

Jan 1st, 12:00 AM

# Chemical protective clothing comfort study: thermal insulation and evaporative resistance from fabric to garment

Liwen Wang  
Iowa State University, liwenw@iastate.edu

Jie Yang  
Iowa State University, jieyang@iastate.edu

Rui Li  
Iowa State University, ruili@iastate.edu

Chunhui Xiang  
Iowa State University, chxiang@iastate.edu

Guowen Song  
Iowa State University, gwsong@iastate.edu

Follow this and additional works at: [https://lib.dr.iastate.edu/itaa\\_proceedings](https://lib.dr.iastate.edu/itaa_proceedings)

 Part of the [Fashion Business Commons](#), [Fashion Design Commons](#), and the [Fiber, Textile, and Weaving Arts Commons](#)

Wang, Liwen; Yang, Jie; Li, Rui; Xiang, Chunhui; and Song, Guowen, "Chemical protective clothing comfort study: thermal insulation and evaporative resistance from fabric to garment" (2017). *International Textile and Apparel Association (ITAA) Annual Conference Proceedings*. 174.

[https://lib.dr.iastate.edu/itaa\\_proceedings/2017/posters/174](https://lib.dr.iastate.edu/itaa_proceedings/2017/posters/174)

This Event is brought to you for free and open access by the Conferences and Symposia at Iowa State University Digital Repository. It has been accepted for inclusion in International Textile and Apparel Association (ITAA) Annual Conference Proceedings by an authorized administrator of Iowa State University Digital Repository. For more information, please contact [digirep@iastate.edu](mailto:digirep@iastate.edu).

Chemical protective clothing comfort study: thermal insulation and evaporative resistance from fabric to garment

Liwen Wang, Jie Yang, Rui Li, Chunhui Xiang, and Guowen Song  
Iowa State University, USA

Keywords: chemical protective clothing, thermal comfort, thermal insulation, evaporative resistance

## Introduction

Chemical protective clothing (CPC) is designed to prevent harm to human body and fatalities from the exposure to chemical and biological substances (Raheel, 1994). The critical issue associated with CPC is the conflict between effective protection and wearer's thermal and movement comfort due to its bulky structure and poor permeability of fabric (Shishoo, 2002). Specifically, encapsulated CPC impairing heat and moisture transfer from human body to environment can cause severe thermal discomfort, even heat stress. To evaluate the thermal properties of clothing, thermal insulation ( $R_{ct}$ ) and evaporative resistance ( $R_{et}$ ) have been widely used. However, few research has been done on thermal properties of CPC fabric and garment systematically.  $R_{ct}$  and  $R_{et}$  are critical thermal properties for both CPC fabric and garment. However, the garment  $R_{ct}$  and  $R_{et}$  can be influenced by various factors other than fabric properties, such as garment structure and air gap size (Chen, Fan, Qian, & Zhang, 2004; Li, Zhang, & Wang, 2013). Therefore, the purpose of this study is to investigate the relationship between the  $R_{ct}$  and  $R_{et}$  of textile material used in CPC and that obtained from CPC garment. The finding in this study will help improve the structure design of CPC.

## Method and Analysis

Seven CPC were evaluated in this study: one single layer Nomex<sup>®</sup> woven fabric (common industry workwear) as control; four non-woven w/o coating CPC from Dupont<sup>®</sup> with one for each protection level: A, B, C, and D; and two double-layer (woven shell and nonwoven lining) military CPC. They were denoted as Nomex, A, B, C, D, M-G, M-C, respectively. The  $R_{ct}$  and  $R_{et}$  of fabrics were tested on a sweating guarded hot plate with/without air gap according to ASTM F1868 standard. Two spacers were applied to create 3mm and 6mm air gap under the fabric respectively. A 35-segment Newton-type sweating thermal manikin was used to measure the  $R_{ct}$  and  $R_{et}$  of the garments as per the standard ASTM F2370. The correlations among the  $R_{ct}$  and  $R_{et}$  of fabrics and garment, fabric thickness and air permeability, and air gap thickness were analyzed.

