

Delivering on the
Promise[™]

Temperature Controlled Packaging: Considerations You Might Not Know



Summary

- Discussion Points
 - Temperature spread based on refrigerant coverage
 - Conditioning – Cold Shock and Refrigerant Bench Times
 - Product Mass and Temperature
 - Opening up Product Temperature Range
 - Ambient Profile and Cost
 - Universal vs Seasonal Solutions
 - Shipping a Box on its Side
 - Cost versus Insulation Choice
 - Cost Versus PCM Choice

BEST PRACTICES: Quality by Design (QbD)

DEFINE THE PROBLEM

Define the Problem

Establish
a team

- Who should be included? What business functions?
 - Engineering/ Packaging
 - Procurement
 - Regulatory
 - Logistics
 - Operations/ Manufacturing
 - Quality/ Validation
 - Marketing
 - End Customer?
 - Other?

Factors For Team to Consider

Performance Needs

- Duration, Temperature, Payload, Ambient Profiles

Regulatory Needs

- Reference Documents, Available Excursions

End User Needs

- Packout Configuration: Universal / Seasonal,
- Ease of use, # of components, weight, pack-out time, dimensional, etc.

Pricing (value) need

- Package Cost, freight cost, physical weight vs dimensional weight

Safety

- Ergonomics

Quality

- Tolerances / testing requirements

Other

- Sustainability, shipping lanes, return-reuse, conditioning, data monitoring, etc.

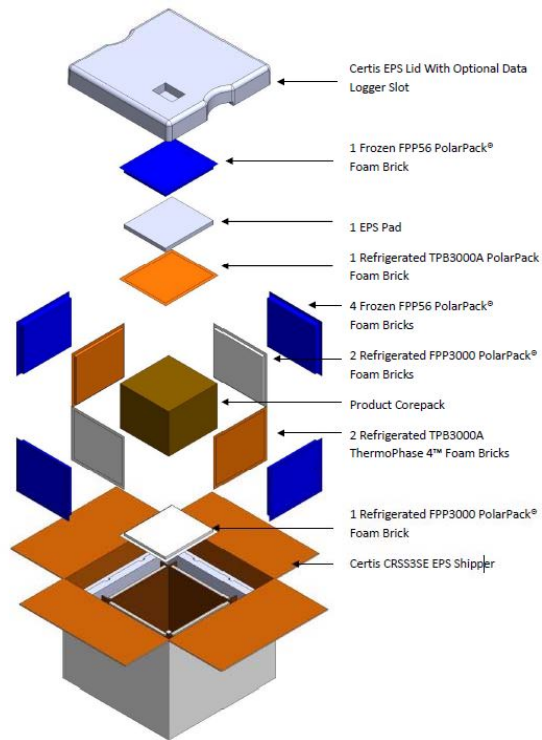
Factors to Consider

- Distinguishing Between Various Factors
 - Cost vs Quality
 - Packaging Cost vs Shipping Costs
 - Costs vs Ergonomics
 - Sustainability
 - Use of Excursion Data vs Design Complexity
 - Ease of Use vs Cost
 - Single use vs Return/Reuse

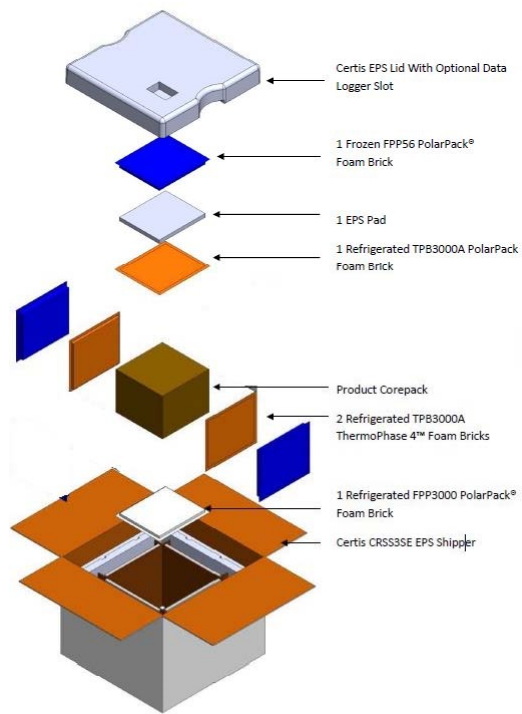
- Different Stakeholders / Different Views

