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Meteorological requirements on airconditioning in relation to human habitat for comfort

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सार — दस वर्ष (1957-66) की अवधि में शुष्क और नम बल्ब तापमानों और पवन चाल के हर घंटे के लिए आंकड़ों का उपयोग करके दिन के 24 घंटों के प्रभावी तापमान-ई टी (मानव-शरीर पर उष्मा प्रतिबल का सूचकांक) के साप्ताहिक माध्य की गणना की गई है। ऐसा चार प्रमुख महानगरों अर्थात् बम्बई, कलकत्ता, मद्रास, नई दिल्ली के लिए किया गया है । 25° सें० के प्रभावी तापमान को असुखद ताप की निम्न सीमा मानकर आलेख तैयार किये गए हैं और उनका विश्लेषण कर विवेचन प्रस्तुत किया गया है । असुखद वातावरण को सुधारने में मानसून शुभारंभ की दशाओं की भूमिका का भी मूल्यांकन किया गया है । मौसम वैज्ञानिक अपेक्षाओं के परिपेक्ष में वातानुकूलन हेतु इन आलेखों की उपयोगिता निर्धारित की गई है और उसका विवेचन किया गया है ।

ABSTRACT. Weekly means of effective temperature — *ET* (an index of heat stress on human body) during th 24 hours of the day, have been computed, utilising hourly dry and wet bulb temperrature and the wind speed based on data for a ten year period (1957-66). This has been done in respect of a major cities, *viz.*, Bombay, Calcutta, Madras and New Delhi. Adopting a 25 deg. *C ET* as the lower limit of thermal discomfort, diagrams have been prepared, analysed and discussed. Role of onset of monsoon conditions in ameliorating the discomfort have been evaluated. The utility of the diagrams in the light of meterological requirements for airconditioning, has been determined and discussed.

1. Introduction

Meteorological parameters like temperature, humidity and wind or any combination of these, largely determine the human comfort in atmospheric environment. Several types of single indices have been proposed for identifying locations and periods best suitable for human beings. Macpherson's (1962) review concludes that "indices based on the heat exchange provide the most satisfactory approach to the problem of the multiple factor index". An useful review has also been provided by Sargent & Tromp (1964). Landsberg (1972) has discussed the subject from the view point of human biometeorology. Steadman (1979) combined dry bulb temperature and the vapour pressure to compute 'apparent temperature' which a typical human being "feels like".

The concept of effective temperature has been widely used in biometeorology as an index of the heat stress on the human body. It has been utilised by heating and ventilating engineers to establish thermal response to a human body by equating prevailing weather conditions to a standard set generally obtained from the effect of still saturated air at a given temperature. A knowledge on the limits of effective temperature within which the human body can function efficiently is necessary. That the effective temperature is a direct function of comfort has been demonstrated by Ford (1968). In a tropical country like India, the upper limit of effective temperature, produces discomfort to functioning of human bodies. Terjung (1967) has illustrated the annual physioclimatic stresses and regimes in USA utilising effective temperature. The methodology was adopted by Chowdhury and Ganesan (1981) to delineate physioclimatic regimes and identify areas of climatic stress and comfort zones in India. Earlier monthly minimum and maximum effective temperatures were computed for different stations in India by Central Building Research Institute (1968). In the present study the effective temperature (*ET*) were calculated graphically from the guide prepared by the American Society of Heating and Ventilating Engineers (ASHVE-1937). The nomogram used (Fig. 1) enable readily determination of *ET* from the dry and wet bulb

