451.524.3 : 697 : 97

An estimate of Thermal Comfort at some stations in India

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(*Received 18 December 1965*)

ABSTRACT. The paper describes briefly how the thermal aspect influences comfort. Since comfort depends not only on the temperature of the air, but also on the relative humidity and air movement, no simple formula to obtain an index involving all the factors is available. In this paper Thom's simple empirical formula for a Discomfort Index $=0 \cdot 4(t_d + t_w) + 15$, where t_d is air temperature and t_w is the wet bulb temperature, is used and the mean hourly values of discomfort index are calculated for different months for the 5 stations, New Delhi, Calcutta, Poona, Madras and Trivandrum. According to Thom, people in the U.S.A., feel discomfort as the index rises above 70 and everyone is uncomfortable by the time the index reaches 79· When the index becomes 86 or higher, in Washington metropolitan area, mass dismissal of employees are permitted. The analysis of Indian data shows that in general, the prevailing DI for India is in the range 76—80 or less, except in the summer months, April-May to September, when it exceeds this value. Poona has the largest number of hour days with DI = or <75. In the range DI=76-80, Poona and Trivandrum have the largest and almost similar values, *viz.*, 8224 and 8343 hour-days respectively but a possible total of 8760 during the year. DI = 86-90 is experienced in the premonsoon months only in New Delhi (368 hour-days), Calcutta (183) and Madras (239). It is generally observed that the indices can be adopted for the tropical Indian conditions also. They will, therefore, be of value to visitors from abroad and to the Indians. They will also be useful to plan air conditioning units for Indian use.

Scarcely a prospective tourist from one latitude to another fails to worry what the climate will be like and whether he can be comfortable during the tour. A number of meteorological factors influence the liveability on the earth's surface, but among them all, the thermal aspect is the most important. The human body works best when its internal temperature is 98°F, and any marked deviation from this temperature results in discomfort, and in extreme cases even to death. In an interesting article, Brunt (1944) has dealt at length on the effects of temperature and humidity in the environments on the human body.

In the metabolic heat production, *viz.*, the heat generated in the body by the process of oxidation of body tissues in the course of digestion and by muscular effort, the main components of control of heat retention and heat loss are through respiration, peripheral blood circulation and secretion by sweat glands. Because of this, the environmental conditions in excess of certain values will cause the skin temperature and later the core temperature to rise or fall beyond the comfort level and sometimes exceed the safety limit. The metabolic heat generated in the body is conducted to the skin by the blood circulation, and is dissipated by radiation, evaporation of perspiration or convective air motion. When the environment is cold the blood vessel near the surface contract and lie deeper in the skin which has the effect of reducing the heat loss to the air by conduction and convection. When one shivers in the cold, it is an attempt to increase heat production in the body by muscular movement. At low temperatures, the internal generation of heat is also accelerated by the release of secretion from certain endocrine glands. However, though both exercise and involuntary shivering may moderate the effect of cold in man these mechanisms are very temporary and for the extreme climatic exposure, are of only emergency value.

Discreditable experiments were conducted during World War II at Dachau by S. Rascher (Harrinton 1954), on the most effective methods of resuscitation for sea or land exposure cases. No less than 103 persons were used, few of whom appear to have survived the complete experimental programme. In one table seven deaths are specifically recorded. The average thermal data on these seven who died from the effects of tank immersion are given in Table 1. From these and other data, it is estimated that during the course of an hour, death resulted after a reduction of 23° to 25° F in average body temperature.

If the environment becomes warmer, the method of heat regulation is different. The capillaries rapidly dilate to let more blood reach the skin from which conduction, convection and radiation can pass more heat more rapidly to the surroundings. With further increase in warmth to temperatures between 80° and 90°F, the sweat glands suddenly begin to secrete; the evaporation of the sweat takes up latent heat and augments the cooling power. When air temperature is higher than body temperature, the body temperature continues to rise, due to loss of heat by evaporation being insufficient, and the pulse

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TABLE 1

Thermal data on clothed human subjects dying after immersion in cold water

	Water temp.	Time of immersion (min)	Time at death (min)	Rectal temp. on removal from bath	Rectal temp. at death
Average	4·6°C (40·3°F)	67	73	28°C (82·4°F)	26·8°C (80·2°F)
Range	4·2°C (39·6°F)	53—98	53—100	26·7—29·2°C	25·0—29·2°C

TABLE 2

Air temperature (t_d) in°F	60	61	62	63	64	67	68	70	72	74
Wet bulb temp. (t_w) in°F	60	57	54	51	48	67	65	61	57	54
Effective temp. (E.T.)	60	60	60	60	60	67	67	67	67	67
Discomfort Index (DI)	63	62	61	61	60	69	68	67	67	66

rate, rate of breathing and body temperature tend to rise. Such a condition rapidly leads one to the various types of heat sickness, stroke, etc.

When the metabolic rate is known, and the skin temperature can be estimated, an equation may be written down expressing the balance between metabolic rate and the loss or gain of heat by radiation, conduction and evaporation in air of any assigned temperature, humidity and air movement assuming the radiating surface to be at air temperature (Buettner 1951). This equation will yield for any assumed temperature, the maximum relative humidity in which the heat balance can be maintained, assuming a definite air movement.

