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TITLE
BASELINE THERMAL RESISTANCE MEASUREMENT OF SOLDIER CLOTHING AND PERSONAL EQUIPMENT

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BASELINE THERMAL RESISTANCE MEASUREMENT OF SOLDIER CLOTHING AND PERSONAL EQUIPMENT

by

W. Durnford

P. Potter

Of

The CORD Group Limited

50A Mount Hope Avenue

Dartmouth, Nova Scotia, CANADA

B2Y 4K9

Project Manager:

Mr. Paul Potter

Telephone: (902) 465-5544

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On behalf of

DEPARTMENT OF NATIONAL DEFENCE

As represented by

Defence and Civil Institute of Environmental Medicine

1133 Sheppard Avenue West

Toronto, Ontario, CANADA

M3M 3B9

DCIEM Scientific Authority:

Mr. Walter Dyck

(416) 635-2192

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TABLE OF CONTENTS

| | |
|----------------------------------|----|
| 1.0 INTRODUCTION | 1 |
| 1.1 BACKGROUND: | 1 |
| 1.2 AIM: | 1 |
| 1.3 SCOPE: | 1 |
| 2.0 REFERENCES | 3 |
| 3.0 METHOD | 4 |
| 3.1 METHODOLOGY: | 4 |
| 3.2 THERMAL MANIKIN TEST SYSTEM: | 4 |
| 4.0 TEST EQUIPMENT | 6 |
| 5.0 TEST CONDITIONS | 7 |
| 6.0 TEST ITEMS | 8 |
| 7.0 TEST PROCEDURE | 9 |
| 8.0 RESULTS | 10 |

ANNEX "A" RAW DATA

EXECUTIVE SUMMARY

There is a large program within the Canadian Forces, the Clothe the Soldier acquisition program, that aims to equip soldiers with improved protective clothing and equipment that will enhance both their protection and capability in a wide range of environmental and operational scenarios. Many items of in-service clothing and equipment will be replaced with items that reflect the state-of-the art in commercially available technology.

Since many replacement items aim to improve environmental protection of the soldier, it is necessary to determine the thermal protection characteristics of both the in-service items intended to be replaced as well as a range of representative options that reflect what is available, off-the-shelf, using current technology.

The CORD Group Limited was contracted by the Defence and Civil Institute of Environmental Medicine to determine the thermal resistance of clothing, footwear, and hand wear. The thermal resistance of these items was determined utilizing a thermal instrumented manikin test system.

This report describes the thermal manikin test system, the protocols and the results for each item tested. A total of 5 tests were conducted, with each test measuring the thermal resistance of a number of items. All of the items were tested in a dry condition only.

The report summarizes the thermal performance for each item tested and the raw data for each test is contained in ANNEX "A".

1.0 INTRODUCTION

1.1 **BACKGROUND:**

There is a large program within the Canadian Forces, the Clothe the Soldier Acquisition program, that aims to equip soldiers with improved protective clothing and equipment that will enhance both their protection and capabilities in a wide range of environmental and operational scenarios. Many items of the in-service clothing and equipment will be replaced with items that reflect the state-of-the-art in commercially available technology.

DCIEM has been tasked to provide Human Factors Engineering support to this acquisition project. Part of that support involves the development of performance-based specifications for each item. Since many replacement items aim to improve environmental protection of the soldier, it is necessary to determine that thermal protective characteristics of both the in-service items as well as a range of representative options intended to replace the in-service items that reflect what is available, off-the-shelf, using current technologies.

Thermal resistance is but one measurable aspect of thermal protection, and, while material thermal resistance can be measured on standardized bench-top equipment, it is also necessary to examine the thermal resistance of the complete piece of kit in order to determine the influence of the design on overall thermal protection.

1.2 **AIM:**

To measure the thermal resistance of in-service and commercial off-the-shelf soldier system clothing, hand wear, and footwear.

1.3 **SCOPE:**

The project will determine, utilizing a standardized, validated and reliable protocol (formally agreed upon between contractor and scientific authorities), the thermal resistance of the following soldier system components:

- a. Footwear. To include the following:
 - 1. gray wool sock (hereafter referred to as sock);
 - 2. new liner sock plus Norwegian General Purpose (green) sock;
 - 3. new liner sock plus light weight version of Marine Corps sock;
 - 4. new liner sock plus thick gray wool sock;
 - 5. new liner sock plus US Marine Corps sock.

- b. Bodywear. To include the following:
 - 1. Combats (shirt & pants) plus tactical assault vest;
 - 2. Combats (shirt & pants) plus Frag vest/single flap;
 - 3. Combats (shirt & pants) plus Frag vest/double flap;
 - 4. Combats (shirt & pants) plus Frag vest/single flap plus tactical assault vest;
 - 5. Combats (shirt & pants) plus Frag vest/double flap plus tactical assault vest.

- c. Handwear. To include the following:
 - 1. Cold Wet Weather Glove conditions I & II;
 - 2. Cold Wet Weather Glove conditions III & I;
 - 3. Cold Wet Weather Glove conditions II & III;
 - 4. Cold Wet Weather Glove conditions I & II;
 - 5. Cold Wet Weather Glove condition III.

2.0 REFERENCES

- 2.1 DSP L2646 Statement of Operational Requirement - Handwear System. National Defence Headquarters: Ottawa.
- 2.2 Morris, et. Al (1997). Cold Wet Weather Glove Dryability Study. Draft DCIEM Technical Memorandum (in progress).
- 2.3 Bossi, L.L.M., & Morris, A., (1996). DCIEM Human Ethics Protocol L155: Development of Cold Wet Weather Glove Performance Specifications.
- 2.4 CORD Document No. R95-018 (1995). Implementation of Test Protocol of Thermal Manikin Test System. The CORD Group Limited, Dartmouth: May 1995.

