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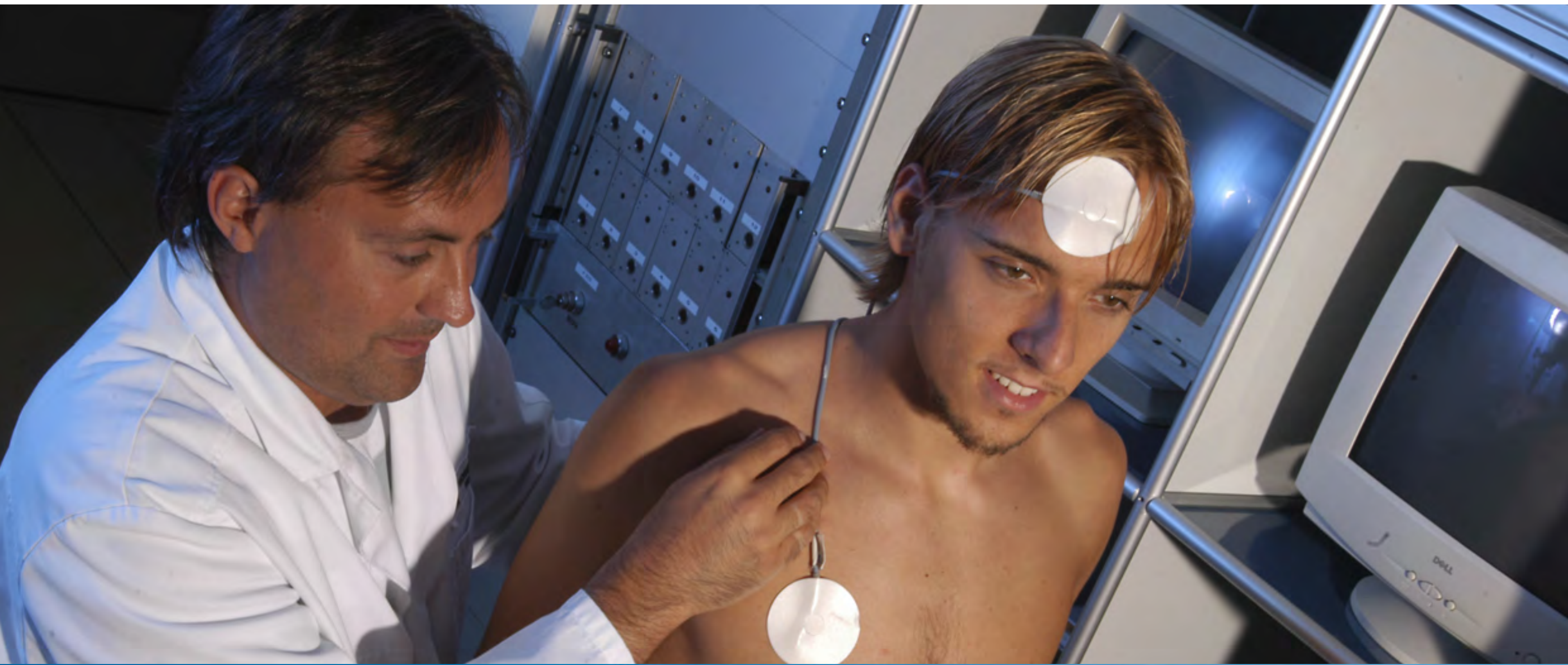

HOW TO IMPROVE COMFORT AND RANGE OF UTILITY OF COMBAT UNIFORMS FOR COLD ENVIRONMENTS

J. Beringer, A. Schmidt · Hohenstein Institute, Boennigheim, Germany

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INTRODUCTION

The overall comfort of combat uniforms for cold environments is not only due to the thermal insulation characteristics of the garments but also influenced strongly by the water vapour resistance ("breathability"). Both insulation and breathability is of great importance for the soldier and it is hard to say if one is more important than the other. Breathability affects the amount of humidity in the microclimate of the garment and thus the perceived wear comfort which is very closely related to the mental and physical performance of the soldier (Figure 1).

Figure 1: Combat uniforms must perform several functions in the most rugged of wearing conditions.

We now understand that low water vapour resistance (i.e. good breathability) extends the range of utility of combat gear to warmer temperatures. This is essential if the clothing system is to have high utility and robust use under cold and warmer conditions and is even more important during period of high physical activity.

Especially for cold protective clothing a low water vapour resistance is of high importance because it leads to reduced sweat accumulation in the clothing system. This is not only the case for "normal" temperatures of 20°C / 68°F but also at freezing point and far below at -20°C / -4°F.

In the following the authors show how to improve cold protective gear producing enhanced human thermoregulation in cold environments as well as thermal and moisture management characterisation methods for fabrics and full clothing systems.

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CHALLENGES AND SOLUTIONS

The human body generates heat energy at a steady state "metabolic rate". It varies from 80 Watts while sleeping up to 800 Watts in very high physical activity. To maintain the body core temperature constant at about 37°C / 98.6°F within a limit of only ±2°C / 3.6°F at varying metabolic rates, the human body has its own thermoregulatory mechanism. Excess energy has to be dissipated by sweat evaporation and an energy loss in cold environments has to be compensated by cold shivering (Figure 2). Both excessive sweating and shivering result in losses in human performance efficiency, so it is much desired to control these consequences through better protective clothing with appropriate thermal insulation. The challenge for clothing designers is to achieve an even energy balance in the clothing system though understanding and balancing breathability and insulation.

