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A NEW LIQUID DISTILLATION TYPE INSTRUMENT FOR INTEGRATING SOLAR RADIATION

by

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Abstract

A liquid distillation type pyranometer with a flat receptor has been developed. Comparison with other radiation meters shows that the calibration factor of the new instrument is practically independent of the elevation angle of the sun and of the albedo of the ground, in contrast to the classical Bellani Spherical Pyranometer.

1. *Introduction*

The principle of a radiation meter for integrating insolation by distillation process was introduced by P. ANGELO BELLANI in 1836 [1]. Many modifications and improvements have been made on the instrument during the following century. A through investigation by COURVOISIER and WIERZEJEWSKI [2] is one of the latest on this field. The instrument constructed by them has participated in the comparison described later.

The Bellani Spherical Pyranometer (Fig. 1) is characterized by a spherical receptor (a). It consists of a metallized glass sphere inside of an evacuated glass globe (b). The inner sphere is partly filled with ethyl alcohol. A tube (c) leads to a graduated condenser (d). The alcohol evaporated in the sphere will collect in the condenser tube. The amount of condensed alcohol is a linear function of the radiation energy on the

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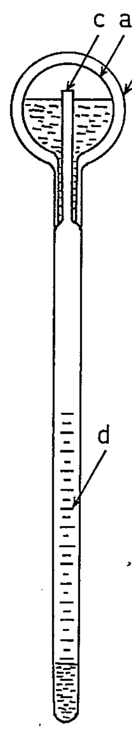

Fig. 1. Construction of the Bellani pyranometer, model Davos Observatory.

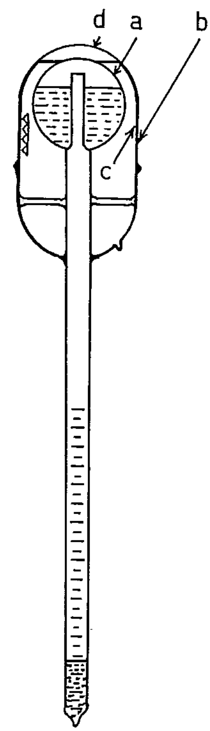

Fig. 2. Construction of the new pyranometer with a flat receptor.

inner sphere. A suitable calibration factor must be derived to convert the amount of collected alcohol into units of radiation energy. Because the receptor is a sphere, the results cannot readily be converted into equivalent radiation on a flat surface.

2. *Construction of the new instrument*

The pyranometer developed and manufactured by the author (Fig. 2) consists of basic parts similar to those at the Bellani pyranometer. The inner sphere (a) is covered with copper and blackened chemically (CuS). The outer globe (b) is silver-plated (c) and polished inside with the exception of a circular area on the top of the globe (d). The radiation exchange is thus possible only through this uncoated area. A circular part of a plane, bounded by the upper edge of the silver plating, acts as the radiation receiving surface of the instrument. All radiation energy through this opening reaches the black surface of the inner sphere either directly or by reflecting from the polished silver surface. Because the receptor is a »flat plate», the amount of collected alcohol is a linear function of the hemispherical radiation incident upon a horizontal surface and can be simply converted into energy units by multiplying the instrument reading by a constant calibration factor (K).

3. *Comparison with other instruments*

The liquid distillation pyranometer with a flat receptor assumed its final shape in December 1967 after a development work of about a year. In the beginning of 1968 it was compared with a spherical pyranometer, type Courvoisier—Wierzejewski (model Davos Observatory) and with a Moll—Gorczynski solarimeter. The comparisons were made at the Jokioinen Observatory of the Finnish Meteorological Institute under the direction of Mr. Pentti Järvi, M.Sc.

