Phase Change Materials [**S**TRATEGY]

BRIEF DESCRIPTION

Phase change materials (PCMs) are materials that are capable of absorbing and releasing thermal energy when they undergo a phase change from solid to liquid and from liquid to solid. When a PCM solidifies, it releases energy in the form of latent heat at a relatively constant temperature. Conversely, when such a material melts, it absorbs heat from the environment. PCMs exhibit a thermal mass effect, repeating the phase changes as ambient temperatures fluctuate, making them ideal for a variety of everyday applications in certain environments that require temperature control.

The phase change material acts as a thermal energy storage medium, such as paraffin wax, collecting and storing energy when it is readily available to be used later when needed. For example, phase change material will absorb heat during winter sunlit hours, and then slowly release the heat over night. The heat is used to supplement the heating needed in the evening and lower the peak demand for heat in the winter season. The shift in peak energy demand can reduce the size and initial cost of heating or cooling systems, lower energy costs, and reduce maintenance costs.

Applications

Conserve energy and maintain comfortable temperatures



(Figure 1) BioPCM[™] installation between Wall/Ceiling Studs

(Source: http://www.phasechange.com/index.php/en/information/installation)

(Figure 2) Installation of Energain® PCM panels

(Source: http://www.edilizianews.it/articolo/1899/soluzione-hightech--- contro-le-dispersioni-termiche-)

(Figure 3) Installation of the PCM-enhanced cellulose insulation

(Source: http://web.ornl.gov/sci/roofs+walls/AWT/ComputerSimulations/ORNL_TM_2007_186.pdf)

HIGH PERFORMANCE TECHNOLOGY STRATEGY (Revision 0, 02-29-2016) Page | 1

Design Notes Locations

- PCMs are best suited for use in hot, dry and marine climates with dynamic daytime/nighttime temperature changes.
- It is not recommended to use PCMs in cold climates.

Installation

- PCMs should be used in conjunction with insulation materials.
- Some types of PCMs require extra care during installation to prevent damage to the PCM encapsulation shell.
- Potential leakage of PCM packages may occur under ambient temperature if punctured or mishandled.
- Energain[®] panel: use DuPont[™] Energain[®] aluminum tape to seal a cut edge or abrasion when using this product.

RelatedGypsum board with microencapsulated PCMsTechnologiesConcrete blocks with microencapsulated PCMs

[ENERGY AND THE ENVIRONMENT]

Energy Savings	 Heating and Cooling Energy PCMs enhance building energy performance. The application of thermal mass effect could reduce building envelope-related energy loss by 20-25% in well-insulated buildings.
Social Benefits	 Thermal Comfort Improve indoor thermal comfort by stabilizing air temperature.
	 Building Life Decrease surface/roof temperatures and thereby extend roof service life.
Environmental Impacts	 Reduce Fossil Fuel Consumption Reduce waste by-products from consuming fossil fuels. Reduce environmental impact due to decreased demand for fossil fuels.
Guiding Principles	 Optimize Energy Performance (Energy Efficiency) Energy savings can be achieved if thermostat set points are lowered. Reduce building envelope rated energy loss by 30% compared to the baseline building performance rating per ASHRAE Standard 90.1-2007.
Associated LEED Credits (NC 2009)	 EAc1: Optimize Energy Performance (up to 19 points) PCMs can contribute to reducing energy consumption for heating and cooling loads inside the building, thus reduce energy cost.
	 IEQc7.1: Thermal Comfort Design (1 point) PCMs can reduce discomfort of indoor environments caused by the outdoor climate extremes from summer solar radiation and temperature drop in the winter by stabilizing air and surface temperatures inside the building.

Product Images



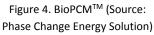


Figure 5. Energain® (Source: DuPont™)



Figure 6. Microtek (Source: MicrotekLaboratories)

Components BioPCM[™]: derivatives of fatty acids, fatty alcohols, esters, emulsifiers, thickening agents and proprietary cross linkers, fire retardants and extinguishers, and a proprietary film.

Energain®: modified paraffin wax with polyolefin elastomer modified encased in aluminum panel (not currently available in the USA).

Microtek: microencapsulated octadecane PCM.

Cost Range

Components	Cost	Unit
BioPCM™	\$5.00 - \$6.00	per square foot
Energain [®] PCM panel	\$4.00 - \$4.50	per square foot
Microtek in cellulose	\$7.50 - \$9.00	per square foot

Product Types

- Each PCM, as mentioned above, has its own phase change temperature range.
 - Each PCM differs in latent heat storage capacity.
 - Microencapsulated PCM must be mixed into cellulose insulation.

