Phase Change Materials (PCMs) and Applications

Space Hardware Design Final Project

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Presented for ASEN 4519

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PROBLEM STATEMENT: to learn the principles of PCMs and which ones are suitable for different applications.

Rationale

- Constant temperature thermal control for long duration
- Energy savings over other insulators
- Mass and volume savings

Background

What are PCMs?

PCM materials have high heats of fusion so they can absorb a lot of energy before melting or solidifying.

A PCM temperature remains constant during the phase change, which is useful for keeping the subject at a uniform temperature.

PCM Definitions

- Heat of Fusion [kJ/kg]: amount of energy required to melt one kg.
- Duration Index [J/(cm^3* ^{o}C)]: Comparison of how long a PCM will remain at a constant temperature during the phase change. Calculated as: D.I. = $h_f \rho / \Delta T$

Design Options

Material	Melt Point [^{o}C]	Heat of Fusion [kJ/kg]	Liquid Density [g/cm^{3}]	Duration Index [J/cm^{3} ^{o}C]
Heptanone-4	-33	209	0.822	2.96
n-Undecane	-26	141	0.740	2.05
TEA-16	-16	289	1.100	7.75
Ethelene glycol	-11.5	179	1.109	5.44
n-Dodecane	-9.6	211	0.749	4.57
Water	0	333	1	13.32
Thermasorb 43	6	163	0.87	7.46
Thermasorb 65	18	173	0.88	21.75
Sodium hydrogen phosphate	36.1	280	1.45	-36.58
Thermasorb 175+	79	200	0.93	-3.44
Thermasorb 215+	101	193	0.93	-2.36

D.I. based on ΔT from melt point to ambient (25 ^{o}C)

Why use different PCMs?

Biological Sample at -10°C

Assume ambient T=25°C

Using TEA-16 (Melts at -16°C; 289 kg/kJ)

D.I. = 7.75

Using n-Undecane (Melts at -26°C, 141 kg/kJ)