Results of the comparison are shown in Table 1. Daily radiation totals were measured with a Moll—Gorczynski solarimeter (in some cases totals of two or three consecutive days were used). The amounts of distilled alcohol were read at the same intervals from the scales of model Wilska and model Davos Observatory pyranometer. The whole comparison period is divided in Table 1 into six subperiods, each of which contains six or seven days. The calibration factor (K) is derived for each subperiod and for both pyranometers. The daily radiation totals given by the pyranometers are now obtained by multiplying the pyranometer readings (which refer to milliliters of distilled alcohol) by the calibration factor K.

The results of the comparison are also represented in Figs.3 and 4. The horizontal scale gives the pyranometer readings in milliliters of alcohol and the vertical scale indicates the simultaneous daily radiation totals recorded with Moll—Gorczynski solarimeter. The results for model Wilska pyranometer are presented in Fig. 3 and those for model Davos Observatory in Fig. 4. The mean temperature during the daytime rose during the comparison period from about -10 to $+5$°C and the highest elevation angle of the sun from about 17° to 32°. The snow cover decreased from 100% to less than 50%.

Table 1. Comparison of radiation instruments at Jokioinen Observatory Feb. 15—Apr. 1. 1968.

Date	Moll—Gorczynski Solarimeter	Model Wilska Pyranometer			Model Davos Observatory Pyranometer		
	Daily radiation total gcal/cm²	Pyranometer reading ml.	Daily total gcal/cm²	Difference	Pyranometer reading ml.	Daily total gcal/cm²	Difference
Feb. 15	58	2.2	64	+6	6.9	55	−3
16	110	2.7	78	−32	17.9	143	+33
17	81	2.7	78	−3	10.9	87	+6
19	220	6.6	191	−29	29.0	231	+11
20	69	3.0	87	+18	7.4	59	−10
21	90	3.4	98	+8	10.5	84	−6
22	87	4.3	124	+37	10.4	83	−4
	Total 715	24.9 K=28.7			93.0 K=7.68		
Feb. 23	119	4.1	119	0	15.9	124	+5
24	7	0.2	6	−1	1.6	13	+6
25	59	1.6	46	−13	6.4	51	−8
26	156	5.2	151	−5	17.1	136	−20
27	204	3.9	113	+9	11.6	93	−11
28	138	4.8	139	+1	16.7	133	−5
29	144	5.2	150	+6	16.4	147	+3
	Total 727	25.0 K=29.0			87.4 K=8.32		
Mar. 1	182	6.4	179	−4	23.6	212	+29
2	44	1.7	48	+4	6.4	55	+11
4	323	11.9	330	+7	35.4	304	+19
5	63	22.3	62	−1	7.0	60	−3
6	42	1.8	50	+8	5.7	49	+7
7	169	5.6	157	−12	19.7	169	0
8	90	3.4	95	+5	8.8	75	−15
	Total 914	32.7 K=28.0			106.6 K=8.58		
Mar. 11	414	13.7	403	−9	41.7	378	−36
12	227	7.5	221	−5	25.7	233	+6
13	141	5.3	159	+18	15.5	140	−1
14	117	4.8	141	+24	13.0	118	+1
15	269	8.4	247	−22	30.1	280	+11
16	42	1.0	28	+14	7.6	69	+27
17	268	9.6	282	+14	29.1	264	−4
	Total 1478	50.3 K=29.4			163.0 K=9.06		
Mar. 18	267	8.9	245	−22	24.2	276	+9
19	276	10.5	288	+12	20.9	238	−38
20	179	6.6	181	+2	17.8	203	+24
21	60	2.3	63	+3	6.4	73	+13
22	90	3.5	96	+6	7.3	83	−7
23	71	2.5	69	−2	6.2	72	+1
	Total 943	34.3 K=27.5			82.2 K=11.4		
Mar. 25	321	12.7	344	+23	19.9	395	+74
26	139	5.9	160	+21	7.9	157	+18
27	60	2.7	73	+13	5.8	115	+55
28	228	6.8	184	−44	7.4	147	−81
29	322	11.0	298	−24	14.7	291	−30
Apr. 1	495	18.8	509	−14	23.2	458	−37
	Total 1565	57.9 K=27.1			78.9 K=19.8		

