U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Opportunities to Apply Phase Change Materials to Building Enclosures

Welcome to the Webinar! We will start at 2:00 PM Eastern Time

Be sure that you are also dialed into the telephone conference call:

Dial-in number: 888-950-6757; Pass code: 6420234

Date: November 11, 2011

Building America® U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America: Introduction

November 11, 2011

Chuck Booten
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- Reduce energy use in new and existing residential buildings
- Promote building science and systems engineering / integration approach
- "Do no harm": Ensure safety, health and durability are maintained or improved
- Accelerate adoption of high performance technologies

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Building America Industry Consortia

Industry Research Teams

- CARB – Consortium for Advanced Residential Buildings
- Alliance for Residential Building Innovation
- BA-PIRC
- NAHB Research Center
- NorthernSTAR – A Building America partner in research, innovation, and real home solutions.
  NorthernSTAR Building America Partnership
- IBACOS – Home Quality + Performance
- BARA – Building America Retrofit Alliance
- bsc – Building Science Corporation
- BIRA – Building Industry Research Alliance …a catalyst for change
- ARIES Collaborative
- Fraunhofer Building America Team
- Dow Building Solutions
  Habitat Cost Effective Energy Retrofit Program
- Nebraska – University of Nebraska-Lincoln; UF – University of Florida
  Building Energy Efficient Homes for America (BeeHa)
- PARR – The Partnership for Advanced Residential Retrofit
- NELC – National Energy Leadership Corps

Today's Speaker

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Dr. Kosny, winner of a 2009 R&D 100 Award for the development of phase-change materials (PCMs), is a leading building envelope researcher with 30 years experiences in the building sciences. Dr. Kosny holds a Ph.D. in Building Physics from the Polish Academy of Sciences. His doctoral research was in area of passive solar systems. Prior to joining Fraunhofer CSE, Dr. Kosny spent 12 years teaching building science as a professor of the Rzeszow Technical University, Poland and 18 years at Oak Ridge National Laboratory. While working for ORNL, he developed a number of high-performance envelope concepts including masonry systems, advanced roofing systems, light-gage steel framing and metal-foam sandwich technologies. He has held a number of faculty positions, published more than 120 technical articles, and has authored numerous patents related to advanced building concepts. He has represented the United States at many international organizations and standards bodies, including the International Energy Agency. He has extensive experience collaborating with industry to commercialize advanced building technologies. Particularly relevant to the proposed presentation, he has worked with most major world manufacturers of PCM technologies to develop novel dynamic building envelopes based on integration of advanced heat storage components, local ventilation strategies, and high-performance insulations (including aerogels, vacuum insulations, reflective insulations, cool coatings, etc.).

Fraunhofer Center for Sustainable Energy Systems

Opportunities to Apply Phase Change Materials to Building Enclosures

Jan Kosny Ph.D.

Building Enclosure Program Lead

November 11, 2011

Cambridge, MA USA

Fraunhofer USA

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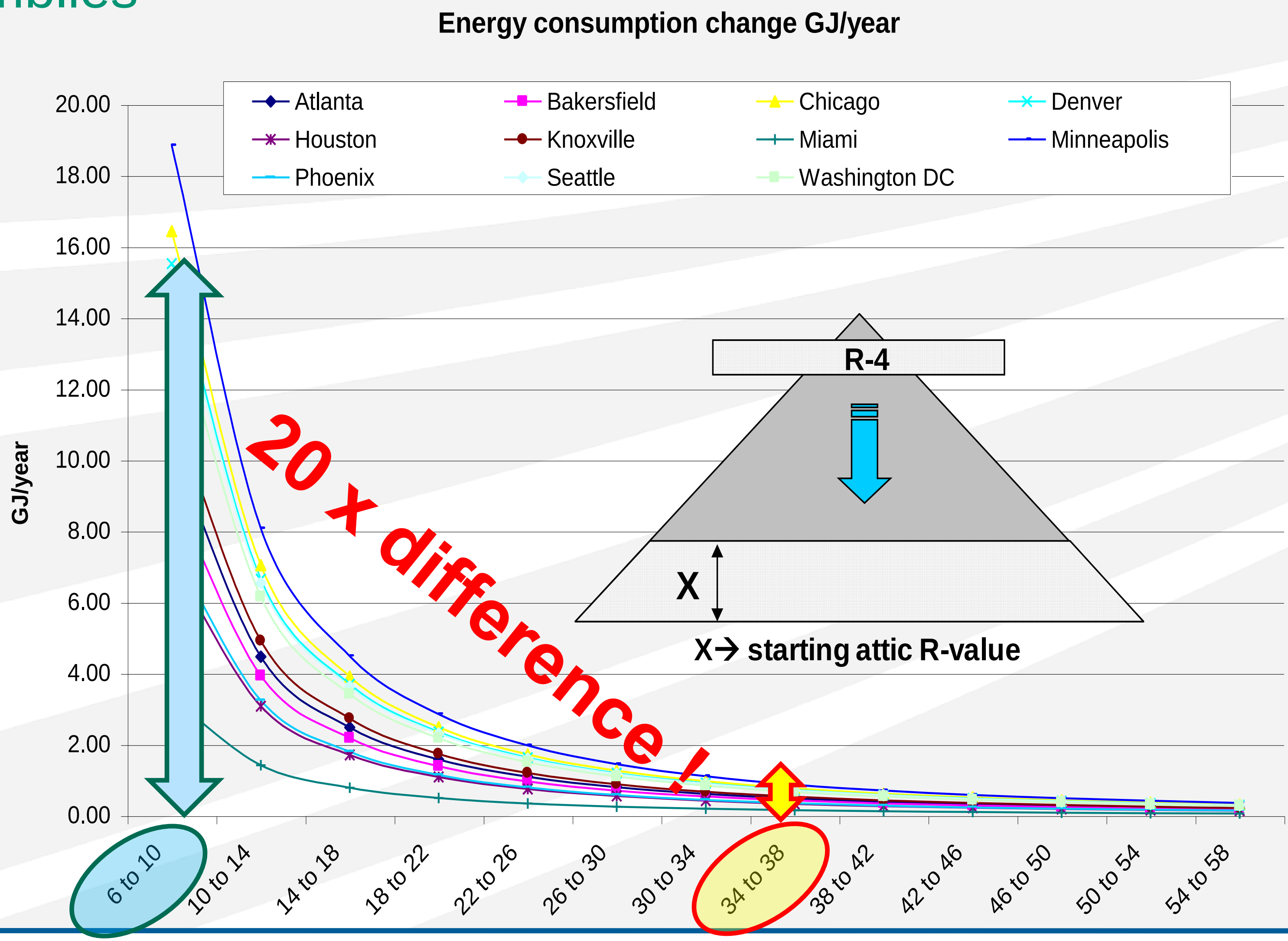
Agenda

- Introduction – A need for proper performance data for PCMs used in building applications - List of Motivations
- 2011 update on the Frasunhofer CSE PCM research
- Challenges of DSC testing and computer simulations
- New Dynamic testing methods and New Performance Label for PCMs
- Dynamic testing with use of Heat Flow Meter Apparatus
- Potential new ASTM and ISO standards for Dynamic Thermal Testing of non-uniform PCM-enhanced products

