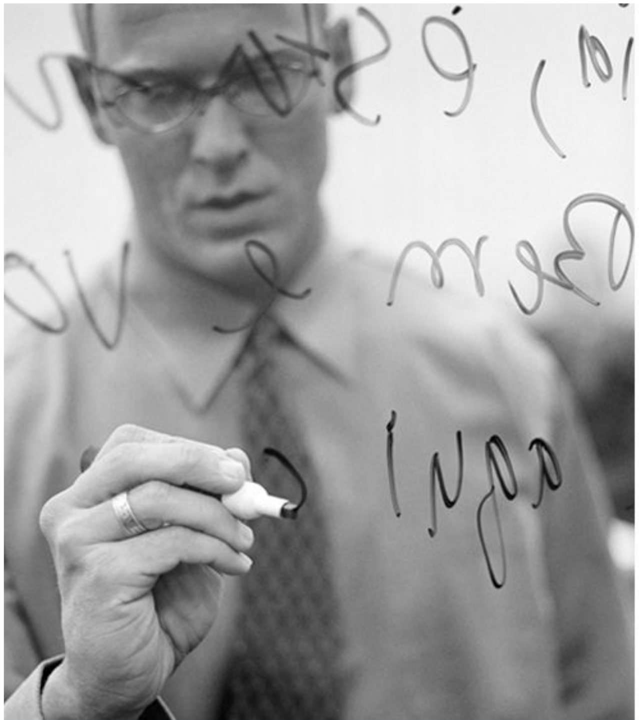
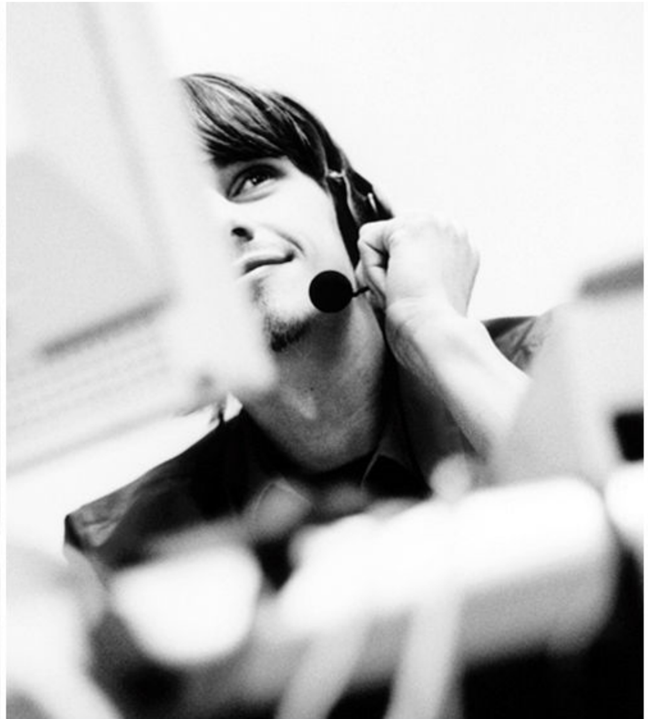




Applied Biosystems

Designing for Cold Chain – what is needed (*from a novice perspective*)

Paul Russell & Jay Crespo

Disclaimer – a Novice

- Newcomers may be surprised that “standardized” information is not available in the public domain about Cold Chain Distribution.
- The intent of this presentation is to
  - identify areas of research
  - motivate companies to share
- This key foundational information will then enable more effective standardized packaging solutions

Overview

- What is Cold Chain Distribution?
- What are we trying to solve?
- What are the costs associated with poor design?
- Basics elements of Insulated Shippers and their variables
- Who is involved and what is research being done?
- Case studies

What is Cold Chain Distribution

- Cold chain = temperature-controlled supply chain
  - *"An unbroken cold chain is an uninterrupted series of storage and distribution activities which maintain a given temperature range"*
- Cold chains are common in the food, pharmaceutical, and also some chemical industries shipments.
- The specific temperature (and time at temperature) tolerances depend on the actual product being shipped.

Wikipedia - Cold chain - http://en.wikipedia.org/wiki/Cold_chain

What are we trying to solve

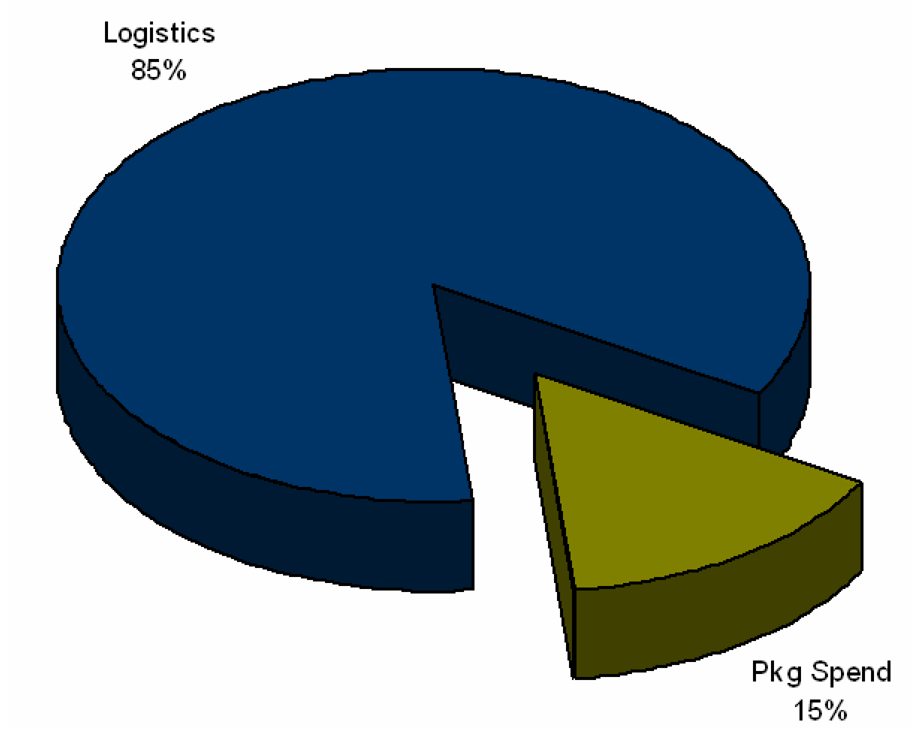
- Purpose:
  - Design a container for cold chain shipment to ensure that the product temperature stays within the proper temperature range for the entire duration of its trip from company to customer.
- Challenge:
  - Elements of a successful design are various and can be interdependent making design decisions difficult.
  - Each of these elements have their own variables which can have a minor to significant influence on the overall performance.
  - Understanding each of these elements and the affect their variables have on the overall performance is critical to designing an efficient/effective cold chain container.
- Goal
  - Identify these elements and their possible variables so further research can be conducted in mapping out these influence and aid the design process.
  - It is also the intent of this paper to encourage packaging professionals & researchers, which have already conducted research in these areas, to come forward with their information to reduce redundant research and improve the industry as a whole.

