EFFECTS OF WIND AND WALKING ON LOCAL CLOTHING INSULATION

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INTRODUCTION

The European Pre-Standard for protective clothing against cold ENV 342:1998 (1) suggests that the testing of thermal insulation should be made on a moving thermal manikin. In this way, the value can be used to match requirements specified by the REQ-method (2) or as realistic input for prediction of thermal stress in other standards. It is known fiom prior work (3,4,5) that insulation values measured with human subjects can be reduced by up to 70% from the value measured on a standing thermal manikin. This paper deals with the variation in local insulation and heat loss caused by wind and walking as well as the affect on total insulation determination associated with the new standard.

MATERIALS AND METHODS

The thermal manikin used is one in the TORE-series that has been described earlier *(6)*. The power transmission, in the walking apparatus, has been made with pneumatic cylinders, which gives a simple and durable construction with a minimum of mechanical components,

Figure 1. The moving thermal manikin TORE, adapted for measurements according to ENV 342 1998.

In this investigation, two types of working clothes with one (loose-fitting) and three layers (tight-fitting) were examined as well as unclothed conditions. The total insulation values differed fiom 0.73, 1.45 to 2.78 clo.

TORE was positioned in the controlled environment of the climatic chamber until steady state was reached. Then the insulation was calculated fiom the measured heat loss. In this study the walking speed was set to 0, 0.37, 0.8 and 1.2 m/s. The measurements were made in the climatic chamber where the wind speed was set to 0.2, 0.5 and 1.0 m/s.

The repeatability for the method used for determination of insulation values was high: the difference between double determinations was less than 5% of the mean value of the two measurements based on 300 independent measurements.

RESULTS

The insulation results are given as percentage of the total insulation (It) measured with a standing manikin during still-wind (0.2 m/s) conditions. The heat loss results are presented as percentage **of** heat loss fiom the body zone compared to the total heat loss. Head, chest and back are single zones. The torso, arms and legs are a summation of all zones divided to three different segments. The torso segment consequently includes the head zone.

The heat loss results show only minor increase from the torso, arms and legs. The combined effect of body movements and wind increases only slightly the heat **loss** fiom the moving limbs.

Table 1. Percentage of the total heat loss*

		Head	Chest	Back	Torso	Arms	Legs
Synthetic	Mean	12.0%	7.4%	8.2%	32.9%	24.3%	42.8%
	SD	1.2%	0.6%	0.3%	1.7%	1.2%	2.6%
Overall	Mean	8.6%	9.7%	9.2%	34.3%	29.7%	36.0%
	SD	2.0%	1.2%	1.0%	3.6%	2.2%	3.7%
Undressed	Mean	4.9%	9.6%	9.0%	33.2%	24.4%	42.3%
	SD	1.7%	0.9%	0.8%	2.3%	1.2%	2.4%

***Values shown are in Watts.**

The loose-fitting overall gave **5%** higher heat loss at the arms and consequently **5%** lower heat loss at the legs. The overall has a higher insulation reduction at the back, probably caused by redirection **of** wind by the garment. Calculations of heat loss fiom the head compared to total heat loss shows that the percentage increases with increasing heat loss fiom **5%** nude to 12% with winter clothing. The head also has the highest reduction fiom standing still-wind conditions to maximum wind and walking speed.

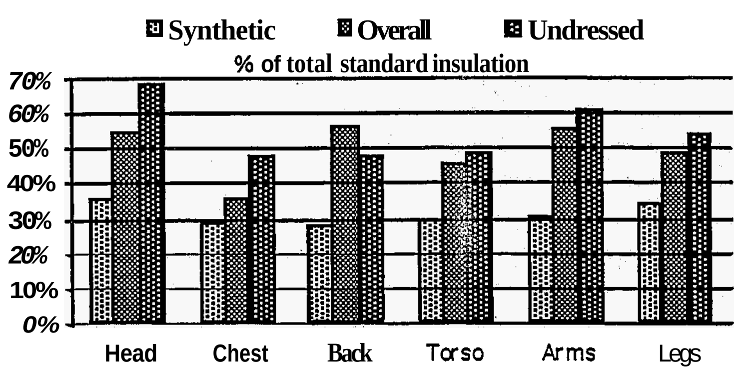

Figure 2. This figure shows the maximum insutlation reduction as a percentage of the total insulation. It occurred in the condition with maximum wind (1.0 $m \cdot sec^{-1}$) and walking speed (1.2 $m \cdot sec^{-1}$).

Table 2. Relative differences between the two calculation methods

	Local	Total
synthetic	**8%**	13%
Overall	**5%**	13%
Undressed	1%	6%

The results from measurements made with the three ensembles have been calculated in two different ways, "Local" and "Total" summation **(7).** The differences, in percent, between the two calculation methods are shown in Table 2. The difference increases with increasing number of layers and the extent of garment overlapping.

The standard suggests that differences between double determinations should be less then ***5%.*** It is obvious that there is a danger in calculating these values in different ways. "Errors" of 25%, or more, can easily occur.

DISCUSSION

In the low-wind and walking-speed region, it seems **to** be only minor redistribution of the heat loss **from** the different body **parts.** This emphasizes the importance **of** proper use of the formulas for calculation **of** total insulation in the proposed standard.

Originally the draft standard (prEN 342:1995) suggested two principles to calculate the total insulation **(8).** If the manikin is covered with exactly the same insulation over all sections, the results from the two formulas are the same. If the heat loss from one or more sections is substantially lower, compared to the other zones, the "Local" formula will give a higher value. The insulation calculated with the "Local" equation would then be substantially higher compared to the "Total," that would give the same value as if the insulation was evenly distributed.

Appropriate clothing design can easily result in high insulation values. By distributing the insulation so that the ensemble has a high insulation on the back and low at the front, the larger heat loss from the back will increase the total insulation with the "Local" equation but not with the "Total" method. This way of calculation combined with high wind speeds can easily lead to overestimation of the protection and increase the **risk of** adverse health effects.

CONCLUSIONS

We conclude the folllowing: (1) Body movements and wind make only slight redistribution of the heat loss at **low** wind and walking speed, (2) The head has the greatest insulation reduction as well as the greatest heat loss increase with increased wind, and **(3)** Insulation calculated by summation of segment heat loss can be substantially higher compared to summation of local insulation values.

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of this study. lead to the conclusion that within the limits studied here and with respect to subjective evaluation, physiological strain and performance, the reduction of the weight is less important than its distribution.