3.0 METHOD

3.1 *METHODOLOGY:*

The thermal resistance of in-service, developmental and commercial off-the-shelf soldier system clothing, hand wear, footwear, and head wear systems was determined using a Thermal Instrumented Manikin Test System. During each test, environment, temperature, skin temperature and power consumption was recorded.

3.2 *THERMAL MANIKIN TEST SYSTEM:*

The Thermal Manikin Test System is a means for evaluating the thermal insulation of thermal protective clothing. In particular, this refers to survival suits for ocean emergencies and, in general, it refers to any human-use apparel. The system consists of a hollow aluminum manikin equipped with temperature sensors and electric heaters connected to a computer system.

In operation, the manikin is dressed in the human-use apparel to be tested and placed in an appropriate environment. The computing equipment then controls the heaters to maintain the skin of the manikin at a set temperature and measures the electrical power required to do so. This power is equivalent to the heat that escaped through the clothing due to the temperature difference across it. The power and temperature differences are then used, along with the known surface area of the manikin to calculate the thermal resistance offered by the apparel.

The system is designed for flexibility and ease of operation. To allow for different types of clothing, different sections of the manikin can be included or eliminated from the test as required.

The basic philosophy on which the design is based is that the thermal performance of a garment can be evaluated by unmanned tests on the whole garment under conditions identical or similar to actual operating conditions. This philosophy dictates that the system employs a life-sized watertight manikin capable of being heated to and maintained at a selected temperature.

Figure 1 gives a total view of the system. The visible components are the Thermally Instrumented Manikin (TIM), the control module, the computer, the environmental temperature sensors and the cables connecting these components. Basically, the manikin provides a shape of human proportions to fit inside the test garment. The combinations of the aluminum shell of the manikin and the output of heaters inside it provide for an approximately uniform temperature over the manikin surface. This temperature is sensed by sensors embedded in the manikin's shell and passed to the control module. The control module houses the programmed data acquisition system, the heater relays and other circuit components. The data acquisition system receives data from the temperature sensors on the manikin and controls the heater relays so that the manikin surface temperature remains constant. It also measures the

environment temperature and the power applied to the manikin and is programmed with the surface area of the manikin. With this temperature, power and area data, it calculates the insulation value of the garment and passes this, along with other pertinent data to the computer. The computer acts as a control and display terminal and post-processor.

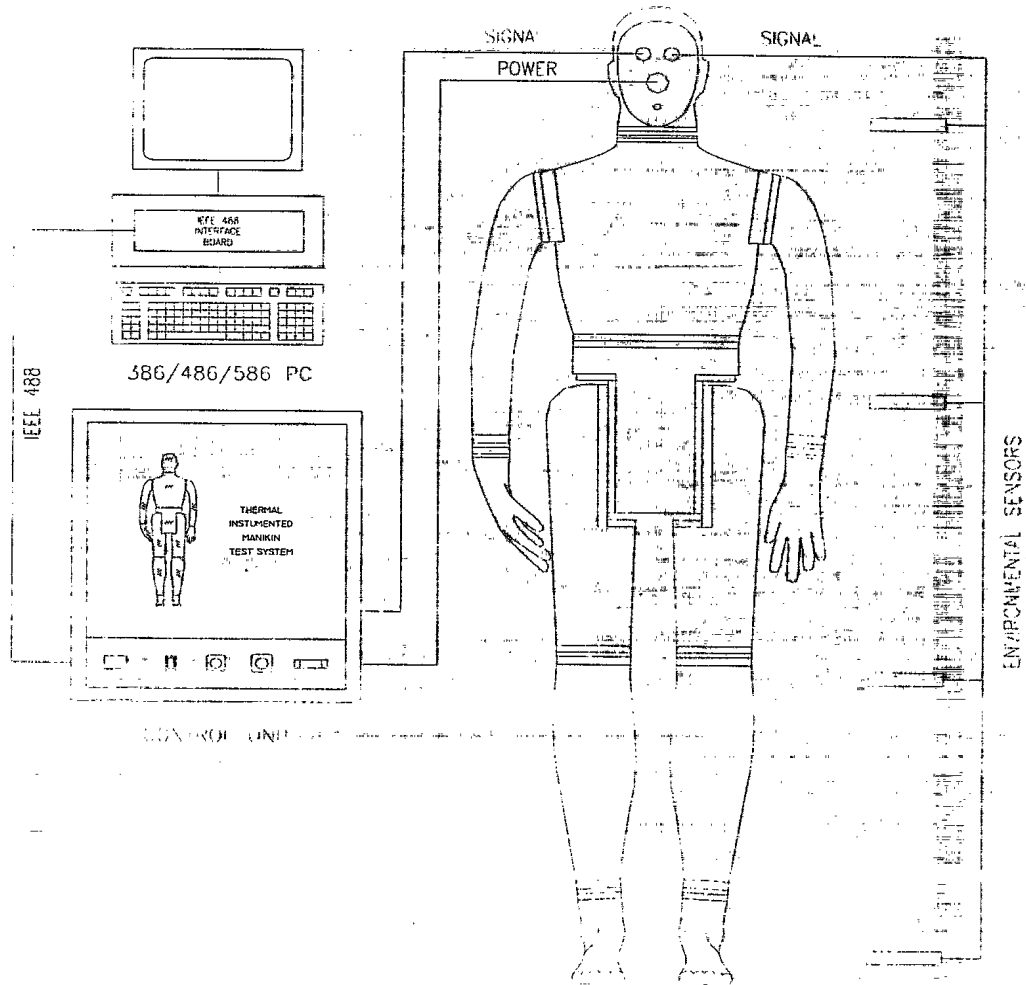


FIGURE 1

4.0 TEST EQUIPMENT

- 4.1 Control Module.
Model #: Micro-Mac 5000. Serial #: 98-9109404-001.
Last Calibration Date: March 23, 1998.
Calibration Due Date: March 23, 1999.
- 4.2 Instrumented Manikin.
Model #: TIM 1.
Last Calibration Date: March 23, 1998.
Calibration Due Date: March 23, 1999.
- 4.3 Desktop Computer.
Model #: AP 65. Serial #: 1505.
Calibration not required.

