

# Phase Changing Material

for Storing Thermal Energy

## OVERVIEW

*by Pawanexh Kohli*



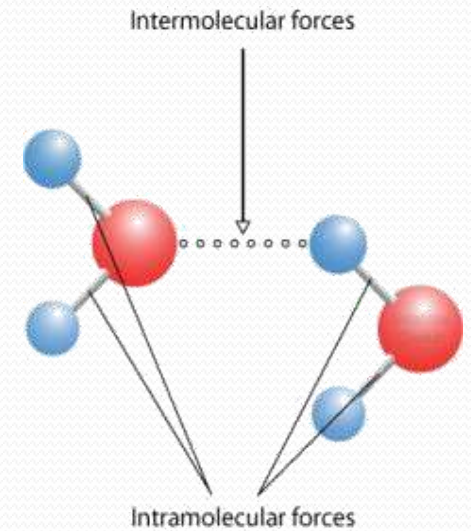
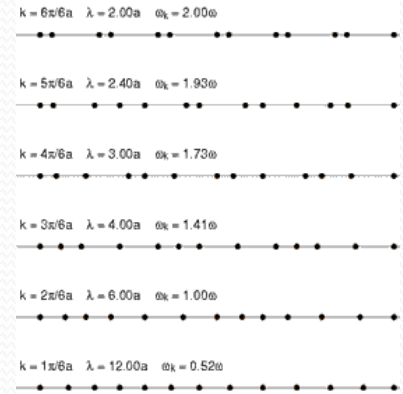
# Overview PCM

## Phase Change or Passive Cooling Materials

- PCM stores **thermal energy** through its molecular phase change point (a temp or energy zone).
- In undergoing a phase change, thermal energy is released or absorbed at almost constant temperature - **thermal inertia**.
- Solid to liquid -> crystalline shape to fluid -> surrounding heat is absorbed (break inter-molecular bonds). Temperature stays steady.
- Liquid to solid -> reverse happens, energy is input (coalesce the molecular structure). Temperature stays constant.
- By utilising this stored thermal charge, **portable** thermal management is effected. PCM allows parcelling out of thermal charge in wide variety of **small & light weight** utilities and assorted applications.
- Much like battery invertors store cheap grid power as backup instead of resorting to other expensive sources - DG Sets.

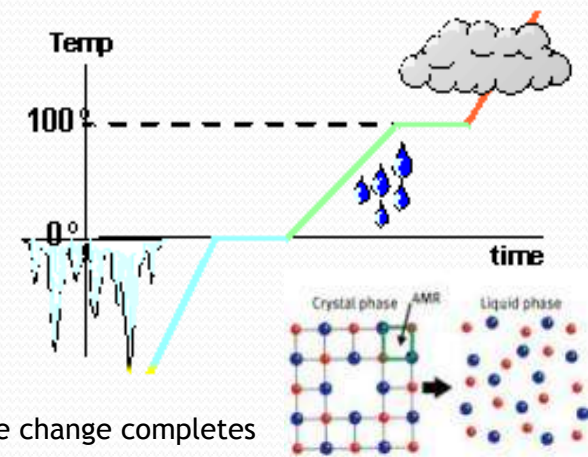
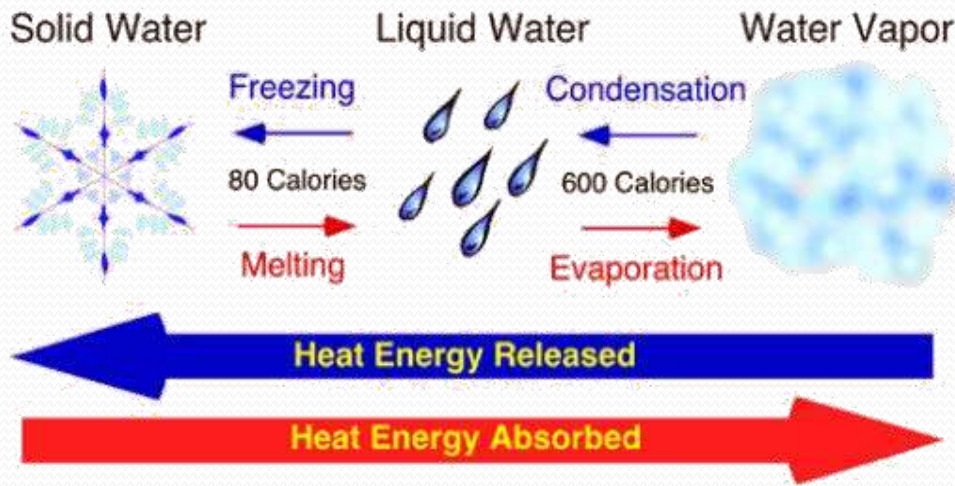
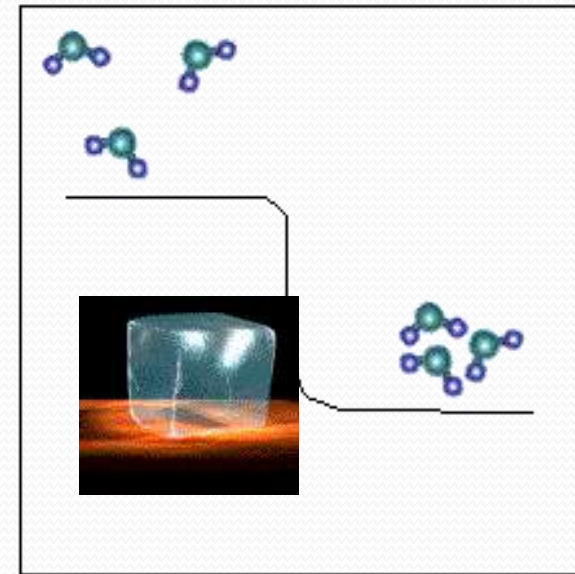
# Simple Energy Definitions

