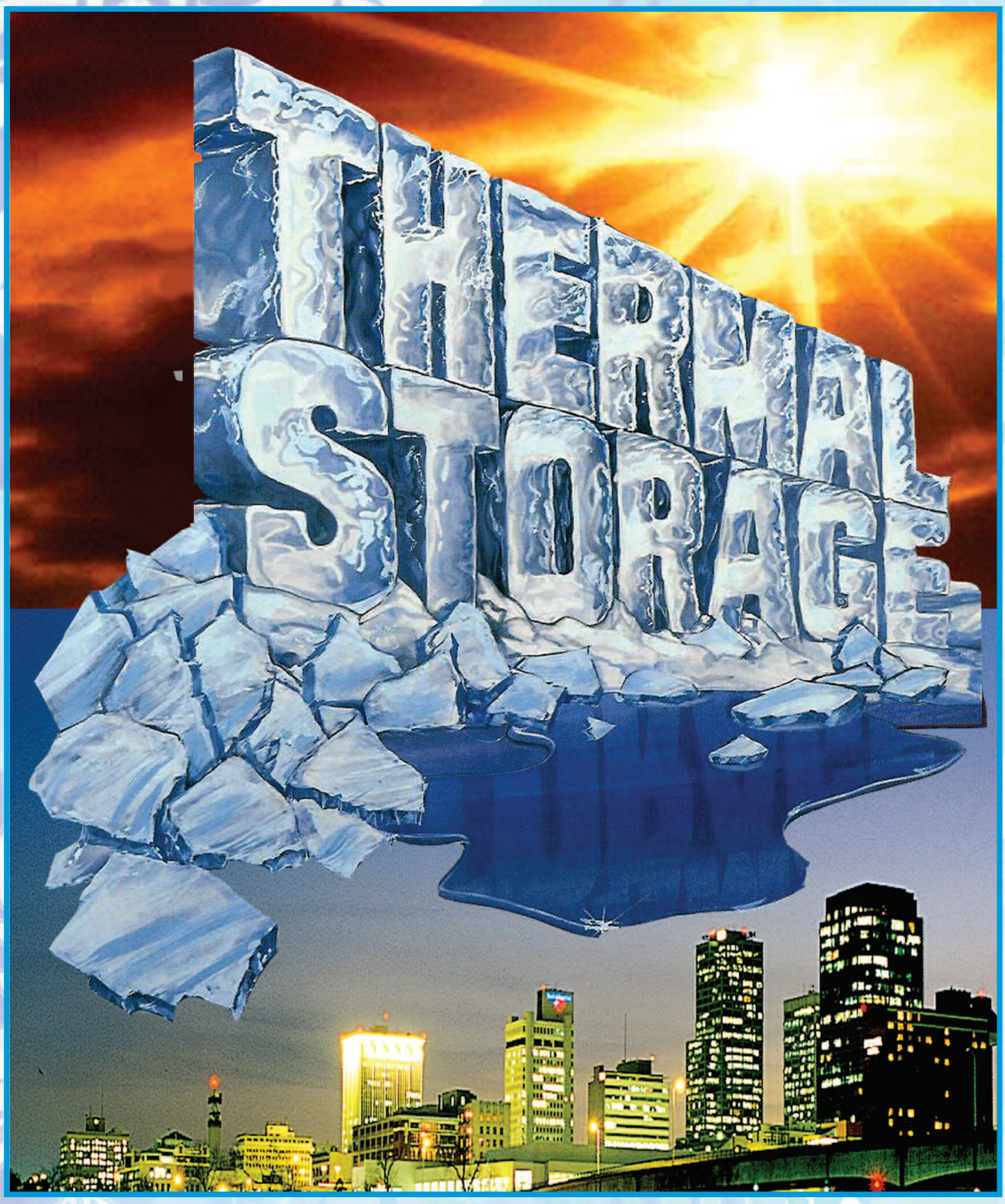
PlusICE™
Phase Change Material

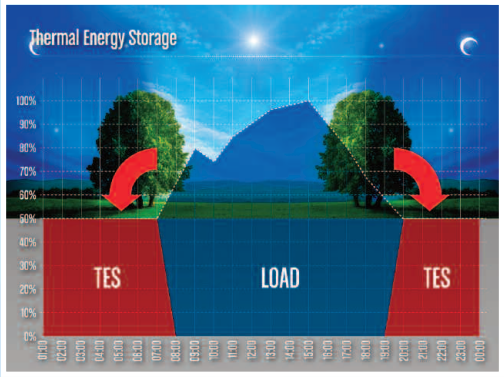


PCM PHASE CHANGE MATERIAL PRODUCTS LIMITED

NATURAL ALTERNATIVE TO REDUCE ENERGY

THERMAL ENERGY STORAGE;

