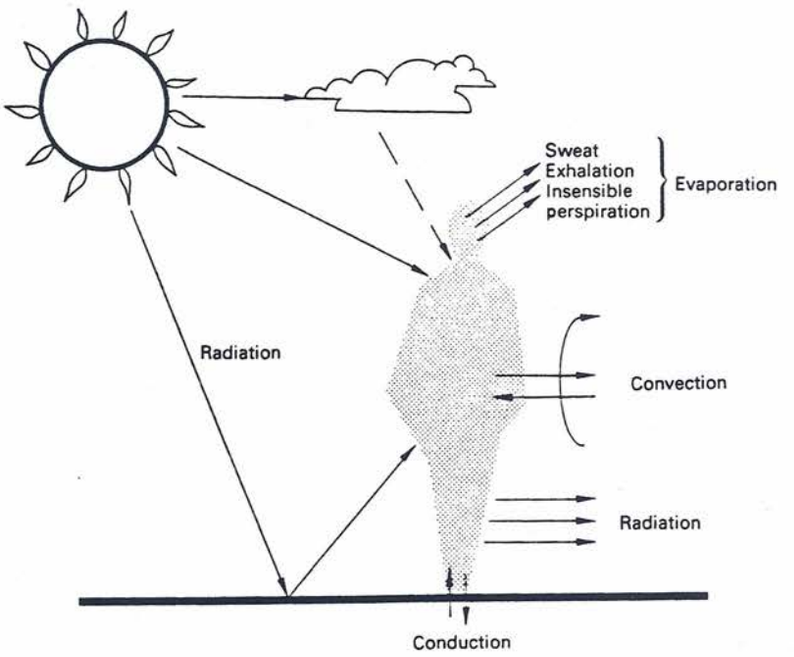
Fig 26
Body heat exchange



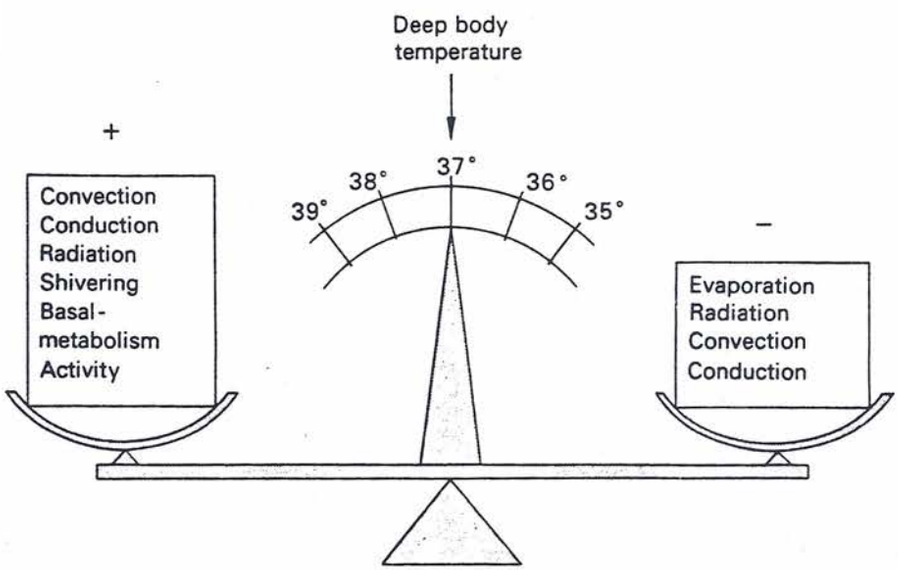
Gain: Met = metabolism (basal and muscular)
Cnd = conduction (contact with warm bodies)
Cnv = convection (if the air is warmer than the skin)
Rad = radiation (from the sun, the sky and hot bodies)

Loss: Cnd = conduction (contact with cold bodies)
Cnv = convection (if the air is cooler than the skin)
Rad = radiation (to night sky and cold surfaces)
Evp = evaporation (of moisture and sweat)

then thermal balance exists when

$$Met - Evp \pm Cnd \pm Cnv \pm Rad = 0$$

Fig 27
Thermal balance of the body



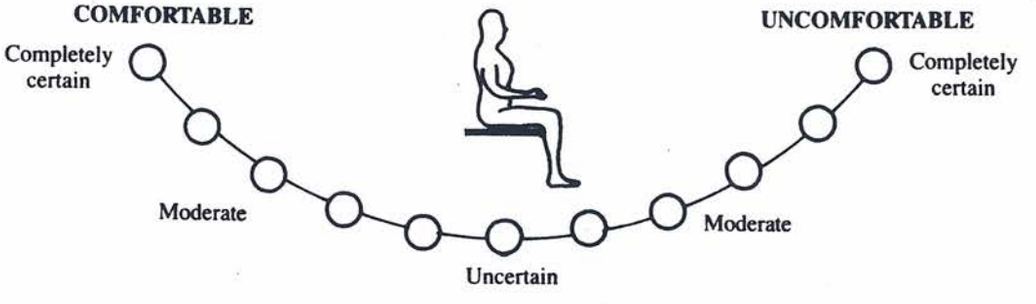
The Thermal Environment

1. Uncomfortable
2. Content with
3. Agreeable
4. Tolerable
5. Unpleasant
6. Inadequate
7. Annoying
8. Undesirable
9. Satisfactory
10. Miserable
11. Satisfied with
12. Good
13. Unacceptable
14. Enjoyable
15. Great
16. Distressful
17. Bad
18. Acceptable
19. Discontent with
20. Pleasant
21. Dissatisfied with
22. Comfortable
23. Intolerable
24. Disagreeable
25. Adequate
26. Desirable
27. Unsatisfactory
28. Gratifying
29. Pleasing
30. Poor
31. Appealing
32. Delightful

Thermal comfort scale in semantic differential format

Comfortable	:	:	:	:	:	:	:	:	**Uncomfortable**
Bad temperature	:	:	:	:	:	:	:	:	**Good temperature**
Pleasant	:	:	:	:	:	:	:	:	**Unpleasant**
Unacceptable	:	:	:	:	:	:	:	:	**Acceptable**
Satisfied	:	:	:	:	:	:	:	:	**Dissatisfied**
Uncomfortable temperature	:	:	:	:	:	:	:	:	**Comfortable temperature**

