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# Thermal Characteristics of the Garment Air-layers by PCM Concentration Changes

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# 상변화물질 농도변화에 따른 의복내 공기층의 열적 특성

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**Abstract**

This study is to determine the effects of PCM concentration on the temperature changes of the air layers of a garment when the environmental temperature changes. The selected PCM was Nonadecane and coated on cotton fabrics with PCM concentrations 10%, 20%, and 30%. The temperature changes of the air layers between fabrics were measured by Human-Clothing-Environment Simulator which measure a dynamic heat transfer. After stabilizing at 34°C for 1 hour, the multi layered garment system were exposed to 5°C or 10°C for 30 minutes and then, exposed to 34°C for 30minutes. The results like following could be obtained. When the environmental temperature changed high to low, temperature of the air layer increased by heating effect of PCM. In the contrast, when the environmental temperature changed low to high, the temperature increase of the air layer was delayed because of cooling effect by PCM. Also, the more concentration of PCM, the bigger the heating effect. Cooling effect showed more clearly at PCM concentration 20%. The temperature differences of the air layers between with PCM fabrics and with non-PCM fabrics were bigger at 10°C than at 5°C. Consequently, though PCM has influenced on the temperature of the air layer by heating and cooling effect, those effects haven't shown in all layers equally. It was shown that the effect of PCM varied according to the layer in the case of multi layered garment system and heat gain as well as heat loss in the outermost layer had to be taken into account.

***Key words:*** Phase change material(PCM), Nonadecane, Concentration, Heating effect, Cooling effect; 상변화물질, 노나데칸, 농도, 발열효과, 흡열효과

## I. Introduction

When heat and moisture transfer efficiently from the body to the environment through the garment so that humans feel satisfaction in the physical, physiological, and psychological aspects, it is said that this kind of wearing situation is 'comfort'. However, if the environmental temperature changes suddenly, keeping comfort becomes a difficult task. At this time, humans will take the sudden change as a thermal impact and feel discomfort. Therefore, the devel-

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opment of intelligent fabrics or garments which can adjust and maintain comfort during a sensible temperature transient is very important and necessary. It is Phase Change Material(PCM) that can help a wearer keep comfort when the environmental temperature changes.

Phase change is a process of going from one physical state to another. PCMs are materials that can absorb, store and release large amounts of energy, in the form of latent heat, over a narrowly defined phase change range, while that material changes state.

Phase Change Materials use chemical bonds to store and release heat. When the melting temperature is attained during a heating process, the phase change from solid to liquid occurs and the PCM absorbs a large amount of latent heat from the surrounding environment. Energy is absorbed by the materal and is used to break down the bonding responsible for the solid structure. This heat is then stored in the PCM and subsequently released in a cooling process starting at the PCM's crystallization temperature. The latent heat will be released to the surroundings when the material cools down. During the entire phase change process, the temperature of the PCM as well as the surrounding substrate remains constant. When the phase change is complete, continued heating/cooling results in a further temperature increase/decrease (Mäkinen, 2006).

A PCM fabric can act as a transient thermal barrier from cold or hot environments. When a PCM fabric is subjected to a hot environment, PCM will absorb this transient heat during the phase change, and it will prevent the temperature of the fabric from rising at the melting point of the PCM. This phase change produces a temporary cooling effect in the clothing layers. In a similar manner, when a PCM fabric is subjected to a cold environment, the PCM releases the stored heat and a temporary warming effect occurs in the clothing layers. This heat exchange produces a buffering effect in clothing layers, minimizing changes in skin temperature. The active thermal insulation effect of the PCM results in a substantial improvement of the garment's thermo-physiological wearing comfort(Ghali et al., 2004).

The best-known PCM is water. In addition to water, more than 500 natural and synthetic PCMs already exist in various forms in nature(Pause, 1995).

Researches on phase change materials have concentrated on the materials such as linear crystalline alkyl hydrocarbons, fatty acids and esters, polyethylene glycols(PEG), quaternary ammonium clathrates and semi-clathrates, hydrated inorganic salts and eutectic alloys.

In these days alkyl hydrocarbons are used exclusively. The alkyl hydrocarbons are chemically stable, non-corrosive, non-toxic, non-hygroscopic and exhibit no supercooling properties. Paraffins are also inexpensive and have a high latent heat per unit weight. They also have disadvantages such as low thermal conductivity, high changes in volume during phase change and flammability(Bendkowska, 2006).

Studies on the effect of PCMs on heat transfer from the body during sensible temperature transient were conducted by many researchers.

Vigo and Frost(1982, 1983, 1985) have incorporated some of these phase change materials into textile fibers and have shown the transitions by differential scanning calorimetry(DSC). Pause(2003) recorded skin temperatures and moisture contents in the microclimate during wearing trials at 21°C, 40%RH. The results showed that cooling effect by heat absorption of the PCM induced a substantial delay in the temperature increase and the delay increased significantly smaller amount of moisture build up in the microclimate.

McCullough and Shim(2006) measured the effect of layers of PCM clothing materials on reducing the heat loss or gain, using an PU foam containing 60% microPCM. The results indicated that the heating and cooling effects lasted approximately 15 minutes and the released heat depended on the number of PCM layers, their orientation to the body and the amount of body surface area covered by PCM garments. Also they conducted an experiment on the effect of PCM-ski ensembles on the comfort of subjects during exercise, and they found no appreciable effect of PCM material on comfort compared to non-PCM ski clothing.

Ghali et al.(2004) analysed the effect of microPCM on the thermal performance of fabric during periodic ventilation. Their results indicated that microPCMs in fabric causes a temporary heating effect when subjected to a sudden environmental change. Li and Zhu(2004) also made the mathematical model of heat and moisture transfer in microPCM textiles. They compared the predictions of temperature changes during combined moisture and temperature transients with experimental measurements and found reasonable agreements.

