Table 2 . . . . Physiological Responses to Heat of Men at Rest and at Work[a]

Effective Temp	Actual Cheek Temp (Fahr Deg)	Men at Rest			Men at Work 90,000 ft-lb of Work per Hour			
		Rise in Rectal Temp (Fahr Deg per Hr)	Increase in Pulse Rate (Beats per Min per Hr)	Approximate Loss in Body Weight by Perspiration (Lb per Hr)	Total Work Accomplished (Ft-Lb)	Rise in Body Temp (Fahr Deg per Hr)	Increase in Pulse Rate (Beats per Min per Hr)	Approximate Loss in Body Wt by Perspiration (Lb per Hr)
60	....	....	....	....	225,000	0.0	6	0.5
70	....	0.0	0	0.2	225,000	0.1	7	0.6
80	96.1	0.0	0	0.3	209,000	0.3	11	0.8
85	96.6	0.1	1	0.4	190,000	0.6	17	1.1
90	97.0	0.3	4	0.5	153,000	1.2	31	1.5
95	97.6	0.9	15	0.9	102,000	2.3	61	2.0
100	99.6	2.2	40	1.7	67,000	4.0[b]	103[b]	2.7[b]
105	104.7	4.0	83	2.7	49,000	6.0[b]	158[b]	3.5[b]
110	....	5.9[b]	137[b]	4.0[b]	37,000	8.5[b]	237[b]	4.4[b]

[a] Data by ASHAE Research Laboratory.
[b] Computed value from exposures lasting less than one hour.

storage is given by the difference between the metabolism and total heat loss.

The small difference between the metabolic rates for the two groups of subjects may be accounted for by difference in activity. Heat exchange between the body and the environment by radiation and convection is greater for the lightly clothed subject, both for cool conditions where there is excessive heat loss, and for very warm conditions where there is transfer of heat from the atmosphere to the body. The two curves for evaporative loss serve to show how physiological control uses evaporation of sweat to maintain equilibrium at high temperatures. Below 75 F, for the normally clothed subject, and below 85 F for the lightly clothed subject, evaporation loss is minimal and constant. Burch[12] has shown that this insensible perspiration reflects the permeability of the skin to the moisture of the body. Above these temperatures, control is obtained by the availability of sweat for evaporation. The difference in the curves above 75 F is probably largely determined by the difference in clothing and activity.

In the zone of evaporative heat regulation, air movement facilitates heat loss if the temperature of the air is not above that of the skin.[13] Under hot, dry conditions air movement may be of little advantage, or even of disadvantage, if it increases the addition of heat to the skin by conduction more than it promotes the loss of heat from the skin by evaporation.

HIGH TEMPERATURE HAZARDS

Studies at the ASHAE Research Laboratory[14] and elsewhere during the past two decades have made available much information dealing with the physiological effects of hot atmospheres on workers, and means of alleviating the distress and hazards associated therewith. Table 2 gives some of the physiological responses of men, at rest and at work, to hot environments. Frequent and continued exposure of workers to hot environments results in physiological derangement affecting the leucocyte count of the blood, and other factors dealing with man's mechanism of defense against infection.

Wherever S (Equation 1) becomes strongly positive and body temperature rises progressively, men will continue to work until body temperature reaches 103 F. When these body temperatures are exceeded, men work with declining efficiency and may be subject to heat stroke.

Heat exhaustion is a circulatory failure is which the venous return to the heart is reduced so that fainting results.[15] Early symptoms of heat exhaustion may include fatigue, headache, dizziness when erect, loss of appetite, nausea, abdominal distress, vomiting, shortness of breath, flushing of face and neck, pulse rate above 150, glazed eyes, and mental disturbances such as apathy, poor judgment, and irritability which usually precede fainting (syncope). Recovery is usually prompt when the man is removed to a cool place and kept lying down for a time, unless he has some other illness such as heart disease.

Heat cramps are painful muscle spasms in extremities, back, and abdomen due, at least in part, to excessive loss of salt in sweating. Formerly common in hot industries, this manifestation of illness due to heat is now greatly reduced by drinking water containing 0.1 percent salt, or by proper use of salt tablets. Heat cramps are readily alleviated by administration of salt solution intravenously.

Heat stroke is a serious effect of exposure to great heat. The body temperature climbs rapidly to excessive levels often above 105 F when for unknown reasons free sweating suddenly stops. At such high temperatures, coma appears and death may be imminent. Emergency measures are required to reduce the excessive body temperature by cooling quickly to avoid irreparable damage to the brain.[16]

The deleterious physiologic effects of high temperatures exert a powerful influence upon physical activity, accidents, sickness, and mortality. Both laboratory and field data show that physical work in warm atmospheres is a great effort, and that production falls progressively as the temperature rises.