What are the costs associated with poor design

- Human factors
  - Patient safety or compromise research results due to product alterations.
    - Withdrawal or government recall of the product and product loss.
    - Exposed company liability and loss of brand equity when doubts are raised about product quality and safety following temperature deviations.
    - In regulated industries, such as pharmaceutical, the fines and penalties imposed can be severe.
- Financial factors
  - Typical cost consideration focuses on container and coolant.
  - Larger financial factor that is significantly impacted by poor design is logistics spend.
    - Too large costs more to ship (next day express air) and use more coolant than required.
  - Compromised product quality, requires replacement
    - Costs = all costs of the initial shipment + product loss + replacement product + new container & coolant + re-shipping fees.
- Environmental factors
  - Growing concerns around global warming and excessive packaging waste
  - Customers looking at environmental attribute of the cold chain containers they receive.
  - Impacts of poor design (ex. A large container hold a very small product) can be:
    - Amount of container materials needing to be recycled or disposed of. In many cases, recycling may not be an option as the products being shipment go into laboratories which deal with biological materials and the packaging waste is not recycled.
    - Amount of fossil fuel used to move the goods and it contribution to green house gases. Small containers allow more packages to travel in the same vessel at the same time reducing the overall impact.

Re-Thinking the Focus Area

- Logistics spend much greater than package material spend (mostly freight)
- Package size/weight drives logistics costs
- So then: focus on reducing package size/weight to reduce logistics spend, not just package material cost



Basics Elements of Insulated Shippers and variables (energy)

- Designs focus on controlling heat transfer
  - Conduction
  - Convection
  - Radiation
- Heat transfer control is accomplished via
  - Thermal insulation
  - Heat exchangers
  - Other methods and devices
- The calculation of heat transfer into an insulated container can be expressed as:

$$\mathbf{Q} = n \times L = A\,(T0 - Tb)/R$$

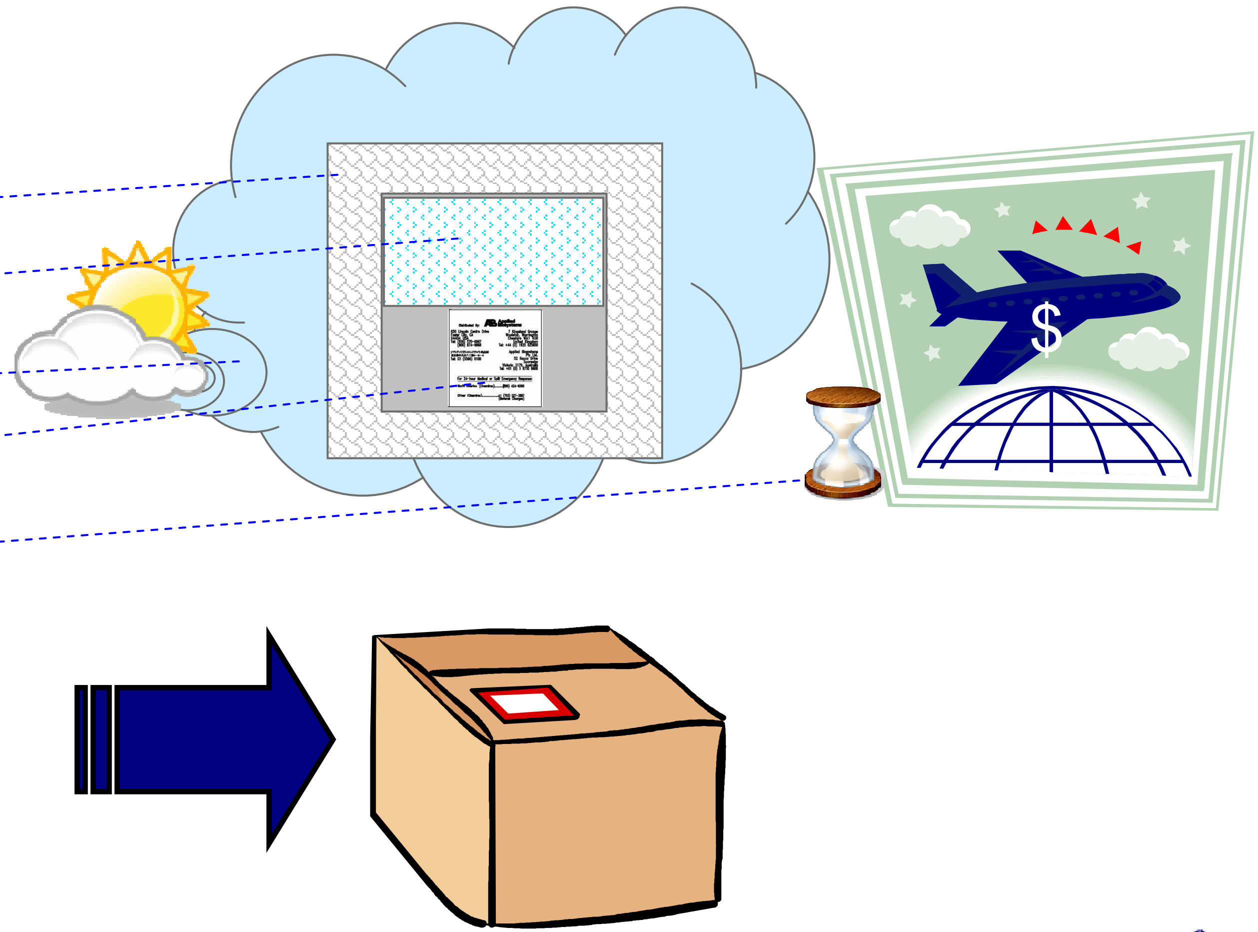
Where:

- n = rate of melting (e.g. lb/hr)
- L = latent heat of coolant (e.g. Dry Ice = 246 BTU/lb)
- A = area of container walls
- T0 = coolant temperature
- Tb = temperature outside the container
- R = resistance to heat flow (R-value)

Basics elements of Insulated Shippers and their variables

CRAPS Model (Kevin O'Donnell and Tom Pringle - Tegrant)

- C = Container
- R = Refrigerant
- A = Ambient temp.
- P = Payload
- S = Shipment time



Container

- Material
  - R-value per inch of thickness
    - High R-Value = Low conductivity
  - Density direct relationship to the R value (1 inch)

Foil-backed bubble pack	R-1 to R-2
Cardboard	R-3 to R-4
Paper loose-fill	R-3 to R-3.8
EPS	R-3.7 LD, 4 HD
Open-cell polyurethane	R-3.6.
Closed-cell polyurethane	R-5.5 to R-6.5.
Polyurethane rigid	R-6.8
Vacuum insulated panel	as high as R-30?

