Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Polymer Testing 25 (2006) 709–716
POLYMER TESTING
www.elsevier.com/locate/polytest

Test Method

Sweating guarded hot plate test method

Jianhua Huang

School of Textile and Material, Wuhan University of Science and Engineering, Wuhan, Hubei 430073, China

Received 19 January 2006; accepted 12 March 2006

Abstract

The sweating guarded hot plate instrument, simulating the heat and moisture transfer from the body surface through clothing material to the environment, was designed for the measurement of thermal resistance and water vapor permeability of fabrics, relating to comfort characteristics of the garment. A number of factors govern the accuracy of the measurement, namely air velocity, leading edge effect, bubbles and wrinkles, membrane effect and so forth. The sweating guarded hot plate apparatus provides reproducible and repeatable results. This steady-state testing equipment, however, needs to be redesigned to assess the characteristics of fabric to transport heat and moisture under transient conditions.

Keywords: Sweating guarded hot plate; Test method; Thermal resistance; Water vapor permeability; Thermal comfort

1. Introduction

The heat and water vapor transfer properties of textile fabrics are dominating determinants of thermal comfort of the wearer. The thermal resistance of a fabric represents a quantitative evaluation of how good the fabric provides thermal barrier to the wearer. The water vapor resistance of the fabric is a critical property for a clothing system which must maintain the human body at thermal equilibrium for the wearer. Clothing, an intermediate medium between the skin and the ambient conditions, with high water vapor permeability allows the human body to provide cooling due to evaporation. At high activity levels or in hot environments, the thermal resistance value alone is inadequate for characterizing and comparing clothing systems. Evaporation of sweat becomes an important avenue of heat loss. In addition, high water vapor permeability is of importance in cold environments to minimize water accumulation in clothing, which leads to an increasing sense of discomfort. Therefore, both the thermal resistance and water vapor resistance of fabrics are required to assess the heat exchange of the human body with the environment, and are related to human perceptions of comfort [1–4].

The guarded hot plate instrument, invented in 1898, is now undoubtedly recognized as the most accurate technique for determining the thermal conductivity of insulation materials [5,6]. The sweating guarded hot plate is able to simulate both heat and moisture transfer from the body surface through the clothing layers to the environment. It measures both the thermal resistance (insulation value) and water vapor resistance of fabrics [7].

E-mail address: wuseksu@wuse.edu.cn.

0142-9418/$ - see front matter
doi:10.1016/j.polymertesting.2006.03.002

2. Fundamental aspects

The general relation dictating the flow of moisture vapor through an equilibrium system is given by Fick's diffusion law [8–10]:

$$\frac{Q}{A \times T} = \frac{\Delta C}{R_d} \tag{1}$$

where Q is the mass of water vapor passing through the system (g), A the diffusion area (m^2), T the diffusion time (s), ΔC the water vapor concentration difference (g/m^3), and R_d the diffusion resistance (s/m).

As for most woven or non-woven permeable fabrics, the diffusion resistance to water vapor transfer is not dependent on the relative humidity on both sides of the fabric. The water vapor transmission rate is proportional to the vapor concentration difference. Since the sweating hot plate is a calorimetric method, eq. (1) can be expressed by:

$$\frac{Q}{A \times T} = \frac{\Delta P}{R_{et} \times \lambda} \tag{2}$$

where ΔP is the water vapor pressure gradient (kPa), R_{et} the evaporative resistance (m^2 kPa/W), and λ the heat of vaporization of water at the plate surface temperature, J/g.

3. Test method

In accordance with ISO 11092, the thermal and water vapor resistance of textiles under steady-state conditions was measured by using the sweating guarded hot plate [11]. As schematically shown in Fig. 1, the apparatus consists of the measuring unit, temperature controller and water supply unit. The measuring unit, see Fig. 2, fixed to a metal block with heating element, is a square porous metal plate with 3 mm thickness. The test section (0.254 × 0.254 m) in the center of the plate is surrounded by the guard heater, which prevents lateral heat leakage from the edges of the specimen. The bottom heater beneath the test section can prevent the downward heat loss from the test section and guard heater section. This arrangement drives heat or moisture to transfer upward only along the specimen thickness direction. A fabric or layered fabric system with a size of 0.508 × 0.508 m (20 × 20 in.) is mounted on the square porous plate that is heated to a constant temperature that approximates body skin temperature (i. e., 35 °C). The plate temperature is measured by the sensor sandwiched directly underneath the plate surface. The electrical power is recorded. The whole apparatus is housed in a chamber so that the environmental conditions can be carefully controlled. For the determination of thermal resistance of the sample, the air temperature is set to 20 °C and the relative humidity is controlled at 65%. Air speed generated by the air flow hood is 1 ± 0.05 m/s. After the system reaches steady state, total thermal resistance of the fabric is governed by:

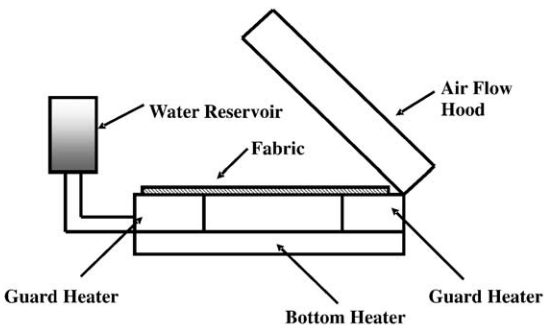

Fig. 1. Schematic diagram of sweating guarded hot plate.

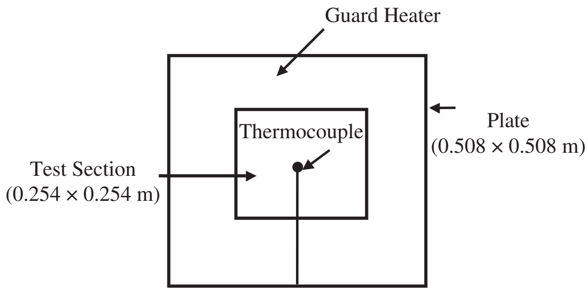

Fig. 2. Top view of measurement unit of sweating guarded hot plate.

$$R_t = \frac{A(T_s - T_a)}{H} \tag{3}$$

where R_t is the total thermal resistance of fabrics plus the boundary air layer (m^2 °C/W), A the area of the test section (m^2), T_s the surface temperature of the plate (°C), T_a the temperature of the ambient air (°C), and H the electrical power (W).

The intrinsic thermal resistance of the fabric (R_f) is obtained by subtracting the thermal resistance of the boundary air layer (R_b) from total thermal resistance. The thermal resistance of this boundary air layer can be measured by performing a test on the bare plate without a sample:

$$R_f = R_t - R_b \tag{4}$$

To measure the evaporative resistance of the sample, distilled water is fed to the surface of the porous plate from a dosing device. The dosing