Most of the PCM that treated in the researches have been octadecane(Choi et al, 2004; Ghali et al., 2004; McCullough & Shim, 2006; Zhang et al., 2006). Octadecane is representative material of commercially available PCM based on paraffin-waxes and microcapsule technology and has also been used in clothes for heating or cooling applications. $T_m$ and $T_c$ of PCM is very important since PCM's thermal insulation effect is dependent on temperature. The closer to body temperature the phase change temperature is, the larger possibility of the occurrence of phase change. $T_m$ and $T_c$ of octadecane is 28.2°C and 25.4°C while $T_m$ and $T_c$ of nonadecane is 32.1°C and 26.4°C(Mäkinen, 2006). From a practical point of view, nonadecane is a more efficient PCM. Nevertheless, for there is no any research about nonadecane, it neeeds to study about that.

The garments made with PCMs will keep a person warm longer than conventional insulations when worn in cold environments. However, in order for PCMs to improve the thermal comfort characteristics of a clothing ensemble in a cold environment, they must produce enough heat in the garment. The efficiency of these effects and their duration are mainly dependent on the thermal capacity of the PCM and, hence, the applied PCM quantity. Consequently, the effects of PCM concentration of the clothing ensemble needs to be examined(Bendkowska, 2006).

Therefore, in this study, it is to investigate the effects of PCM concentration on the air layers of the garment system using nonadecane. When a garment system is composed of multi layered, all layers wouldn't be affected by PCM. In a condition which the environmental temperature changes from high to low and the opposite, it is to determine the effects of PCM concentration on the temperature changes of the air layers of a garment by Human-Clothing-Environment Simulator which measure a dynamic heat transfer.

## II. Materials and Methods

100% cotton fabric(thickness 0.48mm, weight 275g/m$^2$) was treated with PCM by Shillananotech Inc. at three different levels. Coating mixture concentration, the ratio of microcapsule to binder, were 1:9(10%), 2:8 (20%) and 3:7(30%). The selected PCM was Nonadecane($C_{19}H_{40}$, $T_m$ 32.1°C, $T_c$ 26.4°C)(Mäkinen, 2006) and the physical properties of the fabric treated with PCM are shown in <Table 1>.

Human-Clothing-Environment(HCE) Simulator developed by Functional Texitle System Research Lab in Yonsei University was used for the tests(Fig. 1)(Kim et al., 2003). HCE simulator consists of two chambers which provide warm and cold environments and a testing part which includes a hot plate and acryl rings for attaching sensors and fabrics. Temperature of the hot plate was 34±0.5°C. Cotton fabrics untreated and treated with microPCMs composed 4 layers of a garment and the 1st layer was the nearest layer to the hot plate(Fig. 2).

The temperature changes of the air layers between fabrics were measured every 15 seconds and presented in a graph by the average of three tests. After stabilizing at 34°C for 1 hour, the multi layered garment system were exposed to 5°C or 10°C for 30 minutes and then, exposed to 34°C for 30 minutes.

**Table 1. Characteristics of specimen**

| Specimen | Fiber Content(%) | Finish | PCM Conc.(%) | Thickness (mm) | Weight (g/m$^2$) | Add-on (%) |
|---|---|---|---|---|---|---|
| Cotton with PCM | Cotton (100) | Nonadecane(10~15μm), Binder(acryl, 250nm), Knife Coating(150yard/m, 120°C) | 10 | 0.49 | 297.1 | 8.0 |
| | | | 20 | 0.51 | 328.0 | 19.2 |
| | | | 30 | 0.52 | 343.6 | 24.7 |

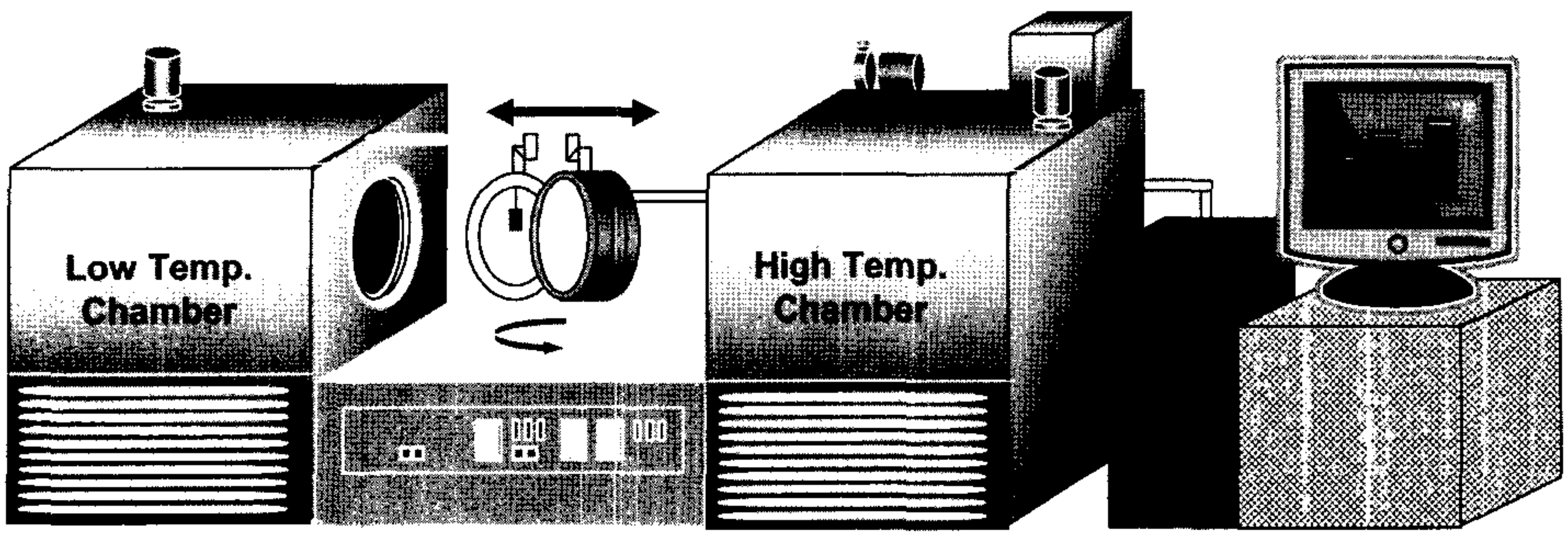
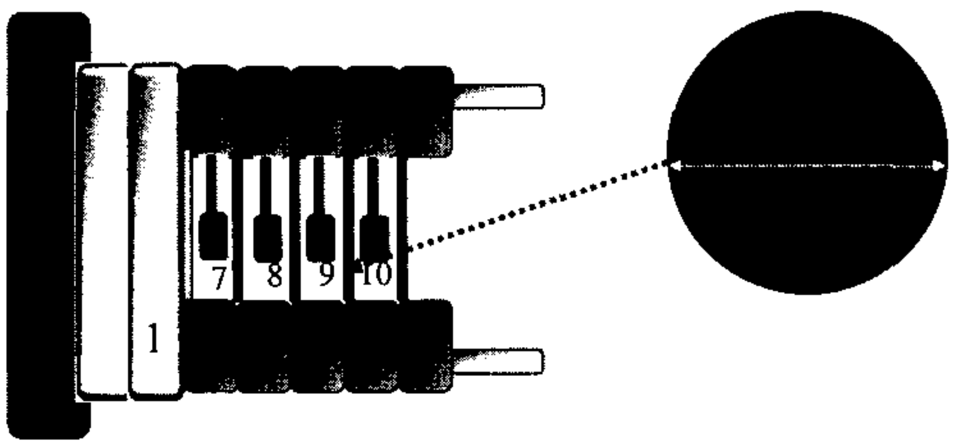



