Introduction & Highlights

Jean Clifford Brutus, PE, PMP

Project Manager

Brookhaven National Laboratory

Brookhaven National Laboratory

- Project Manager in the Collider Accelerator Department
- Bachelor Mechanical Engineer 2011 Stony Brook Universtiy
- Master’s Degree 2012 Stony Brook University
- +12 years experience
- Project Management Professional (PMP) certification – 2016
- Licensed New York State Professional Engineering (PE) - 2018

- Coupled electromagnetic, fluid, thermal & structural simulations
- Superconducting Radio Frequency Cavities (operating at 2K)
- Warm Radio Frequency Cavities
- Microwave structures (waveguide and coax)
- Beam instrumentations (beam dumps)
- Engineering design analyses, overall planning, scheduling and provide operational support.
- Support the RF group with Research and Development (R&D) work for the new Electron Ion Collider (EIC).

Introduction & Highlights

Richard Formato

Director of New Technology

Microtek Laboratories, Inc.

- Director of New Technology, CAVU Group
- BSME UMass/Amherst (1990); MEME WPI (1998)
- 30+ years of industry experience
- Experience Includes Thermal/Fluids Simulation, Materials R&D and Product Commercialization
- Developed and invented several diverse technology solutions (US Patents: 25 issued / 6 pending)

- ➢ Formulated and introduced liquid, gelled pcm product lines
- ➢ Method to simulate thermal packaging through the cold chain
- ➢ Capability to simulate phase change with free convection in enclosed spaces, including validation with experimental results
- ➢ Developed extensive material database comprising key thermal shipper components: insulation, polymers, metals and phase change materials
- ➢ Developed and introduced method to thermally characterize complex product loads
- ➢ Developed and introduced tool to compare shipper ambient temperature profiles
- ➢ Developing shape stable, radiation curable organic PCMs for use in thermal shippers
- ➢ Developing compostable, flexible refrigerants for use in thermal shippers

Introduction & Highlights

Alexis Dagenais Everell

Technical Lead- Thermal Management Engineer

The Lion Electric

Summary:

Mechanical Engineer and entrepreneur with interest in sustainable energy and enviromental issues.

Actual :

Lion Electric - lead the development of thermal management systems for trucks platforms and modifications to existing platforms. We are in the commercial transportation sector - buses and trucks.

Lion is a very dynamic and creative company. Focus on fast innovation application and hard problem solving.

Relevant experiences (11 years):

- Modeling, Design and construction of 10 Landfill biogas recovery system, collection networks (piping and civil engineering)
- Energy and Thermal modeling for LEED Buildings. Organization of energy simulations: 200k$ in financial support gain per project.
- Energetic and quantitative analysis of residual material within a 100 km radius (paper, cardboard, plastics, etc.) (2020) - Identification of a 178 kT/year potential of mainly CRD, having 2,570 TJ of calorific value
- Entrepreneur : Thermal sizing of a heat storage system and geothermal system. Reduction of power consumption by 50%.

THERMAL MANAGEMENT EXPO

WEDNESDAY AUGUST 31

SYSTEMS & DESIGN

Moderator

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The Lion Electric

1:00pm-2:00pm: Thermal Design 101: Assessing Approaches to Design in the Execution of Successful Thermal System Architecture

sli.do Join the discussion via:
www.slido.com eventcode: CEX22

Design Process: Temperature Controlled packaging

1. Define System Requirements
2. Identification of Thermal Physics
3. Material Thermal Properties, ICs and BCs
4. Design Process: Iterative Simulation / Prototype / Testing
5. Design Selection: Design Freeze

I. System Requirements:

- Minimum/Maximum Temperature Limits (material capability)
- Thermal Requirements: Temperature Criteria (of product), Duration, Ambient Profile and Product Load
- System Components / Materials (including compatibility)
- System Weight, Volume, Cost, single or multiple use expectations

II. Identification of Thermal Physics

- Conduction, Convection (free/forced), Radiation
- Phase Change, Chemical Reaction, Internal Energy Generation

III. Establish Material Thermal Properties, ICs and BCs

- Density, Specific heat and Thermal conductivity (the big three)
- Enthalpy (latent heat) and Tmelt / Tfreeze
- Thermal contact resistance and properties for radiative exchange (wavelength, absorption, transmission, reflection)
- Ambient Temperature (Profile), External convective heat transfer coefficient (HTC), Initial conditions [IC]
- Symmetric boundary conditions [BC], characterization of product load

