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THERMAL PROPERTIES OF THREE COLD WEATHER ENSEMBLES AND AN UNPOWERED HEATED BASE LAYER ENSEMBLE

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EXECUTIVE SUMMARY

The goal of this project was to determine the efficacy and performance of a heated clothing system when it is used with three Air Warrior ensembles at different environmental conditions. As a first step towards this goal, the passive thermal properties of one heated base-layer (heat off), and three Air Warrior ensembles were measured for baseline information. The three Air Warrior ensembles were light, intermediate and cold weather ensembles. These four ensembles were tested on an ANDI thermal manikin (Thermetrics, Seattle, WA) according to ASTM F1291 for thermal resistances and according to ASTM F2370 for evaporative resistances. Total ensemble thermal resistances for the four clothing configurations ranged from 0.134 to 0.405 °C·m^2/W (0.86 to 2.62 clo), and evaporative resistances ranged from 0.0123 to 0.0742 kPa·m^2/W. Thermal and evaporative resistances of six body regions were also calculated and reported.

INTRODUCTION

Bulky extreme cold weather gloves, boots, and clothing can provide effective thermal protection but may result in unacceptable loss of agility, tactility, and dexterity. Heated garments may provide warfighters with thermal protection needed to perform tasks effectively and without pain and risk of cold injury. Potential applications include: (a) Military Free Fall (MFF) jumpers exposed to extreme cold during descent from high altitudes who suffer low hand temperatures and reduced manual dexterity; (b) arctic medics who lose dexterity when performing emergency medical procedures while wearing lightweight protective gloves; and (c) rotary wing pilots operating in cold conditions who, with heated garments, can wear lighter gloves and fewer layers of passive insulation, thereby improving manual dexterity, mobility, and mission effectiveness.

Human performance is degraded and cold injury risk increases when body temperature drops. Hypothermia occurs when the body core temperature falls below 36°C. When the skin temperature of an extremity begins to fall, it causes discomfort, pain, numbness, performance deterioration, and eventually local cold injury. Hand manual performance deteriorates as hand skin temperatures decrease (1-3). Cold feet affect balance and walking and may increase the risk of slipping (4). The cold injury risk increases significantly when skin temperatures drop below 5°C (5, 6).

Heated clothing is one potential approach to maintain human performance and prevent cold injury during exposure to cold or extreme cold (7, 8). In addition, heated clothing may make it possible to eliminate cumbersome layers within multi-layered cold protective ensemble systems by supplementing the remaining clothing items with an actively heated base layer. Thermal manikin evaluations of heated clothing have shown that the efficacy of heated clothing is dependent on environmental conditions (9). Human studies and simulations by a human thermoregulation model have found that the power required varies with environmental conditions. Heated clothing becomes less effective as environmental temperature decreases due to increased heat loss to the environment (10-12).

The overarching goal of this project is to determine efficacy of heated clothing when various ensembles are worn at different environmental conditions. As a first step towards this goal, baseline thermal manikin evaluations of an unpowered heated base-layer and three Air Warrior clothing and individual equipment (CIE) ensembles were measured and collected as baseline information. The ThermaNOLE Comfort Lab® in the Jim Moran College of Entrepreneurship at Florida State University evaluated thermal properties of four ensembles in collaboration with USARIEM and Human Systems Integration (HSI). This report describes the samples tested, procedures used, and the results collected from the laboratory tests. Future evaluations under non-standard freezing and below freezing temperatures will provide additional data needed to model and validate the use of heated garments to protect warfighters against performance decrements and injury in cold and extreme cold. This future test phase will use a state-of-the-art thermal manikin capable of directly measuring positive and negative heat flux (heat gain or loss) in response to changes in heated garment output, overgarment thermal resistances, and chamber temperature. The data collected will be used to systematically model heated garment thermal performance under a wide range of CIE and environmental conditions.

