 113.5	− 276.3	− 729.3
21	− 798.95	+ 162.7	− 106.5	− 183.8	− 465.7
22	− 633.7	+ 230.2	+ 115.3	− 282.0	− 768.3
23	− 735.23	+ 181.3	− 1.8	− 279.5	− 534.0
24	− 237.8	+ 133.5	+ 109.2	− 182.8	+ 587.3
25	+ 95.7	+ 100.3	+ 20.8	− 293.3	+ 735.7
26	− 106.0	− 94.0	+ 404.3	− 15.7	+ 663.7
27	− 304.3	− 18.7	+ 130.8	+ 81.2	+1088.76
28	+ 156.2	− 44.3	+ 195.2	− 380.5	+1441.61
29	− 117.0	+ 39.7	+ 322.0	− 151.7	+1452.34
30	+ 20.8	− 24.8	+ 322.8	− 20.0	+1383.40
31	− 57.3	− 88.3	+ 155.0	+ 73.0	+1431.19
32	− 3.0	− 90.2	+ 166.8	+ 176.7	+1132.42
33	+ 123.7	− 68.0	+ 329.5	− 116.7	− 674.3
34	+ 166.3	− 32.0	+ 404.2	+ 68.3	− 759.3
35	+ 49.0	− 72.0	− 71.8	+ 74.3	− 757.7
36	− 38.7	− 7.8	− 31.8	+ 34.8	− 480.5
37	− 170.0	− 84.3	+ 230.3	+ 105.7	− 174.7
38	− 178.7	− 162.0	+ 176.0	+ 347.5	− 241.0
39	+ 42.3	− 18.0	+ 152.3	+ 499.7	− 25.7
40	+ 26.2	− 9.2	+ 125.3	+ 422.3	− 307.0
41	+ 22.0	− 26.7	+ 68.8	+1007.66	+ 145.3
42	− 44.5	+ 350.5	+ 30.5	− 348.8	+1440.41
43	− 52.3	− 218.7	+ 167.4	−1401.98	+1478.35
44	+ 113.5	− 69.2	+ 119.3	− 150.2	+ 758.7
45	+ 52.7	− 499.0	+ 39.3	+ 76.7	+ 216.8

[1]) The differences in elevation belong to the levelling on June 10, 1968.

[2]) The height differences levelled with the precise levelling equipment are given to two decimal places.

Table 4. (Continued)

