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Further Studies on the Heat Radiation from the night sky at Poona

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ABSTRACT. The paper contains a discussion of the measurements of sky radiation made at the Central Agricultural Meteorological Observatory with the help of Angstrom's Pyrgeometer during 1945, 1946 and 1949. A study of the mean monthly variation of sky radiation shows that the sky radiation was minimum during winter and maximum during the cloudy monsoon period. Hourly variation of sky radiation during a few clear as well as cloudy nights has also been discussed in the paper. The values of atmospheric radiation measured in the evening and the succeeding morning on a few clear nights have been taken and the decrease in the radiation during the night has been compared with the change in radiation coming from air layers nearest to the ground and it has been shown that the major part of nocturnal variation of sky radiation may be accounted for by the variation in the radiation coming from the air layers nearest to the ground, which undergo nocturnal cooling. It has also been shown that the strength of inversion in the air layers near the ground increases as the net radiation increases.

1. Introduction

The study of the heat radiation from the night sky at Poona with the Angstrom's Pyrgeometer was begun by Ramanathan and Desai who discussed the data recorded by them from January 1930 to February 1931 in a paper published in 1932[1]. This work was taken up later at the Central Agricultural Meteorological Observatory at Poona by Raman[2,3] and still later at Colaba by Narayanaswamy[4].

The present paper contains a discussion of the observations recorded by the present writer at the Central Agricultural Meteorological Observatory with the help of Angstrom's Pyrgeometer during 1945, 1946 and 1949. The instrument was exposed horizontally on the roof of the Field Laboratory at the Observatory where a practically free exposure to the sky was available. A milliammeter was used to measure the heating current and a sensitive galvanometer to indicate the equality of temperatures of the thermocouples fixed to the back of the black and gilded strips in the Pyrgeometer. The net loss by radiation is proportional to the square of the current used, *i.e.*, $R=Ki^2$, where K is the constant of proportionality which depends on the dimensions, resistance and radiating power of the strips. The constant, K was redetermined by the present writer by exposing the instrument to the radiation from a hemispherical cavity scooped out in a block of ice. The constant K was calculated from the relation,

$$Ki^2=\sigma(T^4-T_0^4)$$

T being the temperature of the strips and T_0 that of ice (273°A). Regular observations of the heat radiation from the night sky were made during the period November 1945 to December 1946 and during 1949. Simultaneous observations of air temperature, vapour pressure and the compensating current were recorded. An Assmann Psychrometer was used to record the air temperature and the vapour pressure. These measurements were carried out between 1900 and 2000 IST. The radiation from the night sky was computed from the relation,

$$S=\sigma T^4-Ki^2$$

2. Monthly variation of night sky radiation

The mean monthly values of air temperature, vapour pressure, black body radiation at the temperature of the instrument, the net loss by radiation, the sky radiation and the ratio of the sky radiation to the black body radiation are given in Table 1. In column 2 are given the number of observations on which the means are based. In Table 1, all nights, clear as well as cloudy, are taken into account. In Table 2 are given the mean monthly values of the same quantities as in Table 1 for clear nights only. All nights with high, medium or low clouds near the horizon whose amount is less than one tenth, are taken as clear nights, for, clouds near the horizon have very little effect on the instrument. The results obtained are in general agreement with those arrived at by earlier workers.

In Fig. 1 are plotted the mean monthly values of sky radiation, vapour pressure and air temperature for all nights, clear as well as cloudy. From Fig. 1 we find that the sky radiation increases from January to March, slightly decreases in April and increases again from April to August and again registers a decrease till November after which it shows a slight rise. The maximum radiation is registered in August and this is in keeping with the fact that the southwest monsoon was stronger in August. The sky radiation increases during the monsoon months due to the presence of clouds which radiate like a black body and the increased vapour pressure in the atmosphere. During the winter season the sky radiation is smaller, because the air is cooler and drier. The sky radiation curve shows almost the same tendency as the vapour pressure curve. A sky overcast with low clouds has a pronounced effect on the down-coming radiation when the net loss by radiation becomes as low as even 0.015 cal/cm²/min.

