

# EFFECTS OF WIND AND WALKING ON LOCAL CLOTHING INSULATION

H. Nilsson, I. Holmér and G. Ohlsson

Department of Occupational Medicine, Climate Group National  
Institute for Working Life S-171 84 Solna, Sweden



## 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 IREQ-method (2) or as realistic input for prediction of thermal stress in other standards. It is known from 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 from 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 from 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 from 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 from 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 from the head compared to total heat loss shows that the percentage increases with increasing heat loss from 5% nude to 12% with winter clothing. The head also has the highest reduction from standing still-wind conditions to maximum wind and walking speed.

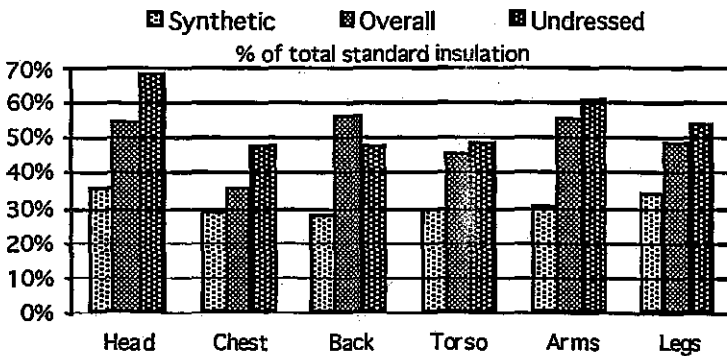


Figure 2. This figure shows the maximum insulation reduction as a percentage of the total insulation. It occurred in the condition with maximum wind ( $1.0 \text{ m}\cdot\text{sec}^{-1}$ ) and walking speed ( $1.2 \text{ m}\cdot\text{sec}^{-1}$ ).

**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 than 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 following: (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.

## REFERENCES

1. ENV 342:1998, Protective clothing against cold. 1998. Comité Européen de Normalisation, Brussels.

2. ISO/TR-11079, Evaluation of cold environments—determination of required clothing insulation (IREQ). 1993. *International Standards Organisation*, Geneva.
3. Nilsson, H., Holmér, I., Ohlsson, G. and Anttonen, H. 1997, Clothing insulation at high wind speeds, in K. Kuklane, I. Holmér and C. Ekeberg (eds.), *Proceedings of Problems with Cold Work*, (Stockholm, Sweden: National Institute for Working Life), 63.
4. McCullough E.A. and Hong S. 1992, A database for determining the effect of walking on clothing insulation. Proceedings of the Fifth International Conference on Environmental Ergonomics, (Maastricht, the Netherlands), 68-69.
5. Olesen B.W., Sliwiska E., Madsen T.L. and Fanger P.O. 1982, Effect of body posture and activity on the thermal insulation of clothing. Measurement by a movable thermal manikin, *ASHRAE Transactions*, 88(2), 791-805.
6. Nilsson H and Holmér I. 1997, Development of clothing measurement methods with the thermal manikin TORE, *Proceedings of 5th Scandinavian Symposium on Protective Clothing* (NOKOBETEF V). (Helsingør, Denmark), 30-35.
7. Nilsson, H. 1997, Analysis of two methods of calculating the total insulation, *Proceedings of a European Seminar on Thermal Manikin Testing*, (Solna: Arbetslivsinstitutet, Department of Ergonomics), 17-22.
8. prEN 342:1995, Protective clothing against cold. 1995. Comité Européen de Normalisation, Brussels.

#### ACKNOWLEDGEMENT

This work was supported by the Swedish Council for Work Life Research. (Former Swedish Work Environment Fund, project no: 94-0428)

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.