TEMPERATURE SPREAD BASED ON REFRIGERANT COVERAGE

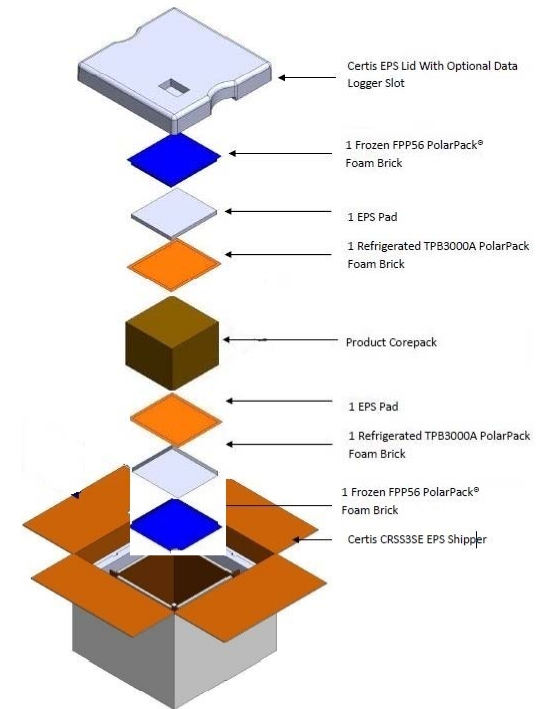
Refrigerant Configurations



6 sided

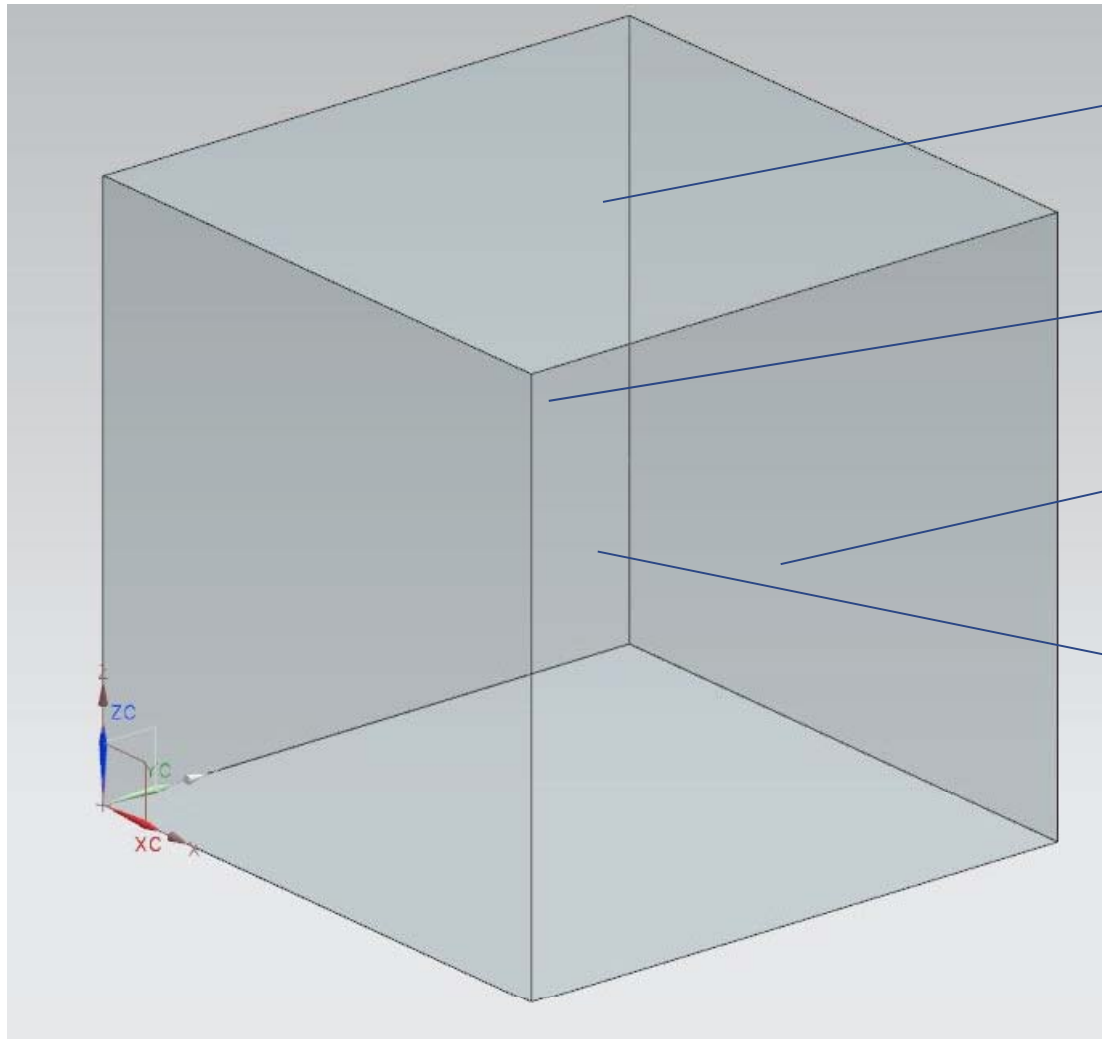


4 sided



2 sided

Product probe locations



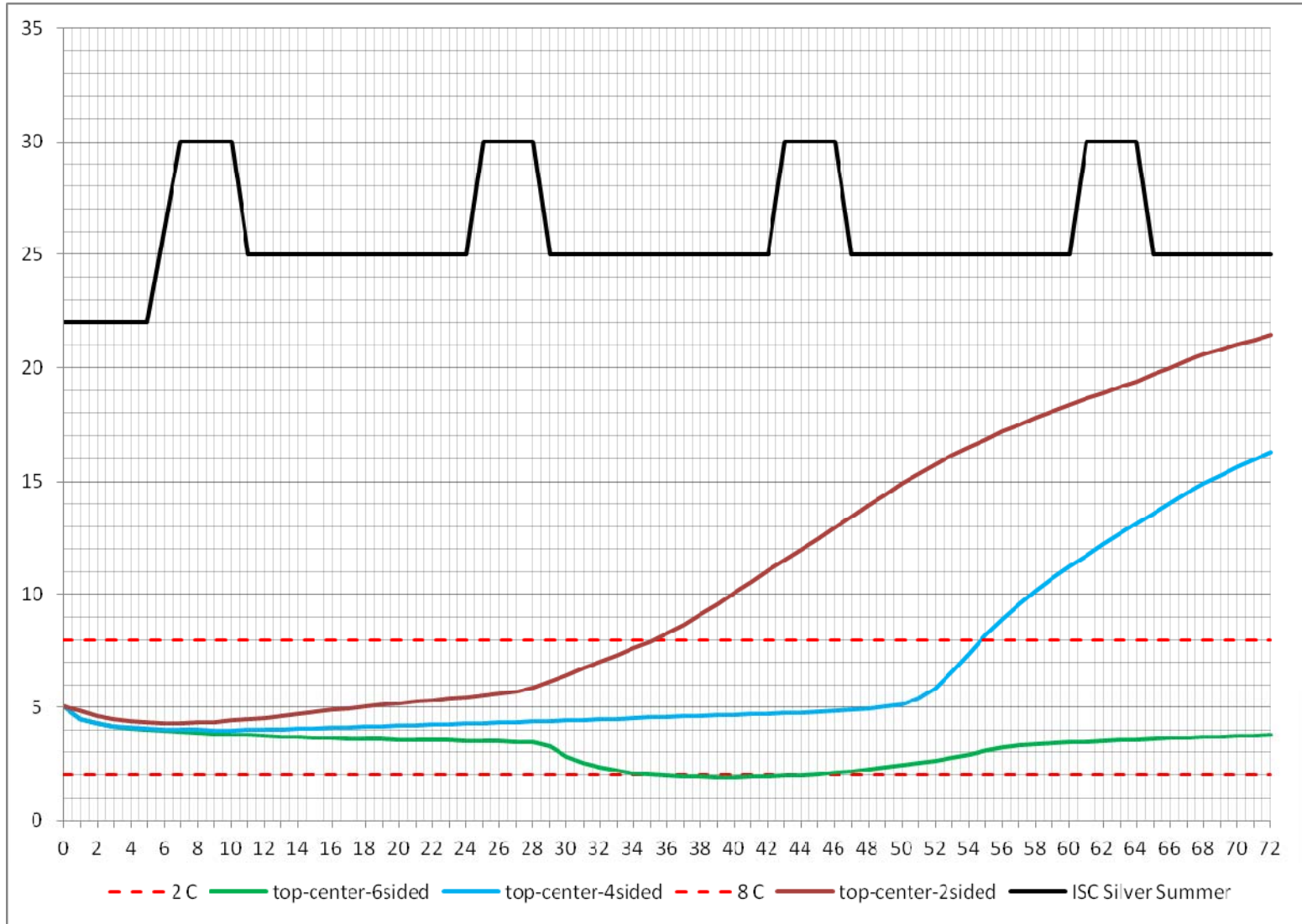
Top Center

Top Corner

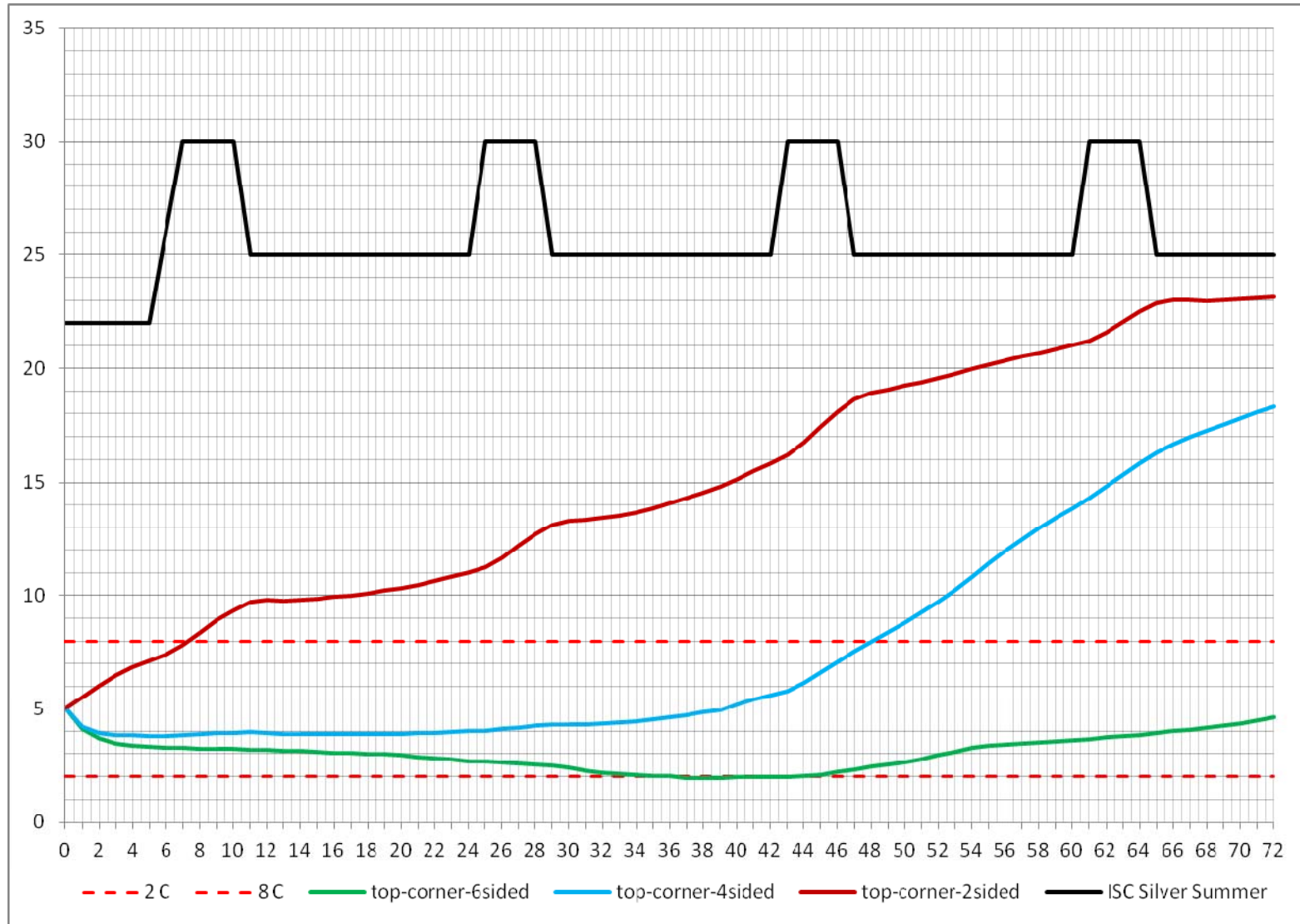
Midside

Center

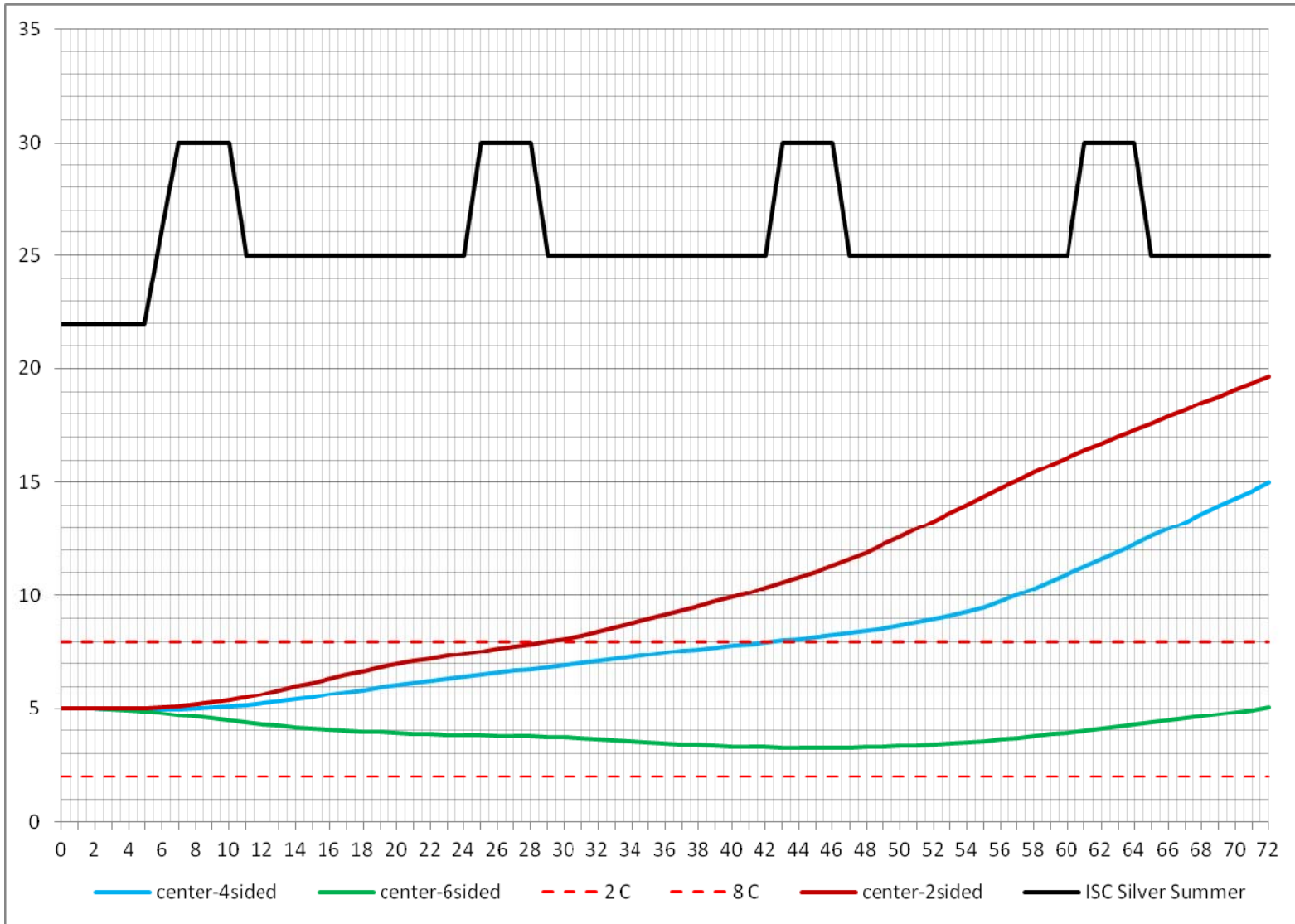
Top Center Probe



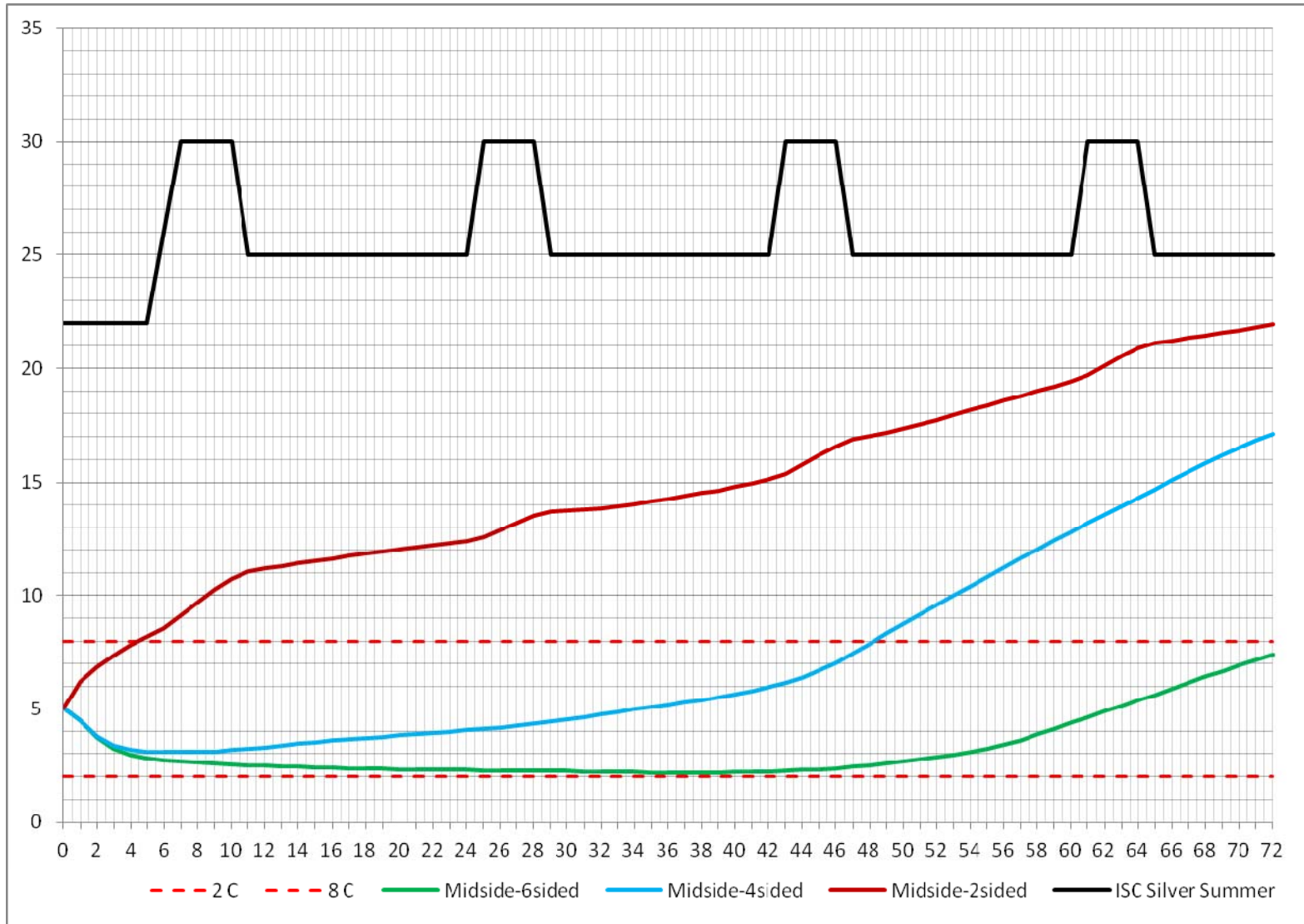
Top Corner Probe



Center Probe



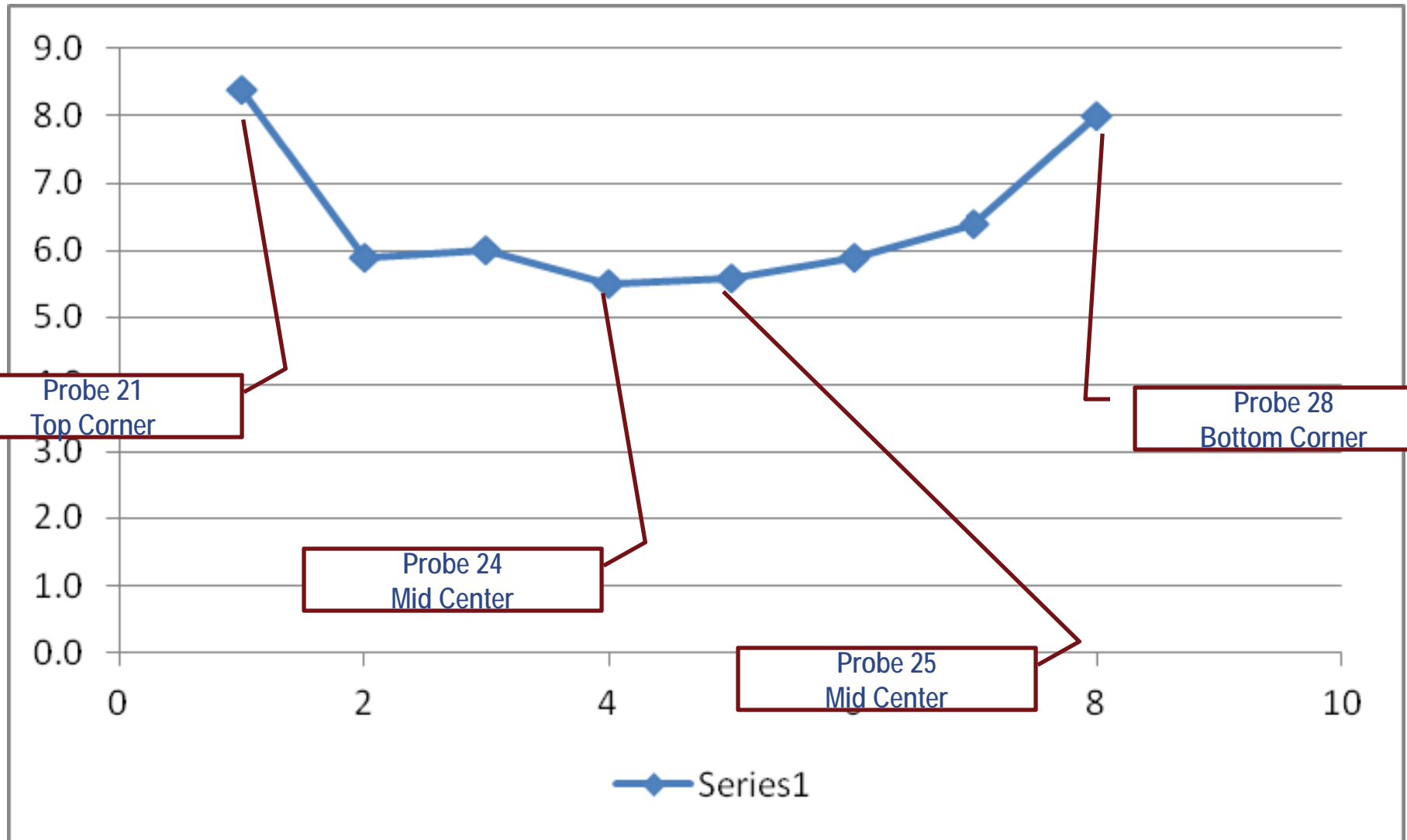
Midside Probe



Product Temperatures in Specification

Design Configuration	Duration in Specification (hours)			
	Top Center Probe	Top Corner Probe	Center Probe	Midside Probe
6-sided	72	72	72	72
4-sided	54	48	42	48
2-sided	35	7	29	4

EF6040 pallet, product probe temperatures by location



CONDITIONING – COLD SHOCK AND REFRIGERANT BENCH TIMES

Preventing Cold Shock

- Cold Shock is the rapid decline in product temperature during the initial packout phase, when frozen refrigerant comes into contact with the product
 - How to prevent cold shock
 - Refrigerated gels or bricks
 - Buffer pads e.g. corrugate, EPS, bubble wrap
 - Bench time for frozen refrigerants
 - PCMs with phase temperatures above cold shock temperatures