MOTIVATION (I): Performance Problems of Conventional Insulations

Conventional insulations work only effectively for low R-value assemblies

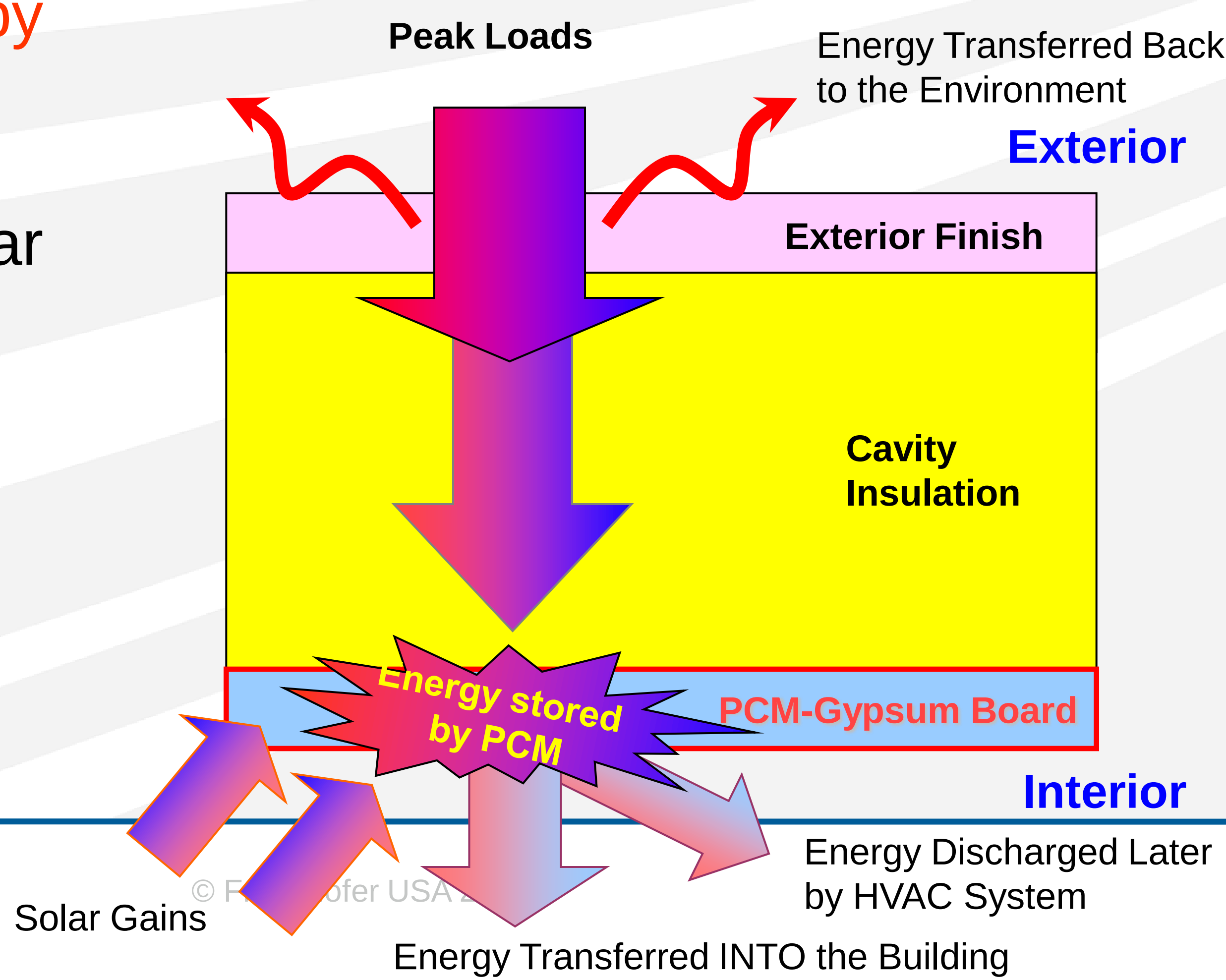


MOTIVATION (II): Different Tactics – Different PCM Configurations

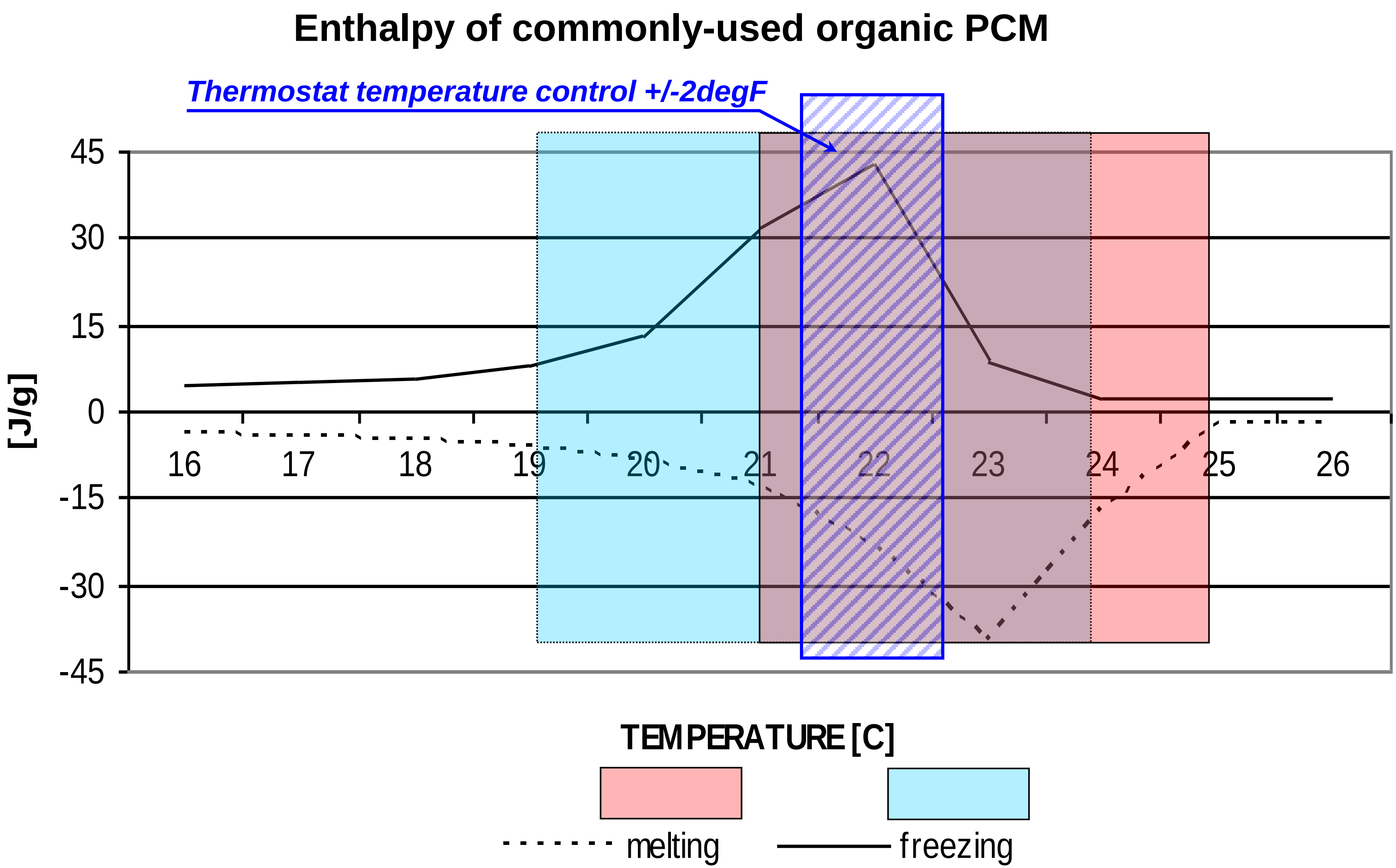
European Approach – PCM-Impregnated Gypsum Board

- PCM charged by interior temperature swings and solar gains through glazing
- Building HVAC system used to discharge PCM

Schematic of Distribution of Heating and Cooling Loads in Old PCM Applications



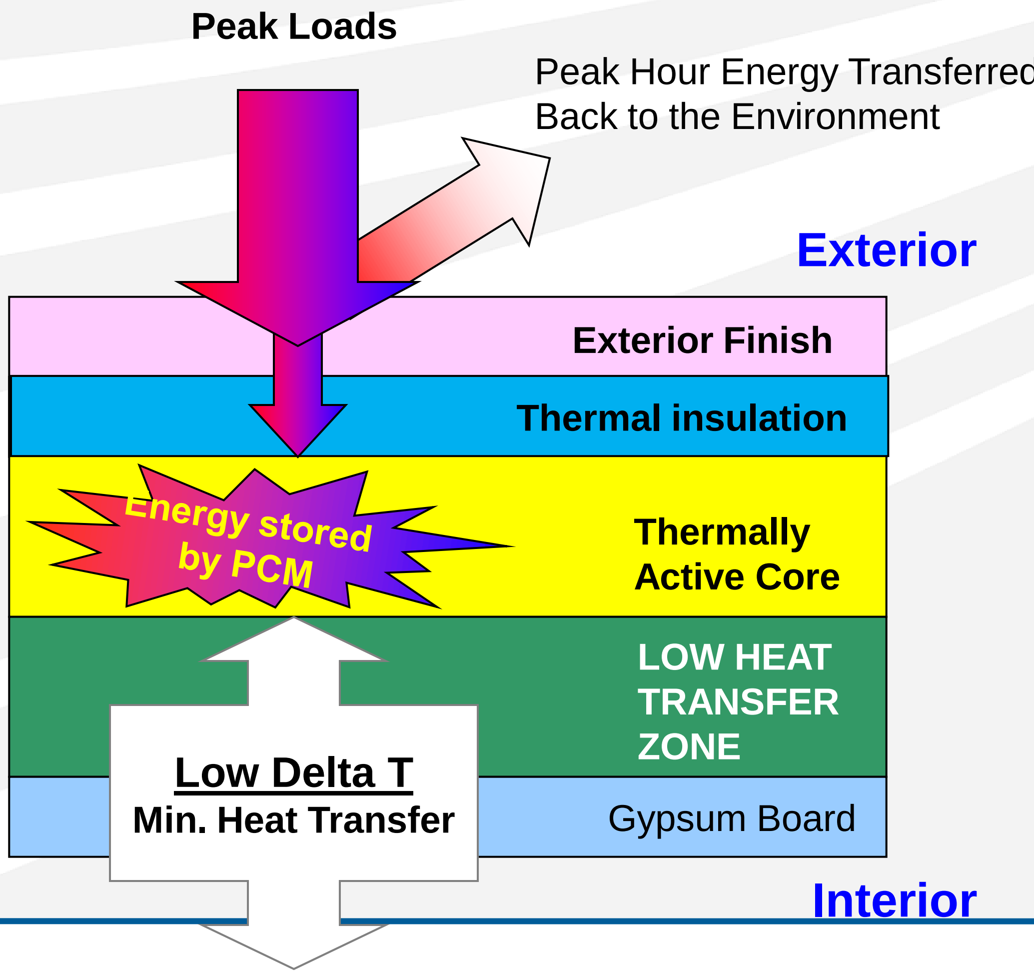
Main Problem with Application of PCM Gypsum Boards in the U.S. Air-Conditioned Buildings



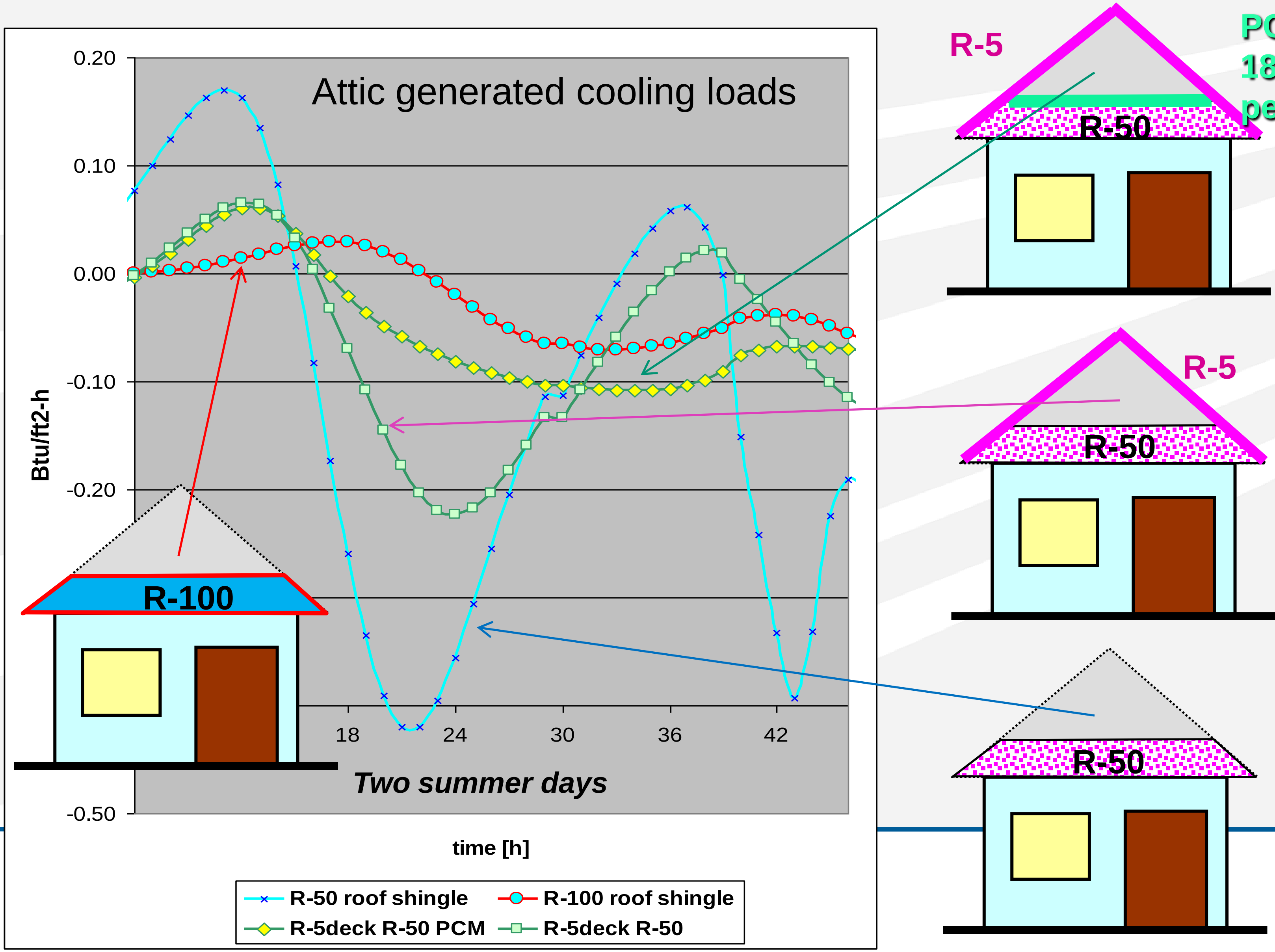
New Approach for PCM Installations In the U.S.