Thermal Energy Storage (TES) is the temporary storage of high or low temperature energy for later use. It bridges the gap between energy requirement and energy use. A thermal storage application may involve a 24 hour or alternatively a weekly or seasonal storage cycle depending on the system design requirements. Whilst the output is always thermal, the input energy may be either thermal or electrical.



Phase Change Materials (PCMs) are products that store and release thermal energy during the process of melting & freezing (changing from one phase to another). When such a material freezes, it releases large amounts of energy in the form of latent heat of fusion, or energy of crystallisation. Conversely, when the material is melted, an equal amount of energy is absorbed from the immediate environment as it changes from solid to liquid.

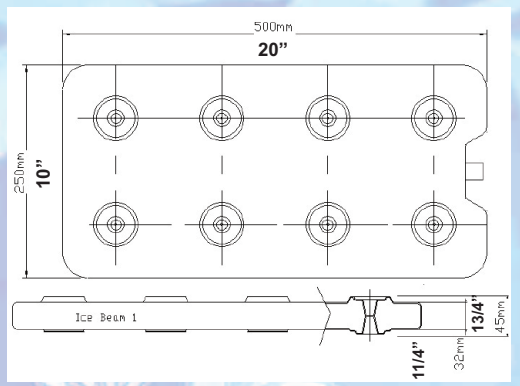
In a majority of the applications, PCM solutions have to be encapsulated in sealed containers. To this end, PCM Products Ltd. have developed many different standard as well as custom-made containers for special applications. These containers can be applied to any water or air based TES systems and can be manufactured using our PlusICE Phase Change Material (PCM) solutions which have operating temperatures between ***-40ºC (-40ºF)*** and ***+117ºC (+273ºF)***

Encapsulated Containers;

FlatICE™

These containers are blow moulded HDPE and can be filled with both negative or positive temperature PCMs up to 50ºC (122ºF) above this temperature would not be suitable due to softening of the plastic and loosing their strength.

When stacked there is a small gap between each container, allowing either air or water to flow easily over the containers while providing a large PCM surface area for heat transfer.



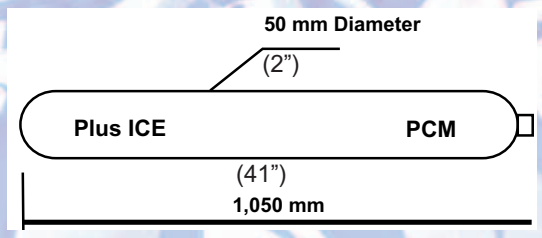
FlatICE custom-made HDPE plastic containers are filled with PlusICE PCM solutions and the filling port fully welded after filling in order to ensure safe and reliable operation. The design of these plastic containers incorporate several internal support columns as well as external guide circles, allowing the containers to be stacked on top of each other forming a self-assembling large heat exchanger within the tank.

The self-stacking concept can be applied for both water and air circuits and the gap between each container provides an ideal flow passage with a large heat exchange surface.