- **Sensible Energy**
  - the portion of the internal energy associated with molecular rotation and vibration - kinetic energies of molecules.
- **Latent Energy**
  - the internal energy associated with the strong intermolecular bonds - also determines the phase of a system.
- **Nuclear Energy**
  - the tremendous amount of energy associated with the strong bonds within the nucleus of the atom itself.



# Energy to Change Phase

- Heat of Fusion
  - Make/Break Molecular Bonding.
- Solid to Liquid - Endothermic
  - Absorbs Energy (Heat).
- Liquid to Solid - Exothermic
  - Releases Energy (Heat).

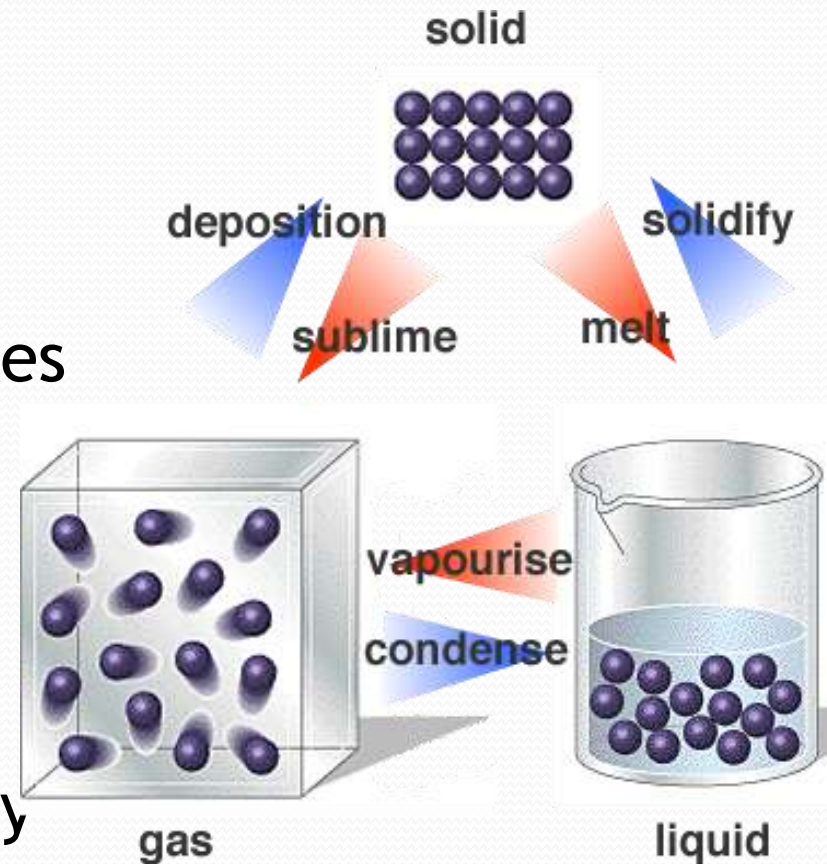


In case of Melting Ice: the ice-water mix remains at 0 °C until all phase change completes

