COMPARISON OF THE STANDARD PYRHELIOMETER Å 158 WITH THE SUB-STANDARD INSTRUMENTS Å 70 AND Å 171

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Introduction

It is well known that the opening angle of a pyrheliometer has some effect upon the measurement of the direct solar radiation. The reason is that the instrument receives, in addition to the radiation from the sun's disc itself, a part of the circumsolar sky radiation. This part is the greater the larger the opening angle of the instrument. The circumsolar sky radiation is greatest very close to the sun's disc, it is increased by aerosols, i.e. by the turbidity of the air. When Courvoisier in 1957 discussed the difference between the Ångström Pyrheliometric Scale and the Smithsonian Scale, he pointed out a difference of 1.77% between comparisons made close to the sea level at Stockholm and at Davos, altitude 1590 m. This difference is obviously due to the fact that the atmospheric turbidity in average is greater at Stockholm than at Davos. Courvoisier expected that there should be, in consequence, a correlation between the turbidity variations on one hand and the variations of comparison readings at Davos on the other hand. But he did not succeed in finding such a relationship.

Nor at Stockholm, there is a striking effect of the variations of turbidity to be found in the series of pyrheliometer comparisons. Nevertheless, such an influence might be expected since the aperture of the reference instrument Å 158 is larger than that of modern instruments. But, random errors of other kinds are generally greater than the variation of the circumsolar sky radiation, this variation being comparatively small since the comparisons are mostly made under cloudless sky when the atmospheric conditions are rather identical.

Lindholm (1963) pointed out the effect of the aperture in differences between series of comparisons made at Davos, Stockholm and Visby between the Swedish reference standard Å 158 and the Smithsonian instrument S 14. He found that the Ångström reference instrument gave 1.2% higher readings at Stockholm than at Davos because of its larger opening angle.

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The question of the affect of the opening angle came into new considerations after the international comparison meetings at Davos in 1964. Firstly from August 24 to September 5, there was a comparison of working standards from the whole world. This meeting was followed by a regional one with participants from European countries. During the first-mentioned meeting, the standard pyrheliometer Å 158 was the instrument referred to. At the same time, the working standard of the Davos observatory was checked, and it served as reference instrument during the European meeting. However, some deviations difficult to explain happened during the latter meeting and the discussions about them became rather animated. Ångström & Rodhe presented 1966 a review on the affect of the circumsolar sky radiation and tried to give a quantitative estimate on a theoretical as well as empirical basis. The discussions about the comparisons at Davos were closed at a symposium in Brussels in May 1966 and were published in a Technical Note No 85 (WMO). In one of the lectures at the symposium, Schöne (1967) presented data from measurements at Potsdam indicating that the affect of the solar sky radiation might have been overestimated by Ångström & Rodhe.

It was mentioned above that the affect of the circumsolar sky radiation was difficult to prove in series of measurements fixed to one location, especially if the variations of atmospheric turbidity there are small. Better results should therefore be achieved if the investigations were performed at two sites under very different atmospheric conditions. At the Swedish Astrophysical Observatory at Capri it should be possible to make the comparisons under high turbidity conditions. After some inquiries to the International Foundation in Bern of the Jungfraujoch Scientific Station, the other place where the turbidity is extremely low, was proposed: The Swiss mountain hotel Gornergrat-Kulm at 3.130 metres above sea level. On this top in the neighbourhood of Zermat and Matterhorn, the foundation had recently equipped a branch station for astronomical investigations.

The Capri station (250 metres above sea level)

Our stay at Capri lasted July 2-14, 1968.
The measurements were made under excellent weather conditions during July 3-13. On the days of the 4th, 7th and 12th the sky was cloudy. Else, the sky was completely clear and the weather almost calm.

The bags with the electrical instruments were placed on two tables under a parasol on the platform in front of one of the instrument houses of the observatory. The pyrheliometers, which were put on the tables beside the shadow of the parasol, were very little disturbed by the wind, partly because it was mostly very calm, partly because of the very good shelter given by the abundant vegetation in the surroundings.

The measurements were generally made from 08.30 a.m. to 02.30 p.m. true solar time. Earlier in the morning and later in the afternoon, the sun radiation varied considerably even during short-time series because of the layers of haze over the sea.

The Gornergrat station (3.130 metres above sea level)

Our stay at Gornergrat lasted July 15-25, 1968.
There are at the hotel Gornergrat-Kulm on the top of the mountain two domes for astronomic observations. One of the domes was established and equipped with instruments by French and Swiss scientists, in the other British scientists from the Astrophysical Institution at the University of Oxford were establishing their instruments. We got their kind permission to make our measurements in the opening of the door of their dome. During our stay the weather was not as good as we wanted it to be. Except the day of departure, when we made some measurements at a provisory site close the hotel where we lived (Hotel Riffelhaus, 2.650 metres above sea level), we had clear sky for measurements only on three days, and then mostly before noon. In the afternoon Fracto Cumulus appeared almost every sunny day.

The pyrheliometer instruments

The following pyrheliometers were compared with each other:

No.	Year of management	Opening angle (Half aperture)	Effective tube length	Instrument constant
Å 70	1905	$2.5 \times 11^{\circ}$	59.2	17.74 IPS
Å 158	1912	$3.0 \times 12^{\circ}$	52.4	13.96
Å 171	1956	$1.9 \times 8^{\circ}$	72.2	8.19
Å 207-1	1958	$0.8 \times 3.5^{\circ}$	171.3	15.27
Å 585	1967	$2.0 \times 8^{\circ}$	70.6	8.47

Geometrical drawings of the instruments are given in the appendix.

The first two of the above-mentioned instruments were made by Rose at Uppsala. The pyrheliometer Å 70 represented at the Institute of Physics at the University of Uppsala from 1905 to 1934 the Ångström International Pyrheliometer Scale. It was repaired by renewed blackening in 1930, in 1951 after a damage which happened 1934, and in 1968. The original instrument constant of 1905 (17.48 ÅE) has been retained but a decrease has been noticed during the last years. Thus, according to comparisons with Å 158 it should in 1951 have been 17.18 ÅE, in 1968 16.88 ÅE.

The instrument Å 158 has been used as the instrument of reference since 1940 when the manufacture of new instruments was taken over first by Albert Lindblad, Stockholm, later by the Swedish Meteorological and Hydrological Institute (SMHI).

The pyrheliometer Å 171 was made by Lindblad in 1956 but the strips were renewed by SMHI in 1963. The strips of the instrument have very equal absorbing powers and electrical characteristics, and thanks to this good symmetry, the instrument is very convenient for use as a reference instrument.

The instrument Å 207-1 was constructed with a long tube by F. Lindholm. It is difficult to manage and its readings are very spread around the mean value. Likely, the instrument should be improved by blackening the inside tube walls and decreasing the electric resistance of the strips.

The pyrheliometer Å 585 is arbitrarily chosen out of the last series of manufacture at SMHI.

Electric auxiliary instruments

For simultaneous readings of two pyrheliometers, two sets of each of the following electric instruments were used: a mirror galvanometer, a milliammeter and a box with variable resistances.

Each set of instruments is placed in a special suitcase, which even was used for transport. The reference instrument Å 158 was always connected up on the same set.

	Reference instrument	Other instruments
Galvanometer, type Norma	No. 815335	No. 1150981
Ammeter, type Siemens V-mV-meter	12776	L56T5-137
with shunt	L40y12-49	L40T5-49

At Capri, during the first four days, a rectifier was used as electric power supply. From July 8 it was replaced by two Ni-Fe storage batteries. At Gornergrat, we used an autocar accumulator.

Unfortunately, in July 3-6, the rectification of the alternating current was incomplete, and the milliammeters, which were constructed for continuous current, gave incorrect readings. In order to find the correction for the readings, a pyrheliometer was shadowed and one of the strips was heated by current from the rectifier and the other from the storage battery. In the circuits of each strip an ammeter and a resistance bow was connected. The thermocouples were joined through a galvanometer. The currents in the circuits of the strips were modified so that the strips were equally heated, i.e. zero current was attained in the galvanometer circuit. The experiment was extended over definite intervals of the ammeter scale and repeated with alternate connection of each strip to the rectifier and the battery.

It was proved (Fig. 12, Appendix) that the ratio between the readings on the ammeters in the battery circuit and the rectifier circuit depended neither on the strength of the current nor on the pyrheliometer. Consequently, it seemed reasonable to attribute a constant correction factor to the readings which we noted when the rectifier was used.

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Instrument tests

The pyrheliometers were checked before and after each transport by means of Courvoisier's "Similarity Test". The test involves measuring the deviation s defined by the equation

$$1 + s = \frac{D_R^S}{D_L^S} \times \frac{D_R^C}{D_L^C} ,$$

where D is the reading of the zero-point galvanometer and the indexes R and L refer to the right and the left strip, respectively, at irradiation (S) and electric heating (C).

In the following table, the s-values found during the journey, before the start and after arrival home are found.

Site and date	Å 70	Å 158	Å 171	Å 207-1	Å 585
Stockholm before departure	-0.20	+0.15	+0.03	-0.16	-0.06
Capri, July 2	-0.24	+0.15	+0.01	-0.15	-0.08
Gornergrat, July 23	-0.21	+0.11	+0.01	-0.13	-0.07
Stockholm after return	-0.22	+0.13	+0.01	-0.16	-0.13

The value of s is a characteristic of each individual pyrheliometer. It depends upon asymmetries in essential qualities, e.g. the blackening and the electric resistance of the strips, the heat exchange between the strips, the thermocouples and the surrounding walls of the tube. A change in s indicates that something has happened since the preceding check, may be a slight damage.

As far as the principal instruments Å 70, Å 158 and Å 171 concerns, the values indicate no such damage. Even Å 207-1 has retained its check value. After return, a small change of the test value of Å 585 is noted. This instrument did not participate in any important comparison, and the significance of the variation has not yet been proved.

The electric instruments were checked too, after each long transport. The milliammeters were tested by comparing them connected up in series in an electric circuit containing a resistance box and a pyrheliometer. After the arrival at Gornergrat, a damage of the milliammeter L56T5-137 was detected. This ammeter had always been connected up on the pyrheliometer subject to comparison with Å 158. The balance mechanism of the pointer was disturbed. The ammeter had got a correction varying with the electric current and depending upon the position of the instrument. Thus, it became necessary to make a comparison between the ammeters at Gornergrat each time before and after the instruments were moved.

Measuring techniques

In order to get simultaneous readings of two pyrheliometers, we had to be two persons, one of us at each set of instruments.

At first, we made a reading of the zero points of the galvanometers when both strips of each of the pyrheliometers were irradiated. Secondly, the left strip was shaded and heated by electric current to zero deflection of the galvanometer. The adjustment and reading of the heating current was made absolutely simultaneously on both sets. Then the right strip was shaded and the adjustment and reading of the current was repeated. After return to the left strip, the zero point of the galvanometer was controlled.

The following average value of the heating current,

$$i_m = 1/4\ (i_L + 2i_R + i_L)$$

where m, L and R indicate the mean value, the left-shadow reading and the right-shadow reading, represents a measurement which usely took about five minutes. The intensity of sun radiation,

$$I = k\ i_m^2 \qquad \text{(k = calibration factor of the pyrheliometer)}$$

and the ratio between simultaneous readings, for example referred to the pyrheliometers Å 158 and Å 171, is determined,

$$Q_{158/171} = I_{158} : I_{171}.$$

Five ratios, usually covering a series of measurements during half an hour, were averaged and correlated to the turbidity parameter mβ.

The determination of the turbidity

The Ångström turbidity coefficient is determined by measuring firstly the total irradiation without a filter, secondly the partial irradiations attained through the red Schott filter RG2 and yellow Schott filter OG1. During the days July 3-22, these measurements were made with the pyrheliometer Å 171, on the 25th with Å 585.

The turbidity coefficient is determined in the morning before beginning the comparison measurements, about noon and in the afternoon. The mean value of the coefficients β_k and β_b attained by means of the red and yellow filters respectively, was applied except when a large difference between the coefficients indicates that one of them is wrong.

The variation of the turbidity coefficient is plotted in a diagram and by means of the curve a value is read off in the beginning and the end of each series of comparison between two pyrheliometers. The altitude of the sun is read on the scale of the pyrheliometer and checked by means of the time noted at each comparison. The latter value forms generally that basis for computation of the relative optical air mass. The atmospheric pressure at the site of measurement is derived from the weather maps at 13.00 GMT on the days in question. The turbidity coefficient is corrected for the atmospheric pressure. The mean value of mβ so attained at the beginning and at the end of each series of comparison, is the turbidity parameter that in the following is correlated to the average Q-value of the series.

The turbidity parameter

In the following table, the distribution of the turbidity coefficient and turbidity parameter in 87 series at Capri, Gornergrat and Stockholm is shown. The Stockholm series are supplementary and measured, in 1968 on April 18, 29 and 30, June 11 and September 6.

β	Capri	Gornergrat	Stockholm	mβ	Capri	Gornergrat	Stockholm
0- 20		15		0- 20		12	
21- 40	8	3	7	21- 40	5	5	2
41- 60	8		3	41- 60	5	1	5
61- 80	15			61- 80	16		2
81-100	10			81-100	6		1
101-120	6			101-120	13		
121-140	8		2	121-140	2		
141-160	2			141-160	7		
161-180				161-180	3		
181-200				181-200			
201-220				201-220			
221-240				221-240			2
Totalt	57	18	12		57	18	12

It is worth mentioning that the turbidity happened to be very low at Capri at the end of our stay there. Further, a very high turbidity occurred at Stockholm on September 6. This was an extremely warm day. The maximum temperature was higher than ever noted at Stockholm in September since 1873.

Weather and temperature

The sky was always clear of clouds when the comparisons were made. The temperature and humidity, measured with a sling psychrometer at the same time as the turbidity, are written in Table 13.

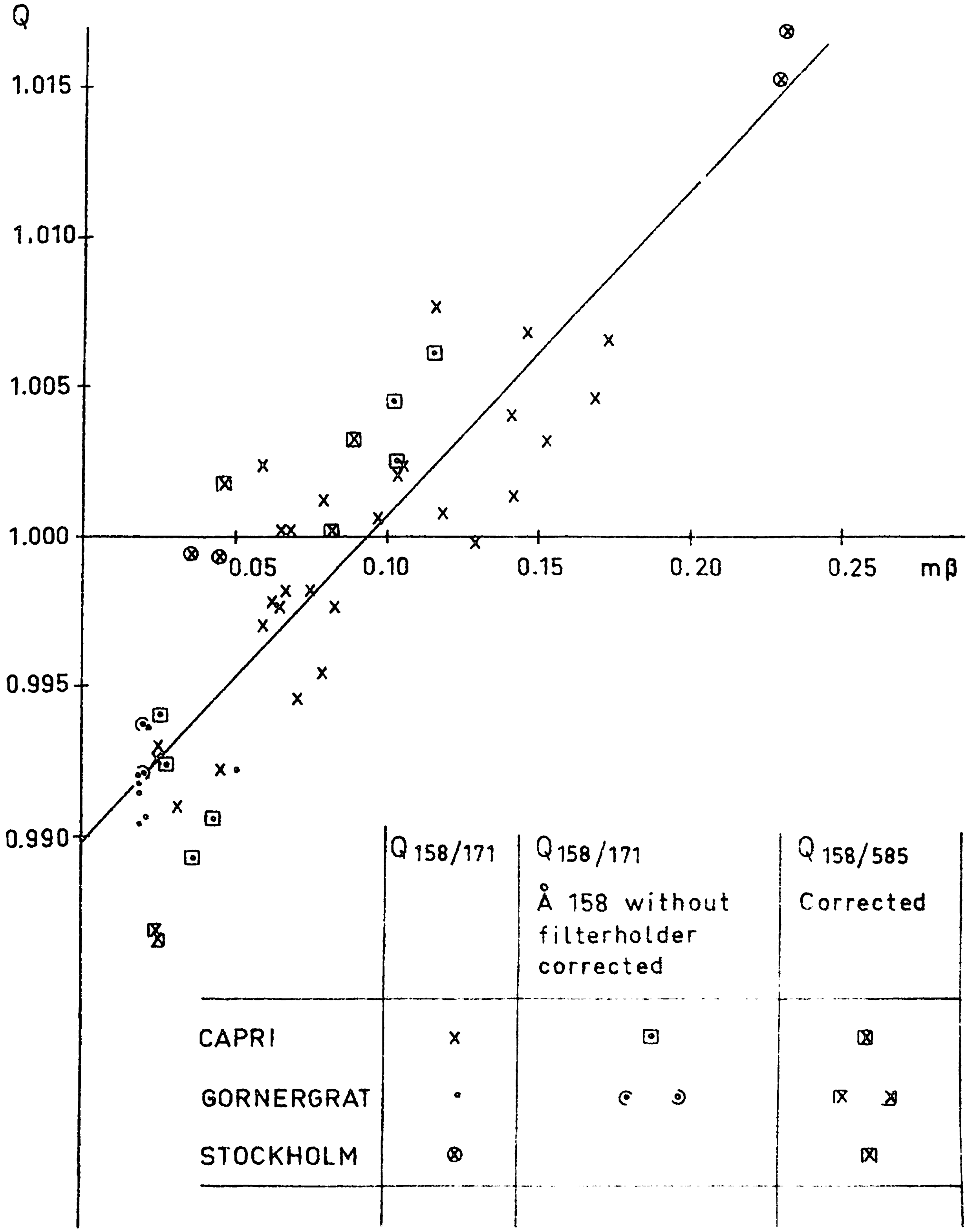
The comparison between Å 158 and Å 171

We made at Capri 174 comparisons between the principal pyrheliometers and put them together into 35 series of about 5 measurements each. Seven measurements were excluded because of their extreme deviations from the mean value.

