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45 Simple relationships among current vapor permeability indices of clothing with trapped-air layer

T. Oohori, L.G. Berglund,' and A.P. Gagge' Hokkaido Institute of Technology, Sapporo, Japan 'John B. Pierce Foundation Laboratory, New Haven, Connecticut, USA

The purpose of this paper is to analyze and compare four current indices and models of evaporative heat transfer through clothing layer.

The effective dry heat transfer coefficient (h') over the temperature gradient $\Delta T=(Tsk\ Ta)$ is $DRY/\Delta T=hF_{cl}$ or $1/(1_a + 1_{cl})$ where h is the sum of h_r and h_c; $I_a(=1/h)$ and I_{cl} are the thermal resistances of the outer-air and clothing respectively; F_{cl} is the Burton's thermal efficiancy factor, that is, the ratio of the dry heat loss when clothed and when unclothed i.e. $F_{cl} =1_a/(1_a+1_{cl})=1/(1+hI_{cl})$. Analogous to the dry heat exchange, the effective evaporative heat transfer coefficient (h_e) of a fully wet surface over the vapor pressure gradient $\Delta P=(P^*_{sk}\ P_a)$ is $EV/\Delta P=h_eF_{pcl}$ or $1/(I_e + I_{cle})$, where he is the evaporative heat transfer coefficient of the outer-air layer; $I_e(=I/h_e)$ and I_{cle} are the evaporative resistances of the outer-air and clothing respectively; F_{pcl} is the Nishi's permeation efficiency factor, namely, the ratio of the evaporative heat loss when clothed and when unclothed: $\mathbf{F_{pcl}=I_e/(I_e+I_{cle})=I/(1+h_eI_{cle})}$.

Several vapor permeability indices were defined which related dry and evaporative heat transfer through clothing layer:

1) Lewis relation (1922) for the non-radiativeair layer:
$L=h_e/h_c \doteq 2.2$ in °K/Torr

2) Permeation index for the outer-air layer (1984):
$i_a=h_e/2.2h=h_c/h$

3) Permeation index for the clothing layer (1983):
$i_{cl}=h_{cle}/2.2h_{cl}=I_{cl}/2.2\ I_{cle}$

4) Permeation index for the total clothing-air layer (Woodcock 1962) :
$i_m = h'_e/2.2\ h' = h_e\ F_{pcl}/2.2\ h\ F_{cl} = (I_a+I_{cl})/2.2\ (I_e+I_{cle})$

The simple relationships among the above permeability indices may be written as follows:

1) $1/i_m=F_{cl}/i_a+(1-F_{cl})/i_{cl}$

2) $F_{pcl}=(I_a/i_aL)/[(I_a/i_aL)+(I_{cl}/i_{cl}L)]=1/(1+h_cI_{cl}/i_{cl})$

3) $(1/F_{cl}-1)i_a=(1/F_{pcl}-1)i_{cl}$

4) $i_m=F_{pcl}i_a+(1-F_{pcl})i_{cl}$.

Our definition of I_{cl}, i_{cl} and I_{cle} ail include the trapped-air between the skin surface and fabric. in a case of low activity, like sedentary, with one-layer clothing, the dry heat may be transferred through the trapped air by conduction and radiation, namely, the effective thermal resistance of clothing is: $I_{cl}=I^*_{cl}+I_{at}$, where I^*_{cl} and I_{at} (**$1/(h_{rt}+h_{ct})$) are the intrinsic resistances of fabric itself and the trapped-air respectively. Similarly, the effective evaporative resistance of clothing is: $I_{cle}=I^*_{cle}+I_{et}$, where I^*_{cle} and let are the evaporative resistances of fabric itself and the trapped-air respectively. Introducing new permeation indices i*cl and iat, the effective permeation index (icl) can be expressed as the average of i^*_{cl} and i_{at}, weighted by new efficiency factors F_{at} and $(1-F_{at})$:

$$1/i_{cl}=F_{at}/i^*_{cl}+(1-F_{at})/i_{at},$$

where $i^*_{cl}=I^*_{cl}/I^*_{cle}L$, $i_{at}=I_{at}/I_{et}L=h_{ct}/(h_{ct}+h_{rt})$ and F_{at} is the thermal efficiencyfactor of the trapped-air:

$$F_{at}=I^*_{cl}/I_{cl}=I^*_{cl}/(I^*_{cl}+I_{at}).$$