Melbourne City Council

PCM-Based Cooling

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Melbourne City Council

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design advice

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EXECUTIVE SUMMARY

This report looks at the possibilities of using Phase Change Material based cooling technologies, working in conjunction with a shower-tower/cooling towers and chilled beams, to cool the Melbourne City Council offices.

Phase Change Materials provide a very efficient thermal storage mechanism because of the latent heat required for a change of phase. A Phase Change Material with a melting point of 13 degrees is required. The suppliers of Phase Change Materials are scarce both domestically and internationally.

Three Phase Change Material-based concepts are explained, and their appropriateness to the project is assessed. These are the Phase Change Material filled spheres, the PlusICE module concept and the PlusICE cells concept.

The Phase Change Material filled spheres is a suitable concept that requires no modification to be suitable for the purpose. However a large reservoir is required to immerse the spheres in the cooling water and subsequent secondary heat exchangers are required to integrate with the chilled beams. The PlusICE Module concept is a highly efficient option that requires the use of a "module" of Phase Change Material filled pipes. This option is more expensive but is more efficient and places less demand on spatial considerations. The third option is the PlusICE cells which are designed for ceiling cooling. Adaptation to the system requirements would be costly and thus a proposal to use them for their intended purpose as ceiling coolers on horizontal ceilings where possible is outlined.

Recommendations to pursue further the PlusICE module concept as the primary cooling device is provided, as well as the suggestion that PlusICE cells be used to cool ceilings where appropriate.

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1 INTRODUCTION

Phase change materials are best thought of as a very efficient thermal storage device. They work on the fact that whilst a material is undergoing a phase change (eg solid to liquid or liquid to gas (and vice versa)) it absorbs/releases a lot of heat energy for no change in temperature until the phase change is complete, similar to the energy required to convert ice to water. This heat is called the latent heat of the material, and varies for different matter.

It is proposed that a Phase Change Material be used that has a low melting point, to efficiently cool Melbourne City Council. Put simply, the Phase Change Material will "store" the coolness of the night, and use it to cool the building during the day.

The building proposal includes a shower tower. This cooling mechanism provides cooling and ventilation via a shower of water adjacent to the building. The shower water will be at a cool temperature, especially at night as it will follow the wet bulb temperature of the air. The shower tower will operate in conjunction with cooling towers to ensure optimal operation.

Thus, if we take a typical summer's day to be a worst case scenario, we can assume that the water flowing through the shower-tower overnight will be at 12 degrees. This is due to the fact that the wet bulb temperature in Melbourne is rarely greater than 12 degrees at night. This cool water can be used to solidify an appropriately manufactured Phase Change Material. During the heat of the day, the chilled beams require water at 16 degrees. The Phase Change Material can cool this water and can do so for sustained periods given the high latent heat required to melt the Phase Change Material before its temperature can rise further.

Thus the ideal temperature for this Phase Change Material is about 13 degrees.

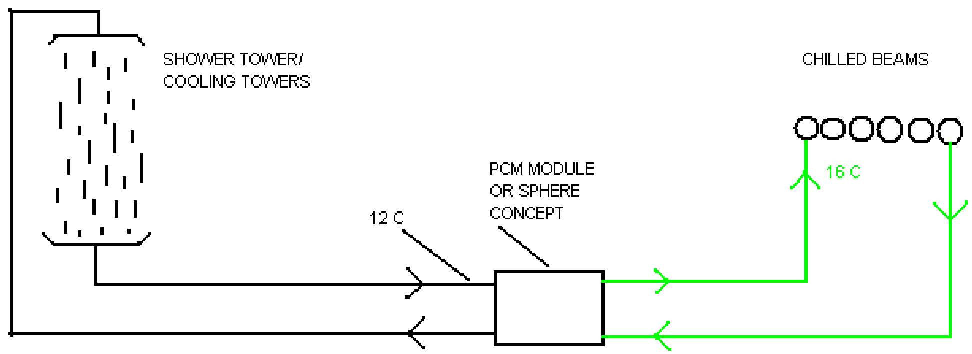

Figure 1 - PCM cooling system schematic

The system works in the following modes in summer:

- Daytime. The cooling mode where water to the chilled beams is cooled by the PCM water.
- Night-time. PCM charging mode where the shower tower water solidifies the PCM for use the next day.

2 SUPPLIERS

Presently, the only supplier that was found to produce Phase Change Material with the appropriate melting point (13 degrees for the application is Environmental Process Systems Limited, based in the UK (epsltd.co.uk). Appendices A.1 and A.2 show cost estimations for the calculated building cooling load of 3631kWh.