Normalized certainty scale



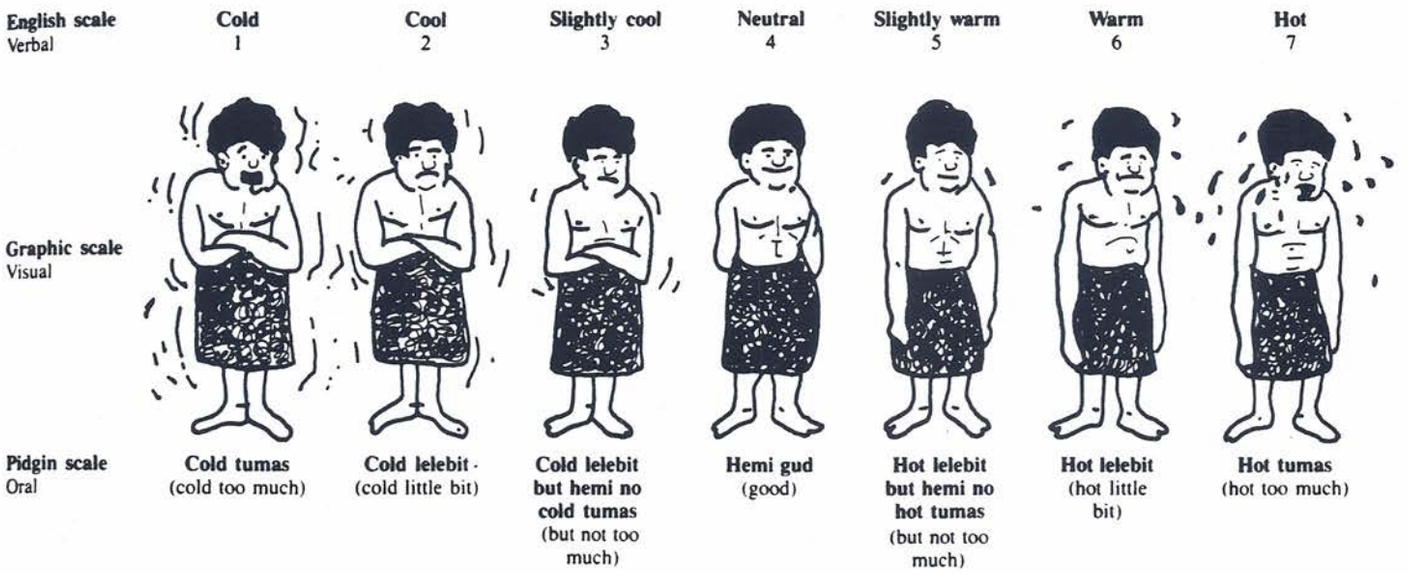


FIGURE 1.3.
Relationship of thermal sensation scales as used by Woolard (1979) with Solomon Islanders.

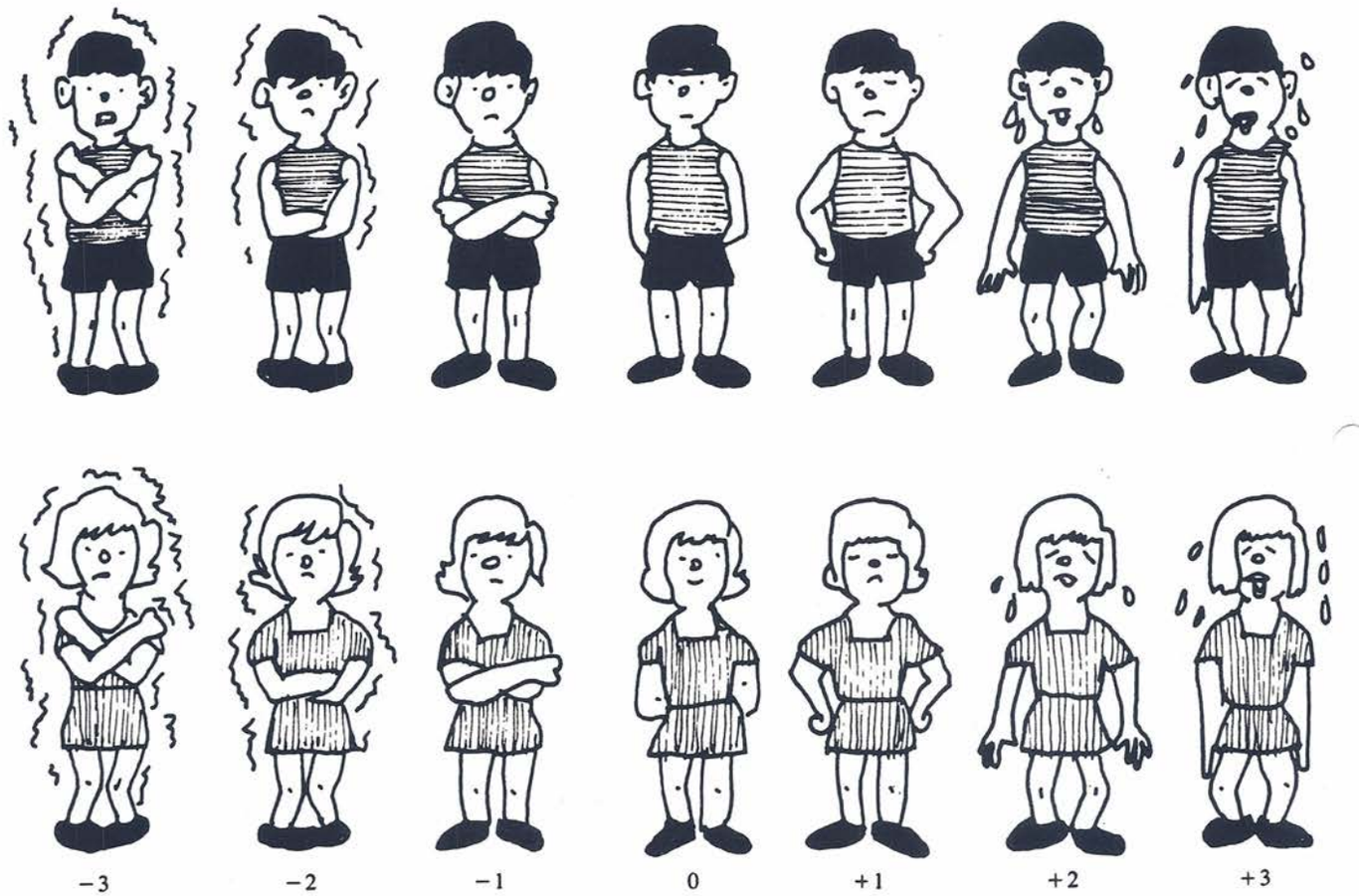


FIGURE 1.4.
Graphic thermal sensation scales for use with children. Verbal instruction: "How warm/cool do you feel now? Point to the picture that best describes how you feel."