- Use fluctuations in exterior temperature and solar irradiation for charging and discharging of PCM
- PCM material has to be able to fully charge and discharge energy during 24-hour dynamic cycle

Schematic of Distribution of Heating and Cooling Loads in PCM-Enhanced Bldg. Envelopes

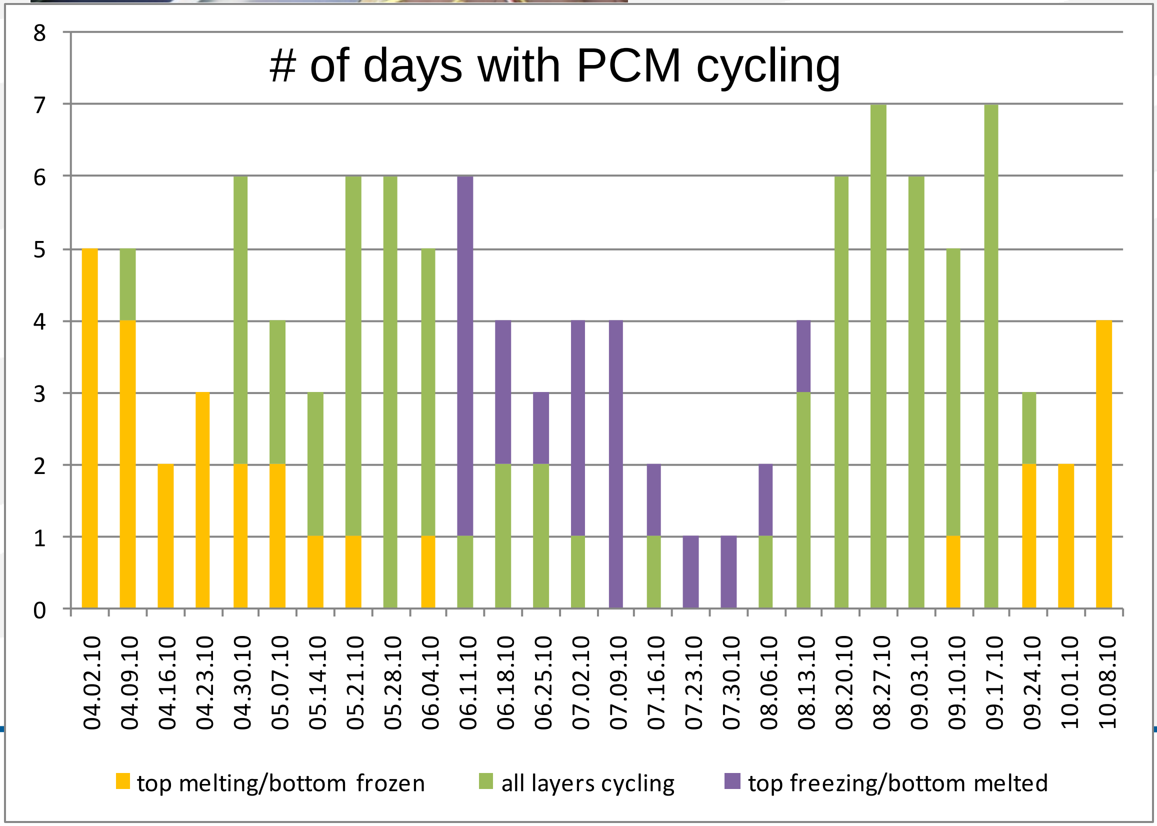


Effectiveness of PCMs in cooling attic applications is well documented *(modeling and field testing results)*



Effectiveness of PCMs in cooling attic applications is well documented *(full-scale field testing – MCA project)*

2010 cooling season



65% - of # days with PCM cycling
50% - of total cooling load reduction
Over 90% - cooling peak-hour load reduction

Effectiveness of PCMs in cooling attic applications is well documented *(Fraunhofer CSE full-scale test hut testing in New Mexico climate)*

Full-scale testing performed for different manufactures of building materials

General results for 2011:

Roofs: up to 60% cooling load reduction
comparing to traditional roof and attic designs

Walls: up to 50% cooling load reduction
comparing to traditional 2x4 wall assembly

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2011 update of the Fraunhofer CSE PCM-database

Over 350 PCMs represented

Company	Location	Product amount	Temp. Range (°C)	Raw Data	Downloaded Flyers	Testing Method
Micro. Labs	USA	17	-30~52	Yes (5)	16	DSC
PCES	USA	4	23~29	Yes (4)	No	DSC
BASF	Germany/ USA	9	21~26	Yes (1)	6	DSC
PCM	UK	127	-114~885	No	5 tables	-
RGEES	USA	16	-27~88	Yes (16)	16	T-history
PLUSS	India	18	-37~89	No	1 table	T-history (In)
ESI	USA	32	-37~151	Yes (8)	1 table	DSC
Climator	Sweden	11	-21~70	No	11	-
JCXT	China	18	5~110	No	No	-
SGL	Germany/ USA	4	22~58°C			DSC
Rubitherm	Germany	49	-10~86°C	No		3-layer Calorimeter
Capzo	Netherlands					

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1. Microtek Laboratories, Inc. (Micro. Labs)

- **Application:** To maintain a regulated temperature within a product such as textiles, building materials, packaging, and electronic.
- **Types of encapsulated PCMs:** MicroPCM's, MacroPCM's, Ignition Resilient PCM's, Formaldehyde-free PCM's, Custom PCM products (Properties could be checked on the website)

Microtek Laboratories, Inc. (Micro. Labs)

Micro. Labs product list	
MPCM28	**Raw experiment data**
MPCM18-D	
MPCM37	
MPCM42	
MPCM52	
Website Info	MPCM (-30)
	MPCM (-30)D
	MPCM (-10)
	MPCM (-10)D
	MPCM 6
	MPCM 6D
	MPCM 18
	MPCM 18D
	MPCM 28
	MPCM 28D
	MPCM 37
	MPCM 37D
	MPCM 43
	MPCM 43D
	MPCM 52
	MPCM 52D

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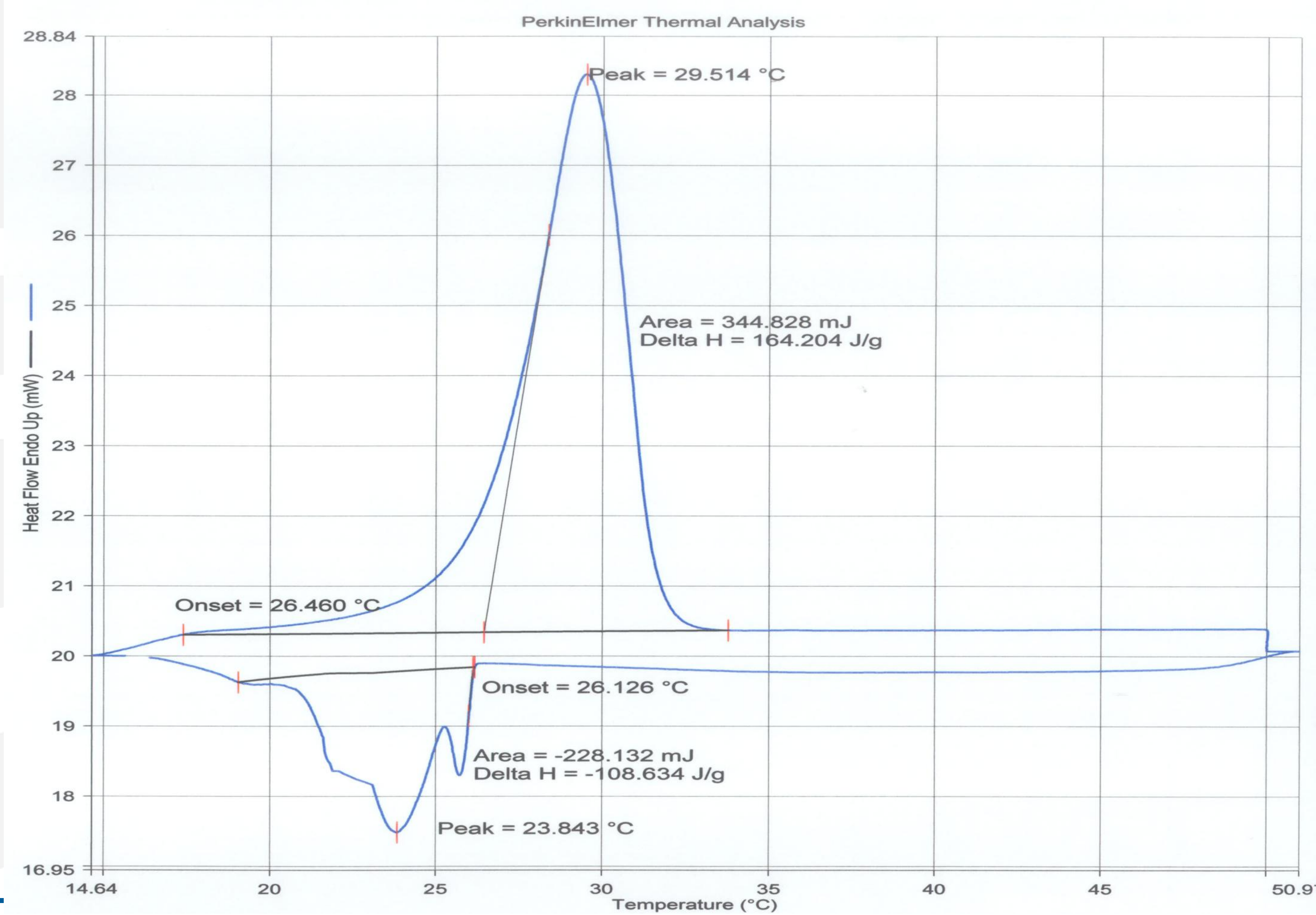
Microtek Laboratories, Inc. (Micro. Labs)



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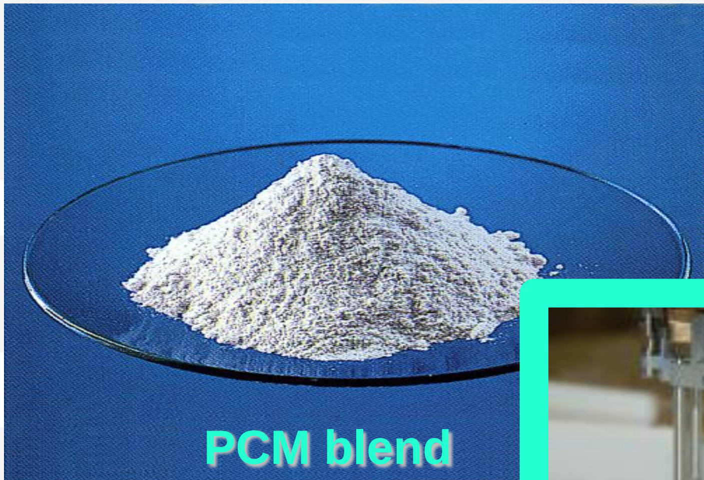
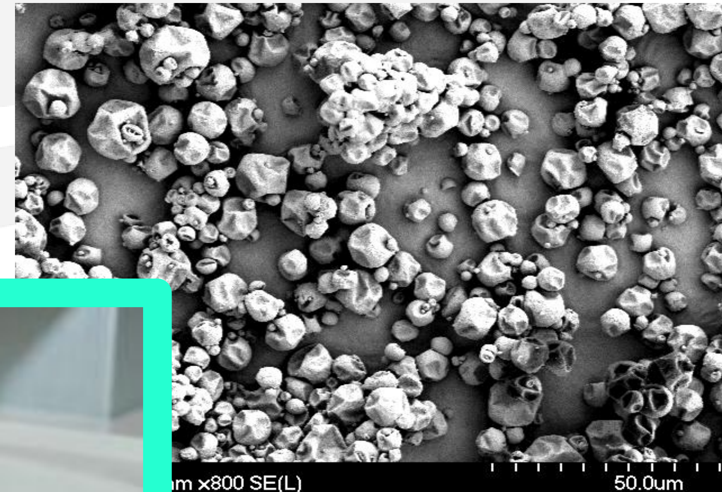
Microtek Laboratories, Inc. (Micro. Labs)

