

COOLING POWER IN THESSALONIKI - GREECE (III)

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*Summary : In this paper the cooling power in Thessaloniki is examined according to observations of 08 : 30 hours and 18 : 30 hours, of the 15 year period between 1957 - 1971. Certain conclusions are expressed as to mean and extreme cooling power values recorded during the period examined, the main conclusion being that the city of Thessaloniki (from the cooling - power view - point) should be classed according to V. Conrad's classification, in the category of relaxing climates.*

### *1. Introduction*

The subject of cooling power (c.p.) in Thessaloniki - Greece has been occupying the authors in the last years (G. Livadas, 1971<sup>1</sup> and G. Livadas - Chr. Balafoutis, 1971<sup>2</sup>). The first paper examined values of c.p., based upon data of systematic observations effected in the Met. Inst. of the University for the period between January 1.1951 to December 31.1956. The second paper examined results of c.p. measurements, from the 13 : 30 h observations (local time = GMT + 2 h), for the twelve year period from 1.1.1957 till 31.12.1968; all these observations had been held in the new building of the Institute (Livadas, 1972<sup>3</sup>).

The material used in the present paper comes from measurements of c.p. taken at the 08 : 30 and 18 : 30 hours observations, and for the period between 1.1.1957 till 31.12.1971 (that is 15 full years). The instruments used for these measurements have always been Hill kathermometers\*.

The observation hours have been chosen for being the hours of the traffic-peak, at least for inhabitants of Greek cities: 08 : 30 h is the

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\* Manufacturers: J. J. HICKS - England, and R. FUESS - West Berlin.

time when working people and students are going to their daily occupations, while 18:30 h, besides being symmetrical to 08:30 as to the mid-day (13:30) observation (with two 5h intervals), which has been studied by the authors in a previous paper (Livadas - Balafoutis 1971<sup>2</sup>) this 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.

In the following Table I are given the number and the percentage of observations effected, and the number and percentage of observations that were impossible because of various reasons, out of a total of 5.478 observations possible.

TABLE I

	08 : 30 h		18 : 30 h	
Observ. realized	5.339	97,5 %	5.032	91,9 %
Impossible (t air > 35 C)	10	0,2 %	23	0,4 %
Withheld (various reasons)	129	2,4 %	423	7,8 %

The seasonal distribution of cases during which measurements have been impossible, because of extremely high air temperature of (tair > 35° C), is given in the following Table II.

TABLE II

	08 : 30h	18 : 30h
May	0	1
June	0	0
July	2	13
August	8	8
September	0	1
Total	10	23

} 100.0 %
} 91.3 %

From the above Table II, we draw the following conclusions as to the distribution of these  $10 + 23 = 33$  cases.

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

2. Cases recorded at 18:30 hours are twice as many as those of 08:30. This fact is in full accordance with the variation of air temperature during the day in Thessaloniki, where as a rule values of air temperature are in the morning (at 08:30 h) 2 - 3° C below those of the afternoon (18:30 h), while wind velocities are almost the same (see Table VII).

2. Mean and Extreme c.p. values at 08 : 30.

Results from the amount of 5.339 observations at 08 : 30 hours, are contained in Table III.

T A B L E III

*Absolute maxima and minima and Monthly mean maxima and minima observed in Thessaloniki at 08:30 hours\*\**