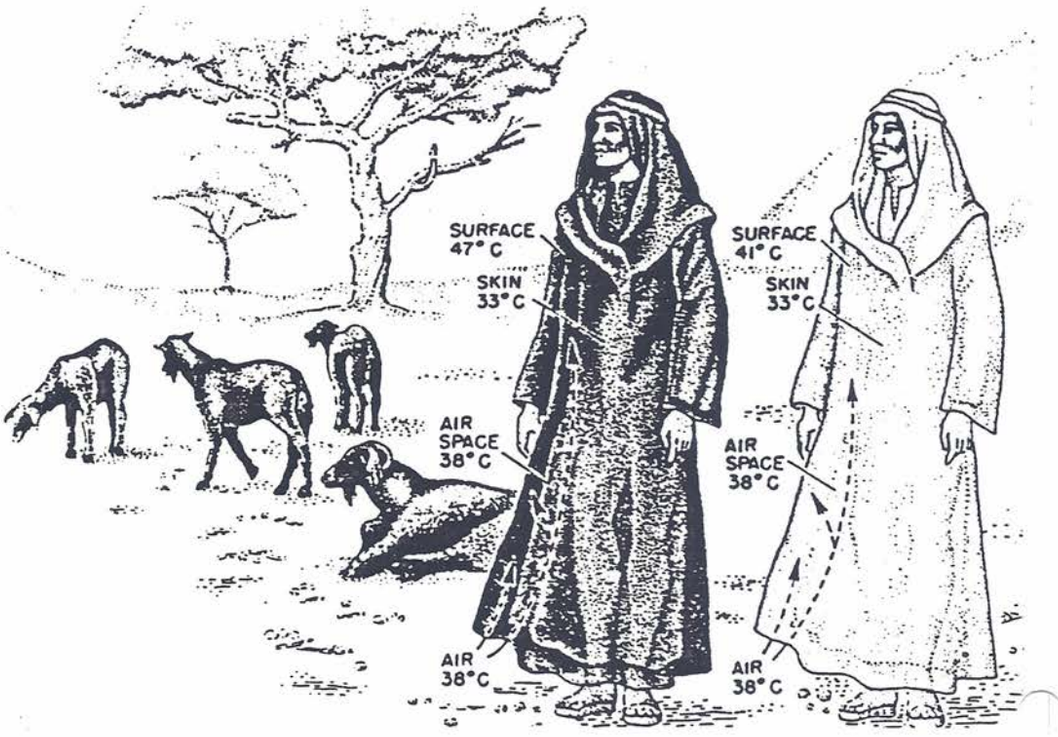


Fig. 4.1: *Measured air and skin temperatures for black and white Bedouin robes.*

A. S hkolink, C. Taylor, V. Finch, and A. Borut, "Why do Bedouins wear black robes in hot deserts ?," Nature, 24 January 1980, 283:375.

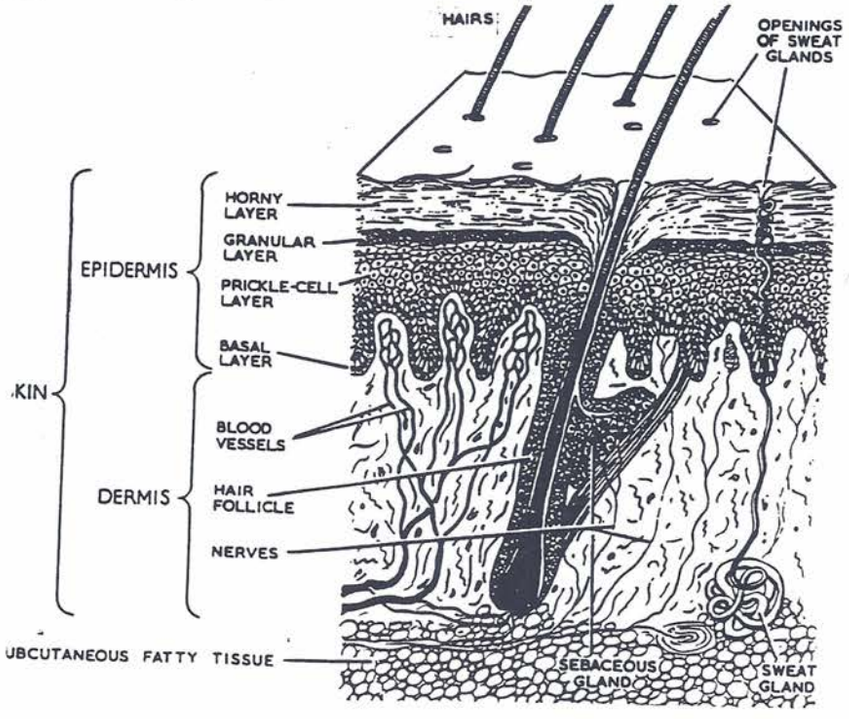


Fig. 4.2: *Section beneath the skin.*

A. Domonkos, Andrews' diseases of the skin. London: W. B. Saunders company 1971.

BASIC THEORY—THERMAL EFFECT OF ACTIVITY

Some common activities are listed below in order of decreasing generated body heat in Btuh. Be sure to include the heat from people in heat gain analyses for summer cooling requirements.

	ACTIVITY	BODY HEAT (BTUH)*
1	 WALKING UP STAIRS	4400
2	 WALKING DOWN STAIRS	1500
3	 WALKING (ABOUT 2 MPH)	750
4	 TYPEWRITING	500
5	 SITTING AT REST (SEE GRAPH ON FOLLOWING PAGE)	400
6	 SLEEPING	300

* THE SYMBOL "BTUH" MEANS BTU'S PER HOUR. A BRITISH THERMAL UNIT (BTU) IS THE AMOUNT OF HEAT REQUIRED TO RAISE 1 LB. OF WATER 1° FAHRENHEIT (F). NOTE THAT A DEGREE IS A MEASURE OF TEMPERATURE, WHEREAS, A BTU IS A MEASURE OF HEAT ENERGY. FOR EXAMPLE, POUR TWO CUPS OF HOT TEA – ONE FULL AND ONE ½ FULL. ALTHOUGH BOTH WILL HAVE THE SAME TEMPERATURE, THE FULL CUP WILL HAVE THREE TIMES AS MUCH HEAT IN BTU'S.

TABLE 4.1

Heat exposure limits for working in a hot environment.

NIOSH		ESSO AND YAGLOU		
Time (Minutes)	WBGT C	Light work WBGT C	Moderate work WBGT C	Heavy work WBGT C
20	----	44.44	41.11	37.77
30	38.33	41.66	38.33	35.00
60	34.33	37.77	35.00	32.22
90	33.05	------	-------	------
120	32.22	35.55	32.77	30.00
180	31.11	34.44	31.66	28.88
240	30.55	-------	--------	-------
Continues (8 hours)	------	32.22	30.00	26.66

After: Brief, R. and Confer, R."Environmental measurements and engineering assessment of heat data." Symposium on standards for occupational exposures to hot environments,Pittsburgh, University of Pittsburgh, 1973, pp.236-39.