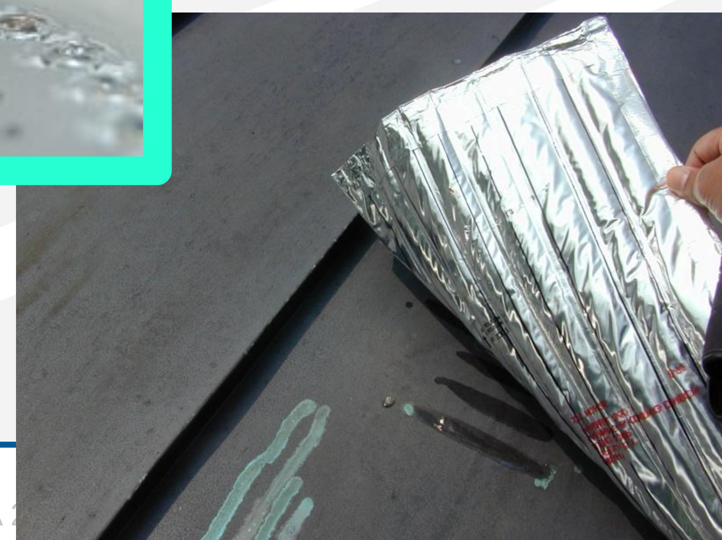
Basic Info	Sample name	MPCM28
	Appearance (Form)	White to slightly off-white color (Wet cake)
	Chemical components	n-Octadecane
	Organic/Inorganic	Organic
Test Data	Test method	PerkinElmer Thermal Analysis (DSC)
	Temp. change rate	5°C/min
	Sample mass	2.100 mg
	Melting Temp.	29.514°C
	Freezing Temp.	23.843°C
	Subcooling range	5.671°C
	Melting overall enthalpy	164.204 kJ/kg
	Freezing overall enthalpy	108.634 kJ/kg
	Melting Temp. range	17.4°C~33.8°C
	Freezing Temp. range	26.1°C~19.1°C

Challenges of DSC testing and computer simulations

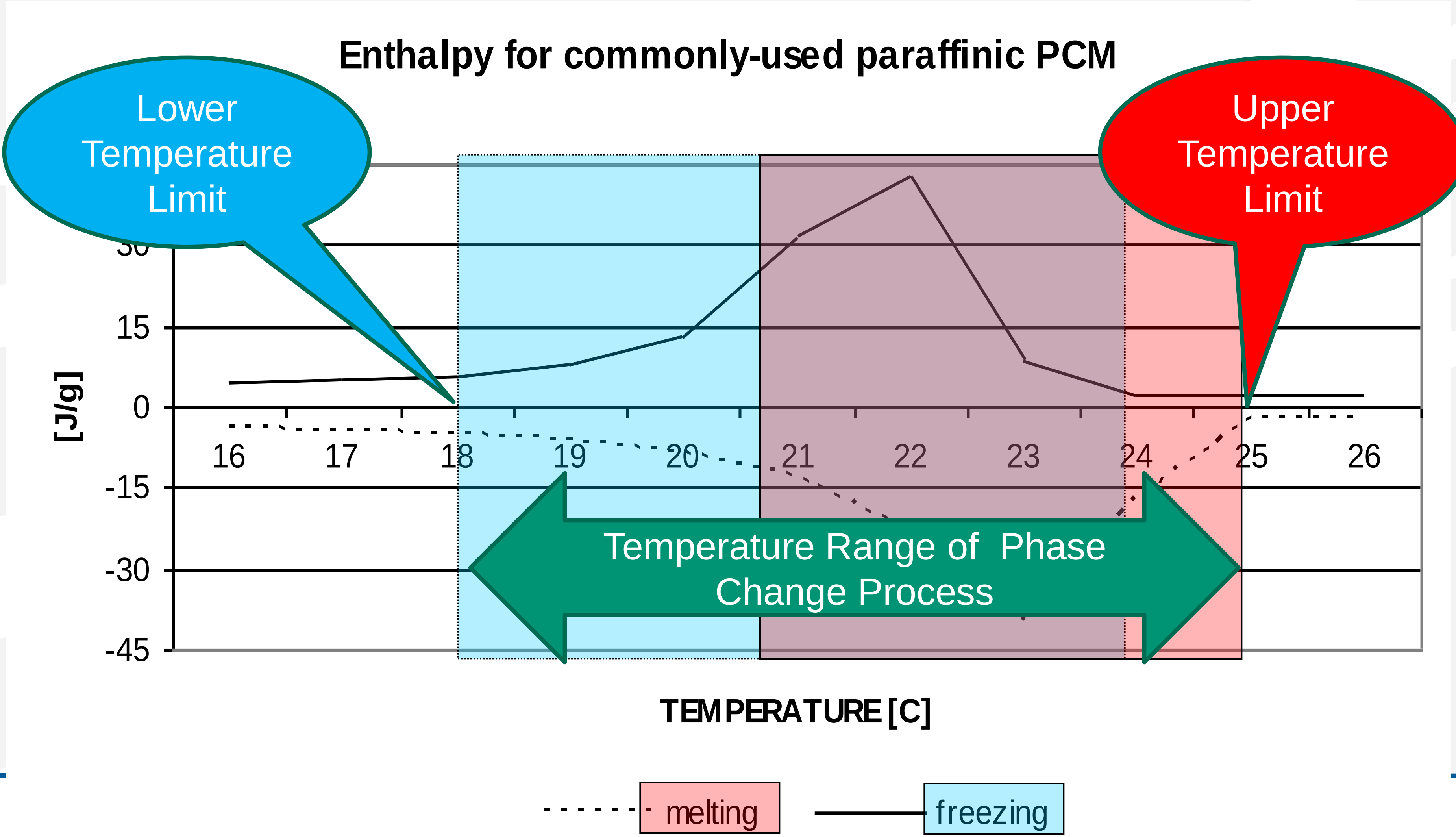
Large Selection of **Non-Uniform PCMs** is in common use today which **cannot be tested in DSC**







Key Temperatures of the PCM Transition Process



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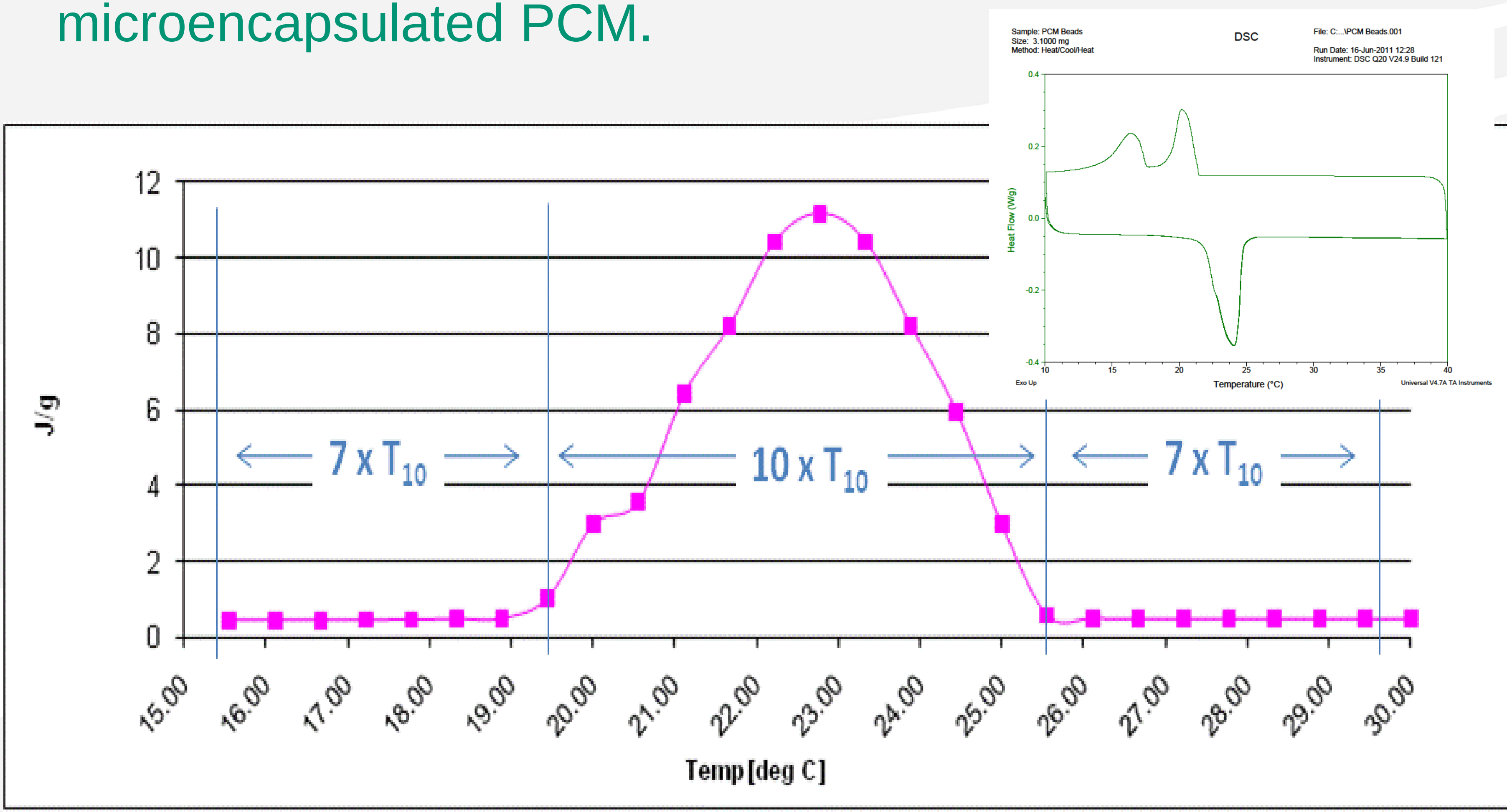
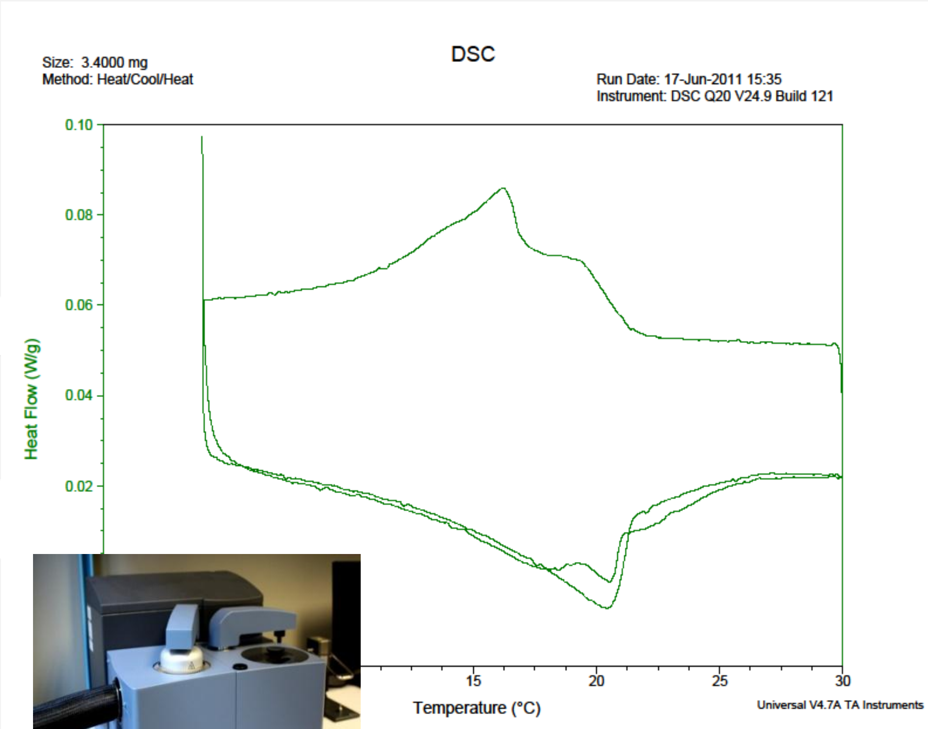
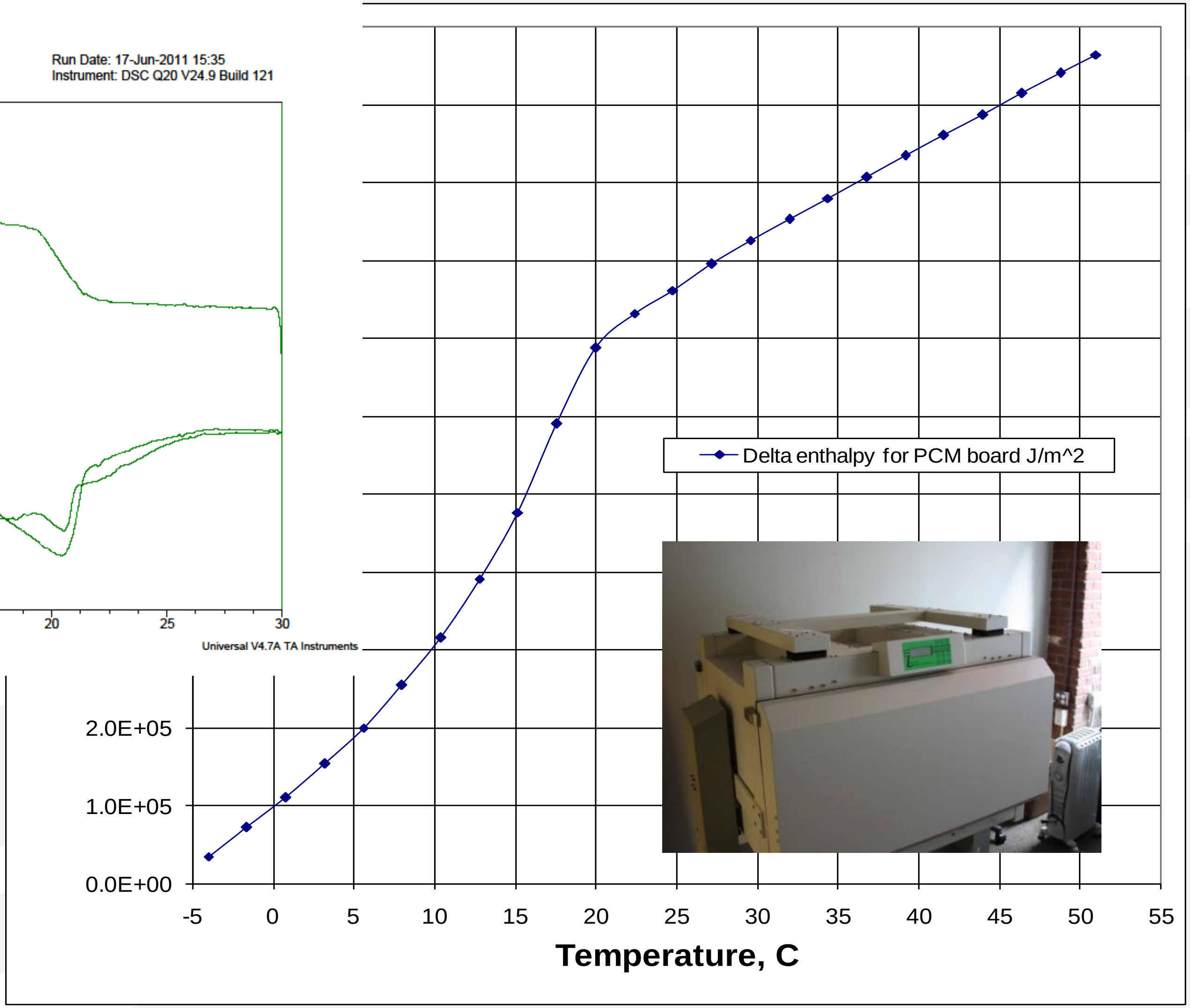
Example of estimation of temperature ranges for DHMA test using ΔH(T) chart for a blend of thermal insulation and microencapsulated PCM.