PCM Type	PCM (C)	PCM (F)	kWh per FlatIce	TES Tank Capacity (kWh/m³)	Weight per FlatIce (kg)	*Ton-hrs per FlatIce (*)*	*TES Tank Capacity (Ton-hr/USG)*	*TES Tank Capacity (Ton-hr)*	*Weight per FlatIce (lbs)*
S46	46	*115*	0.334	67	6.03	*0.100*	*0.072*	*0.538*	*13.30*
S34	34	*93*	0.243	49	7.98	*0.073*	*0.052*	*0.391*	*17.60*
S32	32	*90*	0.293	59	5.55	*0.088*	*0.063*	*0.471*	*12.23*
S30	30	*86*	0.249	50	4.96	*0.074*	*0.054*	*0.400*	*10.93*
S27	27	*81*	0.281	56	5.81	*0.084*	*0.060*	*0.452*	*12.82*
S25	25	*77*	0.276	55	5.76	*0.082*	*0.059*	*0.444*	*12.69*
S23	23	*73*	0.269	54	5.78	*0.080*	*0.058*	*0.433*	*12.74*
S21	21	*70*	0.261	52	5.78	*0.078*	*0.056*	*0.420*	*12.74*
S19	19	*66*	0.244	49	5.77	*0.073*	*0.052*	*0.392*	*12.73*
S17	17	*63*	0.245	49	5.80	*0.073*	*0.053*	*0.394*	*12.78*
S15	15	*59*	0.243	49	5.74	*0.073*	*0.052*	*0.391*	*12.65*
S13	13	*55*	0.243	49	5.76	*0.073*	*0.052*	*0.391*	*12.69*
S10	10	*50*	0.229	46	5.59	*0.068*	*0.049*	*0.368*	*12.32*
S8	8	*46*	0.222	44	5.61	*0.066*	*0.048*	*0.3547*	*12.36*

(*1 Ton-hr = 12,000 Btu)

NATURAL ALTERNATIVE TO REDUCE ENERGY



TubeICE™

TubeICE is a concept based on custom-made plastic containers filled with our PlusICE Phase Change Material (PCM) solutions which have operating temperatures between ***-40°C (-40°F) and +46 °C (+115 °F)***.

They can be stacked in either cylindrical / rectangular tanks for both atmospheric and pressurized systems for a variety of thermal energy storage applications.

TubeICE custom-made HDPE plastic containers are filled with PlusICE PCM solutions and the filling port fully sealed after filling for safe and reliable operation.

The self-stacking concept can be applied for both water and air circuits and the gap between each container provides an ideal flow passage with a large heat exchange surface with minimal pressure drop.

PCM Type	PCM (C)	PCM (F)	kWh per Tubelce	TES Tank Capacity (kWh/m3)	Weight per Tubelce kg	*Ton-hrs perTubelc (*)*	*TES Tank Capacity (Ton-hr/USG)*	*TES Tank Capacity (Ton-hr/ft³)*	*Weight per Tubelce (lbs)*
S46	46	*115*	0.144	67	2.8	*0.041*	*0.072*	*0.538*	*6.2*
S34	34	*93*	0.105	49	3.6	*0.030*	*0.052*	*0.391*	*7.9*
S32	32	*90*	0.126	59	2.6	*0.036*	*0.063*	*0.471*	*5.7*
S30	30	*86*	0.107	50	2.4	*0.031*	*0.054*	*0.400*	*5.2*
S27	27	*81*	0.121	56	2.7	*0.034*	*0.060*	*0.452*	*6.0*
S25	25	*77*	0.119	55	2.7	*0.034*	*0.059*	*0.059*	*6.0*
S23	23	*73*	0.116	54	2.7	*0.033*	*0.058*	*0.433*	*6.0*
S21	22	*72*	0.113	52	2.7	*0.032*	*0.056*	*0.420*	*6.0*
S19	19	*66*	0.105	49	2.7	*0.030*	*0.052*	*0.392*	*5.9*
S17	17	*63*	0.106	49	2.7	*0.030*	*0.053*	*0.394*	*6.0*
S15	15	*59*	0.105	49	2.7	*0.030*	*0.052*	*0.391*	*5.9*
S13	13	*55*	0.105	49	2.7	*0.030*	*0.052*	*0.391*	*5.9*
S10	10	*50*	0.099	46	2.6	*0.028*	*0.049*	*0.368*	*5.8*
S8	8	*46*	0.096	44	2.6	*0.027*	*0.048*	*0.357*	*5.8*

(*1 Ton-hr = 12,000 Btu)

TANK SIZING;

Whether rectangular or cylindrical tank, first using the formulas below to establish the required tank volume.

SI Units;

Load (kWh)
---------- = Tank Volume (m^3)
Capacity (kWh/m^3)

IP Units;

Load (TRh)
---------- = Tank Volume (USG)
Capacity (Ton-hr/USG)

Load (TRh)
---------- = Tank Volume (ft^3)
Capacity (Ton-hr/ft^3)

Once the tank volume is established using the maximum height / diameter requirement of 2.6m (8½ ft) as well as the diameter / width Vs. length ratios of 1:4 ~1:6, the remaining required tank dimensional details can be established.

