PHYSIOLOGICAL DEMANDS ON PROTECTIVE CLOTHING AGAINST COLD ACCORDING TO EUROPEAN STANDARD EN-342

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INTRODUCTION

Personal protective equipment (PPE), in the first place, must provide adequate protection against occupational hazards and mechanically inflicted injuries. However, it is likewise important that PPE also possesses a physiological function, protecting the wearer against heat or cold stress and yielding an at least satisfactory wear comfort. Garments without such a physiological function do not only affect our well-being, but with man working they impede his physical and mental performance and they can even be health-damaging. This knowledge finally has found its way into a number of the new European Standards on PPE. An example is EN-342 "Protective clothing against cold".

METHODS

Protective clothing, designed to be worn at subzero temperatures, must not only effect a sufficiently high thermal insulation, largely independent of the outer wind speed, but they must also be "breathable", enabling a good evaporation of sweat from the body. Without the latter the garment layers next to the body get moist or wet by sweat condensation, losing completely their thermal insulation and leading to hypothermia. According to these demands the standard EN-342 defines 3 criteria to ensure the physiological function of protective clothing against cold:

- the "**resultant basic thermal insulation**" $I_{cl,r}$ (in m^2K/W) of the outerwear in combination with either of 2 different types of "standard underwear" is quantitatively measured with a segmented and movable thermal manikin under defined wind speed and movement conditions.

  $I_{cl,r}$ is related to the nude body surface area and comprises the effective thermal insulation from skin to outer clothing surface, excluding the insulating effect of the boundary air layer at the outer clothing surface. The latter is deduced from a measurement with the nude moving manikin.

- the **air permeability** AP (in l/m^2s) of the outerwear is measured according to ISO/DIS 9237.2 (1993). In cold climate a low air permeability is advantageous, because in outdoor wind conditions it prevents a penetration of cold air through the garment layers into the "microclimate" next to the body, reducing the effective thermal insulation of the PPE.

- the **water vapour resistance** R_{et} (in m^2Pa/W) specific to the outer shell material or the combination of outer shell material and watertight liner, if applicable, is measured using the Skin Model according to ISO 11092 (1993). The lower the water vapour resistance, the better the "breathability" of the clothing.

RESULTS

Following the standard EN-342 the outerwear's air permeability and water vapour resistance are classified into 3 classes each, according to Table 1, expressing the material's physiological quality for the use in cold protective clothing. Class 3 indicates the highest level of performance. Vice versa, with Class 1 for the water vapour resistance not being allowed to exceed 20 m^2Pa/W a minimum "breathability" of the clothing is guaranteed.

The PPE must be labelled with a pictogram (s. Figure 1), showing the resultant basic thermal insulation $I_{cl,r}$ of the total clothing ensemble, comprising either one of the "standard underwear" A or **B** as specified in EN-342. The thermal insulation value is followed by the classes for air permeability AP and water vapour resistance R_{et}, respectively. Obviously 9 different class combinations are possible, with the combination 3/3 indicating the garments with the comparatively best physiological performance.

Class	Air permeability AP in l/m²s	Water vapour resistance Ret in m² Pa/W
3	AP ≤ 20	Ret ≤ 6
2	20 < AP ≤ 150	6 < Ret ≤ 13
1	150 < AP	13 < Ret ≤ 20

Table 1: Classification of air permeability and water vapour resistanc

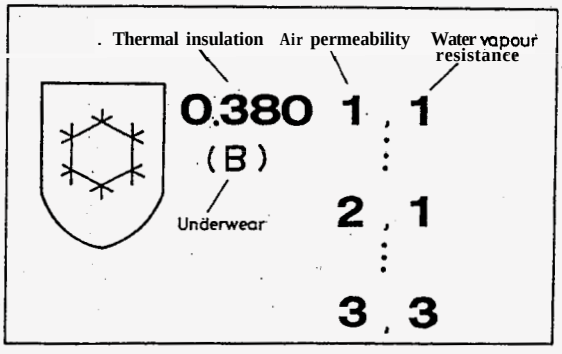

Figure 1: Example of the pictogram for labelling the PPE

The standard **EN-342** contains the following Table **2** which is based on a thermoregulatory model of the human body's energy balance as described in (1). Table **2** shows the user of the PPE, down to which minimum ambient temperatures, with different physical activity levels characterized by the metabolic heat production in W/m², a garment labelled with a specific thermal insulation value can be worn for at least 8 hours with the body maintained at thermoneutral conditions, or for a l-hour exposure with an acceptable rate of body cooling.

The temperatures given in Table **2** are valid only for an ambient air velocity below 0.5 m/s. For higher wind speeds they must be adjusted to wind-chill effects, as explained in **(1).** Also, Table **2** assumes adequately insulating hand-, foot- and headwear which **is** not covered by **EN-342.**

With Table **2** the user of cold protective clothing, with the knowledge of the ambient temperatures, wind speeds, activities and exposure times to be encountered, is informed which thermal insulation value as a minimum must be marked on the label of the outerwear and which type of underwear must be chosen in order to be physiologically suitable for his specific needs.

Minimum ambient temperatures						
Thermal insulation Icl,r	Physical activity very light 90 W/m²		light 115 W/m²		moderate 170 W/m²	
m²K/W	8h °C	1h °C	8h °C	1h °C	8h °C	1h °C
0.15				-3	3	-5
0.23		4	8	-13	-7	-18
0.31	10	-4	1	-23	-18	-31
0.38	4	-12	-6	-33	-29	-44
0.46	-1	-21	-13	-43	-39	-57
0.54	-7	-30	-20	-53	4 9	-70
0.62	-13	-39	-28	-63	-60	
			-35			

Table 2: Minimum ambient temperatures for **PPE** against cold according to **EN-342**

CONCLUSIONS

Because of the direct physiological interaction between body, climate and clothing, which has an essential influence on man's well-being, the physiological testing of PPE is at least as important as the already well-known testing of mechanical and physical properties.

By quantifying and labelling the physiological performance of protectice clothing against cold, based on laboratory tests, the new European Standard **EN-342** makes an important contribution to enabling work at adverse climatic conditions.

REFERENCES

1. ISO/CD **11079** (TR), **1992,** Evaluation of cold environments-Determination of required clothing insulation, I_{req}.