Stake interval No.	1/V h mm	2/V h mm	3/V h mm	4/V h mm	5/V h mm
46	− 41.3	+ 62.2	+ 71.5	+ 53.7	+ 429.7
47	+ 32.0	+ 91.3	− 10.5	− 628.3	+ 224.0
48	+ 135.7	− 89.0	+ 96.3	− 526.2	+ 177.0
49	+ 72.3	− 28.7	+ 87.7	− 787.5	− 354.7
50	− 102.0	+ 268.3	− 21.2	− 531.5	−1164.68
51	+ 117.3	− 188.0	+ 100.8	+1294.33	− 917.34
52	+ 302.7	− 126.2	+ 59.3	+1046.19	+1048.73
53	− 173.3	− 56.2	+ 47.0	+1491.43	+1388.49
54	+ 172.8	+ 57.3	+ 82.8	+1222.30	+ 923.52
55	+ 291.7	− 114.0	+ 18.8	+ 279.7	+ 720.0
56	+ 17.0	− 67.5	+ 15.5	+ 619.3	+ 635.9
57	− 133.0	− 214.0	+ 83.0	+1405.68	+ 308.0
58	− 92.7	+ 28.3	− 78.5	+1413.85	+ 719.7
59	− 285.3	+ 118.3	+ 44.0	+1412.25	+ 642.7
60	+ 85.0	− 90.7	+ 61.3	+1404.54	+ 624.0
61	+ 237.0	− 64.7	+ 96.2	+1400.90	+ 576.3
62	+ 50.7	+ 53.7	− 26.8	+1167.82	+ 580.3
63	− 64.5	+ 11.7	+ 70.2	+ 662.7	+ 569.0
64	+ 310.0	− 16.3	+ 57.5	− 555.3	+ 258.3
65	+ 230.7	− 153.0	+ 13.7	−1230.58	+ 701.0
66	+ 86.5	+ 161.7	+ 123.3	−1391.01	+ 70.0
67	− 445.0	− 130.3	− 73.5	− 929.04	+ 159.0
68	− 184.9	+ 154.3	+ 16.2	− 387.8	+ 252.8
69	− 452.0	− 54.7	− 13.0	+ 71.2	+ 234.0
70	− 315.0	+ 102.0	− 174.3	− 595.2	+ 202.7
71	+ 34.0	+ 24.3	− 107.0	− 178.5	+ 153.0
72	+ 173.0	+ 69.0	− 200.3	− 177.7	+ 638.7
73	− 21.1	+ 120.7	+ 118.5	− 189.2	− 215.0
74	− 334.0	+ 52.0	− 76.5	+ 70.8	+ 176.5
75	− 199.0	− 15.7	+ 72.0	− 935.48	+ 331.0
76	− 43.9	+ 39.7	+ 8.8	− 104.2	+ 73.3
77	+ 24.0	+ 211.0	− 44.3	− 155.8	+ 257.3
78	− 100.0	+ 250.0	+ 36.2	− 964.33	+ 52.0
79	+ 112.0	− 237.0	+ 175.7	− 695.5	+ 371.0
80	− 114.0	+ 56.8	+ 15.0	− 441.5	+ 244.7
81	− 147.0	+ 54.0	+ 252.2	+ 34.7	+ 223.3
82	− 199.0	+ 25.3	+ 103.3	+ 20.3	+ 222.3
83	− 34.0	+ 24.3	+ 177.5	+ 142.7	+ 47.0
84	+ 1.0	+ 61.2	+ 108.2	+ 798.8	+ 181.7
85	+ 14.0	+ 73.0	+ 250.2	+1326.41	+ 155.3
86	− 382.0	+ 25.0	+ 9.8	+1294.06	+ 393.7
87	− 569.5	− 86.0	− 128.8	− 669.5	+ 127.2
88	− 453.0	+ 34.3	− 20.7	+ 145.5	+ 178.3
89	− 623.0	− 82.5	− 162.8	+ 343.0	+ 287.7
90	− 408.5	− 6.0	+ 87.2	− 987.13	+ 470.0
91	− 146.0	− 91.3	− 39.5	− 680.2	+ 502.3
92	− 482.0	− 94.3	− 39.2	− 590.8	− 363.7
93	− 568.0	− 52.7	− 17.0	− 169.7	+ 61.7
94	− 521.5	− 45.0	− 25.2	− 83.2	+ 355.3

Table 4. (Continued)