DSC can be very useful in solving surprising situations



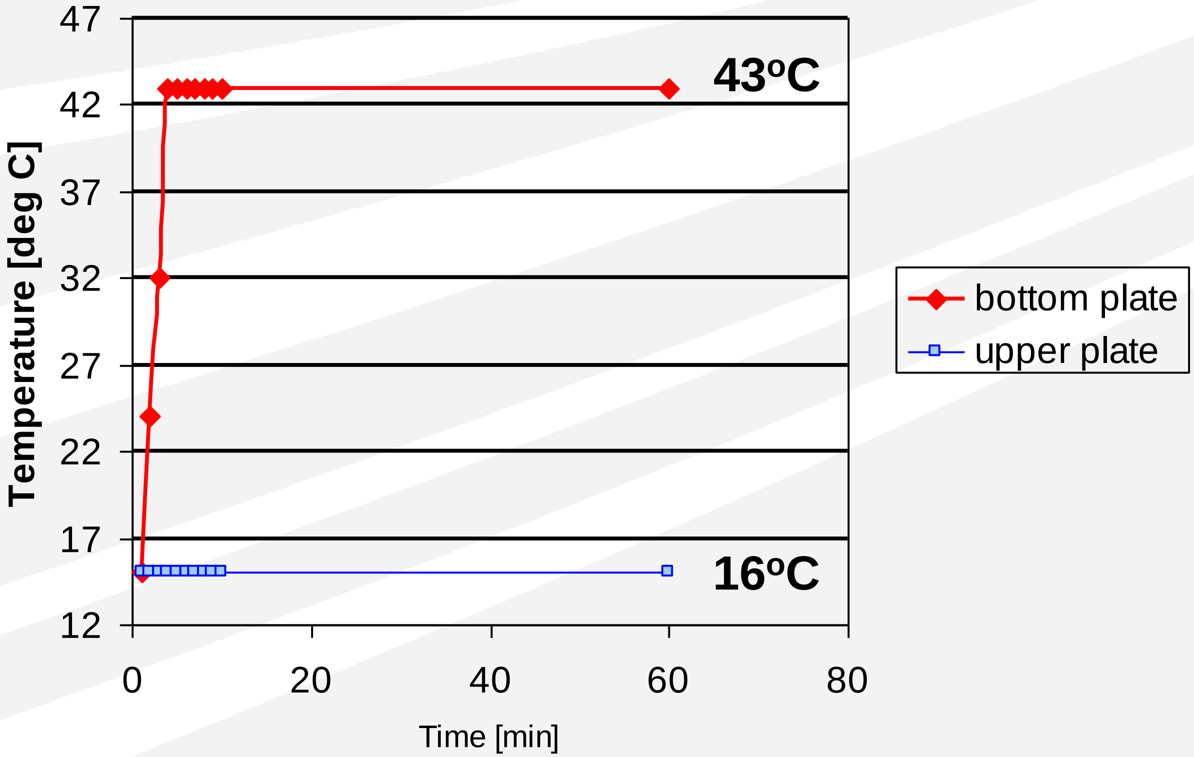


Advantages of Symmetrical Testing Processes

- Transient effects on both plates of HFMA are identical
- Since temperature profile is always symmetrical during the experiment, it is possible to analytically estimate and later subtract mass-related effects on both plates
- Measurement errors generated by heat flux transducers and heat diffusion time lags are identical on both plates
- It is possible to subtract measurement errors generated by heat flux transducers (due to dynamic character of the test)

A standard testing HFMA equipment can be modified to allow dynamic testing of PCM-enhanced products.

Normally the HFMAs are used to measure the apparent thermal conductivity of materials as specified in ASTM C518.

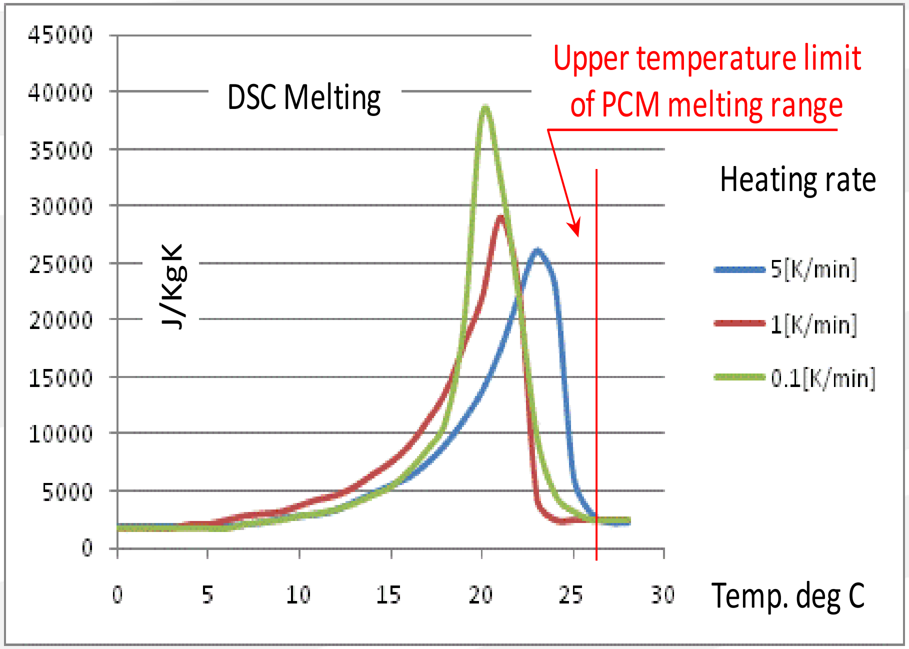


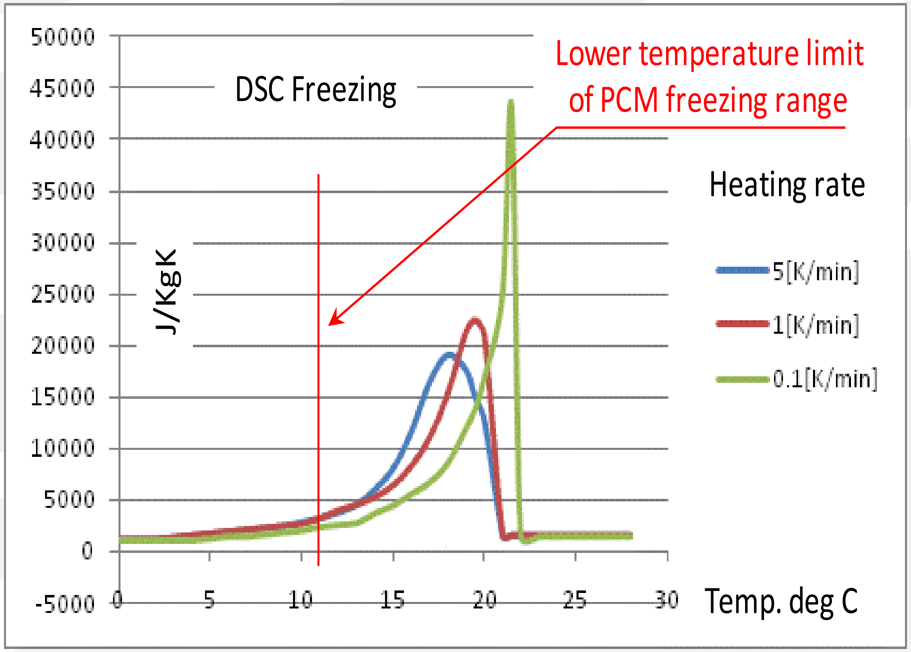
Potential misinterpretation of the enthalpy test data in computer simulations

Most of currently used whole building energy simulation models do not properly represent PCM thermal characteristics

