State-of-the Art and Outlook: Thermal Properties of Phase Change Wallboard Rooms[1]

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Abstract: Phase change energy storage (PCES) has become more and more important in air conditioning and construction energy conservation, and has also become the focus of international research. This paper analyzes the domestic and foreign development of PCES technology and the thermal characteristic-analyzing method commonly applied in building envelopes, proposes future research methods for phase change material wall rooms, and lays a solid foundation for the research of the heat transfer mechanism and thermal characteristics.

Key words: Phase change storage energy; Phase Change wallboard room; Thermal storage & exchange performance; System distinguish; Thermal characteristic.

1. PREFACE

Our country is short of energy. In the term of energy application, the electric power is our mainstay, supporting our national economy. Especially during the later half of the 1980's, electric industries developed rapidly. However, the situation of power supply is still serious, and especially there is a power gap between the peak and the valley in power-supplying system. In order to address this problem, the central government issued the policy of "different prices during different periods" and "electricity-saving program during 1995-2000", which point out that "Saving the electric power during the peak period is an important step to relieve the electricity constrains" [1]. The application of phase change energy storage (PCES) technology can make the good use of "the power balancing between the peak period and the valley period" police, achieving the goal of energy conservation.

The applications of PCES technology have come into being since 1970's, and rise quickly and develop continuously in developed countries. Recently, because of the excellent heat storage capability of the latent heat (the latent thermal energy storage, LTES) and the process of heat storage with almost no temperature changing, the research and application of phase change material (PCM) attract more attention nowadays.

The theory and the application of PCES technology in both construction energy conservation and HVAC domain, related to many fields, such as material science, solar energy, engineering thermal physics, HVAC, etc, belong to a cross- discipline science. The research on the theory and application of PCES technology, giving us a clean、comfortable and energy conservation building environment, brings us economic profits and social benefits with its academic value.

2. THE PRESENT SITUATION OF PHASE CHANGE TECHNOLOGY

Recently, the technology of phase change and chemical reaction energy storage in building domain (includes HVAC) has become a focus. Besides, the Annex 10 (the theme is" phase change and thermal storage of chemical reaction "), lasting for 3 years and starting from 1999 by the subordinate agency of ECES(the Energy

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conservation through energy storage) of International Energy Organization (IEA) has listed the technology of phase change and chemical reaction energy storage as the most important research [3].

The technology of phase change wallboard (PCW) has attracted much attention home and abroad in 1980's. Nowadays, the method is to remake the existing materials by mixing the PCMs and then enhancing the thermal storage capacity of construction materials. For the air conditioning room, the use of the PCW can reduce the initial investment and energy consumption of air conditioning system, improve the indoor environment, and then advance the air conditioning technology. For the heating room, with the policy of difference of electric price between the peak and the valley, the PCW technology can store the heat during the valley period and discharge heat during the peak period, and then achieve energy conservation and relieve the electric power constrains between peak and valley periods [4-5].

Canada, the United States, Japan, Turkey etc.have conducted many deep-going researches on PCW. Feldman D., Hawes D., Banu D., Athienitis A.K. Concordia University, Canada has done lots of studies on PCW. They chose various PCMs and tested on them, and then selected the proper PCMs to make PCW, for instance, butyl stearate [6-7]. In addition, they have done a lot of studies on absorbing PCMs capability of common buildings [8-9], and the compatibility and stability of PCMs and construction materials [10-11]; and tested the flame resistance of PCW [12]. Moreover， they simulated the situation of PCW in the passive solar room, and concluded that the PCW could make the highest indoor temperature decrease by 4 , and the specific heat-solid of PCM is equal to 15% of total heat load [13].

In the U.S.A., Neeper (1990) estimated PCW could transfer 90 % of the residents air conditioning load to during the valley period, and reduce 30% of the equipments capacity, in the Los Alamos national laboratory of America [14]. Karen L(1993) of this laboratory, with the simulation ,found that PCW could reduce 1/3 of the heating equipments capacity in the area whose climate was just like the one of Tennessee, U.S.; while it could reduce 1/2 of the heating equipments capacity in the area whose climate was just like the one of Denver [15]. Tomlinson and Heberl (1990) in the Oak Bridge national laboratory of the United States concluded that in the solar energy room, PCW could obviously reduce the additional energy consumption, with the payback of about 5 years. In the Lawrence Berkeley national laboratory of the United States, Corina Stetiu used RADCOOL to evaluate the performance of PCW combined with mechanical night ventilation and they concluded that in California, the indoor temperature was maintained within comfort range by using PCW combined with mechanical night ventilation, as well as could reduce the required load capacity of mechanical cooling and heating equipment [16-19].J.Kelly Kissock (1998) in Dayton University of the United States used octadecane as PCM to make PCW. By the comparing test which indicated that PCW could improve indoor thermal comfort, and balance load between the peak and the valley periods [20-21].

Takeshi Kondo of KANAGAWA University and Tadahiko Ibamoto of Tokyo Denkis University of Japan researched the thermal storage of PCW [22].They made the PCM with 95% of octadecane and 5% of hexadecane，and put the cross-linked polythene ball into gypsum boards and then made up PCW. By the comparing test, they concluded that PCW could make a steady heat load, improve indoor thermal comfort in the radiation zone, reduce the electric power, and balance load between the peak and the valley periods.

Ahmet Sary, Gaziosmanpasa University, Turkey, conducted a research on the stability test of fat acid, and then concluded that stearic acid; cetylic acid, myristic acid and lauric acid could be used for solar energy storage, because of their stability. Meanwhile, he and another two partners tested the stability of the mixtures between certain two acids among them as PCMs. The result showed that: for the mixtures as PCMs mentioned above, after rapidly recycled, the changes of this melting temperature and dissolving heat were within the

rational range. Besides, by testing the mixture of myristic acid、capric acid and lauric acid, Ahmet Sary and Kamil Kaygusuz obtained its heat transfer characteristics.

