A MODIFIED HOT PLATE FOR GLOVE CONTACT INSULATION MEASUREMENT

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INTRODUCTION

According to the new European Standard EN 511:1993 the protection by gloves against contact cold is tested in accordance with ISO 5085-1:1989 (BS 4745: 1986). Samples are taken from the palm of the hand of one pair of gloves (two samples in total). The sample should be 330 mm in diameter. This is not compatible with EN 511, which requires the sample to be taken from ready-made gloves! A compromise may be the use of samples from several gloves to "cover" the test area or to use materials from the production line. Both ways may introduce significant errors. In order to make the measurements with a sample from an ordinary glove and even without destroying the glove, a new hot plate of minimal size has been developed. The construction of the new instrument is based on the requirements in EN 511 (and ISO 5085:1). The new mini hot plate (MHP) measures the thermal resistance of a glove with constant temperature over the palm area as suggested in EN 511.

MATERIALS AND METHODS

Figure 1 shows the mini hot plate in the measuring set-up with some gloves in the background. The MHP is inside the glove and the required weight is on top of the palm side (pressure 6.9 kPa). The stand is for ambient temperature measurements.

Resistance of the handwear is determined by measuring the power required to maintain a constant temperature gradient between the surface of the heated MHP and the surface of the tested glove. The surface of the MHP is heated so as to provide a uniform surface temperature. In order to do so the surface of the MHP is divided into zones (measuring zone and guard zones) which are densely covered by resistance wires. The surface temperature of each zone is measured by other resistance wires covered and separated from the heating wires by a thin layer of plastic. A computer serves as a regulation and acquisition unit for the system.

The dimensions of the mini hot plate (MHP) are 2x5x7 cm. The measuring zone is shielded by two guarding zones, which are heated to the same temperature as the measuring zone to prevent axial and radial heat transfer. The MHP is made of plastic

foam with a density of 0.2 kg/dm^3. Power to the plate is measured so that it gives an accurate average over the period of the test. The accuracy of the power measurement is within 2% of the reading for the average power for the test period. The MHP is heated by a low voltage DC-power supply. The power supply is stabilised and provides a constant voltage output better than ±0.1%. The setpoint for mean surface temperature is usually set to 34 °C. The sensor wires allow for a representative measure of mean surface temperature over all zones. Local deviations from the controlled mean skin temperature do not exceed ±0.1 °C. The temperature at the surface of the glove is measured by a flat temperature sensor (Swema N3606). The sensor is mounted to an aluminium distance that keeps the lead weight away from the measurement area. This construction gives a faster measurement procedure.

The test apparatus consists of the MHP with measuring and regulation equipment, the weight and a climatic chamber that can provide uniform climatic conditions. The test glove is fitted to the MHP. The ambient temperature is set sufficiently low to minimise the relative error of the regulation. Mean radiant temperature is less than 0.5 °C different from mean air temperature. The air velocity is kept at 0.2±0.1 m/s and the relative humidity is 60±5 %. Turbulence intensity is less than 30 % (one standard deviation of mean air velocity).

Thermal resistance is the resistance to dry heat transfer due to convection, radiation and conduction. The resistance to dry heat loss from the mini hot plate ($R_{contact}$) defines the resistance provided by the handwear but not the air layer above the surface. The average of two independent measurements is used to designate the resistance value of the glove.

When the power consumption (Q_{MHP}) has equilibrated measurements are taken as the average value for a period of 10 minutes. The thermal resistance is calculated by

$$R_{contact} = \frac{\left(T_{MHP} - T_{surf.g}\right)}{Q_{MHP}} \qquad (m^2°C/W) \qquad \text{Equation 1}$$

where T_{MHP} is the surface temperature of the mini hot plate in °C, $T_{surf.g}$ is the glove surface temperature in °C, and Q_{MHP} is the power consumption of the mini hot plate in W/m^2.

The contact resistance of 63 different gloves on the Swedish market were measured. The measurement took place in a climate chamber where the air temperature was kept constant at 23±0.2 °C with relative humidity of 65±5 %. All the gloves were stored inside the chamber for at least 7 days before the measurement took place. All the measurements were taken on the palm of the left hand of the gloves. At least two measurements were made on each of the glove on two different days. The T_{MHP} was set at a constant value of 34.0°C. The $T_{surf.g}$ was recorded.

Figure 1. The mini hot plate (MHP) in the measuring set-up with some gloves in the background. The mini hot plate (MHP) is inside the glove and the weight is on top of the palm side. The stand is for ambient temperature measurements.

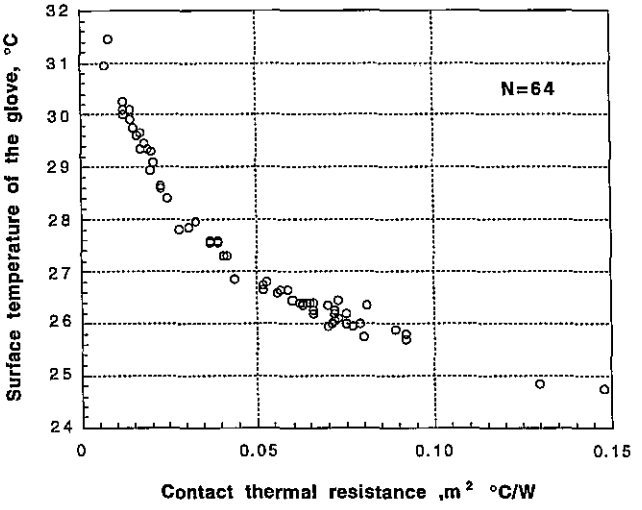

Figure 2. The relationship between the glove surface temperature and the thermal resistance of contact.

RESULTS AND DISCUSSION

The mean thermal resistance value for all 63 glove measurements (double determinations) was 0.050 $m^2°C/W$. The SD for the mean difference between double determinations was 0.0020 $m^2°C/W$. This corresponds to an error of 4 % of the mean. This level is acceptable for a method based on double determinations as required in the standard. If the difference exceeds 4 % a third measurement is taken.

As a consequence of the different thermal resistance the surface temperature of the sample will change. A plot of $T_{surf.g}$ versus thermal insulation of the gloves is shown in figure 2.

The present method appears to present a feasible solution to the problem of measuring contact thermal resistance of gloves. The present version of the standard (EN511) requires the sample to be taken from the palm of the glove. With the suggested method (ISO 5085) several gloves need to be cut up in order to provide the required sample size. Also, the physical arrangement of the individual pieces from the palm of the glove on the hot plate is not properly defined. A possible alternative would be to prepare the sample from staple ware. However, this may differ from the actual layering in the final glove construction. Both problems may be circumvented by the present method, which measures directly on the intact glove.

REFERENCES

EN-511. Protective gloves against cold, 1993.
ISO-5085-1. Textiles - Determination of thermal resistance - Part 1: Low thermal resistance. 1989.