METHODS

SAMPLE DESCRIPTION

Four individual ensembles were tested on an ANDI thermal manikin (Thermetrics, Seattle, WA) (https://thermetrics.com/products/manikin/andi/), as detailed in Table 1 below. Each ensemble was tested for thermal resistance per ASTM F1291 (13) and evaporative resistance per ASTM F2370 (14). The garments and accessories worn for each ensemble are summarized in Table 1. More specific ensemble element details can be found in the “Cold Weather Clothing Ensemble Matrix” and are shown in Appendix D as dressed and tested on the ANDI thermal manikin. Three replicate tests were performed on each ensemble for dry (thermal resistance) and wet (evaporative resistance) testing in a static state (manikin standing; 0.4 m/s air speed).

Table 1. Test Ensembles

Ensembles	Ensemble Elements*
HSI Heated Base Layer System	Heated long sleeve thermal shirt, heated long thermal drawers, vest, heated glove liner, heated boot liner, Army combat boots
Light Ensemble	Short sleeve undershirt, drawer briefs, long sleeve thermal undershirt, long thermal drawers, Army Aircrew Combat jacket, Army Aircrew Combat trouser, Riggers belt, socks, Army combat boots, Gentex HGU-56/P helmet, Flyers' glove GS/FRP-2 (Life Support International, Langhorne, PA), HANZ glove liner (HANZ Extremity Wear, Duarte, CA)
Intermediate Ensemble	Short sleeve undershirt, drawer briefs, long sleeve thermal undershirt, long thermal drawers, Army Aircrew Combat jacket, Army Aircrew Combat trouser, Riggers belt, Intermediate Weather Outer Layer Jacket, socks, Army combat boots, Lightweight Performance Hood (LPH), HGU-56/P helmet, Flyers' glove GS/FRP-2, HANZ glove liner
Cold Weather Ensemble	Short sleeve undershirt, drawer briefs, long sleeve thermal undershirt, long thermal drawers, Army Aircrew Combat jacket, Army Aircrew Combat trouser, Riggers Belt, midweight insulted shirt, midweight insulated drawers, Intermediate Weather Outer Layer Jacket, Intermediate Weather Outer Layer pants, socks, cold weather combat boots, LPH hood, HGU-56/P helmet, U.S. Issue Nomex Air Force HAU 15/P Intermediate Flyer's Glove, HANZ glove liner.

*HSI Heated Base Layer System: Human Systems Integration, Inc., Waltham, MA. TacHEAT heated base layer system. The Light, Intermediate and Cold Weather Ensembles correspond to current Air Warrior clothing and individual equipment configurations.

ANDI SWEATING THERMAL MANIKIN SYSTEM

An “ANDI” instrument is an articulated 35-zone sweating thermal manikin system designed to evaluate heat and moisture management properties of clothing systems. This instrument simulates heat and sweat production making it possible to assess the influence of clothing on the human thermal responses for a given environment. Simultaneous heat and moisture transport through the clothing system, and variations in these properties over different parts of the body can be quantified. The manikin consists of several features designed to work together to evaluate clothing comfort and/or heat stress. Housed in a climate-controlled chamber (Figure 1), the manikin surface is divided into 35 separate sections, each of which has its own sweating, heating, and temperature measuring system. Except for a small portion of the face, the entire manikin surface can continuously sweat.