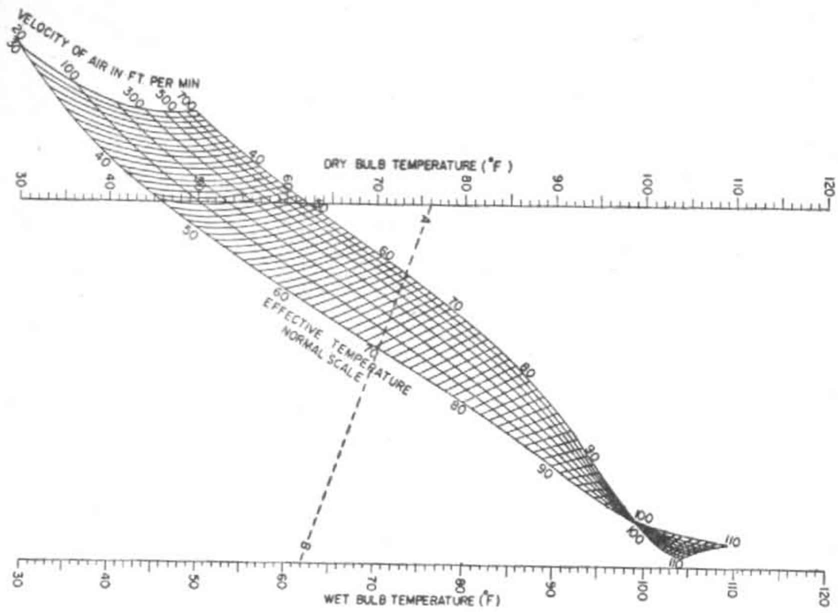

Fig. 1. Thermometric or effective temperature chart showing normal scale of effective temperature (°F)

temperatures and the surface wind speed. The wet bulb temperature, it may be mentioned, is itself a function of wind speed and it is difficult to isolate and quantify the effect due to wind on wet bulb temperature from that of the radiation. A glance at Fig. 1 reveals that for the range of dry and wet bulb normally encountered in India, the overall effect of the increased wind speed on the effective temperature would hardly exceed one degree; even in the driest and most windy environmental conditions, it may not be more than 2°. Therefore, it was felt inspite of the complex nature of wet bulb *vis-a-vis* the wind speed the *ET* as calculated from the nomogram are not viciated but objectively represent the human comfort. Since the present paper deals only with indoor conditions not subjected to direct solar radiation, the effects of solar radiation on comfort have not been taken into account. In some of the studies the effective temperature (*ET*) has been computed from the formula.

$$ET = 0.4\,(T_d + T_w) + 15$$

where, T_d and T_w are respectively, dry and wet bulb temperatures.

2. Data utilised

Hourly dry and wet bulb temperatures and wind speed data for each day during the ten year period (1957 to 1966) in respect of 4 major cities, *viz,* Bombay, Calcutta, Madras and New Delhi have been utilised in this study. Weekly means of temperature, humidity and surface winds at each hour (0 to 24 hrs) were worked out. The *ET* have been plotted for each hour for each of the 52 weeks, analysed and depicted in Figs. 2 to 5.

3. Lower limit of ET in relation to metabolic discomfort

From an experimental work Malhotra (1967) recommends an *ET* of 22.5°C as the upper limit of the physiological comfort temperature. Raman & Rangarajan (1975) utilised mean monthly temperature for 3-hour interval (*i.e.,* synoptic hours) to demarcate zones of human discomfort using 22.5°C *ET* as the limit. However, if effective temperature of 22.5 °C is taken as the lower limit of human comfort in relation to airconditioning operations, it may be seen from Figs. 2-5 that at each of the metropolis, the airconditioning should be operated round the clock, day and night, from (*i*) 14th to 25th week (*i.e.,* 2 April to 18 June) at Bombay, (*ii*) 21st to 39th week (21 May to 24 September) at Delhi, (*iii*) 17th to 43rd week (23 April to 5 November) at Calcutta, (*iv*) 11th to 30th week (12 March to 23 July) at Madras.