- Wall thickness
  - Simply put – the thicker the wall the greater thermal performance
    - What R value is based on

☼ *What is needed: More research & information on performance of current cold chain packaging materials.*

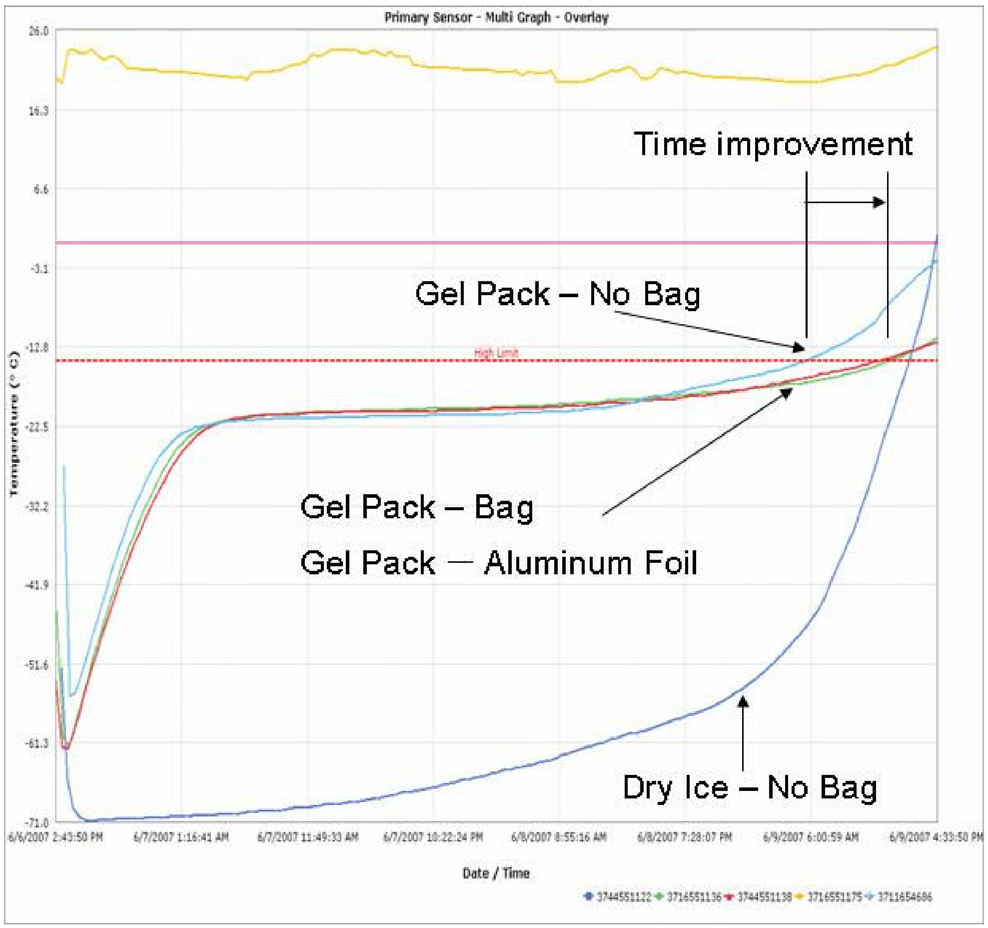
☼ *What is needed: More research & information on the differences in density for a given thickness vs. duration performance.*

☼ *What is needed: More research & information on the differences in wall thickness vs. duration performance of various material types. This should show when additional thickness adds little additional value.*

Global Packaging

Containers (cont.)

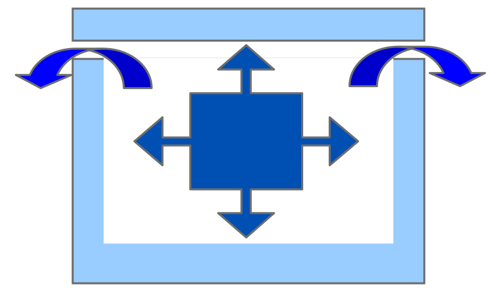
- Films - metalized wraps and aluminum foil have been shown to increase the insulative properties duration time



☼ *What is needed: More research & information on duration performance of various film material types..*

Container (cont.)

- Lid closure design
  - Tongue and groove
    - Double tongue and grove has been claimed to be best
  - Mechanical hold (friction, tape, shrink band)
    - Bellows effect
  - Has the greatest effect on dry ice or frozen shipments
    - Denser cold air is more likely to escape through seems and openings.
- Size
  - Payload area
  - Surface area



☼ *What is needed: More research & information on the differences in closure designs vs. duration performance.*

☼ *What is needed: More research & information on the differences in Payload and surface area vs. duration performance and coolant usage.*

Refrigerant (Cooling Engine)

☼ What is needed: More research & information on the differences in coolants vs. duration performance and amount of coolant usage.

- Dry Ice
  - Greatest amount of thermal energy absorbed.
- Phase Change Gels and Materials
  - Engineered gel absorbs specific amount of thermal energy.
- Frozen Gel (0 degree) – Becomes frozen when stored at 0 degrees Celsius.
- Design Info need
  - Melt index / Sublimation
    - Time – based on amount – more mass the longer duration
    - Size (cubic area)
    - Density

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Ambient Temperature

☼ *What is needed: More public domain information on ambient temperature measurements, profiles in use, and reposts of successful applications.*

- Public profiles – Amgen, ISTA 5B
- Highs
- Lows
- Cycles
- Seasonal
- Statistical Significance (e.g. FDA) and correlation (NASA, USGS)

Global Packaging

Payload

- Mass (thermal mass)
- Size (cubic area)
- Temperature range/tolerance
- Characteristics (stability/excursions)

☼ What is needed: More research & information on the differences in product characteristics vs. impact on duration performance and amount of coolant usage.