Rate of Temperature Change Effects Enthalpy Profiles

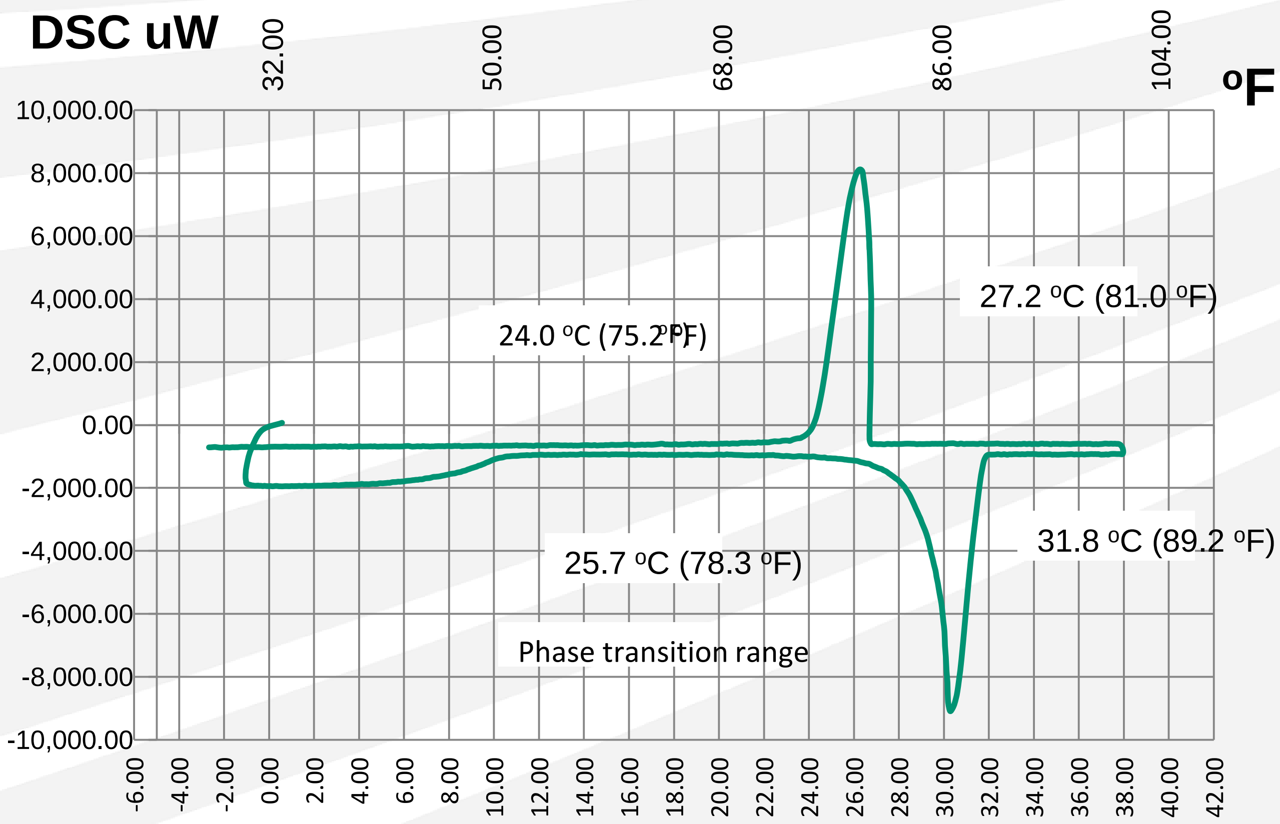
Incorrect DSC data is very often used in whole building computer simulations





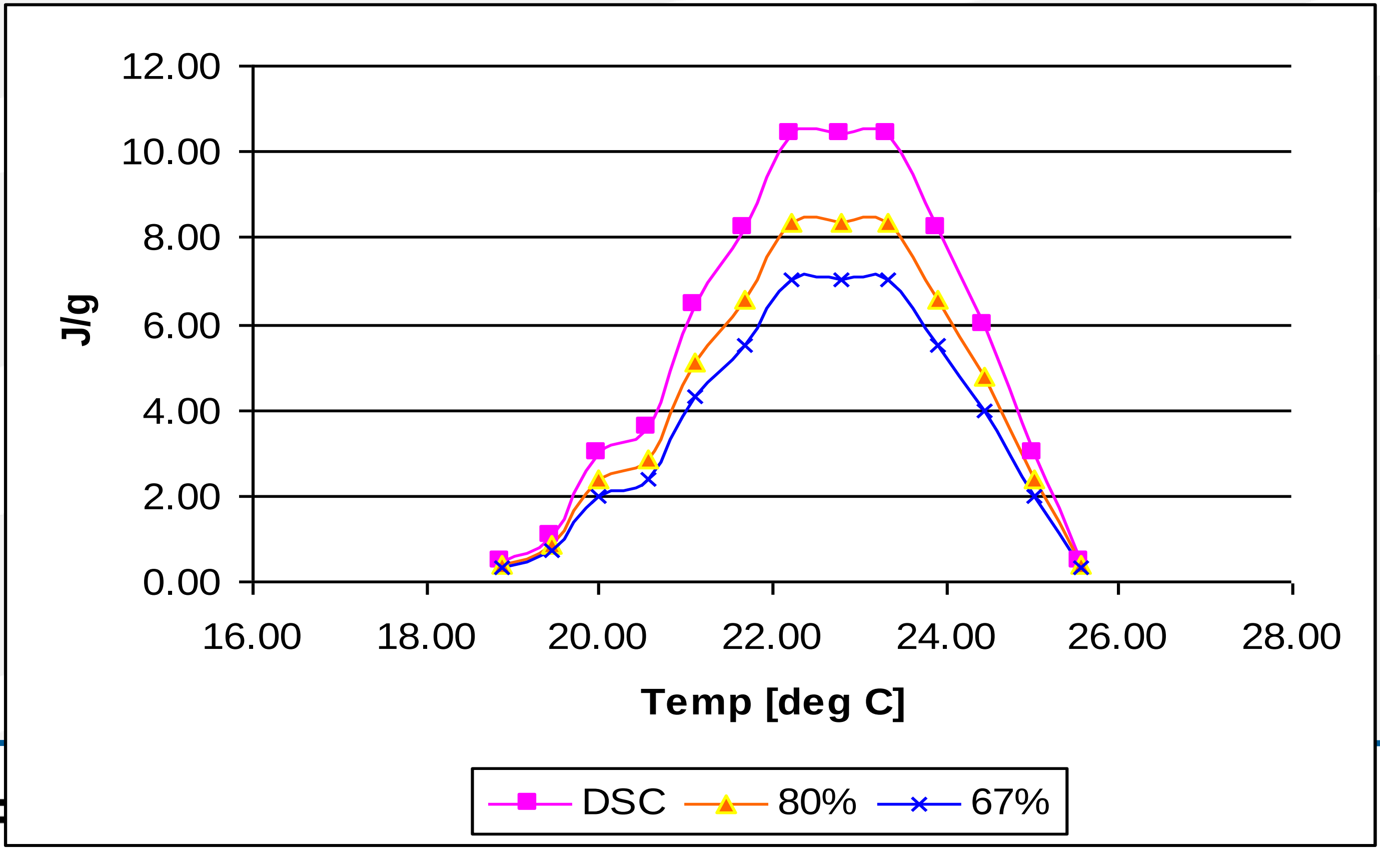
PCM subcooling effect is not properly represented

Estimation of upper and lower temperature limits for sample of the PCM-enhanced material or composites using original DSC test data for PCM (paraffinic PCM data shown).



Need for Development of Δ–Enthalpy Charts for PCM-Enhanced Materials and Systems

- Initial Differential Scanning Calorimeter (DSC) tests for pure PCMs or PCM microcapsules, only
- **Additions to PCM-based blends make a difference;** Dynamic Heat Flow Meter Apparatus tests were introduced in 2006 for PCM-enhanced insulations - fire retardant effect, adhesives, not-working PCM pellets, etc.…



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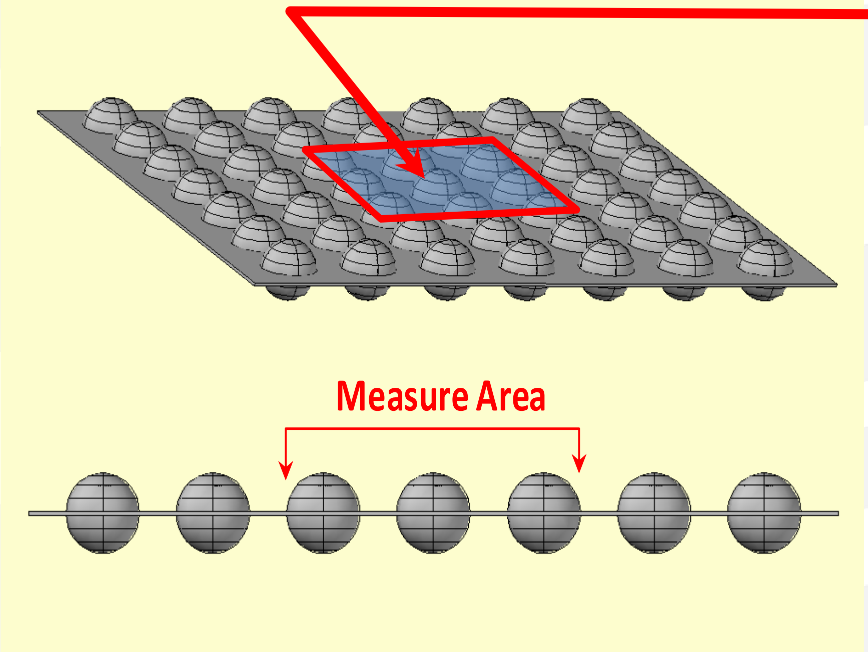
Dynamic Test Methods Used in Analysis of PCMs and PCM-Enhanced Products

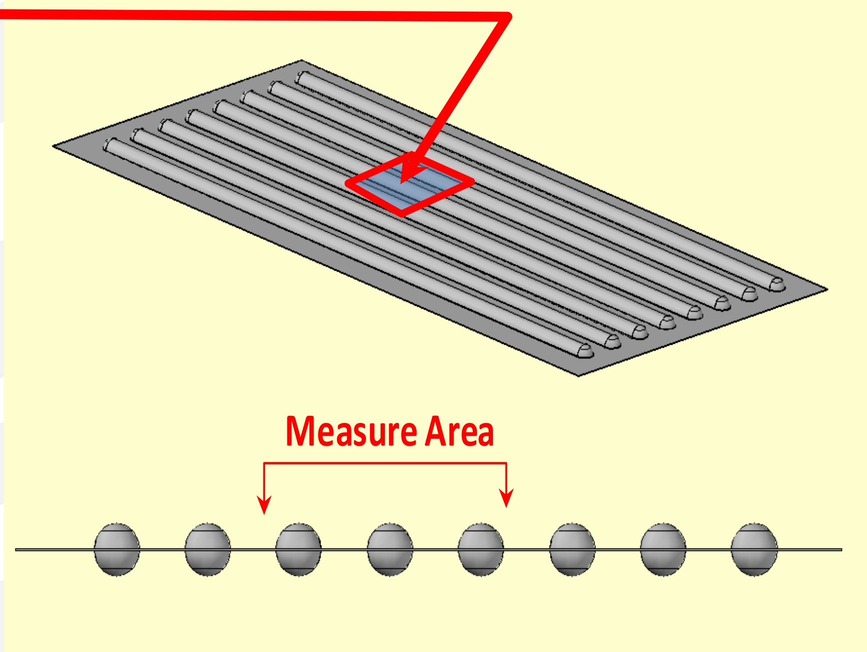
- DSC – only for uniform PCMs
- T-history method
- Dynamic Heat Flow Apparatus Method
  - Symmetrical process
  - Non-symmetrical process
- Dynamic Guarded Hot-Plate Method – only speculations so far
- Dynamic Hot-Box Method

Complex arrays of PCM containers are extremely difficult to test in conventional HFMA equipment

Example of estimation of the measure area for the arrays of PCM pouches or PCM containers.

