Advanced Phase Change Materials (PCMs):
Maintain Product Integrity While Increasing Performance, Operational Efficiency and Sustainability

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Presentation Overview

- Maintaining **product integrity**: Frozen, Refrigerated, CRT
- Enhancing **package performance** using PCMs
- Reducing **package size, weight and volume** made possible via PCMs
- **Packout simplification** and operational efficiency
- One-time and **re-use** options with PCMs
- **Making Sustainability Affordable and Achievable**
TECHNICAL REVIEW
Common Phases of Materials

- Add Heat to a Solid - *It Becomes Liquid*
- Add Heat to a Liquid - *It Becomes Gas*
- Add Heat to a Gas - *It Becomes Plasma*

**Lightning is a Plasma**
Water is a PCM

- Solid (ice) below 0°C
- Solid-liquid transition temperature of 0°C
- Liquid from 0°C to 100°C
- Liquid-gas transition temperature of 100°C
- Water is a gas (steam) above 100°C
Materials Advances - Refrigeration

- **Expanded Use of Phase Change Materials**
  - PCM’s from -40°C to + 40°C
  - Replacements for dry ice
  - Controlled Room Temperature applications
  - 2°C to 8°C applications
  - Macro and micro encapsulation

- **New formats**
  - PCM suspended in bricks
  - Bottles
  - Combined insulation and PCM

- **Sustainability**
  - More and more materials are completely sustainable
  - Formats that can be returned and reused
Advanced PCM’s
Fatty Acids, Paraffins, Eutectic Salts, Hydrated Salts, Inorganics
Advantages of Passive Systems
With Advanced PCM’s

- Insulation alone cannot protect product
- Latent heat more useful than specific heat
- Varying temperature needs can use varying temperature PCM’s
- Remote shipments when no power is available
- Mechanical equipment not necessary
- Very reliable – physics is repeatable
- Enables the use of lower cost insulation
- Low maintenance
- Operate at a nearly constant temperature
PCM vs. water-based gel pack

- PCM phases at +4°C → keeps product >2°C
- Water-based gel phases at 0°C → product drops below 2°C
Insulation Type Comparison

Example: EPS vs PUR vs VIP

- R-Value
- Package Size
- Weight
- Container Cost

Total Cost Can Be Reduced
Insulation Type Comparison

Example: EPS vs PUR vs VIP

EPS PACKAGING Size  PUR PACKAGING Size  VIP PACKAGING Size

32 kgs  18 kgs  9 kgs
Cost vs. Temperature Control

- **High Cost, High Temp Control:** PUR/VIP Advanced PCM
- **High Cost, Low Temp Control:** EPS/PUR Advanced PCM
- **Low Cost, Low Temp Control:** EPS/PUR Water Based PCM
- **Low Cost, High Temp Control:**
# Refrigerant Comparison

## Water vs. Advanced PCM, 2°C to 8°C

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current Design</th>
<th>New Design</th>
<th>Efficiency Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>20.8 kg</td>
<td>16.8 kg</td>
<td>-19%</td>
</tr>
<tr>
<td>’ntl Dimensional Weight</td>
<td>23.8 kg</td>
<td>17.6 kg</td>
<td>-26%</td>
</tr>
<tr>
<td>Box Size</td>
<td>520.7 x 470.0 x 584.2 mm</td>
<td>508 x 469.9 x 431.8 mm</td>
<td></td>
</tr>
<tr>
<td>Box Volume</td>
<td>143.1 Litres</td>
<td>105.7 Litres</td>
<td>-26%</td>
</tr>
<tr>
<td>Payload Size</td>
<td>254.0 x 203.2 x 203.2 mm</td>
<td>273.1 x 235.0 x 203.2 mm</td>
<td></td>
</tr>
<tr>
<td>Payload Volume</td>
<td>10.5 Litres</td>
<td>13.0 Litres</td>
<td>24%</td>
</tr>
<tr>
<td>Duration</td>
<td>48 Hours</td>
<td>72 Hours</td>
<td>50%</td>
</tr>
<tr>
<td>Conditioning</td>
<td>Frozen &amp; Refrigerated</td>
<td>Frozen &amp; Refrigerated</td>
<td></td>
</tr>
<tr>
<td>Bench Time</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Weight (kg per liter) Payload</td>
<td>1.98</td>
<td>1.29</td>
<td>WPE 35%</td>
</tr>
<tr>
<td>% Vol. Payload per Box Vol.</td>
<td>7%</td>
<td>27%</td>
<td>PBR 286%</td>
</tr>
</tbody>
</table>
Cost Comparison
Water Based Refrigerant vs. +4°C PCM