ACCLIMATIZATION

When men move to deserts or to jungles some adaptation to the climate takes place. If work is gradually increased day by day, and if the men can get plenty of water and salt, and can sleep each night, acclimatization may be complete in 7 to 10 days. The acclimatized man works with a lower heart rate, lower skin and rectal temperature, and more stable blood pressure than when unacclimatized. The process of acclimatization requires work in the heat.[17] During the recent war, white troops lived and did hard physical work for long periods in tropical conditions when disease hazards were controlled.

Table 3 . . . . Upper Limits of Environmental Conditions for Acclimatized, Healthy, Young Men in Military Service

Environment	Reactions at the end of 4 hr	
	Rectal Temp F	Pulse Rate
Relatively easy....	Below 101	Below 130
Difficult..........	101 to 102	130 to 145
Impossible........	Above 102	Over 145

In recent tests made at the ASHAE Research Laboratory,[18] subjects were required to perform light work under very hot conditions for a 4-hr period each day. It was found that the ability of a new subject to endure these conditions showed daily improvement for a period of at least 2 weeks. However, after acclimatization was completed, a recess of several days had no effect on the endurance of the subject. Individuals differ widely in their capacity to acclimatize. Acclimatized men lose most of these improvements in a few weeks of temperate climate, even though they are vigorously active. In the course of acclimatization, the sweat glands come to secrete fluid less rich in salt.[19] For all except those carrying out really hard work in hot, dry atmospheres, this effects an important saving in salt loss, and makes all the difference between being exposed and not being exposed to the risk of heat cramps.

The adaptive level changes somewhat with the season. There are also marked differences between the sexes. In the cold zone the thickness of thermal insulating tissues of women is almost double that of men, although the sensory responses to cold are similar. In the hot zone, the threshold of sweating is higher for women. The thickness and insulating value of the clothing worn are also important factors in the determination of the comfort level.

UPPER LIMITS OF HEAT FOR MEN AT WORK

In very hot conditions humidity is the limiting factor, and the wet-bulb temperature assumes great importance. In 1905 Haldane recognized that 88 F wet-bulb was the limit of endurance for coal miners, and later observers have concurred.

A study was made at the Armored Medical Research Laboratory[20] to determine the upper limits of environmental conditions under which a man can perform certain work. Thirteen enlisted men, thoroughly acclimatized to the hot conditions, served as subjects. During each test, the subjects were required to march for 4 hr at the rate of 3 mph, carrying 20 lb packs under a wide range of environmental conditions which were rated as relatively easy, difficult, and impossible, on the basis of the physiological reactions of the subjects at the end of the 4-hr period as shown in Table 3 and Fig. 3.

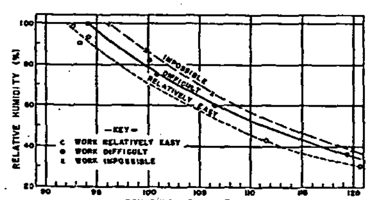

Fig. 3 . . . . Heat Endurance of Acclimatized Subjects Working at a Specific Rate[20]

Recognition of the need of air conditioning for workers in hot industries is growing rapidly. The choice of the type of system to be used in any given instance, must be determined by the air-conditioning engineer after a study of conditions (see Chapter 51, Control of Industrial Environment). In some hot industries where few people are working in large spaces the worker himself, rather than the atmosphere, can be cooled by placing him in a small booth, and blowing cooled air over him, or by circulating cooled air through a loose-fitting suit.[21]

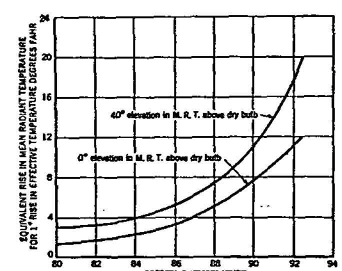

Fig. 4 . . . . Effect of MRT Elevation in Terms of Effective Temperature

The ASHAE Laboratory has studied the effects of walls of higher temperature than the air.[22] The findings are in part shown in Fig. 4. It will be seen that the importance of mean radiant temperature, as compared with that of the effective temperature, decreases as the effective temperature rises; and also, to a certain extent, as the mean radiant temperature itself rises. The lower of the two curves relates to conditions in which the MRT was kept approximately at the level of the DBT. If this curve is followed, it will be seen that, at 80 ET, a little more than 1 deg rise in MRT produces the same effect as 1 deg rise in ET; but when the ET is 92 deg, it takes a rise of 11 F deg in the MRT to produce the same effect as 1 deg rise in ET. The upper curve relates to conditions in which the MRT was kept about 40 F deg higher that the DBT. It will be seen that under these conditions, a rise in MRT is less effective, even at low values of ET; and that it loses its relative effectiveness more rapidly as the ET rises. It should not be assumed, however, that MRT does not matter much. All that these comparisons indicate is that unit rise in MRT becomes less important *as compared with unit rise in ET*, as conditions get hotter. This may be due more to a growing importance of unit rise in ET than to a diminishing