At Gornergrat, the number of measurements was 42 averaged in 9 series. To these are added 21 measurements in five series made at Stockholm between April 29 and September 6.

Thus, there are in total 230 values in 49 series. The variance of the 230 individual variates of Q is $53 \cdot 10^{-6}$, that of the 49 series mean values is $42 \cdot 10^{-6}$.

FIG.1 THE RELATIONSHIP BETWEEN $Q_{158/171}$ AND THE TURBIDITY PARAMETER m/β



Plotting the series mean values in a diagram of the type shown in fig. 1, their relation to the turbidity parameter mβ becomes obvious. The correlation coefficient is 0.911 ± 0.025. The equation of the regression line is

$$Q_{158/171} = 0.108 \text{ m}\beta + 0.9899. \qquad (1)$$

If this relation to the turbidity is paid regard to, the variance of the series mean values decreases from $42 \cdot 10^{-6}$ to $7 \cdot 10^{-6}$.

On the bases of the diagram given by Ångström & Rodhe (fig. 1, 1966), the value 0.14 for the regression coefficient in (1) is evaluated, in stead of 0.108. Thus, the preliminary study mentioned seems to have given a slight overestimate the effect of the turbidity. This was pointed out by Schöne (1967).

Because the relationship between the turbidity parameter and the sun's radiation is a logarithmic function, is it possible to substitute the logarithm of the irradiation (I) for the turbidity parameter. Doing so, we get the diagram shown in fig. 2. The correlation coefficient between $Q_{158/171}$ and ${}^{10}\log I_{158}$ is 0.888 ± 0.031 and the regression equation is

$$Q_{158/171} = -0.970 \log I + 1.0068. \qquad (2)$$

Besides the turbidity, the atmospheric water vapour reduces the incoming sun radiation, but the vapour does not increase the short-wave circumsolar radiation as the aerosols do. Therefore, formula (2), in which I depends on the vapour content and the aerosol content but Q depends only on the aerosol content, is strictly applicable only to humidity conditions similar to those prevailing during the days of our investigation.

Putting Q = 1.0, the regression lines (1) and (2) give mβ = 0.094 and I = 1.175 cal cm^{-2} min^{-1}. The instrument constant of Å 171 refers to comparisons made at Stockholm, and these values of mβ and I are both rather normal there.

The pyrheliometer Å 158 used with and without a filter holder

It is possible to use the instrument Å 158 without its filter holder, but then the opening angle of the instrument is increased from 3.0x12° to 5.5x13°. At the comparisons on July 11, 13 and 20 between the instruments Å 171 and Å 158, the instrument Å 158 was in turns used with (M) and without (U) its filter holder. The ratio

$$Q_{158M/158U} = Q_{158/171} : Q_{158U/171}$$

is computed between adjacent series which are related to almost equal values of the turbidity parameter. The relationship is shown in fig. 3. The number of variates within series under different turbidity conditions is found in the following table together with the average values of mβ and Q.

FIG. 2 THE RELATIONSHIP BETWEEN $Q_{158/171}$ AND THE SUN RADIATION

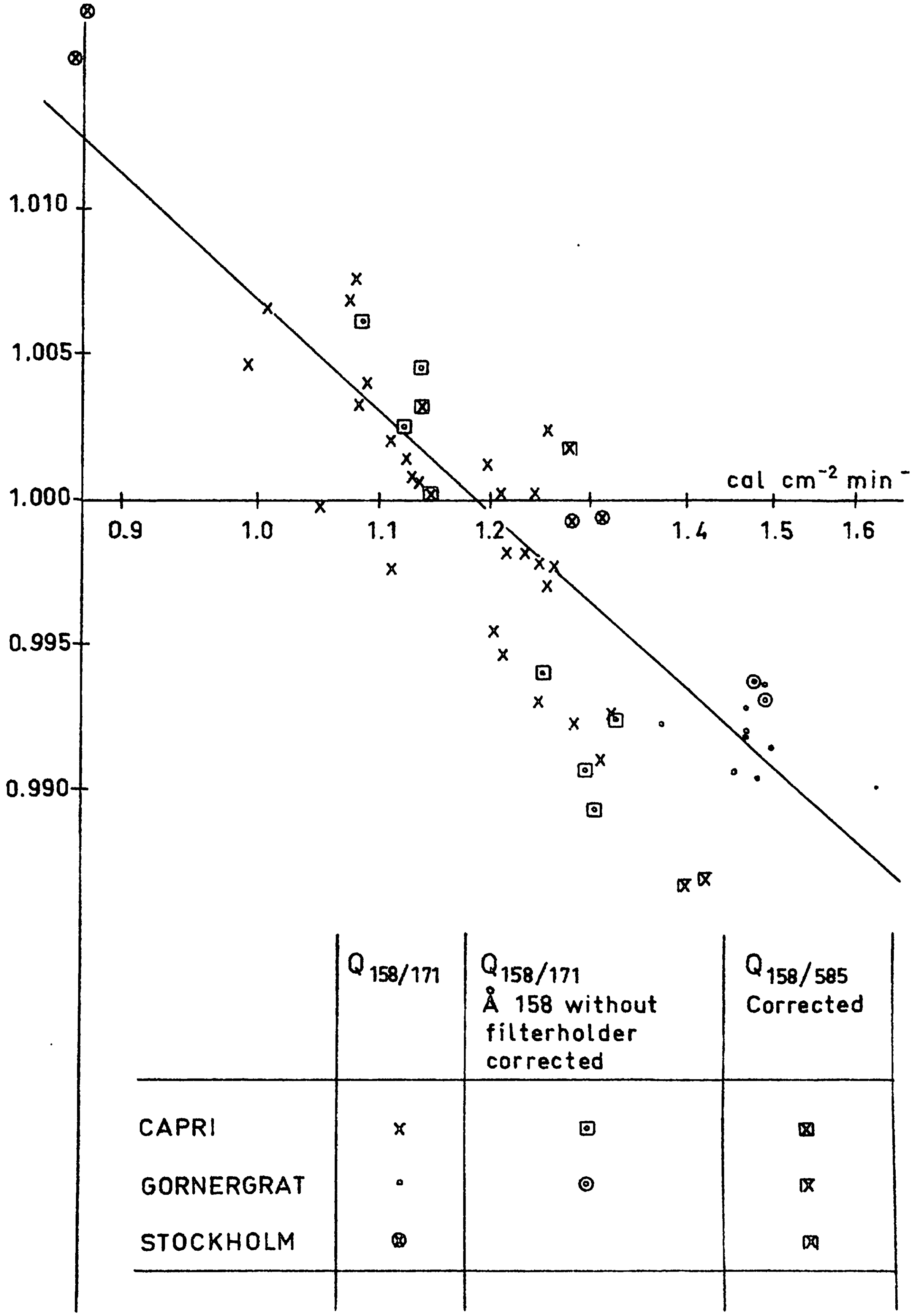
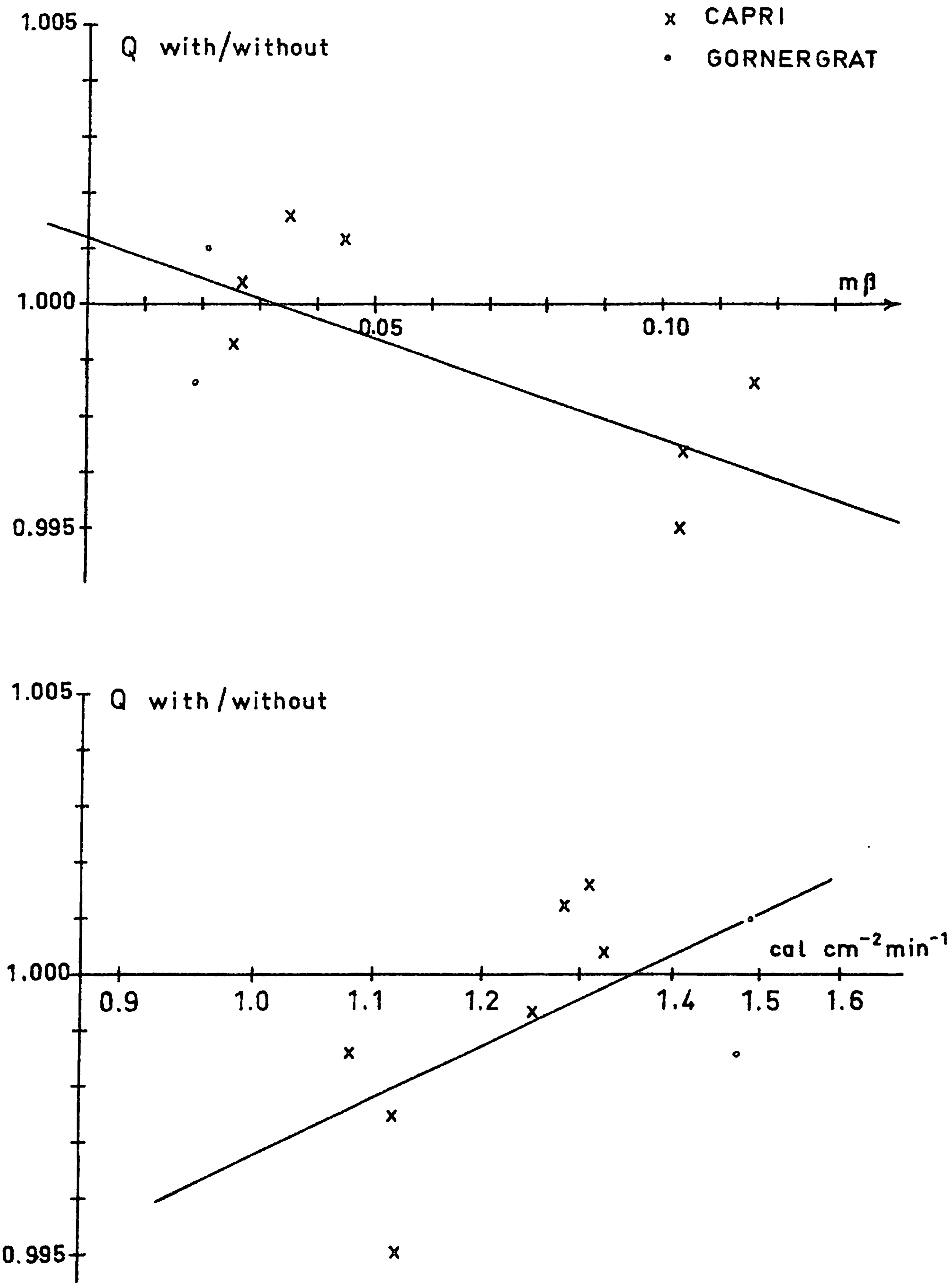
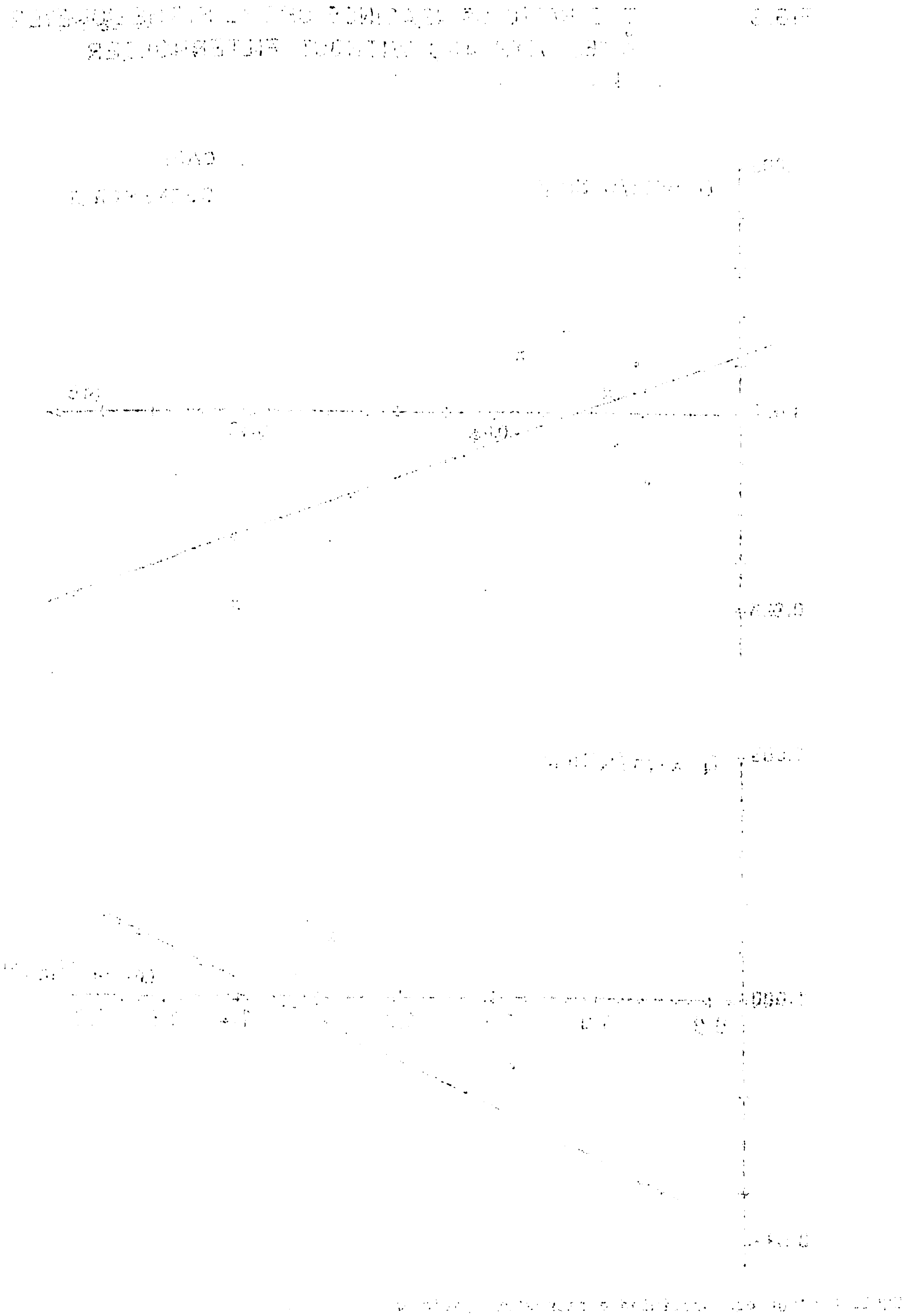


FIG. 3 THE RATIO OF READINGS OF THE PYRHELIOMETER Å 158 WITH AND WITHOUT FILTERHOLDER





	Date	mβ	With filter holder	Without filter holder	$Q_{158M/158U}$
Capri	July 11	0.108	n = 15	n = 14	0.9970 ± 0.0012
Capri	July 13	0.033	20	19	1.0007 ± 0.0009
Gornergrat	July 20	0.021	9	10	0.9999 ± 0.0011

Unfortunately, the number of measurements made under high turbidity conditions is small. On July 13 at Capri, the turbidity parameter did not differ much from the values observed on the high top of Gornergrat.

The difference between the readings when the filter holder of Å 158 is alternatively on and off, seems to be negligible at low turbidity but negative when the turbidity is large. The regression lines in fig. 3 have the forms

$$Q_{158M/158U} = -0.036\ m\beta + 1.0012 \tag{3}$$

and

$$Q_{158M/158U} = 0.025 \log I + 0.9967. \tag{4}$$

When Q = 1.0, mβ = 0.033 and I = 1.36 cal cm^{-2} min^{-1}.

At the preliminary study in 1967, Rodhe got the regression coefficient -0.052 and mβ = 0.15 at Q = 1.0. Thus, the effect of the filter holder of Å 158 was overestimated. Before 1964, however, it was not paid attention to at all.

Of course, the pyrheliometers and so Å 158 especially, should be used with their filter holders on the tube if this minimizes the aperture. Further measurements in order to prove the effect of the filter holder seems to be more a matter of theoretical than practical interest.

After having been corrected by means of equation (3), the comparisons between Å 171 and Å 158 without its filter holder, are included in the diagrams of figs. 1 and 2.

