# Development of a novel refrigeration system for refrigerated trucks incorporating phase change materials

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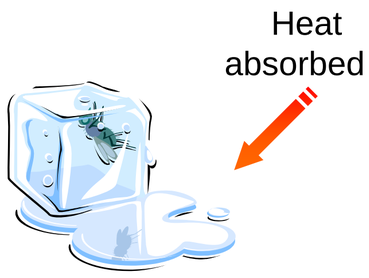
## Introduction

Currently, refrigerated road vehicles use refrigeration systems driven by internal combustion engines, which have drawbacks of:
1. the efficiency of the engine is quite low – only 35–40%[1]
2. a large amount of greenhouse gas emission[2]

## Principle




Phase change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at certain temperatures, is capable of storing or releasing large amounts of energy (such as water).

## Aim

Develop a flat-plate phase change thermal storage unit (PCTSU) experimentally and mathematically to maintain the refrigerated space at -18$^{o}$C for 10 hours.

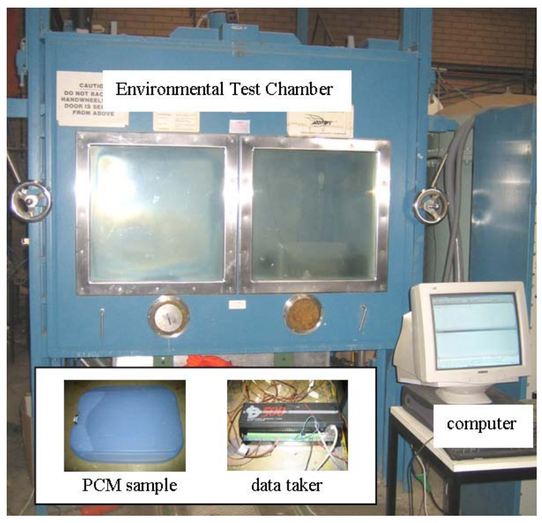
## PCM Development

### *1. Experimental Equipment*

- Environmental test chamber
- Thermocouples
- Datataker DT500
- Computer

### *2. PCMs*

Inorganic salt based water solutions

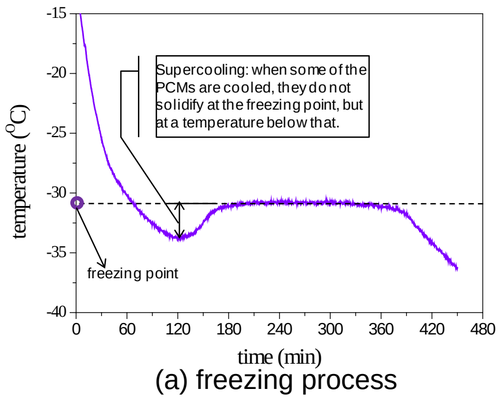



### *3. Experimental Results*

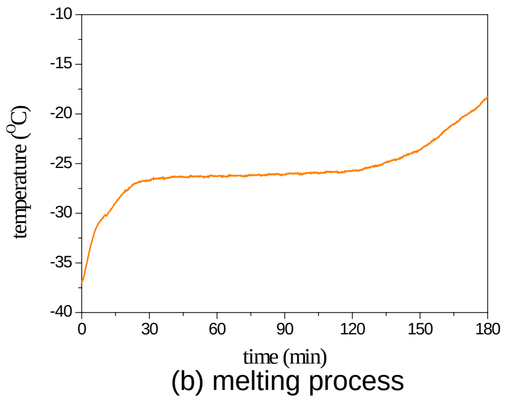
- Freezing & melting points and degree of supercooling of PCM samples

| PCM | Latent heat of fusion (kJ/kg) | freezing point ($^{o}$C) | melting point ($^{o}$C) | No. of samples | No. of cycles | Supercooling (K) |
|---|---|---|---|---|---|---|
| **PCM-30** | **144** | **-30.6** | **-26.7** | **6** | **15+36** | **3.0** |
| PCM-34 | NA | -34.1 | -32.9 | 4 | 9 | 5.8 |