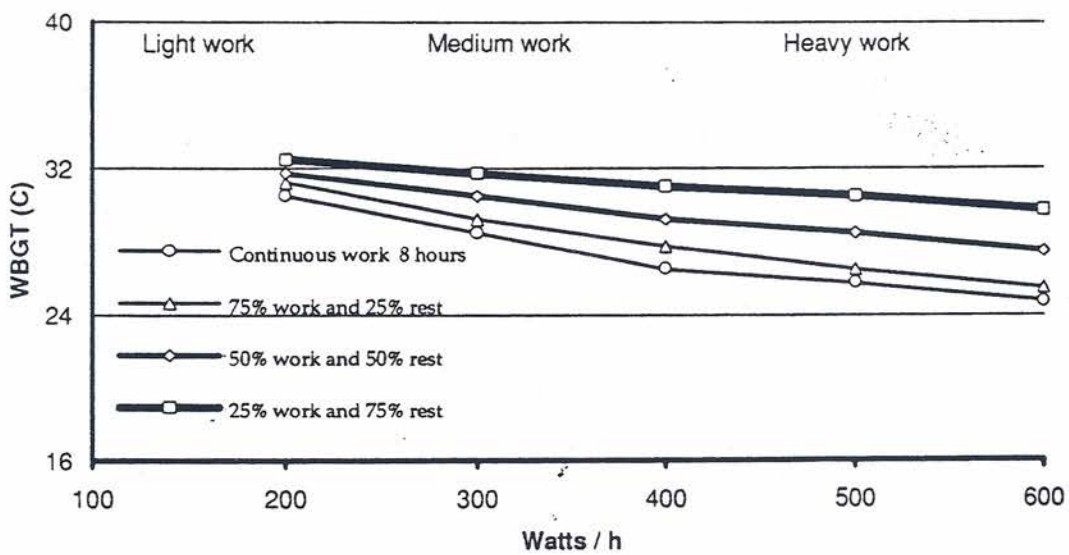
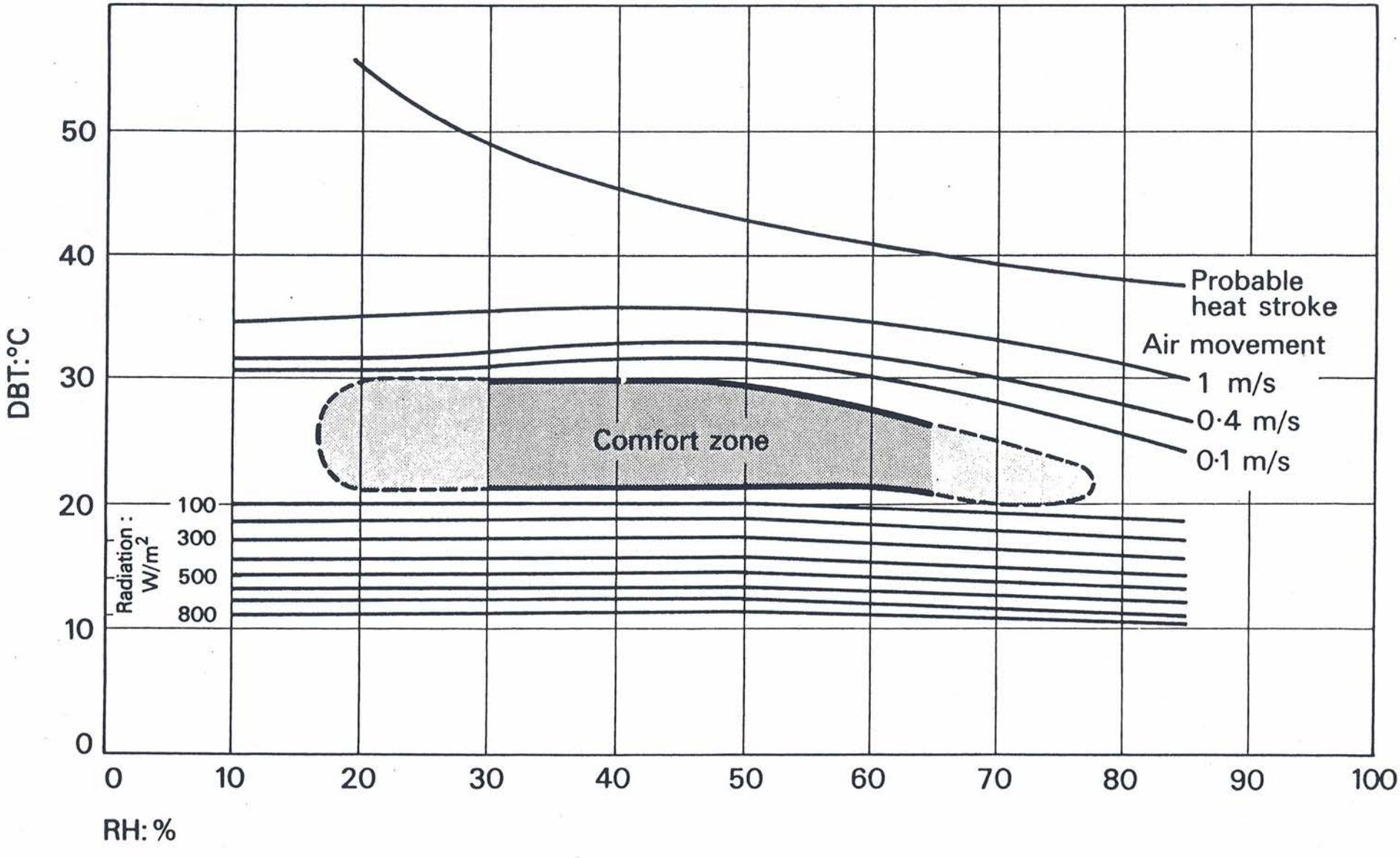


Fig. 4.5: *Limits of permissible heat exposure predicted by the WBGT index.*

Ashrae, fundamentals handbook,New York: Ashrae, 1985, p. 8-30.


