17th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2013, Istanbul, Turkey, 10-11 September 2013

DYNAMIC ANALYSIS OF THE IMPACT OF AIR HUMIDITY ON THE HUMAN BODY AT DIFFERENT TEMPERATURES

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ABSTRACT
The paper is based on the thermal sensation of the human body to the ambient air humidity. Based on the thermal balance of thermal comfort, for the same ambient temperature, is analyzed human temperature and the amount of human heat exchanged with the environment in terms of ambient air humidity change. The purpose of the paper is to determine the ambient temperature intervals associated with thermal sensation respectively the intensity of the cold and hot by changing the amount of moisture. These results will be achieved through several analytical expressions and will be presented through the relevant diagrams.
Key words: temperature, humidity, thermal comfort, moisture.

1. INTRODUCTION
Parameters within the environment that influence into heat exchange include the ambient temperature and water vapor pressure, radiant heat, air movement, and the properties of clothing (insulation and moisture transfer). The data produce the following parameters [1]: Environmental parameters: mean radiant temperature (t_{mr}, ^oC), partial water vapor pressure in ambient air ($p_{w,a}$, Pa), the convective heat transfer coefficient (h_c, W/(m^2.K).); Clothing parameters: Clothing area factor (A_D), effective clothing insulation (I_{ve}, cl=0.155m^2K/W); resistant of clothing to heat transfer R_{ve} (=0,155I_{ve}, m^2 ^0C/W); Physiological parameters: metabolic heat production (M, W/m^2), internal heat production (E_M, W/m^2), body heat storage (A, W/m^2), heat loss or gain via conduction, convection, radiation and evaporation (H, W/m^2), heat loss by skin diffusion ($E_{l,dif}$, W/m^2), skin wittedness and convective and evaporative heat exchange from the respiratory tract (Q_{res}, W/m^2).
Heat balance (thermal equilibrium) is the balance between the rate of heat production and the rate of heat loss [2]. The rate at which heat is produced depends primarily on our metabolic rate. Mathematically, the relationships between the body’s heat production and all its other heat gains and losses are as below:

$P=H;$ or$M-W=Q_{lëk} + Q_{res}$ (1)

Where are:
M –metabolic rate, of body surface area, W/m^2;
W –external work, equal to zero for most activities, W/m^2;
$Q_{lëk} = C+R+E_{lëk}$ –heat lost from skin to environment, W/m^2;
C=$f_{ve}\cdot h_c (t_{ve}-t_a)$–heat losses by convective heat flux, W/m^2;

f_{ve} –factor of clothing, the ratio of a person's surface area while clothed, to the surface area while nude ($=A_{ve}/A_D$):
f_{ve} =1,0+1,29I_{ve} for $I_{ve}\leq 0{,}078$ m^2K/W respectively for $I_{ve}\leq 0{,}5Ve$;
f_{ve} =1,05+0,645$I_{ve}$for $I_{ve}>0{,}078$ m^2K/W respectively for $I_{ve}>0{,}5Ve$;
I_{ve},, V_e –thermal isolation of clothing, ($1V_e$=1cl =0,155m^2 K/W);
h_c– convective heat transfer coefficient, W/(m^{2} ^{0}C:
$h_c=2{,}38(t_{ve}-t_a)^{1/4}$ –by natural convection;
$h_c=12{,}1(v_{rel})^{1/2}$ –by forced convection;
t_{ve} –surface temperature of clothing, ^{0}C;
t_a –air temperature, ^{0}C;
v_{rel}–theaverage wind velocity, m/s;
$R=3{,}95\cdot 10^{-8}f_{ve}[(t_{ve}+273)^4-(t_{mr}+273)^4]$ –heat loss by radiation from the surface of the clothed body, W/m^2;
$E_{lëk}=E_{l,dj}+E_{l,dif}$ –heat losses by sweat evaporation from the skin surface, W/m^2;
$E_{,dj}=0{,}42(M-W-58{,}12)$ –heat transfer by sweat evaporation from the skin surface,W/m^2;
$E_{,dif}=3{,}05\cdot 10^{-3}(p_{w,l}-p_{w,a})$ –evaporative heat transfer via skin moisture diffusion, W/m^2;
$p_{w,l}=256t_{lëk}-3373$ –vapor saturation pressure at skin temperature, Pa;
$t_{lëk}=35{,}7-0{,}0275(M-W)$ –skin temperature, ^{0}C;
$p_{w,a}$ – partial water vapor pressure, Pa;
$Q_{res}=C_{res,s}+E_{res,l}$ –heat losses due to respiration, W/m^2;
$C_{res,s}=0{,}0014M(34-t_a)$ –sensible heat lost by convection, W/m^2;
$E_{res,l}=1{,}72\cdot 10^{-5}M(5867-p_{w,a})$ –latent evaporative heat loss, W/m^2;

Heat balance also can express as below:
$$M-W-E_{lëk}-Q_{res}=R+C=P_{ve}=Z(x) \quad (2)$$
Where are:
$K=C+R$ –sensible heat losses from skin to the surfaces clothing, W/m^2;
$$P_{ve}=\frac{t_{lëk}-t_{ve}}{R_{ve}} \quad (3)$$
-conduction to the surfaces through the clothing, W/m^2,
R_{ve}(=0,155 I_{ve}) -resistant of clothing to heat transfer, m^2 ^{0}C/W;
Mechanical efficiency: η=W/M (4)
Human level activity respectively the: $E_M=M/A_D$ (5)
Where are:
E_M – internal heat production, met (1met=58.15 W/m^2);
$A_D=0{,}202m^{0{,}425}h^{0{,}725}$ –body surface area (physiological variable), m^2;
m –body mass, kg;
h –body height, m;