**Fig. 1. Human-clothing-environment(HCE) simulator.**




1 : Hot Plate
2, 3, 4, 5, 6 : Frames for Sensors and Test Fabrics
7, 8, 9, 10 : Temperature Sensors

**Fig. 2. Sensors and test fabrics in the garment system.**

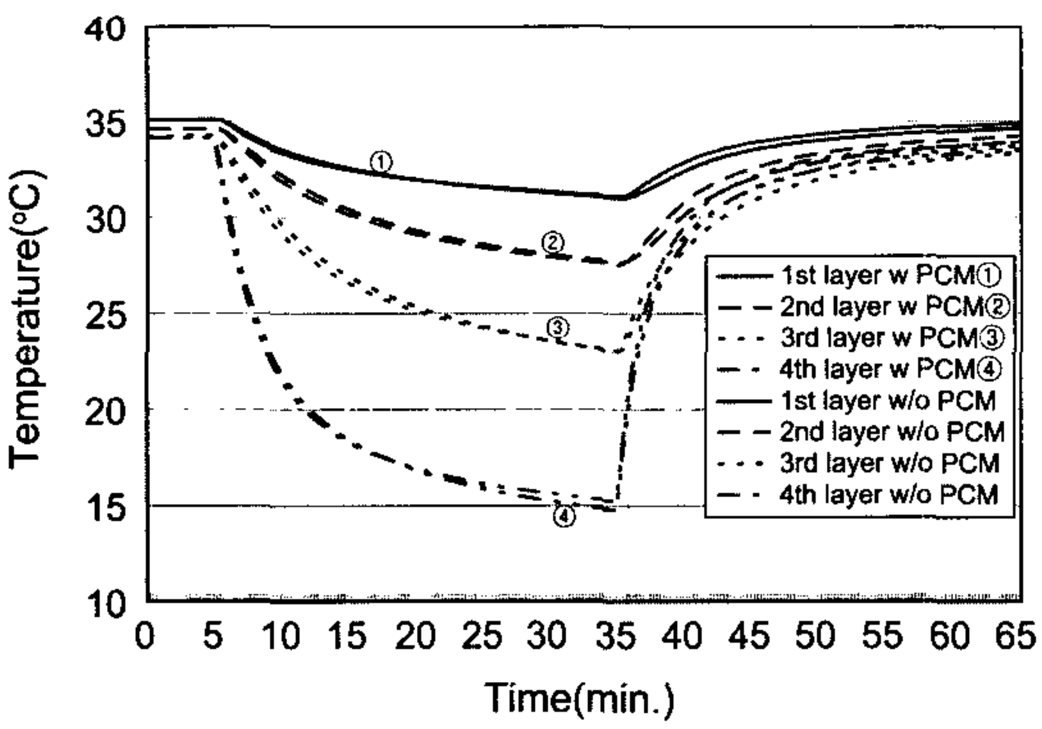



**Fig. 3. Temperature changes of the air layers of a garment at PCM conc. 10%(environmental temperature changes : 34°C→5°C→34°C).**