*Period of observations 1. 1. 1957 - 11.12.1971*

	Absol. max.	Monthly mean max.	Monthly mean $\pm \sigma$ .	Monthly mean min.	Absol. min.
J	<b>57.24</b> (13/1968)	<b>26.09</b> (1968)	<b>20.84</b> $\pm$ 2.40	16.97 (1970)	6.61 (16/1962)
F	51.37 (12/1969)	24.74 (1965)	19.51 2.51	14.94 (1966)	7.56 (18/1971)
M	48.04 ( 3/1957)	19.92 (1969)	17.50 1.45	14.16 (1959)	6.61 (29/1966)
A	43.08 (22/1963)	16.65 (1969)	13.17 1.72	10.21 (1961)	6.08 (22/1964)
M	32.99 ( 8/1957)	13.61 (1970)	10.61 1.24	9.23 (1958)	3.70 (15/1958)
J	24.42 (28/1957)	11.28 (1969)	8.82 1.35	6.74 (1964)	3.39 (25/1957)
J	22.98 ( 1/1964)	11.69 (1968)	7.86 1.56	5.62 (1963)	* *
A	23.87 (13/1965)	10.23 (1965)	<b>7.46</b> 1.28	<b>5.58</b> (1962)	* *
S	28.25 (22/1964)	11.91 (1968)	9.49 1.52	7.14 (1963)	2.59 ( 5/1971)
O	32.72 (31/1969)	13.62 (1970)	11.55 1.35	9.32 (1966)	4.28 ( 1/1967)
N	44.57 (23/1964)	16.47 (1957)	13.73 1.35	11.69 (1960)	6.20 ( 2/1957)
D	50.88 (21/1967)	24.61 (1958)	18.07 2.96	13.64 (1960)	7.55 ( 9/1965)
Year			13.18 $\pm$ 0.75		

\* See Table I.

From *Table III* we observe that: January, being the coldest month of the year, also has the highest mean monthly values of c.p. ( $20.34 \pm 2.40$ ). The above values according to Mörköffer's<sup>9</sup> classification, produce averagely a feeling of cold to discomfortably cold. This same feeling is also attributed as a mean to the other three winter months: December, February, and March. The two preceding months, October and November, and the two months following the winter season, April and May, stay in the 10 - 15 grade of c.p. values giving a feeling of comfortably cold or comfortably cool.

The remaining four months (warm season), belong in the 5 - 10 grade of c.p. values, meaning that in these months we have a comfortably warm feeling.

\*\* Local time: GMT + 2h.

Annual values of cooling power for the period examined have as follows:

Maximum	15.03	(1968)
Mean	$13.18 \pm 0.75$	
Minimum	12.36	(1960 & 1963)

This means that the city of Thessaloniki according to V. Conrad's climatic classification, based upon dry cooling power, belongs in the *relaxing climates*' group.

Thessaloniki, as an average, can be described as a relaxing climate; however, there have been observed values of cooling power that could vie with those of regions whose climate does not enjoy of such good fame.

We observe, for instance, in Table III that during the November to April semester c.p. values  $> 40$  and  $> 50$  have been recorded, while during the second half of the year, which is considered as the warm season, there have been c.p. values  $> 20$ . Meaning that a discomfortably cold feeling may be felt the whole year round, during the 08 : 30 hours observations.

Cooling power values  $> 20$  have a large frequency percentage during the main winter months (i.e. January  $\sim 38,7\%$ ), as can be seen in Table IV.

From this same Table IV we find that c.p. values  $\leq 5.0$  can be observed from May till October, with their maximum frequency in August (25,4 %), meaning that during this warm summer month, in a quarter of the 08 : 30 (local time) observations we already have a discomfortably warm, or hot feeling.

### 3. Mean and extreme c.p. values at 18 : 30.

Results from the 5032 observations effected at 18 : 30 h, during the 15 - year period, have been included in Table V.

From the data of Table V, we draw the following conclusions:

a. January, being the coldest month of the year, has the highest monthly mean value of c.p. ( $20.64 \pm 2.63$ ). This value, according to Mörkoff's classification, produces (as an average) a feeling of *cold to discomfortably cold*. The same feeling is also usually attributed to the other three winter months: December, February and March. The two preceding months and the two following the winter season, stay in the 10 - 15 grade of c.p. values, producing a feeling of *comfortable cold or comfortably cool*.