- PCM temperatures during freezing and melting processes

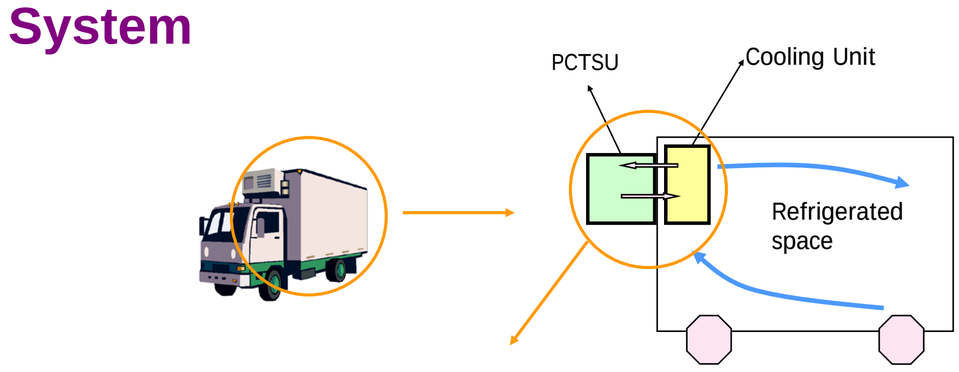



(a) freezing process




(b) melting process

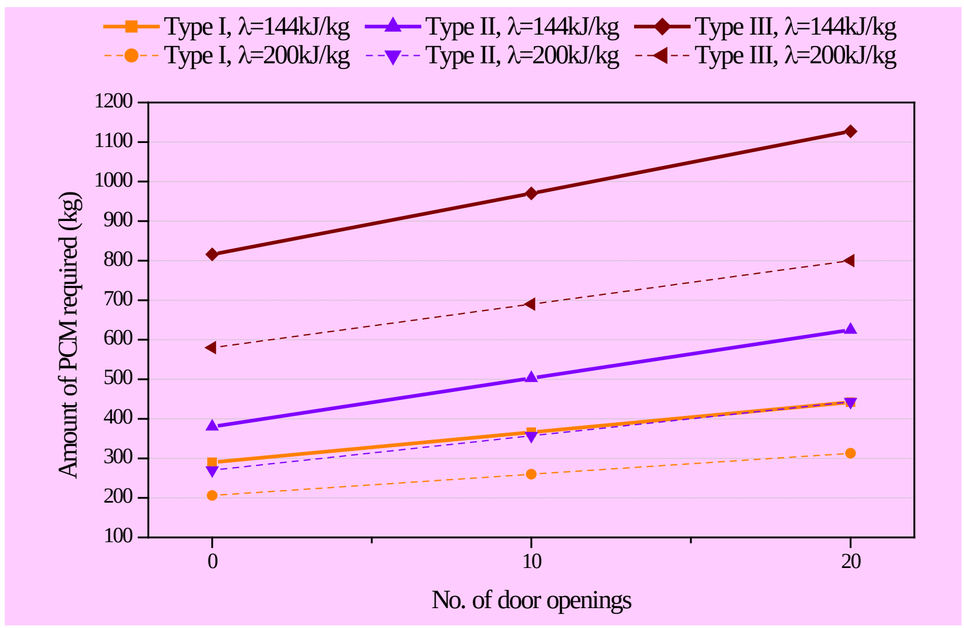
## Configuration of Proposed Refrigeration System




**Charging** – PCM is frozen by cold heat transfer fluid supplied by a refrigeration unit (**not on-board the vehicle**) when the vehicle is not in service. Cooling energy is stored in the PCM.
**Discharging** – PCM will release cooling energy when the truck is on road.

## Mathematical Modeling Results

The amount of PCM-30 required vs. number of door opening during delivery for various sizes of refrigerated vehicles




| | Type I | Type II | Type III |
|---|---|---|---|
| Size of refrigerated space | 3m×2m×1.8m | 4.2m×2.4m×2.2m | 10m×2.4m×2.6m |
| Door size | 2m×1.8m | 2.4m×2.2m | 2.4m×2.6m |
| Fan power (W) | 200 | 300 | 500 |
| Pump power (W) | 200 | 300 | 500 |

## Outcomes

- A novel refrigeration system for refrigerated vehicles incorporating PCM was developed.
- The vehicle is suitable for relatively short, local delivery use.
- The system is expected to have a low noise level, reduced energy costs and no local GHG emission
- A suitable PCM (PCM-30) was experimentally developed to maintain the refrigerated space at -18$^{o}$C
- A mathematical model for flat-plate PCTSU was developed to analyze the thermal performance of the PCTSU
- A simulation model for the refrigeration system was developed using TRNSYS simulation package

## Acknowledgements

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## References

[1] Horuz, I 1999, J. Energy Eng., vol. 125, no. 2, pp. 48–58.
[2] Chatzidakis, S.K & Chatzidakis, K.S 2004, Int. J. Energy Res., vol. 28, pp. 887–97.