PREDICTION OF SWEAT RATE DURING INTERMITTENT EXPOSURE TO HEAT

Jacques B. Malchaire
Occupational Hygiene and **Work** Physiology Unit
Catholic University of Louvain, Belgium

INTRODUCTION

The Required Sweat Rate Index as defined in the ISO **7933** standard [1] is inappropriate under conditions of fluctuating exposure.
The index is calculated from time weighted averages of the required and maximum evaporation rates and assumes that the relation between those parameters and the sweat rate is linear. This is known to be true only in moderately warm working conditions and this averaging leads to gross underestimation of the physiological constraint. The objective of this study was to determine a more adequate time weighting system in order to be able to predict at any time the sweat rate and the hydric balance of the worker.

MODEL

The response R(t) of a first order system to a step function P at time t=O, is given by

$$R(t) = P[1 - \exp(-t/k)]$$

where **k** is the time constant.

This expression can be transformed in a recurrent formula:

$$R_i = R_{i-1} + (P_i - R_{i-1})\,[1 - \exp(1/k)]$$

which shows that the response at time i is equal to the response at the previous time (i-1) plus a fraction (1 - exp(1-k)) of the increment of solicitation, that is of the difference between the solicitation at time i (P_i) and the response at time (i-1).
The objective of the study was to determine the validity of this principle of exponential averaging for the calculation of both the mean skin temperature and the sweat rate.

METHODS

The data base used in the development of the model consisted of the results of several experiments run in climatic chamber. These involved variations in temperature, humidity and metabolic rate according to different **work** schedules. These data included continuous measurement of the skin temperature of the oesophageal temperature and of the sweat production.

The model was later validated on field data collected during an international research project sponsored by the European Coal and Steel Community.

These data consisted of discrete evaluations of metabolic rate **(by** the task decomposition methods) and weight loss (every about **30** minutes, with proper correction for any ingestion and excretion).
The time constants were varied between 2 to **20** minutes for the prediction of the mean skin temperature as well as of the sweat rate. The steady state mean skin temperature was calculated according to the primary parameters following the expression proposed by Mairiaux et al. [2].

RESULTS

The highest correlation coefficients between observed and predicted values were obtained for time constants of **3** min (R = 0.84) for the mean skin temperature and 10 minutes (r = 0.967) for the sweat rate.

Based on this modelling of the **2** parameters, it was possible to compute the average sweat **loss** over 30 min time intervals for the 2 sets of data.

Figure 1 and figure 2 give the corresponding results. The correlation coefficients are respectively 0.949 and 0.780, while they would have been equal to 0.643 and 0.502 without the exponential averaging.

The regression line in the validation study (fig. **2)** was 0.84 SW, + 1.35, indicating a systematic overestimation of the sweat rate at high level.

CONCLUSIONS

A simple model has been developed that allows to predict with increased accuracy, at any time during the exposure to heat, the sweat rate produced by the worker as well as the average sweat loss over a given time interval. This greatly increases the validity of the required sweat rate index to conditions with intermittent or fluctuating exposure. **A** correction formula is proposed to take into account an apparent overestimation of the model at high level of sweating. For the protection of 90% of the population of exposed workers and according to the "danger" criteria exposed in ISO 7933, the correction formula could be:

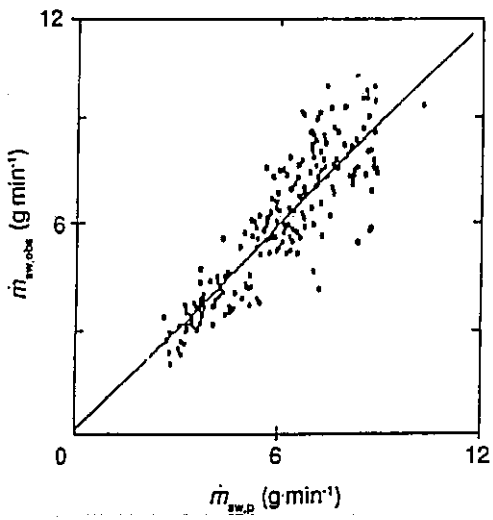
$$SW_{90\%} = 0.84\ (SW, - 1)$$

which is the linearized expression of the two-sided 80% confidence limit of the regression line for individual results and where SW, is the sweat rate (in grammes per minute) given by the model and $SW_{90\%}$ the sweat rate that might be experienced by at least 90% of the population.

REFERENCES

1. International Standards Organization 1990, Hot environments - analytical determination and interpretation of thermal stress using calculation of the required sweat rate. ISO 7933. I.S.O., Geneva.
2. Mairiaux Ph., Malchaire J. and Candas V. 1987, Prediction of mean skin temperature in warm environments. **Eur.** J. Appl. Physiol. 56, 686-692.

<u>Figure 1</u>: **Correlation between observed ($\overline{m}_{sw,obs}$) and predicted ($\overline{m}_{sw,p}$) men sweat rates over 30-min time intervals for individual expriments. $\overline{m}_{sw,obs} = 0.975\ \overline{m}_{sw,p} + 0.1$; r=0.873.**



<u>Figure 2</u>: **Regression between observed ($\overline{m}_{sw,obs}$) and predicted ($\overline{m}_{sw,p}$) mean sweat rates for experiinentsused** for **the validation of** the **model.** ***I regression line*** **$\overline{m}_{sw,obs} = 0.84\ \overline{m}_{sw,p} + 1.35$; *II* 80%confidence limit $\overline{m}_{sw,p,cor} = 0.84\ \overline{m}_{sw,p}$ *- 0.84***