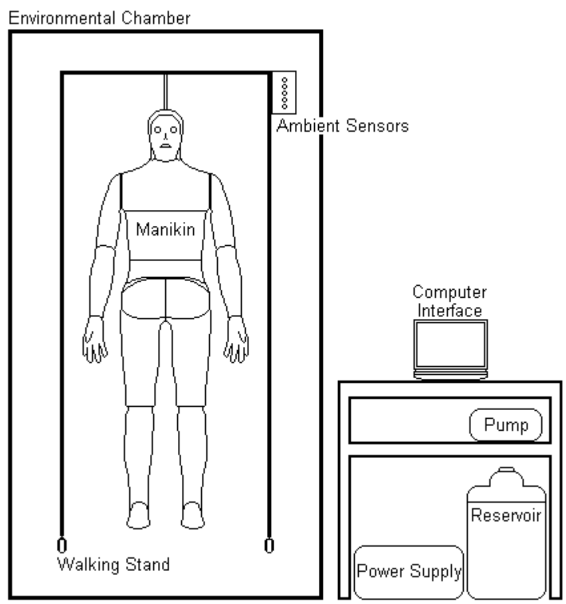

Figure 1. Test Apparatus Setup

Using a pump, preheated water is supplied from a reservoir located outside of the environmental chamber. An internal sweat control system distributes moisture to 140 "sweat glands" distributed across the surface of the manikin. Water supplied to the simulated sweat glands is controlled by operator entry of the desired sweat rate. Each sweat gland is individually calibrated, and the calibration values are used by the control software to maintain the sweat rate of each body section.

Water exuding from each simulated sweat gland is absorbed by a custom-made body suit (known as a “sweating skin” system). This specially designed suit acts as the manikin’s ‘skin’ during sweating tests. It is form-fitted to the manikin to eliminate air gaps and provides wicking action to evenly distribute moisture across the entire manikin surface.

Continuous temperature control for the 35 body segments is accomplished by a process control unit that uses analog signal inputs from separate Resistance Temperature Detectors (RTDs). These evenly distributed RTDs are used instead of point sensors because they provide temperature measurements in a manner such that all areas are equally weighted. Distributed over an entire section, each RTD is embedded just below the surface and provides an average temperature for each section. Software establishes any discrepancy between temperature set point and the input signal and adjusts power to section heaters as needed. Temperature controls are adjustable, by the operator, for each heater control. Figure 2 illustrates the 35 zones of the ANDI model manikin. Additional options exclusive to ANDI include dynamic heat flux sensing and active cooling channels which allow the manikin to be used in high ambient temperatures and in positive or negative heat flux environments.

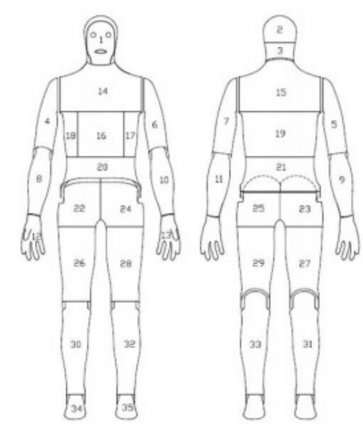

Figure 2. A schematic of the 35 Zone ANDI Manikin

TESTING PROCEDURES

The purpose of this testing was to measure the thermal and evaporative resistance of three cold weather warfighter ensembles and a single heated base layer ensemble, without powered heat to establish baseline resistance measures for each ensemble. Thermal resistances of the ensembles were measured according to the practices listed in ASTM F1291 Standard Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin with (13). The evaporative resistances were measured according to the practices listed in ASTM F2370 Standard Test Method for Measuring the Evaporative Resistance of Clothing Using a Sweating Manikin (14). Tests for thermal resistance occurred under non-isothermal conditions of 20°C/50% relative humidity environment, whereas tests for evaporative resistance are measured in isothermal conditions of 35°C/40% relative humidity, per the standards listed above. Three repetitions were completed for each garment configuration, as specified by these standards.

Table 2. Testing Conditions – Thermal and Evaporative Resistance

	Thermal Resistance	Evaporative Resistance
Air Temperature (°C)	20	35
RH (%)	50	40
Air Speed (m/s)	0.4	0.4
Skin Temperature (°C)	35	35

Thermal resistance values were converted to units of clo and evaporative resistance values were converted to permeability index values. Both sets of units are reported since either one may be commonly used. The reported parameters are listed and described below. See Appendix A for equations and conversions.