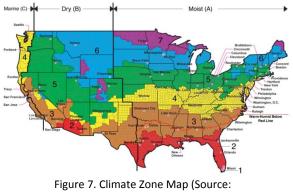
HIGH PERFORMANCE TECHNOLOGY STRATEGY (Revision 0, 02-29-2016) Page | 4

Vendors	Phase Change Energy Solutions (BioPCM [™]) http://www.phasechange.com/index.php/en/
	E. I. du Pont de Nemours and Company (DuPont [™] Energain [®] PCM panel) http://energain.co.uk/Energain/en_GB/index.html
	Microtek Laboratories, inc. (Microencapsulated PCM) http://www.microteklabs.com/micropcm.html
Warranty Info	Warranties for handling and installation are not common due to components of materials (nontoxic substances). May vary by vendor.
Code Restrictions	Local Fire Protection Codes should be consulted before purchase or installation of PCMs. Flammability test may be required before installation.

HIGH PERFORMANCE TECHNOLOGY STRATEGY (Revision 0, 02-29-2016) Page | 5

CASE STUDY 1: BioPCM[™] Installed at Ft. Bragg, NC

ERDC-CERL and Oak Ridge National Laboratory (ORNL) are currently executing a demonstration project to install and evaluate the effectiveness of BioPCM[™] in a building at Ft. Bragg, NC. PCMs were installed in June, 2015, and final results are expected by the end of calendar year 2016.



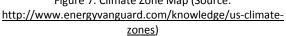




Figure 8. Demonstration Building at Ft. Bragg. (Source: USACE, ERDC-CERL)

- Building Description: DPW Classroom Facility, Building 3-2232, 3,500 sq. ft.
- Location: Ft. Bragg, NC ASHRAE Climate Zone 3 (mild winters and hot summers).
- Original Building Condition: R-19 fiberglass batt insulation laid directly on top of suspended acoustic ceiling. Attic space contained all HVAC ductwork and was not part of the building thermal envelope.
- Case Study Approach: R-19 fiberglass was removed from the building, and 9 inches of dense-pack cellulose insulation was installed on the underside of the roof deck. This brought the HVAC system inside the thermal envelope of the building and provided temperatures sufficient to facilitate the liquid-solid phase change. Temperature, relative humidity, and heat flux was monitored for one year after cellulose insulation. In June 2015, BioPCM[™] were installed to the underside of the cellulose insulation. Building thermal performance monitoring is ongoing.

Phase Change Materials [**C**ASE **S**TUDY]



Figures 9 & 10. Ft. Bragg DPW Classroom Building before (left) and after (right) installation of cellulose insulation below the roof deck and on gable walls. (Source: USACE, Savannah District)



Figures 11 & 12. BioPCM[™] with metallic fireproof covering before installation at Ft. Bragg (left). Attic space after installation of BioPCM[™] below cellulose insulation in the attic space (right). (Source: USACE, Savannah District)

HIGH PERFORMANCE TECHNOLOGY STRATEGY (Revision 0, 02-29-2016) Page | 7

These TechNotes are intended to provide general information for the consideration of design strategies. The TechNotes should NOT be interpreted as an endorsement of any specific product or technology.

CASE STUDY 2: Oak Ridge National Lab (ORNL) Building Demonstration¹

Several homes were constructed in Oak Ridge, TN by Zebra Homes, as part of an ORNL technology demonstration of various energy-saving technologies, including Microtek PCM mixed in with cellulose in the wall cavities. Combined with other energy saving technologies, these homes achieved 83% energy savings when compared to a typical existing home. The homes were completed in March 2013 and listed for sale at \$485,000.

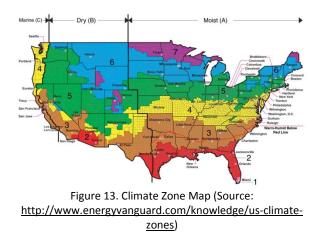




Figure 14. Wolf Creek home containing Microencapsulated PCM combined with blown-in cellulose insulation in Oak Ridge, TN. (Source: ORNL)

CASE STUDY 2: DuPont[™] Energain[®] Commercial Use

DuPont[™] Energain[®] is widely used in Europe, and they are now in the process of adapting their product to the U.S. market. Currently, ERDC-CERL has a Cooperative Research and Development Agreement for "Evaluation of Phase Change Material Concepts in Military Buildings." We have characterized the Energain[®] PCM in the laboratory.

¹ Oak Ridge National Laboratory (ORNL). http://talon.stockton.edu/eyos/energy_studies/content/docs/effstock09/Session 4_2_PCM_in_Buildings/33.pdf

HIGH PERFORMANCE TECHNOLOGY STRATEGY (Revision 0, 02-29-2016) Page | 8

These TechNotes are intended to provide general information for the consideration of design strategies. The TechNotes should NOT be interpreted as an endorsement of any specific product or technology.