Stake interval No.	1/V h mm	2/V h mm	3/V h mm	4/V h mm	5/V h mm
95	− 332.0	− 155.3	− 105.7	+ 191.0	+ 611.0
96	− 455.0	− 117.3	+ 5.3	+ 182.3	− 541.8
97	− 524.8	− 108.5	− 34.8	+ 407.7	+ 118.8
98	− 222.0	− 115.3	+ 13.5	+1026.79	+ 115.7
99	− 159.0	− 164.3	− 18.3	+ 669.81	+ 125.3
100	− 72.0	− 164.7	− 55.8	+ 550.3	+ 165.3
101	− 263.0	− 114.7	+ 20.0	+ 69.3	− 56.7
102	− 130.0	− 175.7	− 5.3	− 59.3	+ 177.3
103	− 68.0	− 180.7	− 68.8	+ 241.7	+ 151.8
104	+ 38.0	− 197.7	+ 19.0	+ 824.38	+ 111.0
105	+ 1.0	− 244.7	+ 0.8	+1517.50	+ 58.0
106	− 305.0	− 233.7	+ 35.0	+1183.02	+ 144.3
107	+ 104.0	− 207.3	+ 4.3	+ 814.03	+ 140.7
108	− 25.0	− 215.2	+ 49.0	− 455.8	+ 50.3
109	− 61.0	− 284.5	+ 60.0	− 600.2	+ 47.3
110	− 69.5	− 194.7	+ 25.7	− 718.7	+ 19.8
111	− 188.0	− 240.0	+ 3.2	− 873.38	− 7.3
112	+ 188.2	− 261.8	− 6.7	− 761.8	+ 94.0
113	− 114.0	− 244.8	+ 77.3	+ 1.3	+ 125.7
114	− 207.0	− 316.7	+ 69.3	+ 427.0	− 14.7
115	+ 76.0	− 159.5	+ 63.7	+ 87.8	+ 111.7
116	− 18.0	− 200.0	+ 16.5	+1148.14	− 19.0
117	− 13.0	−1178.83	+ 69.2	+ 773.8	+ 87.0
118	− 42.0	− 671.7	+ 61.0	+ 767.0	+ 212.3
119	− 53.0	− 295.7	− 47.0	+ 467.8	+ 23.3
120	+ 103.0	+ 291.8	+ 76.3	− 382.3	+ 77.3
121	− 56.0	+ 392.3	+ 44.7	− 750.7	+ 3.3
122	− 18.5	− 66.0	+ 42.7	− 575.8	+ 161.7
123	− 9.0	− 227.0	+ 48.5	+ 644.3	− 26.7
124	0.0	− 553.5	+ 117.3	+ 756.27	+ 227.3
125	− 11.0	−1025.16	+ 88.7	−1378.18	+ 190.7
126	− 14.0	+ 176.3	+ 28.7	−1626.55	+ 153.3
127	− 66.0	+ 805.88	+ 10.3	−1403.69	+ 223.3
128	− 73.0	+ 284.5	+ 157.7	−1439.74	+ 262.0
129	− 99.0	+ 82.7	+ 129.8	−1388.25	+ 191.7
130	+ 17.0	+ 107.0	+ 113.2	−1441.32	+ 455.0
131	+ 108.0	+ 395.7	+ 68.5	− 548.7	+ 340.7
132	+ 21.0	+ 876.49	+ 50.2	− 116.0	+ 161.3
133	− 31.0	+ 546.7	+ 224.5	− 202.3	+ 453.0
134	+ 51.0	− 443.0	+ 148.3	− 73.0	+ 378.0
135	− 45.0	− 556.7	+ 186.7	− 134.3	+ 455.3
136	− 404.0	+ 94.3	+ 156.8	+ 454.3	+ 494.0
137	− 327.0	+ 92.3	+ 90.7	− 598.3	+ 499.0
138	+ 1.0	− 133.5	+ 253.2	+ 300.5	+ 333.3
139	− 268.0	+ 526.7	+ 5.5	− 731.0	+ 451.7
140	− 225.0	+ 356.5	+ 250.5	− 703.0	+ 388.0
141	+ 6.0	− 236.3	+ 237.5	+ 16.7	+ 322.7
142	− 94.0	+ 301.8	− 12.7	− 22.5	+ 201.0
143	− 61.0	+ 153.3	+ 192.5	− 23.3	+ 218.7

Table 4. (Continued)