DRY AND WET (SWEATING) SKIN TESTS

The measurement of heat transfer is a measure of heat flow from the manikin surface (heated to a skin surface temperature of 35°C) through an ensemble into the test environment and is determined for both simulated dry and wet skin conditions. Heat loss parameters, calculated from thermal transport measurements, include:

a. **Total Thermal Resistance (R_t)**, [°C·m^2/W], total thermal resistance (insulation) provided by the manikin, clothing, and air layers. Thermal resistance is often presented in clo units (1 clo = 0.155 °C·m^2/W). Clo is an arbitrary unit of thermal resistance, where an insulation value of 1 clo approximates a typical man's business suit and the amount of insulation is expected to maintain thermal comfort for a person seated in a typical indoor office environment. Typical requirements for intrinsic thermal resistance vary from about 0.5 clo for summer wear to 4 to 5 clo for outdoor winter clothing.

b. **Total Evaporative Resistance (R_{et})**, [kPa·m^2/W], total evaporative resistance provided by the manikin, clothing, and air layers measured under isothermal conditions.

c. **Intrinsic Thermal Resistance (R_{cl})**, [°C·m^2/W], total thermal resistance provided by the clothing only.

d. **Intrinsic Evaporative Resistance (R_{ecl})**, [kPa·m^2/W], intrinsic evaporative resistance provided by the clothing only, measured under isothermal conditions.

f. The **i_m value**, or permeability index.

RESULTS

The average values for R_t, R_{et}, R_{cl}, R_{ecl}, It, i_m, and $Q_{predicted}$, 25°C, 65RH% are reported in Table 3. The measured thermal resistances in air, calm water and water with wave are shown in Table 1. The thermal resistances in air are higher than that in water.

Table 3. Mean R_t, R_{et}, R_{cl}, R_{ecl}, i_m, and dry and wet heat loss at 25°C, 65% RH

Ensemble	R_t	R_{et}	R_{cl}	R_{ecl}	i_m	Q_{dry}	Q_{wet}
	°C·m²/W	kPa·m²/W	°C·m²/W	kPa·m²/W		W/m²	W/m²
HSI Base	0.141	0.0252	0.071	0.0251	0.34	74.7	150.4
Light	0.269	0.0460	0.214	0.0460	0.35	38.4	81.2
Intermediate	0.313	0.0613	0.257	0.0612	0.31	33.3	60.9
Cold Weather	0.421	0.0879	0.366	0.0879	0.29	24.7	43.1

*$Q_{predicted}$, 25°C, 65% RH is the predicted total heat loss from the sum of dry (Q_{dry}) and evaporative heat (Q_{wet}) flux for a 25°C, 65% RH environment consistent with the standard ASTM F1868 THL environment (15).

The thermal resistance of the air layer around the nude manikin standing in 0.4 m/s wind conditions was measured to be 0.0819 °C·m²/W. The evaporative resistance of the air layer around the nude manikin standing in 0.4 m/s wind conditions was measured to be 0.0126 kPa·m²/W.

A clothing factor of 1.48 was used for all cold weather ensemble configurations. A clothing factor of 1.17 was used for the non-heated HSI base layer system. These clothing factors were estimated using “TABLE 1 Clothing Area Factors (f_{cl}) for Typical Protective Clothing” found in ASTM F1291 Standard Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin. A copy of the table can be found in Appendix B.

The regional clothing properties of the four ensembles and the nude manikin were calculated for the head, torso, arm, hand, leg, and foot regions. Each region was calculated by taking the parallel weighted average of the zone grouping for each region.

The head region includes zones 1 -3, the torso region includes zones 14 – 25, the arm region includes zones 4 – 11, the hand region includes zones 12 – 13, the leg region includes zones 26 – 33, and the foot region includes zones 34 – 35. Table 4 shows the regional R_t of the four ensembles as well as the nude manikin. Table 5 shows the regional R_{et} of the four ensembles as well as the nude manikin. This additional data is useful for further analysis of clothing differences as well as input for thermoregulatory models. The nude regional values were calculated from the single repetition present in the manikin testing files.