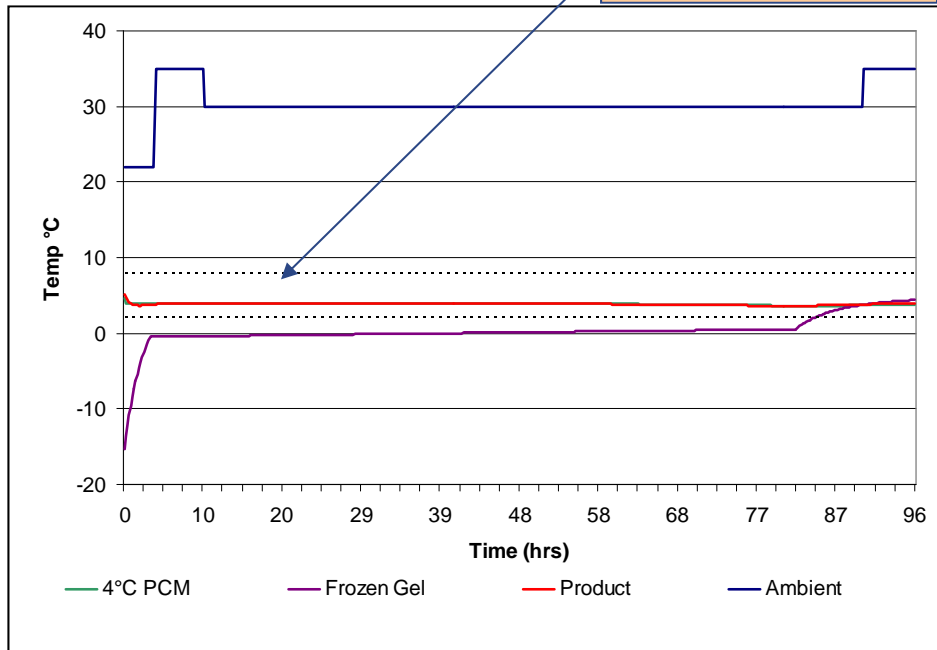


Using PCMs to prevent Cold Shock

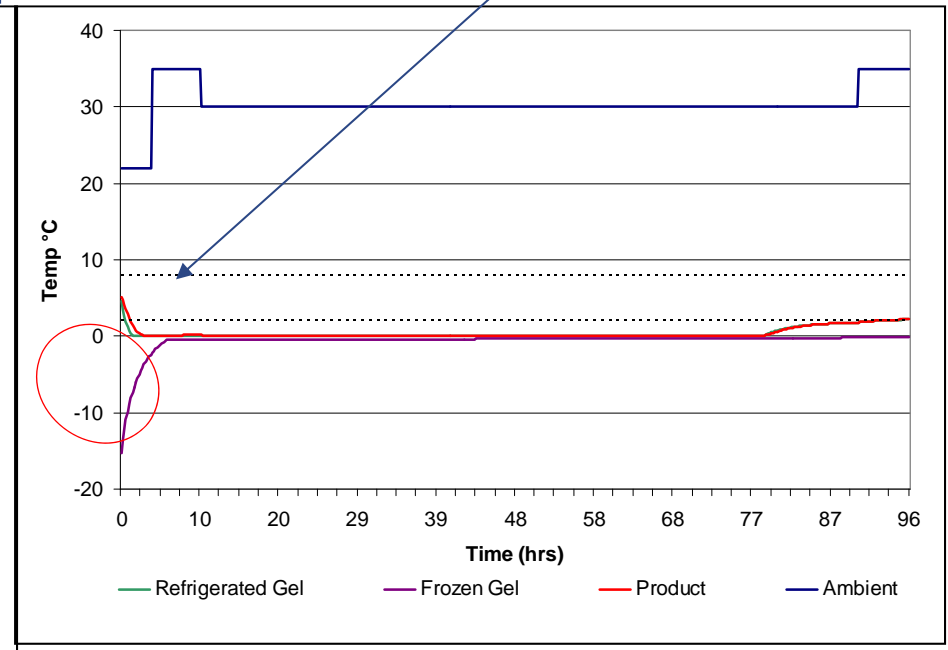
■ PCM vs. water-based gel pack

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

With PCM
PCM keeps
product >2°C

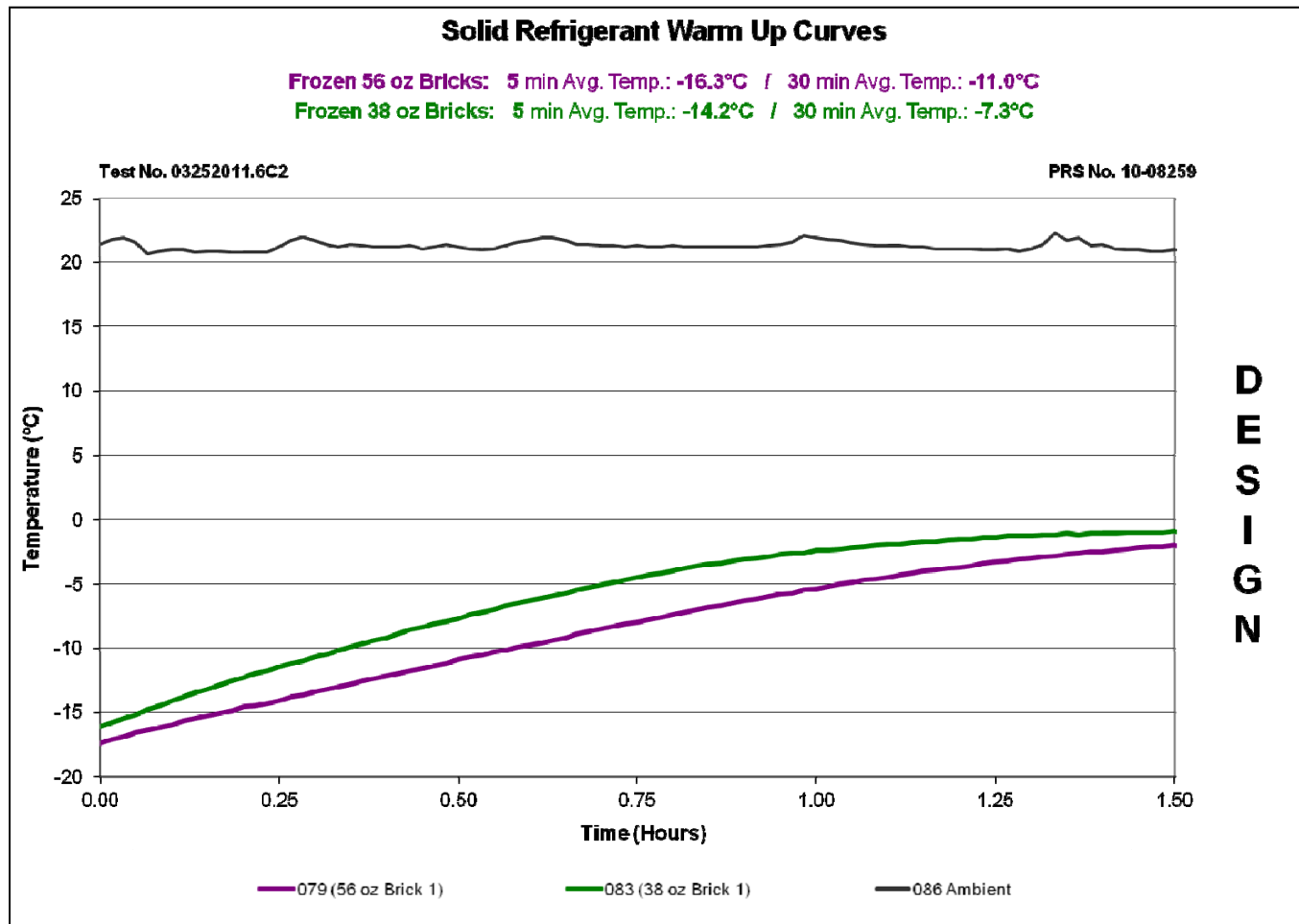


Without PCM
Cold Shock /
Product Frozen



Effect of Bench Time on Refrigerants

- Higher Refrigerant mass requires more bench time for warm up
- Bench time at room temperature can help reduce cold shock

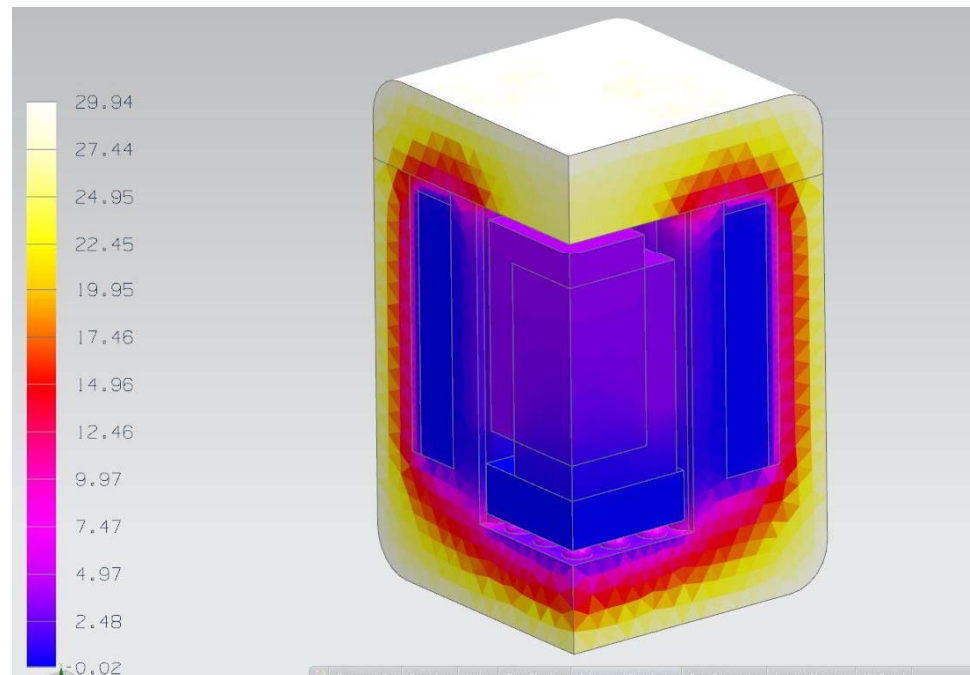


PRODUCT MASS & TEMPERATURE

Impact of Mass and Density

- The rate of change of thermal energy per unit volume
 - To achieve the same change in temperature a greater mass (density) requires a greater rate of change of thermal energy.

$$\dot{E} = \rho c_p \frac{\partial T}{\partial t} dx dy dz$$



Probe Locations and Methodology

- Product packaging and thermal mass
 - Small thermal mass will make product temperatures much more responsive to ambient conditions



Product Load Selection

- Thermal considerations for Product Load selection
 - Thermal Mass or Capacitance
 - Effect of Conduction and Convection

- Product Loads for Testing
 - Bracketing Product Mass for Testing
 - Minimum Load
 - Maximum Load
 - Empty container

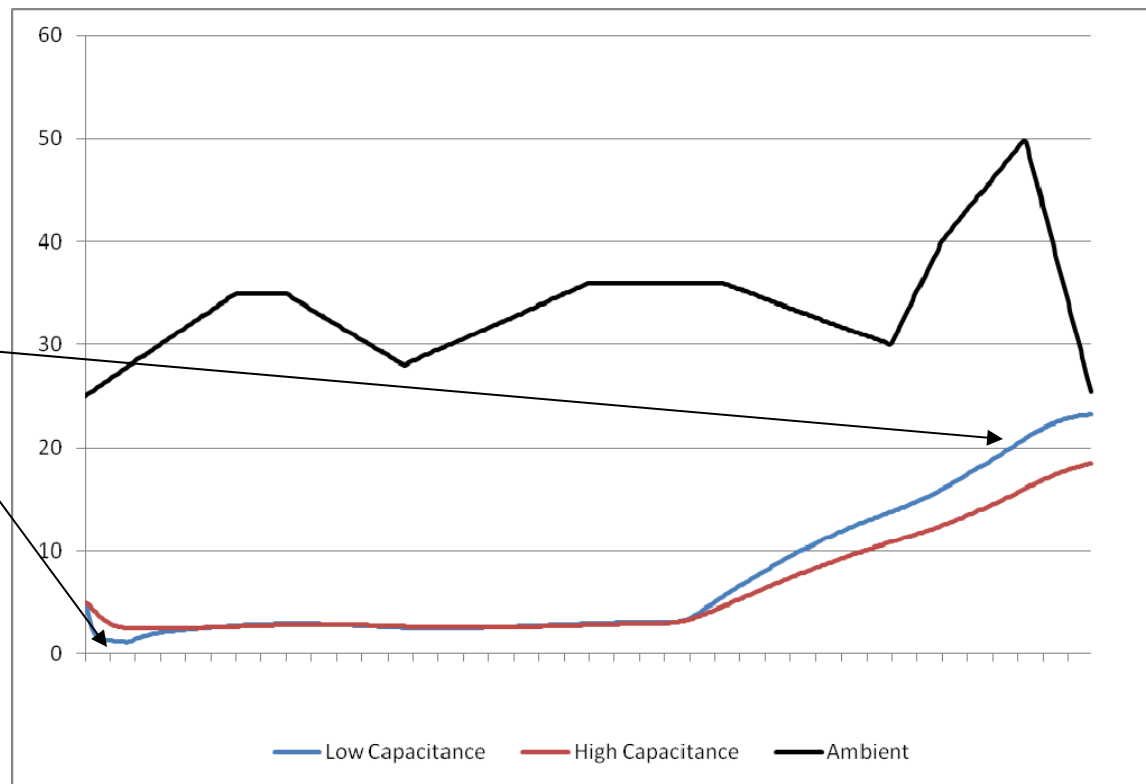


Product Load Selection

■ Thermal Mass or Capacitance

- Defined as the product of mass and specific heat $\rho * C_p$
- Determines the rate of product thermal response to changes in ambient conditions

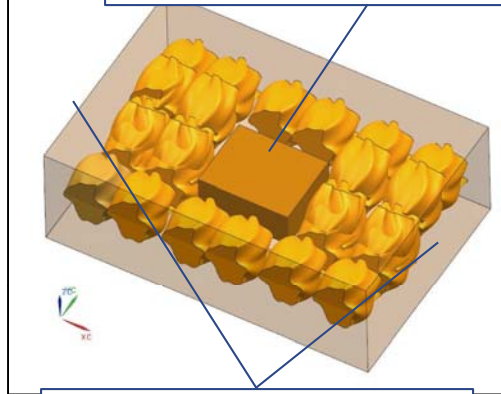
Product with Low Thermal Capacitance will respond more quickly to cold shock and change in ambient conditions



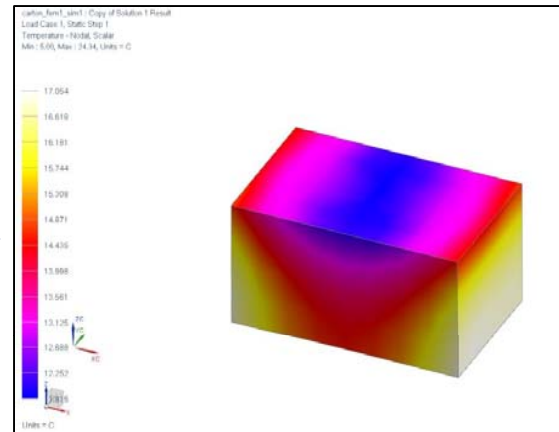
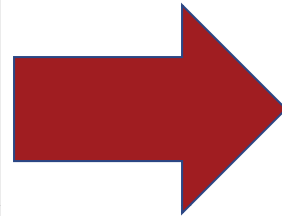
Product Load Selection

Effect of Conduction & Convection

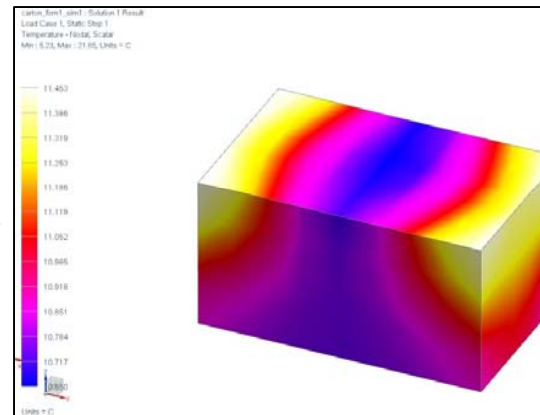
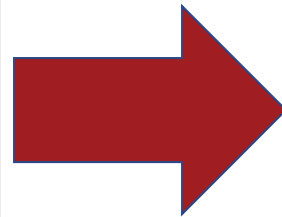
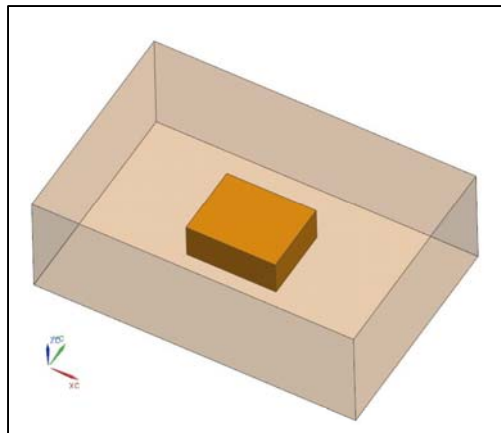
Top Ambient = 5 C



