PROTECTION AGAINST FOUL WEATHER BENEFITS AND DRAWBACKS OF PROTECTIVE MEASURES

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INTRODUCTION

Wet clothing causes discomfort, a sensation of cold, and local and overall cooling of the skin. Wetness drastically reduces the thermal insulation of the clothing, changing the climatic utility range of the clothing. The additional weight of the moisture increases physical load. Thus, there are many reasons for keeping the clothing layers and the skin dry.

The European pre-standard for foul weather clothing, ENV **343,** determines the protective and functional requirements for foul weather clothing ensembles (1). The classification of the most important functional objectives of the foul weather clothing is shown in Tables 1 and 2.

Table 1. ENV 343. Foul weather clothing. Classification of resistance to water penetration according to EN 20811.

Water penetration refstance wp (Pa)	Class 1	2	3
Before pretreatment	≥ 8000	no test req.	no test req.
Before pretreatment, seams	≥ 8000	≥ 8000	≥ 13 000
After each pretreatment	No test req	≥ 8000	≥ 13 000

Table 2. ENV 343. Foul weather clothing. Classification of water vapor resistance according to EN 31092.

Water vapor resistance R_{et} ($Pa \cdot m^2 \cdot W^{-1}$)	Class; 1	2	3
	> 150	$20 < R_{et} \leq 150$	≤ 20

In this study, water-repellent finished and waterproof, but water vapor permeable, materials were evaluated from the clothing physiological point of view.

MATERIALS AND METHODS

Materials

The evaluated fabrics are specified in Table 3. For testing the thermal insulation of the wet clothing, a loose liner was made of a waterproof, water vapor

Table 3. The fabrics: square mass, water penetration resistance (ISO 811) and moisture vapor transmission rate (ASTM E%-95) as declared by the manufacturers.

Fabric	Description	Square mass ($g \cdot m^{-2}$)	Water pen. resistance (mm H_2O)	MVTR ($g \cdot m^{-2} \cdot 24\ h^{-1}$)
PV1	65 %CO/ 35%PES, 10 washes	300		
PV2	65 %CO/ 35% PES, 10 washes, water-repellency finish in last wash	300		
AG	Hydrophilic membrane / PES-weave	115	4000	5000
GF	Microporous membrane/ PA-knit on both sides	103	45000	9500'
HU	Microporous membrane / PES-knit	77	1300	10.11[2] $Pa \cdot m^2 \cdot W^{-1}$
SL	Microporous membrane / PA-knit	60	1900	720
FL	Hydrophilic PU-coating /PA-weave	85	> 2000	9000

[1] Reversed cup method, [2] Sweating guarded hot-plate method (EN 31092)

permeable fabric. The liner (GF) was worn under an outergarmentmade of cotton/ polyester (CO/PES) fabric. When testing a multilayer fabric or clothing ensemble, a cotton/polyester/polychlal (CO/PES/polychlal) knit and a polyamid/polyester (PA/PES) pile layer were added.

Methods

Testing, the protective and functional properties of the fabrics

- **EN 31092.** Water vapor resistance under steady-state conditions (sweating guarded hot-plate test)
- **SFS 568.1.** Thermal insulation, water vapor resistance and the combined effect of heat and moisture. Skin-model method.
- **ISO 811.** Resistance to water penetration. Hydrostatic pressure test.

Testing the thermal insulation of wetted clothing: The clothed test subject was exposed for 2 min to 2 rain showers from a height of 2 m diagonally from each side of the subject (a total of 25 $l \cdot min^{-1}$). The subject then performed light work **(110 $W \cdot m^{-2}$,** no sweating) by stepping for 1 h, ambient conditions: *dry* bulb = ±1°C, wind speed = 1 $m \cdot s^{-1}$, relative humidity = 50 % RH. The thermal insulation of the clothing was determined by the mean skin temperature/mean heat flux method (7 points) **(2).** The clothed subject was weighed before and after the test.

RESULTS

Material tests

All of the materials of the loose liner passed the water penetration test criteria for category 3 for foul weather clothing. The amount of moisture evaporating from the multilayer fabric sample decreased considerably in cold, and the sweating simulation test (T_a = ±1°C) showed no significant difference between the materials, except for material SL with the lowest MVTR (Table 4).

Table 4. The total thermal resistance R_{ctot} and moisture distribution in fabrics. Sweating simulation test (SFS 5681). Ambient conditions: +1°C, 1 m·s⁻¹.

	PV1	PV2	WP	AG	FL	GF	SL	HT
R_{ctot} ($m^2 K \cdot W^{-1}$)	0.12	0.11	0.13	0.11	0.12	0.11	0.11	0.12
Moisture distribution (%)								
Skin, underlayer & thermal layer (%)	21	22	24	20	22	21	26	20
Loose liner & outer layer (%)	10	11	13	16	14	19	21	16
Through the sample (%)	69	67	63	64	64	60	53	64

Rain shower test with test subiects

The amount of water absorbed by the clothing with various outer garments in the rain shower test and its effect on thermal insulation is shown in Figure 1.

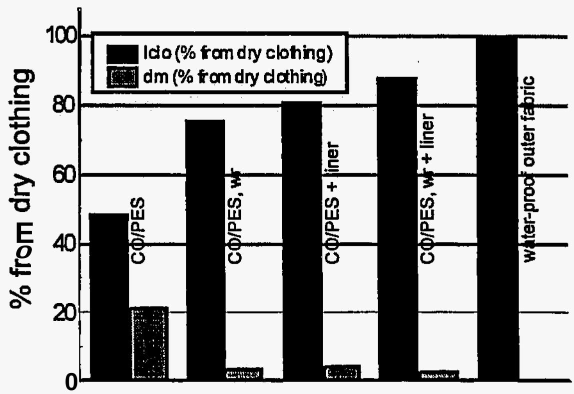

Figure 1. Rain showertest–the mass change of the clothing and the thermal insulation of the wetted clothing (% from dry clothing).

DISCUSSION & CONCLUSIONS

With wetting, the clothing ensemble without any water-repellency lost more than 50% of its thermal insulation. The other ensembles lost insulation corresponding to their water-repellancy. Wet clothing does not provide required thermal insulation determined by the IREQ index (3). Various forms of foul weather protection were beneficial: The water-repellent finishing of the outer COPES garment decreased the water uptake of the clothing by 84%, and the use of a loose liner underneath it decreased it by an additional 4%. A waterproof membrane of the outermost fabric decreased the water uptake by as much as 97%. In cool conditions, the water vapor permeability of the materials decreased. For this reason, in the heaviest work phases, clothing with a waterproof membrane should only be worn when protection is needed against heavy rain or wind. A water-repellent finish of the outer garment provides sufficient protection against light rain.

REFERENCES

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