Table 4. Regional R_t of four ensembles and the nude manikin

Ensemble Name	R_t (°C·m^2/W)					
	Head	Torso	Arms	Hands	Legs	Feet
Nude	0.067	0.087	0.079	0.065	0.086	0.080
HSI Base	0.063	0.258	0.140	0.096	0.110	0.244
Light	0.161	0.371	0.245	0.160	0.256	0.273
Intermediate	0.230	0.478	0.323	0.136	0.257	0.271
Cold weather	0.225	0.653	0.396	0.185	0.411	0.321

Table 5. Reginal R_{et} of four ensembles and the nude manikin

Ensemble Name	R_{et} (m^{2}Pa/W)					
	Head	Torso	Arms	Hands	Legs	Feet
Nude	0.0143	0.0166	0.0110	0.0114	0.0121	0.0107
HSI Base	0.0230	0.0514	0.0225	0.0282	0.0151	0.2164
Light	0.0367	0.0573	0.0396	0.0350	0.0394	0.1188
Intermediate	0.0481	0.0956	0.0564	0.0347	0.0469	0.0983
Cold weather	0.0565	0.1703	0.0708	0.0355	0.0712	0.1139

DISCUSSION

Heated clothing and individual equipment (CIE) with active heating are needed to provide the level of thermal protection necessary for training and deployments in extreme cold conditions. Providing adequate thermal protection for vulnerable hands and feet is of particular concern. An added benefit to heated CIE is that pilots and other personnel needing high levels of dexterity to perform their jobs can also benefit from the use of heated CIE which may reduce the need for cumbersome passive insulation layers.

As a first step, this study determined the passive baseline biophysical characteristics of an unpowered heated base layer and three Air Warrior ensembles (light, intermediate, and cold). The testing, which was performed under standardized ASTM conditions, was accomplished using Florida State University's ANDI thermal sweating manikin (Thermetrics LLC, Seattle, WA).

A second, follow-on, work effort will use the state-of-the-art ANDI manikin to characterize the thermal effects of an actively heated base layer in the context of the three Air Warrior ensembles and freezing and sub-freezing chamber temperatures. This second effort takes advantage of the unique ability of the ANDI manikin to directly measure heat flux (heat gain or loss) and builds on a recent analysis of heated garment performance by Rioux et al. (2022).

Study limitations: data reported here were obtained under controlled laboratory conditions and characterize the thermal and evaporative resistance values of test garment responses to specific environmental conditions. These results should not be used to appraise the safety benefits or risks of the materials or products in extreme use conditions. The relationships between laboratory tests and field performance are complex and do not always practically translate. Clothing comfort is a complex phenomenon determined by many important factors including the garments worn, activity level, and the environmental conditions. The results here within do not address the full range of factors regarding clothing comfort in all potential use scenarios.

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APPENDIX A: CALCULATION OF HEAT TRANSFER PARAMETERS

Vapor pressure calculations

All vapor pressures are calculated from temperature and relative humidity based on Wexler's formulation according to the following calculations:

es = saturation vapor pressure (SVP) in millibars (mb)

$$es = a_1 + a_2(T - T_0) + a_3(T - T_0)^2 + a_4(T - T_0)^3 + a_5(T - T_0)^4 + a_6(T - T_0)^5 + a_7(T - T_0)^6$$

a_1 – a_7 = Coefficients of the sixth order polynomial fits to SVP (See Appendix C)

T = temperature (K)

T_0 = 273.15

P = water vapor pressure (kPa)

$$P = \left[\frac{RH \times es}{100}\right]/10$$

RH = relative humidity (%)

es = saturation vapor pressure (mb)

Calculation of total thermal and evaporative resistance values

R_t = total thermal resistance of clothing and surface air layer (total thermal resistance of surface air layer only if nude) (°C·m^2/W)

$$R_t = \frac{T_s - T_a}{H} A$$

H = power input for the insulation testing (dry) condition (W)

T_s = Temperature of the manikin surface (°C)

T_a = Temperature in the local environment (°C)

