172.

TOTAL EVAPORATIVE RESISTANCE FOR DIFFERENT CLOTHING ENSEMBLES AT THREE LEVELS OF METABOLIC DEMANDS. V. Caravello, C. Ashley, T. Bernard, University of South Florida, Tampa, FL; E. McCullough, University of Kansas, Wichita, KS.

With regard to heat stress, the limiting factor inherent in clothing ensembles is the total evaporative resistance. For the same work demands, the greater the evaporative resistance of the clothing, the lesser the ability to cool by sweat evaporation and hence the lower the environmental contributors to heat stress, especially water vapor pressure, must be. Knowing the evaporative resistance provides a means to compare candidate ensembles. Further, a value for evaporative resistance means that a rational method, such as the ISO Required Sweat Rate, can be used to assess the heat stress exposure. In this study, the evaporative resistance of five clothing ensembles (cotton work clothes, cotton coveralls, Tyvek 1424, NexGen, and Tychem) was determined empirically from wear tests. The ensembles were configured similarly in that there were no hoods. The humidity was held constant at 50% rh, and three levels of metabolic rate (80, 160, 240 W/m^2) were explored. Fifteen heat-acclimated participants (11 men and 4 women) completed trials for all combinations of clothing ensemble and environment. A three-way ANOVA (ensemble, metabolic rate, participants) was used to analyze the data. Significant differences ($p<0.0001$) among ensembles, metabolic rates, participants, and the interaction between ensembles and metabolic rate was found. As expected, Tychem had the highest resistance at 0.034 kPa m^2/W. NexGen was next at 0.027; followed by Tyvek 1424 at 0.026. Coveralls was 0.025, and work clothes was 0.024. Pairwise comparisons adjusted for multiple comparisons were used to locate the differences among ensembles. Tychem was different from all others and NexGen was different from work clothes. We also found that evaporative resistance decreased with increased metabolic rate. This can be explained by the pumping action associated with increased work.

173.

COMPARING THERMAL MANIKIN AND PHYSIOLOGICAL TESTING RESULTS TO ASSESS THE PERFORMANCE OF LIQUID COOLING GARMENTS. K. Semeniuk, J. Dionne, A. Makris, Med-Eng Systems Inc., Ottawa, ON, Canada; T. Bernard, C. Ashley, T. Medina, University of South Florida, Tampa, FL.

Liquid and vapor impermeable clothing ensembles are engineered to protect workers exposed to biological and chemical threats. Regrettably, individual health and safety is compromised due to the added risk of heat stress created by these same ensembles. Limited permeability retards the diffusion of water vapor, producing an extremely humid microclimate that prevents sweat evaporation and thus inhibits active cooling and the ability to transfer heat to the surrounding environment. Therefore, personal cooling systems (PCS) should be used with protective ensembles to reduce the effects of physiological and environmental heat stress. The purpose of this research was to compare the performance results of a PCS liquid cooling garment (LCG) worn under various impermeable ensembles, using thermal manikin and physiological test methods. All tests were carried out in environmental chambers at 35°C. In physiological tests, five male subjects exercised at a metabolic rate of approximately 300 W. A sweating thermal manikin, with surface temperature maintained at 35°C, was used to assess performance while accounting for the effective evaporative heat transfer. To compare methods, the rate of heat transfer was calculated by measuring the mass flow rate and the inlet and outlet temperature of the circulating liquid in the LCG. Average heat transfer rates of 330 and 185 W were measured from the manikin and physiological trials, respectively. Additional physiological variables were also used to assess the significance of the LCG. For the no cooling and cooling conditions, the average rates of change in core temperature were found to be 0.019 and 0.009°C/min, respectively, and the average rates of change in heart rate were found to be 0.80 and 0.15 bpm/min, respectively. LCG heat transfer was successfully measured using both thermal manikin and physiological methods, with the latter results being lower due to the body's thermoregulatory mechanisms and mechanical and metabolic efficiency.

174.

ARE ALL GLOVES CREATED EQUAL? THROUGH THE EYES OF SURFACE INFRARED REFLECTANCE. R. Phalen, S. Que Hee, University of California-Los Angeles, Los Angeles, CA.

Decisions regarding the selection of chemical protective gloves are often based on general permeation guidelines. The major assumption is that glove types are equivalent. The aim of this study was to characterize and compare nine types of powder-free, unlined, and unsupported nitrile gloves using attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectrometry to assess suitability for surface infrared analysis of the dicarboximide fungicide Captan. Within glove, between glove, and between lot variabilities were measured for 13 gloves from 5 manufacturers at 740, 1124, 1252, and 1735 cm^{-1}, the characteristic Captan peak wavelengths. Appreciable glove reflectances will limit sensitivity. Relative humidity (RH) and temperature effects on the surfaces of three gloves were evaluated by preconditioning them overnight at 2 ± 1, 31 ± 1, 55 ± 1, 76 ± 2, and 87 ± 4% RH. For all gloves except one (Best, inner), 1735 cm^{-1} provided the greatest sensitivity. At 1735 cm^{-1}, outer glove absorbances ranged from 0.0074 ± 0.0005 (Microflex) to 0.0195 ± 0.0024 (Safeskin). Average within glove coefficients of variation (CVs) ranged from 2.7 (Best, range 0.9–5.3%) to 10% (Safeskin, 1.2-17%). Within glove CVs greater than 10% were for one brand (Safeskin). Between glove CVs ranged from 2.8 (Best) to 28% (Safeskin). Between lot variation was statistically significant ($p<0.05$) for all lots tested (Best, Microflex, and Safeskin). RH had variable effects dependent on brand and wavelengths. For two gloves (Ansell and Microflex), absorbances at 740 cm^{-1} and 3430 cm^{-1} (-OH stretching) increased significantly ($p<0.05$) with increasing RH. Overall, substantial within glove, between glove, and between lot variabilities were observed. ATR-FTIR is a rugged analytical tool for measuring glove surface reflectance, detecting surface humidity effects, and choosing selective and sensitive wavelengths for infrared analysis of nonvolatile surface contaminants.

175.

CHANGE IN TENSILE STRENGTH AND ULTIMATE ELONGATION OF NEOPRENE AND NITRILE GLOVES AFTER REPEATED EXPOSURES TO ACETONE AND THERMAL DECONTAMINATIONS. P. Gao, B. Tomasovic, NIOSH, Pittsburgh, PA; J. Wassell, NIOSH, Morgantown, WV.

The purpose of this study was to investigate the change in tensile properties of neoprene and nitrile gloves after repeated exposure to acetone and thermal decontamination. Neoprene (Stanzoil N-440) and nitrile synthetic rubber (Ansell Edmont 37-155) gloves were cut into circular swatches with a diameter of about 18 cm. Thicknesses of the swatches were measured in five places and the mean thickness was calculated. Each swatch was mounted at the base of a cylinder-like exposure chamber. Neat 99.7% acetone was poured onto the outer glove surface and the contact continued until steady-state permeation was fully established. The chamber was then disassembled and the swatch was air dried inside a fume hood for about 3 hours followed by thermal decontamination at 100°C for 16 hours using an incubator. Dumbbell-shaped samples were punched from the exposed swatches using an Arbor Press. The tensile strength and ultimate elongation of these samples were measured according to the ASTM D412 Method using the Lloyd Material Testing Instrument. The exposure/decontamination procedure was repeated for a maximum of 10 cycles.

Results from each exposure/decontamination cycle were compared with those obtained for the new glove materials. For neoprene exposed to acetone, the mean tensile strength for the new swatches was 15.0 MPa. The tensile strength consistently decreased to 8.8 MPa after

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