Compared with the foreign countries mentioned above, the research on phase change storage energy theory and its application in our country are not very competitive, let alone the one on PCW. Zhong Zhipeng [23-28], Tsinghua University, made a simulation analysis on the thermal characteristic of PCW combined with night ventilation and put forward some invaluable suggestions. Kang Yanbing [29], Tsinghua University, put forward PCW combined with night ventilation system and set up a model of its operation effect. In his research, using testing equipment, the general order of night ventilation system was obtained after analysis, which laid a theoretical foundation for the application of PCES ceiling.

3. THE PRESENT SITUATION OF METHODS APPILED IN RESEARCH

The thermal characteristic analysis method of traditional building envelope, applying the physics theory of heat transfer to form a heat transfer function of CSPS and then working out the models needed by certain computing method, is the Theoretical Analysis Method. During the period between the ending of 1960's and the beginning of 1970's, D.G. Stephenson and G. P. Mitalas put forward the Reaction Coefficient Method and Z Transfer Function Method. However, they only could work out the dynamic thermal characteristic of wallboard or the roof composed by several layers of homogenate and constant thermal characteristic materials. So, the methods were not feasible and could not work out correct result under the other conditions [30-32].

With computer science, systematic theory, control theory and information theory developing and analysis of construction energy consumption deepening, the systematic distinguishing theory, so-called dynamic thermal characteristic distinguishing theory of building envelope, has come into being to set up a model of dynamic thermal characteristic of building envelope, makes full use of testing function, processing function and data analysis of computer, and has become an active researching branch in HVAC domain. Some foreign scholars conducted researches in that field and obtained several results.

The research, conducted abroad on both construction energy conservation and the thermal characteristic of building envelope, was much earlier than the one done home. Starting in 1970's, there came some reliable and steady soft wares dealing with building envelope system in U.S.A. and used for modeling the process of thermal and moisture transfer in building envelope, such as Physibel, Moist (free), Opaque (free), etc. So far we have not got the access to these soft wares above, and what we should do is to research and develop certain soft wares by our own.

In the preliminary period of the research and based on lots of experiments, the author and other members [33-37] of this research team analyzed the thermal characteristics of PCMs with DSC and other methods, selected PCMs from many, and worked out the optimal mixing rate of PCMs in PCW; researched and developed the PCES wallboard, and analyzed water-absorbing capability and compatibility of PCW; established a testing equipment and system of the PCW room, made the comparison test between the common room and the PCW room both in the same structure, tested the wall surface temperature and heat flow, and analyzed the affects of PCW on the wall surface temperature and heat flow. However, the research the thermal storage and exchange performance and dynamic heat characteristics of PCW room have not yet been carried out on a thorough analysis.

On the basis above, we get that there are almost no well-formed methods and models for the research of the thermal storage and exchange performance and dynamic heat characteristics of PCW room, all the researches are conducted in the testing and experimental period, and the PCES wallboard room in the real sense has not been put into practice. Because PCW is a new kind of building envelope, the research before which was only confined to the thermal characteristic analysis of the single layer building envelope, and nowadays

nobody has been found to conduct a research on the thermal characteristics of the phase change building envelope using the experimental method, so-called Distinguishing Method.

4. THE FUTURE RESEARCH

The research on thermal characteristics of the new kind of PCES wallboard

Analyze the thermal and physical characteristics of PCW with DSC, and the endurance and compatibility of PCW with infrared spectrometric analyzer.

The research on thermal storage and exchange performance of PCW room

Analyze thermal storage & exchange performance of PCW room with System Distinguishing Theory, and then put forward the main factors that affect thermal storage & exchange performance of PCW room

The research on dynamic heat characteristics of PCW room

Based on analysis of method of least squares, distinguish the Z Transfer Function model of dynamic heat characteristics of phase change, using instrumental variable method without non- Gauss Noise; form a space model of dynamic heat characteristics of phase change building envelope, using artificial variable method of system distinguishing method; work out wallboard surface heat-exchanging coefficient, using spectrum analytical method of the surface heat-exchanging process; conduct the research on hot working test and data processing of dynamic heat characteristics of phase change building envelope.

The research on thermal storage and exchange effects of PCW room

Based on the full consideration of the factors which affect thermal storage and exchange performance of PCW room, conduct a research on thermal design of the new kind of PCES building envelope and the conditions under which it can be well applied; analyze the energy storage effect of the combination of PCW room and air conditioning system in summer; analyze the energy storage effect of the combination of PCW room and electrical heating system in winter, the annual energy storage effect and all the influencing factors.

5. CONCLUSIONS

This paper analyzes the theory of heat storage and exchange of PCW room, and the dynamic heat characteristics of PCW. In other words, with the concepts of energy conservation and environmental protection, the organic PCM is mixed into the construction material, with a new kind of energy storage building envelope obtained. The application of theories, such as System Distinguishing Theory, and so forth, for conducting the research on the dynamic heat characteristics of this new kind of energy storage building envelope and the theory of heat storage and exchange of PCW room, could broaden the range of the application of PCES in construction energy conservation domain. The research on the properties of heat storage and exchange of PCW room with its dynamic heat characteristics carried out in deep and thorough manners could surely play an active role in the enhancement of construction energy conservation and thermal comfort of building environment. And all the results from this research could certainly embrace a bright perspective in the application field.

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