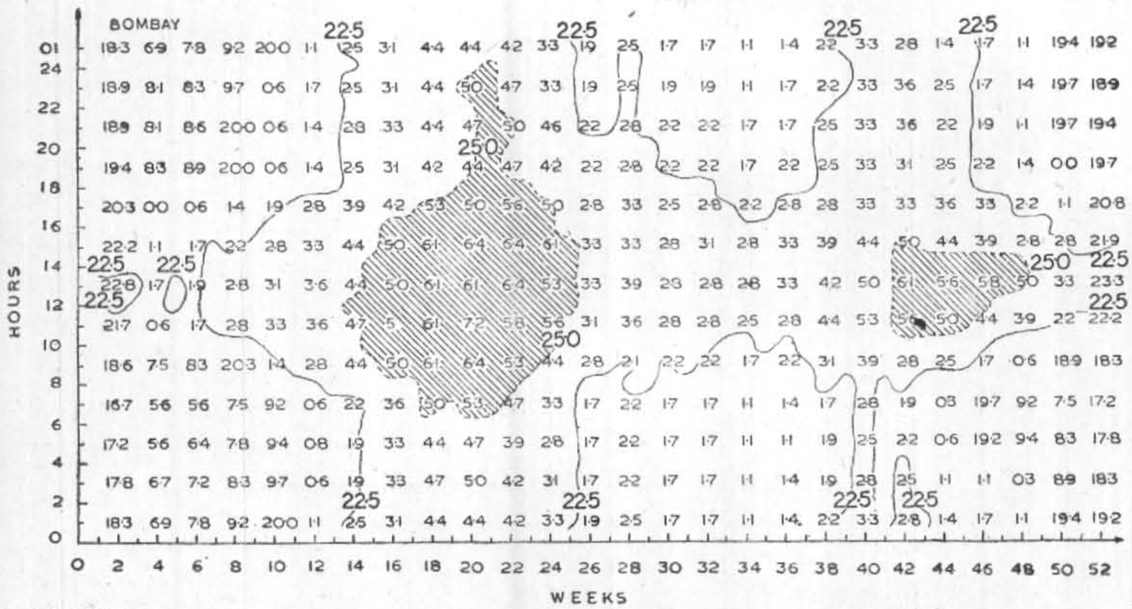

Fig. 2. Weekly distribution of hourly effective temperature in °C at Bombay

This is certainly not supported by the actual personal experience. For example, it has been observed by the senior author that at Nagpur, at the height of the summer season when the maximum temperature is 44-46° C the minimum temperature itself often exceeds 30° C, yet the need for operations of fans, even on such nights, is not essential from approximately 2300/2400 hr to 0700/0800 hr. And in the thermal discomfort, Nagpur has very few parallels in India. Thus the lower limit of 22.5 ° C of the effective temperature for airconditioning appear to be slightly on the lower side.

In this paper, therefore, a higher value of *ET* was chosen as the lower limit of the thermal discomfort. The temperature was somewhat arbitrarily chosen as 25.0°C but as may be seen from the following paragraphs, the arbitrary value is in greater agreement with the conditions actually observed and experienced. Areas having temperatures more than 25° C have been hatched. These denote hours and the weeks of discomfort and when airconditioning is needed at these places.

4. Discussion

Some of the characteristic features of the distribution of the *ET*s are briefly described for the 4 cities. Duration of airconditioning requirement from human comfort point of view are also summarised.

(*i*) *Bombay* — The discomfort would be experienced at this station from 15th to about 24th week, *i.e.,* 9 April to 17 June (Fig. 2). Thus only after the onset of monsoon over the city (normally around 11 June), the climatic conditions become congenial. The *ET* exceeds 25 °C generally between 0900 to 1700 hrs IST, exception being 21st week*, *i.e.,* (3rd week of May) when the discomfort prolongs upto midnight.

A secondary period of discomfort exists after the withdrawal of monsoon when and consequent clear sky conditions, when the day temperature shoots up. Presence of fairly large amount of moisture further aggravates the situation. Locally this phase is normally called "the second summer" and is prominent from 42nd to 46th week, *i.e.,* from 15 October to about 2nd week of November (The daily duration is, however, small lasting from 1100 to 1400 hr).

This particular feature is masked when the analysis is made on the basis of 22.5° C *ET* as the lower limit of discomfort, but has been well brought out on the assumption of 25°C as the base for initiation of discomfort.

(*ii*) *Calcutta* — The distribution of effective temperature at Calcutta is shown in Fig. 3. At this station the period of discomfort is a staggered one, stretching from about 13th week to 41st week (last week of March to second week of

*Note — Please refer to Appendix for dates/months corresponding to weeks.

