## VAPOUR RESISTANCE OF TEXTILES: VISUALIZATION AND MEASUREMENT

Xavier Berger, Hayet **Sari** and Michel Schneider
CNRS - Laboratoire de Thermodynamique - UNSA
Rue **A.** Einstein, Sophia Antipolis, 06560 Valbonne, France

**INTRODUCTION**
The diffusion of water vapour runs through a confined air layer between skin and fabric, the textile itself, and an outer boundary layer (Spencer-Smith, 1977). Measuring the resistance of textiles needs a precise determination of the two air layer resistances, which is difficult to succeed. Going back to the theory of the diffusion process, using a holographic method and a micro-weighing technique, these three resistances were observed and measured. The agreement between theory and observations leads to useful comments.

METHOD
In the ambient atmosphere, Fick's law which governs the process of diffusion leads to Stepban's equation (Holman, 1986). The flow rate of evaporation **m,** and the resistance of the textile **Res** have the following expressions:

$$m = (DA \, M \, P)/(R \, T \, \delta x) * Ln((P\text{-}P_{w2})/(P\text{-}P_{w1})) \tag{1}$$

$$Res = (R \, T \, \delta x)/(D \, M \, l) \tag{2}$$

D is the proportionality constant-diffusion coefficient, **A** the area of transfer, M the molecular weight of the gas, R the universal gas constant, T the Kelvin temperature, P the atmospheric pressure, l the latent heat of vaporization, $P_{w2}$ and $P_{w1}$ the vapour pressures at the ends of the layers (equivalent thickness $\delta x$, Fig. 1) These relations are valid when a linear relation exists between vapour pressure and solvent
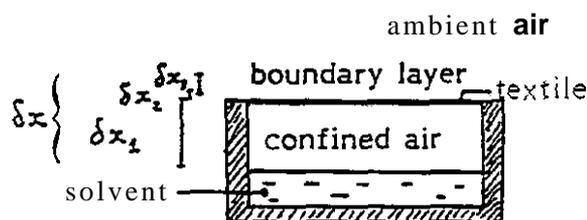


Fig. 1: Schematic setup, showing textile and boundary layers.

concentration, i.e. when the porosity of the textile is not negligible, and when no physico-chemical properties of the textile interfere. Then, the nature of the textile does not intervene, and $\delta x$ *can* be measured by using any arbitrary solvent. An apparatus was build, constituting of **a** shallow dish, covered with textile layers held by flat rings of **0.5** mm thick. The experiment was carried out at ambient air temperature and pressure, still air, and with benzene in place of water. Weighing the apparatus gives two indications: $\dot{m}$ and $\delta x_1$ (confined air layer). Elsewhere, a visualization was got by using a holographic bench, a transparent apparatus to let **the** horizontal laser radiation cross through, and a hologram photographed before installing the apparatus.

RESULTS
$1/\dot{m} = f(\delta x_1)$ is a linear relation. The abscissa at origin corresponds to $\delta x_2 + \delta x_3$, equivalent air thicknesses of the textile and the outer layer (Fig. 2). Using first one fabric layer and subsequently two or three leads to parallel and equidistant lines in Fig. 2. $\delta x_2$ is got from the distance on the **x axis** between two lines. The slope of the lines is in accordance with the theory .01377 for the measurements, in comparison with .0140 for equation 1. The same slope, parallel lines and equidistance were obtained with cotton and silk in place of polyester. Identical equivalent air thicknesses of textiles were obtained when

using water instead of benzene, but the experiment took 3 days. Elsewhere the fringes of interference in the holographic visualization show variations in inclinations and in continuation when crossing the textile. In Fig. 3 are visible the stable confined and outer air layers, got with evaporation of cyclo-hexane. Water vapour shows turbulent flows, so thicknesses of $x_i$ are difficult to be measured.

