

## Assessment of Clothing Permeation Using an Instrumented Heated and Sweating Manikin

**Bernard Warmé-Janville**  
Centre d'études du Bouchet  
BP n° 3, F-91 710 Vert le Petit  
France

**Jean-Yves Pélécand**  
Centre d'études du Bouchet  
BP n° 3, F-91 710 Vert le Petit  
France

ADP012445

### Summary

The body protection of soldiers working in extreme climatic or tropical conditions requires a particular protective clothing that allows them to perform their mission. Protective suits, increasing insulation and reducing sweat evaporation, decrease their physiological capabilities and their ability to work in hot and wet environment. The instrumented thermal and sweating manikin is fitted to simulate human sweating characteristics. In addition to the measurement of vapour permeation, it also allows to quantify precisely the maximal sweat transfert of protective clothing. This measurement allows to underline the part of global insulation due to the wet exchange of the worn protective equipment. Different concepts of clothing are tested with the thermal and sweating instrumented manikin, in comparison with the sweat flow of the naked manikin skin : butyl, battle dress, NBC protective suit (charcoal foam and fabric), and different models of new generation permeable clothing. The test protocol allows to determine quickly the efficiency of sweat permeation through protective equipment. The sweat evaporation is strongly limited by the butyl suit, but in comparaison with naked manikin, NBC permeable protective clothing allow significant flow rate. This evaluation is a complementary and obligatory preliminary step before physiological test on human in laboratory and on the field.

### 1. Introduction

The body protection of soldiers working in extreme climatic or tropical conditions requires a particular protective clothing that allows them to perform their mission. Protective suits decrease their physiological capabilities and their ability to work in hot and wet environment, according to the increasing of insulation and the reducing of sweat evaporation.

### 2. Method

Within the frame of a CEB contract, an instrumented heated and sweating manikin has been designed and manufactured by the French company FENZY to simulate human sweating characteristics. In addition in addition to the measurement of the vapour permeation, it also permits to quantify the maximal sweat transfer through protective clothing. This measurement allows to point out the wet exchange to the global insulation of the worn protective equipment.

A thermal instrumented manikin, with humid skin which evaporates clean water, is heated and regulated by desktop computer. The part of water evaporated through the artificial body is continuously weighted and monitored by the computer. Internal and skin temperatures are continuously measured (16 thermal sensors).

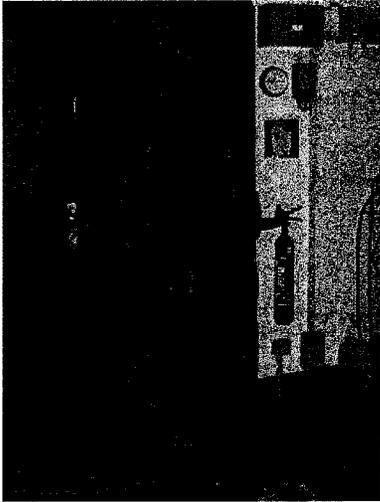


Figure 1: The instrumented thermal and sweating manikin.

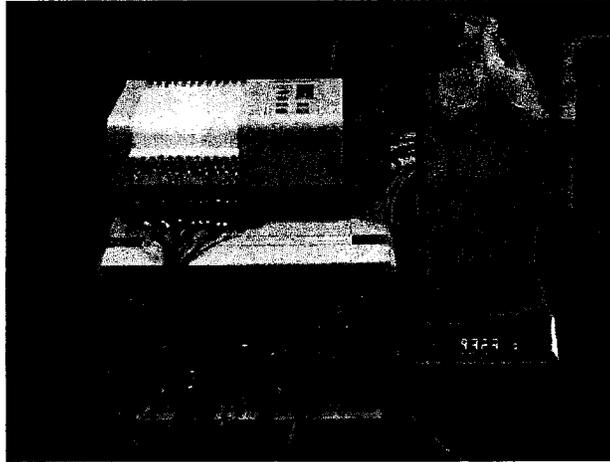


Figure 2 : The command system

#### Technical parameters

- Climatic Chamber	
Ambient temperature	24±0.5 °C
Humidity	60±5%
Wind speed	0.30 m/s-2.0 m/s
- Manikin	
max heating power	400 W/m <sup>2</sup>
Simulated skin temperature	34±0.5°C

#### Measurements

Heating power (Watts)
Heat flow (W/m <sup>2</sup> )
Total evaporated water (g)
Sweat rate (g/h)
Internal and skin temperature (°C)
dry and wet Insulation (Clo)

### 3. Results

Different concepts of clothing are tested with the heated and sweating instrumented manikin, in comparison with the sweat flow naked manikin skin : microporous and impermeable (PVE) protective clothing , battle dress, NBC protective suit (charcoal foam and fabric), and other models of new generation permeable clothing.

situation	Nude dry manikin	Nude wet manikin	battle dress	NBC type MP	NBC type S	NBC type L	PVE suit
Insulation (clo)	1.48+0.02	0.40+0.01	0.53+0.03	0.66+0.04	0.60+0.07	0.54+0.02	1.05+0.08
Heating power (W/m <sup>2</sup> )	57+6	216+11	90+6	80+2	83+6	89+2	58+4
Evaporated Water (g/h)	0.0	1180± 15	162± 11	159± 1.5	375± 111	425± 17	99± 5

Table 1 : Insulation and simulate evaporated sweat through the clothing.  
(First results)

#### 4. Conclusion

This test protocol allows determining quickly the level of sweat permeation through protective equipment. The sweat evaporation rate is strongly limited by the PVE protective suit, but in comparison with the naked manikin, NBC permeable protective clothing allow the highest flow rate and impermeable suit provides condensation on internal layer. These first results need to be continued.

This type of evaluation is a complementary and obligatory preliminary step before physiological test on human in laboratory and on the field.

#### 5. References

[1] A.P. Gagge, A.C. Burton, H.C. Bazett, A practical system of units for the description of the heat exchange of man with his environment. *Science*, 1941, 94, 2445, 428

[2] C. Boutelier, M. Loncle, Conception et réalisation d'un mannequin pour l'évaluation des propriétés thermiques des vêtements. *Conf. internationale sur les aspects Biophysiques des vêtements de protection*. CRSSA-Lyon, pp. 199-204, Juillet 1983.

[3] ASTM 1291-90 Standard test method for measuring the thermal insulation using a heated manikin.