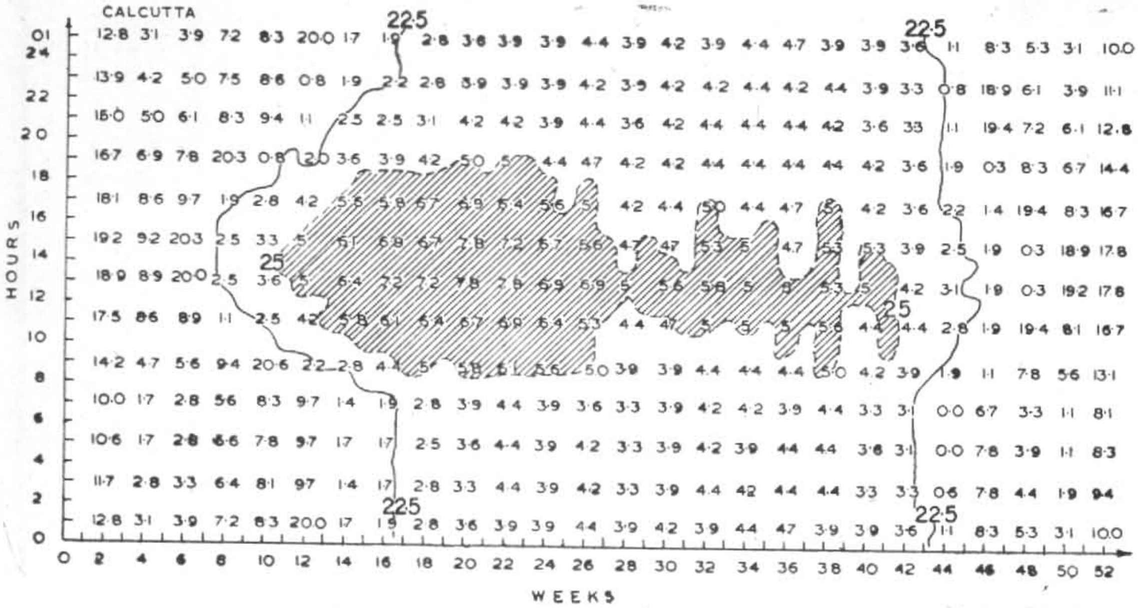

Fig. 3. Weekly distribution of hourly effective temperature in °C at Calcutta

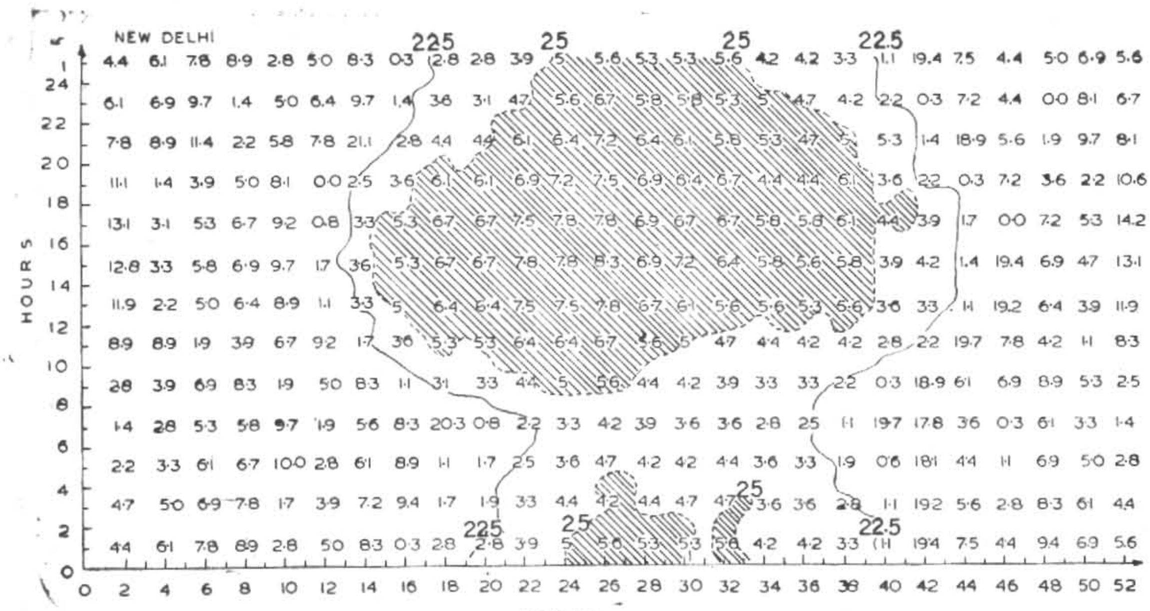

Fig. 4. Weekly distribution of hourly effective temperature in °C. at New Delhi

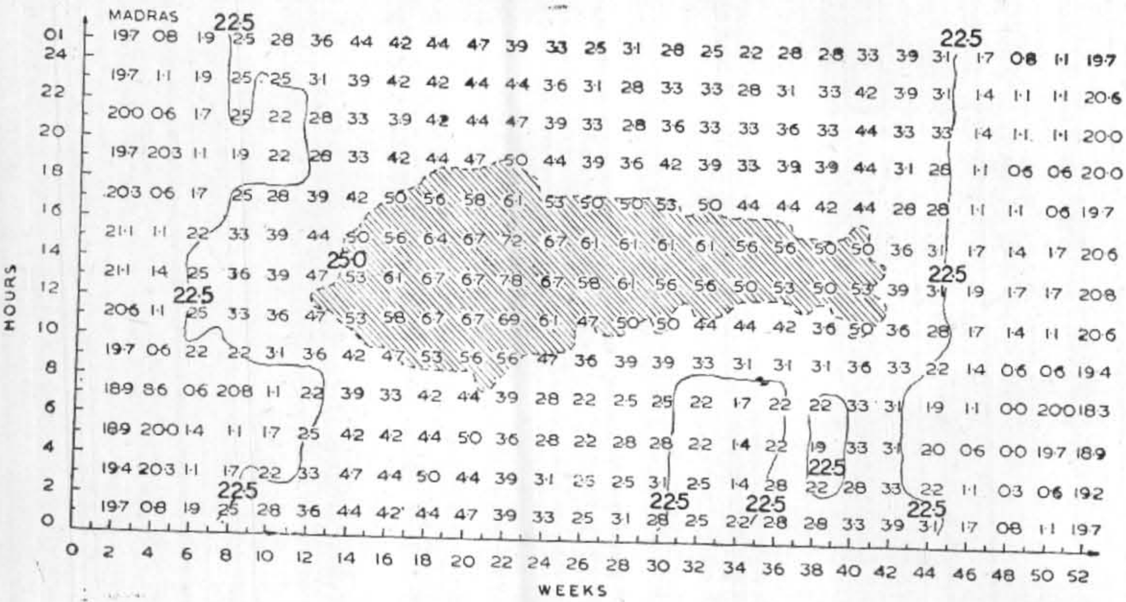

Fig. 5. Weekly distribution of hourly effective temperature in °C at Madras

October). The onset of monsoon and the accompanying subsequent rains, do not appear to bring relief to the residents at Calcutta. The largest value of *ET* are observed between 20th & 22nd week, *i.e.*, 14 May to 3 June or just before the monsoon advance. The daily duration of discomfort is also the longest, *i.e.* from about 0900 hr to 1800 hr except after 3rd week of July when it is mostly restricted from 1100 to 1660 hr.

(*iii*) *New Delhi* — If the magnitude of the *ET* and the duration (both in terms of weeks and hours) are any indication, New Delhi appears to be a worst station among the four stations studied in this work from the point of view of environmental discomfort. The discomfort commences nearly from second week of April (Fig. 4) and lasts till end of September or first week of October. It prevails from 1100 hrs (through during June to first week of July, it is experienced from as early as 0900 hr onwards) and lasts till midnight. In fact the discomfort continues from 4 June to 19 August, even three hours past midnight.

(*iv*) *Madras* — The pattern of occurrence of physiological stress due to climate is slightly different from the other three stations mentioned above. Discomfort at this station is experienced, as may be seen from Fig. 5, from the first week of April and continued uninterrupted till second week of October. Broadly the duration last from 1000 to 1700 hr. Since this station