The human body responds differently to the various factors. In addition, the body has the remarkable ability to adapt itself after a certain length of exposure to a new level of climatic conditions; also differences exist between different individuals in their responses to given atmospheric conditions or changes. Comfort is, therefore, a factor which is difficult to define with clarity. It is not possible to devise an instrument which will produce a response exactly parallel to that of the human body. A measure of climatic comfort for a group of people will reflect only an average of different individuals.

Experience in air conditioning in many countries has shown that it may be accepted that with relative himidity of about 40 to 70 per cent, men doing light work indoors can do so with maximum comfort in air temperature above 60°F and below 76°F

Since comfort depends not only on the temperature of the air, but also on the relative humidity and air movement, an arbitrary index is used which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body. This is called the effective temperature. The numerical value is that of the temperature of still, saturated air which would induce the same feeling of heat or cold in a sedentary worker wearing ordinary indoor clothing, as that given by the actual conditions of temperature, relative humidity and air movement. Effective temperatures are used as the best available measure of human comfort. They serve to indicate the amount of human discomfort and the resulting need for air conditioning.

Though a number of charts of effective temperature at various air temperatures, relative humidities and air movement have been published, for practical purposes, effective temperature normals cannot be easily secured from the large volume of past data of weather conditions. Thom (1959) who studied this problem has suggested a "discomfort index". This index (DI) is obtained by a simple linear adjustment applied to the average of the dry bulb and wet bulb readings.

$$DI=0\cdot4\ (t_d\ +t_w\ )+15$$

All t values are in °F and they are simultaneous readings. The values of discomfort index are in reasonably close agreement with effective temperatures. Table 2 gives the values of air temperature (t_d), wet bulb temperature (t_w), effective temperature (E.T.), and discomfort index (DI), with an air movement of 20 ft/min, which is practically still air.

According to Thom, people feel discomfort as the index rises above 70, with over half uncomfortable with index over 75. Everyone will be uncomfortable by the time the index reaches 79. As the index passes above 80, discomfort becomes more serious. When office conditions in the Washington metropolitan area are such that the index becomes 86 or higher, Government regulations permit mass dismissal of employees who are working under these conditions.

It has to be emphasized that these limits are for the U.S.A. While thousands of the citizens may develop heat stroke under certain ranges in the U.S.A., within a few days time, such conditions may not bother tropical residents. Also, heat strokes may occur only when there is sudden rise in temperatures and there is not sufficient time for the body to adjust its rate of heat production downwards. After adaption has taken place, it may safely stand still higher temperatures.

Since a large number of visitors come into India in all seasons, and since even in India with its variety of climatic regions, people will travel frequently from one place to another, it was felt that a detailed analysis of the temperature data at a few important stations may be useful, not only for the tourists, but in connection with the designing and choice of air conditioners. In India, there are regions in which the discomfort index increases in certain months to values above 85. There are also regions where values of 70 or less are met with during certain months. An analysis of this index will, therefore, indicate how far these criteria are applicable to the residents of India based on their own experiences of discomfort or otherwise.

In this note, an examination has been made of the hourly air temperature and wet bulb temperature for the 5 stations, New Delhi (1950—54), Alipore (Calcutta) (1950—52), Poona (1950—54), Madras (1953—55) and Trivandrum (1953—55). These 5 stations may be considered roughly as representative of the different climatological types in India. For example, Delhi and Calcutta lie in the north, bordering the northern limits of the tropics and experience in addition to the Indian monsoon, the extra-tropical winter also, though influenced to a large degree by the Himalayas.

Poona in the middle region of India (about 1800 ft a.s.l.) is on the lee-side of the Western Ghats and not far from the sea coast, and is still under the influence of the sea-breeze. It is also affected directly by the southwest monsoon, though modified by the Western Ghats. Madras and Trivandrum are in the lower regions of India. While Madras is on the Bay of Bengal coast, Trivandrum is on the Arabian Sea, and the two places experience different types of weather. Based on the data of these stations, one may be able to roughly extrapolate the conditions prevailing in most of the other regions.

The mean discomfort index has been calculated for these stations for each hour of the day in each month. The ranges of discomfort index considered are <70, 70-75, 76-80, 81-85 and greater than 85. Based on these data, Table 3 gives the number of hour-days of discomfort indices of different ranges in each month at these stations. These values have been obtained by adding up the number of days in each hour the particular DI has been experienced. Curves have also been drawn for each month, showing the average number of days in each hour for different ranges of DI (Only 5 diagrams — one in respect of each of the five stations are reproduced here, Figs. 1-5). Isopleths which show the number of days in each hour in the different months discomfort indices exceeding 75, 80 and 85 have also been drawn for these stations (Figs. 6-10). Some of the important features observed from these data are given below.

(1) DI=75 *or less when most people are comfortable*

Table 3 gives the total number of hour-days of different DI ranges in each month for the 5 stations. The number of hour-days with DI equal to or less than 75 during the year is given in Table 4.

In all the stations, DI less than 75 is obtained only in the winter. But in the case of Poona the value occurs during the monsoon also and it is, therefore, observed that this station has the best climate. While Trivandrum is the southernmost station, it is more comfortable than Madras, though values less than 70 are never experienced. At Trivandrum values of DI in the range 70-75 occur during the nights in all the months and the monsoon month of July is more comfortable than even the winter months December to January.

The distribution of the number of hour-days with DI values less than 75 during the day and night are given in Table 5 for the whole year. If we assume that for comfortable living, at least 6 hours of the day and a similar duration at night should be less than 75 on more than 20 days in a month, the month in which this occurs is given within brackets.

