THE COOLING POWER IN THESSALONIKI - GREECE

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The first measurements of the cooling power, as mentioned by THILENIUS & DORNO (I), have been held by Dr. H e b e d e n * in 1826. Early in the 20th century we have F. F r a n k e n h ä u s e r ' s «Homöotherm» in 1911 **, and the «Kata-thermometer» invented by Prof. Sir Leonard HILL (II, III) in 1916. This last instrument, because of its great simplicity and its easy use, has become one of the most widely used for measurements of the cooling power.

In Greece, the first measurements of the cooling power with a Hill Kata-thermometer have been held by B. KYRIAZOPOULOS in 1933 at the site of the Mt. Parnes Sanatorium and at an elevation of almost 1000 meters (IV).

Systematic observations of the cooling power were started in our Meteorological Institute on January 1, 1951, with observation-time at 13 : 30 hours (local time). These observations have been increased, since September 1, 1953 to three daily, and they are carried at 08 : 30 - 13 : 30 - 18 : 30 hours (local time = GMT + 2).

The observation hours have been chosen for being the hours of the traffic-peak, at least for the inhabitants of greek cities: 08 : 30 hours and 13 : 30 hours are the time when working people and students are going to, or coming from their daily occupations, while 18 : 30 hours, besides being symmetrical to 08 : 30 as to the mid-day observation(5h interval), it is also the time at which the greatest part of the inhabitants of a greek city are going either to some social event or to market. The same observation-hours are mentioned by MACHETANZ (V), in his study of the cooling power at the Kenya plateau, in the area of Nairobi.

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* Dr. Hebeden: Trans. Roy. Soc., London 1826, II, p. 69.

** F. Frankenhäuser: Zeitschr. f. Balneol., Berlin 1911/12, Vol. 4, s. 439.

The material used in the present paper, comes from measurements of the cooling power taken at the 13 : 30 hours observation for the period between 1.1.1951 till 31.12.1956, and also from the other two daily observations for the period from 1.1.1954 till 31.12.1956.

Measurements of the cooling power have been taken in the gardens of the University of Thessaloniki, within the enclosure of the Meteorological Station of the Institute of Meteorology and Climatology (elevation 26 m), always in the shade and near the meteorological shelter. The instruments used for these measurements were Hill Katathermometers *.

From the total number of 4.384 observations possible, 4.235 have been realized, that is a percentage of 96,6 %; measurements have been impossible, because of extremely high air temperatures (tair $>$ 35° C) in another 102 cases, that is a percentage of 2,3 %.

TABLE I

	08 : 30	13 : 30	18 : 30	
June	—	19	—	
July	—	34	1	(27.7.1955)
August	—	43	—	
September	—	5	—	
TOTAL	0	101	1	

Observations were withheld for various other reasons in 47 cases, that is in a percentage of 1,1 %.

From TABLE I we draw the following conclusions, as to the distribution of these 102 cases, during which it has been impossible to take the readings of the kata-thermometer because of the extremely high air-temperatures:

1. These cases are seasonally grouped in the warm summer season, and mainly in the months of August and July.

2. Almost the total of these cases occur during the mid-day observation, only once in the afternoon, and never in the morning. This fact is in full accordance with the variation of mean air-temperature in Thessaloniki where, as a rule, values of air-temperature are in the morning (around 08 : 00 hours) 2 - 3° C below those of the afternoon (around 18 : 00 hours).

* Manufacturer J. J. Hicks - England. With factors F = 422 & F = 441.

TABLE II

Mean Monthly and Annual Values of the Cooling Power in Thessaloniki (mg. Cal cm^{-2} sec^{-1})

	08 : 30			13 : 30			18 : 30		
	Cooling power	Air temp. (°C)	Wind vel. m/sec	Cooling power	Air temp. (°C)	Wind vel. m/sec	Cooling power	Air temp. (°C)	Wind vel. m/sec
J	15.74	4.8	1.7	13.73	9.1	2.0	15.19	7.5	1.9
F	14.87	5.1	2.1	13.62	10.3	2.0	14.43	7.9	1.9
M	12.76	7.4	1.3	12.41	13.0	1.8	12.84	10.5	1.4
A	11.05	13.0	1.2	9.16	18.6	1.8	11.38	15.6	1.5
M	7.49	19.2	0.8	6.00	24.1	1.8	7.78	20.9	1.5
J	5.00	24.6	0.7	3.72	29.1	1.9	5.36	26.2	1.8
J	4.23	27.0	0.8	2.56	31.6	1.8	4.22	29.0	1.9
A	4.50	25.9	1.1	2.57	31.9	1.6	4.52	28.2	1.7
S	6.17	21.6	1.0	4.35	27.7	1.6	6.34	23.9	1.4
O	8.10	15.4	1.0	8.10	20.1	1.6	8.30	17.7	1.3
N	11.55	9.6	2.1	10.91	14.2	2.0	11.66	11.5	2.1
D	13.05	5.5	1.4	11.83	11.0	2.0	12.77	8.1	1.5
Year	9.54	14.9	1.3	8.25	20.1	1.8	9.57	17.3	1.7
N	1087			2078			1070		4235

N o t i c e : The air-temperature has been taken from the air - temperature - recorder, which has been functioning inside the meteorological shelter and at a distance of less than 1 m from the site where the readings of the kata-thermometer were taken.