Design Process: Temperature Controlled packaging

IV. Design Process: Iterative Simulation / Prototype / Testing

- Solid Model
- Apply symmetric BCs (1/4 model), thermal couplings, external Ambient Temperature Profile, external HTC, Initial conditions
- Discretize solid model (Mesh), Apply material properties, Configure Solvers
- Run Simulation and Iterate until design meets requirements
- Fabricate Prototype, Establish measurement method/locations, Select test equipment
- Execute test, compare simulation results with test

V. Design Selection: Design Freeze

- If test results agree with simulation results, model has been validated
- Team Design Review (manufacturing, logistics, supply chain)
- If Design approved, design is frozen
- Transfer to manufacturing begins

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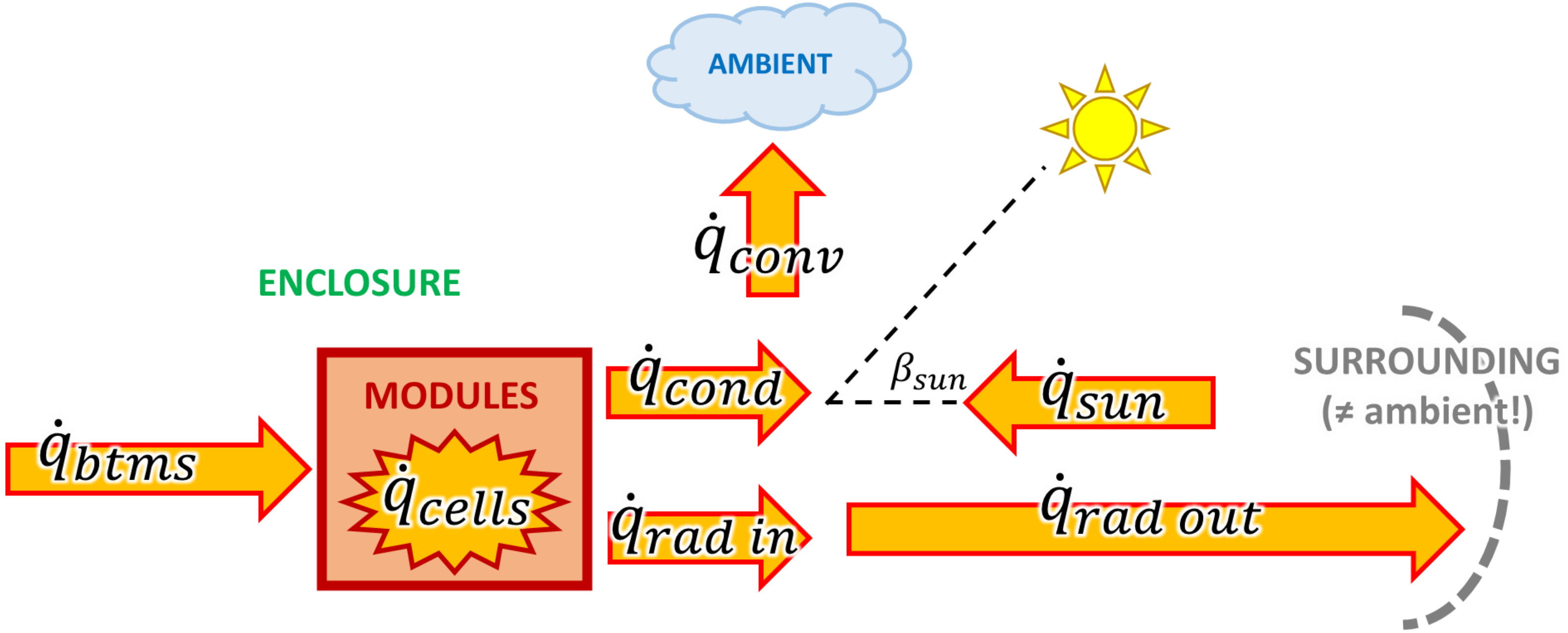
Find the heat transfer values



Focus on the simplest way to meet requirement (choose in order)

1. **Passive cooling :** Air cooled, insulation, reflection, etc

2. **Manage internal generation :** De-Rerating – Slowing process down or Using internal resistance of the battery -energy storage, Mostly Software

3. **Active measure :** Transfering energy, implies electrical or mecanical process

