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DOCTORAL THESIS

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***A mathematical model of thermoregulation of the human body***

# *ABSTRACT*

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# Abstract

The study of human body thermoregulation mechanisms and the development of models having the aim of predicting the physiological response of the body under certain microclimatic conditions have seen an important development in the last ten years. These models are useful instruments for the characterization of the comfort conditions indoor and for the analysis of the risk related to the work in severe microclimatic conditions. These models are important even for the assessment of comfort conditions outdoor, as revealed by the recent European action COST730 that has conducted to the formulation of a new bioclimatic index, the UTCI, Universal thermal Climate Index.

The necessity of a human body thermoregulation model is important not only for the exposed reasons, but even because of the significant development of the physiology of the human thermoregulation system and of the analysis of the thermal exchange mechanisms between man and environment.

The proposed model can be an useful tool in the technological area of the clothing industry (both sportswear and protective clothing) and in the area of vehicles industry, as support in the assessment of thermal comfort inside the vehicles; furthermore the model can be a support tool in the design of HVAC systems.

The forerunner of the majority of thermoregulation models today available in the technical literature is the Stolwijk model with 25 nodes. This model was formulated in the 1970 for the NASA programs Skylab and Apollo. It introduced the distinction between controller (active) and controlled (passive) system, giving a scheme of the human body using several segments. Each segment is composed of concentric layers; each layer is characterized by homogeneous values of the thermo physical and physiological properties. The model, that could be used only in uniform environments and on nude subjects was studied in deep by several researchers aiming to extend its applicability to real situations (non uniform environments, clothed body) and to give to it an increased feasibility thanks to the subdivision in a bigger number of nodes.

At the beginning of the 1990s, the University of Naples Federico II started a research cooperation with the Laboratoire de Psychologie et Physiologie Environmentales of the CNSR in Strasburgo. This cooperation led to the definition of THERMODE (THERmoregulation Model for Disuniform Environment). THERMODE is inspired to the Stolwijk model; its main characteristics were: superior number of segments for the human bosy, possibility of taking into account spatial non-uniformities of thermo hygrometric parameters (so that it was possible to evaluate the main causes of local discomfort indoor, caused by temperature gradients, plan radiant temperature asymmetries, draught, warm and cold floor), and the presence of clothing. This model had a discrete accordance to experimental data in comfort and slight warm conditions but many problems occurred in the prevision of the response in slight cold conditions and of hands and feet.

The aim of this doctoral thesis was to improve THERMODE. The original model was deeply revisited in the passive system part. In particular, the number of segments was increased (at today the number of segments is 193); the clothing modelling has been developed on the basis of the recent developments in the field and new correlations for the assessment of the heat exchange due to respiration have been

introduced. Another step was the optimization of the active system on the basis of the model, both comparing the model itself to other available in the dedicated literature, and individuating new parameters for the control system. The derivation of the new parameters was made by using a computer calculation code. The obtained revised model was called THERMODE 193.