LOGGERS' PROTECTIVE CLOTHING STUDIED WITH THE SWEATING THERMAL MANIKIN AND DURING WEAR TRIALS

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INTRODUCTION

Loggers in Finland work in different weather conditions, and their work is physically hard. Their protective clothing must provide protection against mechanical hazards (leg protection stops the chainsaw if it toches the leg). On the other hand its comfort properties must be optimal, not to cause additional physiological strain. The most important themophysiological properties are thermal insulation and water vapour permeability, but the rainproohess and the air permeability have also to be considered, when chosing protective clothing for loggers. The proposed European standard prEN 342 /1/ classifies cold weather clothing regarding their thermal insulation, water vapour permeability, whereas foul weather clothing is classified regarding watertightness and water vapour permeability according to prEN 343 /2/.

In this study, three different types of clothing solutions for loggers were compared. The clothing materials were: 1) 100 % polyester weave, breathable but not watertight, 2) polyurethane coated polyamide fabric, watertight but non-breathable, and 3) 3-layer laminate with microporous PTFE-film, breathable and watertight. Their thermal insulation and water vapour permeability were determined with the sweating thermal manikin under different environment and sweating conditions. In addition basic material properties were determined using standard test methods. A limited field test was performed, in order to verify the objective results of laboratory tests with subjective statements from the users.

METHODS

The sweating thermal manikin Coppelius, described in /3/, was used to determine the simultaneous heat and water vapour transmission through 2-layer and 3-layer clothing systems. Underneath the protective clothing was a long underwear and a long underwear + a long thermodress, respectively. The environment conditions were chosen to correspond to loggers' work conditions, i.e. the 2-layer clothings were measured in +20, +10 and 0 °C and the 3-layer clothings in +10, 0 and -10 "C. For each clothing combination three different sweating levels were applied: 0, 100 and 200 g/m²·h. The measurements gave the following information under each test condition: heat supply P (W/m²) required to keep the manikins skin temperature constant at +33 "C, thermal insulation I_T for dry tests or I_{Tcorr} for sweating tests (m²·°C/W) /3/, water vapour permeability M_e in % of supplied water, and the regulatory effects (evaporative and wetting) of sweating on the heat loss P_e and P_w (W/m²). The test time was 3 hours for sweating and 2 hours for dry measurements, and two parallell measurements were done for each clothing/test condition combination.

Four loggers in different parts of Finland participated in the field trial during the winter 1993-94. They were provided with jackets made in the three materials, and reported subjective data on their functional properties. Different trousers were not compared in the field trial, as their most important functional requirement is protection and the thermal comfort properties are of less importance.

RESULTS

The dry thermal insulation I_T of the three tested types of clothing was on the same level, between 0,216 and 0,238 m²·°C/W for the 2-layer and 0,290 and 0,298 m²·°C/W for the 3-layer combination, measured in +10 °C. In water vapour permeability M_e, there was however a big difference between the garments. The highest values were achieved for the 2-layer clothing combination and in +20 "C with 100 g/m²·h sweating: 74,5 % for the polyester, 68,7 % for the laminate but only 28,6 for the plastic coated nylon clothing (in the lower temperatures and with the 200 g/m²·h sweating, the condensation in the plastic coated clothing combinations was so severe, that the tests had to be interrupted due to water dropping from the manikin). The addition of a third clothing layer reduced the water vapour permeability about 10 %-units.

Changes in test conditions cause considerable changes in the test results. The required heat supply increses with decreasing temperature and with increasing sweating level, and consequently the thermal insulation decreases. The percent water vapour permeability is higher for the lower sweating level, but the absolute value of evaporation is higher when sweating is high. A decrease in the ambient temperature always causes a decrease in the water vapour permebility, eg. the 2-layer polyester clothing transmits 57,8 % of the supplied 200 g/m²·h

water at + 20 °C, 53,1 % at +10 °C, and 47,0 % at 0 °C.

The physiological reason for sweating is to increase the heat loss from the body by evaporating water in a heat stressing situation. Comparing the results from *dry* and sweating tests, the heat supply in the sweating ones is, of course, higher. This is, however, due not only to the evaporation of water from the manikins surface, but also to the reduced thermal insulation caused by condensation of water in the clothing (wetting). The figure shows the measured total increase in heat suppply in the sweating measurements compared to the *dry* measure-ments, as well as the evaporative and the wetting part. The general tendency is clear: the highest total values are found for the most permeable 2-layer polyester clothing, followed by the laminate, whereas the non-permeable clothing is on a much lower level. In the higher temperatures, the evaporative part is dominant in the permeable clothings, but when the temperature decreases, the wetting part increases rapidly.

The wear trials confirmed generally the results from the manikin measurements. As the difference in breathability is small between the polyester and the laminate clothing but the latter also gives rainproohess, the laminate was rated as the most preferred by all test persons. There were however also remarks about condensation of sweat on the inner surface of the laminate material, particularly on cold days. The non-breathable plastic coated fabric was not accepted by the test persons, due to fast condensation and discomfort.

CONCLUSIONS

The sweating thermal manikin Coppelius *can* be used for quantitative measurements of heat and water vapour transmission properties of protective clothing. The regulative effect of sweating in different work situations can be determined, which is important when estimating the influence of clothing on the thermal stress of humans. This study was devoted to loggers, but the results *can* be applied to other outdoor workers as well.

As a general conclusion it *can* be stated, that the thennophysiologically important water vapour penneablitity cannot be considered as a constant property. It decreases considerably in lower temperatures, and even if this is compensated by an increasing wetting and thereby also heat loss, the thermal comfort is soon lost.

REFERENCES

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