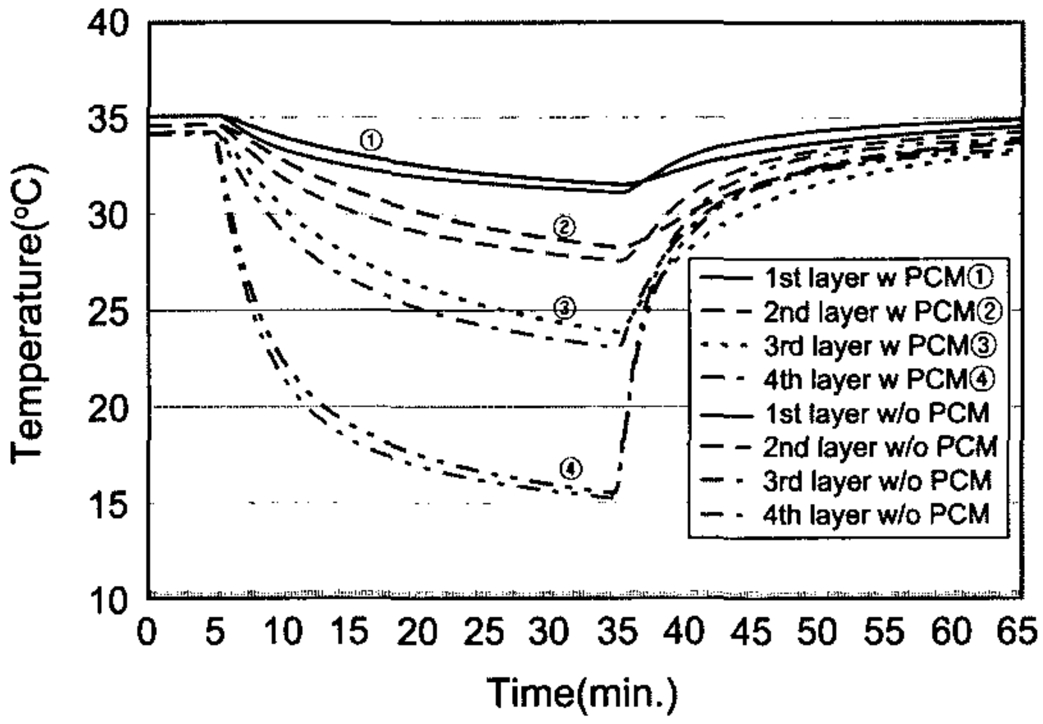



**Fig. 4. Temperature changes of the air layers of a garment at PCM conc. 20%(environmental temperature changes : 34°C→5°C→34°C).**

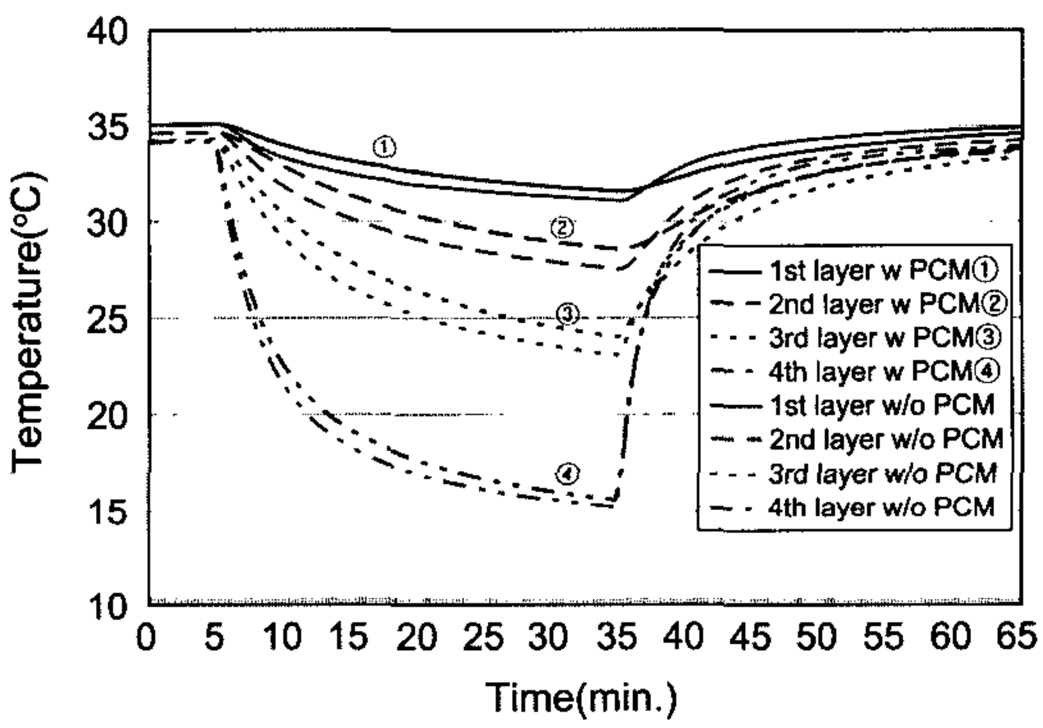



**Fig. 5. Temperature changes of the air layers of a garment at PCM conc. 30%(environmental temperature changes : 34°C→5°C→34°C).**

## III. Results and Discussion

### 1. Heating Effect by PCM

To examine the effects of PCM on the air layers, the temperature changes of the air layer in a garment system were measured as the environment condition changed from high temperature(34°C) to low temperature(5°C). As a result, at 10% concentration, there was no big differences between the air layers with PCM fabrics and the ones with non-PCM fabrics(Fig. 3).

In the case of 20%<Fig. 4> and 30%<Fig. 5>, the temperature of the air layers with PCM fabrics was higher than the temperature of the air layers with non-PCM fabrics. This can be explained as heating effect by PCM. Changing liquid into solid and releasing latent heat around 26.4°C which is a crystallization point of nonadecane, PCM would increase the temperature of the air layer. The phenomenon results in the temperature differences between the air layers with PCM fabrics and with non-PCM fabrics.

PCM did not have influence on all air layers equally. The temperature differences between the air layers with PCM and the ones with non-PCM were not the same(Fig. 4 and 5). The temperature differences of the 1st and the 4th air layer were smaller than the ones of the 2nd and the 3rd air layer. Considering that the temperature of the air layer continued to display over 31°C, it can be conjectured that PCM in the 1st fabrics did not occur the phase change and stayed in the liquid state even when the garment system exposed to the cold environment. However, the temperature of the 1st air layer with PCM showed to be higher than the one with non PCM due to heat insulation by the released heat by PCM of the 3rd and 4th fabrics. The temperature differences were also small in the 4th air layer. Even though PCM in the 4th fabric released heat through the phase change around at the crystallization temperature, the temperature differences were not so big because the layer was the outermost layer and a portion of the released heat would be lost to the low temperature environment.