Stake interval No.	1/V h mm	2/V h mm	3/V h mm	4/V h mm	5/V h mm
144	+ 23.5	+ 5.0	+ 42.8	− 460.6	+ 108.3
145	+ 27.0	+ 50.3	+ 61.0	− 613.6	+ 111.0
146	+ 328.0	− 44.7	+ 206.0	− 183.0	− 147.0
147	+ 471.0	− 4.0	+ 102.8	− 8.5	− 302.7
148	− 711.0	− 43.3	+ 55.7	− 84.5	− 334.0
149	− 659.0	− 60.0	− 55.7	− 46.3	− 372.5
150	− 495.5	− 63.8	+ 56.0	− 1.4	− 516.3
151	− 374.0	− 51.7	+ 51.3	+ 65.0	− 557.7
152	− 195.5	− 55.2	− 65.8	+ 166.8	− 317.7
153	− 126.0	− 23.3	+ 171.3	− 209.3	− 172.3
154	− 58.0	− 41.5	− 57.2	− 342.5	− 87.8
155	− 107.0	− 111.0	+ 80.0	+ 94.3	+ 172.4
156	− 49.0	− 15.3	− 132.2	+ 171.5	+ 342.7
157	− 108.5	+ 10.3	− 150.3	+ 293.3	+ 282.4
158	+ 89.5	− 16.8	+ 95.3	+ 254.8	+ 529.8
159	+ 118.0	+ 46.0	− 55.3	+ 382.0	+ 755.72
160	− 64.0	+ 30.2	—	+ 692.0	+ 835.76
161	− 726.0	+ 35.0	—	+ 743.0	+1001.69
162	− 762.0	+ 2.0	—	+ 260.2	+1070.67
163	− 819.51	+ 115.7	—	+ 415.5	+1207.11
164	− 871.75	+ 137.2	—	+ 441.7	+1102.50
165	− 854.85	+ 55.3	—	+ 523.5	+1119.94
166	− 40.17	+ 138.8	—	+ 250.8	+1078.29
167	+ 996.08	+ 164.0	—	+ 176.7	+1039.96
168	+1113.74	+ 135.8	—	+ 137.0	+ 912.19
169	+ 468.0	+ 192.0	—	− 37.8	+ 894.78
170	+ 314.0	+ 218.0	—	+ 17.3	+ 665.7
171	+ 767.0	+ 164.3	—	− 192.5	+ 432.7
172	+1436.38	+ 301.5	—	− 140.3	+ 404.3
173	+1456.11	+ 212.3	—	− 309.7	+ 498.3
174	+1477.12	+ 153.5	—	− 154.7	+ 146.8
175	+1469.81	+ 409.2	—	− 229.7	+ 203.7
176	+ 167.0	+ 241.7	—	− 291.3	0.0
177	− 611.0	+ 274.3	—	− 373.7	+ 13.3
178	− 72.0	+ 21.7	—	− 149.5	− 164.3
179	+ 102.0	—	—	− 128.8	− 102.5
180	− 111.0	—	—	− 130.3	+ 173.3
181	+ 61.0	—	—	− 26.3	− 416.5
182	+ 379.0[1])	—	—	− 65.7	− 308.2
183	+ 346.0[1])	—	—	+ 186.7	− 334.5
184	+ 253.2	—	—	+ 363.2	− 125.4
185	+ 868.05	—	—	− 99.8	+ 221.1
186	+1380.22	—	—	− 14.7	+ 112.3
187	+1403.24	—	—	+ 263.7	+ 183.6
188	+ 520.0	—	—	+ 277.8	+ 75.0

[1]) Stake No. 182 was loose and was erected for the measurement of every wire. The height differences of the stake intervals Nos. 182—183 belong to the measurement of June 10, 1968.

Table 4 (Continued)

Stake interval No.	1/V h mm	2/V h mm	3/V h mm	4/V h mm	5/V h mm
189	—	—	—	+ 131.2	+ 158.0
190	—	—	—	+ 170.2	+ 73.1
191	—	—	—	+ 3.3	— 605.8
192	—	—	—	— 87.3	— 718.0
193	—	—	—	—	— 295.9
194	—	—	—	—	— 123.0
195	—	—	—	—	+ 102.9
196	—	—	—	—	+ 164.2
197	—	—	—	—	+ 197.9
198	—	—	—	—	+ 833.14
199	—	—	—	—	+ 752.2
200	—	—	—	—	+1288.58
201	—	—	—	—	+1217.24
202	—	—	—	—	+ 577.2
203	—	—	—	—	+ 376.6
204	—	—	—	—	+ 535.3
205	—	—	—	—	+ 571.2
206	—	—	—	—	+ 332.6
207	—	—	—	—	— 701.6
208	—	—	—	—	— 733.8
209	—	—	—	—	+ 645.98
Σh	— 7.586	— 7.978	+ 8.458	— 0.599	+28.442
Σh^2	32.2325	15.6380	2.9405	72.8721	80.0297
Σh^4	35.1	9.8	0.3	98.7	97.7
Σh^6	—	—	—	—	—
Σh^2B	(-109)—(-177)	52—21	12—6	(-340)—(-495)	(-139)—(-299)
Σh^2B^2	—	—	—	20 000	20 000

APPENDIX

Sketch of the Niinisalo calibration base line.