Shipment Time

- Length of required time

☼ What is needed: More public domain information on transit times for different levels of carrier services and lanes. This will help to better establish validation testing and amount of coolant usage.

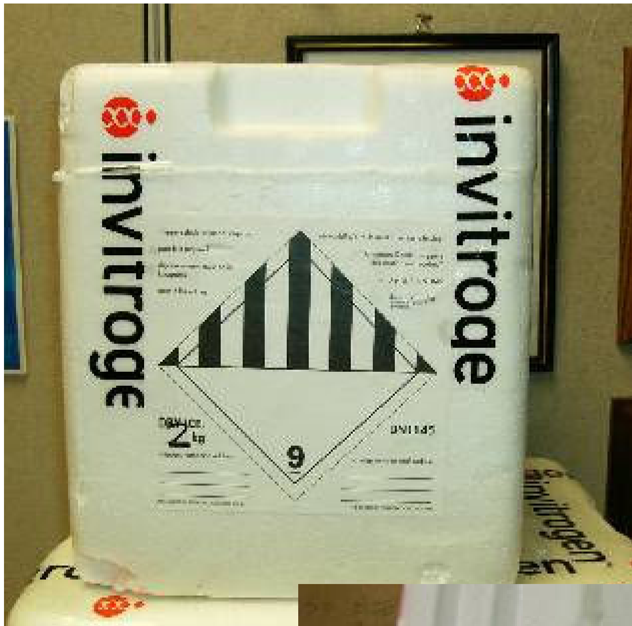
Who is involved

- PDA – Pharmaceutical Cold Chain Interest Group (PCCIG) – www.pda.org
  - PDA Technical Report 39, Revised 2007 Guidance for Temperature-Controlled Medicinal Products: Maintaining the Quality of Temperature-Sensitive Medicinal Products Through the Transportation Environment University
- Cold Chain Committee (C3) - http://www.c3info.org/
- University of Florida – Jean-Pierre Emond (jpedmond@ufl.edu) http://cfdr.ifas.ufl.edu
  - Dr. JEAN-PIERRE EMOND,
  - Professor, Packaging Science, ABE
  - Co-Director, UF/IFAS Center for Food Distribution and Retailing
  - 229 Frazier Rogers Hall
  - Museum Road
  - University of Florida
  - Gainesville, FL 32611-0570
  - (352) 392-1864 ext 229

Case studies

1. Invitrogen vs. Omaha Steaks
2. -23 Phase Change Gel vs. equivalent amount of Dry Ice
3. Express carrier concept boxes
4. Foil Bubble Envelope

Invitrogen vs. Omaha Steaks



Invitrogen vs. Omaha Steaks

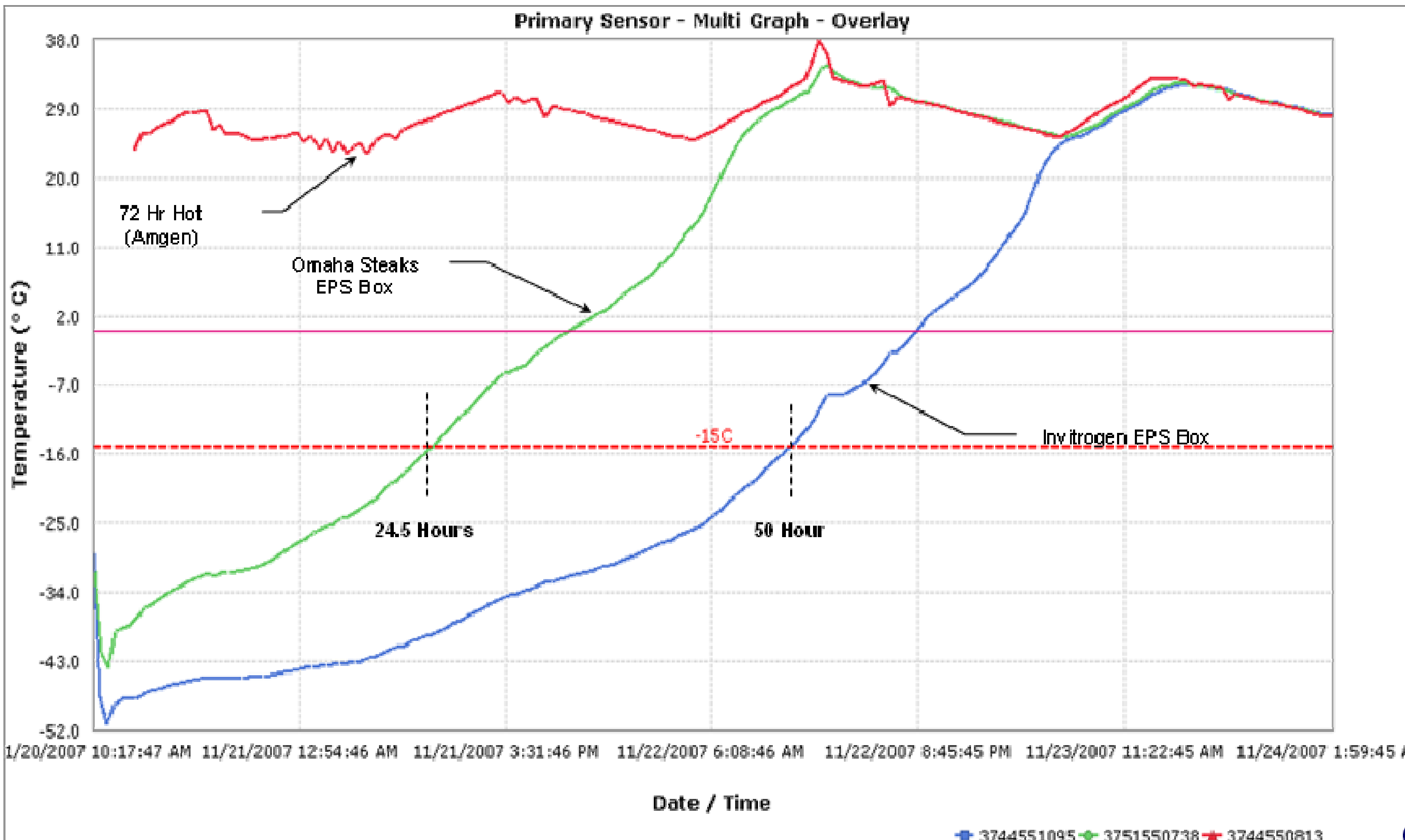
	Outside					Inside payload					wall	Hr	Hr	Hr	lowest
container	L	W	D	Cube	dim	L	W	D	Cube		thickness	below	below	below	temp
Omaha small	16	15	9	2160	11.13	12.3	11	4.75	625.5156	47%	1.5	27	21.5	24.5	-43
Invitrogen	15	12	12	2160	11.13	9.5	6.9	6.5	424.5313		2.375	52	47	50	-51
												93%	119%	104%	19%