# How/What PCM?

## Harnessing the Force of the Molecule

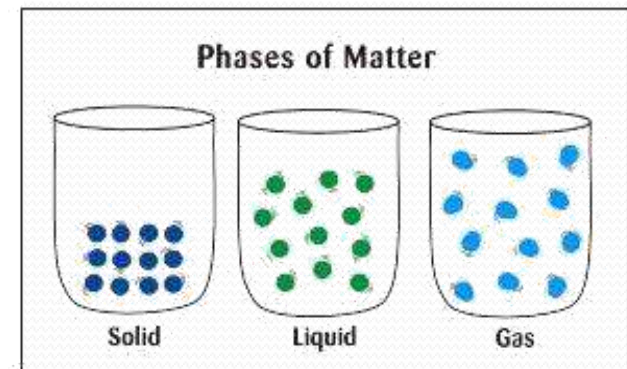
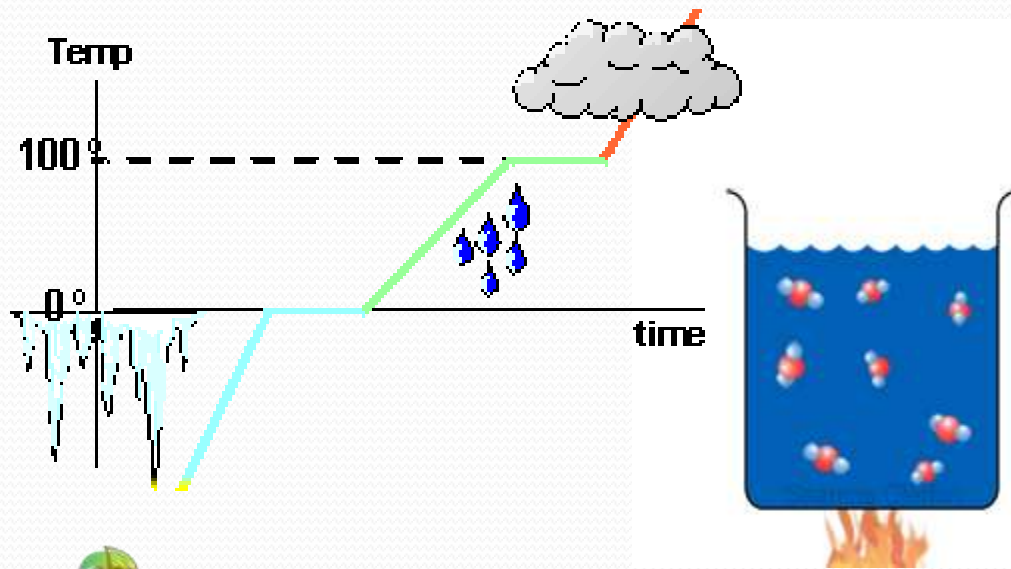
- Four Phases of Matter.  
(4<sup>th</sup> phase is plasma - atomic forces)
- Control the temperature zone when a material makes or breaks the Molecular Force of attraction.
- PCM can be Organic and synthetic mixtures.
- Is a method to store energy at differing desired levels.