is not normally affected by the southwest monsoon, it's influence in ameliorating or otherwise of the discomfort conditions, could not be examined or quantified. However, northeast monsoon which commences from middle of October, does not appear to exert any influence whatsoever, aggravating or otherwise, on the thermal discomfort at Madras.

5. Concluding remarks

The continuing rise in energy cost has simulated a search for various methods of its conservation. The object of this study is to explore possibilities of minimising the use of electric power while keeping people in the state of physiological comfort. Figs. 2 to 5 enable to identify more precisely periods of environmental comfort at the four metropolis, Bombay, Calcutta, New Delhi and Madras. The results obtained are in general consistent with the synoptic conditions actually observed. The diagrams can be effectively used in planning optimum utilisation of electric energy for airconditioning purposes.

Acknowledgement

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APPENDIX

Week	Month	Date	Week	Month	Date
1	Jan	1-7	27	Jul	2-8
2	,,	8-14	28	,,	9-15
3	,,	15-21	29	,,	16-22
4	,,	22-28	30	,,	23-29
5	Jan-Feb	29-4	31	Jul-Aug	30-5
6	Feb	5-11	32	Aug	6-12
7	,,	12-18	33	,,	13-19
8	,,	19-25	34	,,	20-26
9	Feb-Mar	26-4*	35	Aug-Sep	27-2
10	Mar	5-11	36	Sep	3-9
11	,,	12-18	37	,,	10-16
12	,,	19-25	38	,,	17-23
13	Mar-Apr	26-1	39	,,	24-30
14	Apr	2-8	40	Oct	1-7
15	,,	9-15	41	,,	8-14
16	,,	16-22	42	,,	15-21
17	,,	23-29	43	,,	22-28
18	Apr-May	30-6	44	Oct-Nov	29-4
19	May	7-13	45	Nov	5-11
20	,,	14-20	46	,,	12-18
21	,,	21-27	47	,,	19-25
22	May-Jun	28-3	48	Nov-Dec	26-2
23	Jun	4-10	49	Dec	3-9
24	,,	11-17	50	,,	10-16
25	,,	18-24	51	,,	17-23
26	Jun-Jul	25-1	52	,,	24-31 (8 days week)

*In case of leap year this week is of 8 days.