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Published in:
[Publication information missing]

2012

[Link to publication](#)

Citation for published version (APA):
Kuklane, K. (2012). Evaporative resistance of sleeping bags - measurements on a thermal manikin Tore. [Publication information missing], 85-85. <http://www.es-pc.org/>

Total number of authors:
1

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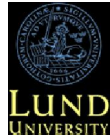
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Evaporative resistance of sleeping bags - measurements on a thermal manikin Tore

Kalev Kuklane

Introduction

- EN 13537 Requirements for sleeping bags
- ASTM-F1720-06 Standard method for measuring the thermal insulation of a sleeping bag using a heated manikin
- ASTM-F2370-05 Standard method for measuring the evaporative resistance of clothing using a sweating thermal manikin
- Moisture accumulation in sleeping bags may be a problem
- **Various “sweating” methods available**



Aims and objectives

- Evaluate evaporative resistance of the selected new reference bags for EN 13537
- Compare mass and heat loss methods in isothermal and non-isothermal conditions with wet underwear instead of textile skin
- Validate skin temperature correction for highly insulating products

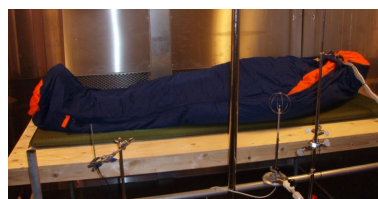
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Methods: materials



UW (standard underwear)



F (Eclipse 100, Bertoni: dawn, mummy shape)



B (Kiowa Comfort 220, VAUDE: synthetic, rectangular)



E (Denali 5 Seasons, Mammuth Ajungilak: synthetic, mummy shape)

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Methods: instrumentation

- **Thermal manikin Tore**
- **Wet underwear** (water content 810 ± 15 g)
- **Humidity and temperature sensors** (EK-H3 equipped with SHT75 sensors, Sensirion AG, Switzerland) **on manikin surface** (12 points) and in air (3 points)
- Weighing scale (Mettler K240 connected to GWB Mettler ID2 MultiRange, Albstadt, Germany, resolution ± 2 g) for continuous mass loss recording
- Air temperature (PT 100 connected to PT-104, Pico Technology Ltd., UK, accuracy ± 0.03 °C)

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Methods: test conditions

- Combined and modified EN 13537 and ASTM-F2370-05
- Manikin surface temperature was set to $T_s = 34$ °C
- Non-isothermal $T_a = 12.0 \pm 0.1$ °C, RH = 77 ± 4 %, $p_a = 1083 \pm 47$ Pa
- Isothermal $T_a = 34.1 \pm 0.1$ °C, RH = 26 ± 3 %, $p_a = 1400 \pm 157$ Pa
- Air velocity 0.29 ± 0.08 m/s

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Methods: calculations

- The dry and wet (apparent) insulation values were calculated according to the **parallel** calculation method of ISO 15831, and were not adjusted to match the values of the reference manikin
- The saturation at evaporation point was **not** assumed to be 100 percent. Water vapour pressure gradient between manikin surface under wet underwear and air was used to calculate evaporative resistance from mass loss and from manikin heat loss
- The calculations followed ASTM-F2370-05. The manikin heat loss was corrected for the dry heat gain (isothermal) or loss (non-isothermal)

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Methods: calculations

- The skin temperature correction equations by Wang et al. (Wang et al. 2010) and Ueno and Sawada (Ueno and Sawada 2011) were validated

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Results

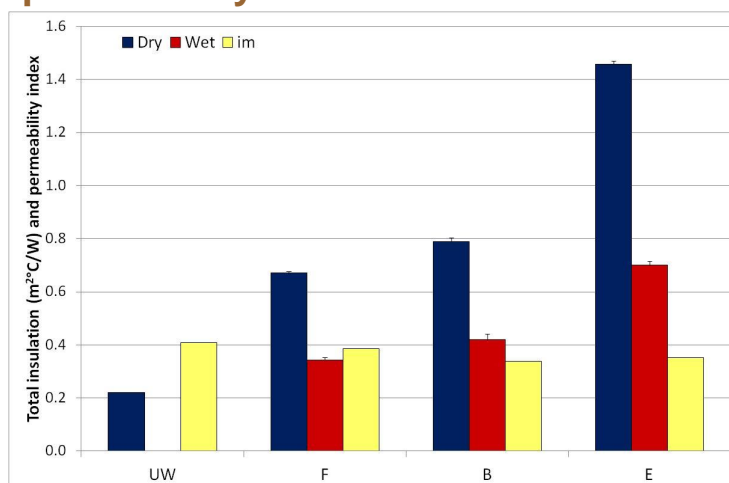
- Minimal difference between skin temperature corrections of Wang et al. (2010) and Ueno and Sawada (2011): 0.5 %
- There was a higher difference with measured interface temperature: 3 %
- For highly insulating products and/or low heat loss conditions ($<50 \text{ W/m}^2$) a new correction was suggested:

$$T_{\text{skin}} = 34 - 0.0395 \times \text{HL}$$

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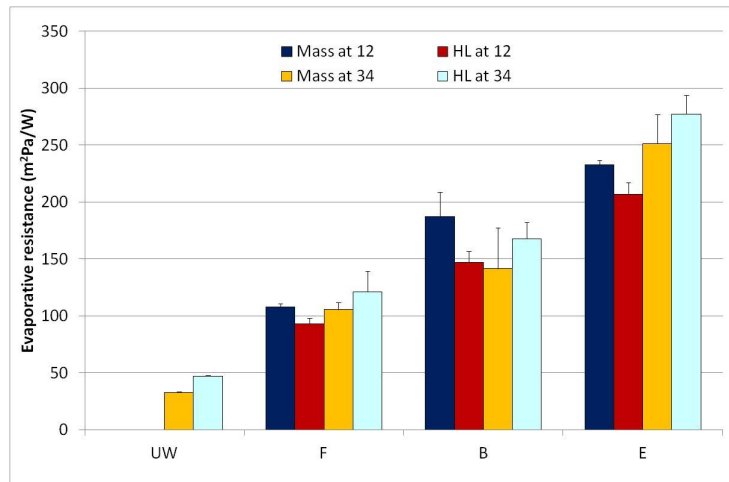
Dry and wet (apparent) insulation and permeability index



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Evaporative resistance from mass and heat loss at 2 environmental conditions



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Conclusions

- Tight fitting underwear that is a part of the system can be utilized as a wet layer next to manikin surface. It will be possible subtract it for clothing intrinsic evaporative resistance (R_{ecl}) estimation
- The suggested skin temperature corrections (Ueno and Sawada 2011; Wang et al. 2010) seem not to be valid at the low range of the heat loss. A separate empirical equation for lower range of heat loss was suggested in this paper: $T_{skin} = 34 - 0.0395 \times HL$
- The test methods and procedures should be standardised depending on the application of data
- Should a higher air velocity be used in order to match material testing?

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Thank you!



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