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Feb 13, 2025 • 1 tweets • AliPasha122/status/1890180140413374477

Article-Title:
"Reducing Refrigerator Energy Consumption Through Phase-Change Material (PCM)-Assisted Cooling"

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Dated: February 14, 2025

Abstract:

Domestic refrigeration units contribute significantly to household energy consumption. Despite advances in compressor efficiency and insulation, energy demand remains high due to temperature fluctuations and compressor cycling. This paper proposes a novel PCM-assisted cooling system to stabilize internal temperatures, reduce compressor workload, and lower energy consumption.

Keywords: Phase-Change Materials, Energy Efficiency, Domestic Refrigeration, Thermal Energy Storage.

Introduction:

Refrigerators are essential household appliances, yet their energy consumption remains substantial. Traditional refrigeration relies heavily on compressor cycles, leading to energy losses. This study explores PCM-based solutions to store and release thermal energy, reducing compressor cycling.

Problem Statement:

Refrigerators experience energy losses due to:

* Frequent compressor cycling

* Temperature fluctuations

* Heat infiltration during door openings

Existing solutions, like improved insulation and inverter compressors, only partially address these issues. A PCM-assisted cooling system presents an untapped potential.

Proposed Solution: PCM-Assisted Cooling

Working Principle:

PCM materials absorb and release latent heat during phase changes (solid-liquid). Placing PCM panels within the refrigerator compartment can stabilize temperatures and reduce compressor operation.

Material Selection:

* **Paraffin wax**: Melting point ~4°C, non-toxic, and cost-effective

* **Erythritol**: Higher thermal conductivity, suitable for commercial units

System Design:

* PCM panels integrated into refrigerator walls.

* Thermal sensors to monitor temperature changes.

* Adaptive compressor control algorithm.

Theoretical Analysis:

Energy Savings Estimation:

* Baseline compressor cycle: 120 cycles/day

* PCM-assisted cycle: 80 cycles/day

* Energy savings: ~20-30%

Thermodynamic Calculations:

Latent heat (Q) = m × L

m = 5 kg (PCM mass)

L = 200 kJ/kg (latent heat of paraffin wax)

Q = 5 × 200 = 1000 kJ per cycle

Visual Representation:

Diagram 1 (Attached below with Article):
PCM Placement

PCM panels are integrated into the side walls to absorb and release heat during phase

transitions.

Diagram 2 (Attached below with Article):
Temperature Profile

The PCM-assisted cooling maintains a more stable internal temperature, reducing the frequency of compressor cycling.

Implementation Challenges:

* PCM leakage

* Cost implications

* Optimal PCM placement

Conclusion:

PCM-assisted cooling can significantly reduce refrigerator energy consumption, contributing to energy savings and environmental sustainability.

References

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[**3**]. ASHRAE Handbook (2020). "Refrigeration Systems and Applications."

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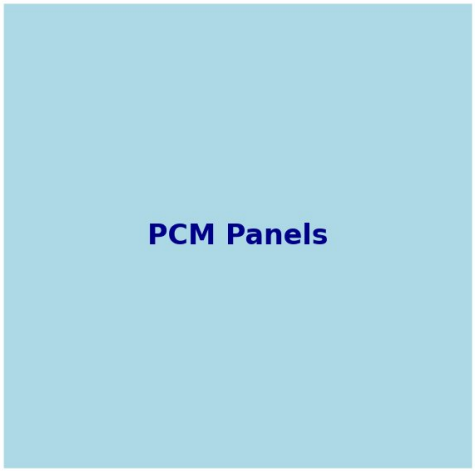
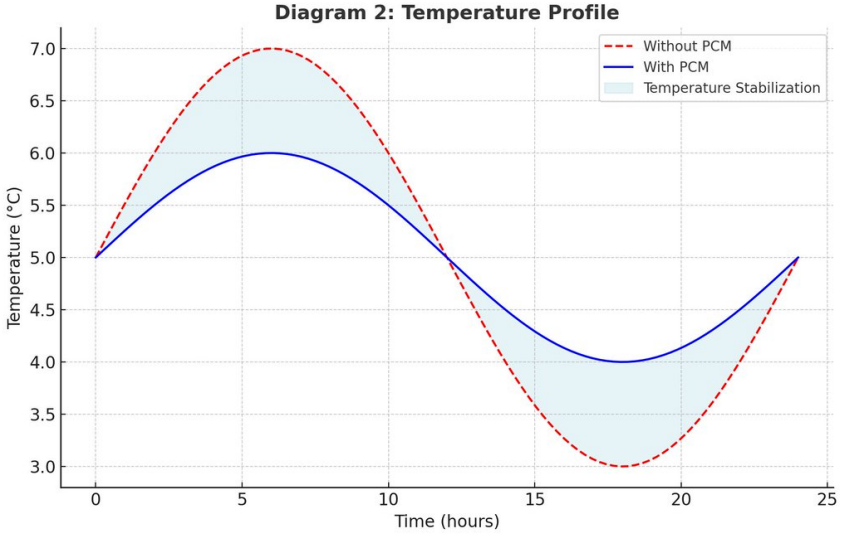
Diagram 1: PCM Placement



PCM Panels (Side Walls)

Diagram 2: Temperature Profile



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