D.I. = 2.05

Plant Chamber at 25°C

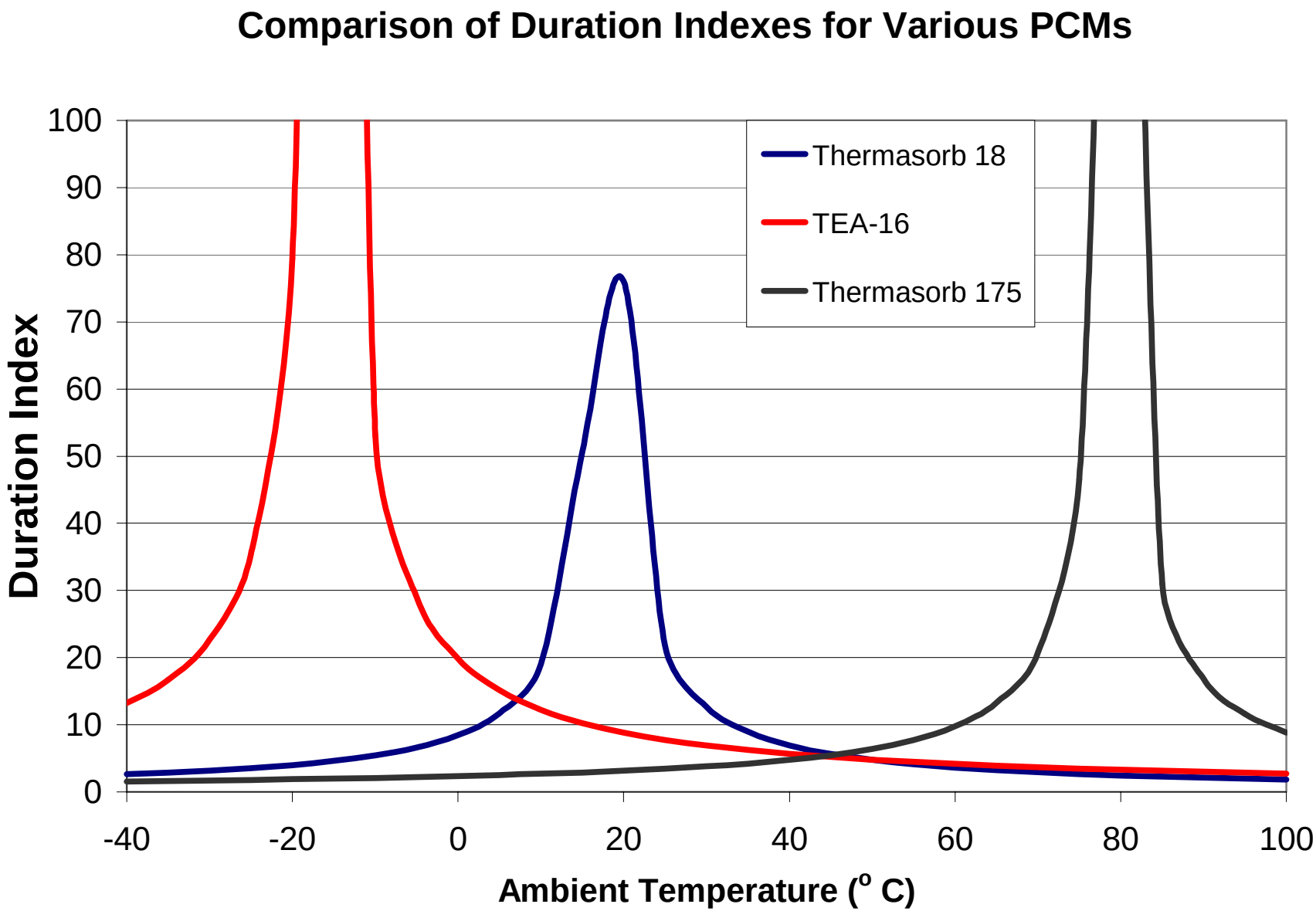
Assume ambient T=30°C

Using Water (Melts at 0°C, 333 kg/kJ)

D.I. = 11.10

Using Thermasorb 65 (Melts at 18°C, 173 kg/kJ)

D.I. = 12.69


Comparison of Duration Indexes for Various PCMs
Duration Index
100
90
80
70
60
50
40
30
20
10
0
-40
-20
0
20
40
60
80
100
Ambient Temperature (° C)
Thermasorb 18
TEA-16
Thermasorb 175

Other considerations

Toxicity: n-Undecane, TEA-16, n-Dodecane are all hazardous materials.

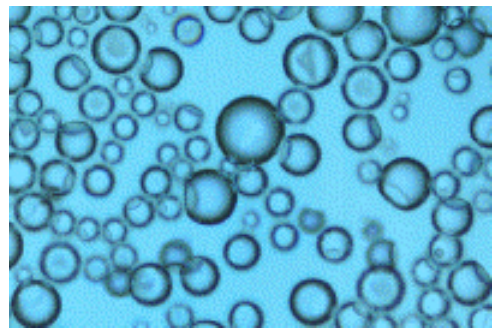
Compatibility: all the previously mentioned are also highly corrosive.

Cost: n-Undecane ($250/L), TEA-16 ($8/kg), n-Dodecane ($116/L)

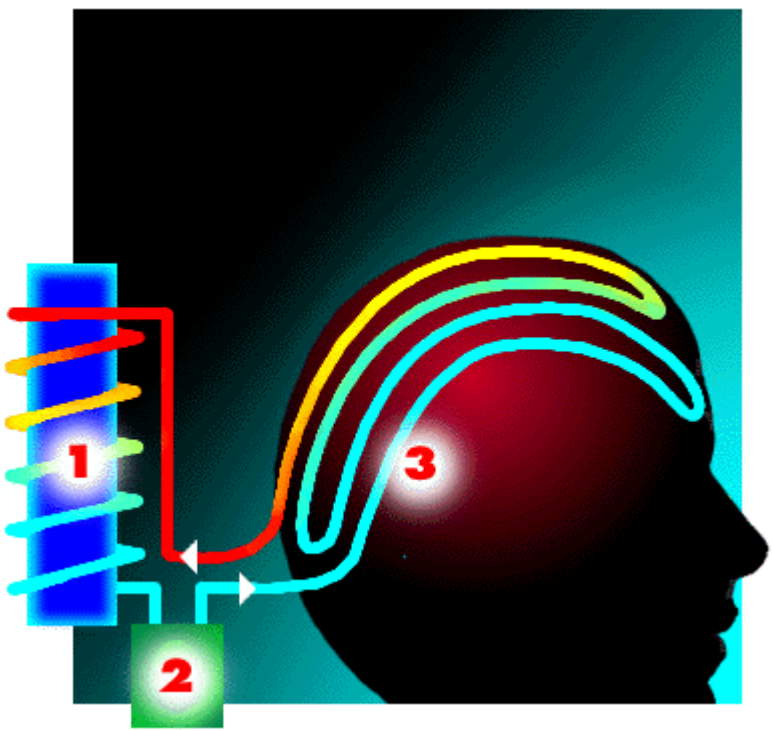
Applications



Cooling Packs



Thermasorb Capsules



Body Cooler

Bridge Warmer

NASA Dive Suit

Building Insulation

References

[1] PCM Thermal Solutions, http://www.pcm-solutions.com

[2] Doerr, Donald F., “Heat Stress Assessment and a Countermeasure,” Biomedical Laboratory Kennedy Space Center, November, 1997.

[3] MicroClimate Systems, Inc., http://www.microclimate.com

[4] Frisby Technologies, http://www.frisby.com

[5] “Phase Change Material Trade Study for the LoTeC Project,” (unknown author; report obtained from Dr. Alex Hoehn).