COMPARISON OF METHODS FOR DETERMINATION OF HANDWEAR INSULATION WITH A BIOPHYSICAL MODEL

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INTRODUCTION

The conventional use of biophysical hand models has been to measure *dry* insulation from area weighted power demand values (1,2). This report describes two alternate methods for measuring *dry* insulation. One method is to determine the combined heat transfer coefficient for convection and radiation from the slope between power demand and multiple temperature differences. The second method consists of determining the total cooling rate of the model. The later method is of interest because it is analogous to complete blockage of blood flow to the human hand as would occur with a severe wound, application of a tourniquet, total peripheral vasoconstriction or blood shunting. The analogy is not wholly complete because the specific heat coefficients (c_p) and masses of the model and a human hand are not equal.

METHOD

A seven section, water resistant aluminum hand model was used to calculate total thermal insulation by determining the change in cooling rate and by measuring power demand while maintaining constant surface temperatures. Insulation is calculated from the slope of power versus the difference between surface and air temperature. Cooling curves for both bare and covered models were generated by heating the model to a selected surface temperature setpoint (30°C), then cutting off the power supply. In this case, insulation is estimated from the relationship between the rate of temperature decline versus time. Power consumption versus temperature difference slope values were generated by measuring tho sectional power consumption required to maintain a 30°C surface setpoint at different test chamber temperatures. Insulation values obtained with a 22-zone copper hand model were used as reference control values. Cooling curves were evaluated by calculating the slope for the natural logarithm of the temperature difference between the model surface temperature and the test chamber over time. Molnar (2) presents a similar calculation method.

TABLE 1. RESISTANCE AND INSULATION (CLO) VALUES FOR ISSUE MILITARY HANDWEAR

Table la. Comparison of two calculation methods and control values

	control		weighted average'		slope	
	$m^2 \cdot K \cdot W^{-1}$	(clo)	$m^2 \cdot K \cdot W^{-1}$	(clo)	$m^2 \cdot K \cdot W^{-1}$	(clo)
bare hand	0.06	(0.4)	0.04	(0.2)	0.05	(0.3)
arctic mitten set	0.38	(2.4)	0.35	(2.2)	0.35	(2.3)
three finger mitten	0.23	(1.5)	0.21	(1.3)	0.21	(1.4)
light duty glove	0.14	(0.9)	0.12	(0.8)	0.12	(0.8)

Table Ib. Comparison of adjusted insulation values to control

	control		weighted average'		slope	
	$m^2 \cdot K \cdot W^{-1}$	(clo)	$m^2 \cdot K \cdot W^{-1}$	(clo)	$m^2 \cdot K \cdot W^{-1}$	(clo)
bare hand	0.06	(0.4)	0.05	(0.3)	0.05	(0.3)
arctic mitten set	0.38	(2.4)	0.38	(2.5)	0.39	(2.5)
three finger mitten	0.23	(1.5)	0.23	(1.5)	0.23	(1.5)
light duty glove	0.14	(0.9)	0.14	(0.9)	0.13	(0.8)

'mean of three repetitions, three values per repetition

FIGURE 1

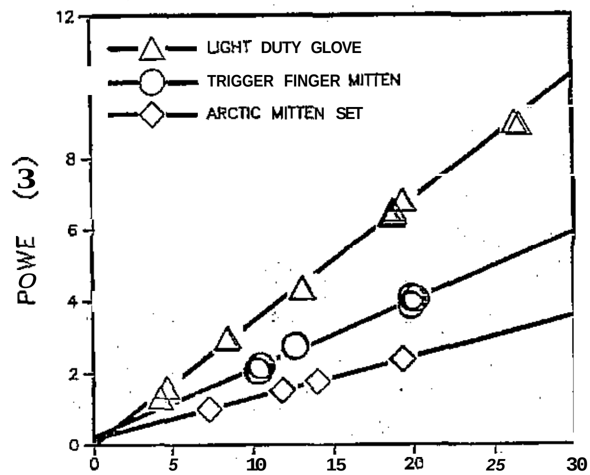

FIGURE 2

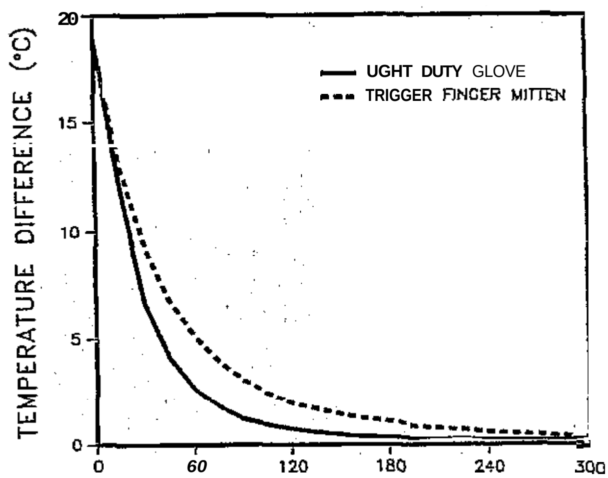

Figure 1. Power **demand vs. temperature** difference **(ΔT)**

Figure 2. Temperature **difference (ΔT)** vs. time

RESULTS

Total insulation values (I_T) were calculated for current **issue military** handwear using **both** the ***area*** weighted power demand **and** slope methods (Table 1a). The **insulation values for the** new hand **calculated by either** method **were** 0.01-0.02 $m^2 \cdot K \cdot W^{-1}$ **less** than **the** control **values obtained** with **the original** copper hand model. **Values calculated by the slope** method **were closer** to **the** control values, **but values** were lower for **both** methods. When **values** were **recalculated** using **a 10% larger total** surface **area** to compensate for **gaps between model** sections, **agreement** with the **control values increased (Table 1b).** The **relationship** between power and the **temperature** difference is **linear,** whereas the relationship between surface temperature and **time is curvilinear (Figures 1,2). The data obtained by cooling down the insulated** hand model **did not** provide comparable **calculated values** for **insulation, but relative levels** of insulation of different handwear are indicated.

CONCLUSIONS

The power **gradient** slope method **demonstrates** an **alternative** method for **calculating total** handwear **insulation (I_T) from power demand, and indicates that the values are** constant **over a range** of **temperature** gradients. However, **the cooling curves generated** by *terminating* **the** power **supply are not, at this time, an acceptable alternative method** for **calculating insulation.**

DISCLAIMER

The views, opinions and/or ***findings*** in **this** report **are** those of **the authors,** and should not **be construed as official Department** of the **Army** position, **policy or** decision, unless so designated by other **official documentation.**

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