The remaining four months of the year (warm season) belong in

*T A B L E I V*  
*Frequencies of e.p. values at the 08 : 30 observation (period: 1957 - 1971)*

c. p. scale	J	F	M	A	M	J	J	A	S	O	N	D	Total	%
0 - 2.5	0	0	0	0	0	0	0	2	0	0	0	0	2	0.04
2.6 - 5.0	0	0	0	0	8	48	84	111	28	3	0	0	292	5.28
5.1 - 7.5	1	0	1	18	75	148	182	177	146	73	13	0	834	15.62
7.6 - 10.0	5	16	41	120	176	115	90	70	129	162	110	30	1064	19.93
10.1 - 12.5	64	73	93	121	99	61	34	36	50	84	144	100	959	17.96
12.6 - 15.0	98	82	93	69	43	32	21	27	39	45	55	94	698	13.07
15.1 - 20.0	116	100	92	72	36	27	23	19	25	58	61	93	722	13.52
20.1 - 45.0	172	138	133	42	17	6	1	3	17	34	61	139	763	14.29
>45.0	7	4	1	0	0	0	0	0	0	0	0	3	15	0.28
Total	463	413	454	442	454	437	435	445	434	459	444	459	5339	99.99
t > 35°C	0	0	0	0	0	0	2	8	0	0	0	0	10	
No DATA	2	10	11	8	11	13	28	12	16	6	6	6	129	

TABLE V

*Absolute Maxima and minima and Monthly mean maxima and minima observed in Thessaloniki at 18 : 30; period of observation 1.1.1957 - 31.12.1971.*

	Absol. max.	Monthly mean max.	Monthly mean $\pm \sigma$	Monthly mean minima	Absol. min.
J	<b>64.58</b> (12/1968)	26.16 (1968)	<b>20.64</b> $\pm$ 2.63	16.62 (1970)	7.49 (13/1966)
F	53.39 (17/1970)	<b>29.17</b> (1965)	19.41 3.63	15.19 (1966)	7.98 (18/1971)
M	43.33 ( 1/1957)	19.73 (1958)	17.02 1.57	14.71 (1959)	5.79 (22/1957)
A	35.10 (15/1970)	18.91 (1969)	14.18 1.82	11.47 (1961)	4.54 (24/1968)
M	29.08 ( 8/1957)	12.96 (1970)	10.62 1.26	7.91 (1958)	* *
J	22.81 (27/1969)	9.99 (1968)	8.27 0.97	6.45 (1964)	2.23 (11/1971)
J	21.31 (12/1969)	10.02 (1971)	<b>6.76</b> 1.40	<b>4.92</b> (1967)	* *
A	22.67 (23/1957)	9.81 (1968)	6.79 1.41	5.03 (1967)	* *
S	25.10 (26/1968)	12.17 (1971)	9.39 1.34	7.41 (1967)	* *
O	31.80 (20/1958)	15.04 (1968)	12.24 1.82	9.67 (1960)	5.64 ( 3/1957)
N	39.39 (30/1957)	16.69 (1964)	13.99 1.07	12.62 (1960)	7.27 (20/1963)
D	59.26 (21/1967)	21.34 (1968)	18.12 2.45	14.35 (1965)	7.87 (11/1957)

Year:

64.58 (12.1.1968)	29.17 (Feb 1965)	13.12 $\pm$ 0.66	4.92 (Jul 1967)
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\* See Table I.

the 5 - 10 grade of c.p. values, meaning that during these months we have a comfortably warm feeling.

Annual values of cooling power for the period examined have as follows:

Maximum	14.62 (1969)
Mean	13.12 $\pm$ 0.66
Minimum	12.01 (1960)

This means that, for the 18 : 30 observation too, the city of Thessaloniki according to Conrad's climatic classification, based upon dry cooling power, belongs in the *relaxing climates* group.

In *Table V* we observe that, during the cold four - months from December to March, c.p. values  $>40$  and  $>50$  have been recorded, while during the remaining eight months all absolute maxima have been above the value of 20.

Cooling power values  $>20$  generally have a large frequency during the winter months (i. e. January 40.0 %) as can be seen in *TABLE VI*.