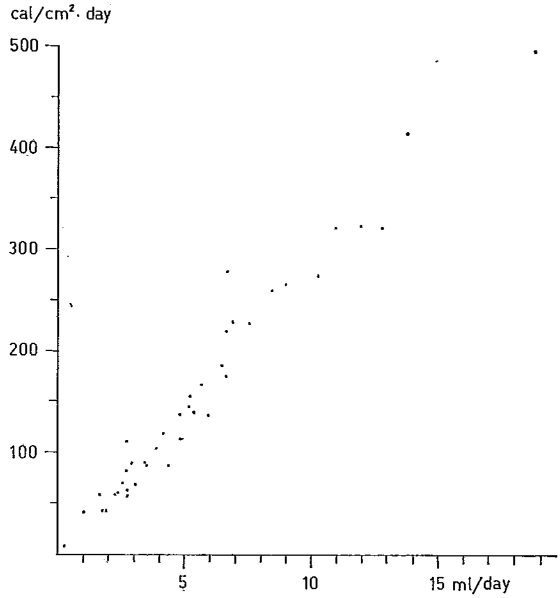

Fig. 3. Pyranometer readings versus daily radiation totals, model Wilska pyranometer.

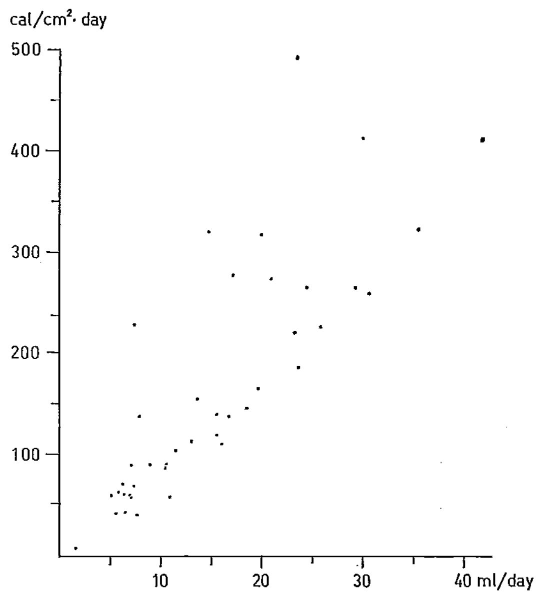

Fig. 4. Pyranometer readings versus daily radiation totals, model Davos Observatory pyranometer.

4. *Discussion*

PEREIRA [3] and VALTANEN [4] have shown that it is possible to obtain satisfactory results in unchanged environmental conditions with the classical spherical pyranometer but the calibration factor K is largely affected by seasonal and other variations in the surroundings of the meter. The present study confirms the same result. Table 1 shows that the calibration factor K for model Davos Observatory increases from 7,68 to 19,8 during the whole period whereas K for the Wilska model remains almost unchanged. The small changes are apparently due to temperature variations. No temperature corrections were made to the readings.

Fig. 3 consequently shows that the correlation between the amount of distilled alcohol and the daily insolation is considerably high in the new construction but rather low in the Davos Observatory model as shown in Fig. 4. It is unnecessary to make a more complete analysis since only one example of each model was examinated.

5. *Conclusions*

The investigation shows evidently that the cosine response of the new pyranometer is nearly perfect while the classical Bellani pyranometer does not follow the cosine law at all.

The integrating accuracy of the new instrument will probably be as good as that in the best short wave radiation meters (after the temperature correction has been derived).

The new pyranometer will fill up the gap which has existed up to now. The instrument is accurate, it does not need electric power, it is simple to use and holds its calibration for years and, finally, it is inexpensive.

6. *Manufacturing of the instrument*

The new pyranometer is manufactured and delivered by the author. (See title page for address). Some tens of pyranometers have been delivered until now.

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