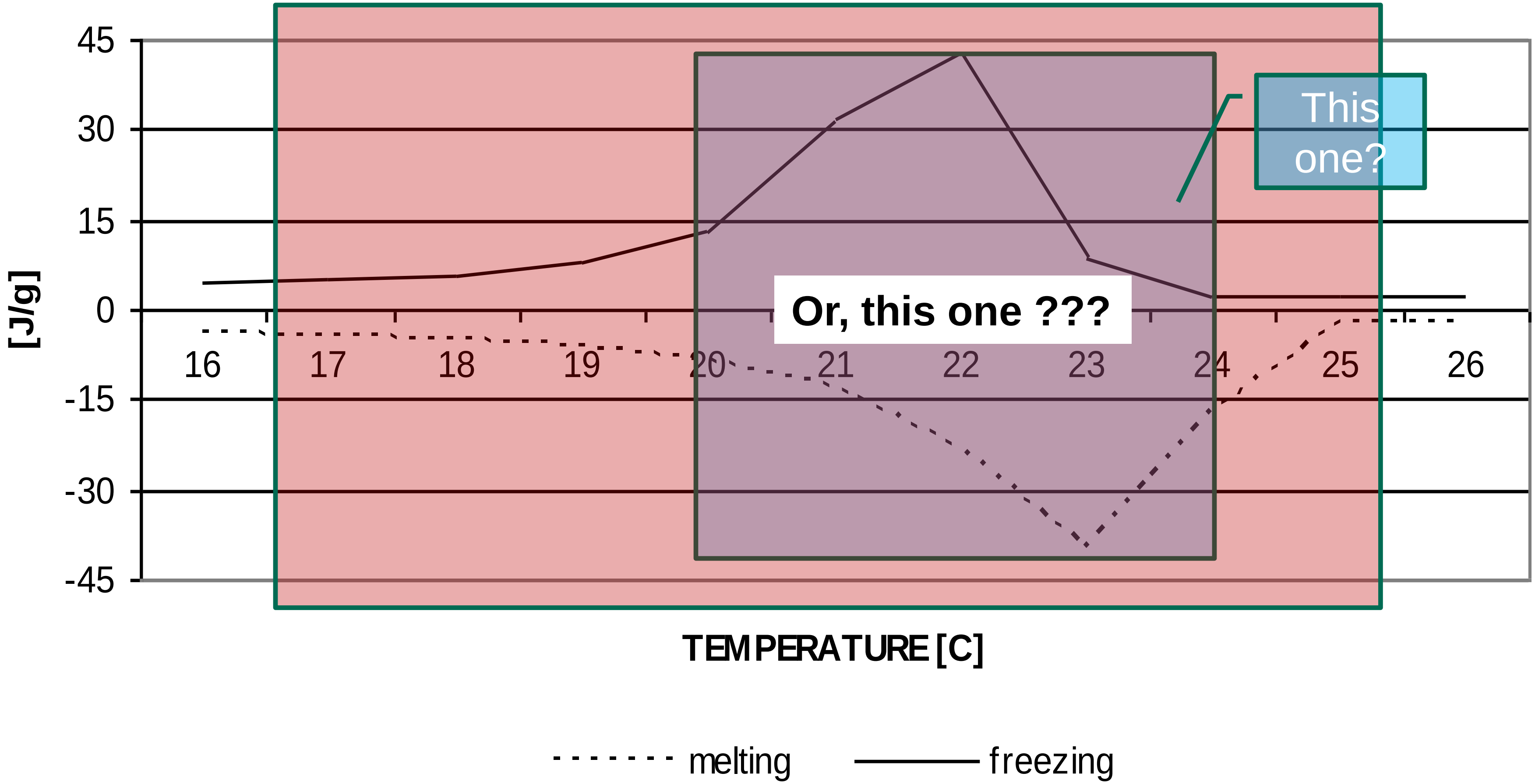
Measure area needs to contain representative geometry of the measured array of PCM containers





Potential area for misuse of the experimental data on PCM-enhanced products for most-likely marketing purposes

For what temperature range PCM enthalpy should be calculated if c_p-related effects are included together with phase transition–related effects?



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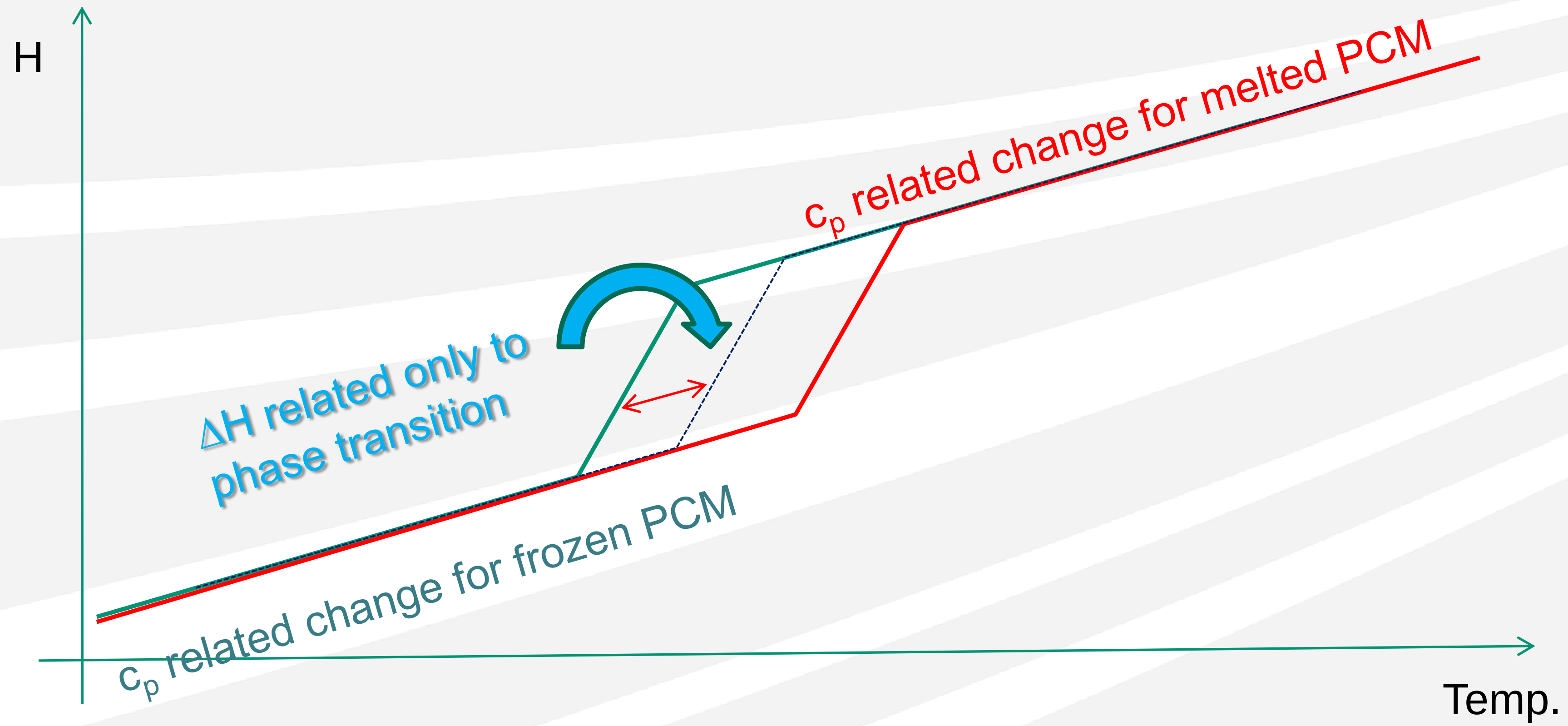
M-value – New Energy Performance Label for PCM-Enhanced Products

Expressing only phase transition-related enthalpy change

Fraunhofer USA

November 11, 2011   Cambridge, MA, USA

Understanding of **Enthalpy Profile** in estimation of M-value



It is possible to analytically estimate and later subtract c_p-related enthalpy changes for both frozen and melted stages of the testing.

Basic Heat Transport Equations:

The one-dimensional heat transport equation for such a case is as follows:

$$\frac{\partial}{\partial t} \quad \rho h \quad = \frac{\partial}{\partial x}\left[\lambda \frac{\partial T}{\partial x}\right]$$

where; ρ and λ are the material density and thermal conductivity, T and h are temperature and enthalpy per unit mass. Heat flux q is given by:

$$q \quad x,t \quad = -\lambda \frac{\partial T \quad x,t}{\partial x}$$

The enthalpy derivative over the temperature (with consideration of constant pressure) represents the effective heat capacity, with phase change energy being one of the components:

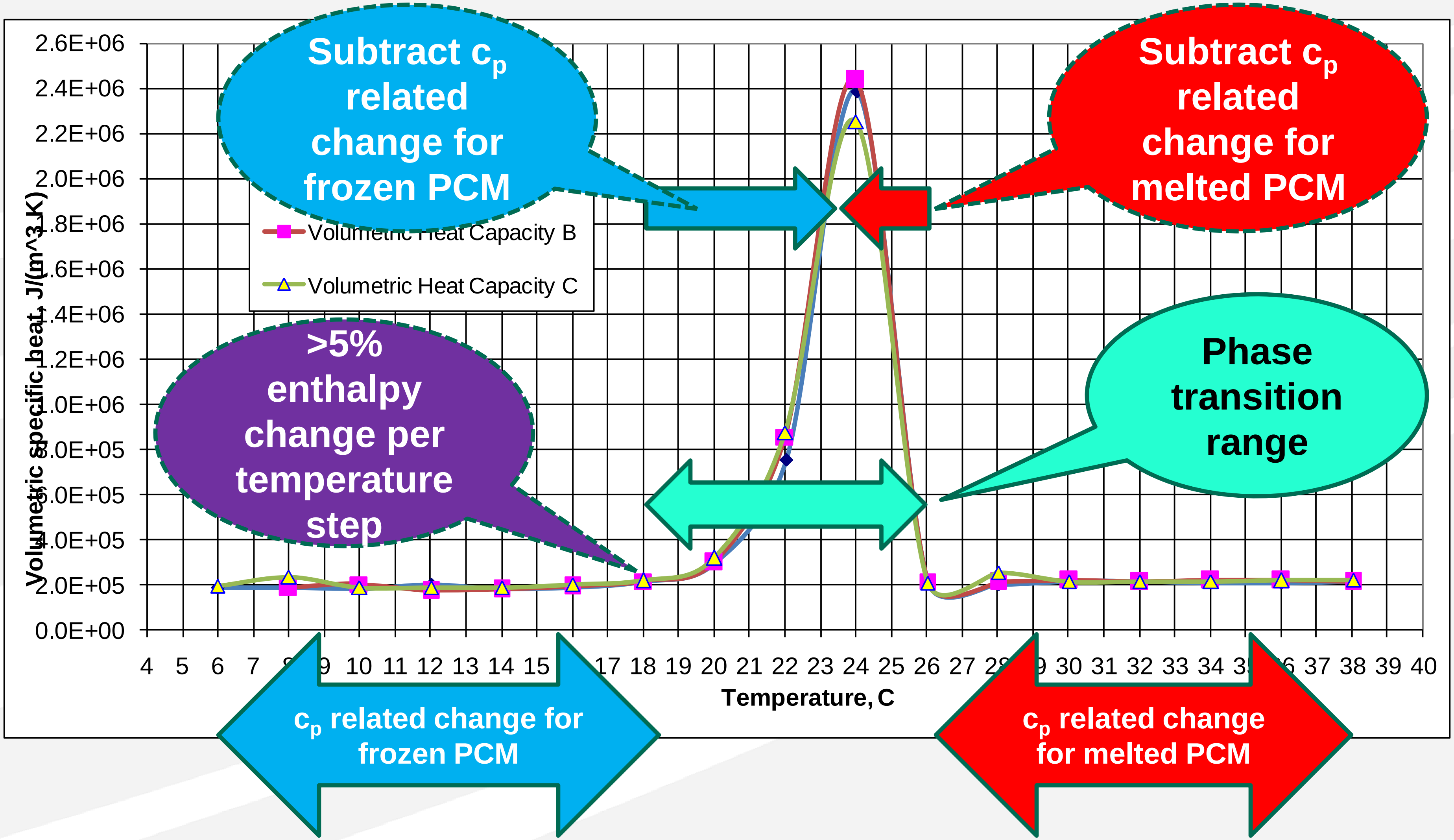
$$c_{eff} \quad T \quad = \frac{\partial h}{\partial T}$$

Effective heat capacity, c_{eff}, for a material which is a blend of insulation and PCM may be expressed as

$$c_{eff} = \quad 1-\alpha \quad c_{ins} + \alpha c_{effPCM}$$

where α denotes the percentage of PCM, c_{ins} the specific heat of insulation without PCM and c_{effPCM} is effective heat capacity of PCM.