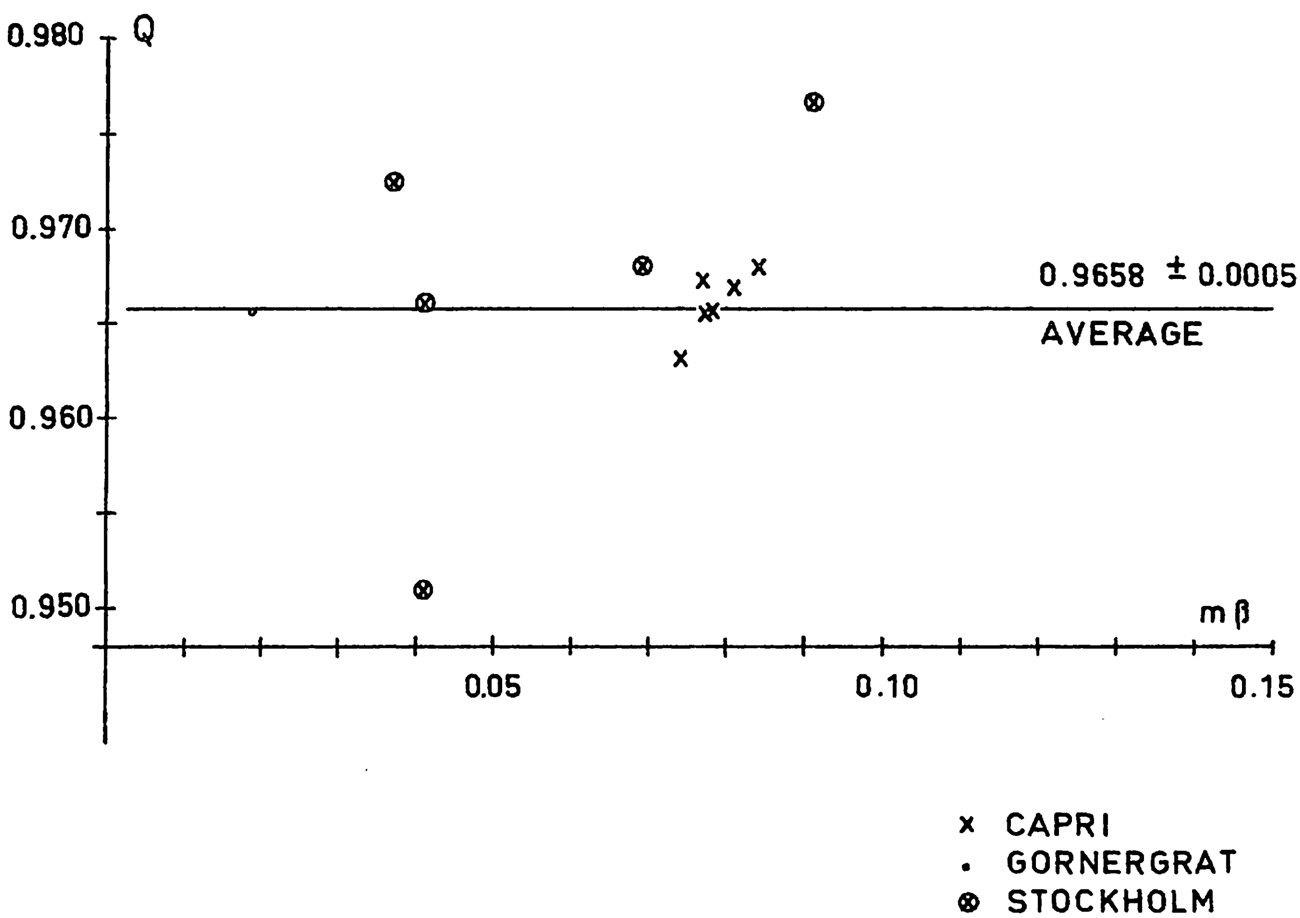
The comparison between the pyrheliometers Å 70 and Å 158

The pyrheliometer No Å 70 is the original reference instrument for the Ångström pyrheliometric scale of 1905. As mentioned above, the calibration factor has changed because of damages of the strips.

Six series of comparisons between the instruments Å 158 and Å 70 were made at Capri, together involving 29 measurements. At Gornergrat, we had two series with 10 measurements. Moreover, we made recently at Stockholm on April 18, 29, 30 and June 11, a number of 25 measurements combined into five series.

The averages of all the series are plotted in fig. 4 in relation to the turbidity parameter as well as to the irradiation. The dots of Capri and Gornergrat are less spread about the mean value than those attained at Stockholm.

FIG. 4 THE VARIATION OF $Q_{158/70}$
WITH TURBIDITY AND SUN RADIATION



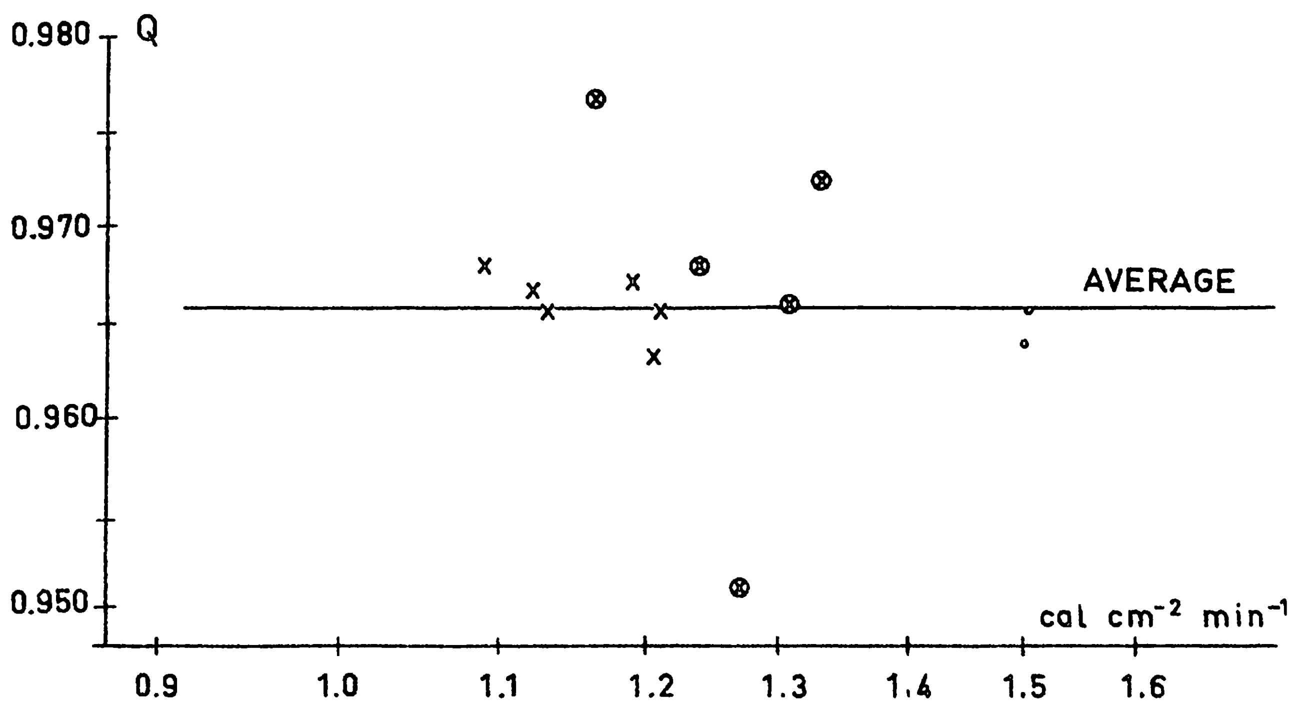
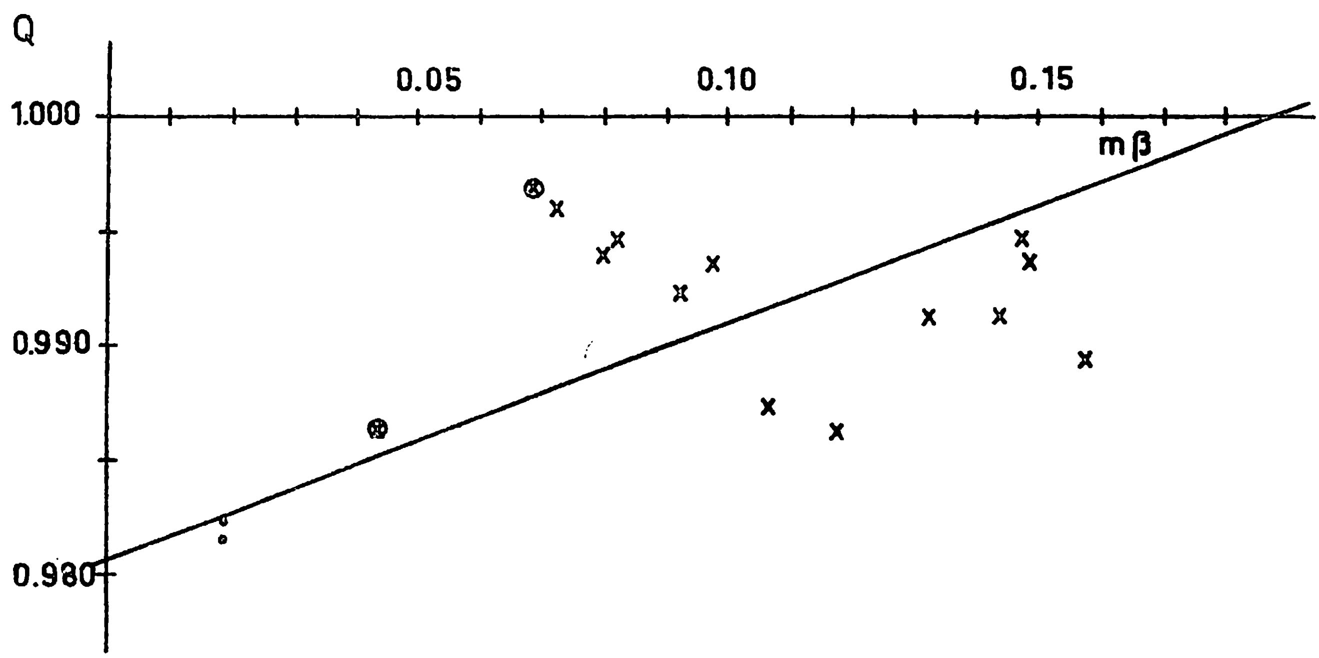
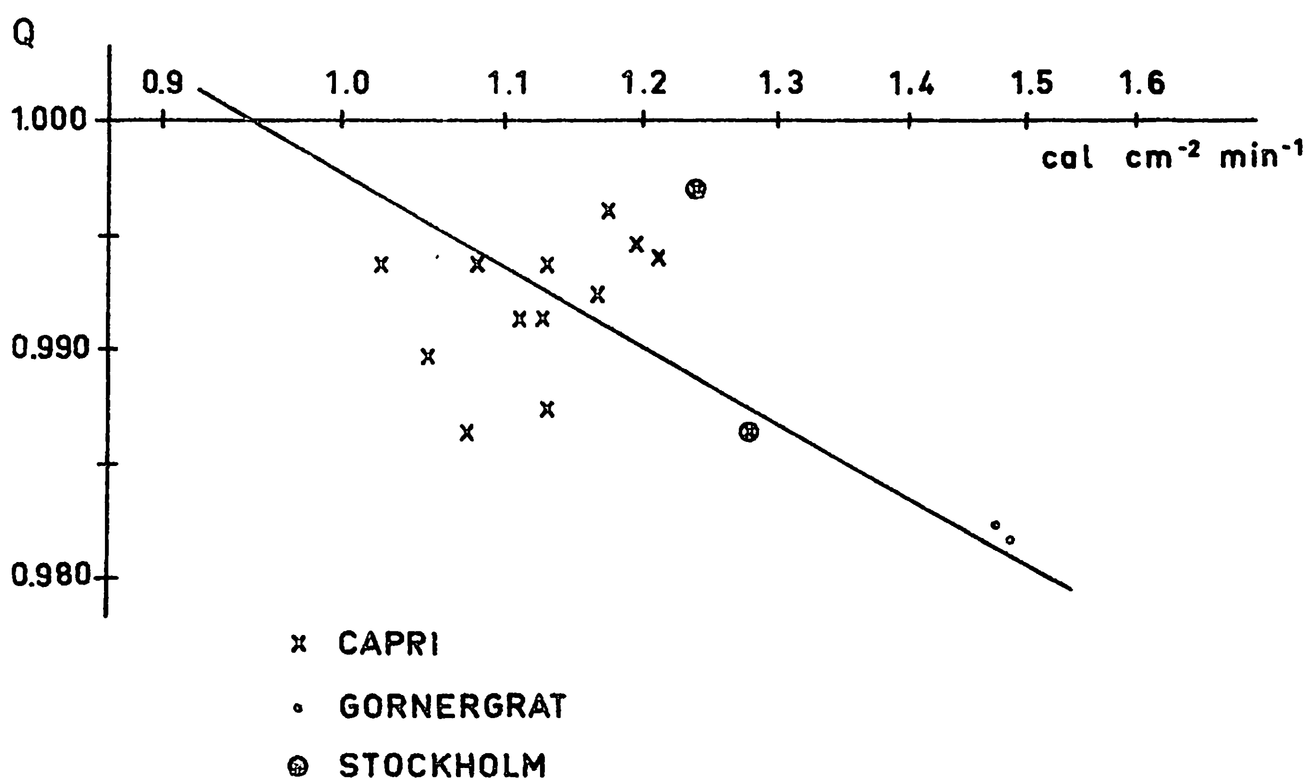
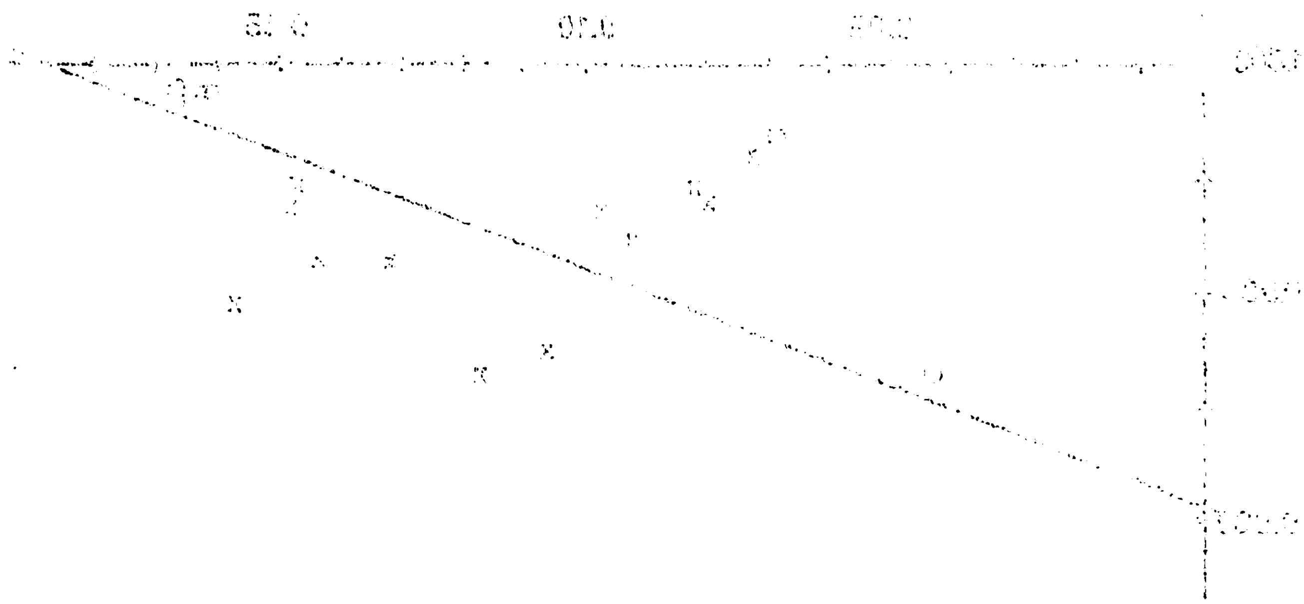
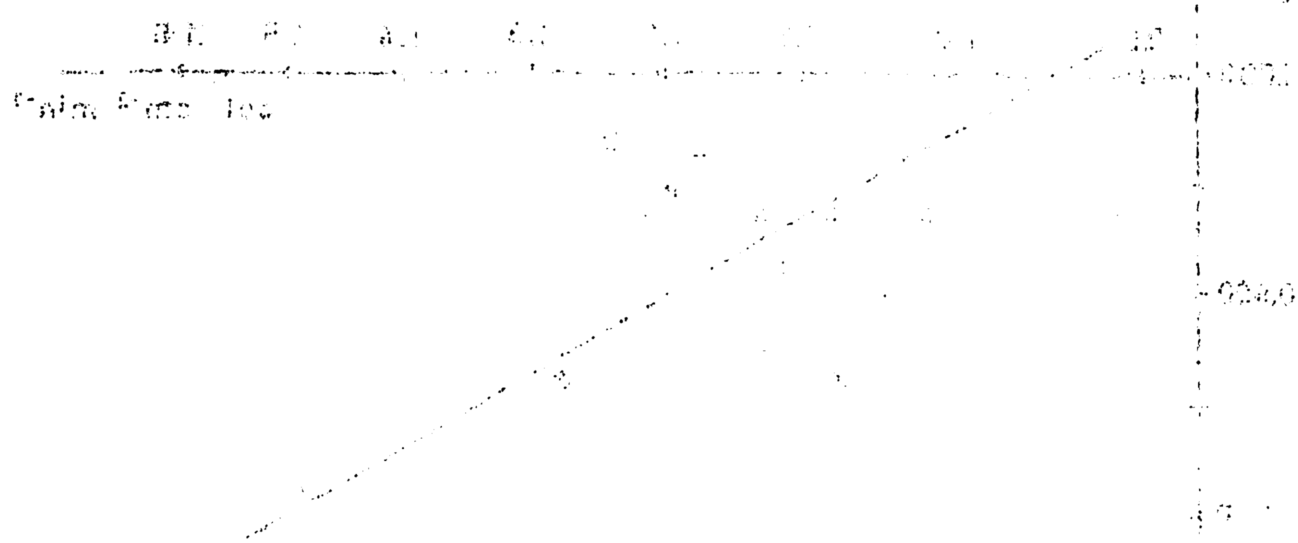


FIG. 5 THE VARIATION OF $Q_{158/207-1}$ WITH TURBIDITY AND SUN RADIATION









Nothing indicates that the relationship between the instruments Å 158 and Å 70 should depend on turbidity.