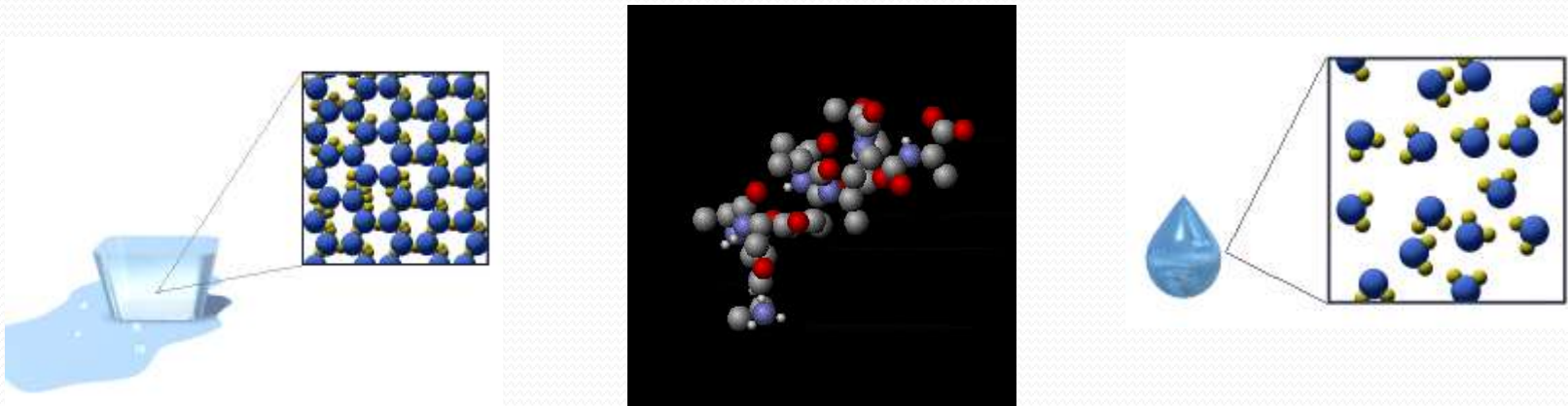
# Thermal Inertia

- The tendency to retain or resist any energy level change.
- Maintains a desired steady state temperature profile.
- Energy stored and output from 170 KJ to 300 KJ per kg.
- Offers a wide array of thermal applications.

- When water freezes, energy is released to surroundings.
- When ice melts, energy is absorbed from surroundings.
- PCM is 'ICE' at controlled, desired temperature levels (example: ice that melts at +20 °C)



# Energy to Change Phase



Different Materials Change Phase at differing energy levels  
With appropriate chemistry, the desired phase change energy level is created.

MATERIAL	SPECIFIC HEAT 20 °C	HEAT OF FUSION @ mp	HEAT OF VAP. @ bp
Water	1.0 cal/g deg	80 cal/g	540 cal/g
Aluminum	0.22 cal/g deg	94 cal/g	2510 cal/g
Ammonia	1.1 cal/g deg	108 cal/g	327 cal/g
Copper	0.094 cal/g deg	49 cal/g	1130 cal/g
Gold	0.032 cal/g deg	16 cal/g	377 cal/g
Iron	0.12 cal/g deg	1510 cal/g	84.52cal/g
Lead	0.032 cal/g deg	5.5 cal/g	205 cal/g
Mercury	0.033 cal/g deg	2.8 cal/g	71 cal/g
Silver	0.056 cal/g deg	26 cal/g	558 cal/g

# Advantages

Environment friendly	<ul style="list-style-type: none"><li>• CFC free, passive cooling solution.</li></ul>
Small carbon footprint	<ul style="list-style-type: none"><li>• Green solution, Clean image, no polluting mobile cooling.</li></ul>
Portability options	<ul style="list-style-type: none"><li>• Opportunity to mix temperature profiles on same transport vehicle, direct-to-home inter-modal option.</li></ul>
Compartmented option	<ul style="list-style-type: none"><li>• Limits thermal exposure of cargo as unit loads need be opened only at point of discharge.</li></ul>
Operational Savings	<ul style="list-style-type: none"><li>• Use existing facility (cold rooms, ice factory, freezers) to recharge or take advantage of differential electrical tariffs.</li></ul>
Load security	<ul style="list-style-type: none"><li>• Each modular unit unsecured only at delivery point.</li></ul>
Reusable solution	<ul style="list-style-type: none"><li>• Stays in users care – easy HACCP and Food safety compliance, Complete Control by user.</li></ul>
Minimal Capital cost	<ul style="list-style-type: none"><li>• Utilise existing dry transport movement (reefer vans not needed + earn carbon credits).</li></ul>

# Advantage Green

- Cost Effective alt to Reefers.
- CFC Free Technology.
- Green Environ-friendly image.
- Reusable Transport Boxes.
- No thermal theft.
- Opportunity to mix loads on same vehicle.
- Direct to Home Option.
- Easy HACCP implementation.
- User retains total control.

Source: TCIL/Snow man/Evergreen/Transport Union

Type of Vehicle	Reefer	Ordinary	Reefer	Ordinary
Vehicle Model	Tata 407	Tata 407	Tata-1109	Tata-1109
Container size	12 feet	12 feet	18 feet	18 feet
Pay load	1.5 ton	3 ton	3.2 ton	6 ton
Freight/Trip (Rest.)	6,500	2,000	8,600	3,500
Freight/Week (Rest.)	40,000	12,500	54,000	23,500

% Saving	69%	59%
Saving / veh / day	4,500	5,100
Saving / veh / month	Rs 1,35,000.00	Rs 1,53,000.00
Saving / veh / annum	Rs 16,20,000.00	Rs 18,36,000.00
Saving / 12 veh / ann	Rs 1,94,40,000.00	Rs 2,20,32,000.00