## Results and Discussion

The  $R_{ct}$  and  $R_{et}$  of fabrics without air gap underneath were significantly lower than that of garments, which could be explained by the large amount of air trapped under the bulky garment. Apparent difference was observed for the  $R_{ct}$  and  $R_{et}$  of fabrics and garments among various types of CPC (Fig 1), which is probably because of the different fabric properties, such as

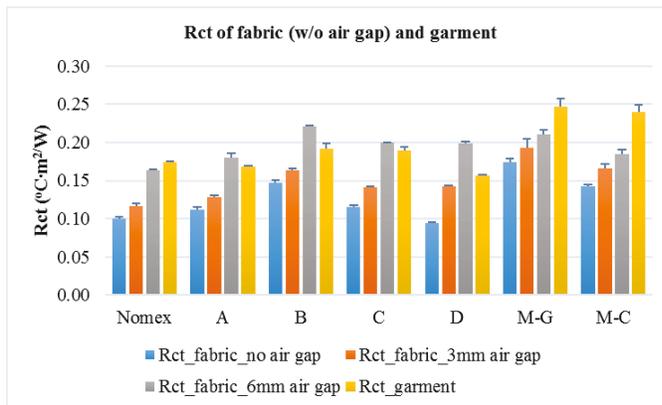


Fig 1. Rct of fabrics and garments

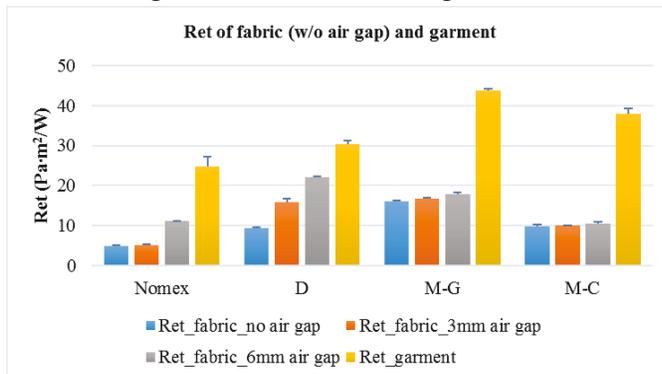


Fig 2. Ret of fabrics and garments (CPC A, B, and C are water vapor impermeable)

to the small sample size.

## Conclusions

The Rct and Ret of CPC fabric are reliable predictor for the Rct and Ret of CPC garments respectively. Air gap contributes significantly to the increase of the Rct of CPC garments and fabrics. Heat dissipation by water vapor transfer through CPC is a complex process and different from other kinds of clothing due to its low permeability or impermeability. Further studies on the influential factors of Ret of CPC garments are needed.

## References

- Chen, Y. S., Fan, J., Qian, X., & Zhang, W. (2004). Effect of garment fit on thermal insulation and evaporative resistance. *Textile Research Journal*, 74(8), 742-748.
- Li, J., Zhang, Z., & Wang, Y. (2013). The relationship between air gap sizes and clothing heat transfer performance. *The Journal of The Textile Institute*, 104(12), 1327-1336.
- Raheel, M. (1994). Chemical Protective Clothing. *Protective Clothing Systems And Materials, 1st edition, Marcel Dekker, Inc., New York*, p39-53.
- Shishoo, R. (2002). Recent development in materials for use in protective clothing. *International Journal of Clothing Science and Technology*, 14(3), 201-215.

thickness and air permeability. Specifically, the extremely high value of Ret for CPC garment A, B, and C than other CPC indicated their water vapor impermeability because of the coating on fabric (Fig 2). The analysis results of Pearson's correlation showed that there was significant, positive correlation between the Rct of fabrics and that of garments ( $p < 0.01$ ), indicating that the Rct of garments could be reliably predicted from that of fabrics. There was a strong but not significant positive correlation ( $r = 0.938$ ) between the Ret of fabrics and that of garments for permeable Nomex, D, M-G, and M-C, which maybe due to the small sample size. A significant positive correlation was found between the Rct of fabric and air gap size, indicating the thicker the air gap, the larger the Rct. However, the Ret of neither fabrics nor garments was found significantly correlated with air gap size, which was inconsistent with previous studies (Chen, 2004). This could be due