The comparison between the pyrheliometers Å 158 and Å 207-1

The pyrheliometer, Å 207-1 which was constructed by Lindholm with a very long tube and a small aperture, was also compared with the reference standard Å 158. At Capri, 60 comparisons were made and put together into 12 series. At Gornergrat, we made 10 comparisons in two series. At Stockholm recent comparisons had been made on April 30 and June 11. In total, the diagrams of fig. 5 are based on 78 measurements in 16 series. The dots are very spread in the diagrams because of the difficulty to get a stable balance between the components of heat transfer in the instrument Å 207-1. Likely, better results should be achieved by blackening the inside walls of the instrument and decreasing the electric resistance of the strips.

The lines of regression, which are drawn in fig. 5, have the coefficients of (1) and (2) derived by comparing Å 171 with Å 158 but they are displaced in order to pass the mean values of the series. The lines rather well fit to the dots of the diagrams. The small number of comparisons does not permit a more exact evaluation of the relationship between the pyrheliometers Å 158 and Å 207-1 than is given by these regressions.

The comparison of the pyrheliometer Å 585

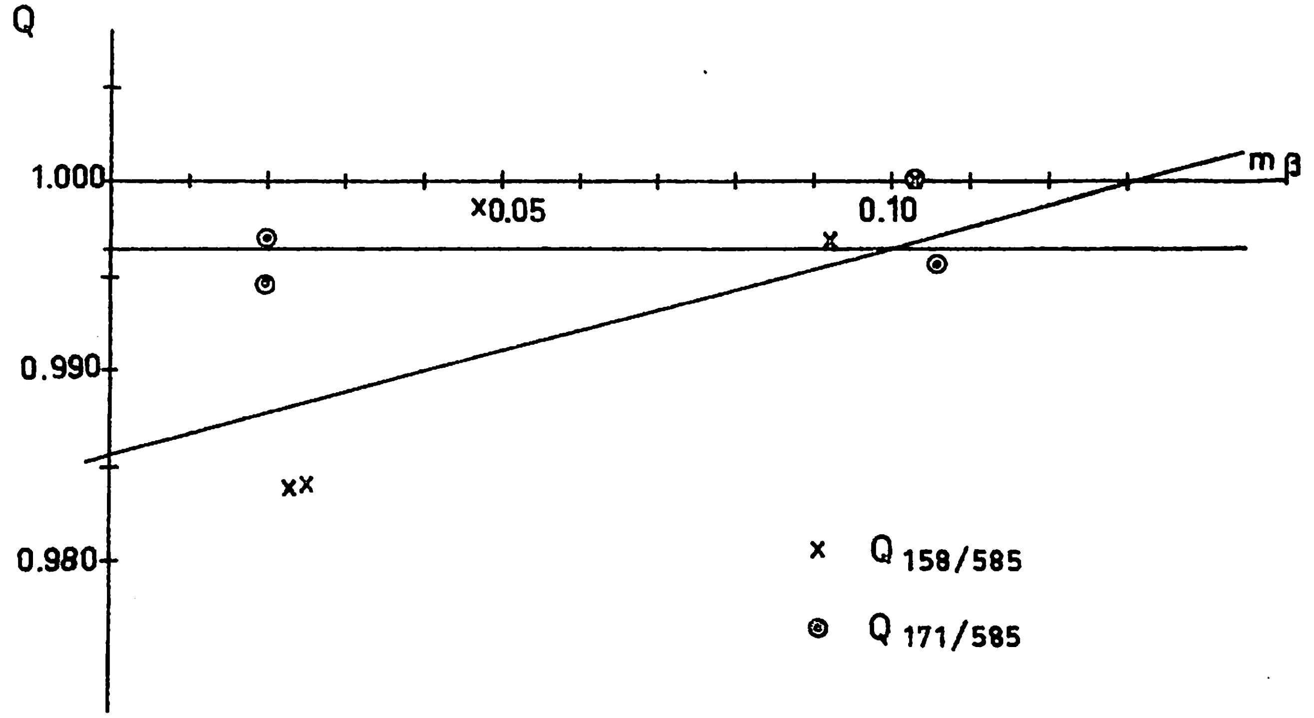
At Capri as well as Gornergrat ten comparisons were made between the instruments Å 585 and Å 158 and additionally 10 comparisons between Å 585 and Å 171. Thus, there are in total 20 comparisons put together in four series of each combination between the instruments Å 171 and Å 158 on one hand and Å 585 on the other. Five comparisons had recently been made at Stockholm on June 11 between Å 585 and Å 158. All the series mean values are plotted in the diagrams of fig. 6.

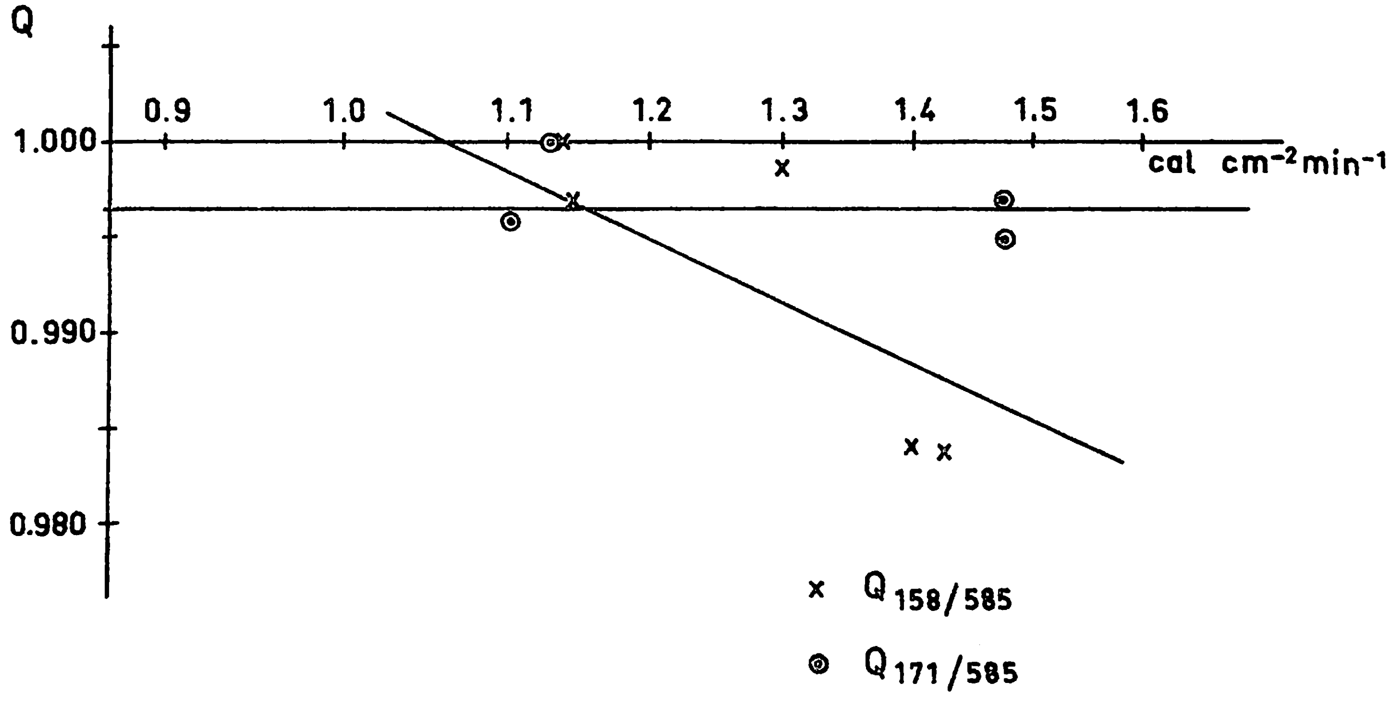
The number of comparisons is too sparse to permit an evaluation of the correlation coefficient. Instead, we have redrawn the regression lines (1) and (2) through the mean value in each diagram.

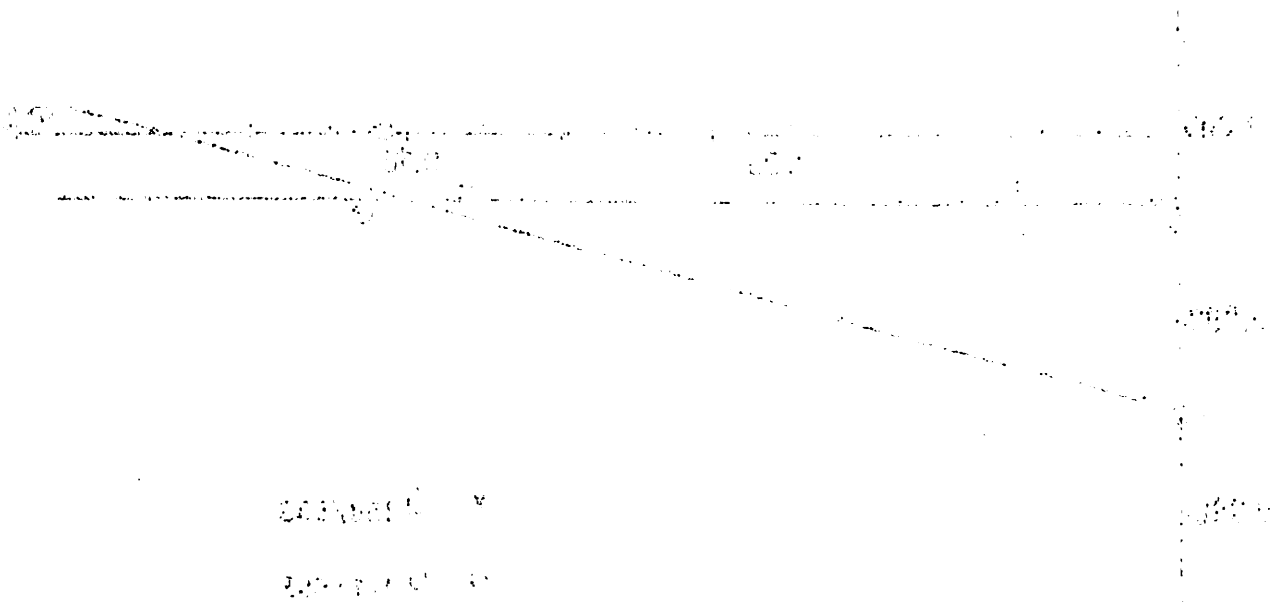
It seems reasonable to say that the relationship between Å 585 and Å 171 is constant and not influenced by the turbidity. But the relationship between Å 158 and Å 585 seems to be the same as the one derived in the case of Å 158 and Å 171. Indeed, the instruments Å 171 and Å 585 have almost the same dimensions and apertures.

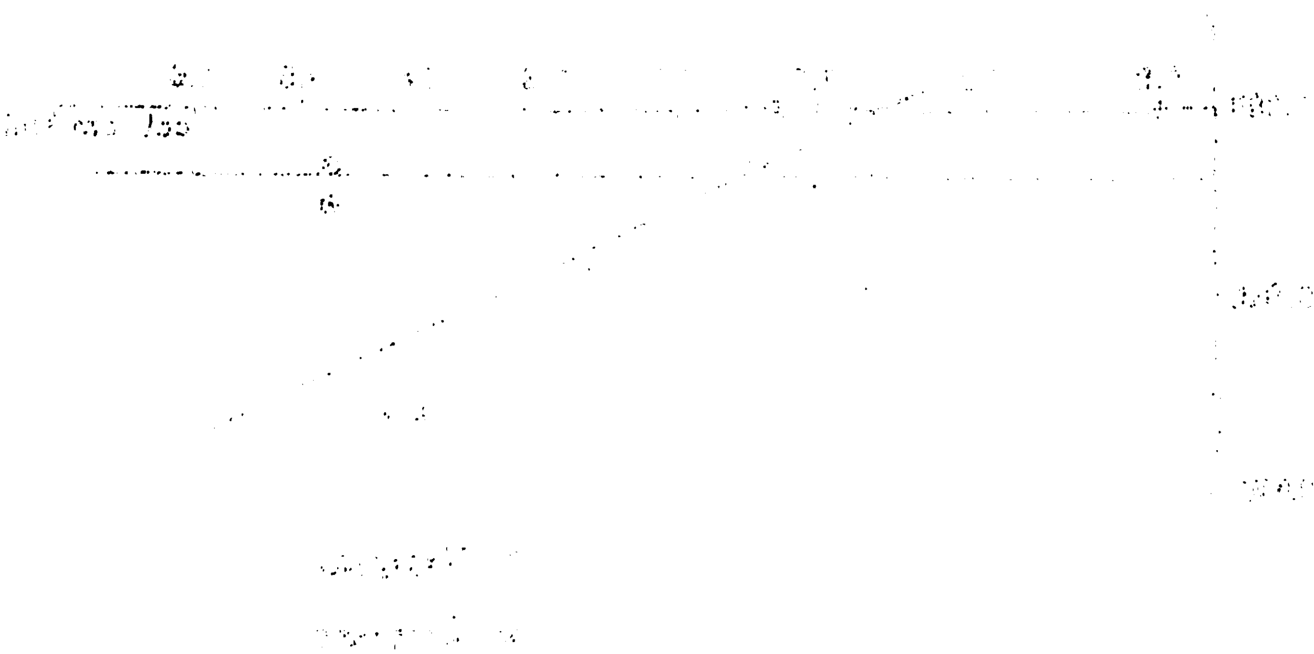
After correction for the calibration factor, the ratios $Q_{158/585}$ are plotted in figs. 1 and 2. It is seen that the values measured at Gornergrat are below the other values measured under low turbidity conditions. Either this variation is random or there has been a slight change in the instrument Å 585 as indicated by Courvoisier's "similarity test" described above.

FIG. 6 THE VARIATION OF $Q_{158/585}$ WITH TURBIDITY AND SUN RADIATION









Summary

The investigation has given information about the relationship between the reference standard Å 158 and a pyrheliometer of modern design, Å 171. Knowing this relationship we may in the future use the pyrheliometer Å 171 as our working standard.

Acknowledgements

I owe many thanks to Mr Helge Björklund, who assisted in the measurements, to Prof. Yngve Öhman, Dr Hans Westin and the staff of the Swedish Astrophysical Observatory at Capri, to the International Foundation of the Jungfraujoch Scientific Station and Dr A.D. Petford, Oxford, who admitted us to the British observatory at Gornergrat, to the Natural Science Research Council at Stockholm which granted our travel expenses, and to my wife, who had the care of the kitchen at Capri.

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Appendix

List of tables and figures in appendix.

Appendix

List of symbols in the tables 1 - 13.

TST	True solar time.
$Å_{158}$	Radiation in cal cm^{-2} min^{-1}, measured with the pyrheliometer enumerated.
$Q_{158/171}$	Ratio of intensity values read simultaneously by means of the pyrheliometers in question.
h	Sun elevation in degrees.
m	Relative optical air mass.
β	Ångström's turbidity coefficient. Further details, see below.
p	Atmospheric pressure in mbs at the site of measurements.
S	Reduction factor for the mean solar distance.
I_T	The total spectrum radiation of the sun, measured without a filter.
I_k	The short-wave component of solar radiation below the wavelength 630 mμ, $I_k = I_T - DR_2 \cdot I_R$, where I_R is the irradiation in the red part of the spectrum, measured by means of a filter glass Schott RG2, and DR2 is the reduction factor of the filter glass.
I_b	The short-wave component of solar radiation below the wavelength 525 mμ, $I_b = I_T - DO_1 \cdot I_G$, where I_G is the irradiation in the yellow part of the spectrum, measured by means of a filter glass OG1, and DO_1 is the reduction factor of the filter glass.
F	The part of the total radiation absorbed by atmospheric water vapour, estimated by means of β.
β_k	The turbidity coefficient estimated by means of I_k.
β_b	Ditto estimated by means of I_b.
$\bar{\beta}$	Either $1/2(\beta_k+\beta_b)$ or a reasonable estimate when there is a too large difference between β_k and β_b.
T	Dry-bulb temperature.
T_w	Wet-bulb temperature.
R	Relative humidity.
e	Vapour pressure in mbs.

Appendix Table 1 Comparison between the pyrheliometers Å 158 and Å 171 at Capri, Gornergrat and Stockholm.