Global Packaging

Omaha Steaks vs. Invitrogen EPS Box Characterization Results

- Dry Ice – 11.13 lbs, 11 lb dim boxes, airport slices
- Payload Qty 1 – 7016 Box, frozen
- Invitrogen – 2.5 in thick, Omaha – 1.5 in thick

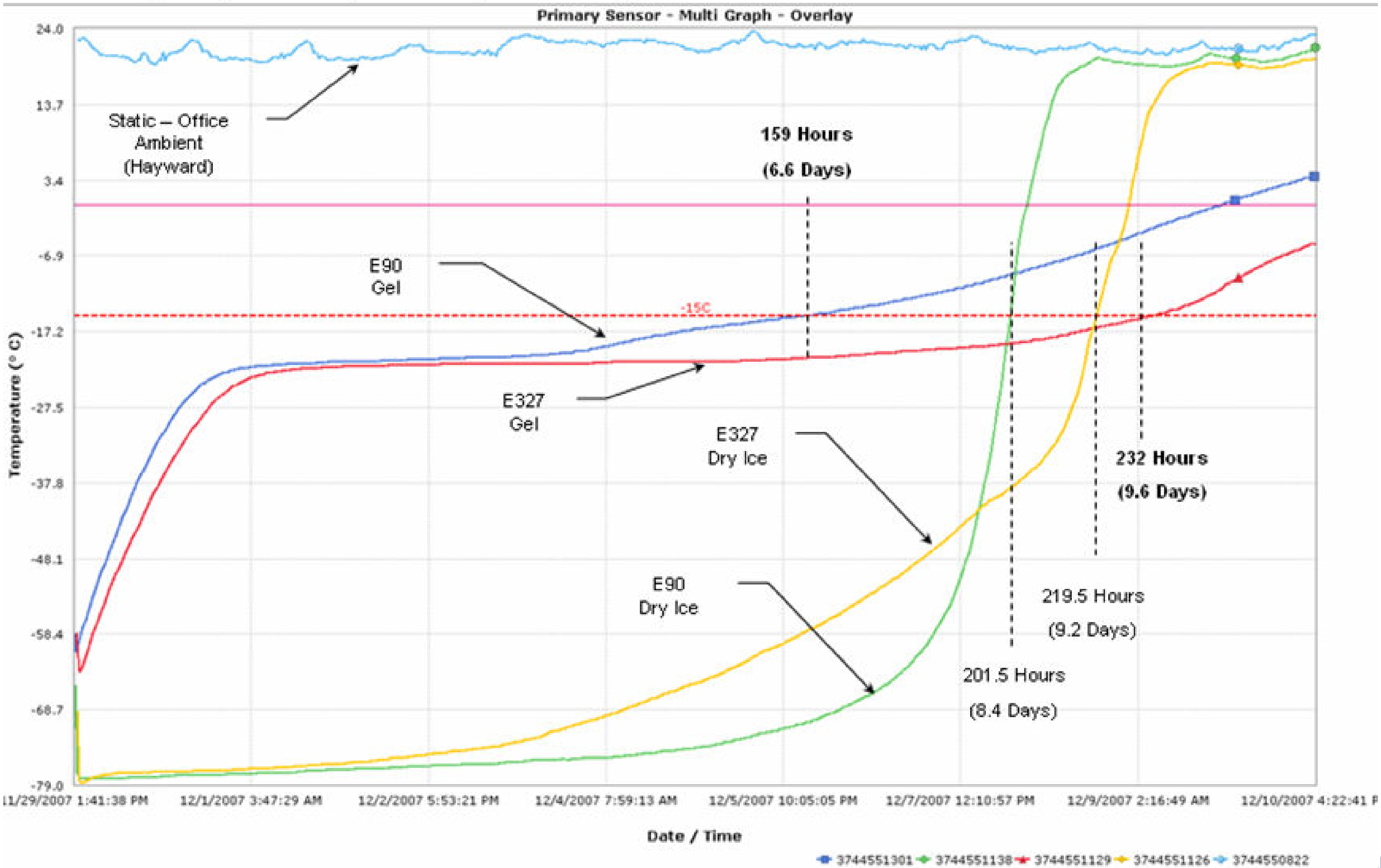
- Same outside DIM (11.134)
- One container had thinner walls and more payload space (47% more space)
- Same amount of coolant (7 lbs of dry ice)



-23 Phase Change Gel vs. equivalent amount of Dry Ice

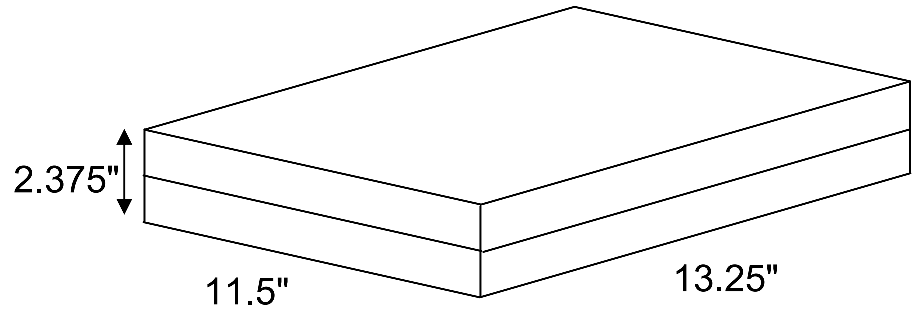
Dry Ice and -23°C Phase Change Gel Characterization Results

