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A study of runway temperature and screen temperature over Santacruz Airport

M. C. PRASAD

Meteorological Office, Bombay

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ABSTRACT. Variations in runway temperature affect air density over the runway and this affects the lift of an aircraft and its effective payload. Temperature measured by an electrical thermometer installed near the runway (indicated as R) has been found to vary with temperature measured by a thermometer placed in a Stevenson's screen (indicated as S) within a wide limit of +5.9° C to—4.0° C This study is based on observations at Santacruz airport and discusses the diurnal, seasonal and annual variations of $(R - S)$. Causes of such variations have also been investigated).

1. Introduction

Accurate forecast of runway temperature is of great importance for economic operations of aircrafts. Variations in runway temperature affect density of air over the runway and this affects the lift of aircraft and its effective payload. There have been occasions when aircrafts have been forced to off-load thousands of Kilograms of their pay-load due to a sudden rise of temperature above the forecast runway temperature. Realising the importance of correct assessment of runway temperature for operational use, ICAO has recommended that the runway temperature should be measured accurately by a temperature panel situated near the runway.

Elements of a distant measuring electrical thermometer installed near the end of the 27—runway at Santacruz airport enables continuous recording of temperature by a self-recording and reading arrangement in the Briefing room and at the Observer's panel in the Control Tower. Prior to installation of this thermometer and on occasions of its failure, temperature recorded by the thermometer kept in the Stevenson's screen at the Radio Sonde/Rawin Observatory used to be supplied for operational use.

Runway temperature (R) has been found to vary widely with the screen temperature (S) during various hours of day and night. For example, temperature recorded over the runway was found to be 5.9°C higher than Stevenson's screen temperature at 1000 hours on 9 February 1975. In contrast, runway temperature was 4.0° C below the screen temperature at 2300 hours on 10 January 1975. Also, runway temperatures were higher by 5.4° C and 4.6° C over the screen temperatures at 1500 hours of 26 January 1975 and 0300 hours of 4 January 1975 respectively. Such large differences are, however, very rare and require special investigations. In the vast majority of cases, the differences are comparatively much smaller. For example, variations are within ± 2° C in about 92 per cent cases and within ± 3°C in about 99 per cent cases, (*vide* Table 1).

De (1963, 1970) has studied the variations in runway and screen temperatures at Dum Dum airport during six synoptic hours: 00, 03, 06, 09, 12 and 18 GMT for the period from 1 February 1959 to 31 October 1962. He found that the average value of $(R-S)$ was less than 1° C with limit of variations of ± 4°C. He attributed this difference to radiation effects.

2. Data used

Hourly Observations for 24 months from 1 January 1975 to 31 December 1976 have been tabulated from the autographic records, of thermograph kept in Stevenson's screen (S) and from the distant reading electrical thermograph kept near the runway (R). Difference of R and S is calculated for different hours and months and mean hourly, monthly, seasonal and annual values of $(R-S)$ are found.

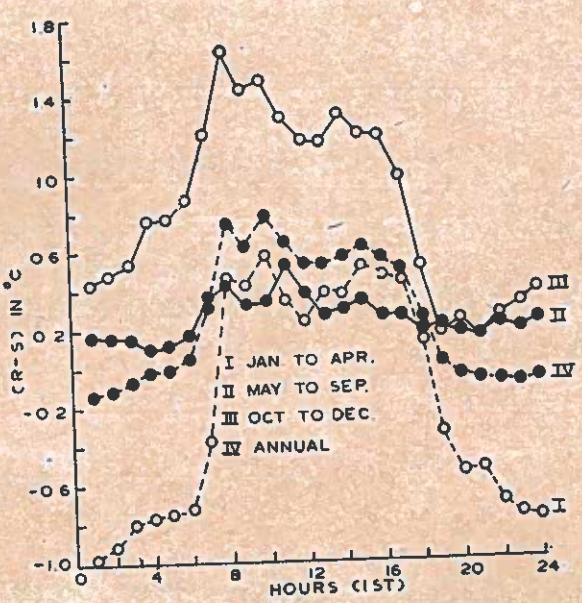

Fig. 1.

