PHYSICAL WORK AND THERMAL EMISSION

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1.0 - DESCRIPTION OF EXPERIENCE

In term of physical theoretical thermodynamics a human body which performs a closed cycle path in a conservative field, as the gravitational field, doesn't execute any mechanical physical work.

However it is common knowledge, that in actual condictions a growing in oxygen consumption and thermal emission is watched in these events.

The difference could be explained not only on the basis of external and internal friction and metabolic heat, but also in difference of efficency along the path and in the occurrence that it is absolutely impossible for muscles to convert the received energy in an utilizable form.

In other words the actual thermodynamical cycle is irreversible; the degree of irreversibility of an "irreversible process" may differ.

In this connection it is helpful to analyze the concept of (quasi-static) equilibrium and non-equilibrium process.

Any non-equilibrium process becomes an equilibrium one if the rate at which the process is realized approaches zero. At the same time every non-equilibrium process is irreversible and every equilibrium process is a reversible one.

In other words, the reason for the irreversibility of actual processes consists in their being in a non-equilibrium state.

The degree of irreversibility could be evaluated by Guy-Stodola equation, and under the assumption that the exercise is performed in quasi-static equilibrium it is possible to analyze separately the forward and reverse pathway of the process.

In our experience, the main goals are to study the athlete's thermoregulation response during positive and negative work exercises, in term of infrared long-wave emission, and to test qyantitatively the new thermodynamical man-environment heat-exchange equation under mechanical work condiction.

The experience in principium is very simple; four athletes perform a weightlifting exercise (40 Kg put on the shoulders) dividend in positive part (going up) and negative one (going down).

To obtain a correct quantitative test a number of physical and physiological parametres have been mesured: velocity, displacement, physical work, O_2 uptake, heart rate, infrared long-wave emission, mean skin temperature, lactic acid and total sweat losses. The samples are in real time, someone every 15" and someone in continuos.

The exercise is divided in three phases:

1 - Closed thermodynamical cycle (zero mechanical work): the athlete goes up and down, sitting to standing and viceversa.

2 - Pure positive work (open cycle): sitting athlete goes up to the standing position with weight and stops, leaves the

weight, and goes down sitting.

3 - Pure negative work (open cycle): standing athlete tarts with weight, and goes down sitting.

2.0 "THEORETICAL EVALUATION OF ENERGY BALANCE" WITH NEW HEAT EXCHANGE THEORETICAL EQUATION

The application of the first principium of thermodynamics confirms us, on the basis of collected data, the energy balance between input and output from athlete's body.

Calculation of mechanical work performed

The evaluation is a very easy application of the classical laws of mechanics, in a conservative field (gravitational field). If the friction is not tacken in account the work is $L = mgh$, where m is the mass of weight and body; during exercise athlete's body perform a closed cycle then it is better to evaluate the open path by subtraction of closed "neutral" cycle.

Calculation of metabolic energy

Metabolic energy is produced by transformation of chemical energy within the organism. Being impossible to assess quantitatively and in useful form these processes, it is normally assumed proportionality between chemical energy produced and oxygen uptake.

Calculation of heat losses

The application of new man-environment heat exchange equation let us evaluate, on the basis of temperature gap between skin and environment, the losses by radiation, convection from the lungs, convection and diffusion from the skin.

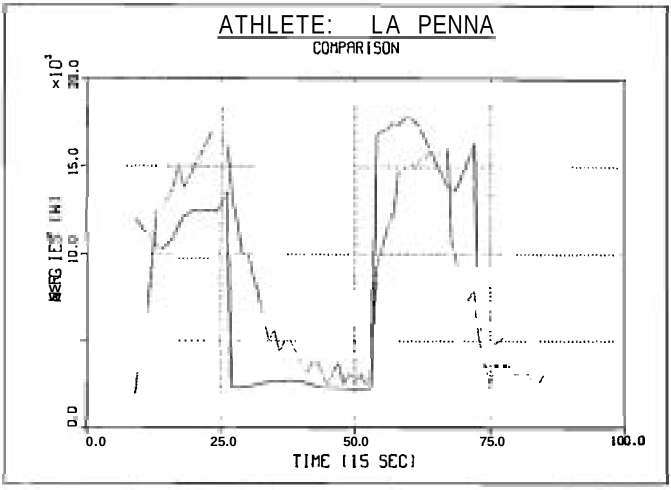
With these tools it is possible to evaluate, in predictive form, loss of availability, difference between starting and last mean skin temperature, sweat losses, efficency which, for human machine, is very low because ordered biological system can perform exeternal work only producing high rate of entropy.

These values are computed in each different path of the thermodynamical cycle: "pure positive work" and "pure negative work.

During "positive" work heat losses are less than the overall metabolic input in good agreement with human efficency.