As one should expect, nights are generally more comfortable than the day. The nights at

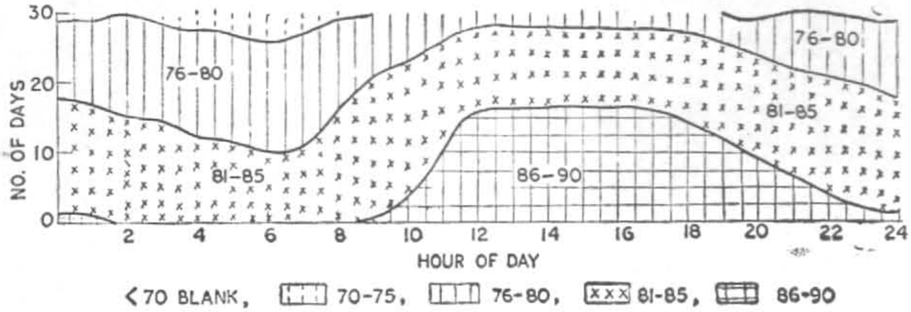

Fig. 1. New Delhi—June

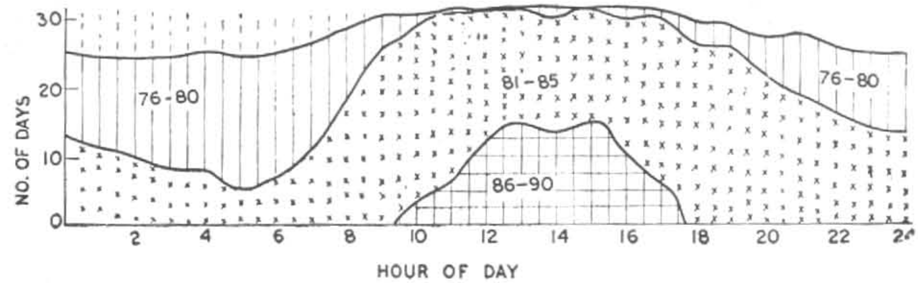

Fig. 2 Alipore—May

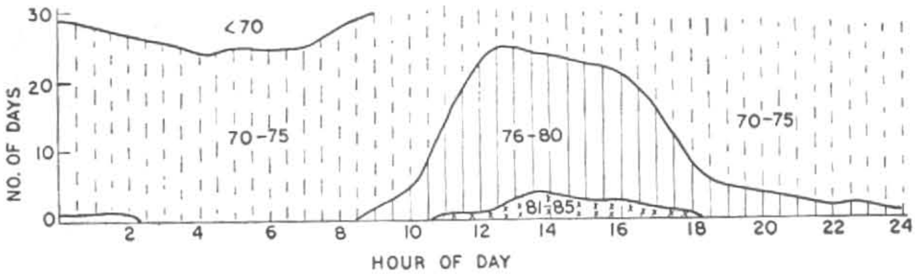

Fig. 3. Poona—September

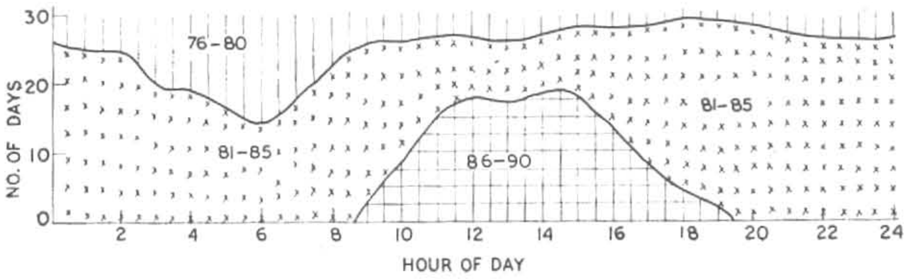

Fig. 4. Madras—May

Figs. 1—4. No. of days of discomfort in each hour of the day