1968	TST	Å 158	Å 171	Q	h	m	β	mβ
C A P R I								
3.7	08.55	1.195	1.197	0.998	47.5	1.35	0.060	0.081
	09.01	1.194	1.195	0.999				
	.05	1.196	1.193	1.003				
	.11	1.188	1.204	(0.986)				
	.17	1.203	1.197	1.005	51.6	1.27	0.061	0.077
	11.33	1.219	1.219	1.000	71.5	1.06	0.064	0.068
	.37	1.213	1.209	1.003				
	.41	1.210	1.212	0.998				
	.44	1.212	1.212	1.000				
	.50	1.203	1.215	(0.990)	72.2	1.05	0.065	0.068
	13.36	1.114	1.122	0.993	63.2	1.12	0.073	0.082
	.40	1.114	1.121	0.994				
	.45	1.114	1.107	1.006				
	.50	1.119	1.114	1.004				
	.53	1.100	1.110	0.991	60.4	1.15	0.074	0.085
5.7	08.44	1.040	1.039	1.001	45.3	1.41	0.096	0.135
	.48	1.034	1.048	0.987				
	.52	1.048	1.052	0.996				
	.58	1.063	1.058	1.005				
	09.04	1.069	1.058	1.010	49.1	1.32	0.095	0.125
	10.45	1.118	1.115	1.003	66.2	1.09	0.090	0.098
	.50	1.147	1.144	1.003				
	.53	1.146	1.139	1.006				
	.57	1.137	1.144	0.994				
	11.00	1.132	1.135	0.997	68.2	1.08	0.089	0.096
	12.00	1.126	1.128	0.998	72.2	1.05	0.110	0.116
	.06	1.129	1.127	1.002				
	.10	1.129	1.127	1.002				
	.13	1.129	1.125	1.004				
	.18	1.125	1.127	0.998	72.2	1.05	0.115	0.121
	13.26	1.101	1.094	1.006	64.6	1.11	0.125	0.139
	.33	1.087	1.083	1.004				
	.37	1.091	1.086	1.003				
	.42	1.087	1.080	1.006				
	.46	1.084	1.083	1.001	61.5	1.14	0.126	0.144
	14.53	1.014	1.012	1.002	50.4	1.30	0.125	0.163
	.57	1.009	1.000	1.009				
	15.01	0.999	0.990	1.009				
	.32	0.947	0.941	1.006	42.3	1.49	0.123	0.183
6.7	09.37	0.989	0.984	1.005	55.0	1.22	0.138	0.168
	.41	0.988	0.985	1.003				
	.45	0.992	0.995	0.997				
	.50	0.996	0.990	1.006				
	.54	0.996	0.984	1.012	56.3	1.20	0.141	0.169
	11.32	1.075	1.079	0.996	71.1	1.05	0.148	0.155
	.36	1.072	1.069	1.003				
	.40	1.075	1.075	1.000				
	.46	1.093	1.082	1.010				
	.52	1.096	1.088	1.007	72.0	1.05	0.144	0.151

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Appendix Table 1 (continued)

1968	TST	Å 158	Å 171	Q	h	m	β	mβ
C A P R I								
6.7	12.44	1.120	1.122	0.998	69.8	1.07	0.134	0.143
	.47	1.130	1.122	1.007				
	.50	1.124	1.120	1.004				
	.56	1.126	1.126	1.000				
	13.01	1.113	1.115	0.998	67.9	1.08	0.131	0.141
	14.24	1.087	1.066	1.020	54.8	1.22	0.119	0.145
	.28	1.087	1.071	1.015				
	.30	1.073	1.072	1.001				
	.35	1.068	1.066	1.002				
	.39	1.060	1.064	0.996	52.1	1.26	0.117	0.147
8.7	09.00	1.203	1.210	0.994	47.0	1.36	0.054	0.073
	.06	1.209	1.219	0.992				
	.10	1.222	1.227	0.996				
	.14	1.219	1.223	0.997				
	.26	1.212	1.219	0.994	52.9	1.25	0.055	0.069
	09.30	1.214	1.216	0.998	53.7	1.24	0.055	0.068
	.33	1.218	1.221	0.998				
	.37	1.217	1.219	0.998				
	.41	1.217	1.219	0.998				
	.45	1.222	1.223	0.999	56.3	1.20	0.055	0.066
	09.49	1.235	1.253	(0.986)	57.0	1.19	0.055	0.065
	.53	1.251	1.252	0.999				
	.58	1.262	1.263	0.999				
	10.02	1.265	1.270	0.996				
	.08	1.271	1.275	0.997	60.3	1.15	0.055	0.063
	11.26	1.269	1.262	(1.006)	70.5	1.06	0.056	0.059
	.31	1.252	1.265	(0.990)				
	.35	1.242	1.246	0.997				
	.40	1.252	1.256	0.997				
	.45	1.266	1.270	0.997	71.6	1.05	0.056	0.059
	11.54	1.270	1.267	1.002	71.9	1.05	0.056	0.059
	.58	1.262	1.261	1.001				
	12.01	1.257	1.249	1.006				
	.07	1.245	1.236	1.007				
	.11	1.251	1.256	0.996	71.7	1.05	0.057	0.060
	12.37	1.253	1.253	1.000	70.3	1.06	0.058	0.061
	.41	1.254	1.255	0.999				
	.45	1.249	1.250	0.999				
	.48	1.243	1.249	0.995				
	.52	1.246	1.251	0.996	68.8	1.07	0.059	0.063
	13.03	1.238	1.237	1.001	67.5	1.08	0.059	0.064
	.08	1.240	1.242	0.998				
	.11	1.243	1.246	0.998				
	.15	1.249	1.246	1.002				
	.19	1.246	1.243	1.002	65.4	1.10	0.061	0.067
	13.57	1.245	1.243	1.002	59.4	1.16	0.063	0.073
	14.00	1.239	1.244	0.996				
	.05	1.237	1.240	0.998				
	.02	1.225	1.229	0.997				
	.13	1.228	1.231	0.998	56.2	1.20	0.064	0.077

Appendix Table 1 (continued)

1968	TST	Å 158	Å 171	Q	h	m	β	mβ	Remarks
C A P R I									
8.7	14.17	1.220	1.231	0.991	56.0	1.20	0.064	0.077	
	.22	1.216	1.217	0.999					
	.25	1.209	1.212	0.998					
	.29	1.195	1.205	0.992					
	.33	1.191	1.195	0.997	53.1	1.25	0.065	0.081	
11.7	10.45	1.063	1.056	1.007	65.6	1.10	0.109	0.120	
	.54	1.069	1.065	1.004					
	11.06	1.074	1.064	1.009					
	.18	1.099	1.091	1.007					
	.28	1.088	1.076	1.011	70.3	1.06	0.105	0.111	
	10.50	1.068	1.062	1.006	66.3	1.09	0.109	0.119	Å 158
	.59	1.078	1.067	1.010					without
	11.06	1.089	1.077	1.011					filter-
	.24	1.091	1.077	1.013					holder
	.34	1.104	1.099	1.005	70.7	1.06	0.104	0.110	
	11.58	1.121	1.121	1.000	71.5	1.06	0.101	0.107	
	12.08	1.118	1.118	1.000					
	.16	1.112	1.107	1.005					
	.35	1.104	1.101	1.003					
	.44	1.130	1.126	1.004	69.3	1.07	0.097	0.104	
	12.03	1.126	1.119	1.006	71.5	1.05	0.101	0.106	Å 158
	.12	1.124	1.117	1.006					without
	.30	1.104	1.100	1.004					filter-
	.39	1.132	1.126	1.005					holder
	.48	1.125	1.120	1.004	68.9	1.07	0.096	0.103	
	13.04	1.139	1.131	1.007	67.1	1.09	0.094	0.102	Å 158
	.07	1.138	1.139	(0.999)					without
	.11	1.138	1.129	1.008					filter-
	.16	1.131	1.124	1.006					holder
	.20	1.135	1.127	1.007	64.9	1.11	0.092	0.101	
	13.49	1.116	1.111	1.005	58.8	1.17	0.089	0.104	
	.52	1.118	1.113	1.005					
	.55	1.112	1.111	1.001					
	.59	1.106	1.106	1.000					
	14.03	1.104	1.105	0.999	58.2	1.17	0.088	0.103	
13.7	09.37	1.291	1.304	0.990	54.5	1.23	0.040	0.049	
	.51	1.281	1.285	0.997	56.9	1.19	0.041	0.049	
	.58	1.274	1.289	0.988	59.8	1.16	0.041	0.048	
	10.58	1.309	1.321	0.991	67.1	1.08	0.039	0.042	
	11.06	1.315	1.322	0.995	68.0	1.08	0.038	0.041	
	09.42	1.274	1.284	0.992	55.4	1.22	0.040	0.049	Å 158
	.54	1.278	1.289	0.991	57.4	1.18	0.041	0.048	without
	10.54	1.314	1.325	0.992	66.6	1.09	0.039	0.043	filter-
	11.02	1.307	1.324	0.987	67.6	1.07	0.038	0.041	holder
	.11	1.323	1.333	0.993	68.6	1.07	0.037	0.040	
	11.22	1.307	1.323	0.988	69.6	1.07	0.036	0.038	Å 158
	.27	1.305	1.324	0.986					without
	.33	1.293	1.303	0.992					filter-
	.37	1.309	1.324	0.989					holder
	.41	1.314	1.324	0.992	70.9	1.06	0.033	0.035	

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Appendix Table 1 (continued)

1968	TST	Å 158	Å 171	Q	h	m	β	mβ	Remarks
C A P R I									
13.7	11.52	1.317	1.331	0.990	71.2	1.06	0.032	0.034	
	.57	1.307	1.320	0.990					
	12.01	1.316	1.324	0.994					
	.06	1.300	1.315	0.989					
	.12	1.319	1.330	0.992	71.1	1.06	0.029	0.031	
	12.26	1.318	1.325	0.995	70.5	1.06	0.027	0.029	Å 158 without filter-holder
	.30	1.321	1.332	0.992					
	.34	1.332	1.339	0.995					
	.36	1.331	1.350	0.986					
	.40	1.335	1.345	0.993	69.4	1.07	0.026	0.028	
	12.50	1.310	1.314	0.997	68.3	1.07	0.024	0.026	
	.54	1.301	1.314	0.990					
	.59	1.324	1.334	0.992					
	13.03	1.337	1.345	0.994					
	.06	1.335	1.348	0.990	66.5	1.09	0.022	0.024	
	13.56	1.277	1.292	0.988	59.1	1.16	0.021	0.024	
	14.01	1.244	1.253	0.993					
	.05	1.246	1.252	0.995					
	.09	1.248	1.254	0.995					
	.13	1.227	1.234	0.994	56.2	1.20	0.021	0.025	
	14.19	1.257	1.261	0.997	55.2	1.22	0.021	0.026	Å 158 without filter-holder
	.22	1.256	1.254	(1.002)					
	.28	1.253	1.263	0.992					
	.31	1.256	1.266	0.992					
	.34	1.244	1.251	0.994	52.5	1.26	0.021	0.026	
G O R N E R G R A T									
19.7	14.29	1.385	1.412	(0.981)					
	.33	1.385	1.391	0.996	50.0	1.30	0.038	0.049	
	.38	1.379	1.394	0.989					
	.50	1.372	1.380	0.994					
	.56	1.365	1.379	0.990	46.3	1.38	0.038	0.052	
20.7	09.07	1.469	1.470	(0.999)					
	.11	1.472	1.479	0.995	47.3	1.36	0.014	0.019	
	.15	1.470	1.481	0.993					
	.19	1.472	1.486	0.991					
	.23	1.468	1.486	0.988	49.2	1.32	0.015	0.020	
	09.28	1.472	1.481	0.994	50.0	1.30	0.015	0.019	Å 158 without filter-holder
	.33	1.475	1.482	0.995					
	.37	1.480	1.495	0.990					
	.41	1.482	1.492	0.993					
	.45	1.484	1.493	0.994	52.5	1.26	0.016	0.020	
	09.59	1.487	1.498	0.993	54.9	1.22	0.018	0.022	
	10.03	1.490	1.500	0.993					
	.07	1.495	1.504	0.994					
	.11	1.489	1.504	0.991					
	.15	1.493	1.498	0.997	56.8	1.19	0.019	0.023	
	10.27	1.489	1.507	0.988	58.3	1.17	0.020	0.023	Å 158 without filter-holder
	.31	1.493	1.502	0.994					
	.35	1.493	1.500	0.995					
	.40	1.493	1.503	0.993					
	.43	1.492	1.503	0.993	60.1	1.15	0.022	0.025	

Appendix Table 1 (continued)

1968	TST	Å 158	Å 171	Q	h	m	β	mβ
G O R N E R G R A T								
20.7	12.59	1.464	1.489	(0.983)				
	13.25	1.476	1.502	(0.982)				
	.30	1.477	1.482	0.997	58.6	1.17	0.023	0.027
	.33	1.473	1.482	0.994				
	.37	1.467	1.478	0.993				
	.40	1.467	1.484	0.989				
	.44	1.469	1.480	0.993				
	.48	1.460	1.473	0.991	56.4	1.20	0.023	0.028
22.7	08.33	1.446	1.457	0.992	40.7	1.53	0.014	0.021
	.36	1.453	1.466	0.991				
	.39	1.454	1.470	0.989				
	.43	1.454	1.469	0.990				
	.47	1.456	1.469	0.991	43.1	1.46	0.014	0.020
	12.37	1.508	1.519	0.993	63.1	1.12	0.017	0.019
	.41	1.504	1.518	0.991				
	.45	1.504	1.514	0.993				
	.53	1.496	1.513	0.989	62.0	1.13	0.017	0.019
	13.05	1.493	1.494	(0.999)				
	13.21	1.485	1.494	0.994	59.3	1.16	0.017	0.020
	.25	1.478	1.499	0.986				
	.28	1.482	1.494	0.992				
	.33	1.486	1.496	0.993				
	.38	1.477	1.496	0.987	57.3	1.19	0.016	0.019
25.7	11.10	1.463	1.477	0.991	61.7	1.14	0.017	0.019
	.13	1.475	1.487	0.992				
	.19	1.469	1.480	0.993	62.3	1.13	0.017	0.019
S T O C K H O L M								
29.4	13.56	1.283	1.284	0.999	40.4	1.54	0.029	0.045
	.58	1.282	1.282	1.000				
	14.00	1.277	1.278	0.999	40.1	1.55	0.029	0.045
11.6	11.01	1.309	1.310	0.999	52.3	1.26	0.028	0.035
	.06	1.311	1.310	1.001				
	.08	1.313	1.319	0.995				
	.13	1.319	1.321	0.998				
	.17	1.317	1.312	1.004	52.9	1.25	0.029	0.036
6.9	12.14	0.860	0.842	1.021	36.9	1.66	0.138	0.229
	.22	0.868	0.858	1.012				
	.26	0.869	0.853	1.019				
	.28	0.869	0.856	1.015				
	.31	0.860	0.852	1.009	36.6	1.67	0.138	0.230
	12.34	0.869	0.850	1.022	36.5	1.68	0.138	0.232
	.38	0.873	0.865	1.009				
	.41	0.876	0.861	1.017				
	.44	0.871	0.854	1.020				
	.48	0.870	0.856	1.016	36.2	1.69	0.138	0.233

Appendix Table 2 Comparison between the pyrheliometers Å 158 and Å 70 at Capri, Gornergrat and Stockholm.

1968	TST	Å 158	Å 70	Q	h	m	β	mβ
C A P R I								
3.7	09.28	1.209	1.261	0.959	53.6	1.24	0.061	0.076
	.34	1.208	1.249	0.966				
	.39	1.210	1.256	0.963				
	.45	1.198	1.241	0.965	56.6	1.20	0.061	0.073
	13.03	1.125	1.164	0.967	68.0	1.08	0.070	0.076
	.08	1.126	1.170	0.962				
	.11	1.150	1.184	0.971				
	.16	1.134	1.174	0.966				
	.21	1.126	1.170	0.962	65.5	1.10	0.072	0.079
9.7	12.18	1.215	1.262	0.963	71.4	1.06	0.074	0.078
	.22	1.210	1.253	0.966				
	.26	1.209	1.252	0.966				
	.32	1.212	1.253	0.967				
	.36	1.209	1.252	0.966	70.3	1.06	0.073	0.077
	12.51	1.194	1.239	0.964	68.8	1.07	0.072	0.077
	.55	1.195	1.235	0.968				
	.59	1.196	1.225	0.974				
	13.04	1.182	1.227	0.963				
	.09	1.186	1.226	0.967	66.7	1.09	0.071	0.077
	14.07	1.137	1.176	0.967	57.6	1.18	0.068	0.080
	.10	1.127	1.174	0.960				
	.14	1.127	1.158	0.973				
	.17	1.121	1.159	0.967				
	.21	1.103	1.141	0.967	55.2	1.22	0.067	0.082
	14.33	1.098	1.136	0.967	53.0	1.25	0.066	0.083
	.36	1.090	1.123	0.971				
	.40	1.094	1.131	0.967				
	.44	1.093	1.129	0.968				
	.48	1.082	1.119	0.967	49.9	1.31	0.065	0.085
G O R N E R G R A T								
22.7	10.02	1.501	1.552	0.967	56.5	1.20	0.015	0.018
	.09	1.498	1.552	0.965				
	.13	1.497	1.557	0.961				
	.17	1.498	1.560	0.960				
	.21	1.503	1.554	0.967	57.2	1.19	0.016	0.019
	10.53	1.506	1.556	0.968	60.8	1.15	0.017	0.020
	.57	1.500	1.556	0.964				
	11.01	1.504	1.556	0.967				
	.04	1.504	1.557	0.966				
	.08	1.502	1.560	0.963	62.1	1.13	0.017	0.019

Appendix Table 2 (continued)

1968	TST	Å 158	Å .70	Q	h	m	β	mβ
S T O C K H O L M								
18.4	13.49	1.186	1.211	0.979	37.4	1.64	0.055	0.090
	.54	1.154	1.184	0.975				
	.58	1.152	1.180	0.976	36.8	1.67	0.055	0.092
29.4	12.00	1.252	1.332	0.940	45.2	1.41	0.029	0.041
	.07	1.252	1.338	0.936				
	.13	1.252	1.334	0.939				
	.15	1.297	1.339	0.969				
	.17	1.290	1.329	0.971	45.1	1.41	0.029	0.041
	12.20	1.292	1.335	0.968	45.1	1.41	0.029	0.041
	.22	1.307	1.354	0.965				
	.27	1.311	1.359	0.965				
	.29	1.311	1.356	0.967				
	.31	1.311	1.360	0.964	44.9	1.42	0.029	0.041
30.4	11.21	1.237	1.269	0.975	45.0	1.41	0.048	0.068
	.29	1.247	1.290	0.967				
	.35	1.235	1.281	0.964				
	.38	1.242	1.288	0.964				
	.40	1.246	1.287	0.968				
	.45	1.242	1.284	0.967				
	.52	1.233	1.269	0.972	45.5	1.40	0.048	0.067
11.6	11.27	1.336	1.373	0.973	53.2	1.25	0.029	0.036
	.31	1.329	1.367	0.972				
	.37	1.331	1.369	0.972				
	.40	1.329	1.369	0.971				
	.42	1.328	1.364	0.974	53.5	1.24	0.030	0.037

Appendix Table 3 Comparison between the pyrheliometers Å 158 and Å 207-1 at Capri, Gornergrat and Stockholm.