TABLE 1 (All Nights)

Months	Number of observations	Air temperature (°A)	Vapour pressure mm of Hg	Black body radiation cal/cm²/min (σT^4)	Net radiation cal/cm²/min	Sky radiation cal/cm²/min (S)	$\frac{S}{\sigma T^4}$
January	42	297.3	8.2	0.639	0.163	0.503	0.787
February	33	298.8	8.6	0.652	0.143	0.509	0.781
March	26	302.1	9.6	0.681	0.129	0.552	0.811
April	16	302.2	12.4	0.682	0.152	0.530	0.777
May	31	300.5	15.7	0.667	0.098	0.569	0.853
June	18	298.5	17.9	0.649	0.073	0.576	0.887
July	8	296.9	18.1	0.636	0.043	0.593	0.932
August	12	296.0	18.1	0.628	0.030	0.598	0.952
September	11	296.9	17.9	0.636	0.074	0.562	0.883
October	17	299.1	12.5	0.655	0.117	0.538	0.821
November	28	294.1	11.0	0.612	0.102	0.510	0.833
December	45	294.1	10.0	0.612	0.099	0.513	0.838

TABLE 2 (Clear Nights)

Months	Number of observations	Air temperature (°A)	Vapour pressure mm of Hg	Black body radiation cal/cm²/min (σT^4)	Net radiation cal/cm²/min	Sky radiation cal/cm²/min (S)	$\frac{S}{\sigma T^4}$
January	40	297.3	8.0	0.639	0.140	0.499	0.781
February	32	298.7	8.5	0.651	0.144	0.507	0.779
March	20	301.5	9.4	0.676	0.137	0.539	0.797
April	16	302.2	12.4	0.682	0.152	0.530	0.777
May	22	301.2	14.7	0.674	0.140	0.534	0.792
June	1	297.1	15.8	0.637	0.086	0.551	0.865
July	—	—	—	—	—	—	—
August	1	296.3	17.5	0.631	0.067	0.594	0.894
September	6	297.3	17.8	0.639	0.100	0.539	0.844
October	14	298.6	15.0	0.650	0.122	0.528	0.812
November	27	294.1	11.0	0.612	0.102	0.510	0.833
December	44	293.7	10.0	0.609	0.110	0.499	0.819

(ALL NIGHTS)

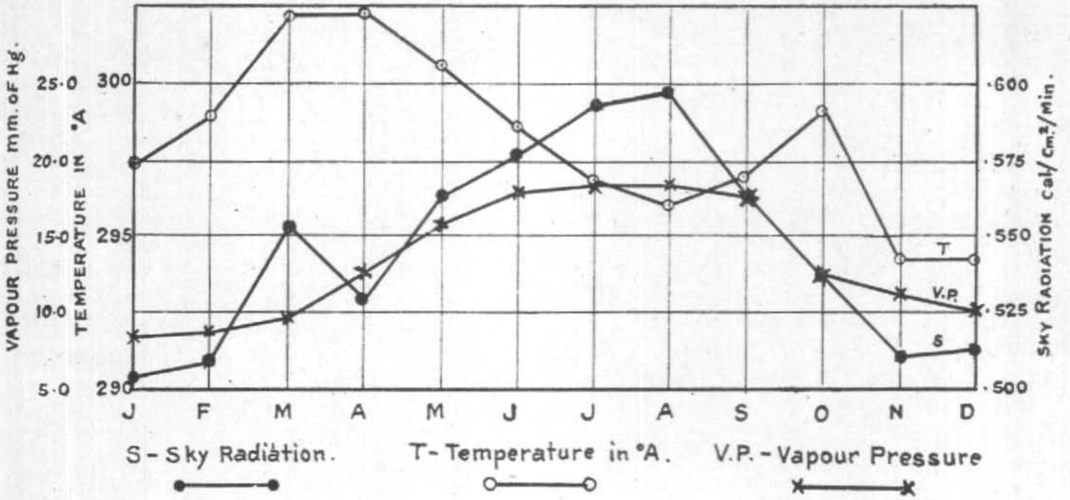


Fig. 1

(CLEAR NIGHTS)

