Thermal Insulation of the Clothing 2nd Royal Hungarian Army in Winter Campaign in the Light of Thermal Manikin Measurements

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Abstract: This paper proposes to give a brief summary of thermal comfort of soldiers of the 2nd Royal Hungarian Army in Winter Campaign, at the River Don in 1943, and call attention to the importance of the proper clothing and the thermal sensation measured by thermal manikin. The soldiers in the proper sense of heat insulating garments affected no cold, and the effects of climatic factors were also reduced. The 2nd Hungarian Army in the Winter Campaign and military organization has been assigned to very difficult major tasks. Neither the desired equipment nor the clothing arrived as needed due to the overload of railways. The large number of freeze damage is also due to the clothing of soldiers, according also to that our results did not meet the criteria of the extreme variability of the weather conditions and the thermal comfort.

Keywords: clothing; thermal comfort; thermal insulation; thermal manikin

1 Introduction

The 70 years of the breakthrough at Don is one of the greatest tragedies in Hungarian history. More than 100 thousands of soldiers died, disappeared or were imprisoned. In addition, the Hungarians did not have cold-weather equipment, which were designed by the Germans, who promised weapons too, which finally never arrived [1]

It is important to identify the way clothing contributed to thermal comfort or discomfort, so our group on the base of the measurement, we defined the heat submission of the thermal manikin dressed in the uniform of the soldier serving at the River Don. The goals of the research projects were mainly carried out at the Department of Building Service Engineering at University of Pécs. We defined it the single body parts and the whole man's heat submission beside air velocity

changing in case of a different operative temperature. We compared the measured values, the reference with a value, and the heat submission of the naked human body. We proved that the heat insulating ability of the clothing worn at the bend of River Don can be measured and the worn clothing did not meet the requirements of thermal comfort [2].

Winter clothing of the 2nd Royal Hungarian Army [3]**:**

- **snow suit (jacket and trousers) and snow tires:** in snowy weather it served the adaptation to the environment
- **panties knitted or woven**: heated the lower leg and the body.
- **trusses**: served for warming the kidneys, the stomach, it is required to wear on the shirt.
- **knitted or woven sleeve:** kept warm the upper body and the arms.
- **leg warmers:** warmed the legs, and it was necessary to be long enough so that it covered the knees.
- **ankle warmers**: kept warm the ankles, it was unnecessary to wear them with boot.
- **knee warmers:** were helpful to keep the knees warm, especially for the ones, whose knees were directly in contact with the cold, such as riders, cyclists or motorbike users. It was always worn outside trousers [3].
- **wool footcloth:** was a good piece for keeping the foot and the ankle warm.
- **boots:** helped protecting the feet.
- **felt boots:** soldiers were **a**llowed to wear them only in dry weather.
- **warming worth:** was helpful keeping the palm warm.
- **snow caps:** were used to prevent the face, but not the head and the neck [3].
- **fur vest:** it served to keep the upper body warm, and it was recommended to wear it over the tunic, but under the jacket.
- **fur gloves:** the mitten fur glove was very helpful in keeping the hands warm.
- **cloth quilt:** was keeping the entire body warm., expect for the face, hands and feet.
- **fur hat/cap**: it was helpful for keeping the head warm, except for the face [3].
- **Field cap:** was worn usually on the snow cap [3].