Example: 3,520 kWh (1,000 Ton-hr) energy storage system using +10°C (50°F) for both rectangular and cylindrical tank options

SI UNITS

From **FlatICE/TubeICE** table for S10 capacity of 46 kWh/m^3
3,520 kWh / 46kWh/m^3 = ~77 m^3 tank volume

77m^3 x ~200 FlatICE/m^3 = 15,400 FlatICE filled with S10
77m^3 x ~440 TubeICE/m^3 = 33,880 TubeICE filled with S10

Rectangular Tank option
77 m^3 / 2.6 m (Hmax) = ~30.0 m^2
Aim for ~1:4 ratio for W vs. L
Tank dimensions 2.5 m (W) x 12.0 m (L) x 2.6m (H)

Cylindrical Tank option
Diameter (Max) 2.6m cross section is 5.3 m^2
77 m^3 / 5.3 m^2 = ~14.5m
Tank dimensions 2.6m (dia.) x 14.5 m (L)

IP UNITS

From **FlatICE/TubeICE** table for S10 capacity of 0.049 Ton-hr/USG
1,000 Ton-hrs / 0.049 Ton-hr/USG =~20,408 USG tank volume
20,408 USG x 0.13368 ft^3/USG = ~2,728 ft^3

20,408 USG x ~0.754 FlatICE/USG = 15,387 FlatICE filled with S10
20.408 USG x ~1.66 TubeICE/USG = 33,877 TubeICE filled with S10

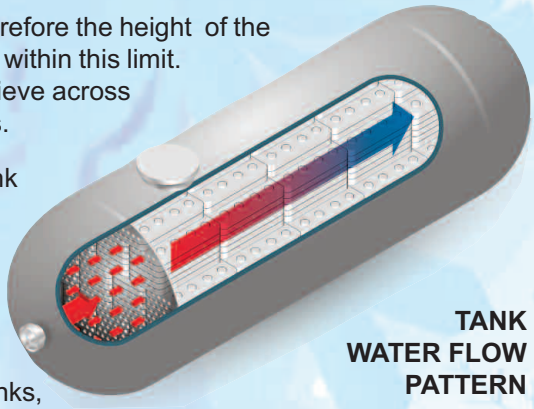
Rectangular Tank option
(728 ft^3 / 8.½ ft (Hmax) = ~ 320 ft^2
Aim for ~1:4 ratio for W vs. L
Tank dimensions 8¼ft (W) x 39 ft (L) x 8½ ft (H)

Cylindrical Tank option
Diameter (Max) 8½ft cross section is 57 ft^2
2,728 ft^3 / 57 ft^2 = ~48 ft
Tank dimensions 8½ft (dia.) x 48 ft (L)

INNOVATION FOR ENERGY SAVING TECHNOLOGIES

FlatICE & TubeICE TANK DESIGN;

FlatICE / TubeICE containers can only be stacked up to 2.6 m (8½ ft) level and therefore the height of the tank is restricted to around 3m (10 ft) and the size of the tank can only be adjusted within this limit. In principal, the longer the tank the larger the temperature difference one can achieve across the tank and the width / length ratios can be adjusted to suit the site requirements.



TANK WATER FLOW PATTERN

Generally concrete tanks can be built below ground, buried and the top of the tank used as a parking area or for landscaping. Alternatively within the basement areas either inside or outside the building. However, if this can not be achieved or is being installed as part of a Retrofit application, sectional tanks can be manufactured and installed on site within the basement / roof areas or outside the building envelope.

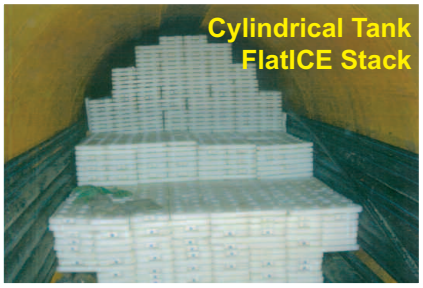
Furthermore, if the storage capacity is too large and the design requires multiple tanks, these can be arranged either in parallel or in a series format to suit the application and available space. Typically the depth of the tank will be 2.6 m (8½ ft) with the internal dimension which corresponding to approx. 65 FlatICE containers high, leaving around 150mm (6") of head room above the containers. Therefore, to estimate the approximate tank size and shape one can use the following formula inline with the FlatICE capacity table.