Comparing <Fig. 3, 4 and 5>, it seems obvious that the higher concentration of PCM, the higher temperature differences of the air layers. It can be known that the more concentration of PCM, the greater heating effect. These contents are summarized into <Table 2>. It can be found that the more concentration of PCM, the bigger average and maximum temperature differences between the air layers with PCM fabrics and the ones with non-PCM fabrics. When the concentration was higher, the time of the maximum temperature differences showed to be later because there was more PCM in the fabric.

The temperature changes of a garment's air layers were also measured as the environment condition was changed from high temperature(34°C) to low temperature(10°C). The results are graphed in <Fig. 6, 7 and 8>.

The test results shown in <Fig. 6, 7 and 8> indicate similar trends that the temperature of the air layers did not display distinct differences between with PCM and with non-PCM at PCM concentration 10% while it showed outstanding differences at 20% and

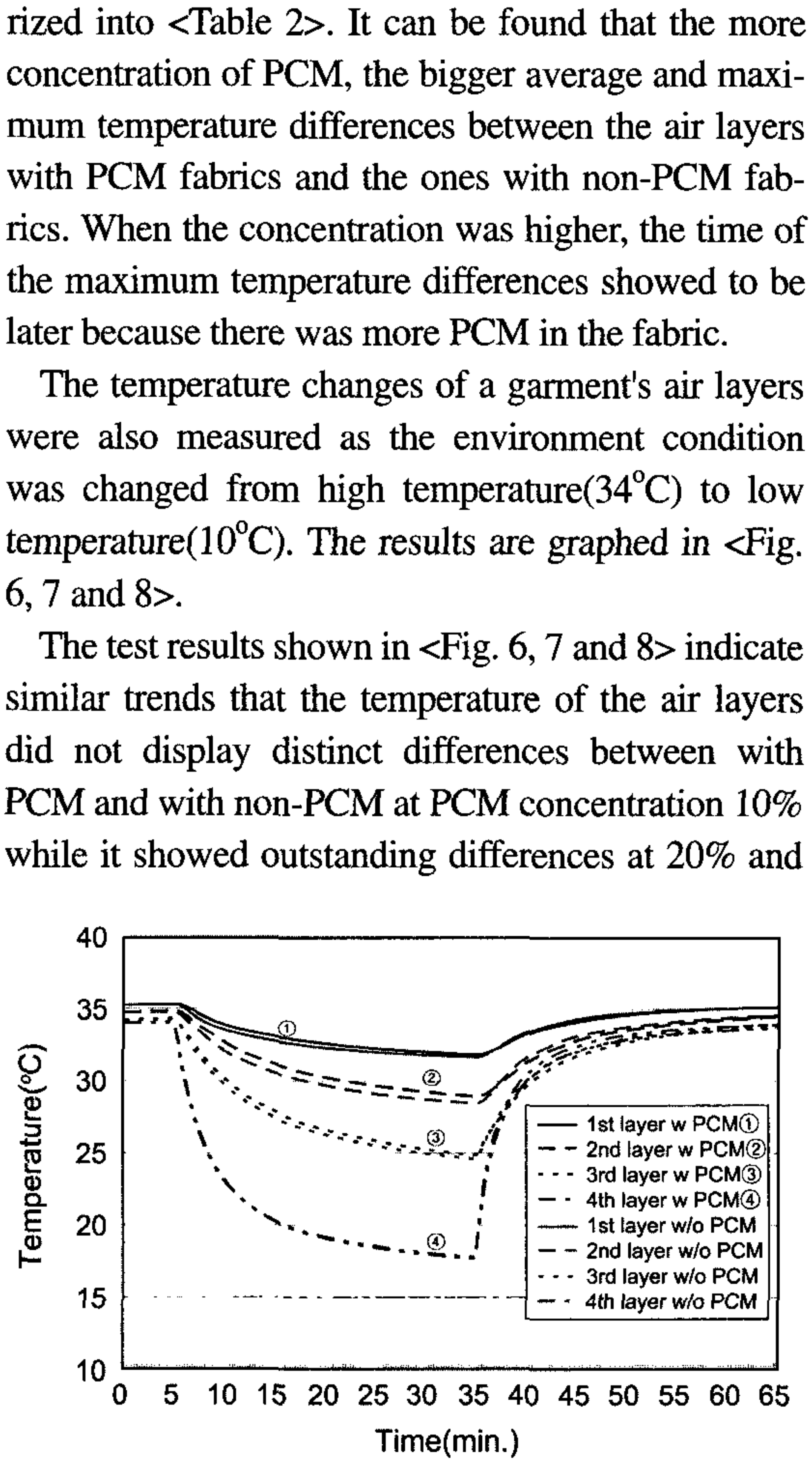



**Fig. 6. Temperature changes of the air layers of a garment at PCM conc. 10%(environmental temperature changes : 34°C→10°C→34°C).**

**Table 2. Temperature differences of the air-layers in a garment system according to PCM concentrations(environmental temp. change : 34°C→5°C)**

| | | 1st layer | | | 2nd layer | | | 3rd layer | | | 4th layer | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% |
| maximum temp. difference* | temp.(°C) | 0.19 | 0.68 | 0.69 | 0.34 | 1.08 | 1.24 | 0.56 | 1.30 | 1.37 | 0.63 | 0.90 | 1.06 |
| | time**(min.) | 4.75 | 6.75 | 6.75 | 4.50 | 9.75 | 12.25 | 4.50 | 8.5 | 8.5 | 1.75 | 2.75 | 2.75 |
| average temp. difference*(°C) | | 0.03 | 0.52 | 0.57 | 0.20 | 0.86 | 1.03 | 0.22 | 1.04 | 1.12 | -0.03 | 0.57 | 0.69 |
| time** when a temp. difference* begins to be over 0.1°C(min) | | 1.25 | 0.75 | 1.00 | 1.00 | 0.75 | 0.75 | 0.25 | 0.25 | 0.25 | 0.00 | 0.00 | 0.00 |

*temp. difference=temperatures of the air-layers with PCM treated fabrics-temperatures of the air-layers with non-PCM fabrics
**time : lapsed time since an environmental temperature has changed to 5°C

30%.