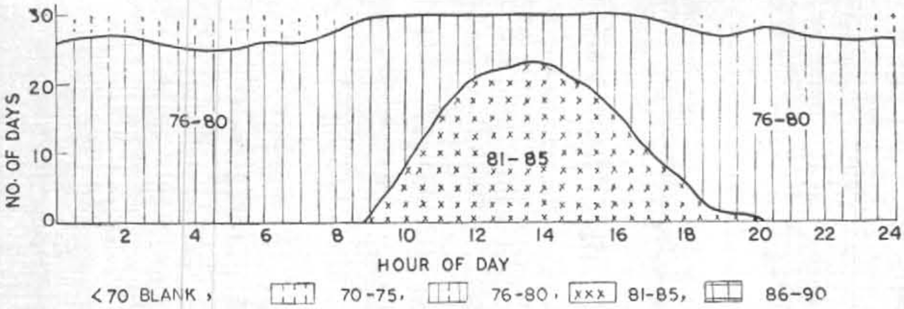

Fig. 5. No. of days of discomfort in each hour of the day, Trivandrum—April

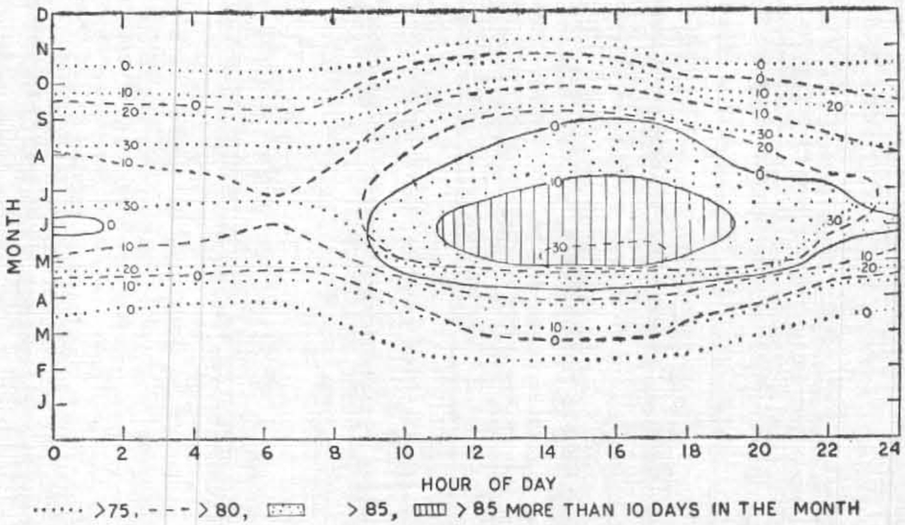

Fig. 6. Isopleths of discomfort indices of different ranges (Number of days in each hour in different months)—New Delhi

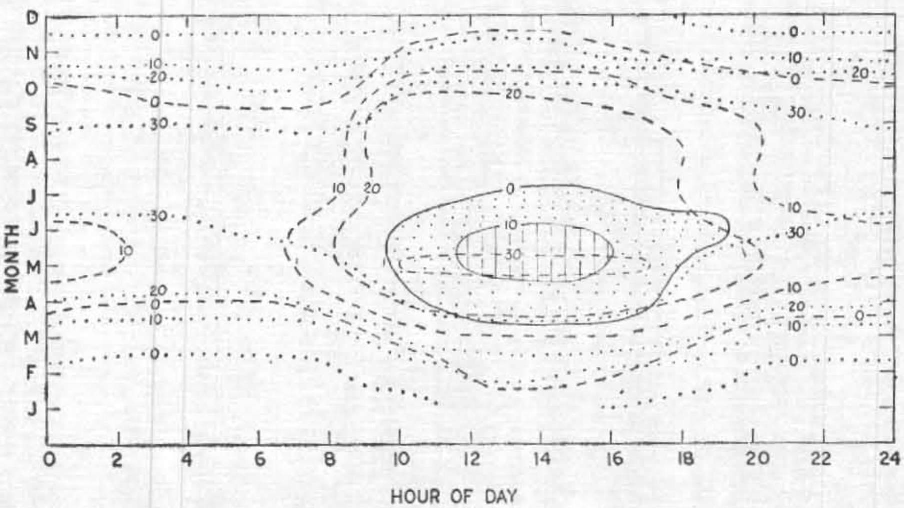

Fig. 7. Isopleths of discomfort indices of different ranges (Number of days in each hour in different months)—Alipore