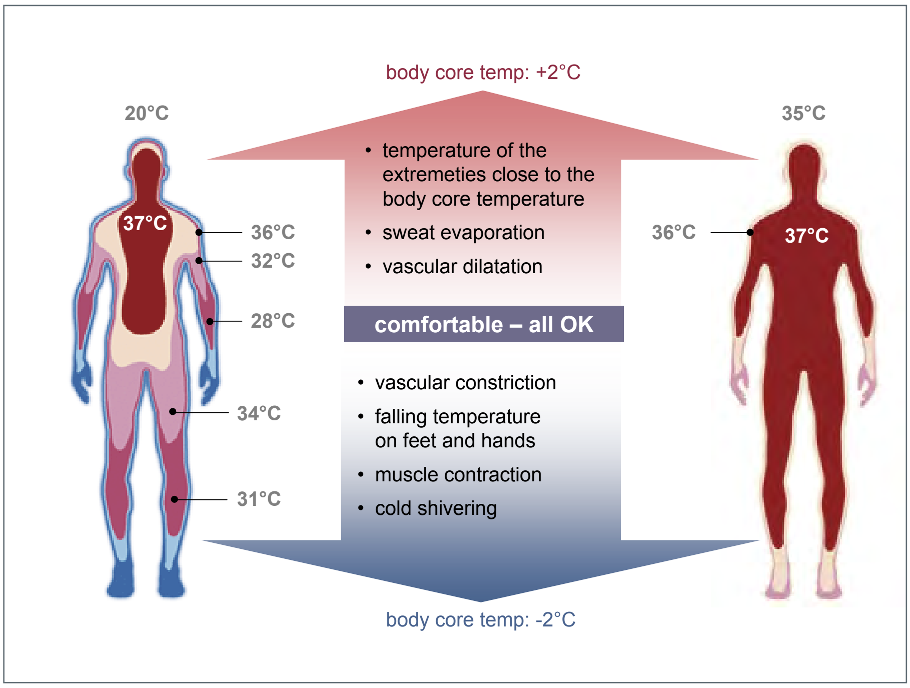

Figure 2: Thermoregulation mechanism of the human body

The thermal insulation of combat uniform in cold environments depends on the ambient temperature and the metabolic rate of the soldier. A good example for this is the European standard EN 342, which measures thermal insulation for cold protective clothing. In this standard, the thermal

Insulation I_{cler} $m^2 \cdot K/W$	Wearer moving activity			
	light 115 W/m^2		medium 170 W/m^2	
	8 h	1 h	8 h	1 h
0.310	-1	-15	-19	-32
0.390	-8	-25	-28	-45
0.470	-15	-35	-38	-58
0.540	-22	-44	-49	-70
0.620	-29	-54	-60	-83

Figure 3: Resultant effective thermal insulation of clothing Icler and ambient temperature (°C) conditions for heat balance at different activity levels and duration of exposure (acc. to EN 342)

insulation of the garment is measured for a maximum wearing time at a certain metabolic rate under known ambient temperature (Figure 3). This information produces the criteria required for optimal performance. Thermal insulation (i.e. thermal resistance) may also be determined on a guarded sweating hotplate, i.e. the Hohenstein skin model (Figure 4) acc. to EN 31092 / ISO 11092. This can be used for fabric measurement and design. When testing whole garments and/or whole clothing systems, thermal manikins acc. to ISO/DIS 15831 are used (Figure 5). Therefore there are good existing systems to aid in the design of cold weather gear that can begin with fabric performance through the entire garment design process.

Figure 4: Hohenstein Skin Model (according to EN 31092 / ISO 11092) in sweating mode

Thermal insulation itself mainly depends on the enclosed air volume in the garment, as air has a very low thermal conductivity and is a good insulator. However, when a garment gets saturate and wet the insulating air is replaced by humidity first as water vapour and then as water, which in contrast is a very good conductor of heat and a much poorer insulator. Therefore, body heat is lost rapidly under wet conditions.

To keep a garment dry from inside while sweat is evaporated by the wearer due to increased physical activity, a low water vapour resistance is essential. To evaluate a fabric in regard of the water vapour resistance also the skin model acc. to EN 31092 / ISO 11092 is used. The lower the water vapour resistance the higher is the breathability.

As a final test sequence, evaluating all performance aspects of a combat uniform for cold environment, are subject wearing trials in a climatic chamber under realistic temperatures and physical activity / metabolic rates (Figure 6).

The subject is equipped with numerous temperature and humidity sensors on the skin and judges his subjective thermal and moisture sensation as well as the resulting overall comfort in distinct time periods and varying conditions.

The subjective perceptions of the wearer and the measured temperature and moisture data are compared and subsequently correlated with the data from the skin model and thermal manikin. This fully validates the wearing trial.