# Cost Benefit Analysis

## Inner City Transport

- Assuming a daily Tertiary distribution of 1MT

Particulars	Chilled Products	
	Current	Proposed
Vehicle Type	Reefer	Normal
Average transportation cost/per kilometer	Rs/km 25	Rs/km 12
Kilometers per Day (To & Fro)	80	80
Transportation Cost/Day (Rupees)	2,000	960
Transportation Cost/Month (Rupees)	60,000	28,800
Charging of PCM Pads/ Month		600
Total Monthly Charges (Rupees)	60,000	29,400
Savings (%)		51%

- Minimal Capital Expenditure. Use existing Dry Vehicles.
- Reduced Storage Lead time for perishable movement.
- Reduced Risks inherent to large High Value load transport.

# Green Technology?!

- Vehicles used have normal dry-freight bodywork-
  - No costly refrigeration systems (both to buy and operate).
- Reduced energy consumed in making of non-insulated truck body.
- Energy Saved due reduced running costs with lower unladen weight.
- Goods are delivered in their own “mini” cold stores; there is no need for refrigerated stores at the delivery point.
- No requirement to have temperature-controlled assembly areas or loading bays at dispatch or receiving location.
- The passive cooling systems are totally silent - ideal for “out of hours” deliveries.
- Further energy/cost requirements not needed to regularly replace old and worn out equipment.
- Passive cooling system can be charged in the freezing plant at the factory without the need for additional equipment.

# How to use

Insulated transport containers can be fitted with PCM. (Design to incorporate cargo requirements).

Similar to existing vaccine carriers but scaled up to suit load and utility.

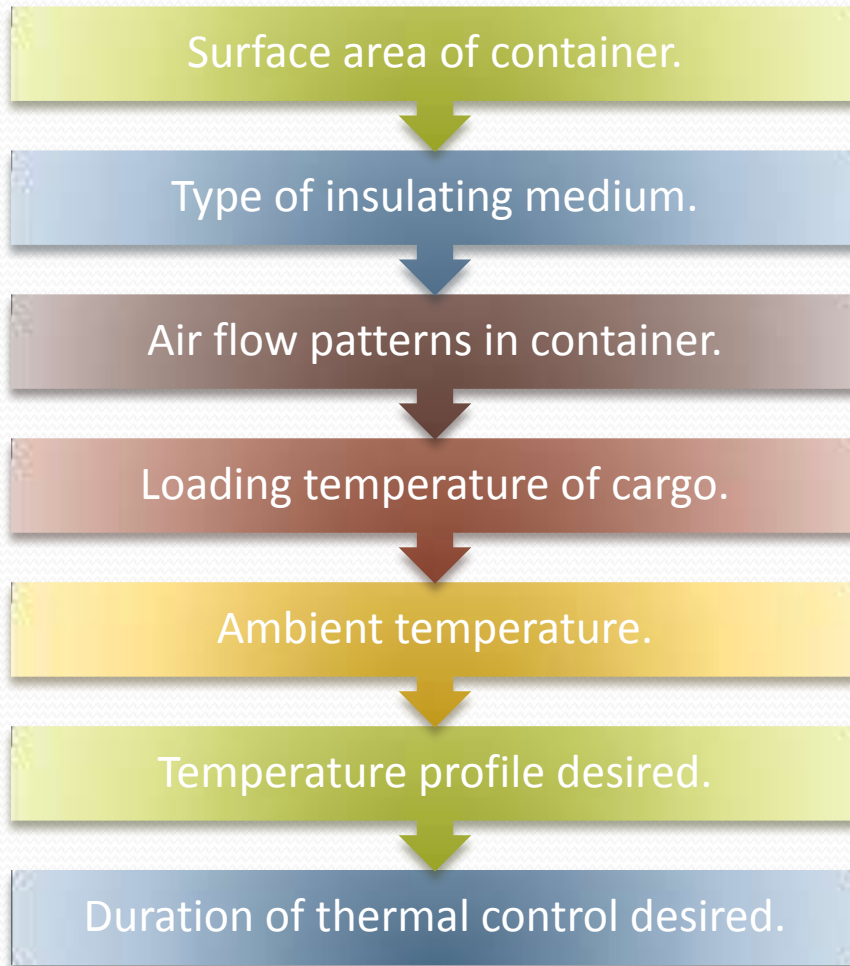
PCM will get depleted as it counters heat ingress through insulation or respiratory load of cargo.