Rectangular Tank FlatICE Stack

Alternatively, the pressurised tanks can be built to accommodate the containers and buried outside or within the building area.

External Concrete Site-built Tank Application

Tanks ideally should be installed as close as possible to the chiller and load to minimise the pipework and pumping energy penalties. If the system requires pressurised tank a cylindrical tank can be constructed to accommodate FlatICE containers with minimum by-pass.



Cylindrical Tank FlatICE Stack

External Rooftop Tank

It is vital to provide an equal flow rate across the tank section and effectively provide as equal water flow rate as possible over the PCM containers and therefore both rectangular and cylindrical tanks must have inlet and outlet diffuser plates to achieve this aim. The ideal tank width to length ratios would be 1:4 ~ 1:6.
In principal, the longer the tank the larger the temperature difference one can achieve across the tank and the width / length ratios can be adjusted to suit the site requirements.

External Pressurised Underground Tank Application

Internal Pressurised Tanks

Rectangular Insulated External Tank

100 m3 Tanks

Modular 40ft Tanks

Over-ground Tank

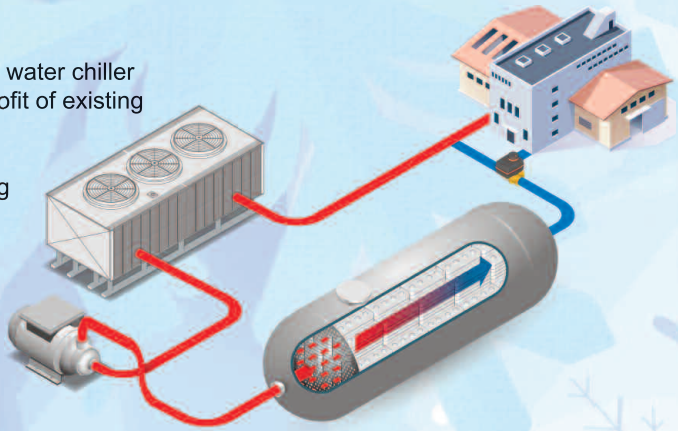
Underground Tanks

Stackable Tanks

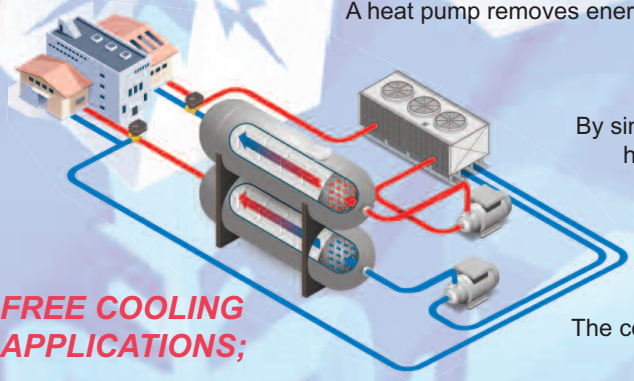
INNOVATION FOR ENERGY SAVING TECHNOLOGIES

CHILLED WATER APPLICATIONS;

Using +8~+10°C (47~50°F) PCM energy storage one can utilise a conventional water chiller without the need for a low temperature Glycol chillers. Hence, ideal for any retrofit of existing chilled water circuits especially for absorption chiller applications. Low ambient temperatures coupled with higher evaporation temperatures offer a significant overall COP (EER) improvement, in the region of 17-36 % depending on the type of unit and location.
PCM energy storage can be considered as a useful tool to spread the loads over a 24 hour period and therefore a carefully balanced PCM energy Storage can not only reduce the initial investment cost but additionally offers reduced operational cost. PCM energy storage acts as a buffer to handle large spikes, hence, steadying overall operation for the system as well as providing a stand-by capability.