Wind velocity was taken from the recordings of the Dines anemograph, installed on the meteorological tower of the Central building of the University, at an elevation of 53 m, and a horizontal distance of almost 30 meters from the site of the measurements.

From the data of TABLE II, we draw the conclusion that January, which is also the coldest month of the year, has the highest mean monthly values of cooling power:

15.74 13.73 15.19

The above values, according to the D o r n o and also the MÖRIKOFER (VI) classifications, give as a mean a feeling of c o l d (for the morning and afternoon), while for the mid-day they give a feeling of c o m f o r t a b l y c o l d o r c o m f o r t a b l y c o o l.

July, which is the warmest month of the year, has the smallest mean monthly values of cooling power:

4.23 2.56 4.22

The above values, according to the Dorno classification, give as a mean for all three daily observations, a warm feeling, while according to Mörikofer they give a discomfortably warm or hot feeling.

In TABLE III we have included mean values, and also the absolute maxima and minima recorded in Thessaloniki during the period examined.

TABLE III

	08 : 30			13 : 30			18 : 30		
	Abs. Max.	Mean	Abs. Min.	Abs. Max.	Mean	Abs. Min.	Abs. Max.	Mean	Abs. Min.
J	31.50	15.74	8.48	29.37	13.73	7.11	31.50	15.19	7.87
F	44.10	14.87	8.48	33.92	13.62	7.23	36.75	14.43	7.74
M	25.95	12.76	6.89	33.70	12.41	4.65	27.56	12.84	5.88
A	21.00	11.05	6.68	23.50	9.16	3.46	23.21	11.38	6.21
M	16.33	7.49	4.73	12.25	6.00	1.96	14.70	7.78	3.34
J	10.50	5.00	1.75	9.00	3.72	—	10.26	5.36	1.69
J	9.18	4.23	1.79	9.59	2.56	—	9.18	4.22	—*
A	8.82	4.50	1.93	10.50	2.57	—	11.32	4.52	1.92
S	15.21	6.17	2.82	10.02	4.35	—	20.05	6.34	2.19
O	16.96	8.10	4.69	20.43	8.10	4.39	15.75	8.30	4.90
N	23.21	11.55	6.39	24.74	10.91	6.21	27.56	11.66	6.89
D	29.40	13.05	7.35	22.05	11.83	6.81	31.50	12.77	7.87
Year	44.10 3.2.54	9.54	1.75 4.6.54	33.92 3.2.54	8.25	*	36.75 3.2.56	9.57	No reading 27.7.55

* See Table I.

The highest values of cooling power have been observed during the month of February, and particularly at 08 : 30 hours and 13 : 30 hours of February 3, 1954 when the highest values have been recorded. As a matter of fact, that day had extremely heavy weather conditions (Air - temperature : — 2.30, Mean 2.73 and maximum wind velocity : 8.7 m/sec. Precipitation : 3.7 mm WEATHER TYPE : IH). (VII). All these cases are included within the «cold» 20-days interval between January 20 - February 10 (LIVADAS (VII)).

We also observe that, values > 20, that is values of cooling power giving a discomfortably cold feeling, can also be recorded during the mid-day observation, from October till April.

Regarding the frequency of values, we give below TABLES IV, V, and VI.

TABLE IV

(08 : 30)

C. p. scale	J	F	M	A	M	J	J	A	S	O	N	D	N	%
0 - 2.5						1	6	4					11	1.0
2.6 - 5.0					3	53	64	60	36	1			217	20.0
5.1 - 7.5			4	5	55	27	21	25	32	44	7	2	222	20.4
7.6 - 10.0	11	7	16	30	24	7		4	13	33	28	22	184	16.9
10 1 - 12 5	17	36	41	35	10	2			4	11	28	33	217	20.0
12.6 - 15.0	26	17	12	10	0				2	1	10	27	105	9.7
15.1 - 20.0	18	9	10	7	1				1	2	11	13	72	6.6
20.1 - 45.0	21	15	9		2						5	7	59	5.4
														100.0
N°. of obs.	93	84	92	89	93	90	91	93	88	92	89	93	1087	
t_a > 35° C	0	0	0	0	0	0	0	0	0	0	0	0	0	
No data	0	1	1	1	0	0	2	0	2	1	1	0	9	

TABLE V

13 : 30

C. p. scale	J	F	M	A	M	J	J	A	S	O	N	D	N	%
0 - 2.5					5	40	83	83	32				243	11.7
2.6 - 5.0			1	4	51	91	63	51	82	14			357	17.2
5.1 - 7.5	1	3	10	48	91	22	3	7	52	86	30	2	355	17.1
7.6 - 10.0	37	31	44	65	33	6	1	0	6	45	60	55	383	18.4
10.1 - 12.5	54	50	57	46	5			1	1	18	38	56	326	15.7
12.6 - 15.0	35	33	36	9						14	26	41	194	9.3
15.1 - 20.0	38	36	29	8						5	19	28	163	7.8
20.1 - 45.0	21	16	9							1	7	3	57	2.7
														99.9
N°. of obs.	186	169	186	180	185	159	150	142	173	183	180	185	2078	
t_a > 35°C	0	0	0	0	0	19	34	43	5	0	0	0	101	
No data	0	1	0	0	1	2	2	1	2	3	0	1	13	