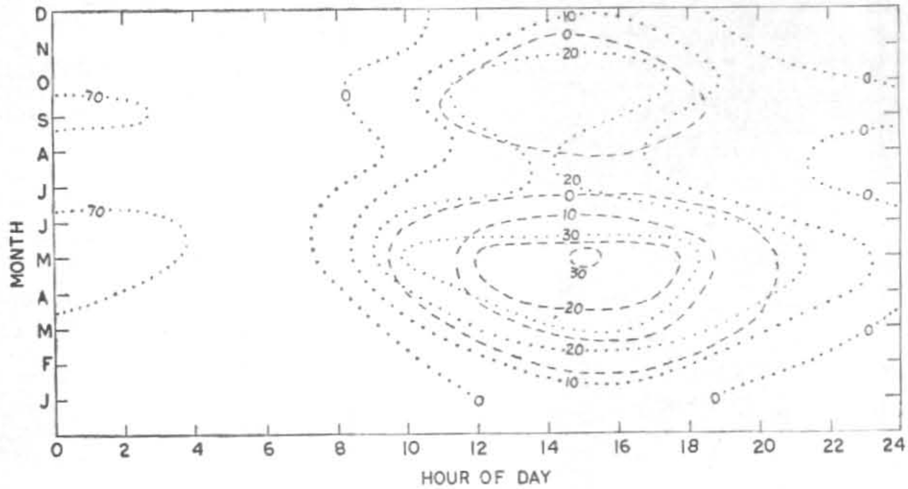

Fig. 8. Poona

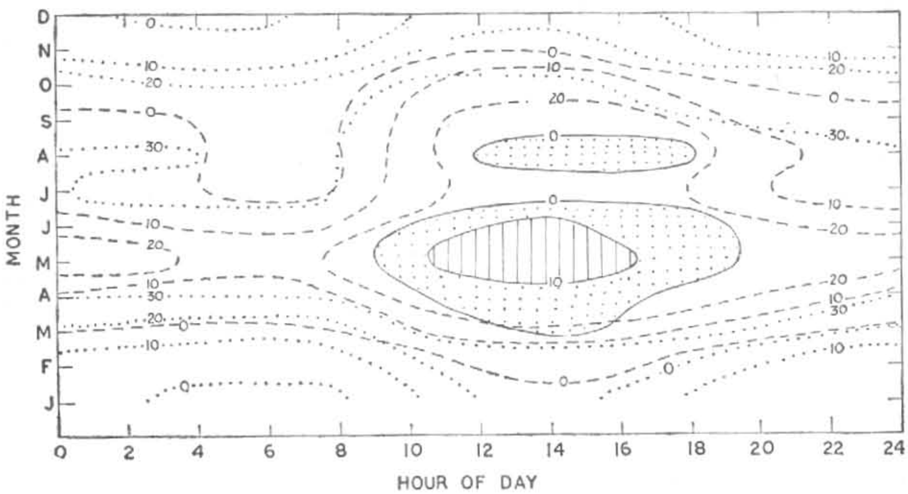

Fig. 9. Madras

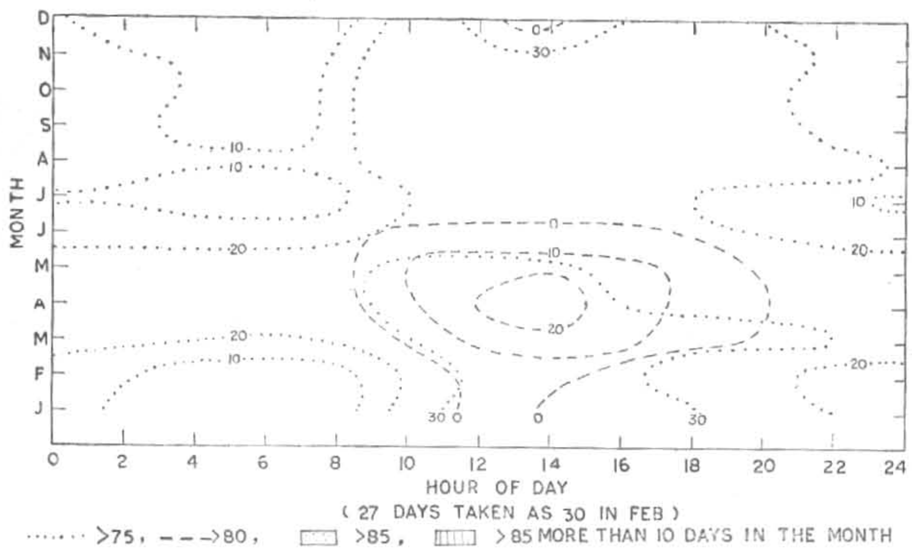

Fig. 10. Trivandrum

Figs. 8—10. Isopleths of discomfort indices of different ranges (Number of days in each hour in different months)

TABLE 3 (a)—New Delhi

No. of hour-days of Discomfort Index of different ranges in each month

	0—24 hrs					Day light (0700—1800)					Night (1900—0600)					DI=80 and below			DI=81 and above		
	<70	70–75	76–80	81–85	86–90	<70	70–75	76–80	81–85	86–90	<70	70–75	76–80	81–85	86–90	0–24 hrs	0700–1800	1900–0600	0–24 hrs	0700–1800	1900–0600
Jan	744	0	0	0	0	372	0	0	0	0	372	0	0	0	0	744	372	372	0	0	0
Feb	627	44	1	0	0	293	42	1	0	0	334	2	0	0	0	672	336	336	0	0	0
Mar	463	206	69	6	0	165	137	64	6	0	298	69	5	0	0	738	366	372	6	6	0
Apr	177	265	181	97	0	47	99	126	88	0	130	166	55	9	0	623	273	351	97	88	9
May	0	75	256	308	105	0	16	69	190	97	0	59	187	118	8	331	85	126	413	287	126
Jun	0	18	188	346	168	0	3	61	163	133	0	15	127	183	35	206	64	142	514	296	218
Jul	0	0	221	445	78	0	0	76	228	68	0	0	145	217	10	221	76	145	523	296	227
Aug	0	0	343	387	14	0	0	121	237	14	0	0	222	150	0	343	121	222	401	251	150
Sep	0	89	369	259	3	0	20	130	207	3	0	69	239	52	0	458	150	308	262	210	13
Oct	248	278	172	46	6	54	139	134	45	0	194	139	38	1	0	698	327	371	46	45	1
Nov	628	88	4	0	0	270	86	4	0	0	358	2	0	0	0	720	360	360	0	0	0
Dec	744	0	0	0	0	372	0	0	0	0	372	0	0	0	0	744	372	372	0	0	0
Total	3631	1063	1894	1894	368	1573	542	786	1164	315	2058	521	1018	73	53	6498	2901	3477	2262	1479	783
P.T.	3631	4694	6498	8392	8760	1573	2115	2901	4065	4380	2058	2579	3597	4327	4380						