Figure 5: Hohenstein Thermal Manikin "Charlie" (according to ISO 15831)

CONCLUSIONS

Combat uniforms for cold environments can be designed for specific climatic conditions and physical activity using existing test procedures and standards. Not only the thermal insulation but also the water vapour resistance of the whole garment is of importance.

A low water vapour resistance ensures sweat evaporation and results in a dry insulation layer and thus less heat loss. The hereby improved overall comfort ensures the mental and physical performance of the soldier under cold environments.

Figure 6: Wearing trials in climatic chamber

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THE HOHENSTEIN INSTITUTE - COMPANY PROFILE

As one of the world's leading independent and accredited textile research and testing laboratories, the Hohenstein Institute (Figure 7) offers a comprehensive range of testing, application-based research and development, consultancy and inspection for high technology and functional military textile articles and many other associated areas.
A team of 345 highly qualified and committed employees in Germany and 160 employees in 34 branch offices worldwide work in the best-equipped, state-of-the-art laboratories to provide our clients with reliable results and solutions. Test designs, for example, can be fully customized to explore the most diverse and specific challenges. Finding answers to such challenges are our speciality.

Figure 7: Headquarters of the Hohenstein Institute at Boennigheim - Germany

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BIOGRAPHY

Dr. Jan Beringer

8 October 1972	Born in Ostfildern near Stuttgart, Germany Family status: married, 2 children
1994 – 1999	Chemistry studies at the University of Stuttgart, Germany
1999	Diploma work at the Institute of Textile and Fiber Chemistry at University of Stuttgart in the research group of Prof. Dr. K. Bredereck
2000 - 2004	Doctoral thesis at the Institute of Textile- and Fiber Chemistry at University of Stuttgart in the research group of Prof. Dr. K. Bredereck
July 2033	Entering the Hohenstein Institute as Head of the Competence Center Innovative Textiles
December 2004	Doctoral examination and publication of the doctoral thesis “Pulp from wheat straw..” (ISBN No. 3832507973)
2006 - 2009	Director of the Department Textile Services and Innovations
Since October 2009	Scientific Head of the Department Function and Care
Fields of work	Textile and fiber chemistry, nanotechnology, clothing physiology, personal protective textiles, industrial laundry, clothing technology and 3D body scanning.

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BIOGRAPHY

Dr. rer. nat. Andreas Schmidt

29.06.1974	Born in Monheim/Rhein Family status: married, 2 children
1993 – 1999	Studying chemistry at the Heinrich-Heine-University, Düsseldorf Degree: Chemist Main focus: Organic Chemistry
1999 – 2002	Research associate at the German Textile Research Center North-West e.V., associated institute to the Gerhard-Mercator-
University	
	Duisburg
23.10.2002	Conferral of a doctorate Title of PhD thesis: Basic research of material separation and dyeing of fiber forming polymers in condensed carbon dioxide
2002 – Sept. 2009	Henkel AG & Co. KGaA, Düsseldorf Head of laboratory „Textile Fibers" Since April 2008: Product development, Area: Area: Coil Coating, Organic Coatings Since Oktober 2008: Head of product development, Area: Metal pretreatment and light metals (Automotive)
	Project Experience:
2004 – 2007:	Leading of an interdisciplinary project-team Topic: Perfumes in fast moving consumer goods (detergents, cosmetics)
2006 – 2008:	Implementation of working field "Technical Textiles"
since October 2009	Director of the Department Function and Care · Hohenstein Institute

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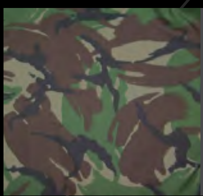
When clothing systems are a matter of vital importance:

>> We offer support from the fibre to the field of operation

TESTING & CERTIFICATION | RESEARCH & DEVELOPMENT | CONSULTING

Hygiene & Biotechnology
- Antimicrobial effects
- Harmful substances
- Protection against insects

Wear Comfort: Important in extreme climates
- Heat and moisture management of clothing
- Skin sensorial properties/perception of textiles on the skin



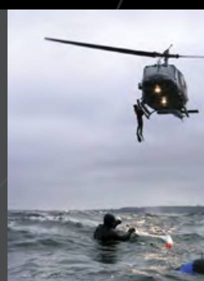
Textile Resistance
- Colorimetry
- Tensile strength
- Abrasion resistance
- Colour fastness

Protective Function
- Heat/flame protection
- Chemical protection
- Hi-Vis warning clothing
- Cut-proof clothing
- UV protection

Acoustic Testing
- Clothing systems
- Gloves
- Shoes

Reprocessing of Textiles
- Assessment of industrial washing procedures
- Transponder technology

Fit & Design
- Tests on fit & workmanship
- Ergonomic optimisation with portable 3D scanner
- Elaboration & examination of Technical Specifications



Immersion Suits/ Sleeping Bags
- Length of survival in immersion suits
- Thermal range of utility of sleeping bags

Thermal Insulation & Breathability
- Footwear
- Socks

Photos by courtesy of Bundeswehr/Zäch/Bienert, U.S. Army, Shutterstock, Wikipedia, Hohenstein Institute

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