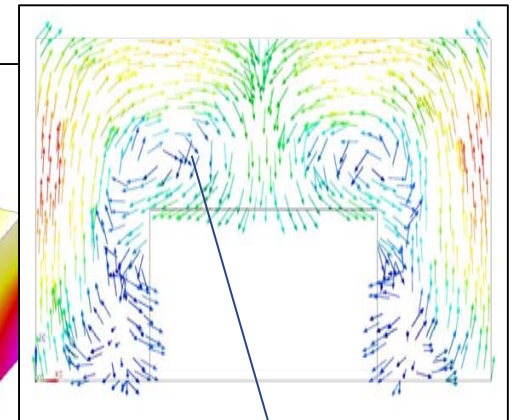
Side Ambient = 22 C



Max Product Temperature = 17 C
Corepack filled with Dunnage



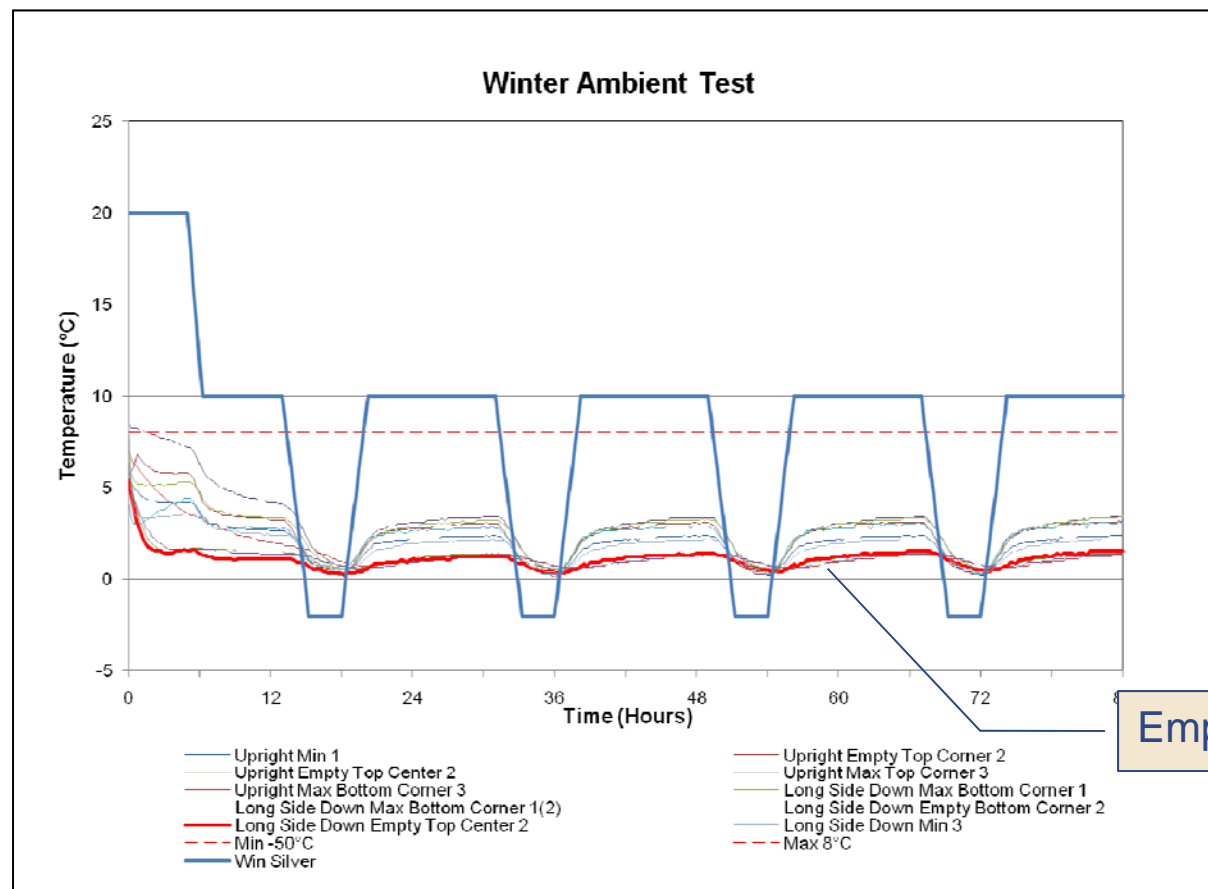
Max Product Temperature = 11 C
Corepack filled with Air



Convection Currents

Product Load Selection

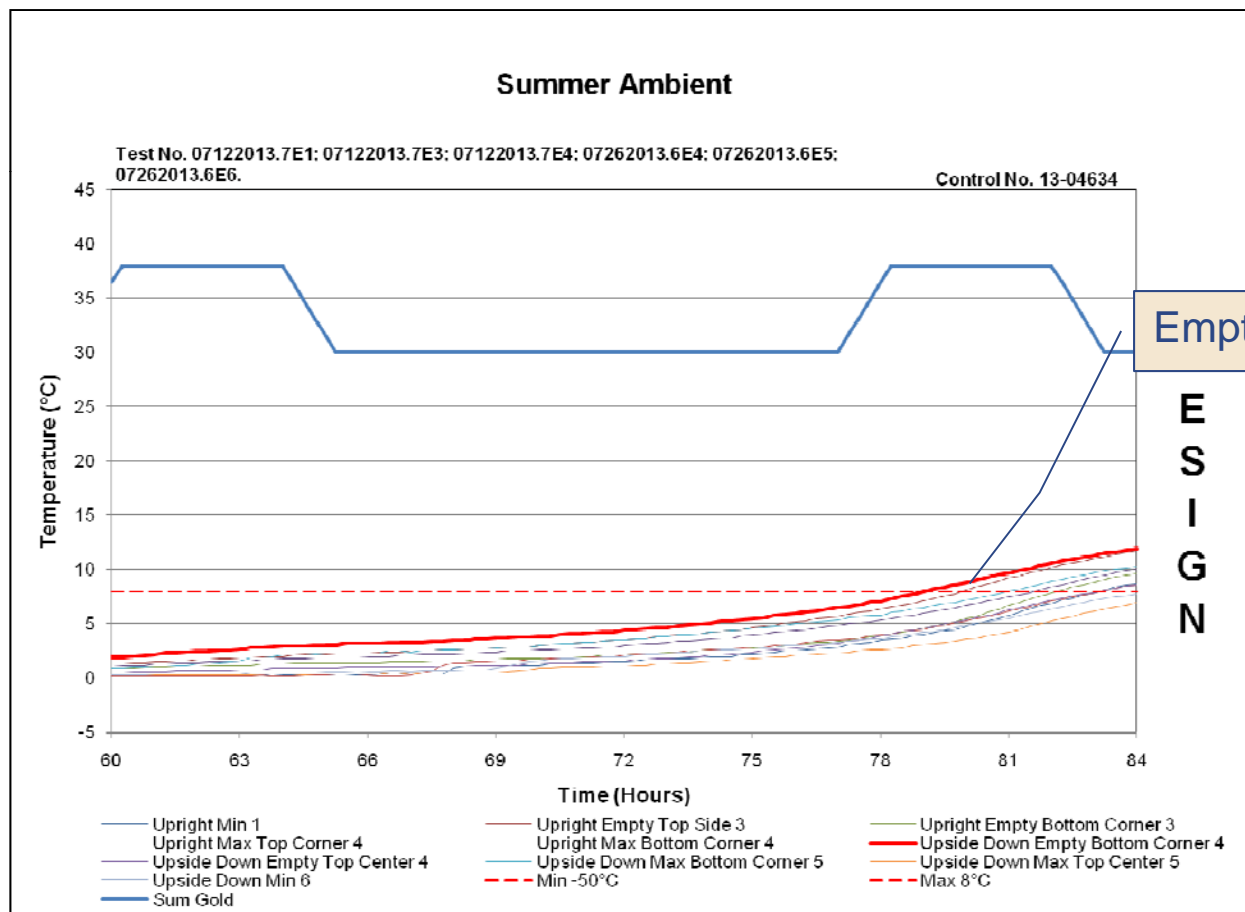
- Difference between Maximum, Minimum and Empty Product Loads
- Winter Ambient indicates that Empty Load Probe will have the lowest or worst case temperature.



Empty Load Probe

Product Load Selection

- Difference between Maximum, Minimum and Empty Product Loads
- Summer Ambient indicates that Empty Load Probe will have the highest or worst case temperature.

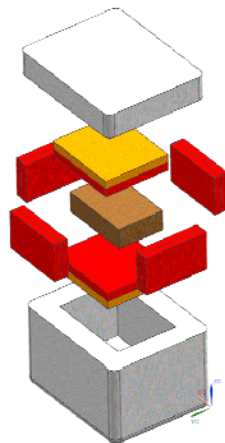


OPENING UP PRODUCT TEMPERATURE RANGE

Effect of Product Temperature Range

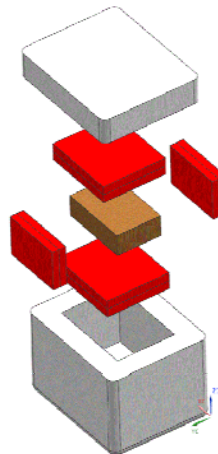
- CRT Case Study
- The narrower the product temperature criteria the more challenging is the thermal design, more refrigerants, more insulation