A = area of the manikin being evaluated (m^2)

W = power input (W)

R_{et} = total evaporative resistance of the clothing and surface air layer (total evaporative resistance of surface air layer only if nude) (kPa·m²/W)

$$R_{et} = \frac{(P_s - P_a) \cdot A}{H_e - (T_s - T_a) \cdot \frac{A}{R_{ct}}}$$

P_s = water vapor pressure at the surface of the manikin (kPa)

P_a = water vapor pressure in the local environment (kPa)

A = area of the manikin being evaluated (1.81 m^2)

H_e = power input for the evaporative testing (wet) condition (W)

T_s = temperature at the manikin surface (°C)

T_a = temperature at the local environment (°C)

R_t = total thermal resistance of the specimen and surface air layer (°C·m^2/W)

Calculation of intrinsic thermal and evaporative resistance values

R_{cl} = intrinsic thermal resistance of the clothing ensemble (°C·m^2/W)

$$R_{cl} = R_t - \frac{R_a}{f_{cl}}$$

R_t = total thermal resistance of the clothing ensemble and surface air layer (°C·m^2/W)

R_a = thermal resistance of the air layer on the surface of the nude manikin (°C·m^2/W)

f_{cl} = clothing area factor (dimensionless)

R_{ecl} = intrinsic evaporative resistance of the clothing ensemble (kPa·m^2/W)

$$R_{ecl} = R_{et} - \frac{R_{ea}}{f_{cl}}$$

R_{et} = total evaporative resistance of the clothing ensemble and surface air layer (kPa·m^2/W)

R_{ea} = evaporative resistance of the air layer on the surface of the nude manikin's sweating surface (kPa·m^2/W)

f_{cl} = clothing area factor (dimensionless)

Calculation i_m

The i_m value (permeability index) is calculated, using total thermal resistance and total evaporative resistance values, from the following formula:

$$i_m = 0.061 \cdot \frac{R_t}{R_{et}}$$

Calculation of Predicted Heat Loss Potential

Predicted Heat Loss Potential (HLP) values are calculated using the total thermal resistance values and total apparent evaporative resistance values, from the following formulas:

$$Q_{predicted}, T, RH = \frac{P_t - P_a}{R_{et}} + \frac{T_s - T_a}{R_t}$$

$Q_{predicted}$, T, RH = [(P_s – P_a) / R_{et}] + [(T_s – T_a) / R_t]

T = specified temperature condition

RH = specified relative humidity

P_s = calculated water vapor pressure at the surface of the manikin (kPa)

P_a = calculated water vapor pressure in the specified local environment (kPa)

A = area of the manikin being evaluated (m^2)

$Q_{predicted}$, T, RH = Predicted HLP for specified environmental conditions (W/m^2)

T_s = specified temperature at the manikin surface (°C)

T_a = specified temperature at the local environment (°C)

R_{et} = total evaporative resistance of the specimen and surface air layer (kPa·m^2/W)

R_t = total thermal resistance of the specimen and surface air layer (°C·m^2/W)

