

VALIDATION OF MATHEMATICAL MODEL PREDICTIONS OF IMMERSION  
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A mathematical model of human thermoregulation has been used to predict survival times for aircrew immersed in calm water at temperatures ranging from 0°C to 22°C wearing clothing providing insulation from 0.09 tog to 1.09 tog (Hayes and Cohen, 1987). The clothing insulations had been measured using an immersed thermal manikin (Allan et al., 1982). This paper describes a study to confirm the validity of these estimated survival times.

The algorithm used in the model was tested by conducting 13 immersions using 4 different subjects (height 1.67m to 1.79m; weight 60.5kg to 76.5kg; mean skinfold thicknesses 5.0mm to 10.7mm) wearing clothing with a range of insulations (0.13 tog, 0.50 tog and 1.05 tog) whilst measuring core temperatures, metabolic rates, skin temperatures, and surface heat fluxes. The subjects were immersed, supported by a lifepreserver, in well stirred water at 6°C to 10°C depending on the clothing worn. Temperatures and heat fluxes were recorded every 2 minutes and oxygen consumption and carbon dioxide production measured every 15 to 20 minutes using a standard open circuit method. Metabolic rate was calculated from these data. Immersions terminated when the subjects' core temperatures fell to 34.5°C or at the subjects' request. The identical subject and environmental conditions were simulated using the model and the individual components of the thermal system compared with the empirical values.

The results demonstrated that the model tends to overestimate the surface heat flux, possibly due to the fact that it also overestimates skin temperature by 2°C to 4°C. However, the predicted metabolic rates were also higher than measured during the immersions, particularly during the early stages. These inaccuracies in the model seem to cancel out such that the rectal temperature predicted by the model was similar to the observed values, although the auditory canal temperature was always lower than that measured in the experiment. In addition, the insulation provided by the clothing assemblies during the immersions was calculated from the heat flux and skin temperature data and the values obtained were in good agreement with those obtained from measurements made using a thermal manikin.

It is concluded that the mathematical model estimates of survival times for aircrew immersed in water are valid.

ALLAN, J.R., HIGENBOTTAM, C., REDMAN, P.J. (1982). Measurement of survival clothing insulation using an immersed thermal manikin. Royal Air Force Institute of Aviation Medicine Report No 475.

HAYES, P.A., COHEN, J.F. (1987). Further developments of a mathematical model for the specification of immersion clothing insulation. Royal Air Force Institute of Aviation Medicine Report No 653.