20°C - 25°C



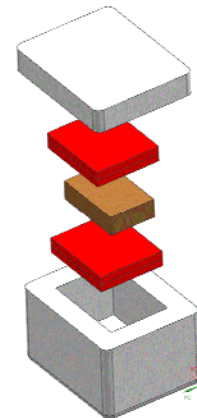
24 lbs of Refrigerant

15°C - 30°C



18 lbs of Refrigerant

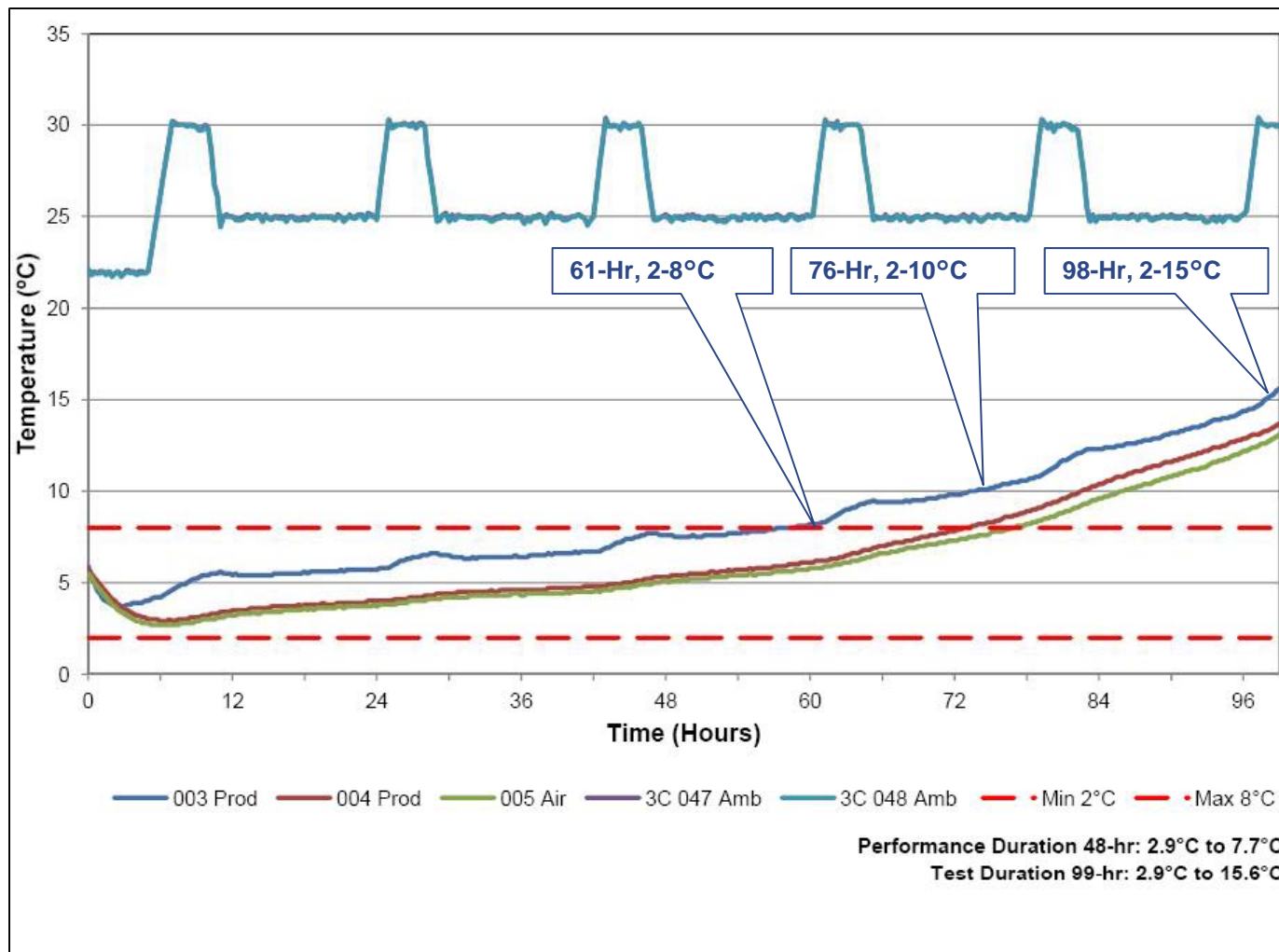
5°C - 30°C



12 lbs of Refrigerant

Effect of Product Temperature Range

Refrigerated Case Study

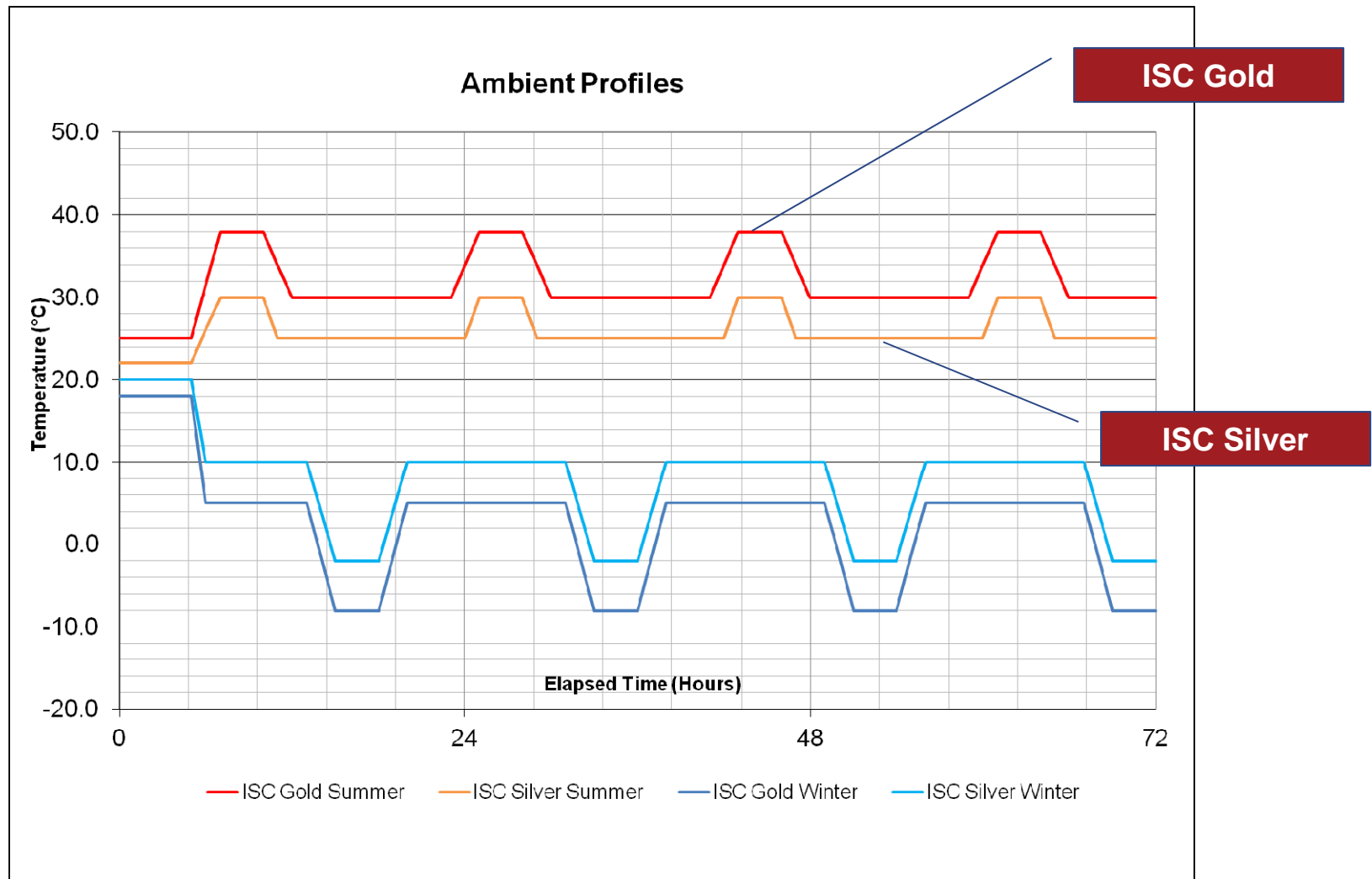


AMBIENT PROFILE AND COST

Effect of Ambient Profiles on Package Design

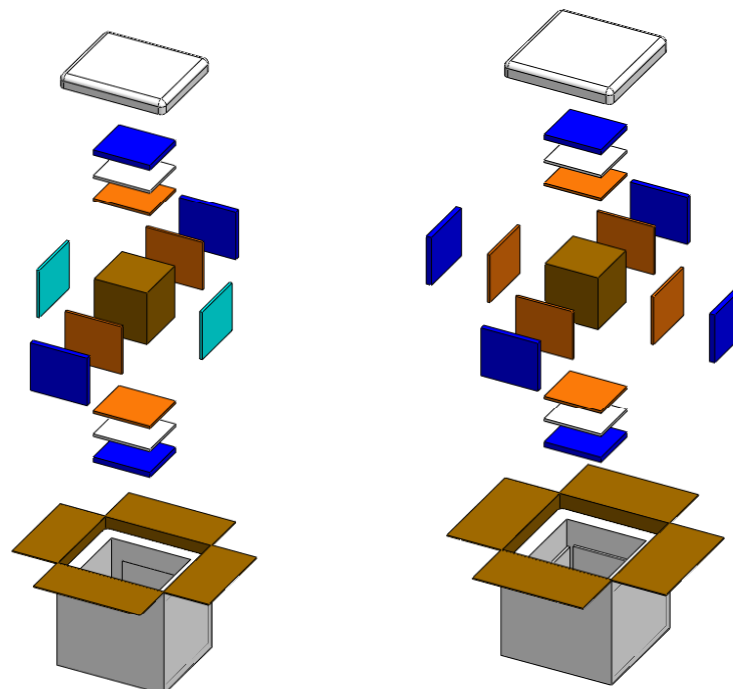
- An more extreme Ambient Profile will have the following impact on TAP design:
 - More refrigerant weight
 - More components
 - Higher insulation e.g. thickness, R-value
 - Higher Cost
 - Larger container dimensions

Effect of Ambient Profiles on Package Design



Effect of Ambient Profiles on Package Design

- ISC Gold profile vs. ISC Silver profile, 48 hours, 2°C to 8°C, Universal



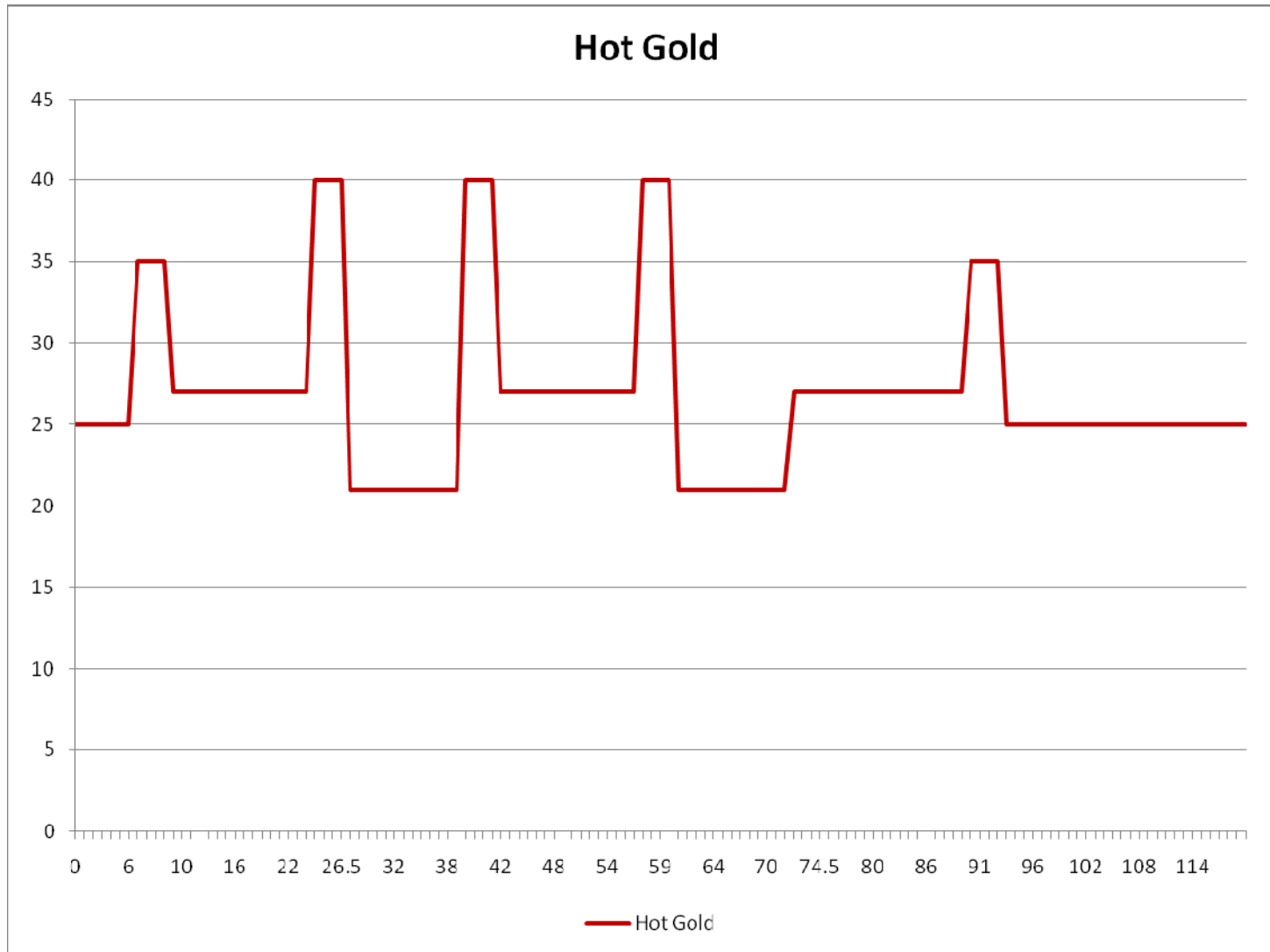
<i>Ambient Profile:</i>	ISC Silver Universal	ISC Gold Universal
Payload Volume (L):	16.4	16.4
Shipper O.D. Volume (L):	109.7	141.2
Number of Components:	11	15
Weight (lbs):	31.6	40.5
Dimensional Weight (lbs):	40	52

UNIVERSAL VS SEASONAL SOLUTIONS

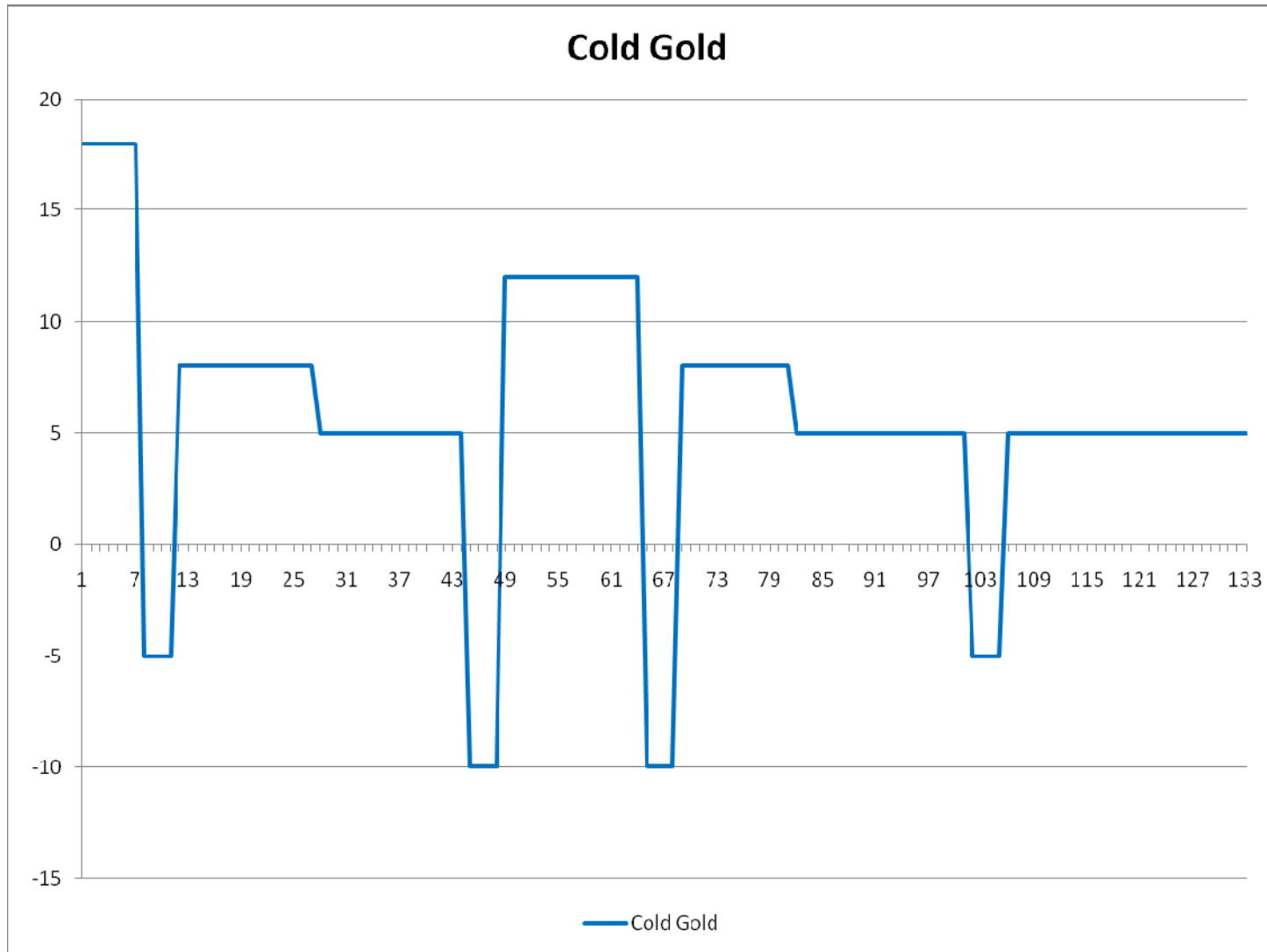
Profile Bracketing

- Packout Configuration
 - Seasonal – One Ambient Profile
 - Simpler Packout
 - Lower Cost
 - Different packouts for each season
 - Possibility of Product Excursions if Seasonal Designs are not transitioned at the right time
 - Universal – One Summer and One Winter Ambient Profile
 - One packout for all seasons
 - Higher Cost
 - Product Temperature Stability year round
 - Bracketed – Upper and Lower Ambient Profiles for Each Season
 - Compromise between Seasonal and Universal
 - Better product stability due to transition between seasons
 - Different packouts for each season