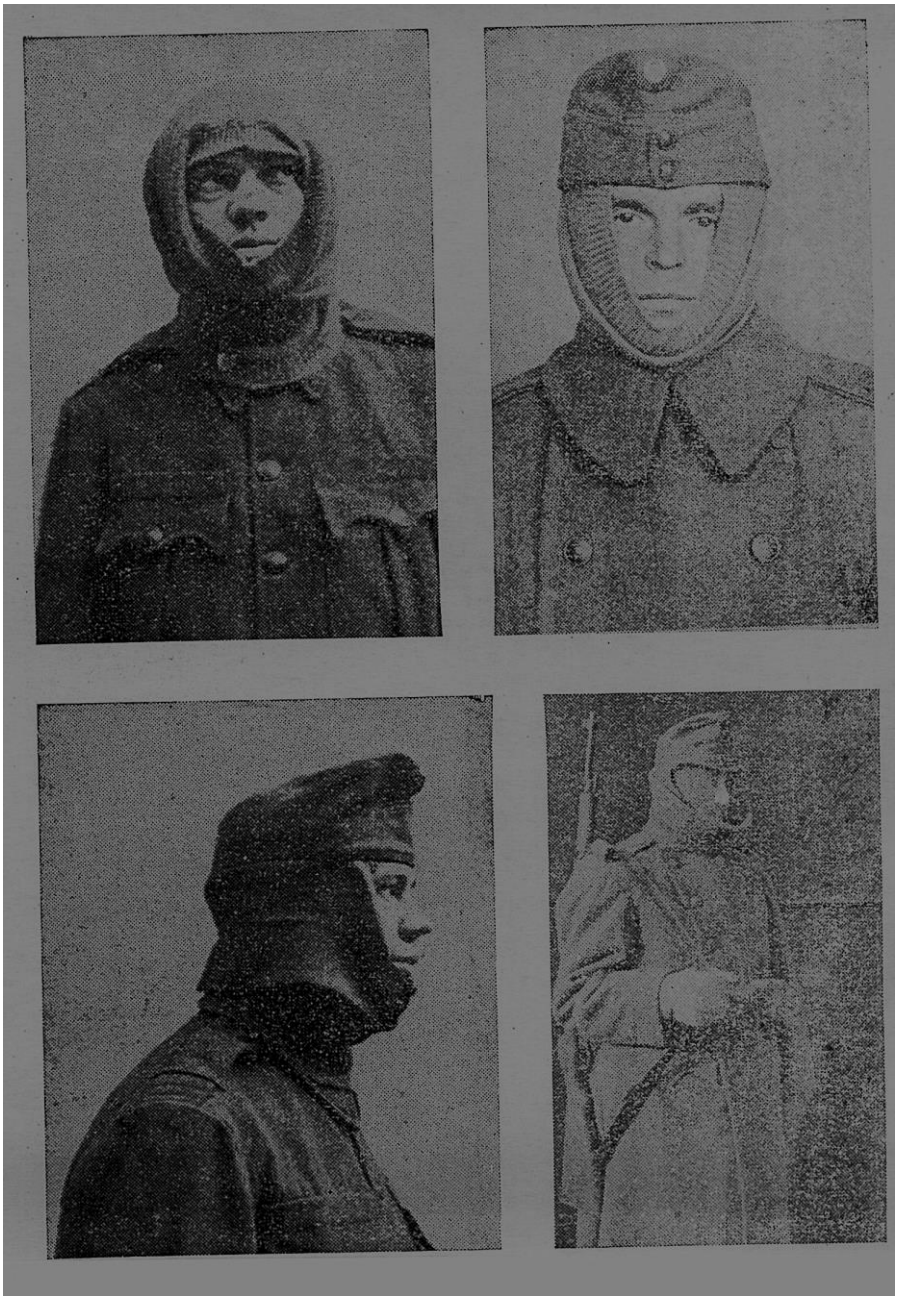

Figure 1
Field cap is worn on the snow cap [3], with copyright permission

Figure 2
Snow cap, which keeps the head, the ears and the neck warm, but not the face [3], with copyright permission