3. Results

3.1. *Number of Observations*

The last row in Table 1 gives the total number of observations available in different months. The number of observations were the least in June (1047) corresponding to about 75 per cent of the total. They were available on about 80 per cent & 85 per cent of occasions in September and October. Data were almost 100 per cent remaining months.

3.2. *Mean and range of values*

The last row in Table 2 gives the monthly and annual mean values of $(R-S)$. It is about a degree (+0.9° C) in October and December, about half a degree (+0.6° C) in August, November and April (−0.4° C) and much less in other months. The average annual diurnal variation is about 1° C (from +0.78° C to −0.14° C).

Table 1 shows the actual as well as the percentage frequencies of $(R-S)$ values of different magnitudes for the different months of the year and the year as a whole. It is seen that $(R-S)$ lies within ± 1° C on nearly 90 per cent of occasions in June, 50 per cent in September and December and 60 to 70 per cent in other months. They are within ± 2° C in about 83 per cent cases in December and February and in more than 90 per cent cases in the other months. They occur between 0° C and +2° C in about 80 per cent cases in October and nearly 67 per cent cases in August, November and December. They lie between 0° C and −2.0° C on 64 per cent occasions in April.

3.3. *Diurnal variation of* $(R-S)$

Table 2 gives the mean values of $(R-S)$ for various hours of the day in different months of the year. It is seen that the mean value of $(R-S)$ is positive throughout the 24 hours of the day in the months of June, July, August, October, November and December, but positive value of $(R-S)$ in mostly less than 0.5° C in June and July. In August $(R-S)$ is about +0.5° C in all the 24 hours of the day. During October, November and December $(R-S)$ exceeds 1.0 C generally between 0700 hours IST and 1700 hours IST and is between +0.5° C and +1.0° C between midnight and 0700 hours IST.

In May and September $(R-S)$ is small throughout the 24 hours, positive during most daylight hours and negative during night hours. In April, $(R-S)$ is small during day time and about 0.5 C to 1.0 C during night hours.

3.4. *Seasonal variation of* $(R-S)$

Depending upon the magnitude and nature of variations of $(R-S)$, the months can be grouped into following 3 seasons:

3.4.1. *January to April*: $(R-S)$ is positive (small) during day hours and negative (about −0.5° C to −1.0° C during night hours.

3.4.2. *May to September*: $(R-S)$ is positive (small) throughout the 24 hours.

3.4.3. *October to December*: The runway temperature is significantly higher than the screen

TABLE 1

Frequency of occurrence of $(R-S)$ in various ranges and their Monthly Percentage frequencies

Range of $(R-S)$	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Annual
>4.0	1	4	1	0	0	0	0	0	0	0	0	0	6
%	0.06	0.29	0.06	0	0	0	0	0	0	0	0	0	0.04
—3.1 to —4.0	10	23	7	2	1	1	2	3	0	0	0	1	50
	0.68	1.68	0.47	0.14	0.07	0.09	0.13	0.20	0	0	0	0.07	0.30
—2.1 to —3.0	60	139	41	35	40	0	4	11	5	0	4	6	345
	4.09	10.18	2.76	2.45	2.71	0	0.27	0.74	0.41	0	0.28	0.40	2.08
—1.1 to —2.0	210	251	240	310	300	14	75	86	225	8	45	46	1810
	14.34	18.38	16.16	21.72	20.35	1.33	5.05	5.81	18.38	0.65	3.12	3.10	10.90
—0.1 to —1.0	422	394	502	610	220	308	549	274	441	109	334	212	4375
	28.81	28.87	33.78	42.75	14.93	29.43	36.99	18.51	36.04	8.92	23.19	14.28	26.37
00 to 1.0	458	365	463	369	633	619	556	650	210	613	662	536	6134
	31.28	26.74	31.16	25.86	42.95	59.12	37.48	43.93	17.15	50.13	45.98	36.13	36.96
1.1 to 2.0	226	121	175	92	254	100	282	341	227	349	300	448	2915
	15.42	8.87	11.78	6.45	17.23	9.55	19.00	23.04	18.54	28.54	20.83	30.19	17.57
2.1 to 3.0	57	52	46	9	25	5	16	100	105	116	80	177	788
	3.90	3.80	3.09	0.63	1.69	0.48	1.08	6.76	8.58	9.48	5.56	11.92	4.74
3.1 to 4.0	13	10	7	0	1	0	0	11	14	27	13	46	139
	0.88	0.74	0.47	0	0.07	0	0	0.74	0.90	2.20	0.90	3.10	0.82
>4.0	8	6	4	0	0	0	0	4	0	1	2	12	37
	0.54	0.45	0.27	0	0	0	0	0.27	0	0.08	0.14	0.81	0.22
No of obs.	1465	1365	1486	1427	1474	1047	1484	1480	1224	1223	1440	1484	16599