Logistics warrant the search for suppliers of a suitable Phase Change Material closer to home. The most prominent supplier of Phase Change Material in Western Australia, TEAPPCM (www.teappcm.com), is currently producing a 7° Phase Change Material and a 22° Phase Change Material, among others. They estimate that about 5 to 6 months would be required from the time a new Phase Change Material is requested, to the time they could produce it, *if* they deemed demand to be strong enough. Contact with the managing director of TEAPPCM, confirmed that the R+D and production of a new Phase Change Material would cost $80,000. The upfront cost of producing a new Phase Change Material would be partly offset by a discount for the actual product. TEAPPCM places commercial estimates at about $5 per kg, but would charge us approximately $2.50 to $3 per kg. Cost estimations for the building cooling load can be found in Appendix A.3.

TEAPPCM distribute the Phase Change Material as the raw material, in 1, 2 and 5 litre containers, as well as in spheres and capsules but do not seem to offer any other housing device. EPS Ltd offer devices to house Phase Change Material, such as those below, to maximise its potential.

Note also that TEAPPCM have specified that while they can aim for a particular temperature Phase Change Material, the end-product may vary from 13 degrees by one or 2 degrees either side which could create an additional risk to the product. Though their product is assessed anyway, this provides the primary argument not to go with this supplier.

3 OPTIONS

3.1 PCM-Filled Spheres Concept

The concept is to have Phase Change Material-filled spheres immersed in a reservoir of water. This reservoir of water is then involved in separate heat exchanges with the chilled beam water 24 hours a day and the shower tower during the night only. This option, in concept, would be least efficient, requiring two modes of heat transfer and thus two opportunities for heat exchange inefficiencies between the Phase Change Material and the various water systems.

Figure 2 - PCM-filled Spheres (MJM Engineering)

A 500m^3 tank will be required, based on a 50/50 ratio of spheres to reservoir water and a requirement of 250m^3 of Phase Change Material.

Both TEAPPCM and PlusICE can accommodate this option. However, PlusICE has recognised that corrosion can occur between the Phase Change Material and the plastic spheres, thereby contaminating the water and leading to corrosion of the rest of the system. Thus they have produced stainless steel spheres which are corrosion resistant and have greater thermal efficiency.

Advantages:-

- Concept requires no modification
- Cheaper (excluding tank) than others, see Appendix A

Disadvantages:-

- Large reservoir required
- Secondary heat exchange required

3.2 PlusICE (EPS Ltd) Module Concept

This concept pumps the fluid through a series of pipes. These pipes are surrounded cylindrically by an annulus cavity containing the appropriate Phase Change Material (E13). The cylinder geometry offers a more efficient heat transfer compared to the spherical balls. This option only accommodates one fluid to be cooled by the Phase Change Material and would thus be unsuitable without:

- modification (i.e. another annulus in the Phase Change Material pipes for a second fluid), or
- secondary heat exchangers.

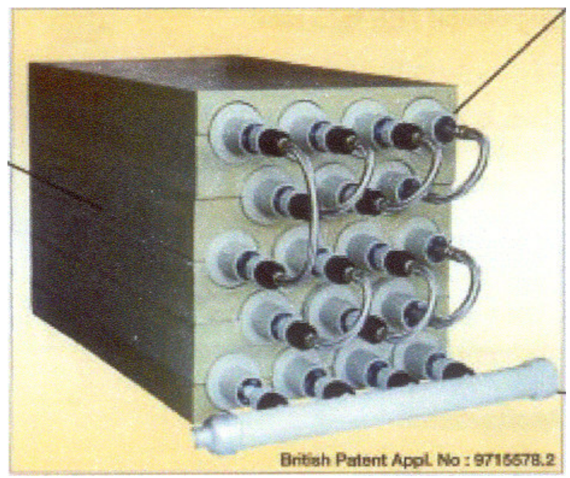

Figure 3- Module Concept by PlusICE

Suitable modification at low cost appears unlikely and a simpler solution would involve the use of a secondary heat exchanger to cool the chilled beam water with the Phase Change Material-cooled shower tower water.

Advantages:-

- More efficient heat exchange
- No reservoir required

Disadvantages:-

- Secondary heat exchanges

3.3 PlusICE (EPS Ltd) Cells Concept

This appears to be a more efficient solution though it does provide other difficulties. It again uses the EPSLTD produced E13 type Phase Change Material. The material is encased in aluminium, in "cells" (long, thin rectangular prisms). The cells are designed for ceiling cooling of air and would require adaptation in this situation.