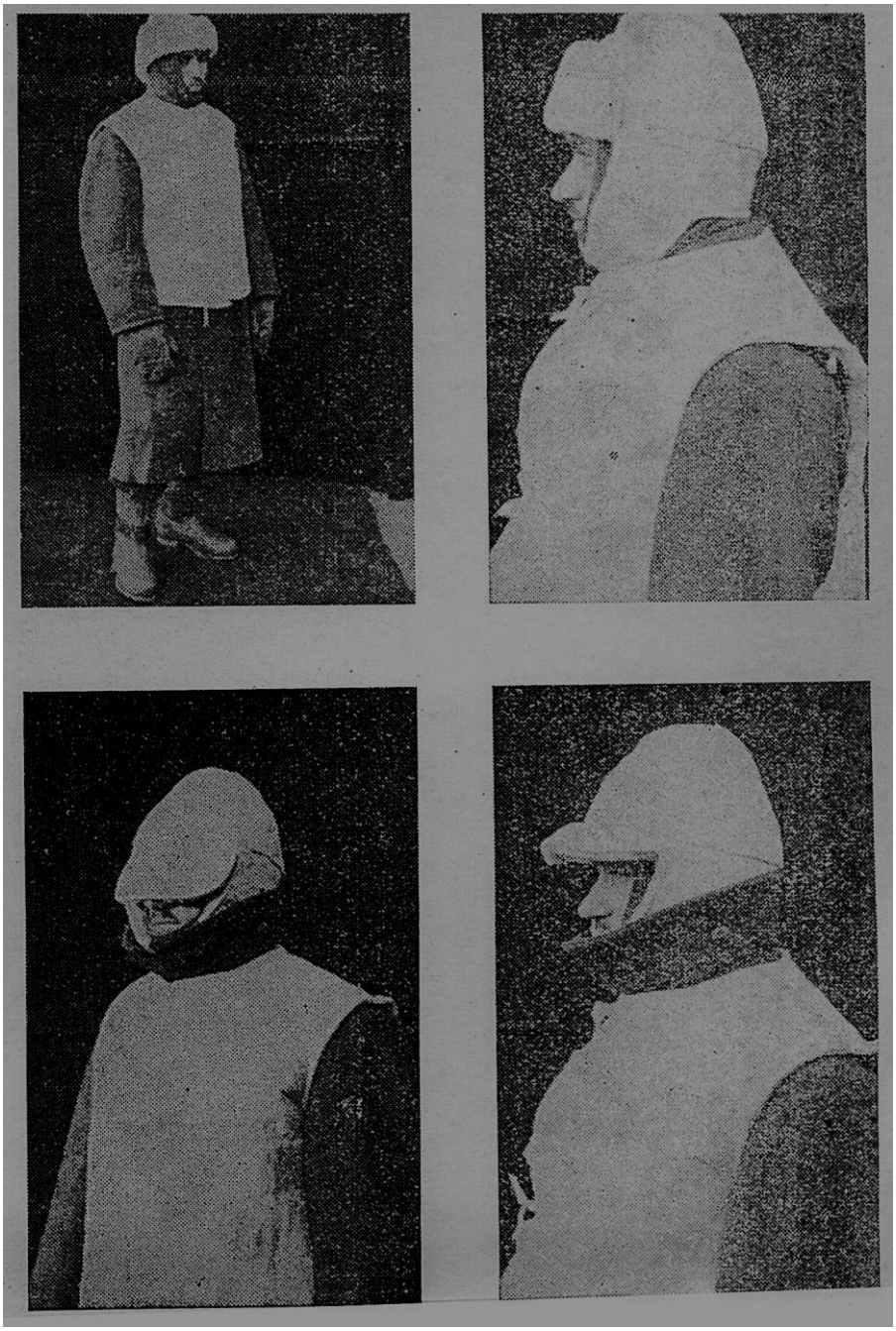

Figure 3
Fur hat, which keeps the head warm, but not the face [3], with copyright permission

2 Thermal Manikin

The clothing of the 2nd Royal Hungarian Army in winter campaign was tested on thermal manikin. The thermal manikin were made in the 1980's, in Hungarian Institute for Building Science, and it made by Swedish experts. Later, this thermal manikin were in the Technical University of Budapest, Department of Building Service Engineering, then from 2010 for research purposes it has been in University of Pécs, Pollack Mihály Technical Faculty, Department of Building Service Engineering, where the manikin got new, advanced datalogger and processing software [4]. The thermal manikin is a model with a body, a control unit and a data logger. The whole body is consisted of 16 body parts (Figure 4). The thermal manikin is a gauge system with big complexity, which was made of an average adult plastic puppet tallying with a man's body sizes. We kept a constant temperature on the body surface heated by electrical power. The electrical power of the 16 parts of the body is measured and logged. During the measurement we measured the body heat loss each parts of the manikin in the clothing under various ambient temperatures [4].

Figure 4
Different body part of the thermal manikin

The medical scientific literature gives the temperature of the human skin from 1919 [5] until nowadays [6]. It is an ongoing research in the medical science [7].

Figure 5 shows the set temperatures of the different body part based on the general medical practice. We developed new software and the set temperature can be changed.

The heat loss and heat sense of the people are influenced by the thermal insulation of clothing.