Charging facility can be village ice factory or an appropriate deep freezer.

For small loads (a farms 100 kg load) can be used to transport in tractor trailers or passenger buses, etc.

Amount of PCM used will define duration index – from a few hours to days.

# Factors to consider



- Phase Change Material are available for various temperature profiles.
- Globally from  $-168\text{ }^{\circ}\text{C}$  to  $+300\text{ }^{\circ}\text{C}$  and more are in development.
- The stated temperature is when the phase change occurs.
- Imagine... ice that melts (changes phase) at  $300\text{ }^{\circ}\text{C}$ .

# Example Grapes

- Properties:
  - Optimum Store -0.5 to 0 °C.
  - Ventilation very Low.
  - Ethylene Production Very Low (<0.1  $\mu\text{l}/\text{kg}\cdot\text{hr}$  at 20° C)
  - Ethylene sensitivity Low.
  - Bruising susceptible Very High.
  - Water Content 81%.
  - Moisture Loss High.
  - Respiration & Heat transfer
    - 102 Watts/ton @ 25 °C (8400 BTUs)
    - 5 Watts/ton @ 0 °C (410 BTUs)



# Advantages for Grape

- No moisture loss with passive cooling - while awaiting transport. PCM counters any heat load.
- Dedicated utility - no tainting risk.
- Complete HACCP control by user.
- For short periods, assists prior pre-cooling.
- Aids smaller unit load movement in lots to plant.
- Protects loads from bruising as unit loads moved in insulated container.
- Reduces load risk and loss - initiates cold chain at plucking.
- Increases spread: as product protected from farther cachement distance upto plant.



# Other Applications

## Phase Change Material

**Energy cannot be destroyed or created  
– it can only change from one form to another.**



# In-Theatre Micro Climate Jackets

## Advantage Warrior

- Jackets to preserve body heat (for Freezing battlefields) or Cool Jackets (for hot climes).
- Controlled Body Temperature.
- Reduced Tension and Anxiety.
- Reduced Thermal Burden (TB).
- Reduces Thermal Fatigue.
- Enhances Recovery Time.
- Increased Peak Performance.
- Increased Endurance.
- Increased Field availability.
- No Moving Parts.
- Modernisation of Infantry.



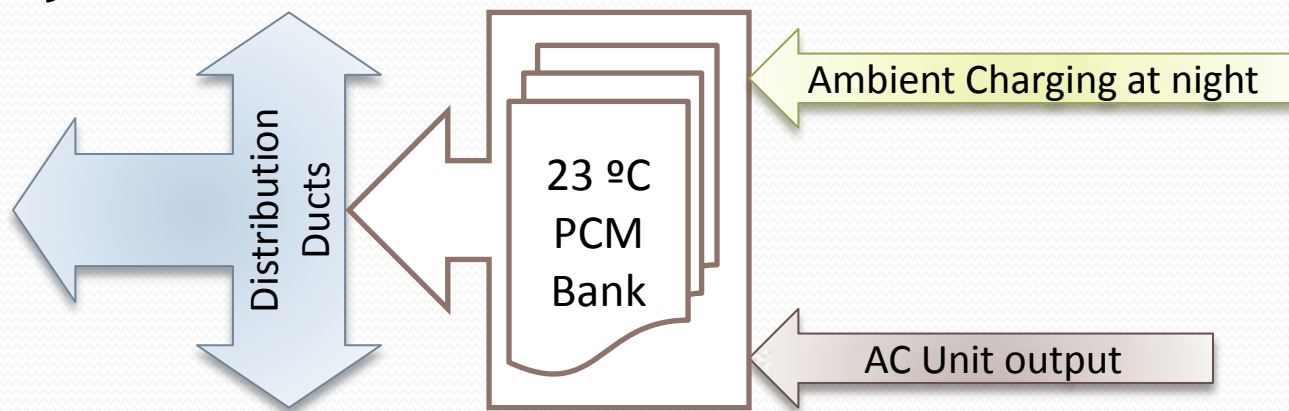
170 to 300 KJ (72 kilo calories) of energy stored

# How will it work

- When body has to regulate temperature, the brain triggers vasodilatation & increases blood flow to the peripheral skin areas of the body.
- The cooling formulation inside the Vest absorbs body's excessive heat, cooling the blood as it circulates through the cardiovascular system.
- As the blood and soft tissue become cooler, lower metabolic activity is required to meet the demand to regulate your body's internal temperature. Less body fluids are forfeited, helping maintain suitable electrolyte balance for proper muscle function and optimum physical performance.
- Individuals will immediately feel the initial cooling effect of the Vest; as the body becomes acclimated to the 29° C temperature, the sensation of cool may decrease; However, the heat is still being drawn away from your body. The effect is similar to that experienced when jumping into a swim-pool; the body gets used to the initial coolness, but the water continues to draw heat away from the body.
- Reduced thermal fatigue translates into prolonged peak performance, sharper shooting, faster response times - a more effective soldier.