Practical determination of M-value based on the DHFMA data

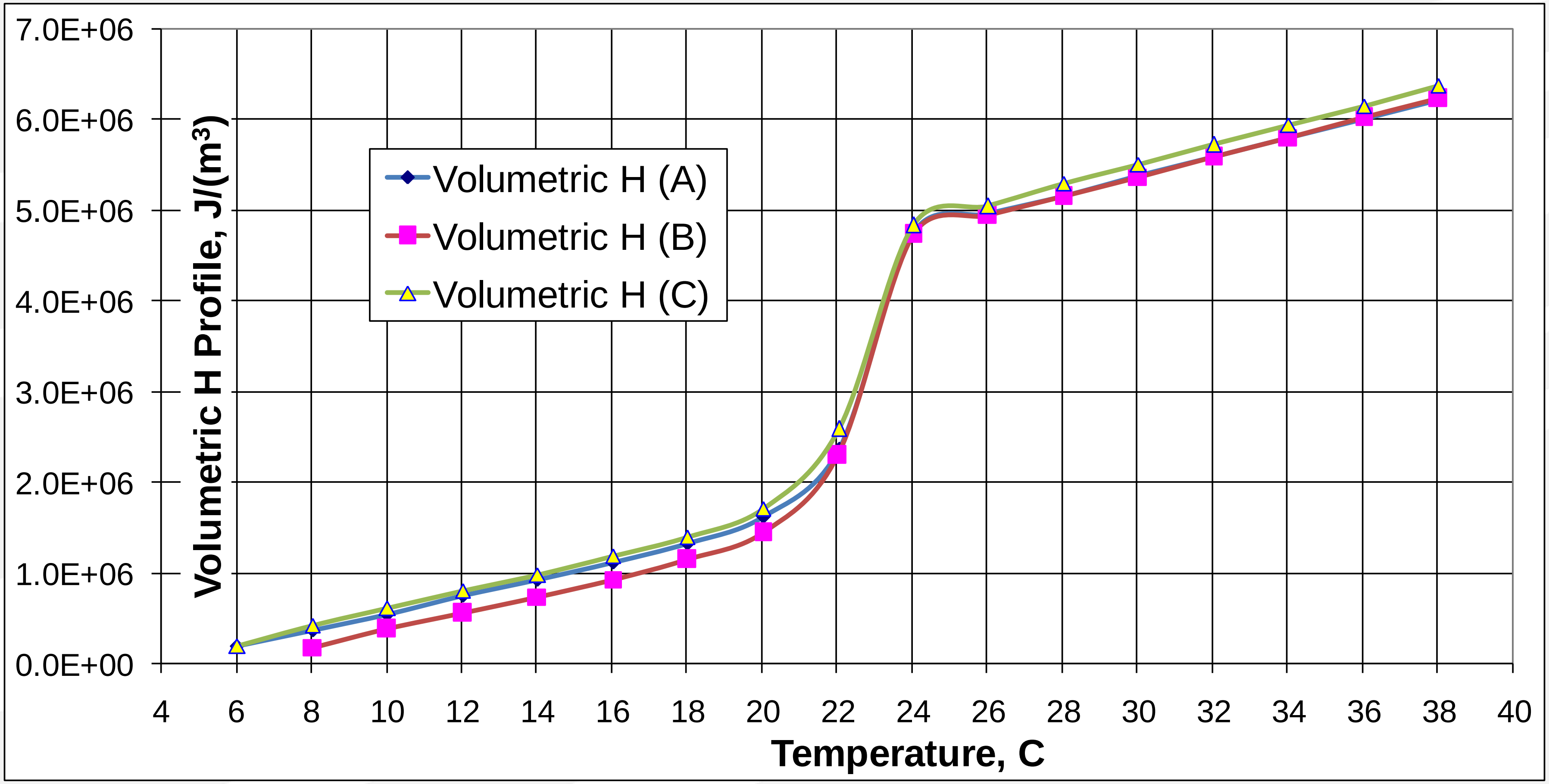


Final Result

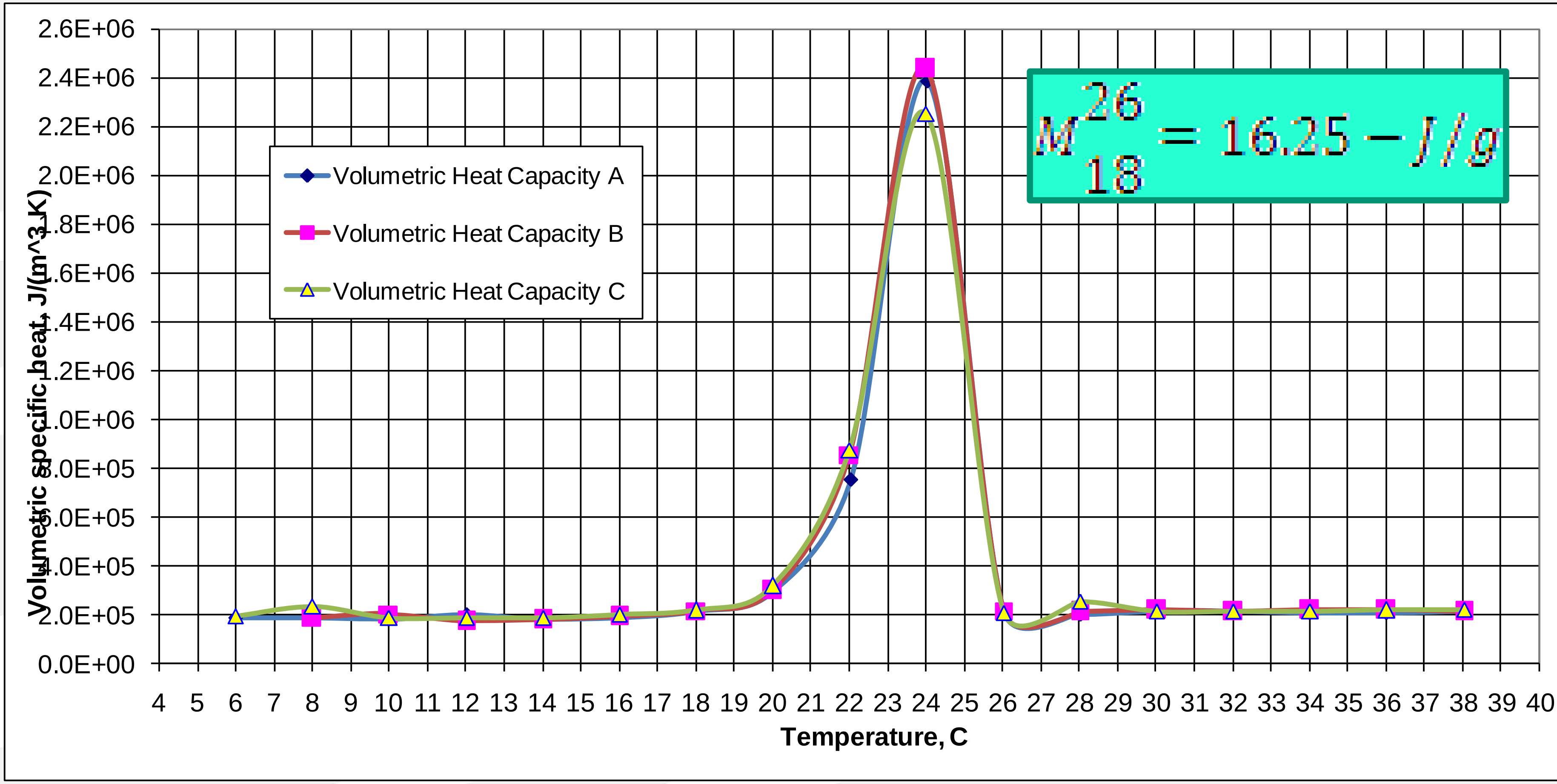
M-value → $M_{T_L}^{T_U}$ [J/g]

Example of Dynamic Heat Flow Metter Apparatus Testing of Loose-Fill Insulations Mixed with Microencapsulated PCM

Enthalpy change profiles for 2°C temperature steps



Final Test Results



Described above measurements yielded the total enthalpy of the tested PCM-enhanced material of 16.25 J/g, with a +/-3.4% difference between the highest and lowest results.

Future Fraunhofer CSE Work

- Addition of new PCMs to the database
- Addition of new PCM-enhanced products???
- Introduction of the uniform performance label for PCMs
- Dynamic testing of more material samples
- Whenever it is possible compare DHFMA data with DSC or T-history test data
- More testing with different temperature steps
- Modeling leading to optimization of the temperature step – as a function of specimens thermal conductivity and thickness
- Field testing of PCM systems
- Development of the ASTM and ISO standards

Thank You!

Any questions ?

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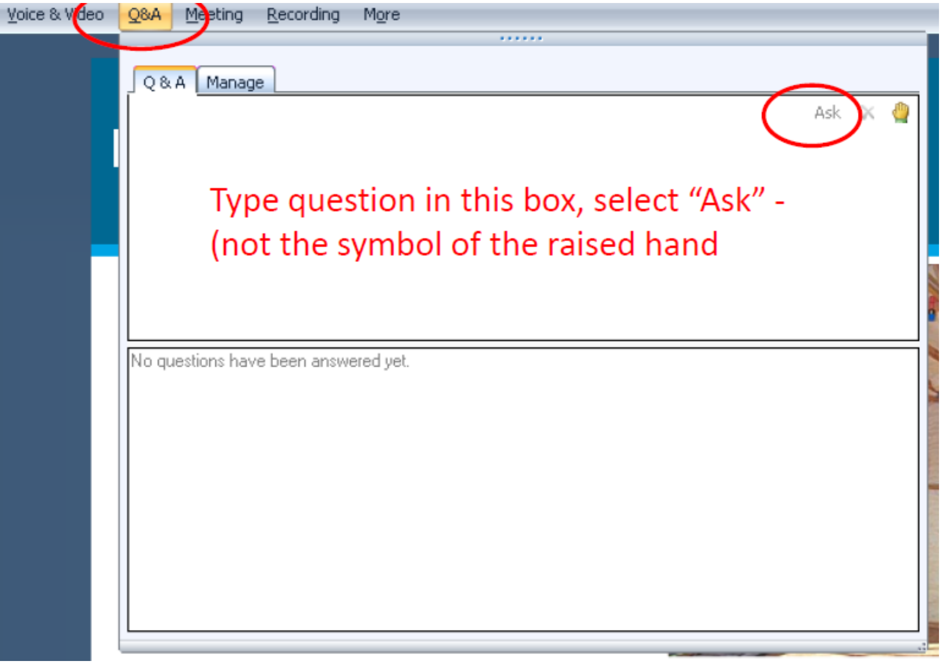
Q&A Session



To submit a question, click on the Q&A link on the top bar of your screen, type the question in the box, and click "Ask."

Our speaker will address as many questions as time allows.

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