Cost Comparison of VIP Packaging with and without PCM

VIP w/ Water-based Gel
VIP w/ GreenBox 4°C PCM

- Total Cost
- Container Cost
- Packaging Cost
- Freight
72-Hour, 2 to 8°C, 13 Litre Solutions
Virtual Temperature Prediction Model (VTPM)
Virtual Temperature Prediction Model (VTPM)
Water Based Refrigerant
(Winter Profile) Prediction 6.0°C to 2.0°C
Actual Chamber Test Results
Water Based Refrigerant
(Winter Profile) Actual 5.8°C to 1.9°C
Virtual Temperature Prediction Model (VTPM)
+4°C PCM Refrigerant
(Winter Profile) Prediction 5.0°C to 2.8°C
Actual Chamber Test Results
+4°C PCM Refrigerant
(Winter Profile) Actual 6.1°C to 2.9°C
Conclusions:

Insulated Package Designs Integrating PCM’s can:

- Hold a variety of tight temperature tolerances
- Increase Weight to Payload Efficiency (WPE)
- Significantly increase Payload to Box Ratio (PBR)
- Simplify pack-out
- Extend transport durations
- Produce lower total cost of ownership
CUSTOMER CASE STUDIES
## Financial Comparison With Advanced PCM’s

96 Hour Minimum Duration, 2°C to 8°C, Universal Packout, 50L Payload

<table>
<thead>
<tr>
<th>Option A:</th>
<th>Option B:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PUR Shipper</strong></td>
<td><strong>VIP Shipper</strong></td>
</tr>
<tr>
<td>96 hour duration</td>
<td>120 hour duration</td>
</tr>
<tr>
<td>Weight: 69.5 kgs</td>
<td>Weight: 36.8 kgs</td>
</tr>
<tr>
<td>Shipping cost: €208.50</td>
<td>Shipping cost: €110.40</td>
</tr>
<tr>
<td>Number of components: 54</td>
<td>Number of components: 38</td>
</tr>
<tr>
<td>Price: €386.46</td>
<td>Price: €486.70</td>
</tr>
<tr>
<td>Total cost: €594.96</td>
<td>Total cost: €597.10</td>
</tr>
</tbody>
</table>

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Customer Case Study

Goal:
- Eliminate freezing of product that must be maintained between 2C and 8C
- Extend number of times the refrigerant can be re-used
- Eliminate bench time conditioning of refrigerants

Solution: Replace water based refrigerants with ThermoPhase® powered by PureTemp® advanced PCM refrigerants in pillow panel format

Result:
- Maintain product and supply chain integrity
- Can now freeze/thaw up to 20,000 cycles
- No bench time after conditioning
Customer Case Study

Opportunities for improvement
» Problems using water based phase change materials with “Do Not Freeze” products
» Eliminate waste produced with single use shippers

Solution: Replace single use shippers and water based refrigerants with Greenbox® reusable VIP shippers and ThermoPhase® powered by PureTemp® advanced PCM refrigerants

Results
» Reduction of loss of product
» Decreased cost per use
» Simplified pack-out - lessens complexity for operators and improves labor efficiency
» Waste reduced 98%
RE-USE/SUSTAINABILITY
Reuse and TCO

Advanced PCMs

- Significantly improves Total Cost of Ownership
- Significantly enhances overall packaging, logistics and supply chain P&L

Re-use

- For customers that want best of everything
  - Reduced TCO, Advanced PCM and superior sustainability position
  - Reduced box price
Going “Green” And Sustainability

- PCMs now have sustainable ingredients
- Possible to reduce total-cost *and* be more environmentally responsible
- Re-use significantly enhances your “green” position
- Green is no longer at an extra cost to you – sustainability is affordable and achievable
DISCUSSION

Questions / Comments