EFFECT OF WIND AND BODY MOVEMENTS ON CLOTHING INSULATION –MEASUREMENT WITH A MOVEABLE THERMAL MANIKIN

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INTRODUCTION

The combined effects of body movements and wind considerably enhance heat loss from the human body. Accordingly, the resultant insulation provided by clothing is reduced (1, 2, 3) and becomes lower than its standard value, measured with a thermal manikin under standing, static conditions (4, 5). This reduction must be accounted for whenever clothing data are required in predictive models (6, 7, 8). In a previous paper we have reported measurements of resultant insulation with a moveable manikin (9). In this report the combined effect of wind and walking speed was measured.

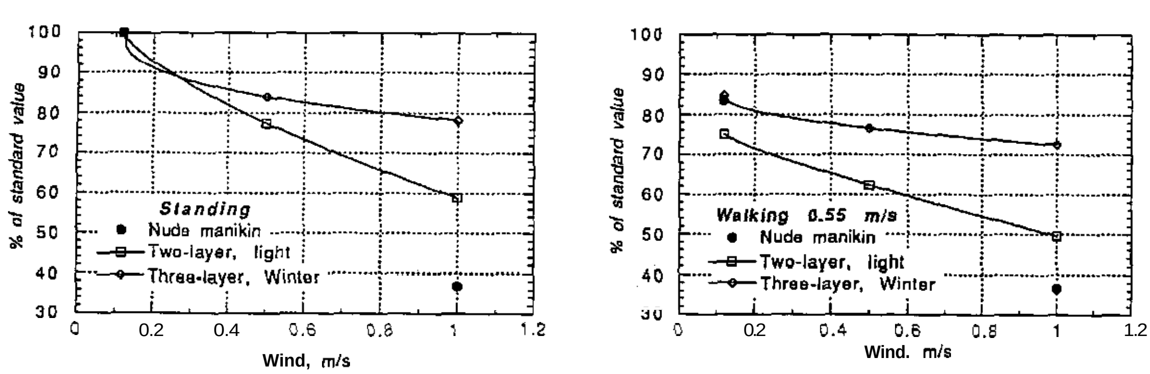
METHOD

The thermal manikin was described in our previous paper (9). In the present study the step rate of the manikin was controlled at 0, 30 and 55 steps/min and the wind speed was set at 0.12, 0.5 and 1.0 m/s. Wind was created by two large fans (Indola, Type VWB 50). A honeycomb was mounted in front of the fans to reduce turbulence. Measurements were carried out in a climatic chamber. Difference between values in repeated measurements of each condition was always lesser than 6 % of the average of the two.

Ensembles were the same as previously described (9); one light, two-layer ensemble for shop workers and one heavy, three-layer cold protective ensemble. In addition, measurements were taken with the nude manikin. Results are given as percentage of the standard insulation value measured with the standing, static maiiikin under wind still conditions (0.12 m/s) (4, 5).

RESULTS AND DISCUSSION

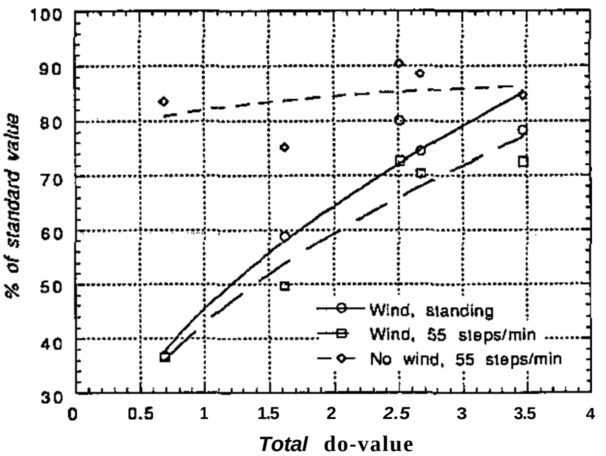
Results reported are based on an analysis of the total insulation values, directly measured with the thermal manikin. The figure below shows the effect of wind speed on insulation for the standing manikin (left) and for walking at 0.55 m/s (right). Insulation decreased as a power function of wind speed. The rate of change was higher at low wind speeds compared to high, but this result was less pronounced with the moving manikin. There was a clear difference between the three "ensembles". Total insulation was reduced by 64 % when manikin was nude. There was no additional effect of walking. The insulation of the two-layer, light clothing was significantly more reduced compared to the winter ensemble. Both reduced further by about 10 % when manikin walked at 0.55 m/s.



The wind effect on the standing manikin for our light clothing was similar in magnitude to data reported by Havenith et al. (2) for three light ensembles. On the other hand, their equation for the combined effects of wind and walking speed predicts about 20 % additional increase in the heat transfer coefficient (≈17 % decrease in total insulation) at 1 m/s. It is readily seen in the previous figure that the extra effect of wind was dependent on type of clothing and varied between 18-34% at 0.5 m/s and between 14-35% at 1.0 m/s.
Apparently, material and composition of an ensemble have great influence on its insulation characteristics. A windproof outer fabric, of course, almost eliminates wind penetration on one hand, but may enhance micro-climate ventilation during exercise, presuming the design and construction is appropriate. With multi-layer clothing ventilation and wind effects are likely to be diminished, because of the difficulties for wind to

penetrate deeper layers. For each of the two ensembles the reduction of insulation was found to be almost the same at a given air velocity, whether it be caused by the action of wind or walking movements.

The figure below depicts measured, resultant total insulation values in % of the standard value for wind, walking and combined wind and walking conditions in relation to insulation thickness. Included in this graph are also values for two other ensembles with a standard insulation of about 2.5 clo.



The reduction of insulation due to wind and walking seems to be dependent on the number of layers – the more layers the smaller be the reduction. In the figures it is clearly seen that the insulation of the winter ensemble reduced lesser than the light clothing. Apparently, the ventilation of the ensemble becomes less effective the more layers are put on. **Also,** the outer layer of the winter clothing is likely to be more wind proof than the light two-layer clothing.

Micro climate ventilation due to body movements appears to be small and almost independent of insulation thickness, at least for moderate walking speeds. On the other hand, the effect of wind alone and in combination with walking decreases sharply with insulation thickness. Havenith et al **(2)** found the opposite effect, compiling data from various sources.

CONCLUSIONS

Clothing insulation is greatly affected by wind. At **low** walking speeds the predominant effect on insulation may be caused by the action of wind on the surface air layer. The number of clothing layers and clothing thickness greatly influences the disturbing effects of wind and body motion. Data on wind and motion effects from the literature are still contradictory and necessitate further systematic studies.

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