*T A B L E V I*  
*Frequencies of e. p. values at the 18 : 30 observation. (period 1957 - 1971)*

	J	F	M	A	M	J	J	A	S	O	N	D	Total	%
0 - 2.5	0	0	0	0	1	3	6	9	0	0	0	0	19	0.38
2.6 - 5.0	0	0	0	1	11	63	105	111	18	0	0	0	309	6.14
5.1 - 7.5	1	0	3	8	67	124	153	152	115	26	5	1	655	13.02
7.6 - 10.0	10	14	31	67	143	119	82	91	128	126	94	28	933	18.54
10.1 - 12.5	55	72	69	104	112	71	28	32	79	114	120	101	957	19.02
12.6 - 15.0	78	65	92	92	59	19	9	9	30	93	75	86	707	14.05
15.1 - 20.0	120	107	125	88	38	16	10	2	18	64	80	94	762	15.14
20.1 - 45.0	167	123	103	47	7	1	1	4	11	22	55	132	673	13.37
>45.0	9	5	0	0	0	0	0	0	0	0	0	3	17	0.34
Total	440	386	423	407	438	416	394	410	399	445	429	445	5032	100.00
t > 35°C	0	0	0	0	1	0	13	8	1	0	0	0	23	
No Data	25	37	42	43	26	34	58	47	50	.20	21	20	423	



From this same Table we find that c.p. values  $\leq 5.0$  may be recorded from April till September, with the highest percentage during the main two summer months, July and August, during which also occurred almost all the cases when measurements were impossible because of extremely high temperatures. As a matter of fact during these two months, in  $1/4$  of the observations we have a discomfortably warm or hot feeling.

#### Discussion.

1. The climate of Thessaloniki, as regards the mean values of dry cooling power (for the 08:30 and 18:30 observation hours), can be defined according to Conrad's<sup>5</sup> climate classification, as a *Relaxing Climate*, since the mean annual values of c.p. are respectively:

Time	Mean	S.D.( $\pm \sigma$ )
08:30	13.18	$\pm 0.75$
18:30	13.12	$\pm 0.66$

(See Tables III & V)

These values agree with the mean annual c.p. value of the 13:10 hours observation, which is  $10.44 \pm 0.56$  mg cal  $\text{cm}^{-2} \text{sec}^{-1}$  (Livadas - Balafoutis)<sup>2</sup>.

2. January, being the coldest month of the year, has the highest mean monthly c.p. values, and also the absolute maxima.

Consequently, *even* from the point of view of dry c.p., this should also be considered as the principal winter month. Moreover, the other two properly winter months of December and February have also high c.p. values.

The recorded absolute maxima are within the limits of absolute maximum values of the rest of the Mid-European area, but exceed the absolute values of the Mediterranean region.

For instance on January 12 and 13, 1968 the following absolute maximum c.p. values have been recorded during consecutive observations.