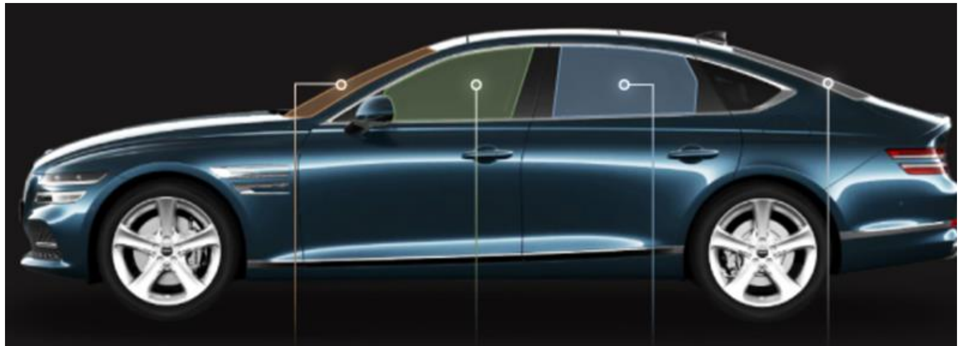
Design measures

- **Convection**
  - Ajust flow rate
  - Limit infiltration

- **Conductivity**
  - Increase heat exchange (changing conductivity or surface of exchange)
  - Reducing conductivity with insulation

- **Radiant heat**
  - Protection shielding or emitting surface

- **Latent heat**
  - Phase change material for batteries help reduce temperature swing
  - No autonomy gain



	Windshield	1st-row window	2nd-row window	Rear glass
UV blockage	97.0%	97.9%	97.8%	65.5%
Infrared light blockage	72.7%	59.0%	57.2%	51.3%
Visible light transmittance	74.4%	71.8%	75.4%	73.3%

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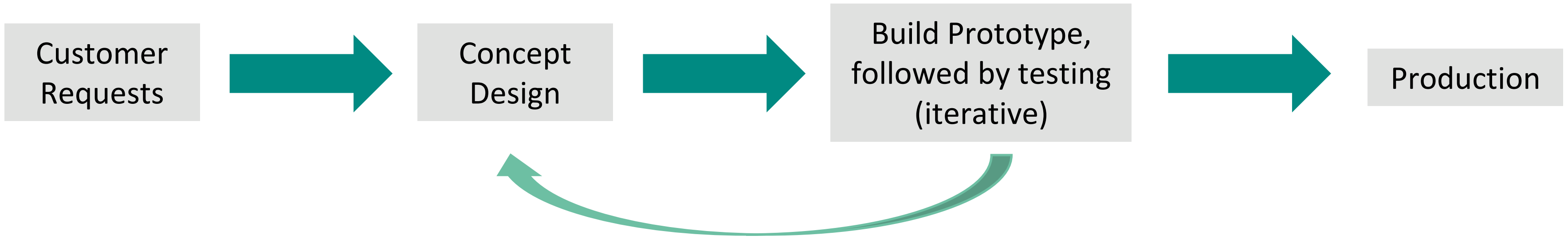
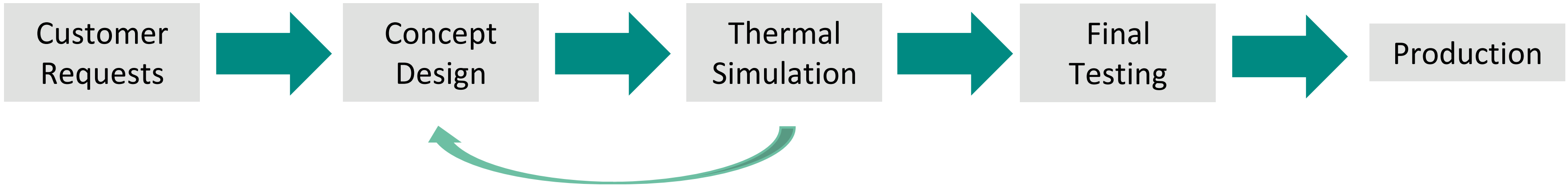
Simulation Speeds Development & Reduces Testing Costs

Without Simulation:



A single <u>build/test iteration</u> typically takes <u>weeks or months</u>

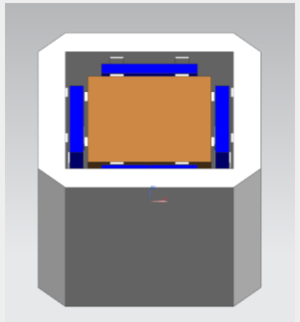
With Simulation:



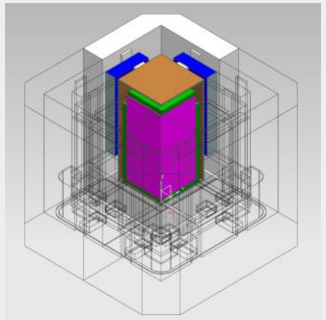
A single <u>simulation iteration</u> typically takes <u>hours or days</u>

Development of Process to Simulate Temperature Controlled Packaging

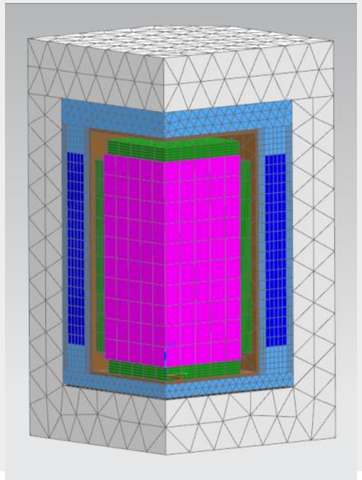
STEP 1:
Create Solid Model



STEP 2:
Apply Symmetry

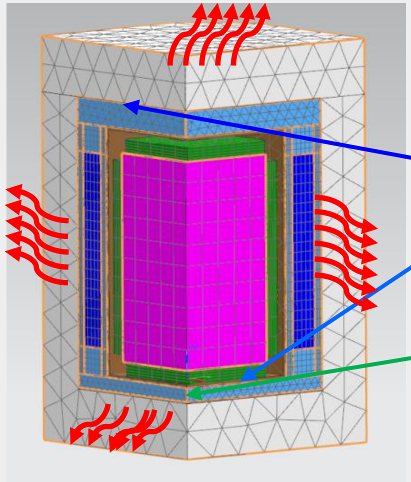


STEP 3:
Create Finite Element Mesh



STEP 4:
Formulate a Thermal/Flow Problem

Convection to the Ambient



Symmetry condition

Thermal-Coupling between touching (solid) surfaces

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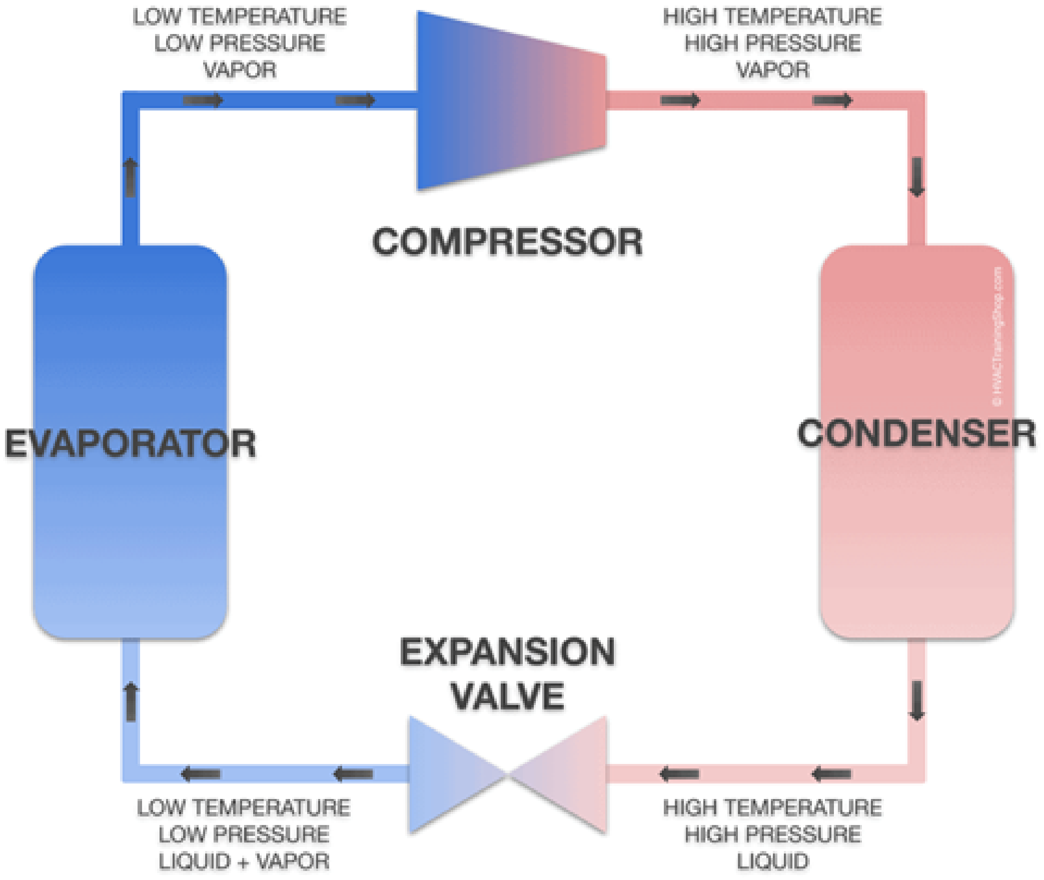
Select cooling system options to fit the needs