DBT:°C
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
RH: %
Probable heat stroke
Air movement
1 m/s
0·4 m/s
0·1 m/s
Comfort zone
Radiation : W/m²
100
300
500
800

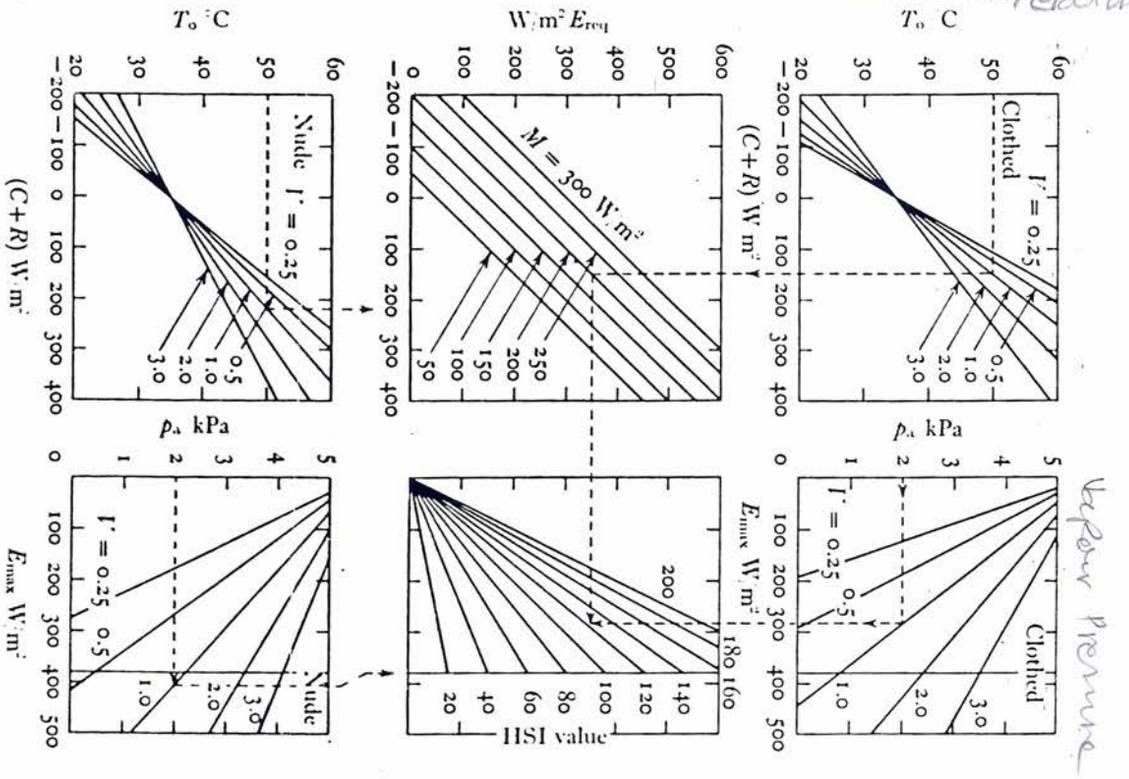


Fig. 4.9: *The heat Stress Index (HSI).*

D. Kerslake, The stress of hot environments,Cambridge:University press 1972, p.225.

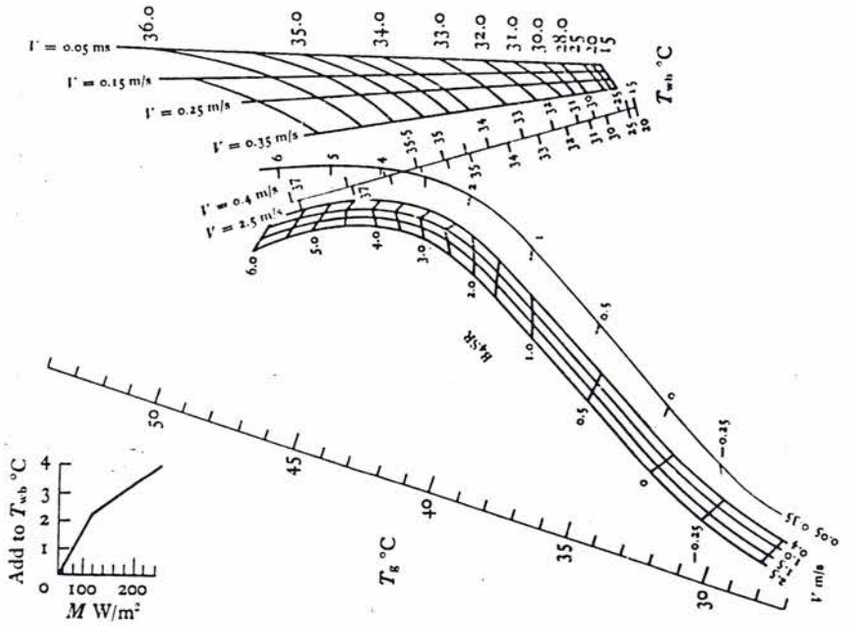


Fig. 4.10: *Chart of the P4SR.*

D. Kerslake, The stress of hot environments,Cambridge:University press 1972, p.234.