As the environment temperature was higher, the temperatures of the air layers were greater than the ones at 5°C. The less extreme the environmental temperature, the more effective the insulation becomes.

Even if all of the fabrics in a garment system were treated with PCM, not all of the PCM would go through phase changes when the garment system went from an warm environment to a cold environment. The PCM closest to the body(hot plate) will probably remain close to skin temperature and stay in the liquid state.

To the contrary, PCM in the 4th fabric layer will get cold and solidify, thus producing some heat but, the heat would be transferred to the outside. It is the reason that the 1st and 4th air layers showed smaller temperature differences than the 2nd and the 3rd air layers.

The temperature differences between with PCM fabrics and with non-PCM fabrics tended to be proportional to the concentration of PCM, similar to the results of 5°C(Table 3).

At the environment temperature 5°C, regardless of PCM concentrations, the temperature differences between with PCM and with non-PCM were highest in the 3rd air layer and, at 10°C, they were in the 2nd air layer.

## 2. Cooling Effect by PCM

As the environmental temperature changes low (5°C or 10°C) to high(34°C), the temperature of the air layer with PCM fabrics increased more slowly and showed to be lower(Fig. 3-8).

At 10% concentration<Fig. 3>, it was difficult to find out the heating effect by PCM but was easy to look up the cooling effect. It is thought that the 1st fabric layer hasn't experienced the phase change

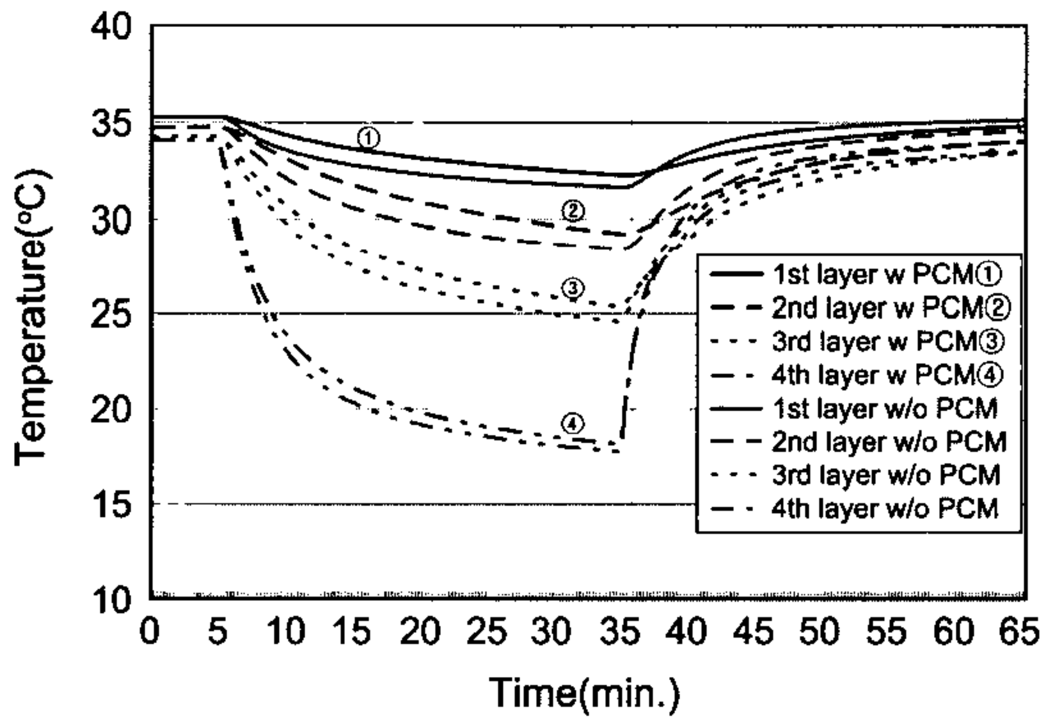



**Fig. 7. Temperature changes of the air layers of a garment at PCM conc. 20%(environmental temperature changes : 34°C→10°C→34°C).**