APPENDIX B: CLOTHING AREA FACTORS (f_{cl}) FOR TYPICAL PROTECTIVE CLOTHING

Ensemble Description f_{cl}	Ensemble Description f_{cl}	f_{cl}
1. Warm Weather Indoor Clothing (Base ensemble)	Short-sleeve shirt, Men's underwear briefs, Khaki pants, Belt, Socks, Athletic Shoes	1.17
2. Cold Weather (Outdoor) Clothing	Base ensemble, Knit hat, Fiberfill jacket, Knit mittens	1.34
3. Chemical Protective Level B Ensemble	Base ensemble, Chemical protective hood, Chemical protective jacket, Chemical protective gloves, Belt, Chemical protective pants	1.60
4. Surgical Ensemble	Men's underwear briefs, Bouffant cap, Surgical mask, Scrub shirt, Scrub pants, Surgical gown, Surgical gloves, Socks, Athletic shoes, Shoe Covers	1.36
5. Cold Weather Expedition Ensemble	Thermal underwear (top and bottom), Cold Weather Expedition Suit, Fiberfill mittens, Men's underwear briefs, Socks, Work boots	1.48
6. Flame Resistant Protective Clothing (calibration ensemble)	Flame resistant long sleeve shirt, Men's underwear briefs, Flame resistant pants, Socks, Athletic shoes	1.22
7. Tyvek Coverall Ensemble	T-shirt, Men's underwear briefs, Socks, Athletic shoes, Tyvek coverall (no hood)	1.21
8. Fire Fighter Turnout Gear	Fire fighter helmet, T-shirt, Fire fighter turnout jacket, Green leather gloves, Men's underwear briefs, Fire fighter turnout pants, Socks, Work boots	1.48
9. Chemical Protective Level A Ensemble	Level A one-piece suit, Respirator, Men's underwear briefs, Socks, Athletic shoes	1.65

[2]: *ASTM F 1291-10 Standard Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin*. 2010.

APPENDIX C: POLYNOMIAL FITS TO SATURATION VAPOR PRESSURE

TABLE 3. Coefficients of the sixth-order polynomial fits to SVP and its temperature derivative over water for the temperature range -50°C - 50°C. Same for ice but for the temperature range -50°C - 0°C. Results for the relative and absolute norms are given. The original data based on Wexler's formulation.

Coefficients	Relative error norm	Absolute norm
	Water vapor	Water vapor
a_1	6.11176750	6.11237757
a_2	0.443986062	0.443868373
a_3	0.143053301E-01	0.142972999E-01
a_4	0.265027242E-03	0.265277571E-03
a_5	0.302246994E-05	0.303440695E-05
a_6	0.203886313E-07	0.202923793E-07
a_7	0.638780966E-10	0.599234475E-10
	Ice	Ice
a_1	6.10952665	6.11129721
a_2	0.501948366	0.502946169
a_3	0.186288989E-01	0.187819100E-01
a_4	0.403488906E-03	0.413580047E-03
a_5	0.539797852E-05	0.572443200E-05
a_6	0.420713632E-07	0.471826455E-07
a_7	0.147271071E-09	0.178255421E-09
	Derivative; water	Derivative; water
a_1	0.444010270	0.443994807
a_2	0.286175435E-01	0.285899617E-01
a_3	0.795246610E-03	0.794469942E-03
a_4	0.120785253E-04	0.121487375E-04
a_5	0.101581498E-06	0.103456665E-06
a_6	0.384142063E-09	0.354662108E-09
a_7	0.669517837E-13	-0.690147330E-12
	Derivative; ice	Derivative; ice
a_1	0.503176636	0.503214671
a_2	0.376859982E-01	0.377082927E-01
a_3	0.126121755E-02	0.126471345E-02
a_4	0.244143919E-04	0.246483786E-04
a_5	0.291045085E-06	0.298694887E-06
a_6	0.203326382E-08	0.215398512E-08
a_7	0.647087051E-11	0.720715829E-11

[3]: Flatau, P.J., R.L. Walko, and W.R. Cotton, *Polynomial Fits to Saturation Vapor Pressure.* Journal of Applied Meteorology, 1992. **Vol. 31**(12): p. 1507-1513.

APPENDIX D TEST ENSEMBLE PHOTOS (AS DRESSED AND TESTED ON ANDI)

Unpowered Heated Base Layer Ensemble (TacHEAT, Human Systems Engineering, Inc., Waltham, MA). This base layer ensemble is placed over the thermal manikin's sweating skin (see gray textile covering manikin head)

Light Ensemble – This ensemble corresponds to the current Lightweight Air Warrior clothing and individual equipment configuration.

Intermediate Ensemble – This ensemble corresponds to the current Intermediate Cold Weather Air Warrior clothing and individual equipment configuration.

Cold Ensemble - This ensemble corresponds to the current Cold Weather Air Warrior clothing and individual equipment configuration.