Fig 35
An example of using corrected effective temperature

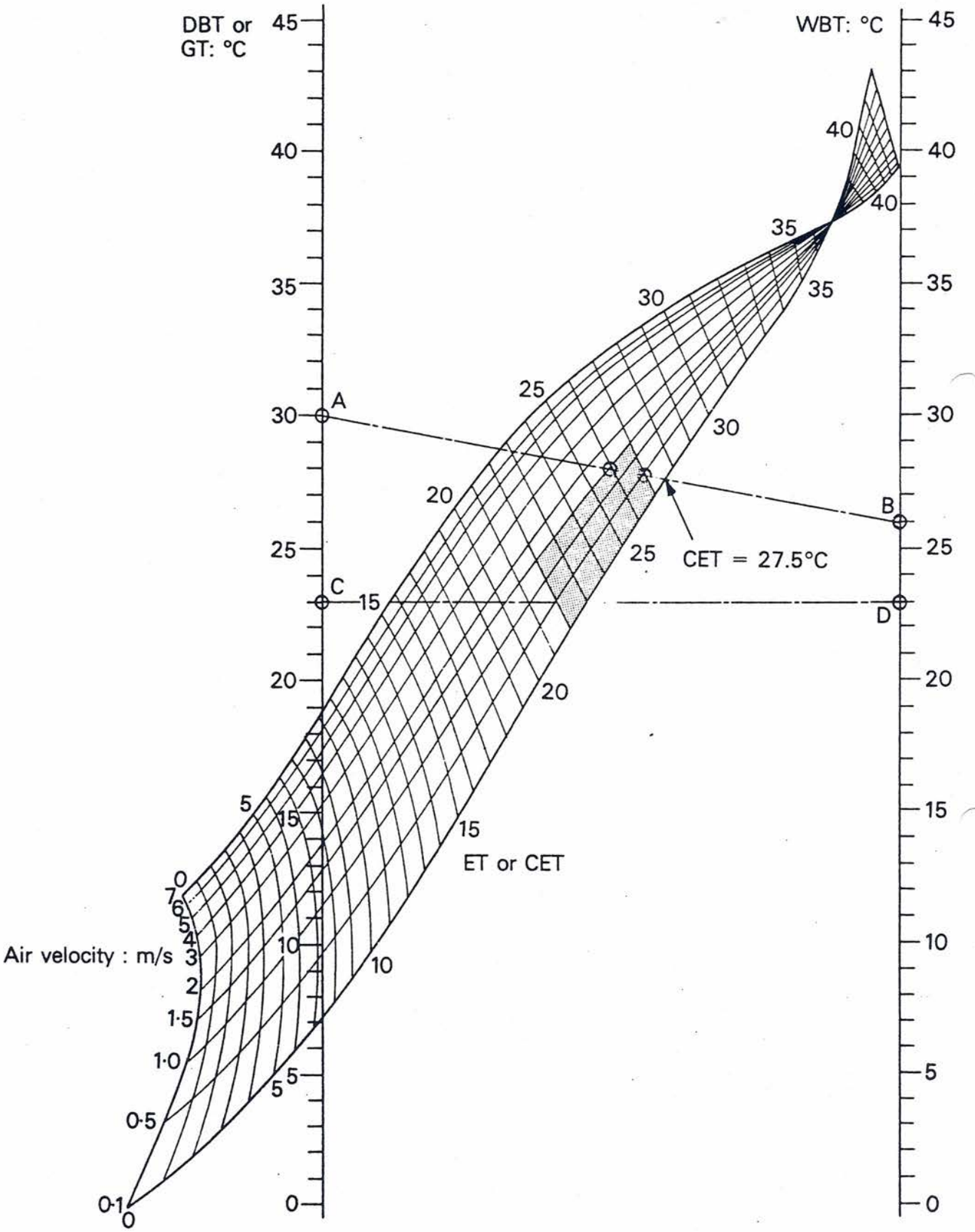
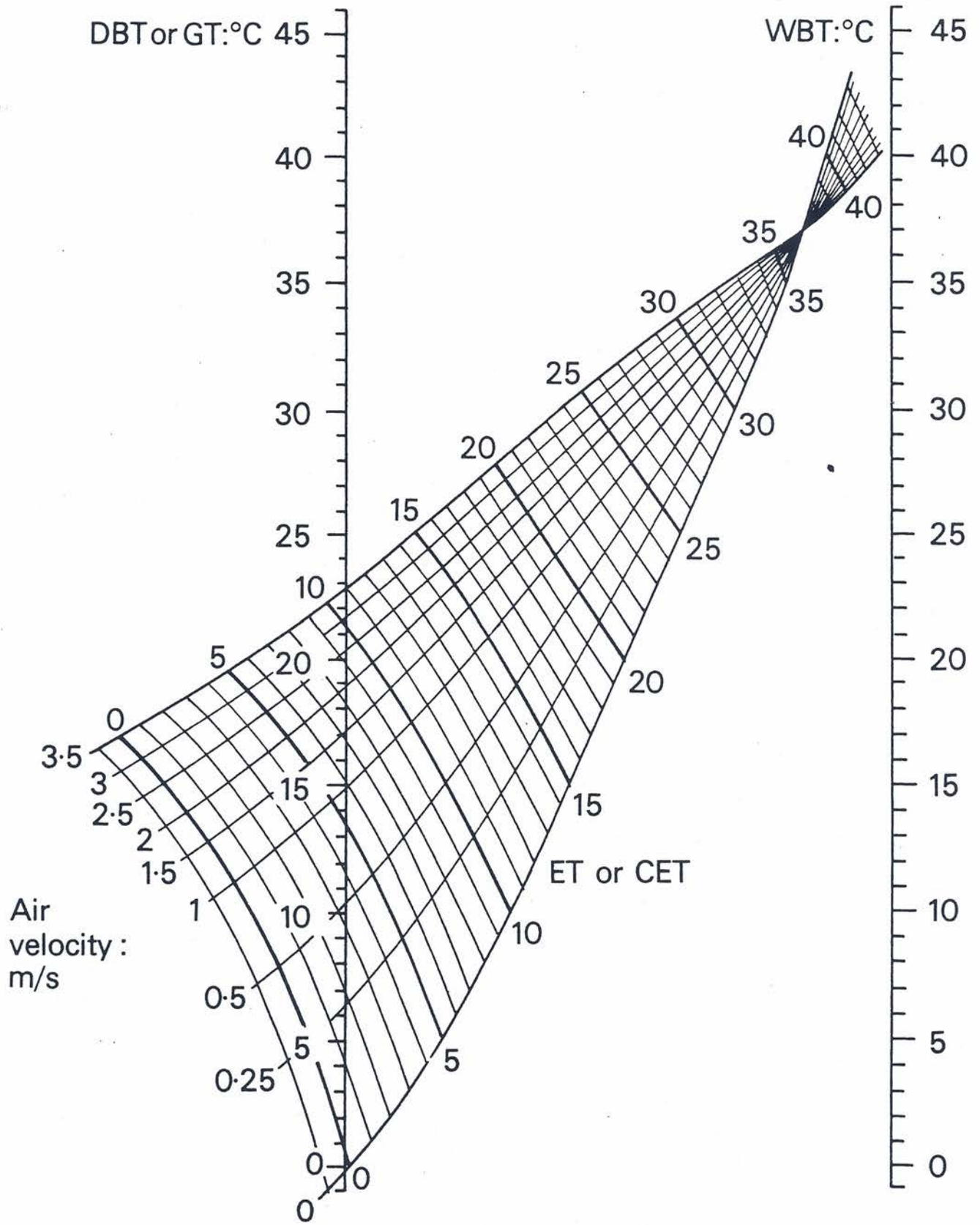


Fig 31
Basic effective temperature nomogram for persons stripped to the waist



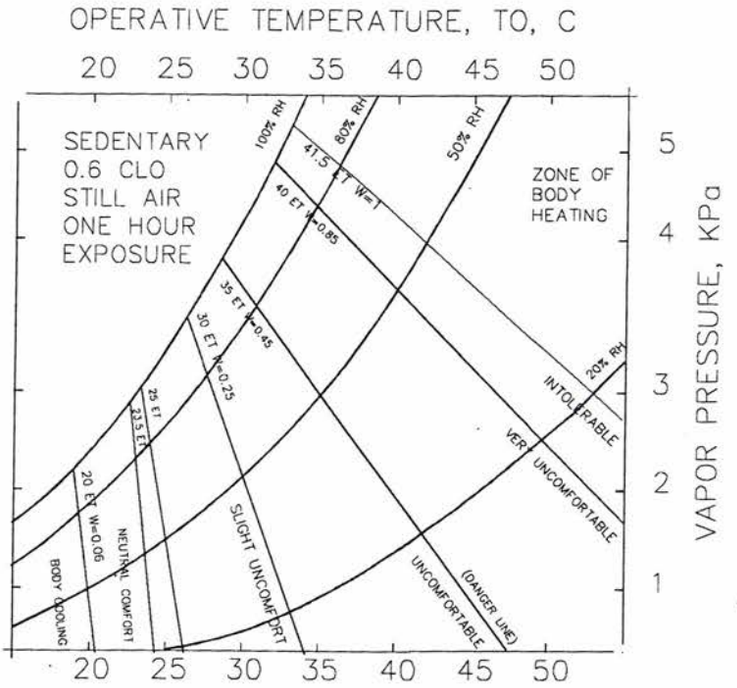


Fig. 4.8: *Pssychrometric chart for ETo* with isotherms for discomfort sensation and the proposed comfort zone and danger threshold.*

Ashrae, Fundamentals handbook,NewYork: ASHRAE, 1985, P. 8-25.