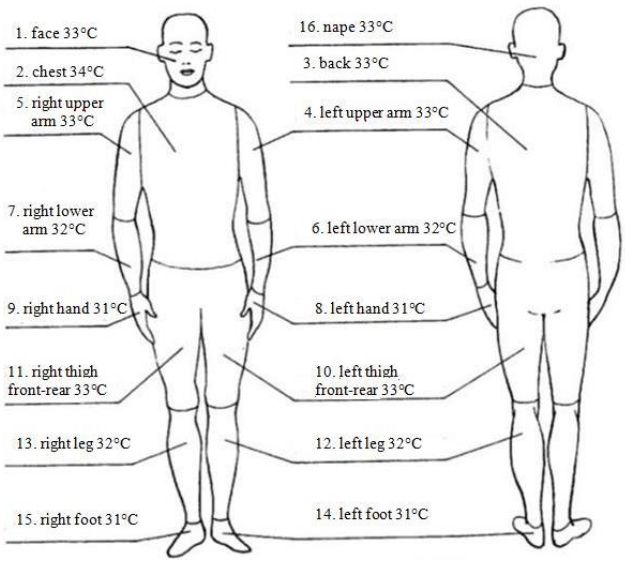

Figure 5
Surface temperature of thermal manikin [8]

3 Thermal Insulation of Clothing

The heat loss and the heat sense of the people are influenced by the thermal insulation of clothing. The convective and radiative heat transfer can be measured on the whole body surface with the thermal manikin. From the surface temperature and heating power data that measured at the body parts of the thermal manikin, by summation of body part area weighted data can be calculated the heat loss of the whole body and the thermal insulation of the clothing. The total insulation, that is thermal insulation of clothing and boundary air layer around clothing, can be calculated as follows [9], [10], [13]:

$$I_T = I_{cl} + \frac{I_a}{f_{cl}} \tag{1}$$

where:

I_T – total thermal insulation of clothing and boundary air layer, m^2K/W

I_{cl} – thermal insulation of clothing, m^2K/W

I_a – thermal insulation of boundary air layer, m^2K/W

f_{cl} – clothing area factor, that is the ratio of the outer surface area of the clothed body to the surface area of the nude body, -

To calculate the total thermal insulation we measured the heat loss of the thermal manikin dressed in the examined clothing. To calculate the boundary air layer around the body we measured the heat loss of the nude thermal manikin.

The used parallel calculation method [9], [11], [14] determines the total thermal insulation as an area-weighted average of the local insulations.

$$I_{T,\ parallel} = \frac{\left[\left(\sum_i f_i \cdot T_i\right) - T_a\right] \cdot A}{\sum_i H_i} \qquad \frac{m^2 \cdot K}{W} \tag{2}$$

We have to calculate the thermal insulation of boundary air layer around the nude body (I_a) similarly to the method of calculation of total thermal insulation.

The clothing area factor – the value of f_{cl} – can be determined by measurement, but approximate, indirect calculation is also possible, which correlation can be used [12]:

$$f_{cl} = 1 + 0{,}28 \cdot I_{cl} \tag{3}$$

In the practice the clo unit is used for the thermal insulation of clothing with the definition:

$$I_{cl} = I_{cl}\,[m^2K/W] / 0{,}155 \quad [clo] \tag{4}$$

4 Measurements and Results

The thermal manikin used the clothing of the 2nd Royal Hungarian Army in different outdoor temperatures (Figure 6).

Figure 6
Thermal manikin wearing the clothing of the 2nd Royal Hungarian Army

Figure 7 shows the specific heat loss of the body parts at the clothing of the 2nd Royal Hungarian Army was measured under different outdoor temperatures. The body part without clothing (such as the face) causes the high heat loss. The heat loss of legs and foots are relatively high.