P.T.—Progressive Total

TABLE 3 (b)—Calcutta

No. of hour-days of Discomfort Index of different ranges in each month

	0—24 hrs					Day light (0700—1800)					Night (1900—0600)					DI=80 and below			DI=81 and above		
	<70	70–75	76–80	81–85	86–90	<70	70–75	76—80	81–85	86–90	<70	70–75	76–80	81–85	86–90	0–24 hrs	0700–1800	1900–0600	0–24hrs	0700–1800	1900 0600
Jan	581	156	7	0	0	212	153	7	0	0	369	3	0	0	0	744	372	372	0	0	0
Feb	367	224	72	9	0	114	142	71	9	0	253	82	1	0	0	663	327	327	9	9	0
Mar	170	273	246	55	0	72	46	199	55	0	98	227	47	0	0	689	317	317	55	55	0
Apr	32	106	292	256	34	1	17	89	219	34	31	89	203	37	0	430	107	323	290	253	37
May	0	74	191	395	84	0	8	38	242	84	0	66	153	153	0	265	46	219	479	326	532
Jun	0	6	288	364	62	0	0	76	223	61	0	6	212	141	1	294	76	218	426	284	142
Jul	0	0	458	283	3	0	0	140	229	3	0	0	318	54	0	458	140	318	286	232	54
Aug	0	0	436	308	0	0	0	115	257	0	0	0	321	51	0	436	115	321	308	257	51
Sep	0	5	440	275	0	0	2	128	230	0	0	3	312	45	0	415	130	315	275	230	45
Oct	0	138	461	145	0	0	35	200	137	0	0	103	261	8	0	599	235	364	145	137	8
Nov	313	283	115	9	0	85	170	96	9	0	228	113	19	0	0	711	351	360	9	9	0
Dec	568	168	8	0	0	207	157	8	0	0	361	11	0	0	0	744	372	372	0	0	0
Total	2031	1433	3014	2099	183	691	730	1167	1610	182	1340	703	1847	489	1	6478	2588	3890	2282	1792	490
P.T.	2031	3464	6478	8577	8760	691	1421	2588	4198	4380	1340	2043	3890	4379	4380						

P.T.—Progressive Total

TABLE 3 (c)—Poona

No. of hour-days of Discomfort Index of different ranges in each month

	0—24 hrs					Day light (0700—1800)					Night (1900—0600)					DI=80 and below			DI=81 and above		
	<70	70–75	76–80	81–85	86–90	<70	70–75	76–80	81–85	86–90	<70	70–75	76–80	81–85	86–90	0–24 hrs	0700–1800	1900–0600	0–24 hrs	0700–1800	1900–0060
Jan	543	166	35	0	0	190	147	35	0	0	353	19	0	0	0	744	372	372	0	0	0
Feb	422	160	83	7	0	138	114	77	7	0	284	46	6	0	0	665	329	336	7	7	0
Mar	284	199	194	67	0	89	65	152	66	0	195	134	42	1	0	677	306	371	67	66	1
Apr	97	263	202	158	0	29	65	114	152	0	68	19	88	6	0	562	208	354	158	152	6
May	28	296	219	201	0	8	65	105	194	0	20	231	114	7	0	543	178	365	201	194	7
Jun	0	410	247	63	0	0	104	194	62	0	0	306	53	1	0	657	298	359	63	62	1
Jul	0	590	154	0	0	0	226	146	0	0	0	364	8	0	0	744	372	372	0	0	0
Aug	8	627	107	2	0	2	264	104	2	0	6	363	3	0	0	742	370	372	2	2	0
Sep	34	505	163	18	0	7	191	144	18	0	27	314	19	0	0	702	342	360	18	18	0
Oct	178	369	209	18	0	39	126	189	18	0	109	243	20	0	0	726	354	372	18	18	0
Nov	414	222	82	2	0	110	167	81	2	0	304	55	1	0	0	718	358	360	2	2	0
Dec	523	183	38	0	0	171	163	38	0	0	352	20	0	0	0	744	372	372	0	0	0
Total	2501	3990	1733	546	0	783	1697	1379	521	0	1718	2293	354	15	0	8224	3859	4365	536	521	15
P.T.	2501	6491	8224	8760	8760	783	2480	3859	4380	4380	1718	4011	4365	4380	4380						

P.T.—Progressive Total

TABLE 3 (d)—Madras

No. of hour-days of Discomfort Index of different ranges in each month

	0—24 hrs					Day light (0700—1800)					Night (1900—0600)					DI=80 and below			DI=81 and above		
	<70	70–75	76–80	81–85	86–90	<70	70–75	76–80	81–85	86—90	<70	70–75	76–80	81–85	86–90	0–24 hrs	0700–1800	1909–0600	0–24 hrs	0700–1800	1900–0600
Jan	32	540	172	0	0	19	197	156	0	0	13	343	16	0	0	744	372	372	0	0	0
Feb	39	347	277	9	0	17	84	226	9	0	·22	263	51	0	0	663	327	336	9	9	0
Mar	0	177	411	152	4	0	41	186	141	4	0	136	225	11	0	588	227	361	156	145	11
Apr	0	0	326	370	24	0	0	71	265	24	0	0	255	105	0	326	71	255	394	289	105
May	0	0	128	483	133	0	0	44	195	133	0	0	84	288	0	128	44	84	616	328	288
Jun	0	0	258	402	60	0	0	69	232	59	0	0	189	170	1	258	69	189	462	291	171
Jul	0	28	468	247	1	0	6	163	202	1	0	22	305	45	0	496	169	327	248	203	45
Aug	0	16	424	288	16	0	4	134	218	16	0	12	290	70	0	440	138	302	304	234	70
Sep	0	29	463	227	1	0	3	163	193	1	0	26	300	34	0	492	166	326	228	194	34
Oct	0	118	520	106	0	0	25	241	106	0	0	93	279	0	0	638	266	372	106	106	0
Nov	51	418	251	0	0	26	133	201	0	0	25	285	50	0	0	720	360	360	0	0	0
Dec	99	512	133	0	0	33	217	122	0	0	66	295	11	0	0	744	372	372	0	0	0
Total	221	2185	3831	2284	239	95	710	1776	1561	238	126	1475	2055	723	1	6237	2581	3656	2523	1799	724
P.T.	221	2406	6237	8521	8760	95	805	2581	4142	4380	126	1601	3656	4379	4380						