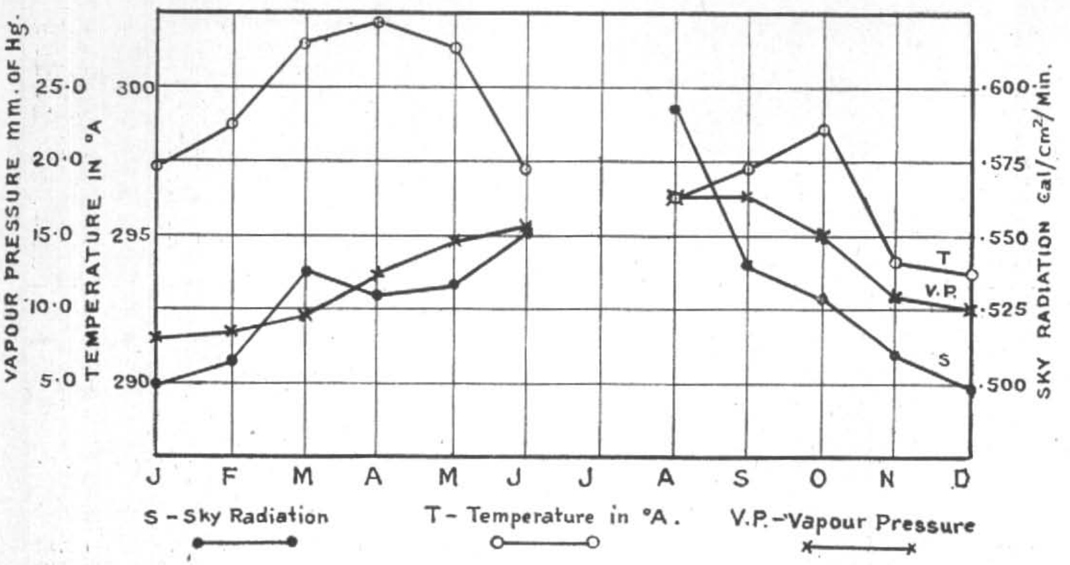


Fig. 2

In Fig. 2, the sky radiation, vapour pressure and temperature are plotted for clear nights only, thus eliminating the cloudy nights. From Fig. 2, we find a gradual increase in sky radiation from January to March, a slight decrease in April, an increase till August and a decrease thereafter. Here also the maximum value of sky radiation is recorded in August. From Figs. 1 and 2, we find that the curve representing sky radiation has almost the same tendency as the vapour pressure curve.

3. Hourly variation of night sky radiation

Hourly observations of heat radiation from the night sky were made during a few nights. Tables 3 and 4 give the hourly observations on two clear nights. Observations were made on a few cloudy nights also.

Table 3 gives the hourly values of air temperature, vapour pressure, black body radiation at the temperature of the instrument, sky radiation etc., on a night in November 1945. The sky was clear except for cloud traces at the horizon at 0100 IST which had practically no effect on radiation. The air temperature (in °A), vapour pressure and the sky radiation are plotted in Fig. 3. From the figure it can be seen that the sky radiation follows the same trend as the temperature. Both temperature and humidity influence sky radiation. From 0400 to 0500 IST the vapour pressure shows an increase while the sky radiation registers a decrease. This can be explained by the fact that the temperature markedly decreases during the same time. Table 4 represents similar readings taken on a clear night in February 1946 and in Fig. 4 are plotted the hourly values of temperature, vapour pressure and

TABLE 3 (Clear Night)

Date	Time	Air temperature (°A)	Vapour pressure mm of Hg	Black body radiation cal/cm^2/min (σT^4)	Net radiation cal/cm^2/ min	Sky radiation cal/cm^2/min (S)	$\frac{S}{\sigma T^4}$	Clouds
25.11.45	2000	293.5	5.7	0.607	0.141	0.466	0.768	Clear
	2100	293.2	5.6	0.605	0.134	0.471	0.779	,,
	2200	291.8	5.5	0.593	0.130	0.463	0.781	,,
	2300	291.8	5.5	0.593	0.130	0.463	0.781	,,
	2400	291.6	5.4	0.592	0.128	0.464	0.784	,,
26.11.45	0100	289.5	5.4	0.575	0.128	0.447	0.777	Cloud traces at the horizon
	0200	287.3	5.8	0.558	0.121	0.437	0.783	Clear
	0300	287.0	5.6	0.555	0.115	0.440	0.793	,,
	0400	286.3	5.4	0.550	0.121	0.429	0.780	,,
	0500	285.0	5.5	0.540	0.116	0.424	0.785	,,
	0600	284.2	—	0.534	0.113	0.421	0.788	,,

