Defence Science Journal, Vol. 4, No.2, April 1954, pp. 90-92

ON SOME EXPERIMENTS OF HEAT TRANSFER

By M. P. Murgai, N. C. Majumdar and R. N. Sharma, Defence Science Organisation, Ministry of Defence, New Delhi.

ABSTRACT

This note describes the results of some experiments on the heat transfer, in an earthenware vessel, used for storing and cooling water in the summer season, and depending for its cooling effect on the evaporative loss. This vessel makes a good approach to a human body, all covered with sweat, and lends itself to an alternative method of measurement of the parameters, in the basic equation of the heat balance of the human body. The results obtained are comparable to those of Brunt, got by observations on human beings.

The basic equation of the heat balance of the human body is given by

$$M+S=R+C+E$$

where M is the metabolic rate of heat generation, S the storage of heat in the body, R and C the radiation and convection loss or gain depending on the environmental conditions, E is the loss of heat due to evaporation of the sweat from the body surface. M is measured by the exchange apparatus, S can be estimated from consideration of the specific heat of the human body, E gets known from the loss of weight of the body in a certain time. The observation technique does not separate the measurement of R and C, and in general we have

$$R+C=K\,(T_1-T_2)$$

K being a constant, T_1 the temperature of the skin, T_2 that of the environment in °C. The value of K reported by Brunt[1] on the basis of a series of independent experiments is given by :

$K=3\cdot6+16v^{\frac{1}{2}}$ K cal./met^2 hr °C, v being the velocity in met./sec. This enables T and C to be separated into

$$R=3\cdot6\ (T_1-T_2)$$
$$C=16v^{\frac{1}{2}}\ (T_1-T_2)$$

regarding the temperature of the radiating surfaces the same as that of the surroundings. The convective and evaporative loss both together, on the other hand are related to the total heat content of air by the relation

$$C+E=A\,(I_1-I_2)$$

A being a constant, I_1 and I_2 the total heat content of the air at the skin temperature and the temperature of the ambient air respectively. Internal energy, the diffusion of which is the convective loss of heat C may be separated out

$$C=A\ Cp\ (T_1-T_2)=16v^{\frac{1}{2}}\quad {}_1-T_2)$$
$$A=16v^{\frac{1}{2}}/Cp=(200/3)\,v^{\frac{1}{2}}$$

In the environment conditions where the air temperature is greater than the skin temperature, there is always a convective gain and an evaporative loss. The two will balance each other if the evaporative loss can be increased. This however is not possible in a human body and in a rapidly moving hot air current the evaporative loss may not be able to keep pace with the convective gain and the skin temperature may rise. An earthenware vessel used for storing and cooling water in the summer season, and depending for its cooling effect on the evaporative loss, makes a good approach to a human body all covered with sweat, and lends itself to an alternative method of measurement of the convective gain. This vessel placed in a uniform current of air, will always come to a steady state, as opposed to the human body, when the evaporative loss=the convective gain. The air velocity can be measured by a Kata thermometer, and the rate of evaporative cooling by the loss of water in a certain time. We have : $E=C=av^{\frac{1}{2}}(T_1—T_2)$, neglecting radiation ' a ' is to be determined. The observational data are compiled in the table below

TABLE 1

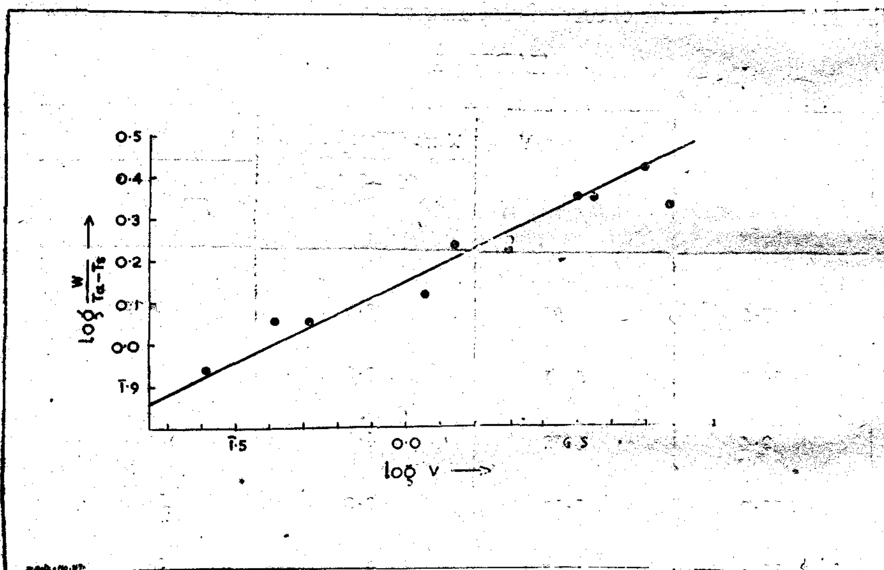
Serial No.	Evaporative Loss W gm./hr.	Air Velocity V meter/sec.	Tem. difference between air and water (Ta—Ts)°C	W / Ta—Ts gm./hr. °C
1	7·2	0·26	8·3	0·87
2	10·2	0·41	8·9	1·15
3	9·4	0·52	8·3	1·13
4	11·0	1·15	8·3	1·33
5	16·4	1.35	9·4	1·74
6	16·2	2·00	9·6	1·69
7	13·6	2·04	7·6	1·79
8	21·4	3·20	9·4	2·28
9	20·0	3.50	8·8	2·27
10	22·8	5·00	8·6	2·65

In Fig. 1, log W/(Ta—Ts) has been plotted against log V. The points are found to lie almost in a straight line, with a slope 2/5 instead of ½. This is because the radiation correction has not been taken into account. The relation between the evaporation rate and air velocity is found to be

$$W=1\cdot4\ V^{2/5}\ (Ta—Ts)\ gm\ /hr.$$

The surface area comes out to be about 0·041 m², considering the surface to be approximately spherical with a mean diameter of 4·5″. Taking 0·58 K Cal/gm as the latent heat of evaporation of water at the observed temperature, the evaporation loss E as well as convective loss C in K Cal/met² hr., is found to be given by the expression $E = C = 20\ V^{2/5}\ (Ta - Ts)$ K Cal/met². hr. For human body, we have Brunt's/expression, namely,

$C = 16\ V^{\frac{1}{2}}\ (T_1 - T_2)$. Obviously, it is the radiation factor which is mainly responsible for the difference between the two expressions. Thus, from these preliminary observations, it may be concluded that for practical purposes, an earthenware vessel is comparable to the nude human body so far as heat exchange by convection is concerned.



REFERENCE

1. Brunt, D. Proc. Phys. Soc. London 59, 713, 1947.