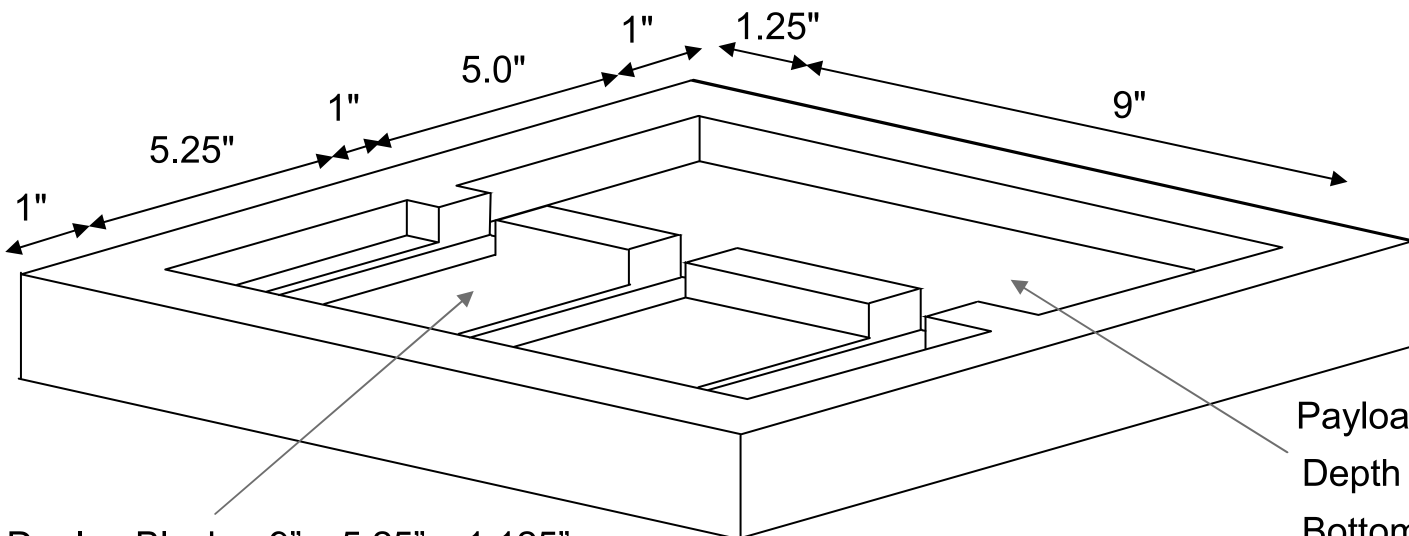
- Gels conditioned in -80˚C Freezer, equivalent amount of coolant by weight
- Payload Qty 1 – 7016 Box, frozen or refrigerated where applicable



Express Package Concept

Box – Medium (ID)
13.25" x 11.5" x 2.375"

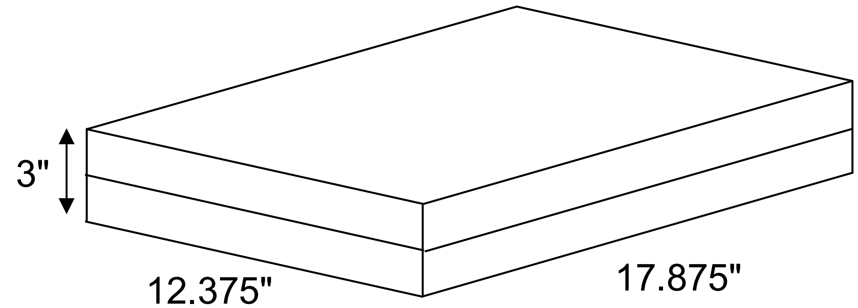


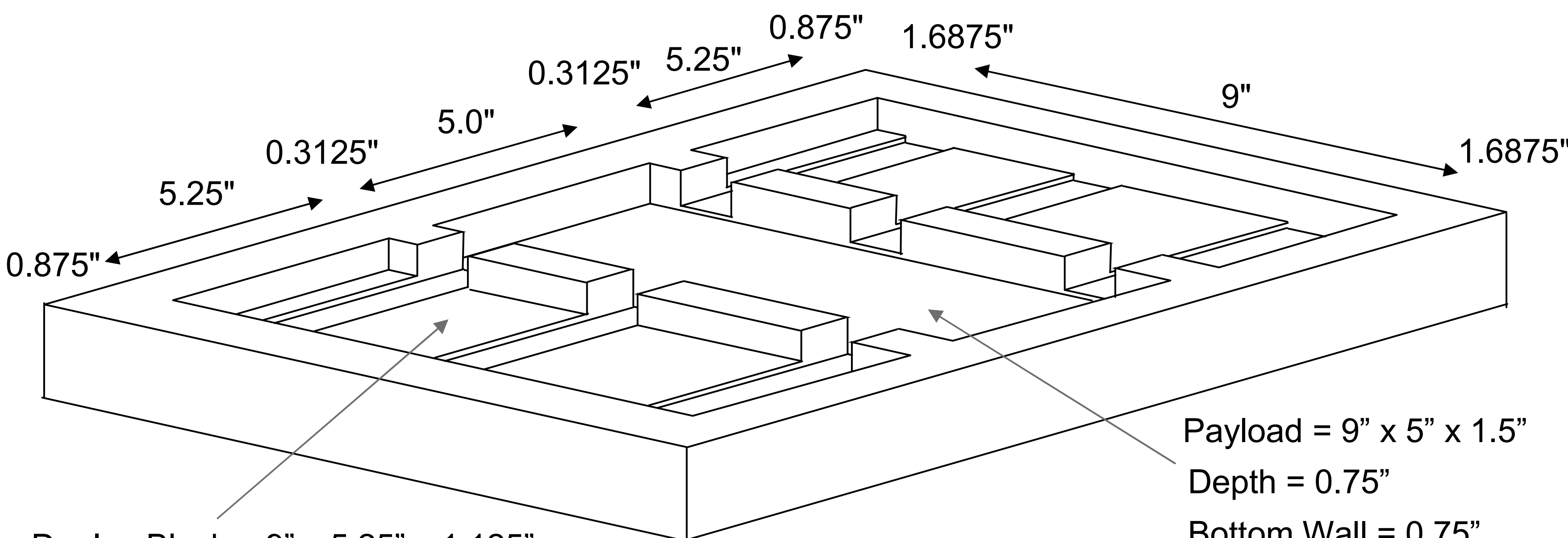


Dry Ice Block = 9" x 5.25" x 1.125"
Depth = 0.5625"
Channel .125"

Payload = 9" x 5" x 1.5"
Depth = 0.75"
Bottom Wall = 0.4375"