Table 4.2

Scale of ET* and related human sensory, physiological and health responses for prolonged exposures.

ET*	TEMPERATURE SENSATION	DISCOMFORT	REGULATION OF BODY TEMP.	HEALTH
40	Very hot	Limited tolerance very uncomfortable	Failure of free skin evaporation	
35	Hot	Uncomfortable		Increasing danger of heat-stroke
30	Warm	Slightly Uncomfortable	Increasing Vasodilation sweating	
25	Slightly warm **Neutral** Slightly Cool	**Comfortable**	**No registered sweating** Vasoconstriction	**Normal health**
20	Cool	Slightly uncomfortable	Behavioral changes	
15				Complaints from dry mucosa
10	Cold Very Cold	Uncomfortable	Shivering begins	Impairment peripheral circulation

Ashrae, Fundamentals handbook,NewYork: ASHRAE, 1985, P. 8-26.

location	*minimum*	*optimum*	*maximum*
UK, winter[1]	14	17	20
summer[2]	—	18	22
US, winter[3]	15	20	23
summer[3]	18	22	26
Sydney, summer[4]	—	22	25
Singapore[5]	24	—	27
Limits probably valid for most tropical regions	22	25	27

1. T. Bedford. *Warmth factor in comfort at work.* Medical Research Council, Industrial Health Research Board, Report No. 76. HMSO, 1936.
2. D. E. Hickish. 'Thermal sensations of workers in light industry in summer' in *Journal of Hygiene*, 53, 1955, No. 112.
3. C. P. Yaglou. 'The comfort zone for man. . .' in *Journal of Industrial Hygiene*, 9, 1927, 251.
4. E. G. A. Weiss. 'Air conditioning and working efficiency' in *Architectural Science Review*, July 1959, 68–76.
5. C. G. Webb. *Ventilation in warm climates.* BRS Overseas Building Notes, No. 66, March 1960, 2.

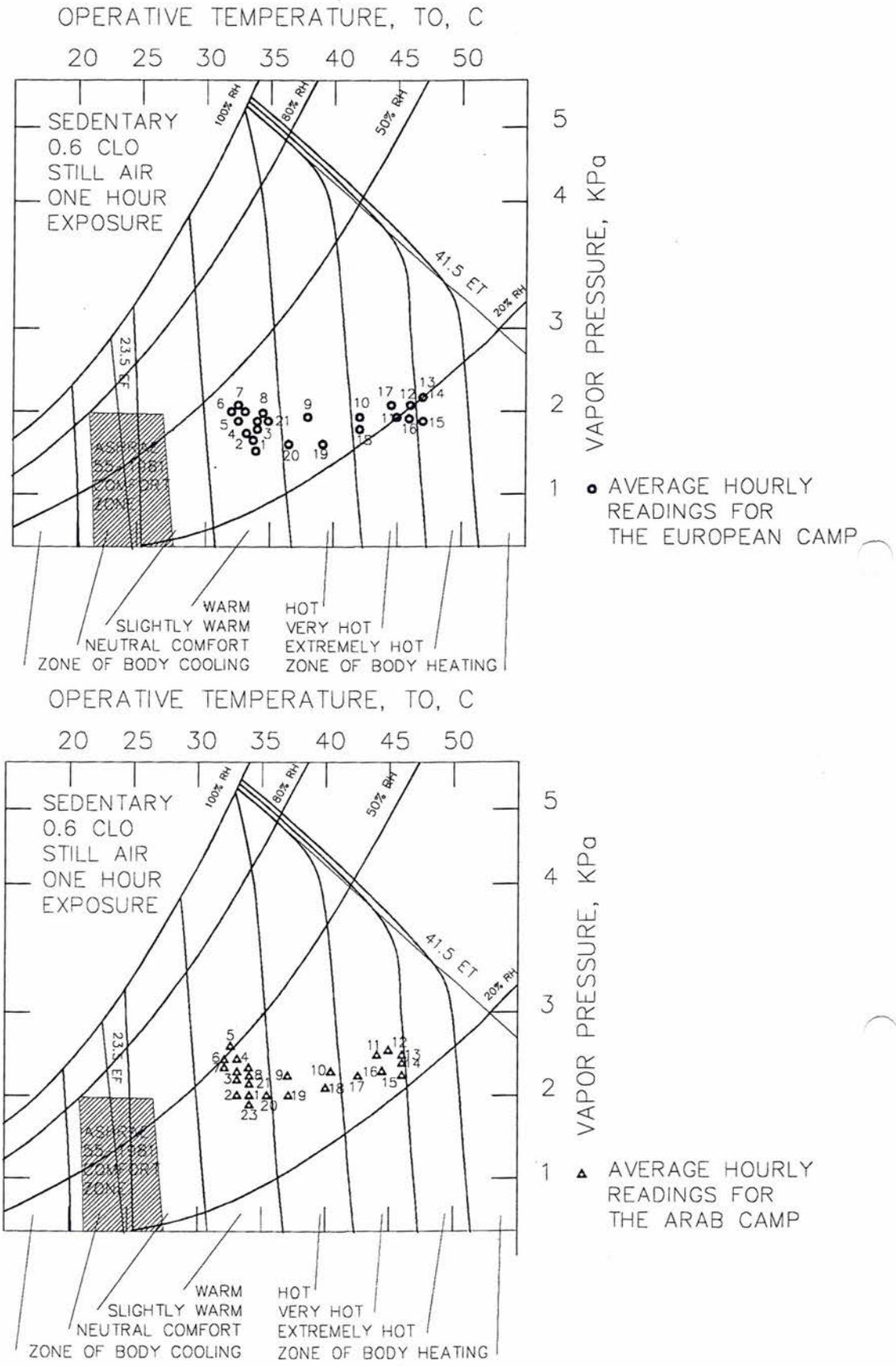


Fig. 4.15: *Analysis of thermal sensations for subjects exposed to the hot environment of pilgrimage tents in the European camp and in the Arab camp during the Hajj of 1989.*