TABLE 4 (Clear Night)

Date	Time	Air temperature (°A)	Vapour pressure mm of Hg	Black body radiation cal/cm^2/min (σT^4)	Net radiation cal/cm^2/min	Sky radiation cal/cm^2/min (S)	$\frac{S}{\sigma T^4}$	Clouds
16.2.46	2030	296.8	12.6	0.635	0.131	0.504	0.793	Clear
	2100	296.2	12.9	0.630	0.128	0.502	0.796	,,
	2200	295.1	13.6	0.620	0.128	0.492	0.794	,,
	2300	293.7	13.0	0.609	0.117	0.492	0.807	,,
	2400	293.2	12.9	0.605	0.116	0.489	0.807	,,
17.2.46	0100	291.6	12.3	0.592	0.108	0.484	0.818	,,
	0200	290.3	12.4	0.580	0.108	0.472	0.814	,,
	0300	289.8	11.9	0.577	0.108	0.469	0.812	,,
	0430	289.0	11.6	0.571	0.106	0.465	0.873	,,
	0500	288.0	11.4	0.563	0.101	0.462	0.820	,,
	0530	287.8	11.2	0.561	0.103	0.458	0.817	,,
	0600	288.0	10.7	0.563	0.103	0.460	0.817	,,

sky radiation. In Fig. 5 are given similar values for a night in January 1949. From these tables and figures, we see that the variation of night sky radiation can be explained by the variation in temperature and vapour pressure. Fig. 6 represents the measurements made on a cloudy night in May 1946. Cloud amount and type at the various hours of observation are also marked in the figure. Clouds have a very pronounced effect on the down-coming radiation which varies according to the amount and type of cloud. Even a patch of cloud at the zenith has a marked influence. On the cloudy night in May 1946, at 2200 IST the net loss by radiation reached a value 0.036 cal/cm²/min when seven-tenths of the sky was covered with stratocumulus and at 0545 IST the net loss by radiation was as low as 0.026 cal/cm²/min when the sky was overcast with stratocumulus.

4. Atmospheric radiation on clear nights and its dependence on the temperature and moisture content of the lower layers of the atmosphere

Ramanathan and Ramdas[5] as well as Ramdas, Sreenivasaiah and Raman[6] have discussed the dependence of atmospheric radiation on clear nights on the temperature and moisture content of the lower layers of the atmosphere. By dividing the spectrum of the temperature radiation of water vapour of the atmosphere into three groups of wave lengths, the energy in the three groups being S_1, S_2, S_3 where S_1 relates to the region 8.5 to 10.5μ and 3.5 to 4.3μ where the decimal absorption coefficient is less than 1, S_2 to the region where the decimal absorption coefficient lies between 1 and 10 and S_3 to the region (5.1 to 7.9μ and >15.3μ) where the absorption coefficient is greater than 10, they have arrived at the relation,

$$S=S_2+S_3-S_2\, exp\,(-3/2\, k_2\, w),$$

where S is the total atmospheric radiation, k_2, the absorption coefficient in the S_2 region and w, the precipitable water vapour in the atmosphere. The S_3 radiation is coming from the air layers nearest to the ground and the temperature of this layer is nearly equal to the temperature of the air near the Pyrgeometer.

The values of atmospheric radiation measured in the evening and the succeeding morning on a few nights have been taken and the decrease of the atmospheric radiation during the night has been compared with the change in S_3 radiation. The results are summarised in Table 5.