P.T.—Progressive Total

TABLE 3 (e)—Trivandrum

No. of hour-days of Discomfort Index of different ranges in each month

	0—24 hrs					Day light (0700—1800)					Night (1900—0600)					DI=80 and below			DI=81 and above		
	<70	70–75	76–80	81–85	86–90	<70	70–75	76–80	81–85	86–90	<70	70–75	76–80	81–85	86–90	0–24 hrs	0700–1800	1900–0600	0–24 hrs	0700–1800	1900 0600
Jan	0	298	444	2	0	0	82	288	2	0	0	216	156	0	0	742	370	372	2	2	0
Feb	0	253	416	3	0	0	74	259	3	0	0	179	157	0	0	669	333	336	3	3	0
Mar	0	82	552	110	0	0	24	239	109	0	0	58	313	1	0	634	263	371	110	109	1
Apr	0	53	521	146	0	0	9	207	144	0	0	44	314	2	0	574	216	358	146	144	2
May	0	79	526	139	0	0	24	211	137	0	0	55	315	2	0	605	235	370	139	137	2
Jun	0	225	481	14	0	0	75	271	14	0	0	150	210	0	0	726	346	360	14	14	0
Jul	0	385	359	0	0	0	128	244	0	0	0	257	115	0	0	744	372	372	0	0	0
Aug	0	237	506	1	0	0	74	297	1	0	0	163	209	0	0	743	371	372	1	1	0
Sep	0	241	479	0	0	0	60	300	0	0	0	181	179	0	0	720	360	360	0	0	0
Oct	0	270	474	0	0	0	73	299	0	0	0	197	175	0	0	744	372	372	0	0	0
Nov	0	267	453	0	0	0	71	289	0	0	0	196	164	0	0	720	360	360	0	0	0
Dec	0	328	414	2	0	0	88	282	2	0	0	240	132	0	0	742	370	372	2	2	0
Total	0	2718	5625	417	0	0	782	3186	412	0	0	1936	2439	5	0	8363	3968	4375	417	412	5
P.T.	0	2718	8343	8760	8760	0	782	3968	4380	4380	0	1936	4375	4380	4380						

P.T.—Progressive Total

TABLE 4

	Hour-day	DI range
New Delhi	4694	< 70 in 3631 hr-days
Calcutta	3464	< 70 in 2031 hr-days
Poona	6491	< 70 in 2501 hr-days
Madras	2406	< 70 in 221 hr-days
Trivandrum	2718	< 70 in no day

TABLE 5

No. of hour-days with DI< 75 during day and night

	Day	Night
New Delhi	2115 (Oct—Mar) (6 months)	2579 (Oct—Apr) (7 months)
Calcutta	1421 (Nov—Feb) (4 months)	2043 (Nov—Mar) (5 months)
Poona	2480 (Nov—Feb and Aug—Sep) (6 months)	4011 (Jan—Dec) (12 months)
Madras	805 (Dec—Jan) (2 months)	1601 (Nov—Feb) (4 months)
Trivandrum	782 (No month)	1936 (Nov—Feb and July) (5 months)

Trivandrum are better than those at Madras and compare almost with those at Calcutta.

Usually the winter months are the best months during the year, at each station and the effects of winter are less and less towards lower latitudes. But the southwest monsoon which occurs in the summer modify the position very much, particularly at Poona and Trivandrum, which are directly affected by the current from the Arabian Sea.

While values of DI less than 75 are considered to be comfortable, very low values of indices, *e.g.*, below 60 can be uncomfortable. These values, may occur occasionally in winter only at Delhi. Discomfort will be felt particularly by those in the southern regions of India when they travel to the north in winter. The southerners have less body heat production, and they do not produce as much heat or increase in response to

TABLE 6

No. of hr-days when DI $\leqslant$ 80

Station	Year	Day	Night
New Delhi	6498	2901	3597
Calcutta	6478	2588	3890
Poona	8224	3859	4365
Madras	6237	2581	3656
Trivandrum	8343	3968	4375

TABLE 7

No. of hr-day in a year when DI>80

New Delhi	2262
Calcutta	2282
Poona	536
Madras	2523
Trivandrum	417

TABLE 8

Station	Day		Night	
New Delhi	May—Sep	(5)	Jun—Jul	(2)
Calcutta	Apr—Sep	(6)	—	
Poona	May	(1)	—	
Madras	Apr—Sep	(6)	—	
Trivandrum	—		—	

TABLE 9

	No. of hr-days when DI>80	Av. daily duration
New Delhi	523 (Jul)	17 hours
Calcutta	479 (May)	15 hours
Poona	201 (May)	6 hours
Madras	616 (May)	20 hours
Trivandrum	146 (Apr)	5 hours

cold as quickly as do the northerners who are already adjusted to the climate. This problem of adaption applies equally to the northerner when he goes to south. In winter, people in the north develop a higher rate of combustion. When they go south, therefore, they may experience difficulty in finding comfort at what the southerners would call a pleasant temperature, because their heat production continues high for some time after arrival.