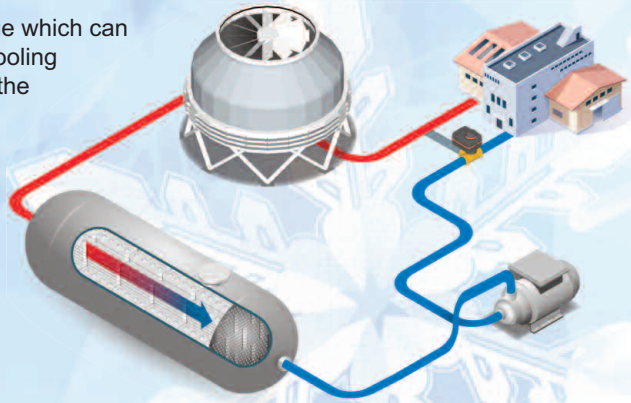
HEAT PUMP APPLICATIONS;



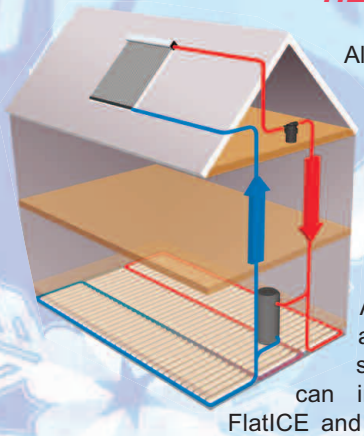
A heat pump removes energy from one side of the refrigeration circuit either using air/water or ground sources and transfers that energy into the other side of the refrigeration cycle.
Although this is a very efficient way to generate heat, if the removed energy is later required it can be considered as a waste.
By simply storing this waste energy in the form of +10°C (50°F) for cold or +46°C (115°F) hot PCM energy storage, one can utilise this stored energy during peak periods and as a result the heat pump size as well as the overall system energy usage can be reduced by as much as 50% by spreading the load over a 24 hour cycle.
A heat pump combined with PCM energy storage not only reduces running costs due to lower over-night electricity rates but also provides an increased combined COP (EER), which effectively reduces the overall power requirement as well.
The combination of these two benefits can reduce the overall running cost of the system.

FREE COOLING APPLICATIONS;

In certain climates the night-time ambient temperatures offer cool energy storage which can be used for day-time cooling. Using a PCM energy storage offers energy free cooling options. Cooling towers are designed to run during hours of darkness, freezing the PCM energy storage which is then released as cool during the day.
Design is based on having a cooling tower on the roof to utilise lower wet bulb temperatures to charge 15°C (59°F) PCM tanks located in the basement without any mechanical refrigeration i.e. chillers.
The night-time cool energy is stored in PCM tanks over-night and during day-time this stored energy is distributed throughout the building via chilled ceilings to soak up the internal and solar gains.



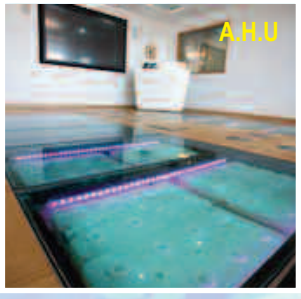
HEAT RECOVERY;

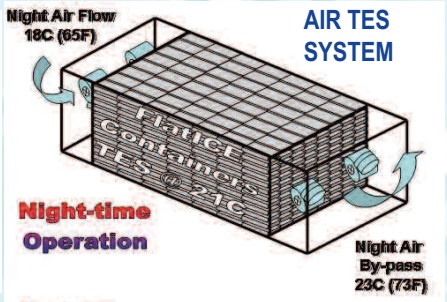


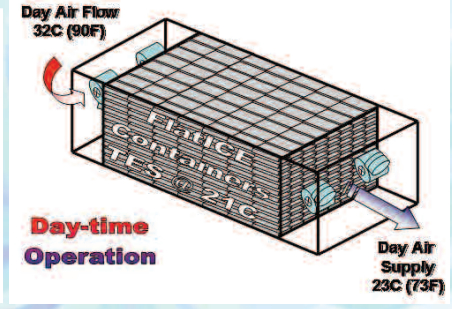
Although conventional solar collectors may not be able to generate enough energy to fully charge the domestic hot water tank during winter months, they are still capable of generating low grade heat of around 30~35°C (86~95°F), which is more than enough to charge the PCM modules during the daytime. Once the sun's energy is stored within the PCM containers they keep the occupied space warm. This way the space conditions can be stabilised over a 24 hour day and night cycle.