# HVAC for Buildings

- Overnight at low occupancy times, cooler night air used to charge 23 °C PCM.
- Next morning, PCM bank is used as initial heat exchange system reducing electricity load for 4 to 6 hours daily.



Various temperature profiles and applications are possible from this simple energy saving concept.

# Thermal Management Systems

- **Helmet Inserts** - Simple, effective heat burden relief; re-useable attachment fixes directly to underside of helmet.
- **Blood Carrier Packs** - Keeps blood in battlefield between 2 to 10 °C. Increase efficacy of medical aid during tactical operations.
- **Food Carriers** - keeps cooked food supplies warm during transit. Enhanced distribution of rations.
- **Material Cooling** - applied to firing chambers, keeps metal within thermal limits longer; reduce weapon jams.
- **Heat Storage** - as backup for body warmers even after source battery has died.
- **Temperature Controlled Transfer Case** - sophisticated, microprocessor based Hybrid System maintaining the temperature within a narrow range of low temperature keeping perishables in profile range.



# Latent Storage for Consumers

- Hand Warmers for Winter.
- Smart Textiles (thermo regulated)
  - Bullet Proof Jackets.
  - Airforce Pilot Suits.
  - Army Parkas.
  - Pillows, Sleeping Bags, Quilts.
  - Nappies, Bandages.
  - Sports wear.
- Motorcycle Helmet Coolers.
- Lamp Shade Liners for Winter heating.
- Car Seats for Winter and Summer.
- Beverage Vending Machines.



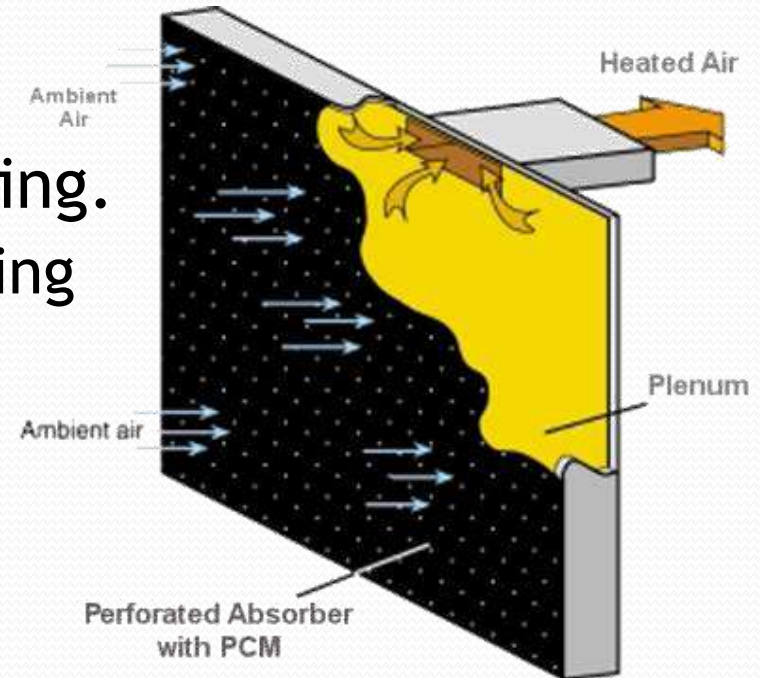
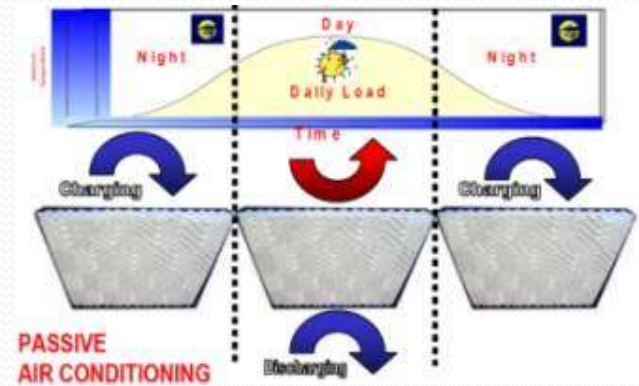
# Lamp Heat & PCM

- Winter evenings, 18 °C - bed lamps are on, generating heat.
- Lights off time 10PM - temp drops to 14-11 °C.
- Midnight - temp is 7 °C, electric heaters are running continuously.
- PCM coated lamp shades (or lamp Body) will trap heat when lamps are lit and then dissipate overnight, keeping room warmer.
- PCM based body on electric heaters will also store heat in case of power outage.