TABLE 2

Table showing mean values of (R—S) during various months and hours

Hours in I.S.T.	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Annual Average
1	—0.56	—1.50	—1.01	—0.86	—0.01	+0.16	+0.15	+0.53	+0.04	+0.68	+0.07	+0.54	—0.14
2	—0.59	—1.20	—0.92	—0.92	—0.08	+0.19	+0.18	+0.53	0.0	+0.61	+0.21	+0.66	—0.11
3	—0.45	—1.12	—0.87	—0.78	—0.17	+0.28	+0.12	+0.55	—0.02	+0.70	+0.34	+0.58	—0.07
4	—0.26	—1.18	—0.85	—0.79	—0.25	+0.19	+0.08	+0.48	0.0	+0.93	+0.66	+0.72	—0.02
5	—0.30	—0.97	—1.07	—0.68	—0.21	+0.17	+0.15	+0.47	—0.04	+0.88	+0.63	+0.81	—0.01
6	—0.35	—1.07	—0.84	—0.69	—0.02	+0.20	+0.19	+0.49	+0.0	+0.86	+0.68	+1.07	+0.04
7	—0.17	—0.94	—0.68	+0.24	+0.33	+0.46	+0.28	+0.59	+0.17	+1.30	+0.86	+1.44	+0.32
8	+0.48	+0.31	+0.80	+0.27	+0.46	+0.46	+0.31	+0.64	+0.30	+0.88	+1.52	+2.48	+0.74
9	+0.82	+0.29	+0.51	0.0	+0.26	+0.24	+0.33	+0.57	+0.22	+1.42	+0.99	+1.85	+0.62
10	+0.82	+0.62	+0.85	+0.03	+0.62	+0.45	+0.44	+0.65	+0.55	+1.72	+1.07	+1.62	+0.78
11	+0.55	+0.27	+0.62	—0.08	+0.45	+0.51	+0.31	+0.73	+0.61	+1.57	+0.86	+1.38	+0.64
12	+0.45	+0.25	+0.43	—0.20	+0.25	+0.31	+0.33	+0.57	+0.40	+1.51	+0.93	+1.05	+0.52
13	+0.56	+0.52	+0.53	—0.06	+0.20	+0.27	+0.23	+0.48	+0.11	+1.41	+0.85	+1.21	+0.52
14	+0.76	+0.41	+0.49	—0.18	+0.24	+0.25	+0.26	+0.61	+0.10	+1.39	+1.13	+1.35	+0.56
15	+0.85	+0.53	+0.76	—0.07	+0.21	+0.24	+0.29	+0.72	+0.20	+1.14	+1.08	+1.37	+0.61
16	+0.91	+0.39	+0.67	—0.10	+0.05	+0.14	+0.28	+0.68	+0.12	+1.09	+0.95	+1.52	+0.55
17	+0.83	+0.44	+0.65	—0.19	—0.02	+0.25	+0.16	+0.64	+0.22	+0.87	+0.61	+1.42	+0.49
18	+0.34	+0.19	+0.29	—0.32	—0.07	+0.19	+0.12	+0.63	+0.06	+0.63	+0.18	+0.73	+0.24
19	—0.56	—0.27	—0.11	—0.46	—0.10	+0.19	+0.11	+0.56	+0.17	+0.33	+0.02	+0.21	0.0
20	—0.65	—0.83	—0.32	—0.45	—0.01	+0.17	+0.10	+0.57	—0.03	+0.30	+0.31	+0.06	—0.06
21	—0.94	—0.13	—0.51	—0.61	+0.01	+0.23	+0.13	+0.49	—0.09	+0.25	+0.20	0.0	—0.08
22	—0.85	—0.97	—0.35	—0.67	+0.03	+0.28	+0.14	+0.58	—0.01	+0.48	+0.06	+0.22	—0.09
23	—0.72	—1.04	—0.58	—0.78	—0.01	+0.23	+0.13	+0.57	—0.02	+0.56	+0.14	+0.25	—0.10
24	—0.54	—1.08	—0.75	—0.85	+0.02	+0.24	+0.21	+0.54	+0.03	+0.55	+0.27	+0.33	—0.08
Monthly Average	+0.02	—0.34	—0.09	—0.39	+0.09	+0.26	+0.21	+0.58	+0.15	+0.92	+0.61	+0.95	+0.24