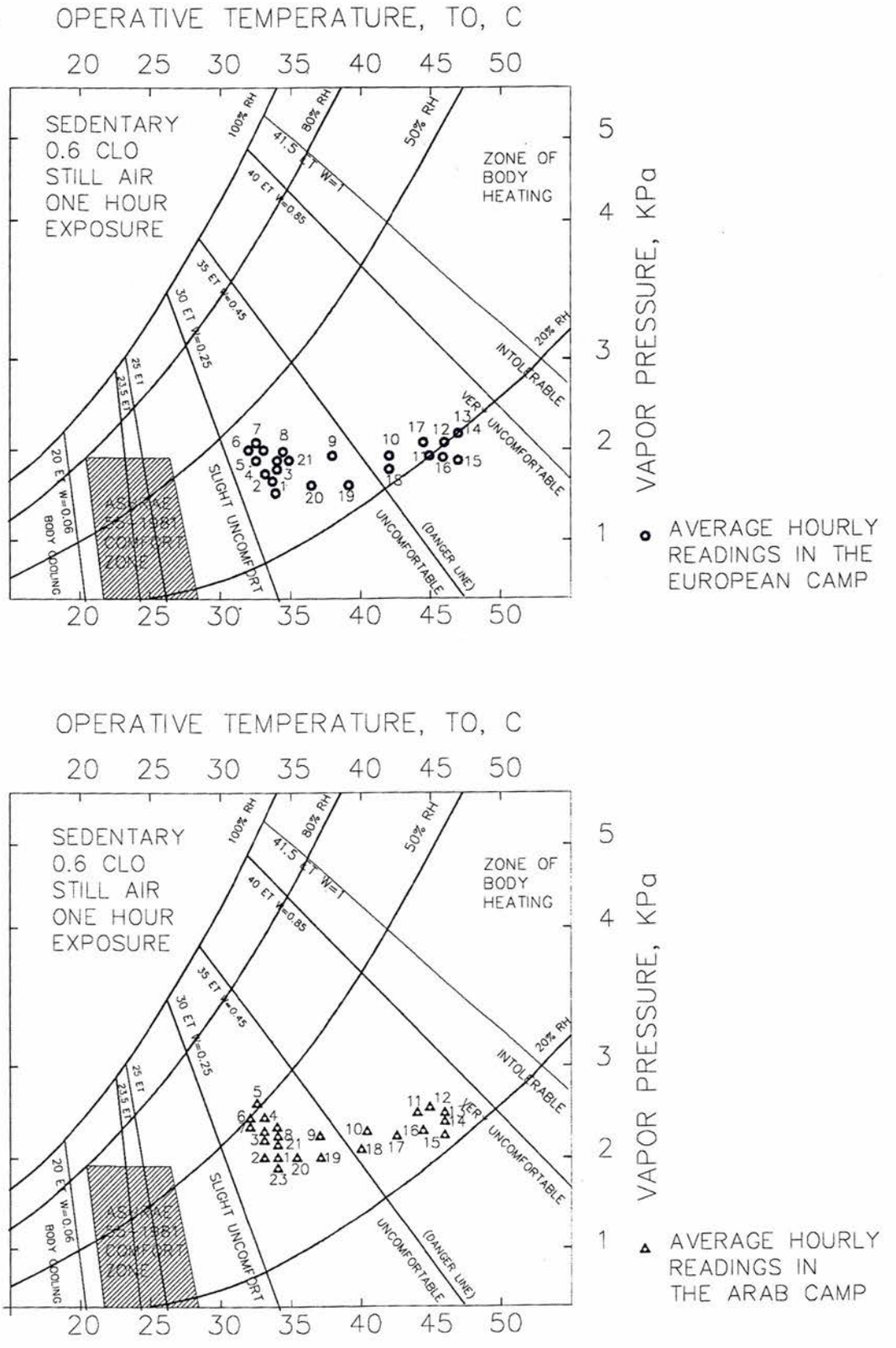


Fig. 4.14: *Analysis of discomfort sensations for subjects exposed to the hot environment of the pilgrimage tents in the European camp and in the Arab camp during the Hajj of 1989.*

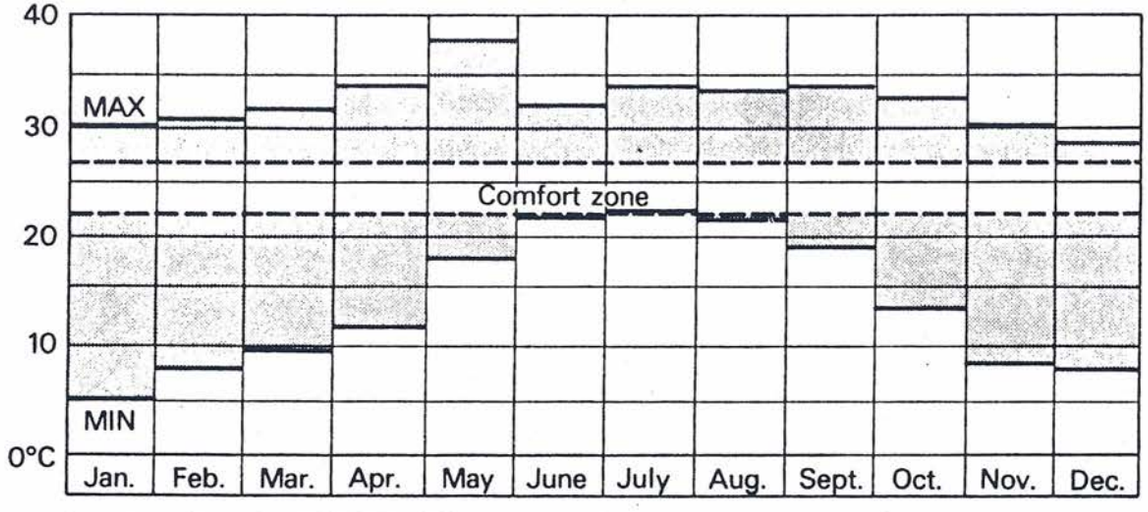
Table 5.III summarizes the nominal range of environmental factors covered by each of the indices.

Table 5.III

Range of the indices

Index	Metabolic rate (kcal/h)	D.B.T. (°C)	W.B.T. (°C)	Air velocity (m/sec)
Effective Temperature	Rest only	1–43	1–43	0·10– 3·5
Resultant Temperature	Rest only	18–45	18–45	0·10– 3·0
P.4S.R.	100–350	27–55	15–36	0·05– 2·5
Heat Stress Index	100–500	27–60	15–35	0·25–10·0
Index of Thermal Stress	100–600	20–55	15–35	0·10– 3·5

Fig 34
Effective temperature histogram (Baroda)



Location: Baroda (72°15'E. 22°15'N. 35m)
Maximum = ET based on monthly mean maxima of DBT and p.m. humidity.
Minimum = ET based on monthly mean minima of DBT and morning humidity
Assumed: MRT=DBT and air velocity less than 0·1 m/s