DEVELOPMENT OF A THERMAL HAND TEST SYSTEM

F. Timothy O'Neill and Norman L. Bryar
Fourth International Conference on Environmental Ergonomics
Austin, Texas

INTRODUCTION

A series of Thermal Hand Test Systems (THTS) have been developed by Measurement Technology NW to measure the thermal insulation of handwear both in field and laboratory tests. The THTS's include a multi-sectioned, partially articulated cast aluminum hand and a micro-computer based thermal measurement and control system. The development leading to the construction on the most recent THTS is discussed here.

METHOD

Thermal Analysis: A thermal model was constructed using ANSYS finite element code to investigate the effect on two dimensional surface temperature profiles of heater placement, non-uniform wall thickness, material conductivity, and convection coefficient variation. The design criteria was a surface temperature uniformity of ± 0.5 °C across any single region. Minimum heater size was based on published, total body, maximum sensible and latent heat rejection values (1). Because it was assumed that the finger sections rather than the palm or wrist presented worst-case conditions relative to achieving isothermal temperatures at the surface, a quarter-symmetry model of a finger was developed. This analysis established minimum aluminum skin thickness and heater spacing for anticipated heat fluxes.

Casting: Hand dimensions from a number of male subjects were compared with the anthropometric 75th percentile American male right hand(2). A silicon rubber mold was made from the best candidate. Wax forms were then splash cast in the master mold for investment casting. A cast plug was also pulled from the master mold for use as a dimensional standard during assembly of the thermal hand.

Error Budget Analysis: A worst case error budget analysis of the thermal measurement and control system was implemented on a computer spreadsheet. The design criteria were accuracies of ± 0.25 °C for temperature measurement, and ± 10 mW for heat flux measurement for each region . This analysis considered the effects of A/D and D/A quantization, power supply regulation, sensor tolerance, temperature coefficients in the heaters, and signal conditioning component tolerances. The resulting design met all performance criteria.

Construction: The cast skin region supports were machined from a tough epoxy-glass composite material to near fit. The integration of the composite substructure, cast skin regions, and heaters and sensors was done by labor intensive cut-and-fit techniques. The interface electronics are mounted on printed circuit boards located in a standard industrial enclosure. The menu driven software was developed on a PC 286 in the ASYST high level control and instrumentation language.

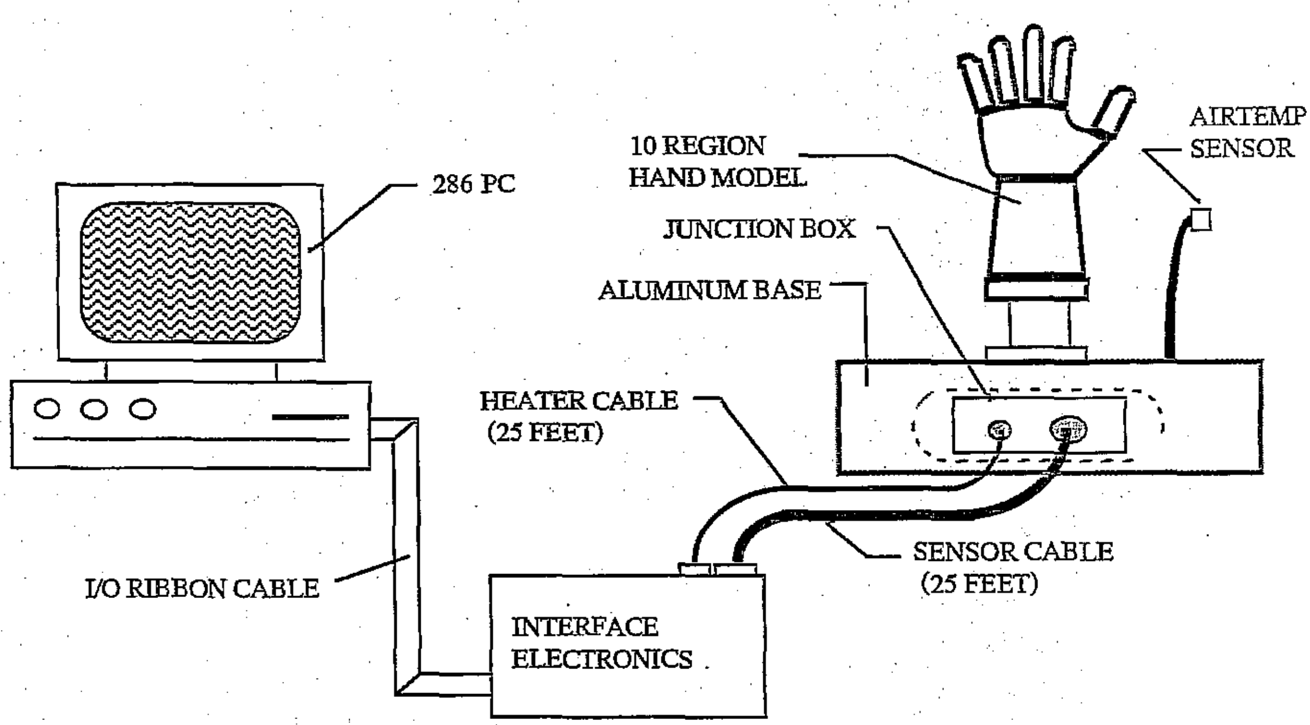
RESULTS

The THTS is shown schematically in Figure 1.0. The hand model consists of 10 thermally isolated regions including a thermal guard at the proximal cross-section of the wrist/forearm section. Partial articulation of the digits facilitate donning and doffing of hand wear. All wires are terminated inside a sealed, desiccated box so that a water soaked glove can be tested without harming the model. The Hand model is connected to the interface electronics by two 25 foot all-weather cables. The operator interface is implemented on a dedicated PC 286 microcomputer located near the interface enclosure. The system control software provides menu access to all operating parameters, data analysis and storage, and debug functions.

The THTS was tested in an environmental chamber using setpoints of 25.0° C, and 3.0° C, respectively. Surface temperature settling times to zero mean error typically took between 50 and 65 minutes for gloves and mittens with Clo values from 0.7 to 2.0. A bare hand clo of 0.3 was measured. Skin temperatures measured by the system compared well with those measured with small gage thermocouples glued to the outer surface. The PID control algorithm was able to control surface temperatures to zero mean error with ±0.25° C maximum excursion for set points from 5° to 35° C, in each region.

CONCLUSIONS

A development effort has resulted in the successful construction of a series of THTS's. The design approach, beginning with a thermal and an error budget analysis, resulted in a robust operator friendly instrument for the accurate measurement of clo values in handwear.



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1) Astrand, P. and K. Rodahl. 1977 Textbook of Work Physiology: Physiological Bases of Exercise. McGraw-Hill Book Company, New York, NY
2) Anthropometric Source Book (Webb Associates, 1978).