VAPOUR TRANSFER THROUGH **FABRIC**
polyester — 1,2,3 layers



$y = 0.01377 \ x + 0.1151 + (0,1,2) \ 0.02237$

external boundary layer + one fabric layer:
7.23 mm + 1.12 mm
one fabric layer + 0.5 mm

solvent
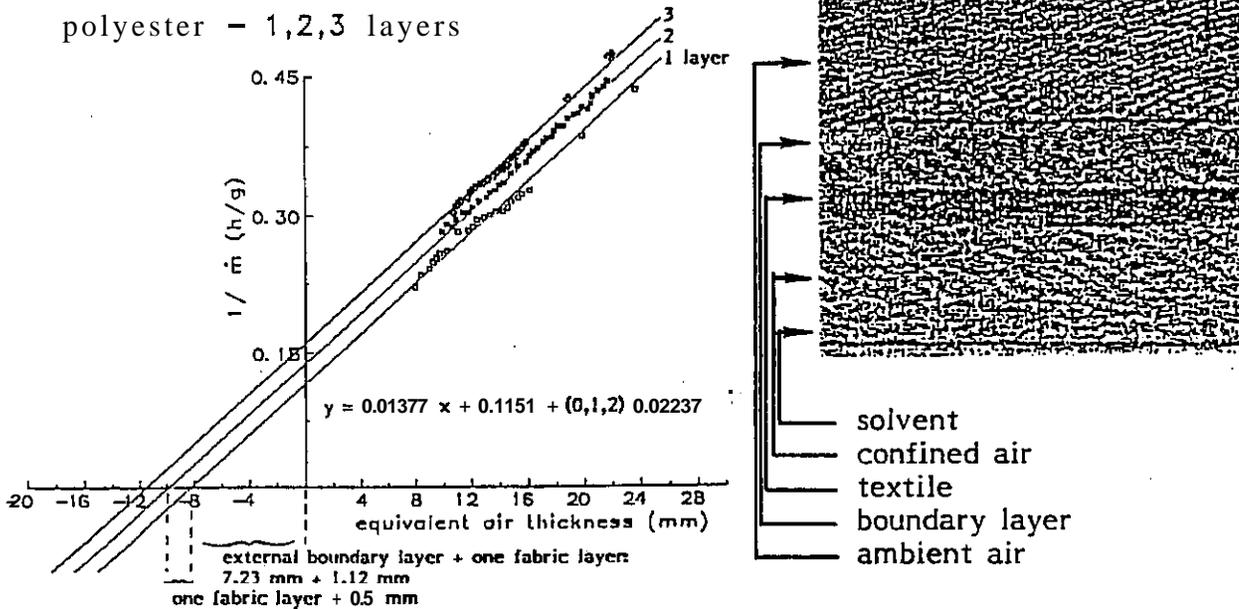confined air
textile
boundary layer
ambient air

Fig. 2 $1/\dot{m} = F(x_1)$ Evaporation of benzene; micro-weighing.

Fig. 3 Fringes of interference got with evaporation of cyclo-hexane; holography.

CONCLUSION

The simplicity of the technique allows measurements which can be compared with theoretical results. To get this, no gradient of temperature exists between the evaporating liquid surface and the environment, the confined and outer air layers are stable. These details are not kept with the dish method. Moreover, this micro-weighing technique is less expensive than a skin model method (Dolhan and Farnworth, 1985): the phenomenon is only diffusive, not perturbed by any permeo-dynamical air circulation due to a forced air circulation above the textile, or by any wick or resistive contact effect with a hot humid plate. Holography convinces to visualize the resistances of air layers and fabric, turbulences, disturbances from furs, permeo-dynamical air renewals. Micro-weighing has confirmed the diffusion process as independent of the nature of the textile (McCullough et al., 1989), as far as no physico-chemical reactions to water vapour (Farnworth et al., 1990) and a non-negligible porosity (uncoated textiles) exist. Using benzene could appear surprising, but was an easy way to prove the accordance between theory and measurements. Moreover, benzene allows a **6.5** times greater flow rate of evaporation, a heavy vapour making stable air layers. Finally, it remains that air renewals of the confined air and air layer resistances are generally more important than the textile resistance. The textile is mainly an interface to create and maintain air layers around the body.

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