1968	TST	Å 158	Å 207-1	Q	h	m	β	mβ
C A P R I								
3.7	12.28	1.181	1.182	0.999	71.4	1.06	0.068	0.072
	.33	1.198	1.192	1.005				
	.37	1.173	1.185	0.990				
	.40	1.164	1.178	0 988				
	.47	1.151	1.153	0.998	69.8	1.07	0.069	0.074
5.7	09.14	1.074	1.091	0.984	50.9	1.29	0.095	0.123
	.20	1.088	1.087	1.001				
	.26	1.080	1.098	0.984				
	.32	1.079	1.104	0.977				
	.38	1.086	1.103	0.985	55.3	1.22	0.093	0.113
	11.27	1.130	1.149	0.983	70.9	1.06	0.097	0.102
	.32	1.132	1.149	0.985				
	.37	1.138	1.146	0.993				
	.40	1.134	1.149	0.987				
	.44	1.129	1.143	0.988	71.9	1.05	0.104	0.109
	12.50	1.126	1.140	0.988	69.3	1.07	0.122	0.131
	.54	1.130	1.145	0.987				
	.59	1.129	1.139	0.991				
	13.04	1.130	1.134	0.996				
	.11	1.114	1.120	0.995	66.8	1.09	0.124	0.135
	14.30	1.078	1.088	0.991	53.8	1.24	0.126	0.156
	.34	1.075	1.080	0.995				
	.37	1.065	1.072	0.993				
	.41	1.026	1.041	0.986				
	.45	1.014	1.033	0.982	51.1	1.28	0.125	0.160
6.7	10.02	1.014	1.018	0.996	59.4	1.16	0.142	0.165
	.08	1.014	1.023	0.991				
	.17	1.028	1.024	1.004				
	.22	1.032	1.039	0.993				
	.27	1.028	1.045	0.984	63.4	1.12	0.145	0.162
	12.10	1.088	1.083	1.005	71.9	1.05	0.141	0.148
	.17	1.090	1.091	0.999				
	.20	1.081	1.100	0.983				
	.27	1.080	1.082	0.998				
	.30	1.086	1.098	0.989	71.0	1.06	0.137	0.145
	14.03	1.105	1.100	1.005	58.5	1.17	0.122	0.143
	.07	1.101	1.102	0.999				
	.10	1.088	1.121	0.971				
	.13	1.101	1.116	0.987				
	.16	1.094	1.099	0.995	56.3	1.20	0.120	0.144

[illegible]

Appendix Table 3 (continued)

1968	TST	Å 158	Å 207-1	Q	h	m	β	mβ
C A P R I								
9.7	09.08	1.110	1.119	0.992	49.6	1.31	0.076	0.100
	.12	1.118	1.135	0.985				
	.15	1.119	1.133	0.988				
	.27	1.144	1.131	1.011				
	.33	1.152	1.161	0.992	54.1	1.23	0.077	0.095
	09.46	1.148	1.157	0.992	56.4	1.20	0.078	0.094
	.50	1.158	1.166	0.993				
	.54	1.164	1.176	0.990				
	.57	1.169	1.176	0.994				
	10.00	1.174	1.184	0.992	58.5	1.17	0.078	0.091
	11.16	1.192	1.199	0.994	69.3	1.07	0.078	0.083
	.19	1.193	1.199	0.995				
	.23	1.190	1.198	0.993				
	.27	1.188	1.196	0.993				
	.31	1.188	1.190	0.998	70.8	1.06	0.077	0.082
	11.45	1.205	1.212	0.994	71.5	1.06	0.076	0.081
	.49	1.206	1.211	0.996				
	.52	1.211	1.215	0.997				
	.56	1.208	1.215	0.994				
	12.01	1.211	1.224	0.989	71.7	1.05	0.075	0.079
G O R N E R G R A T								
22.7	08.58	1.467	1.494	0.982	44.9	1.41	0.014	0.020
	09.02	1.472	1.496	0.984				
	.06	1.475	1.503	0.981				
	.10	1.478	1.506	0.981				
	.15	1.479	1.503	0.984	47.6	1.35	0.014	0.019
	09.22	1.479	1.508	0.981	48.7	1.33	0.015	0.020
	.27	1.486	1.513	0.982				
	.31	1.490	1.515	0.983				
	.35	1.489	1.519	0.980				
	.42	1.486	1.513	0.982	52.0	1.27	0.015	0.019
S T O C K H O L M								
30.4	11.03	1.230	1.238	0.994	44.3	1.43	0.048	0.069
	.10	1.237	1.245	0.994				
	.13	1.243	1.239	1.003	44.7	1.42	0.048	0.068
11.6	13.25	1.294	1.311	0.987	50.7	1.29	0.034	0.044
	.29	1.294	1.313	0.986				
	.31	1.258	1.272	0.989				
	.35	1.261	1.280	0.985				
	.37	1.273	1.294	0.984	49.9	1.31	0.034	0.045

Appendix Table 4 Comparison between the pyrheliometers Å 158 and Å 585 at Capri, Gornergrat and Stockholm.

1968	TST	Å 158	Å 585	Q	h	m	β	mβ
C A P R I								
10.7	11.57	1.129	1.137	0.993	71.7	1.05	0.098	0.103
	12.01	1.136	1.135	1.001				
	.05	1.136	1.135	1.001				
	.08	1.144	1.141	1.003				
	.12	1.147	1.149	1.002	71.4	1.06	0.098	0.104
	12.23	1.144	1.147	0.997	71.0	1.06	0.097	0.103
	.27	1.145	1.149	0.997				
	.31	1.149	1.150	0.999				
	.35	1.146	1.153	0.994				
	.39	1.143	1.145	0.998	69.8	1.06	0.096	0.102
G O R N E R G R A T								
25.7	08.42	1.393	1.419	0.981	41.8	1.50	0.017	0.025
	.45	1.398	1.419	0.985				
	.50	1.403	1.423	0.986				
	.53	1.404	1.428	0.983				
	.57	1.408	1.429	0.983	44.3	1.43	0.017	0.024
	09.10	1.415	1.442	0.981	46.4	1.38	0.017	0.023
	.15	1.421	1.446	0.983				
	.19	1.426	1.446	0.986				
	.23	1.432	1.453	0.986				
	.26	1.433	1.458	0.983	48.9	1.33	0.017	0.023
S T O C K H O L M								
11.6	13.41	1.282	1.285	0.998	49.6	1.31	0.035	0.046
	.47	1.280	1.282	0.998				
	.48	1.282	1.280	1.002				
	.50	1.286	1.289	0.998				
	14.06	1.256	1.260	0.997	47.5	1.36	0.035	0.048

Appendix Table 5 Comparison between the pyrheliometers Å 171 and Å 585 at Capri and Gornergrat.

1968	TST	Å 171	Å 585	Q	h	m	β	mβ
C A P R I								
10.7	13.08	1.132	1.130	1.002	66.7	1.09	0.094	0.102
	.13	1.136	1.137	0.999				
	.15	1.136	1.133	1.003				
	.18	1.126	1.130	0.996				
	.21	1.129	1.129	1.000				
	.24	1.124	1.124	1.000	64.5	1.11	0.093	0.103
	13.51	1.108	1.112	0.996	60.3	1.15	0.091	0.105
	.54	1.108	1.111	0.997				
	.58	1.103	1.111	0.993				
	14.01	1.107	1.108	0.999				
	.06	1.095	1.102	0.994	58.1	1.18	0.091	0.107
G O R N E R G R A T								
25.7	10.10	1.473	1.482	0.994	55.3	1.22	0.017	0.021
	.15	1.471	1.478	0.995				
	.18	1.476	1.485	0.994				
	.22	1.477	1.485	0.995				
	.25	1.475	1.483	0.995	57.2	1.19	0.017	0.020
	10.37	1.467	1.479	0.992	58.6	1.17	0.017	0.020
	.40	1.475	1.481	0.996				
	.44	1.483	1.482	1.001				
	.48	1.472	1.478	0.996				
	.52	1.478	1.481	0.998				
	.57	1.478	1.480	0.999	60.6	1.15	0.017	0.020

Appendix   Table 6   Turbidity measurements at Capri, Gornergrat and Stockholm

1968	TST	h	p	$S \cdot I_T$	$S \cdot I_k$	$S \cdot I_b$	$S \cdot F$	β_k	β_b	$\bar{\beta}$
C A P R I										
3.7	08.43	46.2	985	1.193	0.440	0.257	0.274	0.061	0.060	0.060
	10.53	68.1	985	1.281	0.482	0.300	0.261	0.068	0.054	0.061
	14.08	57.0	985	1.151	0.440	0.273	0.324	0.083	0.067	0.075
5.7	08.27	43.1	988	1.071	0.361	0.216	0.265	0.104	0.092	0.098
	09.42	56.9	988	1.138	0.422	0.251	0.290	0.096	0.090	0.093
	11.06	69.4	988	1.181	0.440	0.280	0.295	0.101	0.077	0.089
	12.24	71.2	988	1.168	0.428	0.240	0.240	0.114	0.127	0.120
	13.52	59.6	988	1.113	0.391	0.224	0.243	0.127	0.128	0.127
	15.37	40.4	988	0.965	0.306	0.193	0.280	0.139	0.107	0.123
6.7	09.18	50.7	989	1.001	0.406	0.191	0.290	0.094	0.147	0.135
	11.12	69.9	989	1.097	0.394	0.214	0.239	0.142	0.162	0.152
	13.07	66.5	989	1.149	0.406	0.230	0.226	0.126	0.134	0.130
	14.47	49.7	989	1.097	0.380	0.210	0.237	0.111	0.120	0.116
8.7	08.12	40.1	993	1.143	0.426	0.208	0.307	0.053	0.089	0.053
	11.12	69.8	993	1.311	0.499	0.299	0.245	0.056	0.056	0.056
	12.24	70.9	993	1.297	0.499	0.300	0.260	0.057	0.056	0.057
	14.38	51.3	993	1.197	0.442	0.266	0.278	0.070	0.062	0.066
9.7	08.15	40.5	995	1.091	0.400	0.220	0.294	0.070	0.078	0.074
	10.45	66.5	995	1.213	0.474	0.266	0.278	0.071	0.088	0.080
	13.19	64.6	995	1.219	0.464	0.285	0.289	0.076	0.065	0.071
10.7	11.29	70.8	992	1.164	0.443	0.292	0.255	0.100	0.065	0.100
	14.16	55.1	992	1.113	0.423	0.248	0.313	0.091	0.089	0.090
11.7	09.45	56.9	987	1.058	0.393	0.231	0.313	0.119	0.113	0.116
	14.17	54.8	987	1.114	0.427	0.253	0.324	0.088	0.084	0.086
12.7	08.29	43.0	985	1.008	0.371	0.215	0.335	0.098	0.093	0.095
13.7	08.19	41.0	986	1.301	0.449	0.272	0.206	0.043	0.034	0.039
	10.35	64.7	986	1.361	0.523	0.304	0.228	0.036	0.047	0.041
	13.13	65.0	986	1.388	0.540	0.336	0.256	0.026	0.018	0.022
G O R N E R G R A T										
19.7	13.30	56.9	697	1.478	0.550	0.330	0.147	0.036	0.041	0.038
20.7	08.37	40.8	701	1.508	0.566	0.338	0.160	0.008	0.013	0.010
	11.00	62.2	701	1.550	0.587	0.353	0.132	0.019	0.027	0.023
22.7	08.15	38.5	700	1.502	0.548	0.330	0.145	0.013	0.014	0.013
	11.15	62.9	700	1.569	0.595	0.364	0.133	0.015	0.019	0.017
	14.10	52.8	700	1.521	0.579	0.355	0.164	0.016	0.017	0.016
25.7	09.45	52.5	750	1.512	0.580	0.340	0.160	0.011	0.023	0.017
S T O C K H O L M										
18.4	11.36	41.3	1016	1.228	0.426	-	0.221	0.055	-	0.055
22.4	11.06	40.9	1014	1.151	0.399	-	0.244	0.071	-	0.071
29.4	11.51	45.2	1007	1.295	0.487	-	0.263	0.029	-	0.029
30.4	10.49	45.5	1003	1.258	0.456	-	0.248	0.048	-	0.048
11.6	10.13	49.1	1021	1.351	0.502	-	0.230	0.026	-	0.026
	14.15	49.0	1021	1.307	0.484	-	0.241	0.037	-	0.037
13.6	10.03	48.4	1022	1.279	0.490	-	0.281	0.032	-	0.032
	13.50	49.0	1022	1.305	0.513	-	0.296	0.020	-	0.020
6.9	12.04	37.0	1021	0.829	0.285	0.153	0.236	0.137	0.138	0.138

Appendix Table 7 Series averages of comparisons between the pyrheliometers Å 158 and Å 171 at Capri, Gornergrat and Stockholm.

1968	TST	I_T	mβ	Q	Remarks
C A P R I					
3.7	08.55	1.197	0.079	1.001	
	11.33	1.211	0.068	1.000	
	13.36	1.112	0.083	0.998	
5.7	08.44	1.051	0.130	1.000	
	10.45	1.136	0.097	1.001	
	12.00	1.128	0.118	1.001	
	13.26	1.090	0.141	1.004	
	14.53	1.006	0.173	1.007	
6.7	09.37	0.992	0.169	1.005	
	11.32	1.082	0.153	1.003	
	12.44	1.123	0.142	1.001	
	14.24	1.075	0.146	1.007	
8.7	09.00	1.213	0.071	0.995	
	09.30	1.217	0.067	0.998	
	09.49	1.262	0.065	0.998	
	11.26	1.256	0.059	0.997	
	11.54	1.257	0.059	1.002	
	12.37	1.249	0.062	0.998	
	13.03	1.243	0.065	1.000	
	13.57	1.235	0.075	0.998	
	14.17	1.206	0.079	0.995	
11.7	10.45	1.079	0.116	1.008	
	10.50	1.086	0.115	1.006	Å 158 without filterholder, corrected.
	11.58	1.117	0.105	1.002	
	12.03	1.122	0.104	1.003	Å 158 without filterholder, corrected.
	13.04	1.136	0.102	1.004	Å 158 " " , " .
	13.49	1.111	0.104	1.002	
13.7	09.37	1.284	0.046	0.992	
	09.42	1.299	0.044	0.991	Å 158 without filterholder, corrected.
	11.22	1.306	0.037	0.989	Å 158 " " , " .
	11.52	1.312	0.032	0.991	
	12.26	1.327	0.028	0.992	Å 158 without filterholder, corrected.
	12.50	1.321	0.025	0.993	
	13.56	1.248	0.025	0.993	
	14.19	1.253	0.026	0.994	Å 158 without filterholder, corrected.
G O R N E R G R A T					
19.7	14.29	1.375	0.051	0.992	
20.7	09.07	1.470	0.019	0.992	
	09.28	1.479	0.020	0.994	Å 158 without filterholder, corrected.
	09.59	1.491	0.022	0.994	
	10.27	1.492	0.020	0.993	Å 158 without filterholder, corrected.
	12.59	1.469	0.027	0.993	
22.7	08.33	1.453	0.021	0.991	
	12.37	1.499	0.019	0.991	
	13.21	1.482	0.019	0.990	
25.7	11.10	1.469	0.019	0.992	
S T O C K H O L M					
29.4	13.56	1.281	0.045	0.999	
11.6	11.01	1.314	0.036	0.999	
6.9	12.14	0.865	0.230	1.015	
	12.34	0.872	0.232	1.017	

Appendix Table 8 Series averages of comparisons between the pyrheliometers Å 158 (with and without filterholder) and Å 171 at Capri and Gornergrat.

1968	TST	I_T	mβ	Q_1	Q_2	Q_1/Q_2	$Q_{158/171}$
				with filterholder	without filterholder	with/without	corrected
CAPRI							
11.7	10.45	1.079	0.116	1.0076	-	0.999	
	10.50	1.086	0.115	-	1.0090		1.006
	11.58	1.117	0.105	1.0024	-	0.997	
	12.03	1.122	0.104	-	1.0050		1.003
	13.04	1.136	0.102	-	1.0070	0.995	1.004
	13.49	1.111	0.104	1.0020			
13.7	09.37	1.284	0.046	0.9922		1.001	
	09.42	1.299	0.044	-	0.9910		0.991
	11.22	1.306	0.037	-	0.9894	1.002	0.989
	11.52	1.312	0.032	0.9910	-		
	12.26	1.327	0.028	-	0.9922	1.000	0.992
	12.50	1.321	0.025	0.9926	-		
	13.56	1.248	0.025	0.9930	-	0.999	
	14.19	1.253	0.026	-	0.9937		0.994
GORNERGRAT							
20.7	09.07	1.470	0.019	0.9918	-	0.999	
	09.28	1.479	0.020	-	0.9932		0.994
	09.59	1.491	0.022	0.9936	-	1.001	
	10.27	1.492	0.020	-	0.9926		0.993

Table 9 Series averages of comparisons between the pyrheliometers Å 158 and Å 70 at Capri, Gornergrat and Stockholm.