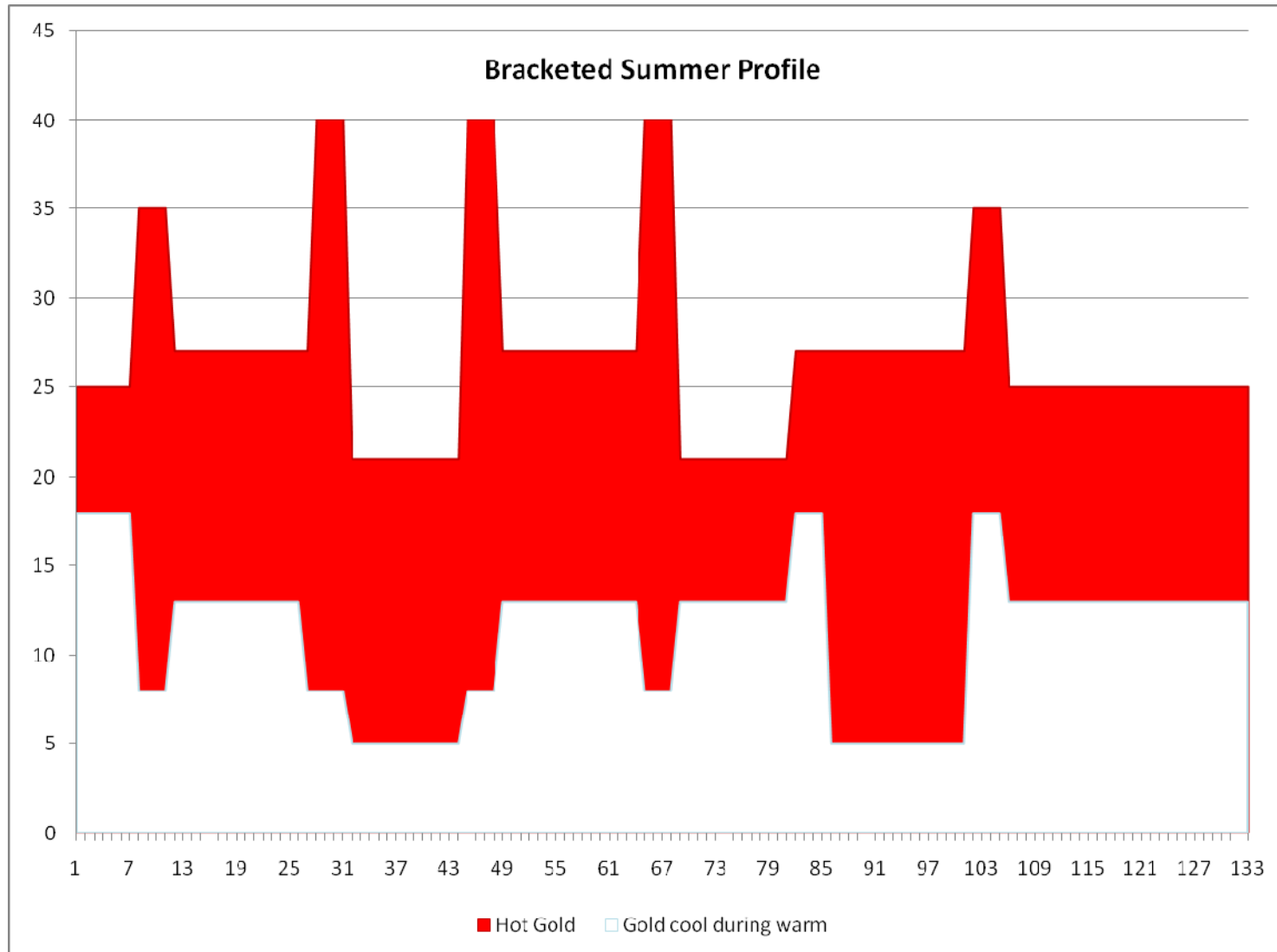
Profile Bracketing



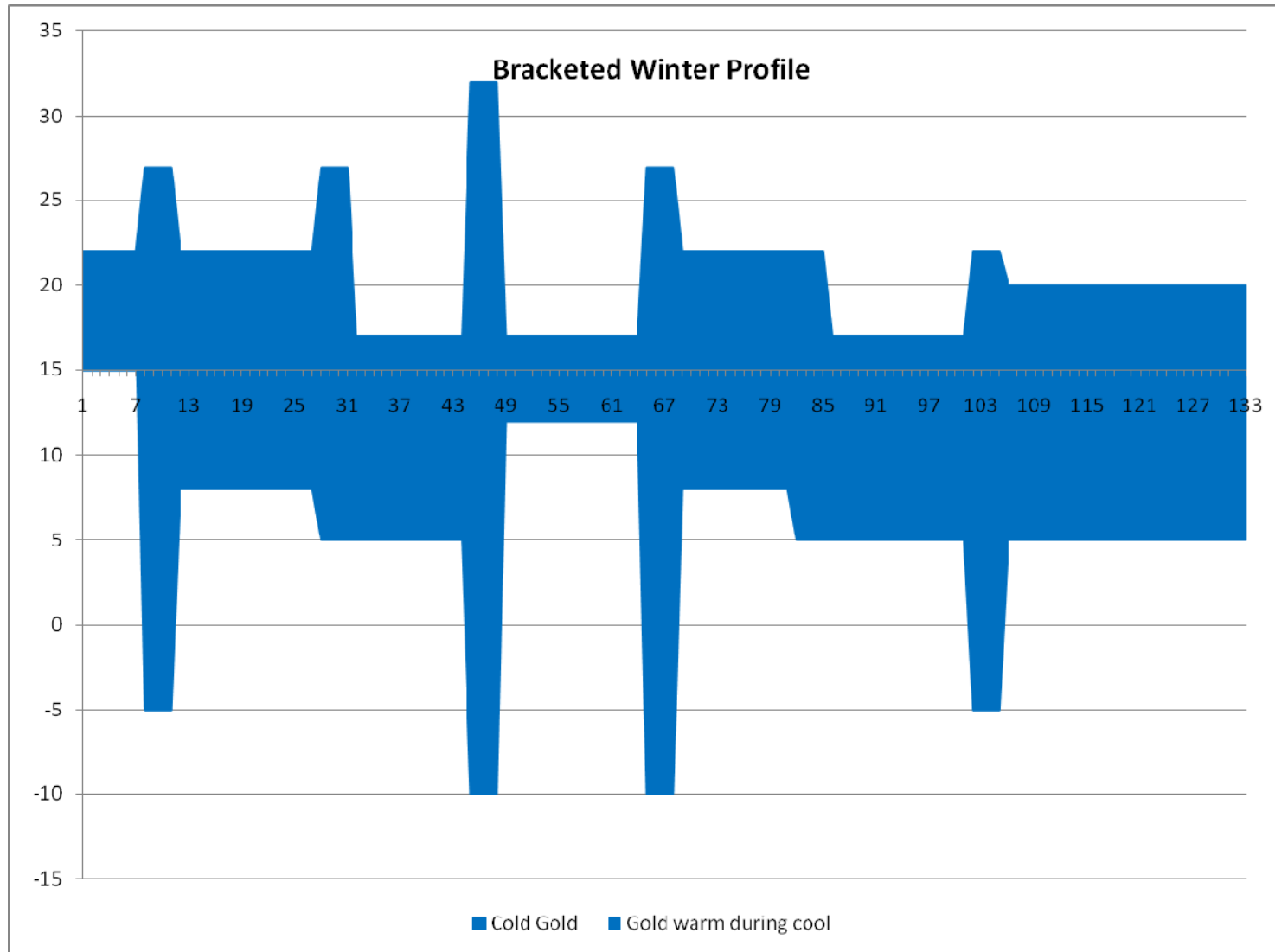
Profile Bracketing



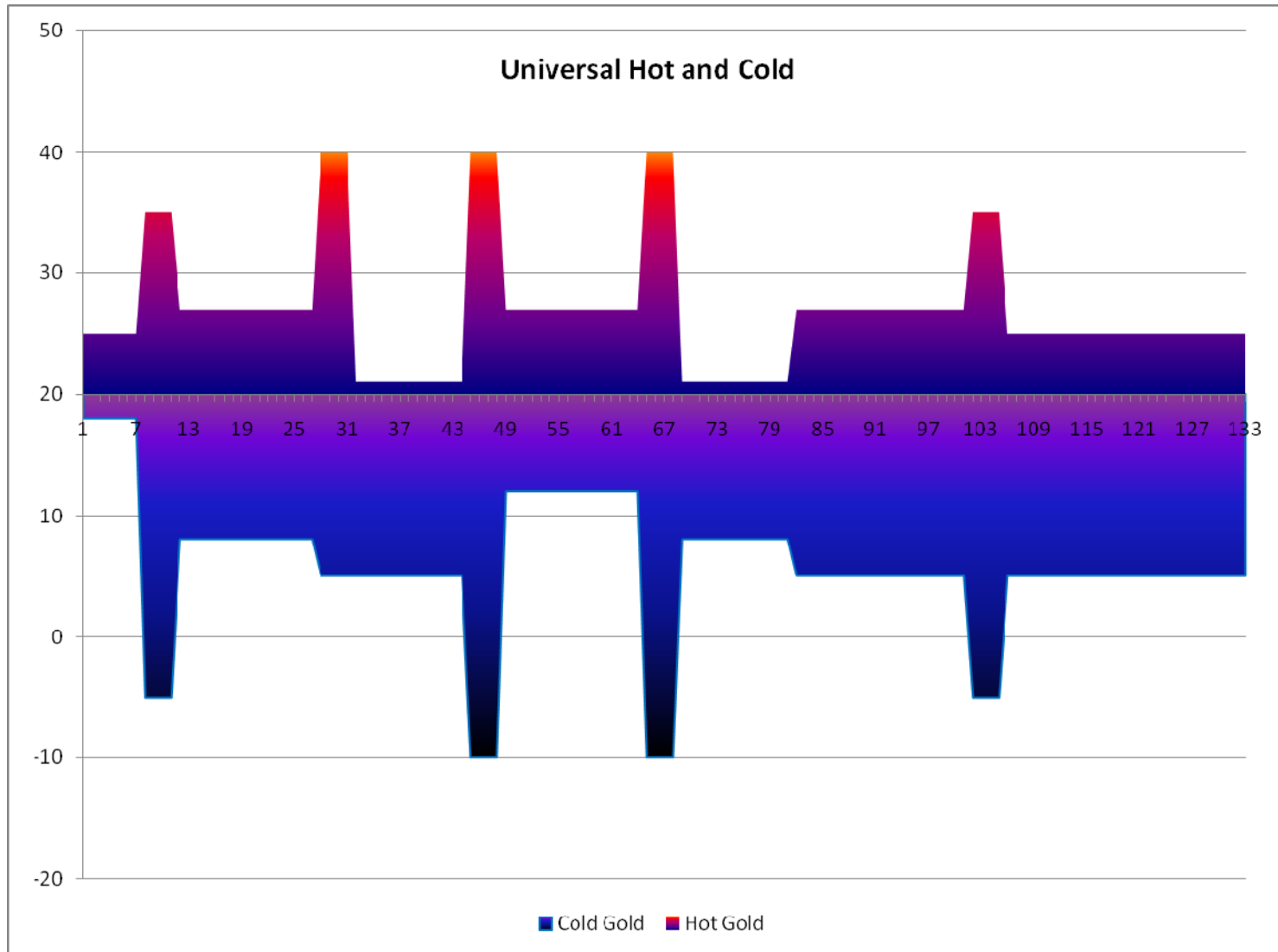
Profile Bracketing



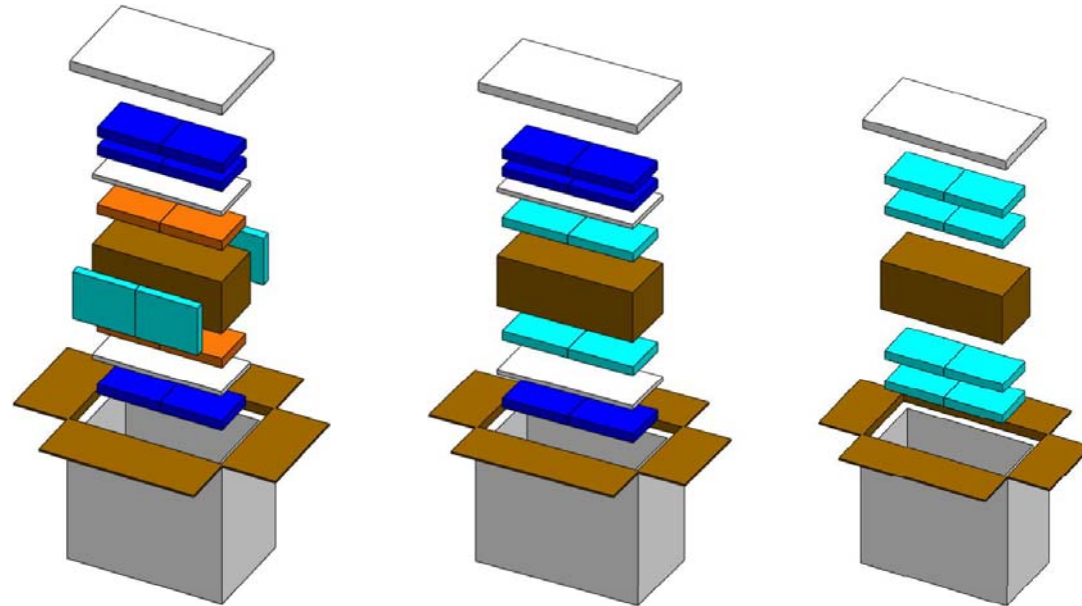
Profile Bracketing



Profile Bracketing



Profile Bracketing: Total Cost of Ownership

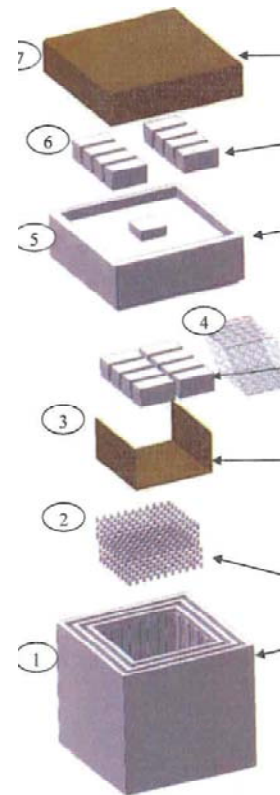


2-8C / 96-Hours	Stratta™ , Universal	Stratta, Summer	Stratta, Winter
System Weight	30 lbs	24 lbs	22 lbs
International Dim Wt.	31 lbs	27 lbs	27 lbs
System Price	\$81	\$54	\$54
Shipping Cost	\$62	\$54	\$58
Total Cost	\$143	\$108	\$106

SHIPPING A BOX ON ITS SIDE

Impact of Orientation

- Experience with a small parcel shipping system qualified in the upright orientation only



Impact of Orientation

Carrier A

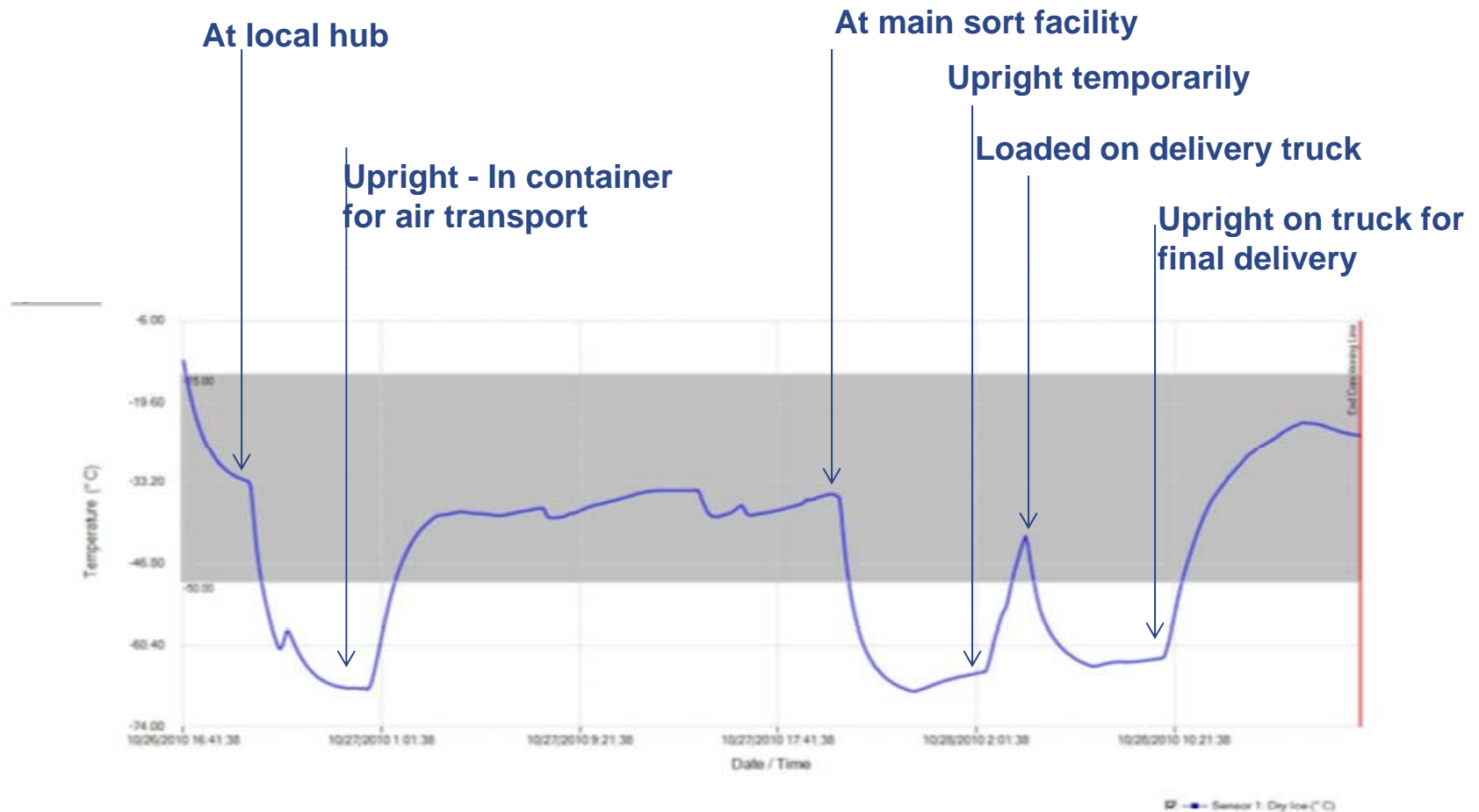
- “Place shipping labels on the package’s largest surface. While we cannot ensure compliance with markings such as “Up” arrows or “This End Up,” properly placing the shipping label increases your chance for the preferred orientation.”