(2) DI *in the range 76—80*

According to Thom (1959), at values of DI above 75, more than half the population are expected to be uncomfortable and everyone is uncomfortable by 80. This is, therefore, the range in which transition from comfort to discomfort takes place. It may be feasible to make oneself comfortable in this range by simple adaptations of living conditions or dress. It may be assumed that for the conditions prevailing in India, places where DI does not exceed 80 are fairly comfortable. The number of hour-days when DI is 80 or less during the year and also during the daylight hours and at night are given in Table 6.

One may say generally that the prevailing discomfort index for India is below 80. Even in this, New Delhi, Calcutta and Madras fall under one category, while Poona and Trivandrum are another. A similar categorisation holds for the day and night also. It is observed that except for 536 hour-days in Poona and 417 at Trivandrum, the rest fall under DI less than 80. According to this criterion, Trivandrum and Poona are the most comfortable places in India.

(3) DI *in the range 80—85*

When DI is in the range 80—85, everyone is expected to be uncomfortable and it becomes serious at the higher values. The number of hour-days in the year when DI is greater than 80 is given in Table 7.

This obviously confirms the conclusion drawn in the previous section. The months in which DI >80 on the average for more than 6 hours during the day and a similar period at night are given in Table 8.

It is seen from the above that at Delhi, Calcutta and Madras DI >80 extending for more than 6 hours occurs during the day in the premonsoon dry months and the monsoon months extending upto September. It occurs only during the premonsoon month of May at Poona; DI greater than 80 are not experienced at Trivandrum, for more than 6 hours during the day or the night.

The monthly increase in the number of hour-days in this range is large from April to May at Delhi and from March to April in Calcutta and

TABLE 10

Station	No. of hour-days	
	Period	Max. in month
New Delhi	368 (May—July)	168 (June)
Calcutta	183 (April—June)	84 (May)
Madras	239 (April—June)	133 (May)

Poona. It occurs in stages from month to month from March to May at Madras while at Trivandrum, it is from February to March.

The number of hour-days when DI exceeds 80 in the worst month and their average daily duration are given in Table 9.

While the months increase in DI >80 is rapid after the winter months, the establishment of more comfortable conditions, *viz.*, values less than 80, occur after the summer as described below —

New Delhi—DI values decrease appreciably from September to October when winter conditions set in after the withdrawal of monsoon.

Calcutta—The decrease is steady and gradual from month to month and reach lower values only in November when winter conditions set in.

Poona—In this station, the conditions are different from the others and comfortable season suddenly sets in with the onset of monsoon in June and continues to be so for nearly 10 months till April.

Madras—The decrease of DI values higher than 80 occurs gradually and are wiped off only in November.

Trivandrum—In this station which has the minimum number of hour-days in the year with values of DI exceeding 80, more pleasant conditions begin to prevail suddenly with the onset of the monsoon in June.

(4) *DI in the range 86—90*

According to Thom (1959) when office conditions in the Washington metropolitan area are such that the index becomes 86 or higher, Government regulations permit mass dismissal of employees who are working under these conditions. From the Indian data considered in this note, it is observed that the value of DI exceeds 85 only at Delhi, Calcutta and Madras during the summer. The total number of hour-days in the year and the months in which they usually occur are given in Table 10.

It can be seen from Fig. 1 that at Delhi values of DI exceeds 85 on more than 15 days in June and it occurs between the hours 12·00 to 18·00 (6 hours). It is also noticed that occasionally it may occur as early as 09 to 10 hours and extend in the evening upto midnight.

At Calcutta (Fig. 2), it occurs for about 12 days in May from about 13 to 15 hours (2 hours); occasionally this discomfort may start as early as 10 hours, and extend in the evening upto 17 hours.

At Madras, on the other hand (Fig. 4), it may occur on more than 15 days in May during the hours 11 to 16 (5 hours). This degree of discomfort may start as early as 09·00 hours and extends in the evening upto 19·00 hours.

The months just preceeding the onset of the monsoon (May to June) are the worst.

While the general features of the DI in excess of 85 are described in the above paragraphs, more detailed information can be obtained from Figs. 1-10 and Table 3.

From the above analysis of Indian data based on the scales of discomfort indices adopted in the U.S.A., one may infer that these indices also conform to the general feelings of the people in India. Indian nationals in the different regions have adapted themselves to these conditions by suitable clothing and housing to mitigate as much as feasible the rigours of the discomfort, particularly in the summer; while this investigation will be of great use to foreign visitors, it is felt that it will be equally valuable to the local population, including air-conditioning engineers.

While very low values of DI are only of short duration and occur in the northern parts of India as indicated by the conditions, prevailing in Delhi in winter, and particularly in December and January, it is not so in the rest of India. While cold can be mitigated to a considerable degree with increased clothing and other means, the discomfort at high temperatures cannot be reduced very much except by employing air conditioners and these only in confined regions. Their cost is so high that its general use will be greatly limited. Also, marked cooling of the interiors can be dangerous owing to the chill and shock experienced when the hot moist body suddenly passes into a cool, dry place. Therefore, even here, one should adopt indoors a dehumidification with only a small degree of cooling.

The authors are thankful to Shri N. R. Kachare for his valuable help in the computation of discomfort indices from the hourly values of air temperature and wet bulb temperature at the different stations. S. P. Venkiteshwaran is thankful to the Council of Scientific and Industrial Research, New Delhi for a Research Grant and to the Director General of Observatories, New Delhi for affording the necessary facilities to conduct the investigation.

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