1968	TST	I_T	mβ	Q
CAPRI				
3.7	09.28	1.206	0.074	0.963
	13.03	1.132	0.077	0.966
9.7	12.18	1.211	0.078	0.966
	12.51	1.191	0.077	0.967
	14.07	1.123	0.081	0.967
	14.33	1.091	0.084	0.968
GORNERGRAT				
22.7	10.02	1.499	0.018	0.964
	10.53	1.503	0.019	0.966
STOCKHOLM				
18.4	13.49	1.164	0.091	0.977
29.4	12.00	1.269	0.041	0.951
	12.20	1.306	0.041	0.966
30.4	11.21	1.240	0.068	0.968
11.6	11.27	1.331	0.037	0.972

Appendix Table 10 Series averages of comparisons between the pyrheliometers Å 158 and Å 207-1 at Capri, Gornergrat and Stockholm.

1968	TST	I_T	mβ	Q
C A P R I				
3.7	12.28	1.173	0.073	0.996
	09.14	1.081	0.118	0.986
	11.27	1.133	0.106	0.987
	12.50	1.126	0.133	0.991
	14.30	1.052	0.158	0.989
6.7	10.02	1.023	0.155	0.994
	12.10	1.085	0.147	0.995
	14.03	1.098	0.144	0.991
9.7	09.08	1.129	0.097	0.994
	09.46	1.163	0.092	0.992
	11.16	1.190	0.082	0.995
	11.45	1.208	0.080	0.994
G O R N E R G R A T				
22.7	08.58	1.474	0.019	0.982
	09.22	1.486	0.019	0.982
S T O C K H O L M				
30.4	11.03	1.237	0.068	0.997
	13.25	1.276	0.044	0.986

Table 11 Series averages of comparisons between the pyrheliometers Å 158 and Å 585 at Capri, Gornergrat and Stockholm.

1968	TST	I_T	mβ	Q
C A P R I				
10.7	11.57	1.138	0.103	1.000
	12.23	1.146	0.102	0.997
G O R N E R G R A T				
25.7	08.42	1.401	0.025	0.984
	09.10	1.425	0.023	0.984
S T O C K H O L M				
11.6	13.41	1.277	0.047	0.999

Table 12 Series averages of comparisons between the pyrheliometers Å 171 and Å 585 at Capri and Gornergrat.

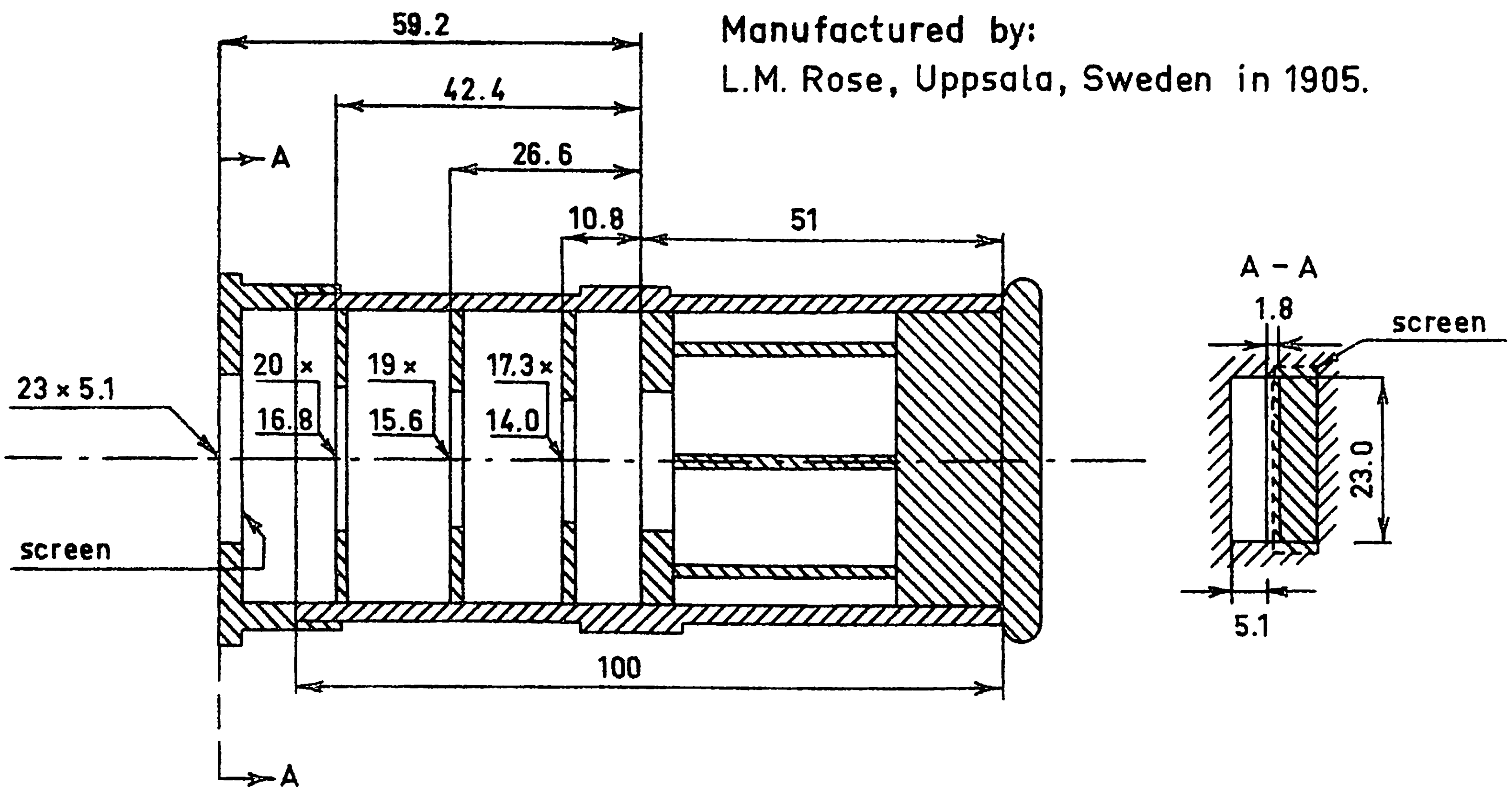
1968	TST	I_T	mβ	Q
C A P R I				
10.7	13.08	1.130	0.096	1.000
	13.51	1.104	0.104	0.996
G O R N E R G R A T				
25.7	10.10	1.474	0.020	0.995
	10.37	1.476	0.020	0.997

Appendix Table 13 Temperature and humidity measured at the same time as the turbidity in table 6.

1968	TST	T	Tw	R	e	F	m	Remarks
CAPRI								
3.7	08.43	+25.4	+19.5	57	18.5	0.265	1.39	
	10.53	+27.8	+19.5	45	16.8	0.252	1.08	
	14.08	+29.5	+19.0	37	15.3	0.313	1.19	
5.7	08.27	+25.0	+18.9	56	17.7	0.256	1.46	
	09.42	+27.0	+18.5	44	15.7	0.281	1.19	
	11.06	+28.6	+19.0	40	15.7	0.285	1.07	
	12.24	+30.5	+20.5	40	17.5	0.232	1.06	
	13.52	+29.0	+19.2	39	15.6	0.235	1.16	
	15.37	+28.5	+22.8	61	23.7	0.271	1.54	
6.7	09.18	+26.8	+20.0	53	18.7	0.281	1.29	
	11.12	+29.1	+20.5	45	18.1	0.231	1.07	
	13.07	+30.5	+20.2	39	17.0	0.219	1.09	
	14.47	+30.0	+21.6	47	19.9	0.229	1.31	
8.7	08.12	+26.0	+19.0	51	17.1	0.297	1.55	
	11.12	+29.8	+22.3	52	21.8	0.237	1.07	
	12.24	+28.5	+22.4	58	22.6	0.252	1.06	
	14.38	+30.5	+22.9	52	22.7	0.269	1.28	
9.7	08.15	+27.2	+22.8	68	24.5	0.284	1.54	
	10.45	+29.8	+22.8	54	22.7	0.269	1.09	
	13.19	+30.5	+23.3	54	23.6	0.280	1.11	
10.7	11.29	+31.0	+24.6	59	26.5	0.247	1.06	
	14.16	+30.9	+25.0	61	27.2	0.303	1.22	
11.7	09.45	+28.2	+24.2	69	26.4	0.303	1.19	
	14.17	+30.5	+23.6	55	24.0	0.313	1.22	
12.7	08.29	+27.5	+23.4	70	25.7	0.324	1.47	
13.7	08.19	+22.8	+19.4	72	20.0	0.199	1.52	
	10.35	+26.2	+19.0	50	17.0	0.247	1.11	
	13.13	+27.0	+20.3	54	19.3	0.248	1.10	
GORNERGRAT								
19.7	13.30	+3.1	+0.6	68	5.2	0.143	1.19	
20.7	08.37	+1.0	-3.3	45	2.9	0.155	1.53	ice on wet bulb
	11.00	+2.2	-1.3	57	4.0	0.128	1.13	" " " "
22.7	08.15	+2.2	-3.0	27	1.9	0.140	1.61	ice on wet bulb
	11.15	+1.7	-3.0	33	2.3	0.129	1.12	" " " "
	14.10	+3.5	-1.5	41	3.2	0.159	1.26	
25.7	09.45	+7.9	+4.5	62	6.6	0.155	1.26	
STOCKHOLM								
18.4	11.36	+13.6	+7.5	41	6.4	0.219	1.51	
22.4	11.06	+16.5	+9.8	42	7.9	0.241	1.53	
29.4	11.51	+14.0	+7.9	42	6.7	0.259	1.41	
30.4	10.49	+15.4	+9.2	43	7.5	0.244	1.40	
11.6	10.13	+18.5	+10.6	36	7.7	0.223	1.32	
	14.15	+20.8	+12.0	34	8.3	0.234	1.33	
13.6	10.03	+24.7	+16.7	44	13.7	0.272	1.34	
	13.50	+28.0	+18.4	39	14.7	0.287	1.33	
6.9	12.04	+25.3	+18.1	50	16.1	0.232	1.66	

COMPENSATION PYRHELIOMETER by K. Ångström No 70

Manufactured by:
L.M. Rose, Uppsala, Sweden in 1905.

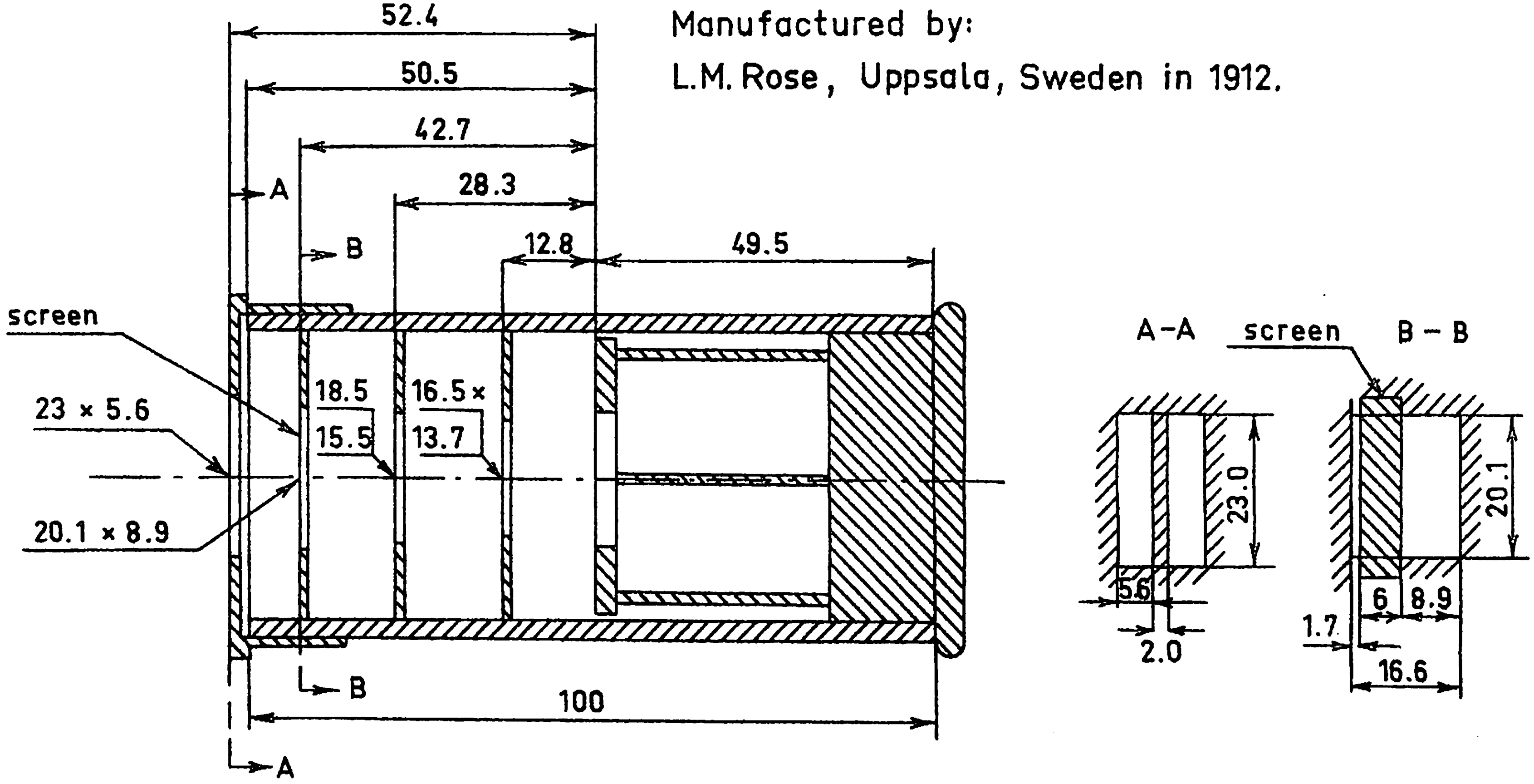


The strips: 19.6 × 2.0
Note: All values are given in mm

FIG 7

COMPENSATION PYRHELIOMETER by K. Ångström No 158

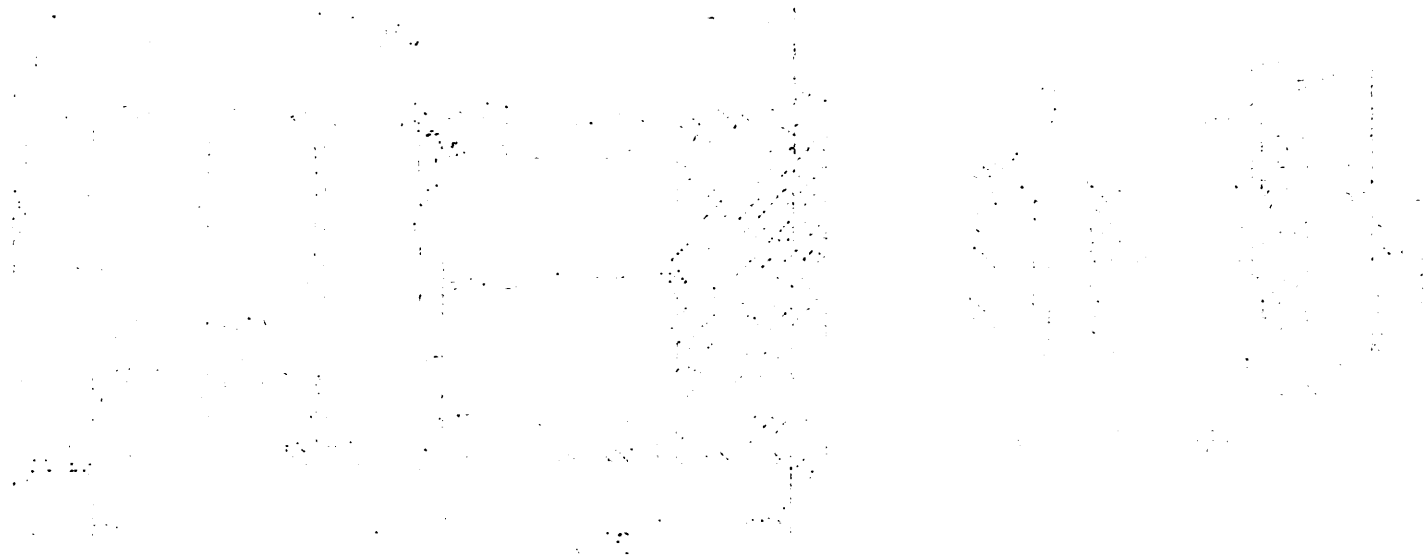
Manufactured by:
L.M. Rose, Uppsala, Sweden in 1912.