TABLE VI

	18 : 30													
C. p. scale	J	F	M	A	M	J	J	A	S	O	N	D	N	%
0 - 2.5						1	7	7	1				16	1.5
2.6 - 5.0					8	37	49	58	26	1			179	16.7
5.1 - 7.5			2	8	42	47	29	22	44	45	11	1	251	23.5
7.6 - 10.0	11	14	25	21	27	3	3	4	12	25	25	14	184	17.2
10.1 - 12.5	27	27	21	28	8	2		1	3	12	20	36	185	17.2
12.6 - 15.0	15	17	26	22	6				1	3	13	25	128	12.0
15.1 - 20.0	19	14	6	7					0	3	8	8	65	6.1
20.1 - 45.0	20	12	12	2					1	0	8	7	62	5.8
														100.0
N°. of obs.	92	84	92	88	91	90	88	92	88	89	85	91	1070	
$t_a > 35°C$	0	0	0	0	0	0	1	0	0	0	0	0	1	
No data	1	1	1	2	2	0	4	1	2	4	5	2	25	

Discussion.

— The climate of Thessaloniki, as regards the mean annual values of cooling power, could be defined according to V. CONRAD's classification (VIII) as a hot climate since the mean annual value of the cooling power at 13 : 30 hours is 8.25 cal cm^{-2} sec^{-1} - While if we consider as mean value the sum total of all three daily observations divided by three the mean value becomes 9.12 but is still in the same grade of the above mentioned classification.

— During the mainly winter - cold two - months period of January - February, the highest mean montly values for all three daily observations are recorded, with January leading with the highest values and February following close behind.

The winter months of March and December produce as regards the cooling power, the same feeling of cold (relaxing climate).

By comparing the two non-winter months of April and October we find that the vernal month of April is by far colder than the autumnal month of October, since the cooling power values of the first are definitely higher than those of the last, and especially so during the morning and afternoon observations.

— The high cooling power readings of March and the supremacy of April over October, back the characterization of winter in the northern Greek area as t a r d y (LIVADAS (VI, 1X) and are explained by the frequency of cold invasions during the spring, and the sudden drops in air temperature that are caused by these invasions.

TABLE VII

	08 : 30		13 : 30		18 : 30	
	c.p.	t_{air}	c.p.	t_{air}	c.p.	t_{air}
April	11.05	13.0	9.16	18.6	11.38	15.6
October	8.10	15.4	8.10	20.1	8.30	17.7

— The main summer two-months period of July and August has the smallest mean monthly values of cooling power. The warmer month of July slightly exceeds August as to the feeling of discomfortably warm (h o t c l i m a t e). The above two months of the very warm period, consist the interval during which the northern Greek area is included in the hot-dry season of the Eastern Mediterranean.

Also the warm moths of June and September can be considered as summer months, as regards readings of the cooling power.

— January has the highest frequency of values > 20.0, with February following and, as mentioned above, having the absolute maxima of cooling power recorded during the period examined, and March coming next.

— The greatest frequency of cooling power values that are < 2.5, belong to the months of July and August and with these should be included as «discomfort» cases, the 102 cases of TABLE I, when due to air temperatures above 35 °C, it has been impossible to take the readings of the kata-thermometer.

— In classifying the frequency of cooling power values, according to the feeling that they produce, we come to the following conclusions:

1. Atmospheric surroundings in the open air, during the mid-day hours produce at a rate of 1/3 of the whole year, a feeling varying from «comfortably warm» to «discomfortably warm» (V. Conrad: h o t c l i m a t e).

2. The feeling of c o l d or d i s c o m f o r t a b l y c o l d surroundings, is in proportion half of the w a r m, and almost the same for all three observation-hours.

TABLE VIII

Produced feeling	08 : 30		13 : 30		18 : 30	
0 0 - 5.0 Warm - comf. warm	21.0%		28.9%		18.2%	
5.1 - 15.0 Comf. cool - comf. cold	67.0%		60.5%		69.9%	
15.1 - 20.0 Cold	6.6%	12.0	7.8%	10.5	6.1%	11.9
> 20.1 Discomfortably cold	5.4%		2.7%		5.8%	

3. The feeling of c o m f o r t a b l e s u r r o u n d i n g s appears at a sufficiently high percentage, varying between 60 - 70 %.

4. From the above mentioned TABLE VIII rises a fact, well known to all the inhabitants of the city of Thessaloniki: that the best and most c o m f o r t a b l e time of day is that around sunset time. Indeed the 18 : 30 hours' observation seems to be, as regards the distribution of cooling power values the less warm (18.2 %) and the most comfortable one (69.9 %).

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