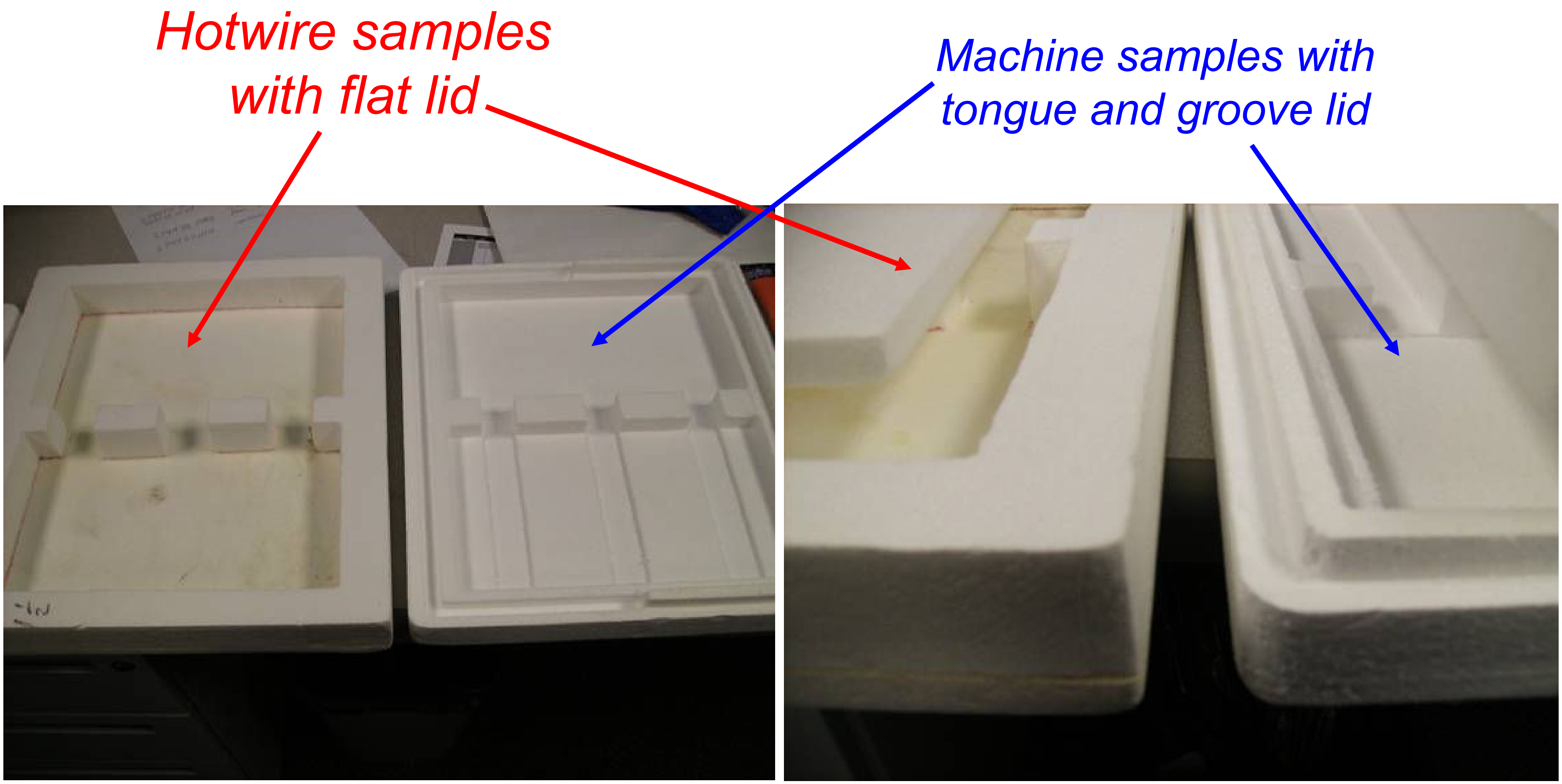
Box – Large (ID)
17.875" x 12.375" x 3"





Payload = 9” x 5” x 1.5”
Depth = 0.75”
Bottom Wall = 0.75”

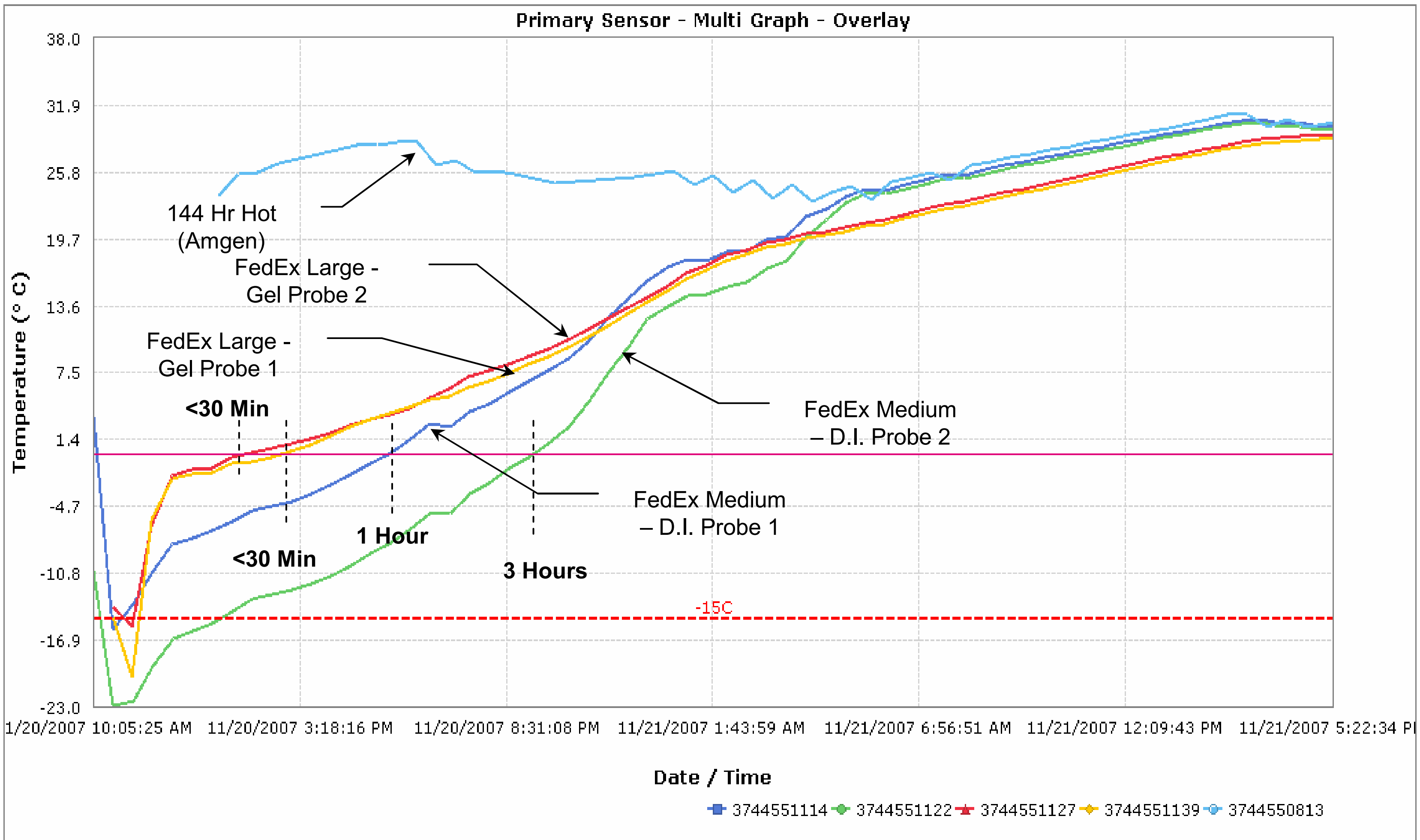
Dry Ice Block = 9” x 5.25” x 1.125”
Depth = 0.5625”
Channel .125”