temperature throughout the 24 hours of the day—being particularly so during the day time when it exceeds 1°C.

The results of seasonal and annual variations are shown graphically in Fig. 1.

4. Discussion

The main contribution to the difference between R and S lies in the difference in the nature of the surface over which thermometers have been installed. Experiments of Johnson and Davies have shown that the highest temperature on the globe may reach 93°C and yet the screen temperature recorded is about 57°C. Eaton in America measured 51°C at an asphalt road whereas the air temperature over a nearby lawn was only 37°C. In another experiment Johnson and Davis measured 60°C on a tar-macadam layer, 55°C for a sand surface and 44°C for a grass surface on the hottest part of the same day. These experiments clearly illustrate that the nature of surface material plays a vital part in determining the temperature at a place and its range of diurnal variation.

The Stevenson's screen is installed over an area having green vegetation, whereas the runway is made of concrete. Hence, the runway surface generally absorbs more heat during daytime and radiates more during the night as compared to the Stevenson's screen area. Hence $(R-S)$ will be generally positive during day time and negative during night. On hot day when the skies are clear, the concrete surface of the runway becomes much hotter than the Stevenson's screen area compared to day with overcast skies as in monsoon season. Similarly, on clear nights, R will be generally lower than S as compared to cloudy nights. Consequently, diurnal range of $(R-S)$ will be more in winter with clear skies and small in monsoon months.

The runway thermometer is installed close to the takeoff point. The hot air given out by the aircraft engines may raise the temperature in the neighbourhood and will be felt more during night than during day. When surface wind is strong as during noon, this heat is dispersed out quickly and it contributes little to the value of $(R-S)$. When wind is calm, as is generally the case during winter nights, the heat given out by aircraft engines stagnates near the runway and the runway thermometer reads higher. The author would like to stress here that the temperature shown by the airport instrument's panel is the correct temperature and this alone should be used for providing take-off data to aircrafts. If, on rare occasions, during winter nights, when the airport temperature panel fails and the temperature has to be supplied on the basis of reading taken from Stevenson's screen at the RS/RW building, the author feels that on such occasions the recorded temperature should be increased slightly (by about a degree) to account for this effect and to meet the operational needs. In actual practice, the take-off temperaure is generally given one degree higher to account for such factors.

5. Conclusions

(*i*) The difference between the runway temperature and the screen temperature is generally small-both monthly and annual averages being about 1°C.

(*ii*) The unway temperature is higher (1 to 2° C) than the screen temperature during day time particularly when the skies are clear and is less (0.5 to 1.0 C) than the screen temperature during clear nights.

(*iii*) The difference is small during monsoon months.

(*iv*) The difference is mostly due to the difference in the nature of the surface over which the thermometers are installed and due to non-dispersal of heat given out by aircraft engines.

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References

Brunt, D., 1939, Physical and dynamical Meteorology.

De, A. C., 1963, *Ind. J. Met. Geophys.*, **14**, 4, pp. 441-446.

De, A.C., 1970, *Ind. J. Met. Geophys.* **21**, 4, pp. 77-82.

Priestley, C. H. B. Turbulent—Transfer in the lower atmosphere.

Sutton, O. G., 1953, Micrometeorology Chapters 5 and 6.

Sutton, O. G., Atmospheric Turbulence.