5.0 TEST CONDITIONS

5.1 For the testing performed in January 1999, testing was conducted under relatively warm environmental conditions (as outlined in DCIEM's Cold Wet Weather Glove Dryability Study (see reference 2.2).

5.1.1 Ambient Temperature: 18 ± 2 °C

5.1.2 Air Flow: 0 m/s

5.1.3 Relative Humidity: 60.0 - 70.0 ± 5 %

Despite the unintentional changes in the temperature conditions, the ambient conditions are not critical to the results rather it is the difference between the ambient and body temperature, and that the latter was maintained constant across all conditions.

6.0 TEST ITEMS

- 6.1 Thermal Instrumented Manikin dressed in soldier's clothing and personal equipment ensembles described in table 6.2.1, 6.3.1, and 6.4.1.
- 6.2 Table 6.2.1 illustrates the footwear requested.
- 6.3 Table 6.3.1 illustrates the body wear requested.
- 6.4 Table 6.4.1 illustrates the hand wear requested.

| Run # | Footwear (same for both feet) |
|-------|--|
| 1 | Light gray wool (size 11) sock plus CF Combat Boot MK III |
| 2 | Medium black liner sock plus medium dark green very long Norwegian general purpose sock plus CF Combat Boot MK III |
| 3 | Medium black liner sock plus heavy gray wool sock plus CF Combat Boot MK III |
| 4 | Medium black liner sock plus light green, light weight, Seneca general purpose sock (L10) plus CF Combat Boot MK III |
| 5 | Medium black liner sock plus light green, heavy weight, DPSC sock (H10) plus CF Combat Boot MK III |

Table 6.2.1

| Run # | Body wear |
|-------|--|
| 1 | Cotton T-shirt, cotton boxers, combat shirt & pants plus tactical assault vest (TAV) |
| 2 | Cotton T-shirt, cotton boxers, combat shirt & pants plus Frag vest – one flap on one shoulder |
| 3 | Cotton T-shirt, cotton boxers, combat shirt & pants plus Frag vest – one flap on each shoulder |
| 4 | Cotton T-shirt, cotton boxers, combat shirt & pants plus Frag vest/single flap plus TAV vest |
| 5 | Cotton T-shirt, cotton boxers, combat shirt & pants plus Frag vest/double flap plus TAV vest |

Table 6.3.1

| Run # | Hand wear | |
|-------|--|--|
| | Left | Right |
| 1 | Condition I – insulation compressed (11A) | Condition II – insulation uncompressed (5A) |
| 2 | Condition III – insulation just a little compressed (6E) | Condition I – insulation compressed (11A) |
| 3 | Condition II – insulation uncompressed (5A) | Condition III – insulation just a little compressed (6E) |
| 4 | Condition I – insulation compressed (11A) | Condition II – insulation uncompressed (5A) |
| 5 | NUDE | Condition III – insulation just a little compressed (6E) |

Table 6.4.1

7.0 TEST PROCEDURE

The soldier's clothing and personal equipment ensembles were tested using the procedures as directed in CORD Document No. R95-018 Implementation of Test Protocol of Thermal Manikin Test System, May 1995. The manikin was lifted using an overhead hoist. The manikin was positioned in the middle of the vertical storage frame and was adjusted to give a 60 KG compression on the foot wear.

Entering all pertinent information into the system's computer started a warm up period, while all sections of the manikin were warming up to the selected skin temperature. During that time, the conditions for the prescribed tests were implemented. Once all sections of the manikin reached the set point, the test automatically commenced. The test duration was four (4) hours to achieve steady state condition.

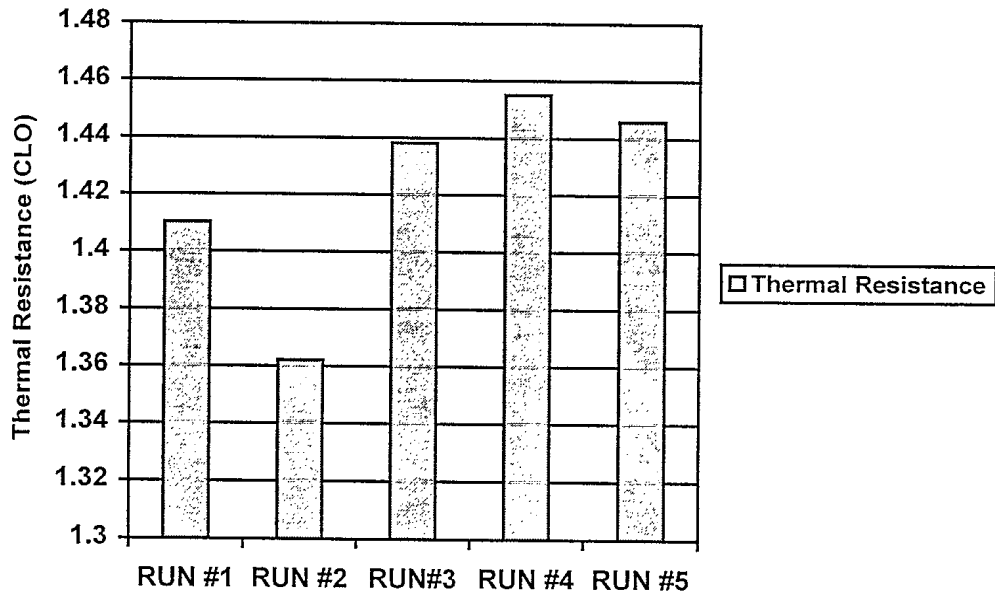
8.0 RESULTS

8.1 Table 8.1.1 illustrates final results of the footwear testing rounded to four decimal points in an air temperature of 18 - 20° C using two (2) samples of each item type.