The strips: 19.4 × 2.0

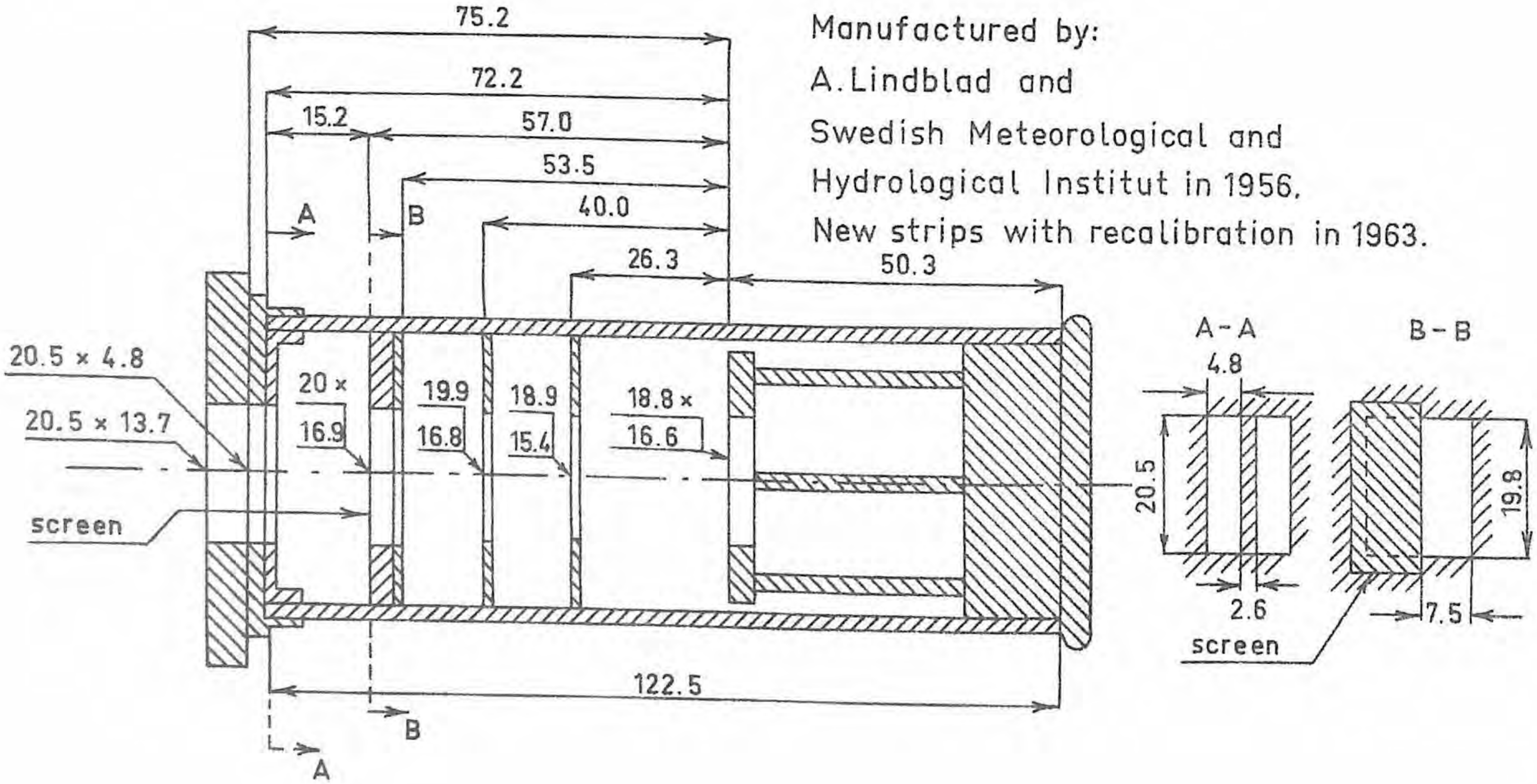
Note: All values are given in mm

FIG 8



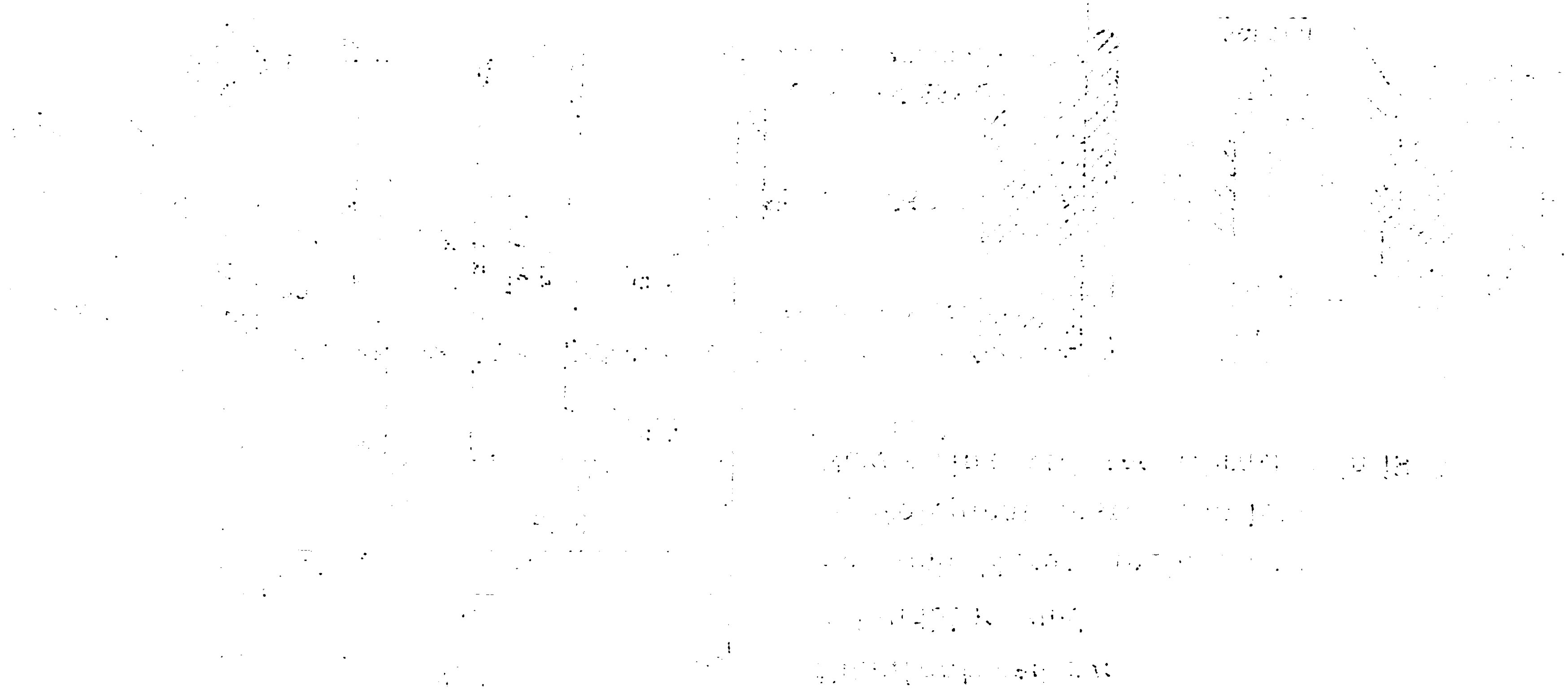
COMPENSATION PYRHELIOMETER by K. Ångström No 171

Manufactured by:
A. Lindblad and
Swedish Meteorological and
Hydrological Institut in 1956.
New strips with recalibration in 1963.

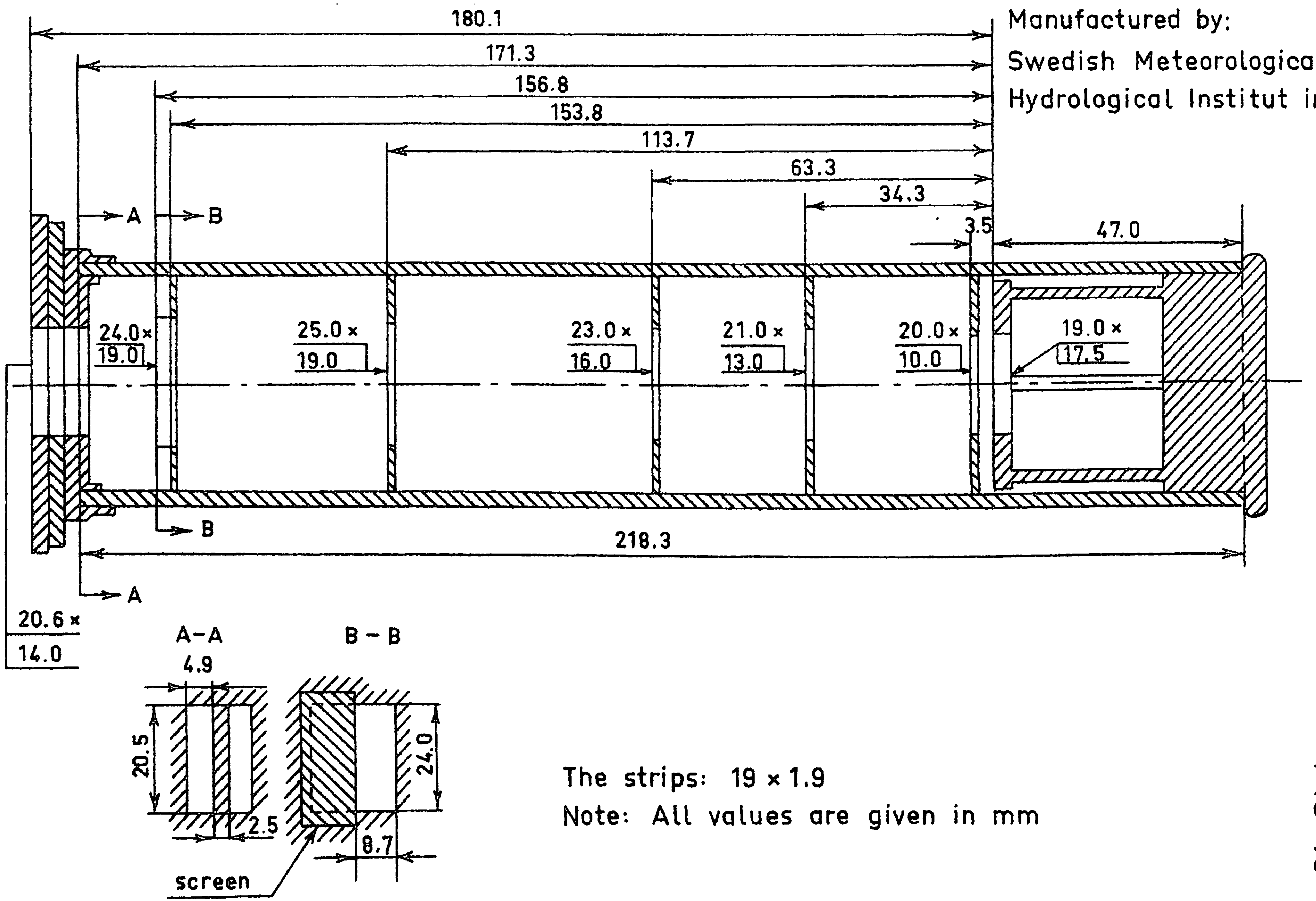


The strips: 18.8 × 1.9
Note: All values are given in mm

FIG 9



COMPENSATION PYRHELIOMETER by K. Ångström No 207-1



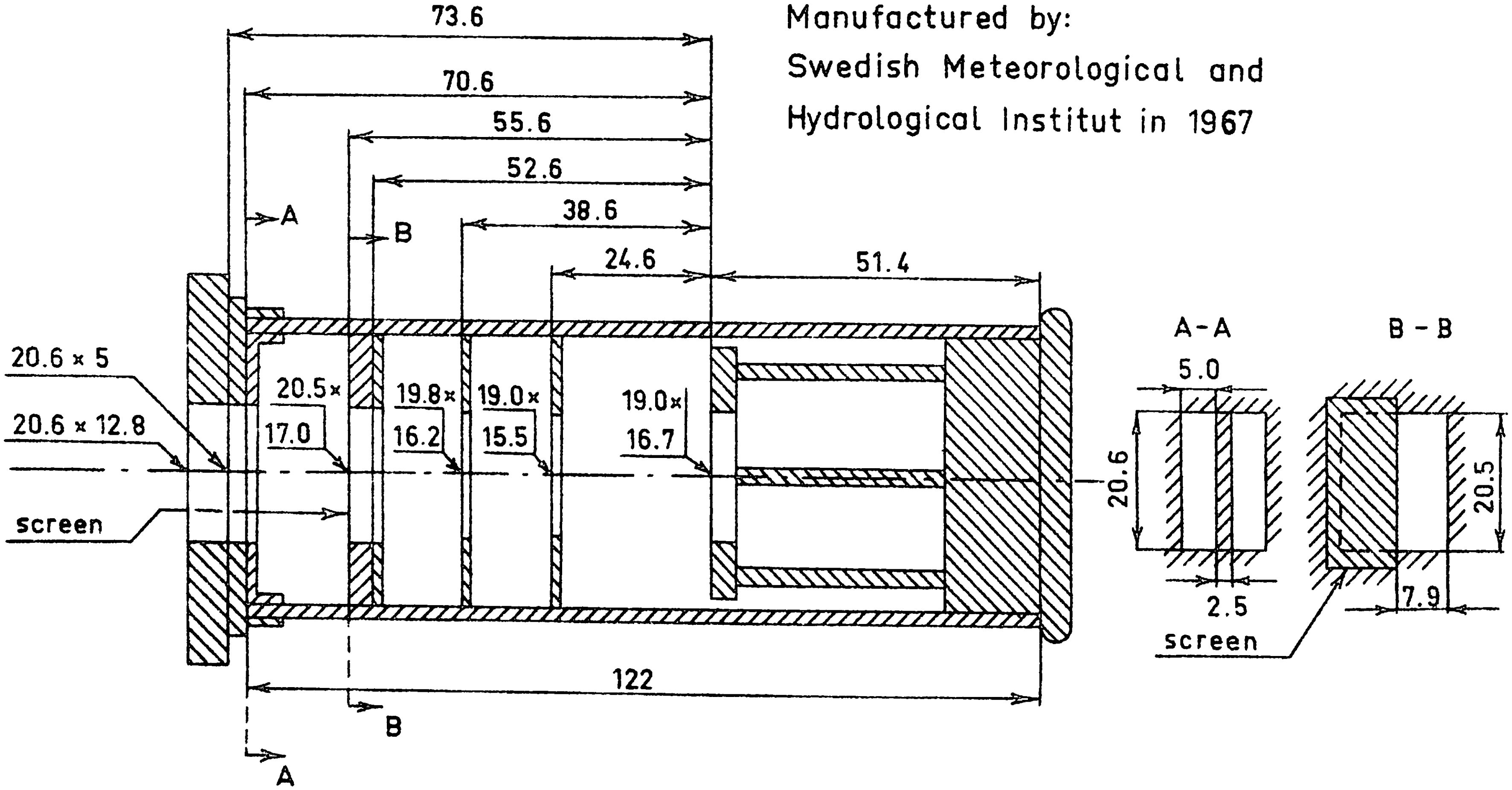
Manufactured by:
Swedish Meteorological and Hydrological Institut in 1958

The strips: 19 × 1.9
Note: All values are given in mm

FIG 10

COMPENSATION PYRHELIOMETER by K. Ångström No 585

Manufactured by:
Swedish Meteorological and
Hydrological Institut in 1967



The strips: 19 × 1.9

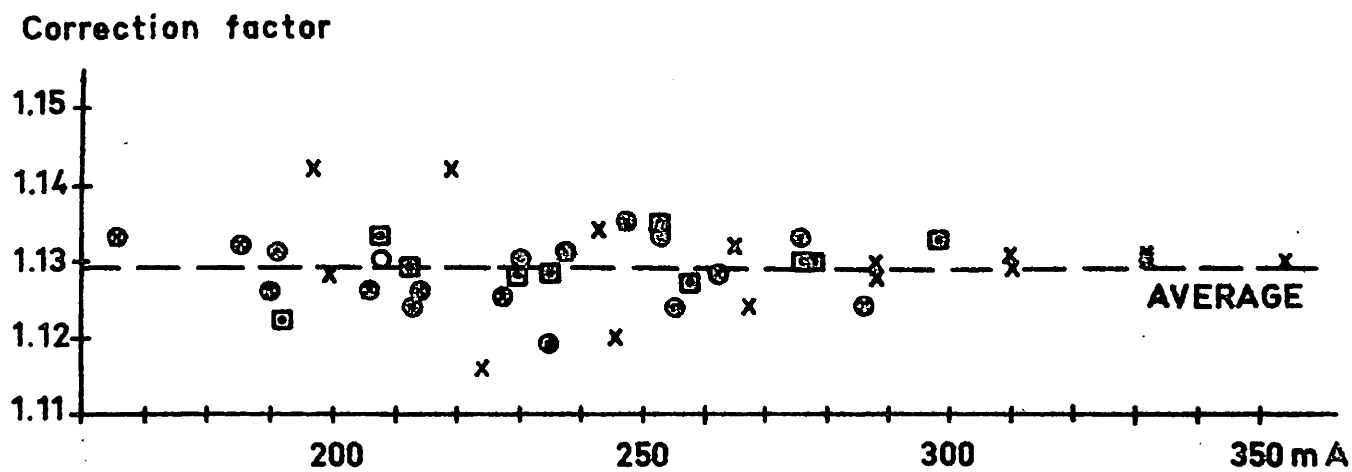
Note: All values are given in mm

FIG 11

FIG.12

APPENDIX CORRECTION FACTOR INCOMPLETE RECTIFICATION OF HEATING CURRENT

Capri July, 3-6, 1968



The dots refer to the following instruments:

⊗ Å 70 × Å 171

⊙ A 158 ▣ Å 207-1

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