ARE STANDARD TESTS OF COLD PROTECTION BY FOOTWEAR RELEVANT AND VALID?

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Summary: The present international standards for safety, protective and occupational footwear EN ISO 20344 – 20347 classify footwear as cold protective by a pass/fail test where the limits are set for an allowed 10 °C temperature drop inside the footwear at a sole location during 30 minutes at a temperature gradient of about 40 °C. In a test of five footwear including a summer sandal it was shown that all could pass the test, since performance is basically determined by the sole insulation only. The standard does not discriminate between good and poor cold protective footwear and should be replaced by a more relevant and valid test, for example with a heated foot model.

Keywords: heated foot model, test method, thermal insulation, subzero environment
Category: thermal manikin application

1. Introduction
The present European (CEN) and international (ISO) standards for safety, protective and occupational footwear EN ISO 20344 – 20347 (2004) classify footwear as cold protective by a pass/fail test. In a previous study we could show that a simple rubber boot, not intended for use in the cold, would pass this test mainly due to its thick sole (Kuklane et al., 1999b). Also it was obvious that the test did not discriminate between high insulation and low insulation boots, due to its single criterion. Thermal foot models have been developed that provide total, as well as segmental, insulation values that consider the three dimensional heat fluxes from the foot, through the footwear to the environment (Kuklane et al., 1999a, Kuklane, 2004).

2. Method
In this study selected occupational footwear for use in warm, temperate as well as slightly cold conditions were selected and subjected to tests with EN 344 and a thermal foot model. Sample included sandals and fur insulated boots.

2.1 EN ISO 20344
The footwear is filled with small steel balls and placed in a climatic chamber at -10 °C. The temperature drop is measured with a sensor placed at the middle of the sole inside the footwear during 30 minutes. A temperature drop less than 10 °C indicates that the shoe passes the test. When the sandal was measured with EN 344 the open parts were covered with paper in order to accommodate the steel balls.

2.2 Thermal foot model
The thermal foot model (Kuklane et al., 1999a) is a heated full scale model of a human foot. Surface temperature of the “skin” is kept constant at 34.0 °C by a computer program. Heat loss is continuously measured every 10 seconds. Steady state heat losses are recorded after about 30 minutes and the thermal insulation is calculated by dividing the temperature gradient by the heat loss. The foot model comprises 8 different segments, allowing separate determination for example sole and ankle insulation values.

3. Results and discussion
Thermal insulation value was highest for the insulated boots (table 1). The value for the rubber boot was 12 % lower and for the sandal 27 % lower.

EN ISO 20344 measures the temperature drop in one point of the sole inside the footwear. It is obvious that the insulation of the sole itself and, in particular, the conditions at the local measuring point will have a great influence on the result. Sample S (sandal) is an open footwear with a thick sole. The total insulation is low but the insulation of the sole part as measured with the foot model was the highest of all samples. This may explain why this footwear passed the cold test in EN ISO 20344.

All footwear was approved as cold protective according to EN 344. It is clear for the user that a sandal, a mesh shoe or a thin textile shoe are not cold protective. However, it is misleading that safety footwear, that has as low insulation as those mentioned above, may be classified as cold protective according to the present standard (EN ISO 20344). The user gets a deceiving safety feeling and may be exposed to higher risks. As practically all occupational footwear may pass this cold test, the method is neither relevant nor valid as an international standard and should be withdrawn. A test based on measurements with a heated foot model would be much more relevant and reliable.
Table 1. Footwear and the total insulation values (m²°C/W) of the mid-sole and of all foot zones (toes, sole, heel and dorsal foot). During thermal foot tests, a thin sock was used in combination with the footwear. Air layer insulation for the tested footwear conditions (va = 0.29±0.03 m/s) was Ia = 0.085 m²°C/W.

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Upper material</th>
<th>Sole material</th>
<th>Weight (g)</th>
<th>Ifoot</th>
<th>Isole</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Rubber boot</td>
<td>Polyvinyl chloride</td>
<td>PVC</td>
<td>839</td>
<td>0.184</td>
<td>0.291</td>
</tr>
<tr>
<td>F</td>
<td>Heat prot. boot</td>
<td>Cow chrome leather</td>
<td>One layer of synthesized rubber</td>
<td>737</td>
<td>0.200</td>
<td>0.330</td>
</tr>
<tr>
<td>H</td>
<td>Cleanroom footwear</td>
<td>Synthesized leather</td>
<td>Two layers of new foaming polyurethane</td>
<td>332</td>
<td>0.208</td>
<td>0.335</td>
</tr>
<tr>
<td>R</td>
<td>Indoor shoe</td>
<td>Synthesized leather / mesh</td>
<td>Two layers of new foaming polyurethane</td>
<td>288</td>
<td>0.202</td>
<td>0.320</td>
</tr>
<tr>
<td>S</td>
<td>Open sandal</td>
<td>Synthesized leather</td>
<td>One layer of foaming polyurethane</td>
<td>261</td>
<td>0.151</td>
<td>0.371</td>
</tr>
</tbody>
</table>

References