| Run # | Description | Footwear (same for both feet) | | |
|-------|--|-------------------------------|--------|---------|
| | | Thermal Resistance Result | | |
| | | Left | Right | Average |
| 1 | Light gray sock with Combat boot MK III | 1.6121 | 1.2085 | 1.4103 |
| 2 | Blk liner sock plus Norwegian sock plus Combat boot | 1.4873 | 1.2369 | 1.3621 |
| 3 | Blk liner sock plus heavy gray sock plus Combat boot | 1.5489 | 1.3276 | 1.4383 |
| 4 | Blk liner sock plus lt green Seneca sock plus Combat boot | 1.7046 | 1.2056 | 1.4551 |
| 5 | Blk liner sock plus heavy green DPSC sock plus Combat boot | 1.5901 | 1.3018 | 1.4460 |

Table 8.1.1

8.2 Graph 8.2.1 illustrates the average thermal resistance results for the footwear.



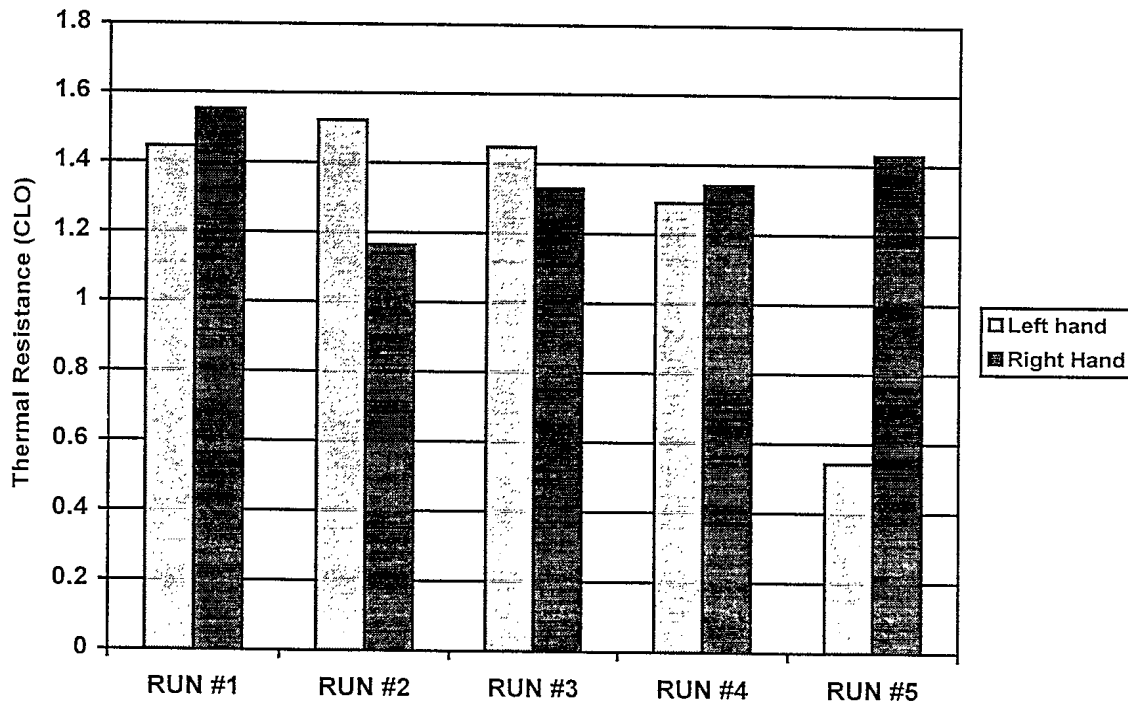
Graph 8.2.1

8.3 Table 8.3.1 illustrates final results of the hand wear testing rounded to four decimal points in an air temperature of 18 - 20° C using two (2) samples of each item type.

| Run # | Hand wear | | |
|-------|-----------|--|---------------------------|
| | Hand | Description | Thermal Resistance Result |
| 1 | L | Condition I – insulation compressed (11A) | 1.4455 |
| | R | Condition II – insulation uncompressed (5A) | 1.5520 |
| 2 | L | Condition III – insulation just a little compressed (6E) | 1.5215 |
| | R | Condition I – insulation compressed (11A) | 1.1649 |
| 3 | L | Condition II – insulation uncompressed (5A) | 1.4482 |
| | R | Condition III – insulation just a little compressed (6E) | 1.3293 |
| 4 | L | Condition I – insulation compressed (11A) | 1.2899 |
| | R | Condition II – insulation uncompressed (5A) | 1.3407 |
| 5 | L | NUDE | 0.5425 |
| | R | Condition III – insulation just a little compressed (6E) | 1.4292 |