Hotwire samples with flat lid
Machine samples with tongue and groove lid

Express Carrier Box Characterization Results

Hotwire samples with flat lid

- Gels conditioned in -80°C Freezer,
- Payload Qty 1 – 7016 Box, frozen or refrigerated where applicable
- Custom hot wired EPS box placed inside stock shipping mailer, thermal wrap, thickness of less than 1 inch, no lid closing features

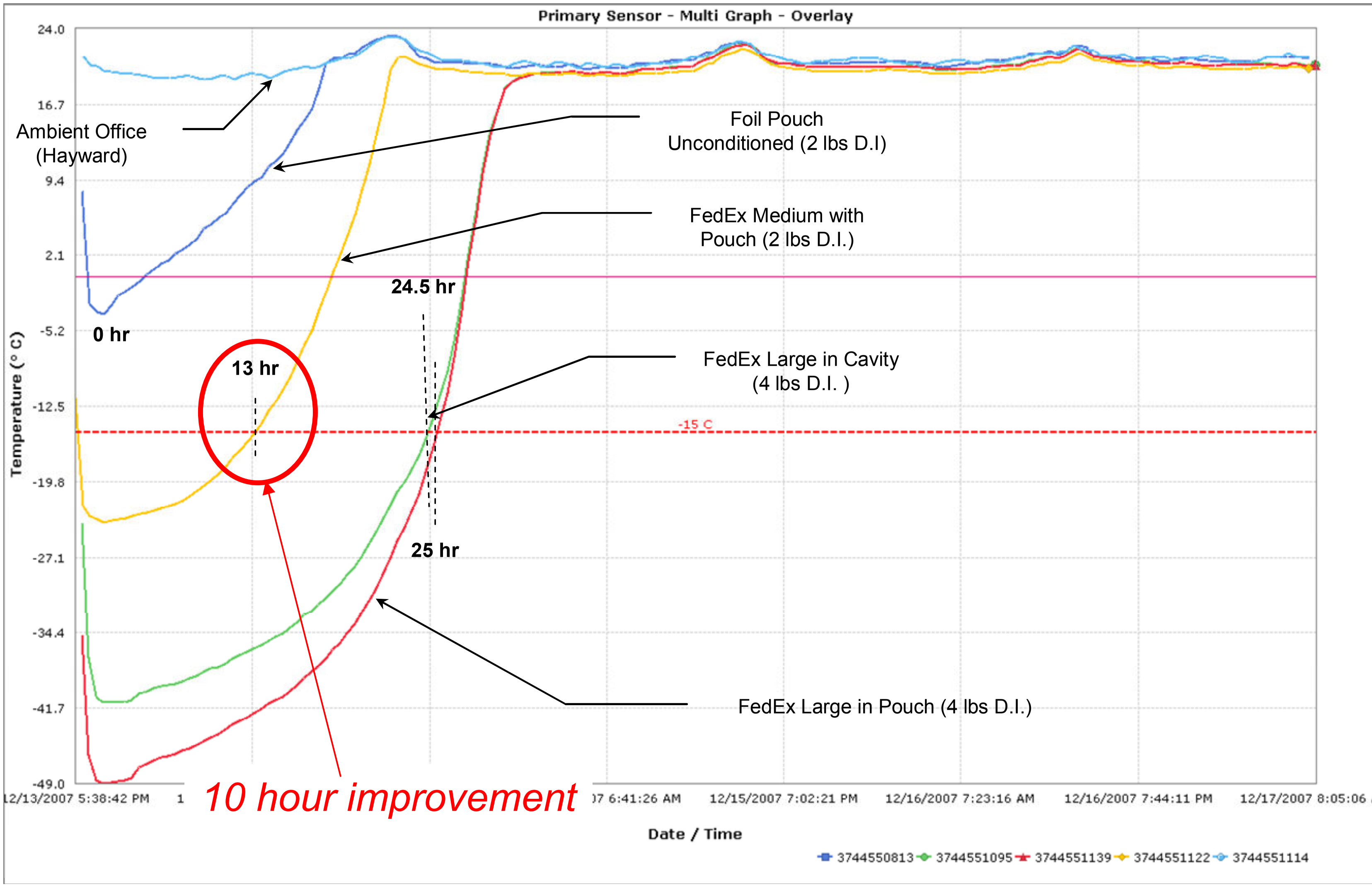


Foil Bubble Envelope added to the mix for fun

Express Carrier Box Dry Ice Characterization Results

Machine samples with tongue and groove lid

- Dry ice coolant
- Payload Qty 1 – 7016 Box, unconditioned
- Custom EPS box placed inside stock shipping mailer, EPS with tongue and groove closing features



Conclusion

- Where from here?
  - Encourage universities to conduct of research in identified areas
  - Motivate companies to share their research and findings
  - Publish all on a website to benefit the industry and help establish industry standards for common solutions
    - Starting share location www.talkpkg.com