Carrier B

- “**Note:** *Carrier B* does not provide special handling for packages with "Fragile", package orientation (e.g., "UP" arrows or "This End Up" markings), or any other similar such markings.”

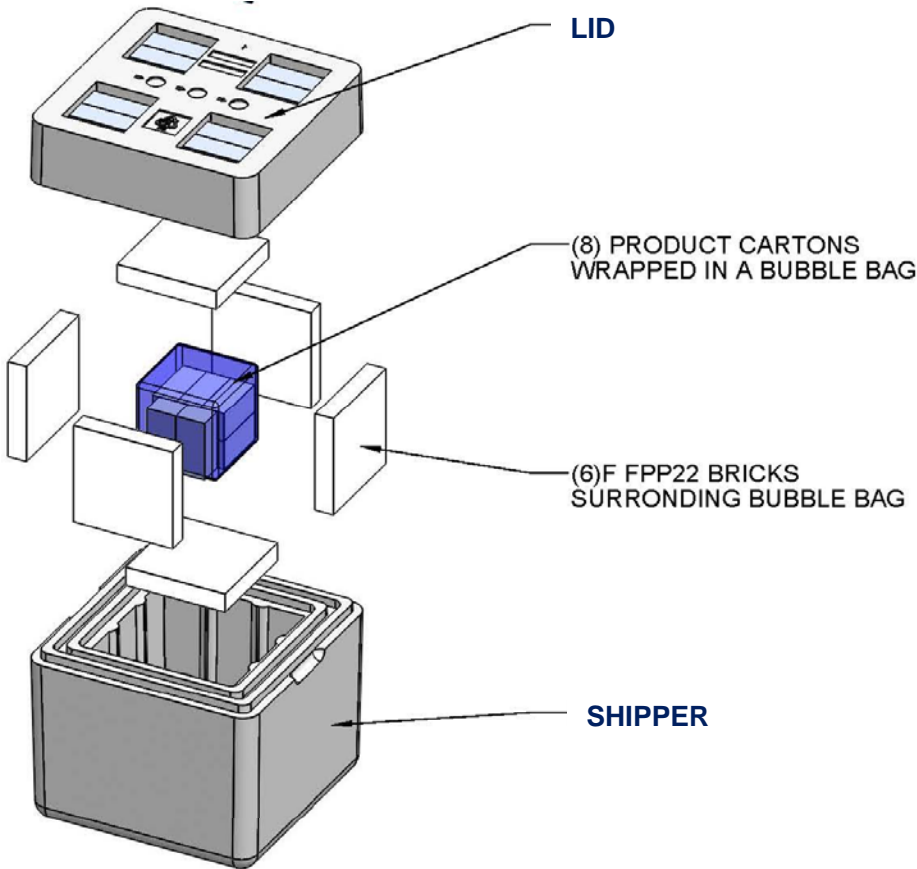


Impact of Orientation



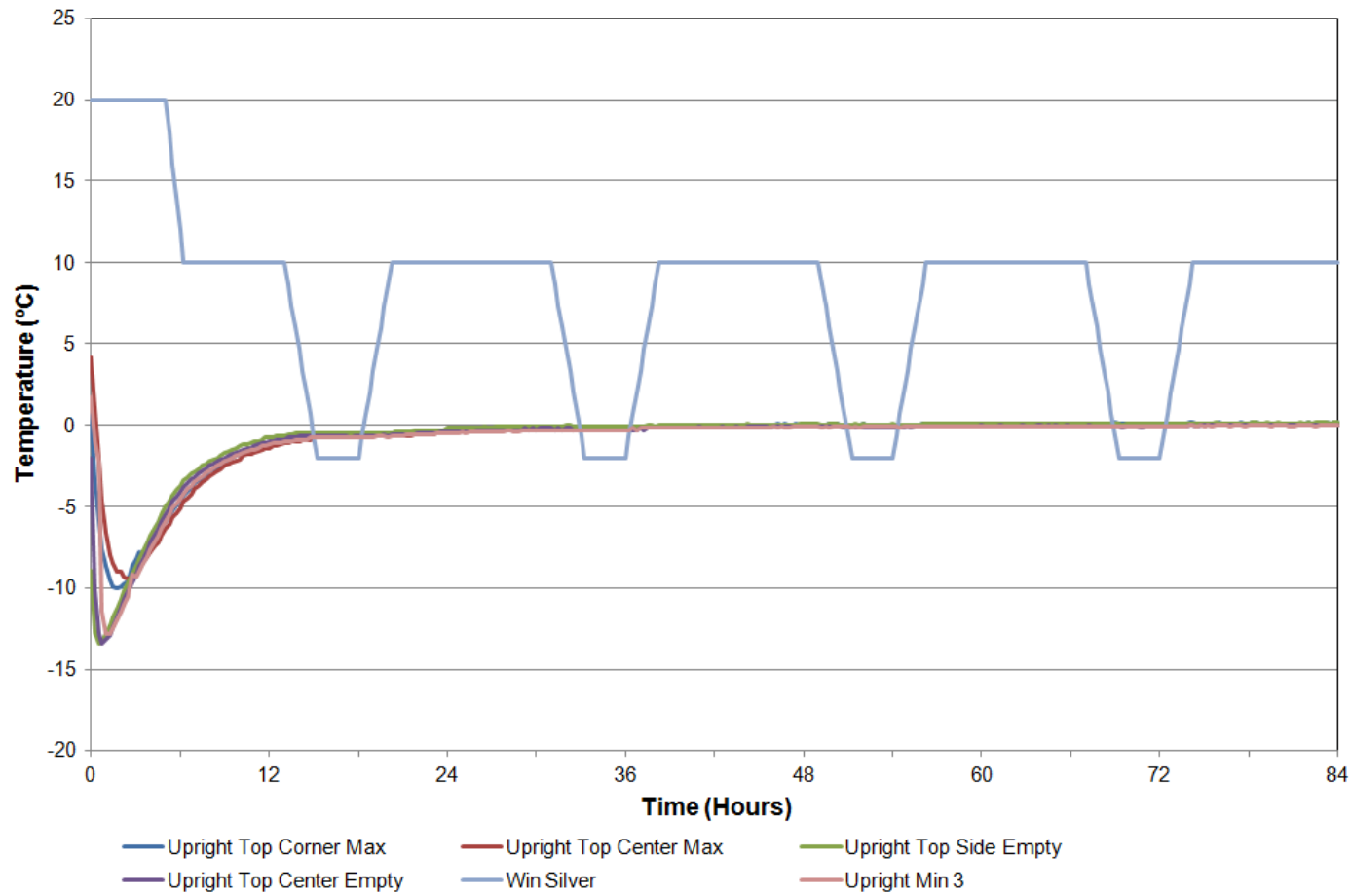
Case Study 1

- EPS Shipper with six sided frozen water based Polar Packs

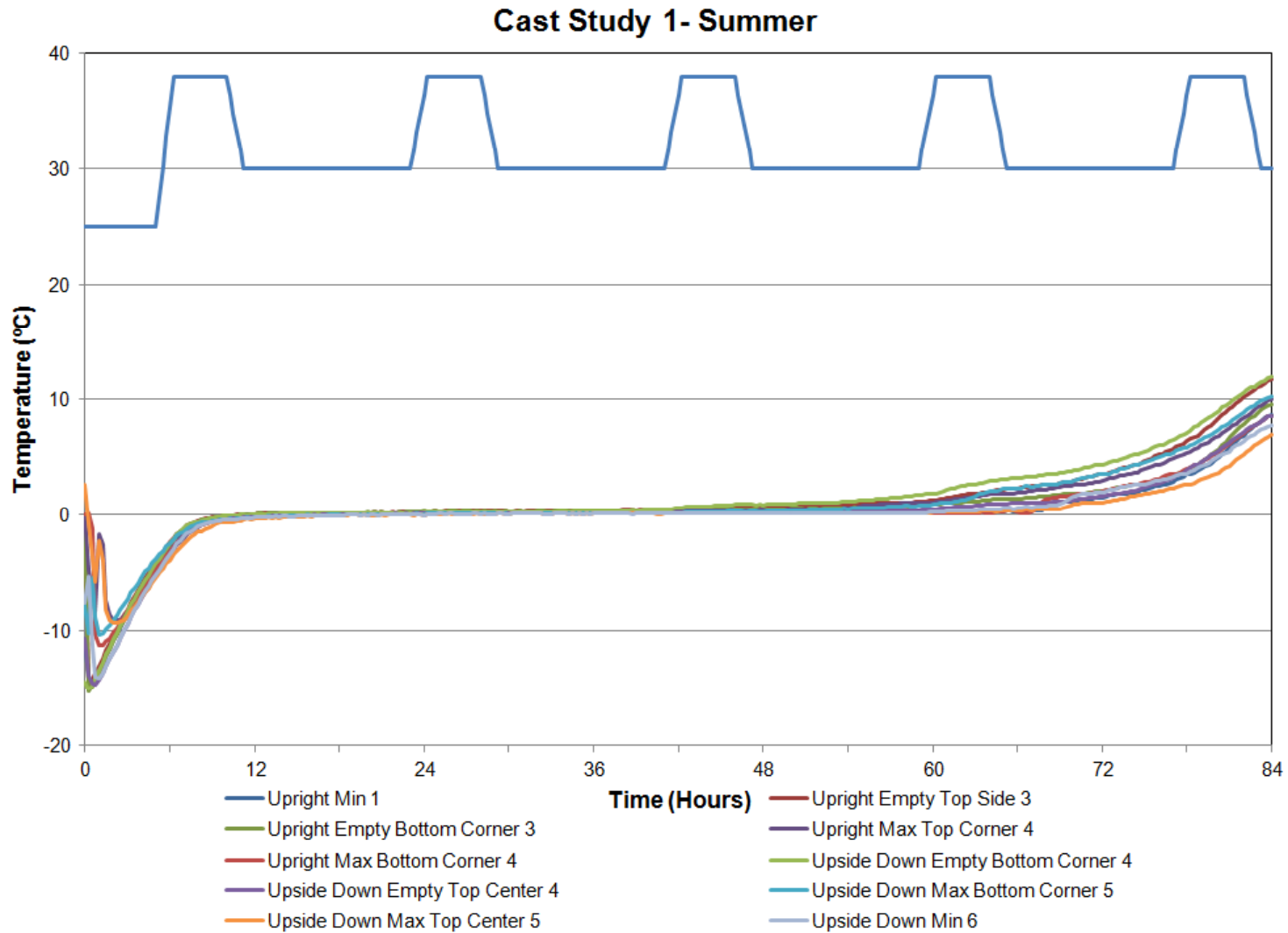


Case Study 1

Case Study 1- Winter

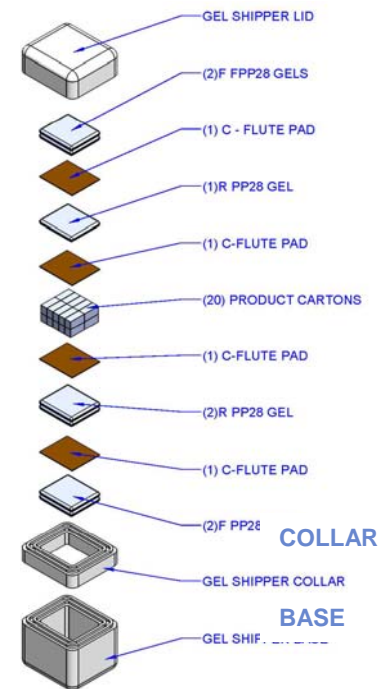


Case Study 1



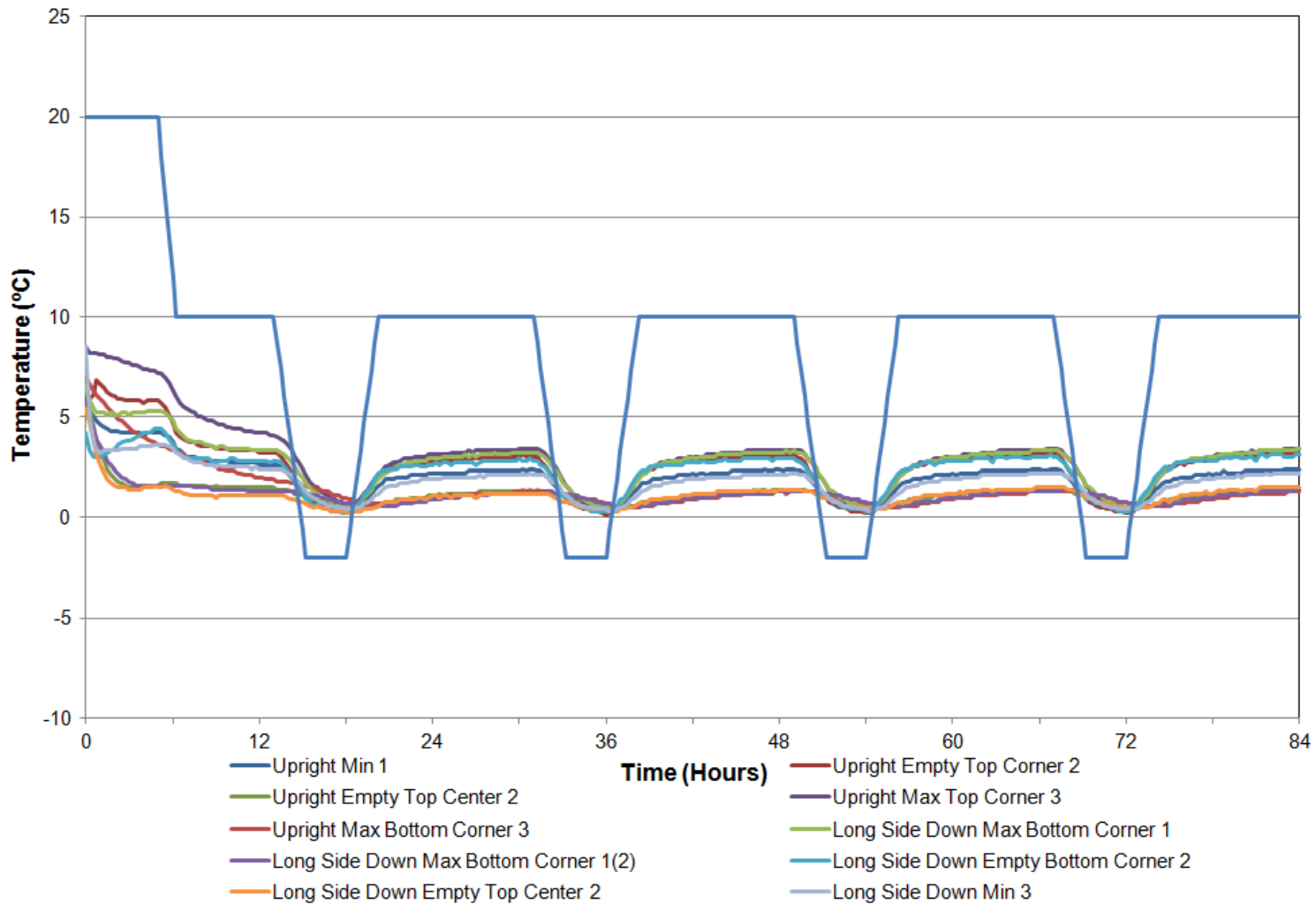
Case Study 2

- EPS shipper with two sided coverage
- Utilizes both refrigerated and frozen Polar Packs