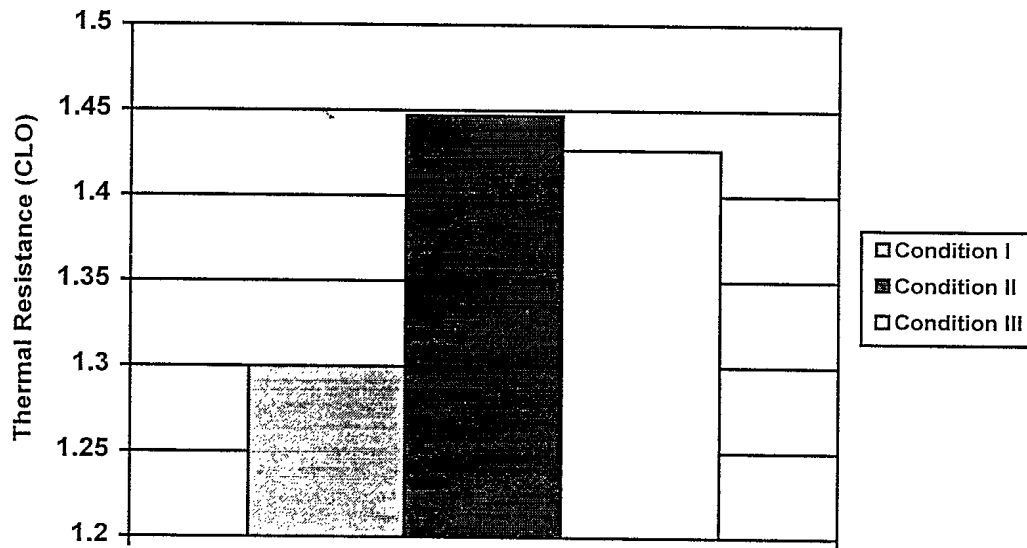
Table 8.3.1

8.4 Graph 8.4.1 illustrates the thermal resistance results for the three insulation conditions for the hand wear.



Graph 8.4.1

8.5 Graph 8.5.1 illustrates the average thermal resistance results for the three insulation conditions for the hand wear.



Graph 8.5.1

8.6 Table 8.6.1 illustrates final results of the body wear testing rounded to four decimal points in an air temperature of 18 - 20° C using one (1) sample of each item type.

| Run # | Body Wear | |
|-------|--|------------|
| | Description | Result CLO |
| 1 | T-shirt, boxers, combat shirt & pants, tactical assault vest (TAV) | 1.3907 |
| 2 | T-shirt, boxers, combat shirt & pants, Frag vest /single flap | 1.5732 |
| 3 | T-shirt, boxers, combat shirt & pants, Frag vest /double flap | 1.3630 |
| 4 | T-shirt, boxers, combat shirt & pants, Frag vest /single flap, TAV | 1.4606 |
| 5 | T-shirt, boxers, combat shirt & pants, Frag vest /double flap, TAV | 1.3496 |

Table 8.6.1

8.7 Tables 8.7.1 illustrates final results of the body wear testing showing sectional values rounded to four decimal points in an air temperature of 18 - 20^o C using one (1) sample of each item type.

| Section | Thermal Insulation Value (CLO) for Body wear | | | | |
|-----------|--|--------|--------|--------|--------|
| | Run # | | | | |
| | # 1 | # 2 | # 3 | # 4 | # 5 |
| Right Arm | 1.0994 | 1.1649 | 1.0419 | 1.0384 | 1.0897 |
| Left Arm | 1.0942 | 1.1613 | 1.0068 | 1.1648 | 1.1391 |
| Right Leg | 1.8218 | 2.2425 | 1.8664 | 1.8978 | 1.7821 |
| Left Leg | 1.5097 | 1.7207 | 1.5239 | 1.4967 | 1.5330 |
| Abdomen | 3.6373 | 3.9997 | 4.6639 | 5.1643 | 3.8250 |
| Buttocks | 1.4775 | 1.6850 | 1.7633 | 1.6766 | 1.5258 |
| Chest | 1.4683 | 1.8060 | 1.5520 | 1.9703 | 2.0087 |
| Back | 1.7228 | 4.7274 | 3.2909 | 3.8089 | 3.3246 |

Table 8.7.1

**ANNEX "A"
RAW DATA**



TEST NUMBER: 1549
 TEST TITLE: BASELINE THERMAL RESISTANCE MEASUREMENT OF SOLDIER CLOTHING AND PERSONAL EQUIPMENT.
 FILE NAME: C:\TIM I_V 1.22\M902sal.tml
 DATE OF TEST: 01-15-1999
 START TIME: 12:14:56
 DESCRIPTION OF SUIT TESTED: COMBAT SHIRT&PANTS, TACTICAL ASSAULT VEST, CF COMBAT BOOTS MK III, LH-CONDITION I (11A), RH-CONDITION II (5A).
 UNDERGARMENTS: COTTON T-SHIRT, COTTON BOXER SHORTS, LIGHT GRAY WOOL SOCKS.
 ENVIRONMENT: STILL AIR.
 POSITION: HANGING ON HOOK.
 HUMIDITY: 60
 ENV. FLOW SPEED:
 DIRECTION:
 CABLE LENGTH: Short (50ft)
 ADDITIONAL INFORMATION:

STOP TIME: 16:14:56 MINUTES SINCE START OF TEST: 240.00
 ENVIRONMENT TEMPERATURE:
 INSTANTANEOUS: 19.36 AVERAGE OVER TEST TIME: 17.97

| SECTION | SETPOINT | SKINTEMP | TEMP DIFF (Deg C) | | POWER (WATTS) | | INSULATION (CLO) | |
|------------|----------|----------|-------------------|---------|---------------|--------|------------------|--------|
| | (Deg C) | (Deg C) | INSTANT | AVERAGE | ST | LT | ST | LT |
| Head | 33.00 | 32.98 | 13.62 | 14.98 | 18.34 | 19.01 | 0.6500 | 0.6899 |
| Chest | 33.00 | 33.08 | 13.71 | 15.08 | 9.08 | 10.32 | 1.5170 | 1.4683 |
| Back | 33.00 | 33.07 | 13.70 | 15.06 | 9.50 | 9.38 | 1.5478 | 1.7228 |
| Abdomen | 33.00 | 33.02 | 13.65 | 15.06 | 1.57 | 1.47 | 3.0883 | 3.6373 |
| Buttocks | 33.00 | 33.11 | 13.74 | 15.04 | 6.02 | 5.65 | 1.2689 | 1.4775 |
| Right Arm | 33.00 | 33.10 | 13.74 | 15.02 | 10.44 | 10.01 | 0.9642 | 1.0994 |
| Left Arm | 33.00 | 33.05 | 13.69 | 15.04 | 7.31 | 9.05 | 1.2326 | 1.0942 |
| Right Hand | 33.00 | 32.97 | 13.61 | 15.02 | 2.71 | 3.07 | 1.5888 | 1.5520 |
| Left Hand | 33.00 | 33.10 | 13.73 | 15.02 | 3.14 | 3.23 | 1.3587 | 1.4455 |
| Right Leg | 33.00 | 33.01 | 13.64 | 15.02 | 16.74 | 18.95 | 1.8735 | 1.8218 |
| Left Leg | 33.00 | 32.99 | 13.62 | 15.00 | 23.19 | 21.28 | 1.2578 | 1.5097 |
| Right Foot | 33.00 | 33.06 | 13.69 | 15.06 | 5.69 | 5.51 | 1.0635 | 1.2085 |
| Left Foot | 33.00 | 33.15 | 13.79 | 15.12 | 4.13 | 4.08 | 1.4522 | 1.6121 |
| Overall | | | | | 117.85 | 121.00 | 1.2989 | 1.3907 |