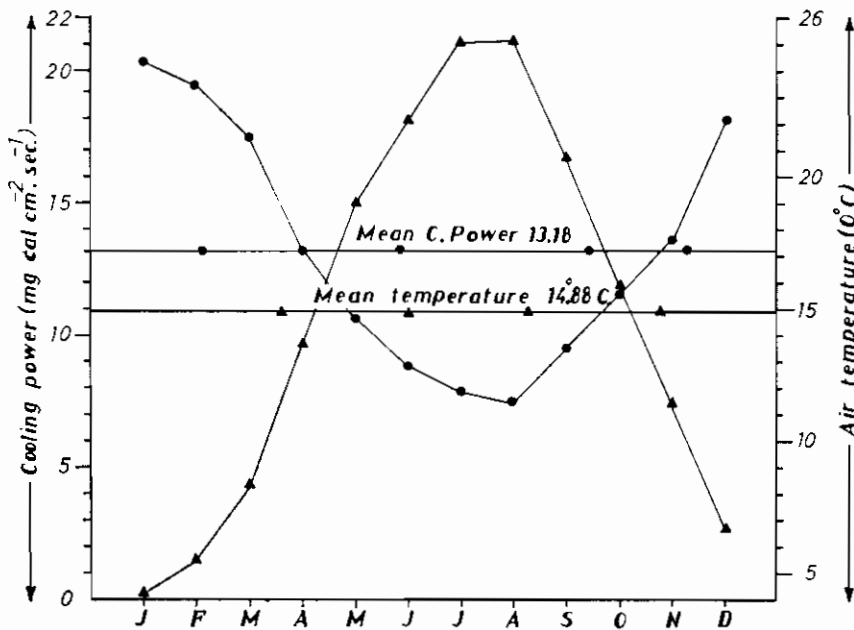
Date	Time	Cooling power	Weather Type
12.1.1968	18:30	64.58 mg cal $\text{cm}^{-2} \text{sec}^{-1}$	VII/XI
13.1.1968	08:30	57.24 »	XI
13.1.1968	13:30	54.16 »	XI

In the above case, the prevailing weather type has been initially VII<sup>a</sup>, that is the area of Thessaloniki was within the cold sector of

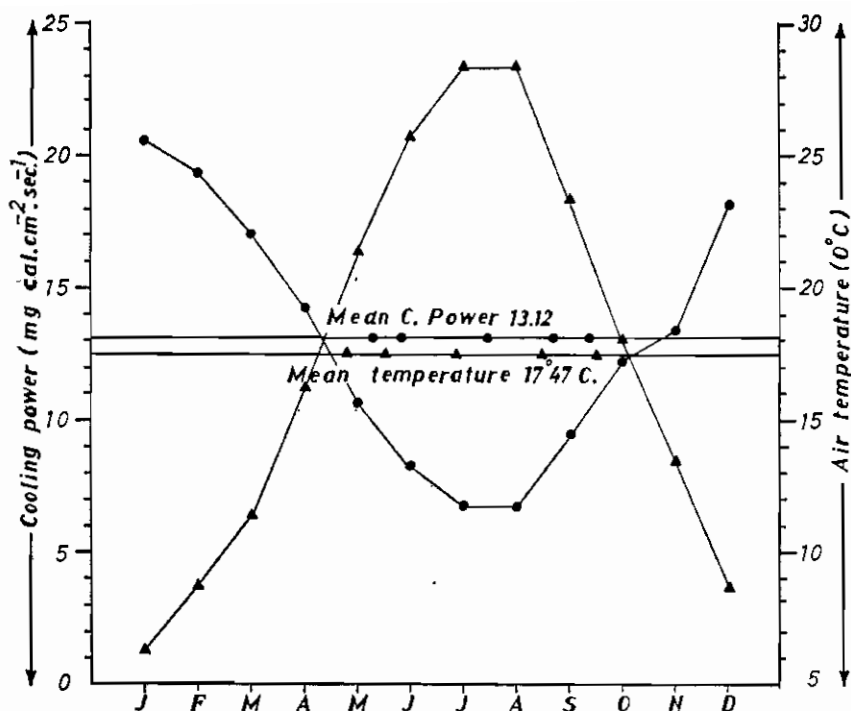
a depression centered over the Aegean Sea, which entails heavy rain or snow with strong northerly winds in the area of Thessaloniki. Then weather conditions developed into W.T. XI<sup>6</sup> meaning that the characteristic north-westerly wind of the Axios valley (bearing the popular name «Vardaris») was blowing (Mariolopoulos<sup>7</sup>, Kyriazopoulos<sup>8</sup>, Philippson<sup>9</sup>, Livadas<sup>6,10</sup>).

It should be noted here that in the case of 13.1.1968 has also been recorded the absolute minimum of air temperature for the 1893 - 1971 period (inside the met. screen), that is  $-12.6^{\circ}\text{C}$ .