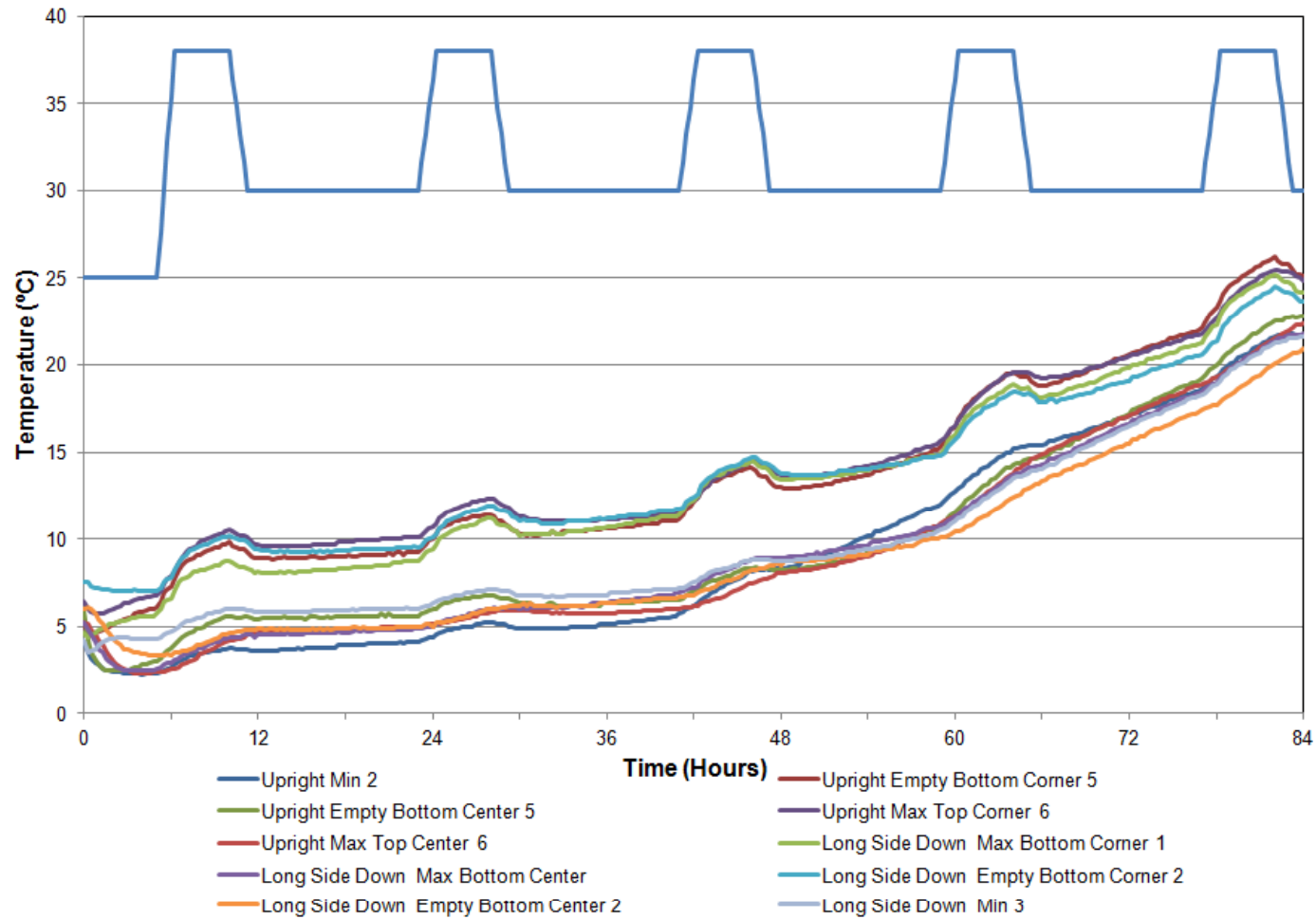
Case Study 2

Case Study 2- Winter



Case Study 2

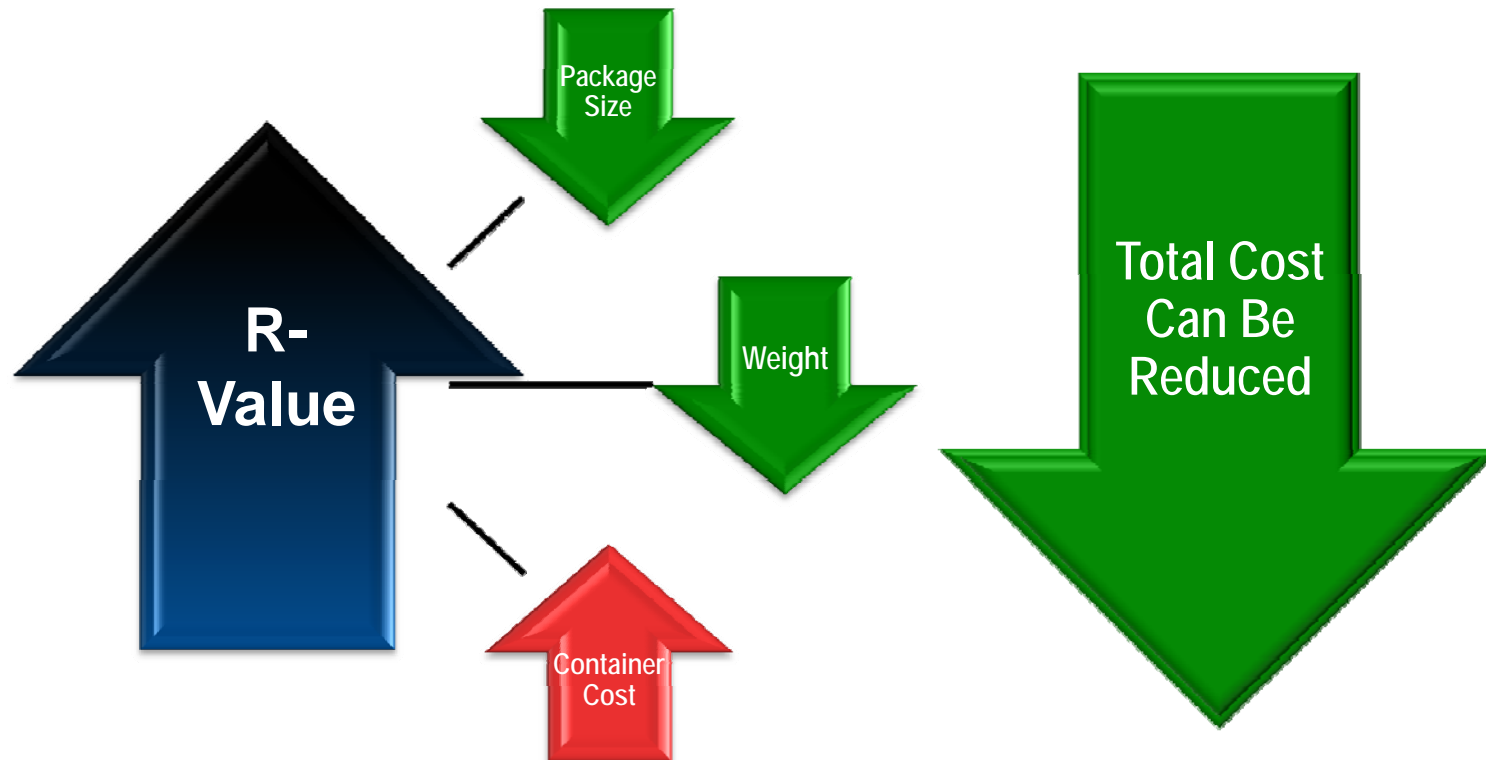
Case Study 2- Summer



COST VS INSULATION CHOICE

Insulation Type Comparison

Example: EPS vs PUR vs VIP



Insulation Type Comparison

Example: EPS vs PUR vs VIP

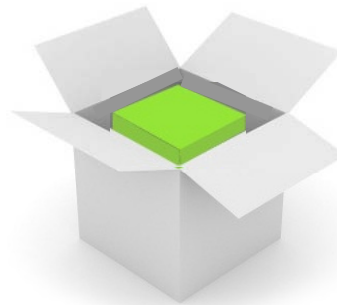
32 kgs



PAYLOAD
1L

EPS PACKAGING Size

18 kgs



PAYLOAD
1L

PUR PACKAGING Size

9 kgs

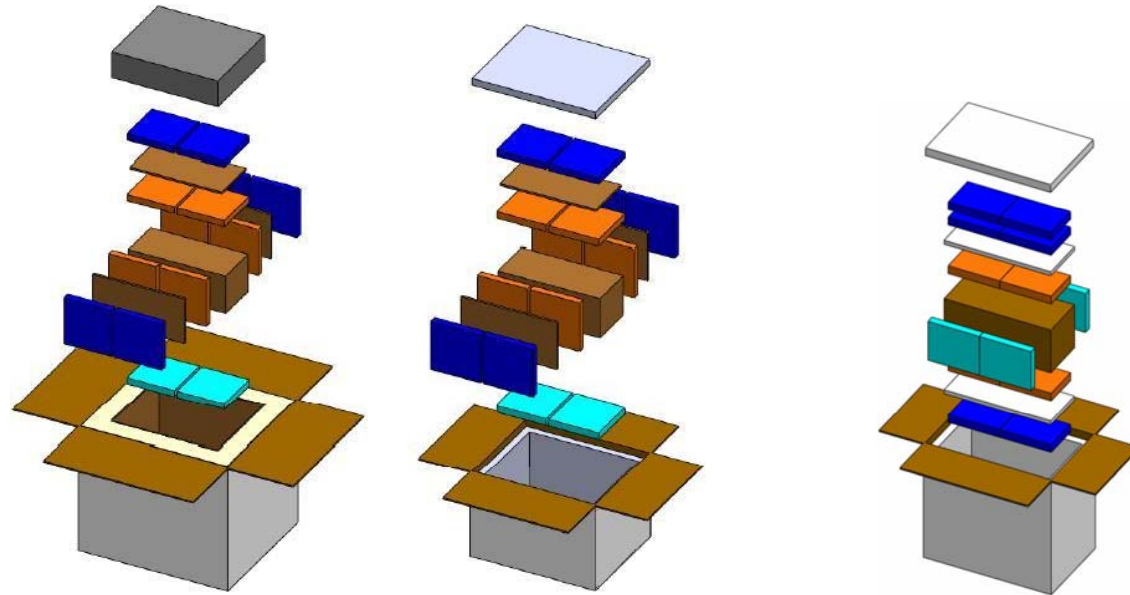


PAYLOAD
1L

VIP PACKAGING Size

5" PUR = 1" VIP

Total Cost of Ownership: Case Study

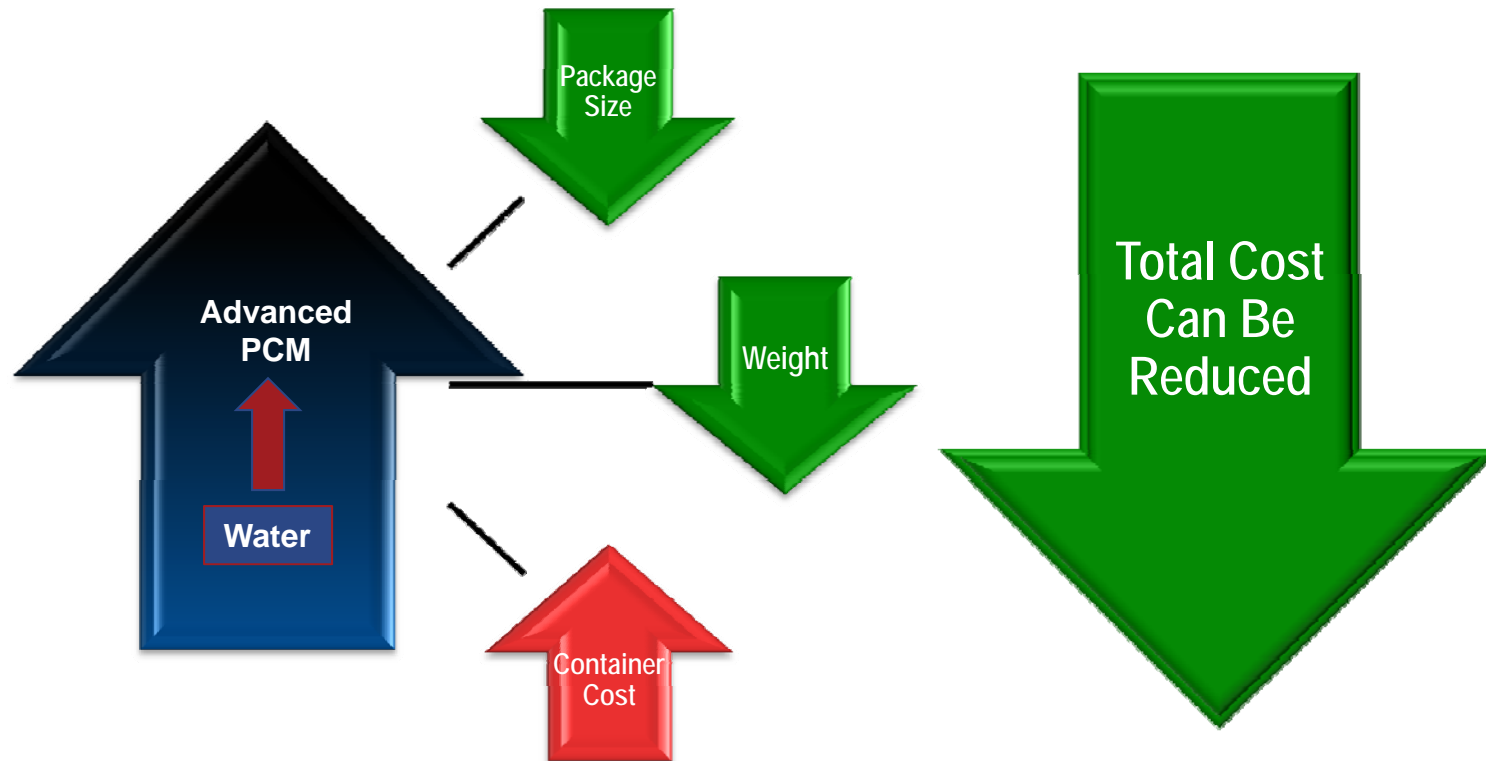


2-8C / 96-Hours, Univ.	PUR	VIP	Stratta™ (EPS/VIP)
System Weight	38 lbs	32 lbs	30 lbs
International Dim Wt.	55 lbs	24 lbs	31 lbs
System Price	\$92	\$118	\$81
Shipping Cost	\$110	\$64	\$62
Total Cost	\$202	\$182	\$143

COST VS PCM TYPE

PCM Type Comparison

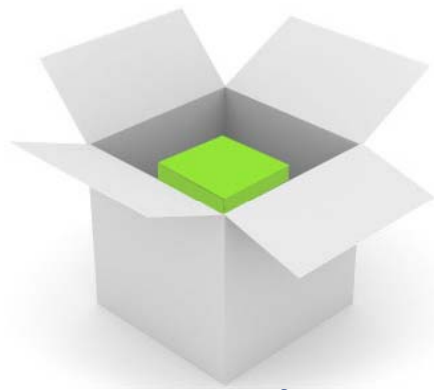
Example: Water vs Advanced PCM



PCM Type Comparison

Example: Water vs Advanced PCM

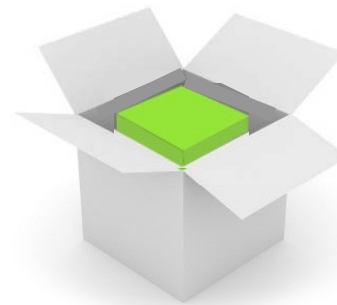
25 kgs



PAYLOAD
1L

Packaging Size w/water

12 kgs



PAYLOAD
1L

Packaging Size w/Advanced PCM

Thank You!

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& CREATE THE **FUTURE** OF THE COLD
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