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56 Prediction of moisture permeability *of* clothing worn

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Now that moisture permeation of clothing worn has received extensive studies (Woodcock, 1962; Nishi and Gagge. 1970; Goldman, 1974), prediction models seem to have been satisfactory for a practical use. Nevertheless, significance of porosity of fabric and clothing design has been insufficiently discussed to date. The present study deals with these essential factors for further improvement of the prediction models.

1) Porosity as related to moisture permeability

Mekjavic et al (1986) observed the rate of gas **(N_2)** exchange through fabric, demonstrating that moisture permeability correlated linearly with air breathability. Using the same method, a curvilinear relationship between air breathability and porosity was then found. Thus, porosity is directly related to moisture permeability of fabric.

2) Clothing design as related to clothing microenvironment

Any attempt to extrapolate thermal characteristics of clothing worn from those of fabric used would likely involve inherent problems which are due largely to the difficulty of estimating clothing design such as clothing fit, area (Acl) covered by clothing worn and the number of openings. In support of finding solution, however, these functions may be incorporated in clothing microenvironment **($V\mu$)** and ventilation index (VI) in one way or another. For example, the average thickness of clothing microenvironment can be simply derived by dividing **$V\mu$** by Acl. Thus, **$V\mu$** and VI are certainly related to clothing design.

3) Prediction of moisture permeability of clothing worn

Based on the prediction equation proposed by Kakitsuba et al (1981), a new prediction equation for moisture permeability of clothing has been proposed:

$$Esk/(hea \cdot \Delta P_V) = ¥/\{1 + hea ¥/he\mu + 1/hecl\} \qquad (1)$$

where. Esk = the rate of evaporation from the skin **$(Kcal/m^2 \cdot hr)$**, he = the evaporative heat transfer wefficient $(kcal/m^2 \cdot hr \cdot torr$, a = ambient air; μ = microenvironment; **cl** = clothing layer), ¥ = porosity (**N.D** , $0 \le ¥ \le 1$) and ΔP_V = vapor pressure difference between the skin and ambient air (torr). When ¥ becomes small (<0.1) or ventilation is being kept high as observed in daily clothing assembly, the general equation 1 is reduced to:

$$Esk/(hea \cdot \Delta P_V) = ¥/(1 + hea/hecl) \qquad (2)$$

and hecl can be defined as:

$$hecl = Dw \cdot \lambda / (R_V \cdot Tcl \cdot lg) \qquad (3)$$

where, Dw = the **diffusivity** of water vapor **(m^2/hr)**, λ = **the latent heat of vaporization** ***(Kcal/kg)***, R_V = the gas constant for water vapor ***$(torr/m^3 \cdot kg^oK)$***; Tcl = temperature at clothing layer (OK) and ig = thickness of clothing layer (m). On the other hand, when ventilation is so limited that microenvironment becomes appreciable resistance to moisture permeation, equation 1 can be rewritten as:

$$Esk/(hea \cdot \Delta P_V) = ¥/(1 + 0.43 \cdot ¥ \cdot hea \cdot Icl) \qquad (4)$$

where, **Icl** = insulation of clothing layer **(clo)**.

The values of the permeation factor $\{Esk/(hea \cdot \Delta P_V)\}$ for helicopter suits were obtained from human experiments, and showed a *close* agreement with those predicted with equation 4.

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