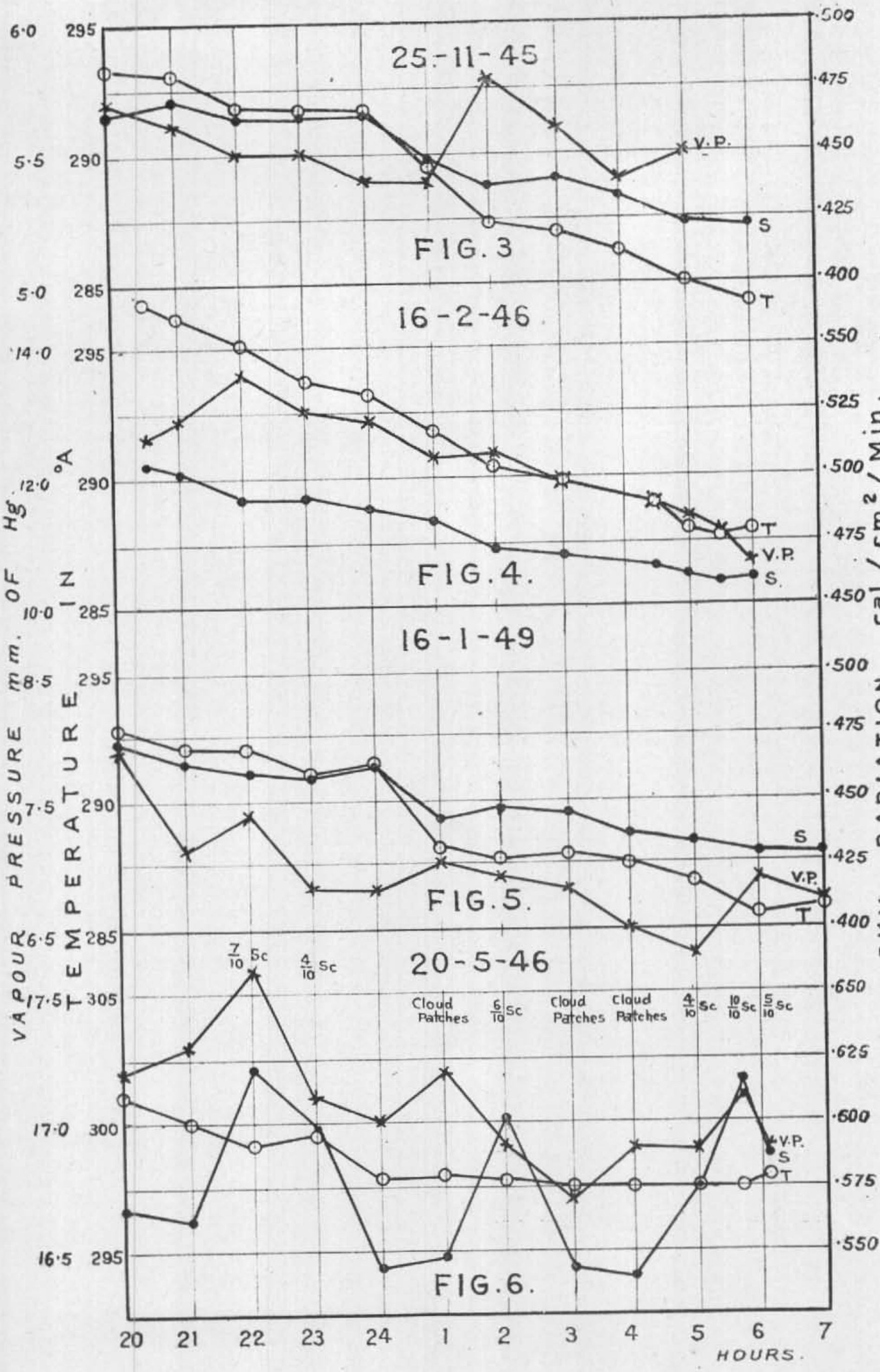
It can be seen from the table that the major part of the nocturnal variation of the sky radiation is accounted for by the variation in the radiation that is coming from the air layers nearest to the ground which is affected by nocturnal cooling.

5. Net radiation and the depression of grass minimum temperature below Stevenson screen minimum

During night time the grass minimum thermometer, exposed in the open, radiates like a black body and registers a temperature lower than the minimum thermometer in the Stevenson screen. The difference between the Stevenson screen minimum temperature and the grass minimum temperature is more on winter nights when the net loss by radiation is more due to clear skies and drier atmosphere.

