

# Effects of Body Postures on Clothing Air Gap in Protective Clothing

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## Abstract

Air gaps layer between clothing and wearer's body plays an important role in heat transfer in protective ensembles. The distribution and size of these air gaps are used to determine thermal performance of the protective clothing, which are dependent not only on garment style and fit but also on all kind of shapes of body motions. In this paper a three dimensional (3D) body scanning technique was used to scan the surface of the nude and the dressed that can measure accurately the distribution and size of air gaps between the human body and clothing. In leg-upright, leg-lifting and leg-withdrawing positions that simulated the human motion of running, the clothing air gaps were scanned and measured respectively. A new method for the measurement of air gaps was used, which can reasonably reflect the size between the fabric and the corresponding test sensor. The results show that clothing air gaps are associated with body motions. The clothing air gaps vary with the different postures. And the degree of knee joint flexion affects the deformation of skin and thus the change of air gaps between skin and clothing. The findings can be used to establish heat transfer model to predict thermal performance of protective clothing in motion.

*Keywords:* Air Gaps Layer; Body Posture; 3D Body Scanning; Protective Clothing

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## 1 Introduction

While determining the performance of protective clothing for emergency operations, the primary concern is the protection from thermal hazard. The protective clothing has to reduce heat transfer from the fire to the skin in order to minimize skin burn damage during a flash fire. Laboratory test methods for measuring the thermal protective performance of protective clothing should simulate the heat hazards present at the fire scene as accurately as possible [1]. The study on the performance of thermal protective clothing should not separate wearers from the clothing. However, the previous researches [2-6] almost focused on the performance of protective clothing in upright position and not able to take into account body motions of the wearer in a flash fire.

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In fact, it is not good enough to evaluate the thermal protection of protective clothing by just depending on the materials and the full garment design. The suffered heat hazards of firefighters due to body motions in a fire must be taken seriously. This is because different postures of body motions not only affect the intensity of thermal exposure but also change the air gaps between skin and clothing. The distribution and size of these air gaps plays an important role in heat transfer in protective clothing [7], which can obviously affect the ways of thermal conduction, convection, and radiation from the fire to the body skin [8]. Simultaneously, the firefighter may easily suffer second burn from thermal storage in the protective clothing because of the change of body motions. Of course, the firefighter needs to make a variety of actions responding to an urgent fire. Therefore, full consideration for the effects of the firefighter's motions on protective clothing in a fire is urgent right now.

Although some researchers have measured the air gap layer distribution between protective garments and thermal manikins in the upright position [5, 6], as well as simulated running motion using a thermal-leg system that has only compared different material performance [9], no specific research which measured clothing air gaps in different body motions could be found. Furthermore, the previous measurement of air gaps were based on the average distance between the surface of the nude and the dressed in circumference, which cannot properly reflect the air gap size between the fabric and the corresponding test sensor.

The purpose of this research is to divide the leg movement of running into three body postures and measure air gaps in protective clothing using three dimensional (3D) body scanning technique. The measurement of air gaps has taken into account of the corresponding size between each sensor and clothing. At the same time, the changes of clothing air gaps in different postures of body motions are discussed, which can improve the comfort of protective clothing and help to establish better heat transfer model to predict thermal performance of protective clothing in moving.

## 2 Methods

In this study, the experimental protocol was scanning the surface of nude subject and the dressed respectively using an American TC<sup>2</sup> 3D white light body scanner (NX-16, Textile and Clothing Technology Co., USA). The air gaps of three body postures between the human body and clothing, simulating the leg running, were scanned. And a new method was used to measure the distance between the fabric and the corresponding test sensor.

### 2.1 The Subject and the Garment

The physical data of male subject were as follows: age 28 years, height 176.9 cm, and weight 76.5 kg. Table 1 showed body measurements referred to GB/T5703-1999 basic human body measurements for technological design [10].

The style of experimental sample was a traditional one-piece protective coverall. The fabric was a 100% cotton drill, with a weight of 235 g/cm<sup>2</sup>. The size of the coverall was also included in the Table 1, according to the requirement of standard of GA 10-2002 protective clothing for Firefighters [11].