During "negative" work heat losses are bigger than overall energy input; this is not a violation of energy balance principium, because heat surplus is mainly produced by muscular viscosity, parasite external friction and internal chemical source of energy.

The result are produced in graphical form and in term of integral value.



ATHLETE: LA PENNA

Starting weight: [illegible] Kg

Final weight : [illegible] Kg

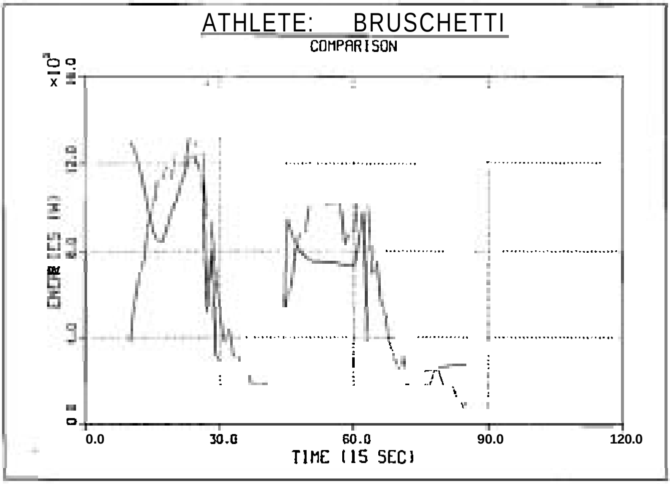
Starting mean basal temperature of the skin [illegible] K

Final mean basal temperature of skin 305.27 K

Computed sweat produced: 0.214 Kg

Computed temperature increasing: 0.38 K

TABLE 1



ATHLETE: BRUSCHETTI

Starting weight: 82.400 Kg

Final weight : 82.200 Kg

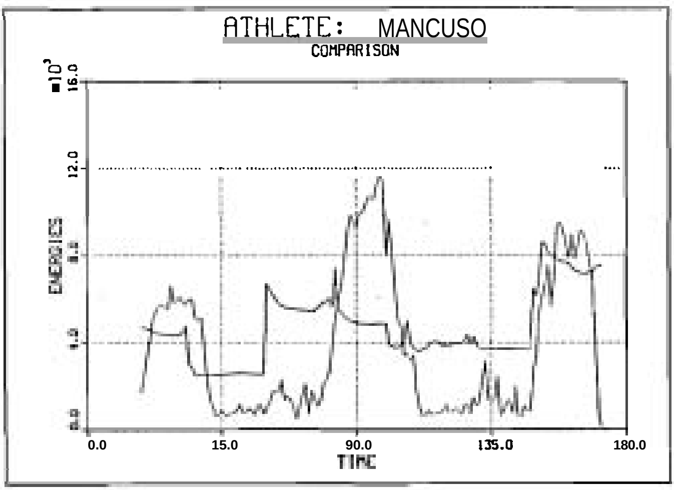
Starting mean basal temperature of the skin 305.10 K

Final mean basal temperature of skin 307.20 K

Computed sweat produced: 0.133 Kg

Computed temperature increasing: 0.22 K

TABLE 2



ATHLETE: MANCUSO

Starting weight: 82 Kg

Final weight :

Starting mean basal temperature of the skin 302.89 K

Final mean basal temperature of skin 303.78 K

Computed sweat produced: 0.188 Kg

Computed temperature increasing: 0.75 K

TABLE 3

3.0 EXPERIHENTAL RESULT

Only the data about oxygen consuption, mean skin, environmental temperatures and sweat losses are experimentally token in continuos during performance; the application of new heat exchange equation allows us to rebuilt dynamics of the energy output which is proportional to the algebric difference between oxygen input and external work performed or received.
If the results are in good agreement it means that it is possible, applying classical thermodynamics, to know the energetic evolution of athletes starting only from body surface mean skin temperature and ambient temperature, kind of work (light, heavy, maximal), pressure and humidity. The only final data are the weight variation and the skin temperature gap of the athlete depending from the sweat losses.

For La Penna and Bruschetti, who performed positive and negative work (Fig. 1 2), our equation, till now, foresees only for 55 % sweat production, under 65 % evaporation hypothesis and 5 to 11 % the increasing of body temperature (Tables 1 and **2)**.

In the Mancuso exercise (Fig. 3) the weight was 60±0.100 Kg before and after the experience; this limit case is very interesting for testing our theoretical results in fact our equation has two different predictions depending from the input source: thermocouples or thermocamera (Table 3). The former gives Am = 200 g and the latter Am = 180 g, in very good agreement with experimental data. The thoretical final temperature increment is 0.18 °C and the experimental is 0.89 °C from thermocouples, while from thermocamera 0.75 °C is the theoretical forecast and **-2.8 °C** is the experimental.