TABLE 5

Date	Time (IST)	Temperature (°A)	Sky radiation cal/cm²/min	ΔS cal/cm²/min	ΔS_3 cal/cm²/min
25.11.45	2000	293.5	0.466	0.046	0.035
	0600	284.2	0.420		
2. 2.46	2015	297.1	0.494	0.049	0.037
	0520	287.0	0.445		
16. 2.46	2030	296.8	0.504	0.045	0.032
	0600	288.0	0.459		



S - Sky Radiation. T - Temperature in °A. V.P. - Vapour Pressure.

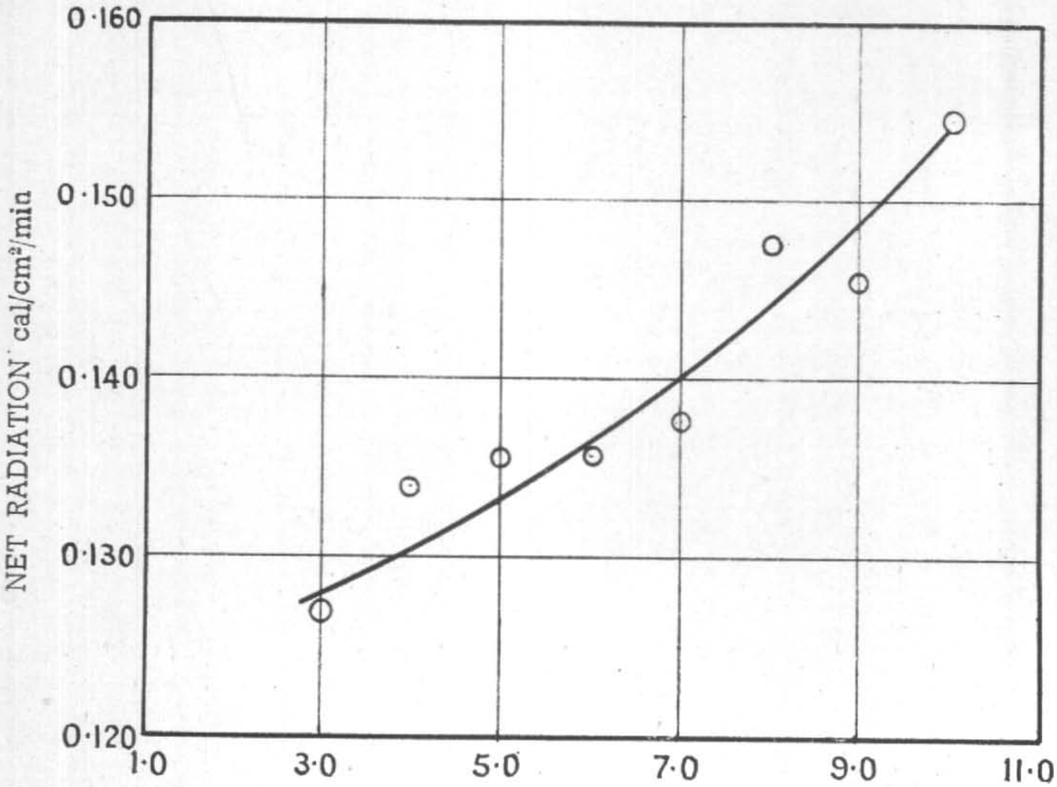


Fig. 7

The values of net radiation measured between 1900 and 2000 IST have been compared with the values of the depression of grass minimum temperature below Stevenson screen minimum temperature recorded the next day morning. The grouped means of the depression and the net radiation are given in Table 6. For the purpose of this table, only clear nights have been taken into account.

TABLE 6

Stevenson screen minimum minus grass minimum (°F)	No of occasions	Net radiation cal/cm²/min
3.0	3	0.127
4.0	7	0.134
5.0	33	0.136
6.0	51	0.136
7.0	41	0.138
8.0	19	0.148
9.0	10	0.146
10.0	3	0.155

The values are plotted in Fig. 7. It can be seen from the figure that the depression of grass minimum temperature below Stevenson screen minimum tends to increase as the net radiation increases.

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