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A TWO-DIMENSIONAL MODEL OF THE HUMAN THERMAL SYSTEM

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All mathematical models actually used to predict human performance under various conditions are two-dimensional models which assume that physical and physiological variables in each major anatomical element, such as the trunk or an extremity, are radially symmetrical about the axis of the element. Although that appears to be an acceptable assumption in many cases, there are situations in which it is probably not acceptable. A good example is provided by an individual wearing an anti-exposure suit with integral flotation that prevents full immersion in cold water. Several experimental studies have shown the anomalous result that rectal temperature may increase during prolonged immersion in cold water, even though the subject is very uncomfortable and shivering vigorously. One-dimensional models do not offer a convincing explanation for such observations, because they cannot adequately account for peripheral variations in afferent thermoregulatory stimuli and for large regional variations in thermal flux to the environment.

The one-dimensional human thermal model developed by the second author has been extended to allow temperatures in all of the major elements to vary with radial and angular position, as well as with time, in response to circumferential variations in garment properties and environmental conditions. An implicit, alternating direction, finite-difference method is used to solve the transient-state heat conduction equation. The accuracy of the method has been established by comparing computed results obtained from the numerical solution with those obtained from an analytical solution for the special case of constant physical properties and no perfusion or metabolic heat generation.

The method has been used to analyze the response of a subject to accidental immersion in cold water when there is a marked asymmetry in peripheral boundary conditions, as described in the introduction. These results provide interesting new insights into thermoregulatory response to such situations, and suggest that this is an area in which additional experimental investigation should be conducted.