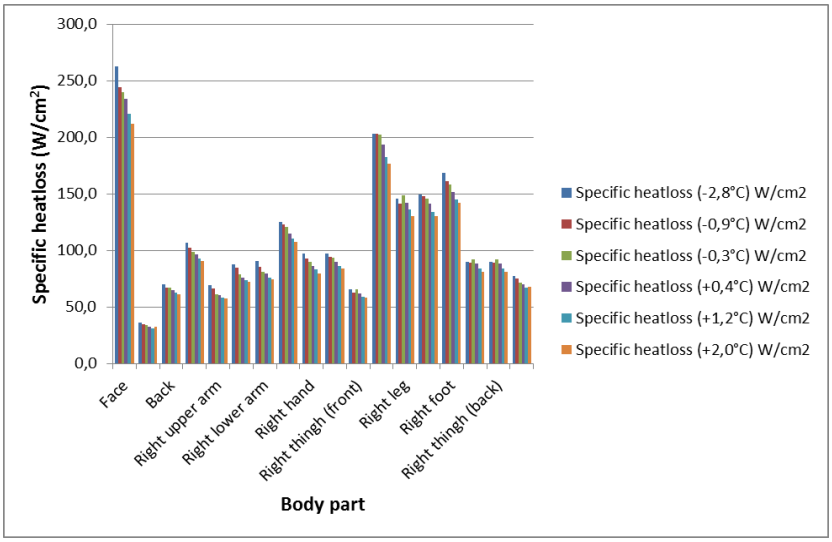

Figure 7
Specific heat loss of body parts in the clothing of the 2nd Royal Hungarian Army under different outdoor temperature

As an example we show the specific heat loss of the right thigh in the clothing of the 2nd Royal Hungarian Army under different outdoor temperatures (Figure 8).

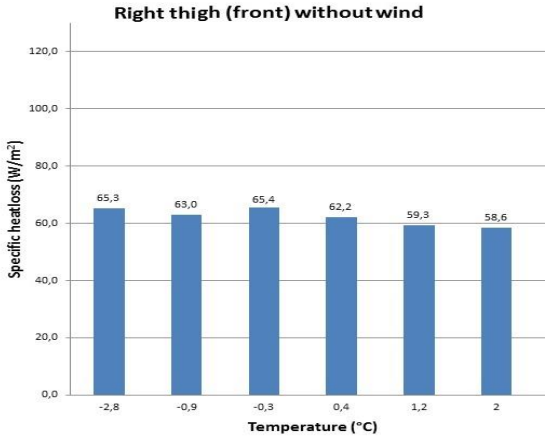

Figure 8
Specific heat loss of the right thigh in the clothing of the 2nd Royal Hungarian Army under different outdoor temperatures without wind

The effect of the wind on the heat loss of the human body is significant. A relatively strong wind (15 km/h) was used below, while the -2.5 ^{0}C heat loss of the whole body nearly doubled its volume (Figure 9).

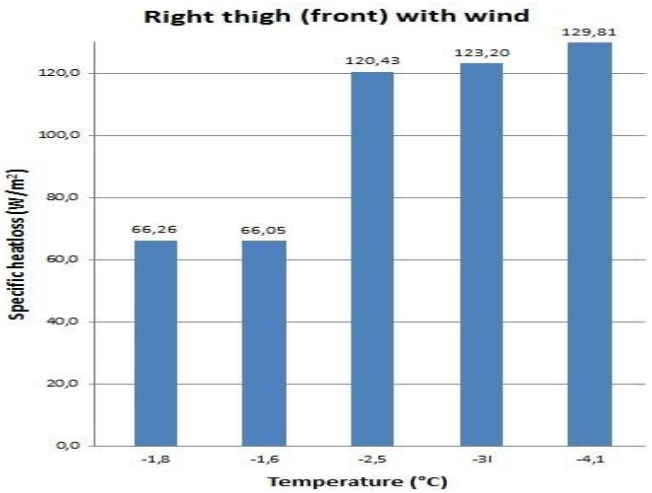

Figure 9

Specific heat loss of the right thigh in the clothing of the 2nd Royal Hungarian Army under different outdoor temperatures with wind

Conclusion

The calculation of the thermal insulation of the clothing was based on the equation (1),(2),(3) and (4), the result is 2,57 clo. The thermal insulation of the clothing of the 2nd Royal Hungarian Army is too low for the given outdoor temperature.

The measurements with thermal manikin justified, that the thermal insulation of the clothing of the 2nd Royal Hungarian Army in Winter Campaign, at the River Don in 1943 is measurable and the clothing worn did not meet the expectations.

The 2nd Hungarian Army in the Winter Campaign and military organization has been assigned to very difficult major tasks. The large number of freeze damage is also due to the clothing of soldiers, according also to that our results did not meet the criteria of the extreme variability of the weather conditions and the thermal comfort.

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