The surface temperature of clothing, ^{0}C, expressed from equations (3) and (4):
$$t_{ve}=t_{lëk}-0{,}155I_{ve}(M-W-E_{lëk}-Q_{res})$$
The mean radiant temperature [3], ^{0}C, from equation (2):
$$t_{mr}=\left[\frac{f_{ve}\cdot h_c\cdot(t_{ve}-t_a)+3{,}96\cdot 10^{-8}\cdot f_{ve}\cdot(t_{ve}+273)^4-(M-W-E_{lëk}-Q_{res})}{3{,}96\cdot 10^{-8}\cdot f_{ve}}\right]^{1/4}-273 \quad (6)$$
Partial water vapour pressure: $$\mathrm{pw}(x):=\frac{x\cdot p}{0.622+x} \quad (7)$$
The relative humidity $$\phi_i(x)=\frac{p_w(x)}{p_{wsi}(x)} \quad (8)$$

2. DYNAMIC ANALYSIS OF THE IMPACT OF AIR HUMIDITY ON THE HUMAN BODY AT DIFFERENT TEMPERATURES

In continuity of paper is analyzed the influence of moisture in the conditions of human thermal equilibrium for: human body mass 80kg, human body height 1.8m, external work 10W/m^2, metabolic rate 1met, effective clothing insulation 1cl, average velocity 1.5m/s, air temperature -15, -5, 15 ^{0}C, and absolute humidity *x =0.01, 0.02, ..0.07*. The diagrams below on the figures 1, 2, 3 and 4 show the change parameters related to the equation of human thermal equilibrium in connection with temperature, heat and mass transfer respectively depending of relative humidity.

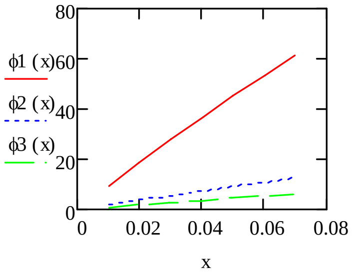

Figure 1. Changing the relative humidity by absolute humidity x =0.01, 0.02, ..0.07 and air temperature -15, -5, 15 ^{0}C

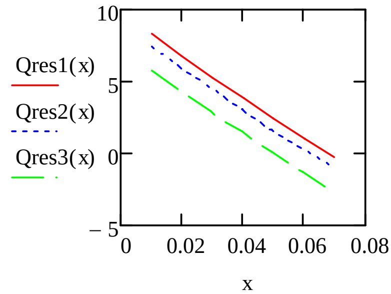

Figure 2. Changing of heat losses due to respiration by absolute humidity x =0.01, 0.02, ..0.07 and air temperature -15, -5, 15 ^{0}C

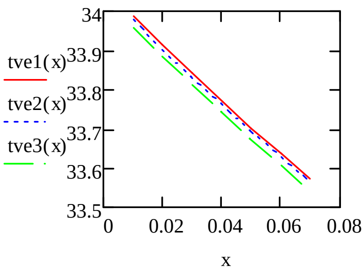

Figure 3. Changing of surface temperature of clothing by absolute humidity x =0.01, 0.02, ..0.07 and air temperature -15, -5, 15 ^{0}C

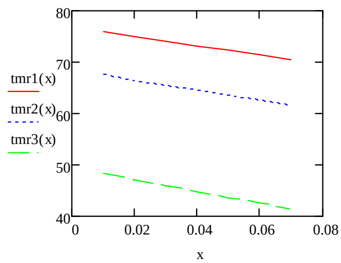

Figure 4. Changing of the mean radiant temperature by absolute humidity x =0.01, 0.02, ..0.07 and air temperature -15, -5, 15 ^{0}C

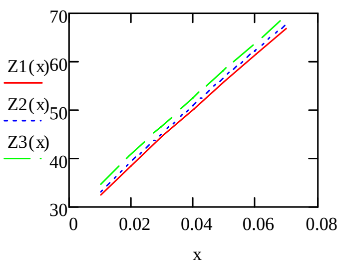

Figure 5. Changing of conduction to the surfaces through the clothing by absolute humidity x =0.01, 0.02, ..0.07 and air temperature -15, -5, 15 ^{0}C

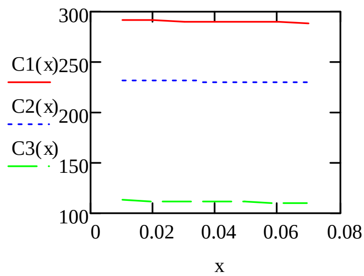

Figure 6. Changing of heat losses by convective heat flux by absolute humidity x =0.01, 0.02, ..0.07 and air temperature -15, -5, 15 ^{0}C

3. CONCLUSION

In order to protect the thermal equilibrium, as shown in above equations and diagrams, we can conclude that change of relative humidity causes change of almost all other parameters. For low temperature (e.g. -15^{0}C) shows that the relative humidity is very high and it increases with increasing absolute humidity. The respiration Heat is also high at low temperature sand it decreases with increasing absolute humidity. The same thing happens with tve(x), tmr(x) and C(x). It is interesting to note that Z(x) is lower at lower temperatures and that it increases with increasing absolute humidity, i.e. the heat spent more when the air has more moisture and high temperature than when the air has low moisture and temperature.

4. REFERENCES

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