

been determined. In similar experiments at the *Harvard School of Public Health*, the majority of the subjects were unable to detect sensations of humidity (*i.e.*, too high, too low, or medium) when the relative humidity was between 30 per cent and 60 per cent with ordinary room temperatures which is in accord with other studies^{48,49}.

INFLUENCE OF AIR MOVEMENT

Air movement has a powerful influence on the factors involved in thermal equilibrium of the body. An understanding of the phenomena involved is best had through a consideration of the purely physical factors involved in the effect of air movement on heat dissipation from inanimate surfaces by radiation, convection and evaporation. Thermal equilibrium of the human body is more complex because of the physiological control exercised in permitting the body surface temperature to drop when factors influencing heat loss are unavoidably increased without additional clothing and by the making available of perspiration for evaporation.

Air movement does not affect radiation loss, provided there is no change in the skin temperature. However, if there is excessive cooling and lowering of the skin temperature due to increased convection loss, then radiation loss (which varies as the differences of the fourth power of the absolute temperatures of the radiator and receiver) decreases. It has been shown by the work at the *John B. Pierce Laboratory of Hygiene*⁵⁰ and by the A.S.H.V.E. Research Laboratory⁵¹ that radiation may thus actually decrease due to air movement in relatively cool atmospheres.

Convection loss from any surface, including that of the clothed body, is greatly increased by air movement, provided the surface temperature remains the same. In cool atmospheres, unless increased clothing is worn, heat loss due to air movement may be accompanied by a drop in body surface temperature.

Heat loss by evaporation is greatly increased by air movement, provided surface temperature and moisture available for evaporation (or the wetness of the surface) are constant. However, since in the human body perspiration is only made available when there is need for increased evaporative heat loss due to reduction in convection loss, increased air movement is accompanied by decreased perspiration and evaporative cooling in moderately cool atmospheres. In very hot atmospheres, particularly with low vapor pressure, evaporative cooling may be increased by air movement so as to increase the maximum temperature level at which thermal equilibrium may be maintained. Results of studies at the A.S.H.V.E. Research Laboratory⁵² and at the *John B. Pierce Labora-*

⁴⁸Humidity and Comfort, by W. H. Howell (*The Science Press*, April, 1931).

⁴⁹Effect of Variation in Relative Humidity upon Skin Temperature and Sense of Comfort, by U. Miura (*American Journal of Hygiene*, Vol. 13, 1931, p. 432).

⁵⁰Loc. Cit. Note 13.

⁵¹Loc. Cit. Note 11.

⁵²A.S.H.V.E. RESEARCH REPORT NO. 691—Cooling Effects on Human Beings Produced by Various Air Velocities, by F. C. Houghten and C. P. Yaglou (A.S.H.V.E. TRANSACTIONS, Vol. 30, 1924, p. 193). A.S.H.V.E. RESEARCH REPORT NO. 717—Effective Temperature with Clothing, by C. P. Yaglou and W. E. Miller (A.S.H.V.E. TRANSACTIONS, Vol. 31, 1925, p. 89). A.S.H.V.E. RESEARCH REPORT NO. 690—Air Motion, High Temperatures and Various Humidities—Reactions on Human Beings, by W. J. McConnell, F. C. Houghten and C. P. Yaglou (A.S.H.V.E. TRANSACTIONS, Vol. 30, 1924, p. 167). A.S.H.V.E. RESEARCH REPORT NO. 718—Work Tests Conducted in Atmospheres of High Temperatures and Various Humidities in Still and Moving Air, by W. J. McConnell and C. P. Yaglou (A.S.H.V.E. TRANSACTIONS, Vol. 31, 1925, p. 101).

*tory of Hygiene*⁵³ give data on the effect of air movement on heat dissipation for normally clothed, standing and seated subjects, and for lightly clothed and semi-reclining subjects, respectively. Fig. 9, resulting from A.S.H.V.E. research, shows the increase in dry-bulb and wet-bulb temperatures for the same effective temperature with air velocities ranging from 20 to 700 fpm.

Air velocities may be used for effective cooling; however, great care must be exercised to avoid drafts due to uneven cooling of the body surface. During the heating season air velocities in excess of 25 to 30 fpm usually give undesirable effects. With summer cooling and air conditioning higher velocities up to 40 or 50 fpm, if properly controlled, seem to give satisfactory conditions free from sensation of draft, while with higher ambient temperatures even higher air velocities may be used. In this connection it may be emphasized that drafts are interpreted⁵⁴ as local sensations of excessive coolness, and that even while very high air movement in relatively warm air increases the rate of heat loss from local parts of the body, it may improve the comfort of the occupant, so long as that part of his body surface is not excessively cooled.

THE FOUR VITAL FACTORS

From the preceding discussion it is clear that thermal environment cannot properly be adjusted to the requirements of human health and comfort without control of all the four basic factors:

1. Air temperature (free from radiation effects).
2. Air movement.
3. Humidity.
4. Mean radiant temperature of surrounding surfaces.

According to the recommendations of the Sub-Committee on the Hygiene of Environmental Conditions in the Dwelling⁵⁵, it is of great importance in all research studies to make an accurate record of each of the four independent factors governing bodily heat exchanges, temperature, movement and humidity of the air, and mean radiant temperature of the surrounding surfaces. For this purpose the committee suggested in the interest of comparability the use of the following four types of instruments or others yielding similar data:

1. Silvered dry-bulb thermometers or hair-pin thermometers (Bargeboer).
2. Silvered dry Kata-thermometers or the hot-wire anemometer.
3. Psychrometer, wet- and dry-bulb, whirling or ventilated.
4. Globe thermometer (Vernon) or the dry resultant thermometer (Missenard).

In this country, the shielded thermometer, or a very fine wire thermocouple, has been found more convenient for determining the true dry-bulb temperature. Fine, hot-wire anemometers are rapidly replacing the use of the Kata thermometer for measuring low air velocities, while some

⁵³The Influence of Air Movement on Heat Losses for the Clothed Human Body, by C.-E. A. Winslow, A. P. Gagge and L. P. Herrington (*American Journal of Physiology*, October, 1939, Vol. 127, p. 505).

⁵⁴A.S.H.V.E. RESEARCH REPORT NO. 1086—Draft Temperatures and Velocities in Relation to Skin Temperature and Feeling of Warmth, by F. C. Houghten, Carl Gutberlet and Edward Witkowski (A.S.H.V.E. TRANSACTIONS, Vol. 44, 1938, p. 289).

⁵⁵Housing Commission of the League of Nations, adopted at Geneva, June 25, 1937.