Total Power (W) For All Sections: 121.005
 Total Area (Square Meters): 1.736
 Overall Insulation Resistance (CLO): 1.3907

TEST NUMBER: 1550
 TEST TITLE: BASELINE THERMAL RESISTANCE MEASUREMENT OF SOLDIER CLOTHING AND PERSONAL EQUIPMENT.
 FILE NAME: C:\TIM I_V 1.22\M902sa2.tml
 DATE OF TEST: 01-18-1999
 START TIME: 10:48:09
 DESCRIPTION OF SUIT TESTED: COMBAT SHIRT AND PANTS, FRAG VEST - ONE FLAP ON LEFT SHOULDER, CF COMBAT BOOTS MK III, LH-CONDITION III (6E), RH-CONDITION I (11A).
 UNDERGARMENTS: COTTON T-SHIRT, COTTON BOXERS, MEDIUM BLACK LINER SOCK, MEDIUM DK GREEN VERY LONG NORWEGIAN GENERAL PURPOSE SOCK.
 ENVIRONMENT: STILL AIR.
 POSITION: HANGING ON HOOK.
 HUMIDITY: 70
 ENV. FLOW SPEED:
 DIRECTION:
 CABLE LENGTH: Short (50ft)
 ADDITIONAL INFORMATION:

STOP TIME: 14:48:16 MINUTES SINCE START OF TEST: 240.10
 ENVIRONMENT TEMPERATURE:
 INSTANTANEOUS: 18.07 AVERAGE OVER TEST TIME: 18.21

| SECTION | SETPOINT | SKINTEMP | TEMP DIFF (Deg C) | | POWER (WATTS) | | INSULATION (CLO) | |
|------------|----------|----------|-------------------|---------|---------------|--------|------------------|--------|
| | (Deg C) | (Deg C) | INSTANT | AVERAGE | ST | LT | ST | LT |
| Head | 33.00 | 32.96 | 14.89 | 14.74 | 19.62 | 20.06 | 0.6644 | 0.6433 |
| Chest | 33.00 | 33.06 | 14.99 | 14.84 | 9.17 | 8.26 | 1.6415 | 1.8060 |
| Back | 33.00 | 33.05 | 14.98 | 14.84 | 2.74 | 3.37 | 5.8628 | 4.7274 |
| Abdomen | 33.00 | 33.02 | 14.95 | 14.82 | 0.97 | 1.31 | 5.4345 | 3.9997 |
| Buttocks | 33.00 | 33.04 | 14.97 | 14.82 | 3.85 | 4.89 | 2.1622 | 1.6850 |
| Right Arm | 33.00 | 33.08 | 15.01 | 14.88 | 10.12 | 9.36 | 1.0873 | 1.1649 |
| Left Arm | 33.00 | 33.19 | 15.12 | 14.94 | 5.83 | 8.47 | 1.7071 | 1.1613 |
| Right Hand | 33.00 | 33.11 | 15.04 | 14.90 | 4.25 | 3.52 | 1.1225 | 1.3394 |
| Left Hand | 33.00 | 33.10 | 15.03 | 14.90 | 3.50 | 3.05 | 1.3379 | 1.5215 |
| Right Leg | 33.00 | 33.11 | 15.05 | 14.87 | 11.07 | 15.25 | 3.1258 | 2.2425 |
| Left Leg | 33.00 | 33.06 | 14.99 | 14.84 | 18.86 | 18.47 | 1.7023 | 1.7207 |
| Right Foot | 33.00 | 33.06 | 14.99 | 14.83 | 4.36 | 5.30 | 1.5192 | 1.2369 |
| Left Foot | 33.00 | 33.04 | 14.97 | 14.81 | 3.98 | 4.33 | 1.6370 | 1.4873 |
| Overall | | | | | 98.31 | 105.62 | 1.7074 | 1.5732 |

Total Power (W) For All Sections: 105.625

Total Area (Square Meters): 1.736

Overall Insulation Resistance (CLO): 1.5732

TEST NUMBER: 1551
TEST TITLE: BASELINE THERMAL RESISTANCE MEASUREMENT OF SOLDIER CLOTHING AND PERSONAL EQUIPMENT.
FILE NAME: C:\TIM I_V 1.22\M902sa3.tml
DATE OF TEST: 01-18-1999
START TIME: 16:17:24
DESCRIPTION OF SUIT TESTED: COMBAT SHIRT AND PANTS, FRAG VEST - ONE FLAP ON EACH SHOULDER, CF COMBAT BOOTS MK III, LH-CONDITION II (5A), RH-CONDITION III (6E).
UNDERGARMENTS: COTTON T-SHIRT, COTTON BOXERS, MEDIUM BLACK LINER SOCK, HEAVY GRAY SOCK.
ENVIRONMENT: STILL AIR.
POSITION: HANGING ON HOOK.
HUMIDITY: 70
ENV. FLOW SPEED:
DIRECTION:
CABLE LENGTH: Short (50ft)
ADDITIONAL INFORMATION:

STOP TIME: 20:17:25 MINUTES SINCE START OF TEST: 240.00
ENVIRONMENT TEMPERATURE:
INSTANTANEOUS: 18.87 AVERAGE OVER TEST TIME: 19.11

| SECTION | SETPOINT | SKINTEMP | TEMP DIFF (Deg C) | | POWER (WATTS) | | INSULATION (CLO) | |
|------------|----------|----------|-------------------|---------|---------------|--------|------------------|--------|
| | (Deg C) | (Deg C) | INSTANT | AVERAGE | ST | LT | ST | LT |
| Head | 33.00 | 32.94 | 14.07 | 13.82 | 26.00 | 24.75 | 0.4740 | 0.4889 |
| Chest | 33.00 | 33.06 | 14.19 | 13.94 | 8.59 | 9.03 | 1.6602 | 1.5520 |
| Back | 33.00 | 33.07 | 14.20 | 13.95 | 4.23 | 4.55 | 3.6033 | 3.2909 |
| Abdomen | 33.00 | 33.03 | 14.16 | 13.92 | 1.42 | 1.06 | 3.5438 | 4.6639 |
| Buttocks | 33.00 | 33.03 | 14.16 | 13.92 | 4.84 | 4.39 | 1.6240 | 1.7633 |
| Right Arm | 33.00 | 33.09 | 14.22 | 13.97 | 9.40 | 9.83 | 1.1084 | 1.0419 |
| Left Arm | 33.00 | 33.12 | 14.25 | 14.03 | 10.59 | 9.17 | 0.8858 | 1.0068 |
| Right Hand | 33.00 | 33.12 | 14.26 | 14.01 | 3.15 | 3.34 | 1.4358 | 1.3293 |
| Left Hand | 33.00 | 33.11 | 14.24 | 14.00 | 3.65 | 3.01 | 1.2126 | 1.4482 |
| Right Leg | 33.00 | 33.12 | 14.25 | 14.01 | 22.46 | 17.25 | 1.4585 | 1.8664 |
| Left Leg | 33.00 | 33.06 | 14.19 | 13.95 | 19.18 | 19.60 | 1.5848 | 1.5239 |
| Right Foot | 33.00 | 33.07 | 14.20 | 13.95 | 4.85 | 4.64 | 1.2941 | 1.3276 |
| Left Foot | 33.00 | 33.02 | 14.15 | 13.92 | 5.09 | 3.91 | 1.2088 | 1.5489 |
| Overall | | | | | 123.43 | 114.52 | 1.2869 | 1.3630 |

Total Power (W) For All Sections: 114.519

Total Area (Square Meters): 1.736

Overall Insulation Resistance (CLO): 1.3630

TEST NUMBER: 1552
TEST TITLE: BASELINE THERMAL RESISTANCE MEASUREMENT OF SOLDIER CLOTHING AND PERSONAL EQUIPMENT.
FILE NAME: C:\TIM I_V 1.22\M902sa4.tml
DATE OF TEST: 01-19-1999
START TIME: 11:24:16
DESCRIPTION OF SUIT TESTED: COMBAT SHIRT AND PANTS, FRAG VEST - ONE FLAP ON LEFT SHOULDER, TACTICAL ASSAULT VEST, CF COMBAT BOOTS MK III, LH-CONDITION I(11A), RH-CONDITION II(5A).
UNDERGARMENTS: COTTON T-SHIRT, COTTON BOXERS, MEDIUM BLACK LINER SOCK, LT GREEN LT WEIGHT SENECA GENERAL PURPOSE SOCK(L10).
ENVIRONMENT: STILL AIR.
POSITION: HANGING ON HOOK.
HUMIDITY: 70
ENV. FLOW SPEED:
DIRECTION:
CABLE LENGTH: Short (50ft)
ADDITIONAL INFORMATION:

STOP TIME: 15:24:23 MINUTES SINCE START OF TEST: 240.10
ENVIRONMENT TEMPERATURE:
INSTANTANEOUS: 21.22 AVERAGE OVER TEST TIME: 20.92

| SECTION | SETPOINT | SKINTEMP | TEMP DIFF(Deg C) | | POWER (WATTS) | | INSULATION (CLO) | |
|------------|----------|----------|------------------|---------|---------------|-------|------------------|--------|
| | (Deg C) | (Deg C) | INSTANT | AVERAGE | ST | LT | ST | LT |
| Head | 33.00 | 32.96 | 11.74 | 12.04 | 18.59 | 17.62 | 0.5528 | 0.5982 |
| Chest | 33.00 | 33.03 | 11.81 | 12.10 | 5.50 | 6.17 | 2.1574 | 1.9703 |
| Back | 33.00 | 33.05 | 11.83 | 12.11 | 2.92 | 3.41 | 4.3475 | 3.8089 |
| Abdomen | 33.00 | 33.03 | 11.81 | 12.10 | 0.14 | 0.83 | 20.0000 | 5.1643 |
| Buttocks | 33.00 | 33.01 | 11.79 | 12.09 | 4.15 | 4.00 | 1.5774 | 1.6766 |
| Right Arm | 33.00 | 33.02 | 11.80 | 12.10 | 9.05 | 8.54 | 0.9560 | 1.0384 |
| Left Arm | 33.00 | 33.10 | 11.88 | 12.15 | 4.71 | 6.86 | 1.6614 | 1.1648 |
| Right Hand | 33.00 | 33.02 | 11.80 | 12.09 | 2.95 | 2.86 | 1.2657 | 1.3407 |
| Left Hand | 33.00 | 33.01 | 11.80 | 12.08 | 3.24 | 2.91 | 1.1333 | 1.2899 |
| Right Leg | 33.00 | 33.13 | 11.91 | 12.17 | 12.36 | 14.74 | 2.2154 | 1.8978 |
| Left Leg | 33.00 | 33.04 | 11.83 | 12.11 | 18.72 | 17.33 | 1.3529 | 1.4967 |
| Right Foot | 33.00 | 32.99 | 11.77 | 12.06 | 4.41 | 4.42 | 1.1805 | 1.2056 |
| Left Foot | 33.00 | 33.00 | 11.78 | 12.08 | 3.05 | 3.08 | 1.6802 | 1.7046 |
| Overall | | | | | 89.78 | 92.79 | 1.4732 | 1.4606 |

Total Power (W) For All Sections: 92.786
Total Area (Square Meters): 1.736
Overall Insulation Resistance (CLO): 1.4606

CORD

TEST NUMBER: 1554

TEST TITLE: BASELINE THERMAL RESISTANCE MEASUREMENT OF SOLDIER CLOTHING AND PERSONAL EQUIPMENT.