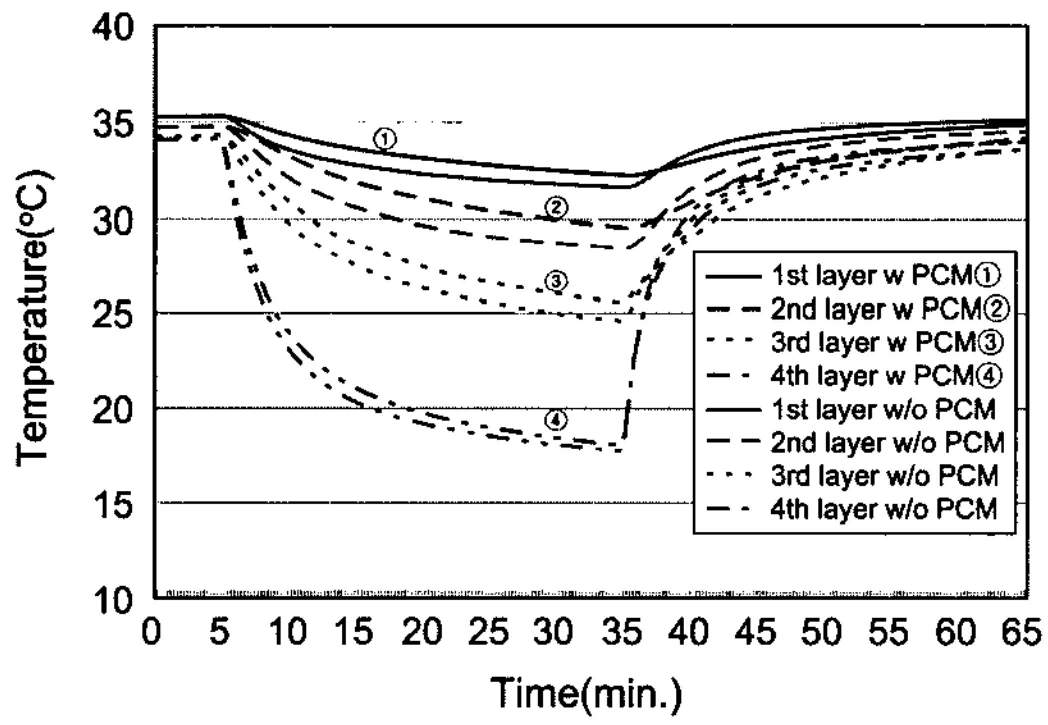



**Fig. 8. Temperature changes of the air layers of a garment at PCM conc. 30%(environmental temperature changes : 34°C→10°C→34°C).**

**Table 3. Temperature differences of the air-layers in a garment system according to PCM concentrations(environmental temp. change : 34°C→10°C)**

| | | 1st layer | | | 2nd layer | | | 3rd layer | | | 4th layer | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% |
| maximum temp. difference* | temp.(°C) | 0.36 | 0.84 | 0.82 | 0.60 | 1.21 | 1.37 | 0.45 | 1.09 | 1.23 | 0.26 | 0.88 | 0.93 |
| | time**(min.) | 4.25 | 6.75 | 6.75 | 7.5 | 12.25 | 12.25 | 5.50 | 10.75 | 10.75 | 2.00 | 3.25 | 3.50 |
| average temp. difference*(°C) | | 0.27 | 0.71 | 0.70 | 0.52 | 0.98 | 1.17 | 0.34 | 0.87 | 1.03 | -0.03 | 0.62 | 0.57 |
| time** when a temp. difference* begins to be over 0.1°C(min) | | 0.00 | 0.75 | 0.75 | 0.25 | 0.75 | 0.75 | 0.50 | 0.50 | 0.50 | 0.50 | 0.00 | 0.25 |

*temp. difference=temperatures of the air-layers with PCM treated fabrics-temperatures of the air-layers with non-PCM fabrics
**time : lapsed time since an environmental temperature has changed to 10°C

**Table 4. Temperature differences of the air-layers in a garment system according to PCM concentrations(environmental temp. change : 5°C→34°C)**

| | | 1st layer | | | 2nd layer | | | 3rd layer | | | 4th layer | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% |
| maximum temp. difference* | temp.(°C) | 0.49 | 0.69 | 0.65 | 0.66 | 1.07 | 0.96 | 0.84 | 1.19 | 1.01 | 0.97 | 0.99 | 0.71 |
| | time**(min.) | 3.75 | 9.00 | 8.00 | 4.25 | 8.25 | 7.25 | 3.75 | 7.25 | 7.25 | 2.00 | 5.50 | 5.75 |
| average temp. difference*(°C) | | 0.33 | 0.47 | 0.43 | 0.43 | 0.73 | 0.60 | 0.53 | 0.83 | 0.61 | 0.59 | 0.72 | 0.41 |
| time** when the temp. of the 4th layer begins to be over the temp. of the 3rd layer(min) | | | | | | | | | | | 3.50 | 3.25 | 3.00 |

*temp. difference=temperatures of the air-layers with PCM treated fabrics-temperatures of the air-layers with non-PCM fabrics
**time : lapsed time since an environmental temperature has changed to 34°C

**Table 5. Temperature differences of the air-layers in a garment system according to PCM concentrations(environmental temp. change : 10°C→34°C)**

| | | 1st layer | | | 2nd layer | | | 3rd layer | | | 4th layer | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% | 10% | 20% | 30% |
| maximum temp. difference* | temp.(°C) | 0.16 | 0.66 | 0.62 | 0.34 | 1.03 | 0.95 | 0.39 | 1.04 | 0.97 | 0.56 | 0.96 | 0.87 |
| | time**(min.) | 3.50 | 8.75 | 8.75 | 4.75 | 9.50 | 9.00 | 5.00 | 6.50 | 6.50 | 1.50 | 4.50 | 4.75 |
| average temp. difference*(°C) | | 0.06 | 0.42 | 0.36 | 0.17 | 0.68 | 0.56 | 0.24 | 0.73 | 0.61 | 0.35 | 0.64 | 0.58 |
| time** when the temp. of the 4th layer begins to be over the temp. of the 3rd layer(min) | | | | | | | | | | | 3.50 | 3.25 | 3.50 |

*temp. difference=temperatures of the air-layers with PCM treated fabrics-temperatures of the air-layers with non-PCM fabrics
**time : lapsed time since an environmental temperature has changed to 34°C

since the melting temperature of nonadecane is 32.1°C. Changing solid phase to liquid phase and absorbing latent heat in the 2nd fabric layer, PCM began to delay the temperature increase of the 2nd air layer after 2-3 minutes exposure to high temperature environment. Temperature differences between with PCM fabrics and with non-PCM fabrics are presented in <Table 4 and 5>.

Interestingly, the temperature of the 4th air layer was higher than the one of the 3rd air layer since 3-3.5 minutes. In <Fig. 3>, as the garment system is exposed to 34°C, it can be seen that the temperature change in the air layer begins from the 4th air layer and proceeds in the order of the 3rd, 2nd, 1st air layer. The high temperature of the 4th air layer seems to originate from the fact that the 4th air layer is the outermost layer and gains heat from outer environment.