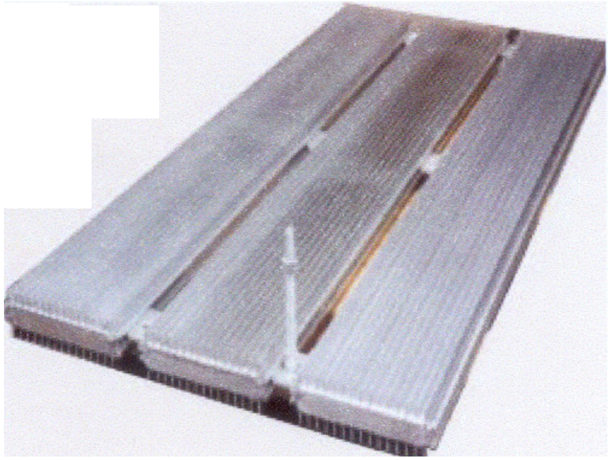

Figure 4- PCM Cells as provided by PlusICE

The cells could be suspended longitudinally in a reservoir, allowing the water to flow either side of the cells, maximising the surface area contact with the water. The required adaptation would be to provide a suitable sealing mechanism between the cells to allow the shower tower and chilled beam fluids to flow either side of the cells.

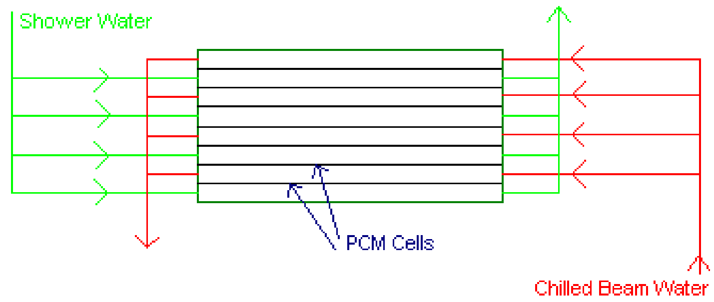

Figure 5 - Cross-flow Heat Exchanger with Phase Change Materials

Depending on the Phase Change Material and aspect ratio of the cells, EPSLTD claim that as much as 2.4kWh/m^2 can be obtained. E13 has a latent heat of 249MJ/m^3.

Advantages:-

- Highest efficiency
- Reduced heat exchange losses

Disadvantages:-

- Custom made/adapted cells
- Higher cost of housing compared to spheres

The intended use of this concept is to have them suspended from the ceiling to cool the rising warm air. The 'wavy' ceilings of much of the proposed building make this impractical, however a use for these may be found on floors where the wavy ceilings are not used, such as in the basement.

4 RECOMMENDATIONS

1. Whilst the Phase Change Material spheres concept would work quite well, the timeframe and uncertainty of sufficient local production point toward the adoption of the established technologies provided by PlusICE. Though PlusICE also offer Phase Change Material spheres, the size of the reservoir required will require more space than other options.

2. The PlusICE module concept should be used as the primary cooling mechanism in the building.

3. Secondarily, it is proposed that the PlusICE cells be used for their intended purpose as ceiling coolers in the lower and underground levels of the building where the flat ceiling enables their use.

APPENDIX A – ECONOMIC ANALYSIS FOR PCM OPTIONS

4.1 A.1 PlusICE Modules

Note: each module averages 1000kWh of cooling.

Daily Cooling Load	DCL + 25%	Qty reqd	Unit Cost £	Transport £	Total £	Exchange Rate (10th Mar)	Total $
3631	4538.75	5	£ 49,500	£ 4,600	£270,500	0.3824	$707,374

4.2 A.2 Plus ICE Spheres

Note: the analysis below does not include the cost of the tank required to house the PCM-filled spheres. Also, the figures are for plastic spheres. It is expected stainless steel ones are more expensive.

Daily Cooling Load	DCL + 25%	Qty reqd (spheres)	Unit Cost £	Transport £	Total £	Exchange Rate (10th Mar)	Total $
3631	4538.75	295853	£ 0.5	£ 12,000	£159,927	0.3824	$418,218

4.3 A.3 TEAPPCM Spheres

Note: the analysis below does not include the cost of the tank required to house the PCM-filled spheres. Also remember that the TEAPPCM will take 6 months of R+D to engineer and that even then an exact performance of 13 degrees is not guaranteed.

Daily Cooling Load	DCL + 25%	Qty reqd (kg)	Unit Cost £	Start-up Cost	Total £
3631	4538.75	116710.7143	$ 3	$ 80,000	$430,132