SPECIAL APPLICATIONS;

Although the most efficient way to charge and discharge PCM based energy storage systems is with water based circuits, air can in fact also be used to charge the FlatICE and TubeICE containers for any air handling applications. This energy storage can be based on using either the night-time cool energy for free day-time cooling applications or utilising the day-time free heat energy by storing during day-time for use during night-time heating applications. Air based PCM energy storage can be applied acting like an air handling unit whereby the FlatICE stack acting as the energy bank. On large sites a rectangular tunnel can be built and if the air is forced from one end of the FlatICE energy storage bank the FlatICE acts like a heat exchanger to store the night-time cool energy for use during the day-time, this provides free cooling for the building. It is a self regulating system whereby if the passing air is higher than the PCM, it melts the PCM solution and if it is colder than the PCM solution it freezes the PCM. Hence, a PCM air thermal energy storage offers an ideal free heating / cooling option.







WORLD LEADER IN ENERGY SAVING TECHNOLOGIES

PlusICE World-wide Application Samples

Air Conditioning Applications;

A wide range of PlusICE solutions offer a wide range of air conditioning and comfort cooling applications. PlusICE solutions have been applied for passive cooling tiles, plaster boards and heat pipe passive cooling units as a direct air cooling application.
PlusICE solutions are also applied for indirect TES applications like chilled ceiling / cooling tower free cooling circuits as well as heat rejection TES applications in a number of formats.

Night Charging

Day Disharging

Refrigeration Applications;

Night Charging

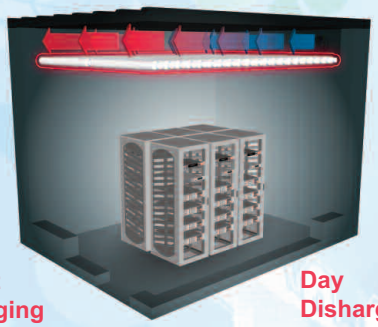
Day Disharging

TES can be applied at both the cold and hot side of the refrigeration cycle. PlusICE beams are used to provide free sub-cooling for the refrigeration circuit.

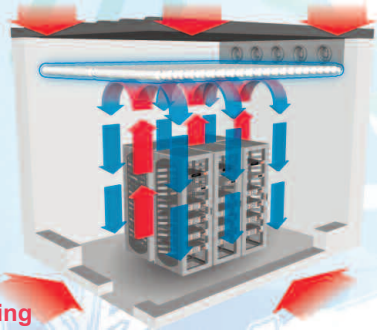
Eutectic plates provide ideal low cost and simple refrigeration around the world. PCM Products also offers standard cold boxes to match these plates for medicine, food and other wide temperature ranges are offered by the PlusICE solution enabling designers around the world to apply this PCM technology in many ways in order to stabilise heat loads and match the heat load and time balance for a more economical and reliable operation. Loads in dairies, breweries, industrial processes and food factories can be simply balanced by PCM TES systems to suit the operating temperatures of the system.

Passive Cooling Applications;

PCM solutions between 21°C (70°F) and 34°C (93°F) range offers ideal free passive cooling for air conditioning / electronic chamber / enclosure /and passive cooling shelter applications without any mechanical refrigeration.
Variations such as granules, powder and rubber formats enable designers around the world to apply TES technology in many interesting and challenging ways from drinks can cooling sleeve, all the way up to space applications.



Night Charging

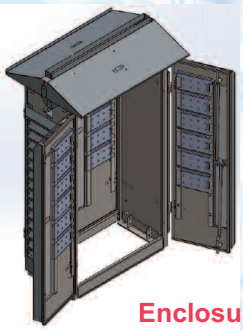


Day Disharging

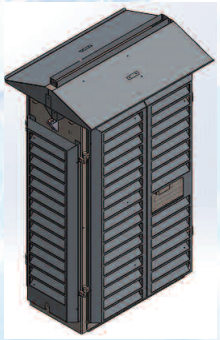
Special Applications;

PCM Products recently extended their PlusICE range down to -117°C (-134°F) which offer the possibility of very low temperature TES and this new range has opened the door for cryogenic / low temperature TES application.
Although having a wide range and various standard ice packs PCM products also offers extensive product development services for any custom-made ice packs solutions to match the required size and capacity.

Battery



Enclosures



TECHNICAL SUPPORT

PCM Products offer full system design support to assist in proper selection and integration into existing or new installations as part of our customer commitment.

We offer full consultancy on product development on a strict confidentiality basis and the possibility of Licensee options for local manufacturing. Please consult our technical **sales team at sales@pcmproducts.net** for your specific application or visit our web site **www.pcmproducts.net**

For additional information contact;

Distributor/Installer Stamp

PCM

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