- Refrigeration loop

OR

- Cooling loop – Coolant (phase change or not)
- Fan and/or pump
- High Delta T - needed with ambiant temp



Responding to different Heat-Transfer fluid criterias

- What is available in your system and your surroundings (water, air, space,)
- Environmental and Security issues
  - Ammonia is risky
  - Hydrocarbon refrigerant are phase out (Ozone and GHG issues)
- Price
- Pressure, enthalpy and COP
- Temperature range

- Examples:
  - Batterie system use an array of fluids : Air, Water, Refrigerant
  - Spaceship mostly use radiant heat and Rocket use propellant for cooling fluid
  - High temps phase change salt in Nuclear Power

Pros and Cons of Tailored options

Pros

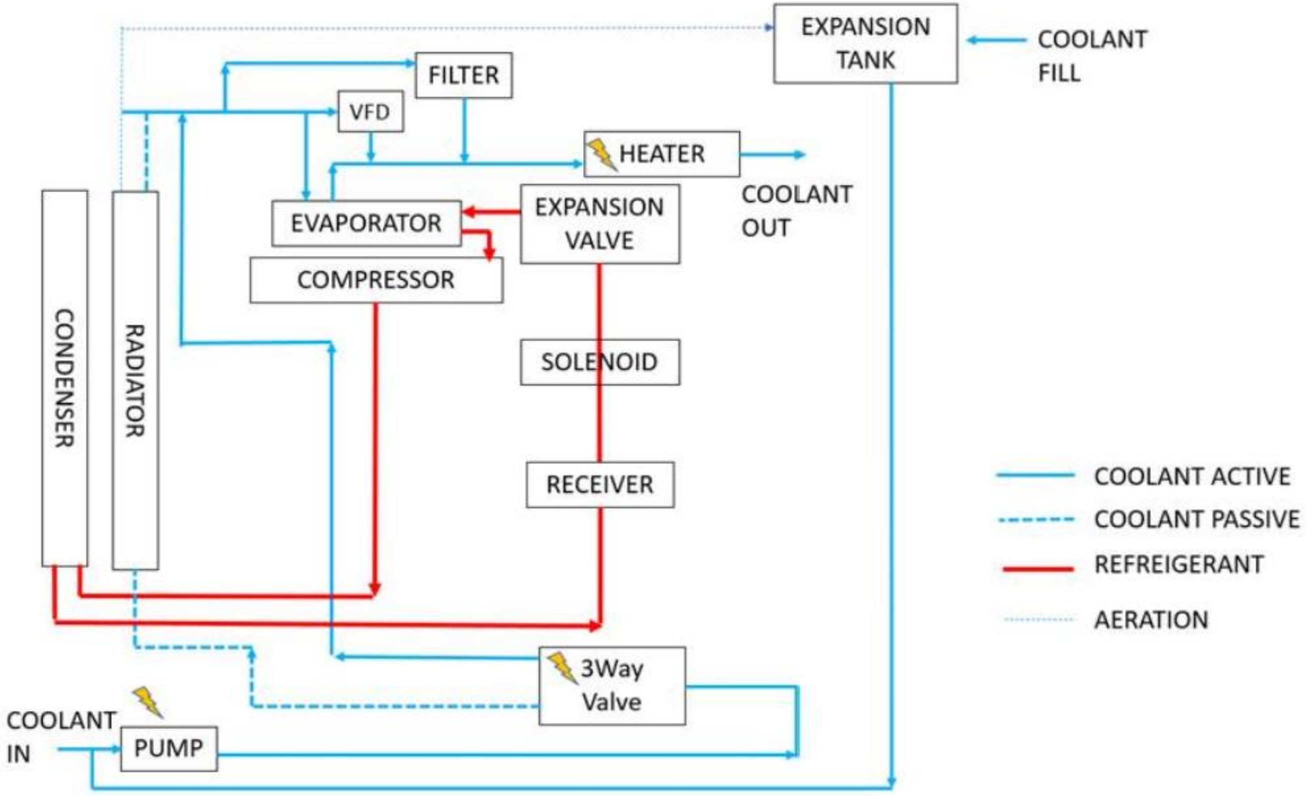
- Power + Efficiency – Improved performance
- Lowering Refrigerant Quantity
- Reusing part - Fan for Radiator and Condenser