As the temperature difference between the air layer and environment is small, the results of 10°C showed smaller the maximum and average temperature differences and a shorter time which the maximum temperature difference displayed, in comparison with the results of 5°C.

## IV. Conclusions

In order to investigate the heating effect and cooling effect by PCM concentration changes, the temperatures of the air layers were measured using the HCE simulator and the conclusions as follows were obtained.

1. When the environmental temperature changed from high to low, changing liquid phase to solid phase and releasing heat, PCM made the temperature of the air layer increase. On the contrary, when the environmental temperature changed from low to high, changing solid phase to liquid phase and absorbing heat, PCM delayed the temperature increase of the air layer.

2. It was founded that the more concentration of PCM, the bigger the heating effect. Cooling effect

showed more clearly at PCM concentration 20% .

3. Even if the increase of concentration of PCM induced the increase of heating effect and cooling effect, when PCM concentration increased from 10% to 20% improved the effects more highly than when the concentration increased from 20% to 30%.

4. Even though the cold conditions changed from 5°C to 10°C, the temperature changes by PCM concentrations indicated similar trends.

5. Though PCM has influenced on the temperature of the air layer by heating and cooling effect, those effects haven't shown in all layers equally. It was revealed that the effect of PCM varied according to the layer in the case of multi layered garment system and heat gain as well as heat loss in the outermost layer had to be taken into account.

## References


Bendkowska, W. (2006). Intelligent textiles with PCMs. In H. Mattila (Ed.), *Intelligent textiles and clothing* (pp. 35-62). Cambridge : Woodhead Publishing Limited.

Choi, K., Cho, G., Kim, P., & Cho, C. (2004). Thermal storage/release and mechanical properties of phase change materials on ployester fabrics. *Textile Res. Journal, 74*(4), 292–296.

Ghali, K, Ghaddar, N., Harathani, J., & Jones, B. (2004). Experimental and numerical investigation of the effect of phase change materials on clothing during periodic ventilation. *Textile Res. Journal, 74*(3), 205–214.

Kim, E., Yoo, S., Shim, H., & Kim, J. (2003). Developing the man-clothing-environment simulator for dynamic heat and moisture properties of fabrics. *Fibers and Polymers, 4*(4), 1–10.

Li, Y. & Zhu, Q. (2004), A model of heat and moisture transfer in porous textiles with Phase change materials. *Textile Res. Journal, 74*(5), 447–457.

Mäkinen, M. (2006). Introduction to phase change materials. In H. Mattila (Ed.), *Intelligent textiles and clothing* (pp. 21-33). Cambridge: Woodhead Publishing Limited.

McCullough, E. A. & Shim, H. (2006). The use of phase change materials in outdoor clothing. In H. Mattila (Ed.), *Intelligent textiles and clothing* (pp. 63-81). Cambridge: Woodhead Publishing Limited.

Pause, B. (1995). Development of heat and cold insulating membrane structures with phase change material. *Journal of Coated Fabrics, 25*, 59–68.

Pause, B. (2003). Nonwoven protective garments with thermo-regulating properties. *J. of Industrial Textiles, 33*(2), 93–99.

Vigo, T. L. & Frost, C. M. (1982). Temperature sensitive hollow fibers containing phase change salts. *Textile Res. Journal, 55*(10), 633–637.

Vigo, T. L. & Frost, C. M. (1983). Temperature sensitive hollow fibers containing polyethylene glycols. *J. Coated Fabrics, 12*(4), 243–254.

Vigo, T. L. & Frost, C. M. (1985). Temperature adaptable fabrics. *Textile Res. Journal, 55*(12), 737–743.

Zhang, X., Wang, X., Tao, X., & Yick, K. (2006). Structures and properties of wet spun thermo-regulated polyacrylonitrile-vinylidene chloride fibers. *Textile Res. Journal, 76*(5), 351–359.



## 요 약

본 연구는 상변화물질의 농도가 의복내 공기층의 온도변화에 미치는 영향을 연구하고자 하였다. 상변화물질로는 노나데칸을 사용하였으며 농도는 아크릴 바인더 대비 10%, 20%, 30%로 조절하여 면직물에 코팅처리하였다. 동적 열전달 측정장치인 Human-Clothing-Environment Simulator을 사용하여 고온에서 저온 이동시 다시 고온이동시의 의복내 온도변화를 측정하였다. 외부 환경온도는 고온은 34도, 저온은 5도와 10도를 하였으며 먼저 34도에서 한시간 동안 컨디셔닝한 후에 5도 또는 10도에 30분 동안 노출시켜 의복내 온도변화를 측정하였고 다시 34도에 노출시켜 30분동안 의복내 공기층에서의 상변화물질의 열적 거동을 살펴보았다. 그 결과 상변화물질처리된 직물로 이루어진 의복내 공기층은 고온에서 저온이동시 상변화물질의 발열효과로 인해 미처리 직물보다 높은 온도를 나타내었으며, 저온에서 고온이동시에는 흡열효과로 인해 미처리 직물보다 온도상승이 느리게 나타났다. 농도가 증가할수록 상변화물질에 의한 발열효과는 증가하는 것으로 나타났으며 흡열효과의 경우에는 20%에서 큰 변화를 갖는 것으로 나타났다. 농도변화에 따른 미처리와 처리직물 사이의 차이를 보면, 10%에서 20% 증가시에 나타난 차이가 20%에서 30% 농도변화시에 나타난 차이보다 크게 나타났다. PCM 처리된 모든 직물들이 상변화를 겪는 것은 아니었으며 직물층에 따라 상변화를 하였고 최외곽층의 경우에는 상변화물질에 의한 흡열발열현상외에도 외부로의 열손실을 겪기 때문에 이에 대한 고찰이 있어야 하는 것을 알 수 있었다.