3. The annual variation of c.p. and air temperature is illustrated in Graph I and Graph II. These graphs show that the annual variation of c.p. values (according to the 08:30 h and 18:30 h observations) is inversely proportionate to that of air temperature: as air temperature increases, c.p. decreases, and vice-versa, the two curves tending to become the reflected image of each other.



GRAPH I



GRAPH II

T A B L E V I I

Mean Monthly Air temperature wind velocity and c.p. during the period 1957 - 1971 in Thessaloniki

	Air Temp. (°C)	08 : 30 hour		18 : 30 hour		
		c.p.	Wind veloc. km/h	Air Temp.	c.p.	Wind veloc. km/h
J	4.07	20.84	7.34	6.28	20.64	7.47
F	5.47	19.51	6.98	8.78	19.41	7.83
M	8.34	17.50	6.13	11.31	17.02	7.00
A	13.66	13.17	4.36	16.28	14.18	7.45
M	18.99	10.61	4.16	21.41	10.62	7.05
J	23.07	18.82	5.21	25.65	8.27	9.36
J	25.05	7.86	5.56	28.27	6.76	9.77
A	25.08	7.46	4.37	28.31	6.79	7.66
S	20.82	9.49	4.85	23.27	9.39	5.95
O	15.85	11.55	4.01	17.97	12.24	3.88
N	11.42	13.73	4.20	13.43	13.99	4.33
D	6.68	18.07	5.91	8.68	18.12	6.85
Year	14.88	13.18	5.26	17.47	13.12	7.05

4. In classifying the frequency of cooling power values of the 08:30h and 18:30h observations, according to the feeling that they produce, we come to the following conclusions.

TABLE VIII

Produced feeling		Observations		
		08:30	13:30*	18:30
Discomfortably hot	$t_{\text{air}} > 35^{\circ}\text{C}$	0.19	5.30	0.45%
» warm	0. - 5.0	5.31	16.00	6.49
Comf. warm - Comf. cool	5.1 - 15.0	66.46	58.97	64.33
Cold	15.1 - 20.0	13.50	9.75	15.07
Discomfortably Cold	>20.0	14.54	9.96	13.65

\* (LIVADAS - BALAFOUTIS \*).

a) The feeling of *comfortable surroundings* has a high enough percentage (59 - 66 %) in Thessaloniki during the whole day.

b) The feeling of *cold* or discomfortable (bracing) cold, has the same percentage for both observations (28.04 - 28.72 %); the percentage is reduced to 18.71 % for the mid-day observation.

c) The feeling of discomfortably warm or hot has its largest percentage (as should be expected) during the observation of 13:30 h, the other two observations having almost the same ratio (5,50 - 6,94 %).

d) The mean annual values are the same for both observations of 08:30 and 18.30 hours (13,18 and 13,12). We attribute this to the fact that, although the air temperature is usually lower by 2,6° C than that of the afternoon, wind velocities are higher by 1,79 km/h during the afternoon observation.

## ΠΕΡΙΛΗΨΙΣ

Μελετᾶται ἡ ταχύτης ἀποψύξεως εἰς τὴν πόλιν τῆς Θεσσαλονίκης, κατὰ τὰς ὥρας παρατηρήσεων 08 : 30 καὶ 18 : 30 καὶ διὰ τὴν 15ετῆ χρονικὴν περίοδον 1957 - 1971.

Ἐξάγονται δὲ συμπεράσματα ὡς πρὸς τὰς μέσας καὶ ἄκρας τιμὰς τῆς ταχύτητος ἀποψύξεως διὰ τὴν ὑπὸ μελέτην περίοδον. Τὸ βασικώτερον τούτων εἶναι ὅτι, ἡ Θεσσαλονίκη ἀπὸ ἀπόψεως ταχύτητος ἀποψύξεως, κατατάσσεται συμφώνως πρὸς τὴν κατάταξιν Conrad εἰς τὰ Relaxing κλίματα.

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