FILE NAME: C:\TIM I_V 1.22\M902sa6.tml

DATE OF TEST: 01-25-1999

START TIME: 13:00:47

DESCRIPTION OF SUIT TESTED: COMBAT SHIRT AND PANTS, FRAG VEST - ONE FLAP ON EACH SHOULDER, TACTICAL ASSAULT VEST, CF COMBAT BOOTS MK III, LH-NUDE, RH-CONDITION III (6E).

UNDERGARMENTS: COTTON T-SHIRT, COTTON BOXERS, MEDIUM BLACK LINER SOCK, LT GREEN HEAVY WEIGHT DPSC SOCK (H10).

ENVIRONMENT: STILL AIR.

POSITION: HANGING ON HOOK.

HUMIDITY: 70

ENV. FLOW SPEED:

DIRECTION:

CABLE LENGTH: Short (50ft)

ADDITIONAL INFORMATION:

STOP TIME: 17:00:53

MINUTES SINCE START OF TEST: 240.10

ENVIRONMENT TEMPERATURE:

INSTANTANEOUS: 18.28

AVERAGE OVER TEST TIME: 18.92

| SECTION | SETPOINT | SKINTEMP | TEMP DIFF (Deg C) | | POWER (WATTS) | | INSULATION (CLO) | |
|------------|----------|----------|-------------------|---------|---------------|--------|------------------|--------|
| | (Deg C) | (Deg C) | INSTANT | AVERAGE | ST | LT | ST | LT |
| Head | 33.00 | 32.92 | 14.64 | 14.01 | 24.60 | 23.44 | 0.5209 | 0.5232 |
| Chest | 33.00 | 33.00 | 14.72 | 14.08 | 7.16 | 7.04 | 2.0640 | 2.0087 |
| Back | 33.00 | 33.08 | 14.80 | 14.15 | 4.38 | 4.56 | 3.6220 | 3.3246 |
| Abdomen | 33.00 | 33.03 | 14.75 | 14.11 | 0.79 | 1.31 | 6.6221 | 3.8250 |
| Buttocks | 33.00 | 33.03 | 14.74 | 14.11 | 4.70 | 5.14 | 1.7414 | 1.5258 |
| Right Arm | 33.00 | 32.99 | 14.70 | 14.07 | 8.87 | 9.46 | 1.2154 | 1.0897 |
| Left Arm | 33.00 | 33.02 | 14.74 | 14.11 | 8.64 | 8.15 | 1.1223 | 1.1391 |
| Right Hand | 33.00 | 33.12 | 14.84 | 14.20 | 3.69 | 3.15 | 1.2731 | 1.4292 |
| Left Hand | 33.00 | 33.03 | 14.75 | 14.12 | 8.40 | 8.10 | 0.5460 | 0.5425 |
| Right Leg | 33.00 | 33.00 | 14.71 | 14.09 | 19.84 | 18.18 | 1.7054 | 1.7821 |
| Left Leg | 33.00 | 33.00 | 14.72 | 14.08 | 19.57 | 19.67 | 1.6110 | 1.5330 |
| Right Foot | 33.00 | 33.06 | 14.78 | 14.15 | 5.00 | 4.80 | 1.3060 | 1.3018 |
| Left Foot | 33.00 | 33.01 | 14.73 | 14.09 | 3.63 | 3.85 | 1.7662 | 1.5901 |
| Overall | | | | | 119.27 | 116.84 | 1.3815 | 1.3496 |

Total Power (W) For All Sections: 116.840

Total Area (Square Meters): 1.736

Overall Insulation Resistance (CLO): 1.3496

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

| DOCUMENT CONTROL DATA | | |
|--|--|---|
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| <p>3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title)</p> <p style="text-align: center;">Baseline thermal resistance measurement of soldier clothing and personal equipment.</p> | | |
| <p>4. AUTHORS (Last name, first name, middle initial)</p> <p style="text-align: center;">W. Durnford, and P. Potter</p> | | |
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There is a large program within the Canadian Forces, the Clothe the Soldier acquisition program, that aims to equip soldiers with improved protective clothing and equipment that will enhance both their protection and capability in a wide range of environmental and operational scenarios. Many items in-service clothing and equipment will be replaced with items that reflect the state-of-the art in commercially available technology.

Since many replacement items aim to improve environmental protection of the soldier, it is necessary to determine the thermal protection characteristics of both the in-service items intended to be replaced as well as a range of representative options that reflect what is available, off-the-shelf, using current technology.

The CORD Group Limited was contracted by the Defence and Civil Institute of Environmental Medicine to determine the thermal resistance of clothing, footwear, and hand wear. The thermal resistance of these items was determined utilizing a thermal instrumented manikin test system.

This report describes the thermal manikin test system, the protocols and the results for each item tested. A total of 5 tests were conducted, with each test measuring the thermal resistance of a number of items. All of the items were tested in a dry condition only.

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- Thermal resistance
- Sock system
- Cold wet weather glove
- Fragmentation vest
- Tactical assault vest

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