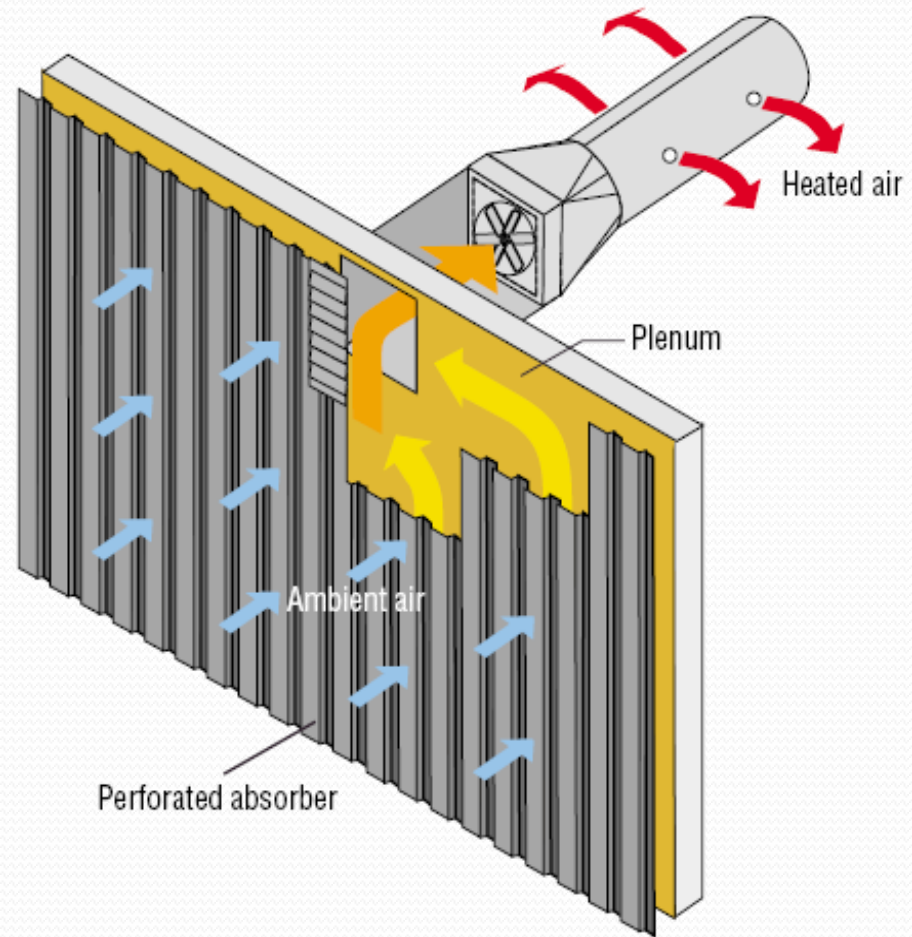
# Latent Storage in Construction

- Structural Cladding
  - Walls tiles
  - Roof tiles
  - Underfloor heating/cooling
- Enhanced Cooling Towers.
- Passive Structural Airconditioning.
  - Solar/Thermal for room warming in winters.
  - Combine with Solar Heaters.



# Solar Wall

- A Hollow space (6" Plenum) is created on South facing wall of a building.
- In winters, sunlight heats this space - usually filled absorbent (black wool).
- Air is sucked through this plenum into the building to keep inside warm.
- PCM granules can be used in this space to store solar heat.



# Is it in use?

- Lower energy and fuel costs in past kept PCM utilisation low.
- Limited use today - telecom shelters largest application.
- US Army using jackets for desert warfare.
- Australian cricket team used cooling jackets based on PCM.
- Australia has a complete building utility saving energy consumptions.
- Israel uses for solar thermal energy storage.
- Hybrid (powered and PCM storage) based utilities are being developed.
- Building HVAC systems (charge PCM in low load conditions) being developed.

Fini



[pxkohli@crosstree.info](mailto:pxkohli@crosstree.info)

+91-9990399638

Thank You