Cons

- Complexity
- Weight

Improvement possible:

- Heat pump loop for heating efficiency
- Low side/High side heat exchange for higher efficiency with 1234y



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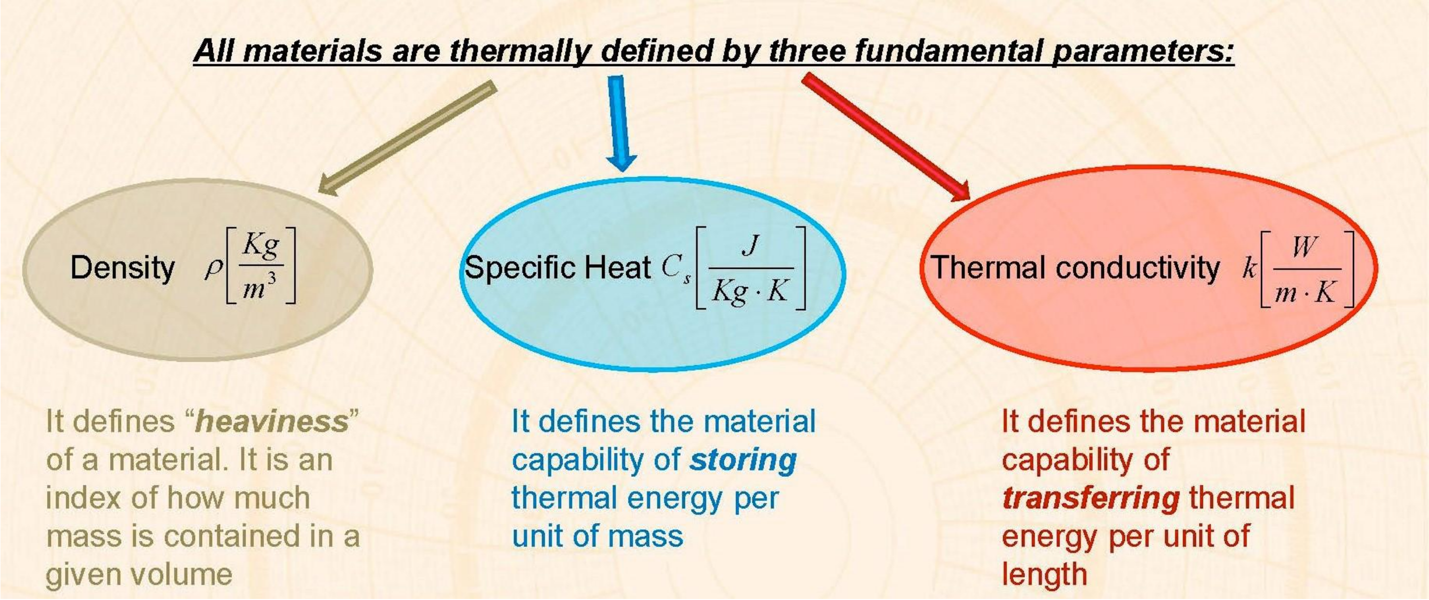
Key Thermal Material Properties: Example, how characterize product load

- Key material properties for simulation of transient thermal behavior: **Density (ρ), Specific Heat (c_s) and Thermal Conductivity (k).**



- In theory, this sounds simple, but in practice the full gamut of product loads is encountered:

- Large containers tightly packed, fully filled with drug (gelatinous pills).
- Many tightly packed, small vials filled with liquid vaccine or
- Small number of loosely packed, syringes, pre-filled with 0.5ml of vaccine.

- Experience indicates volumetric heat capacity shows good modeling results:

$$VHC = \rho \cdot C_S = \left[\frac{J}{m^3 \cdot K}\right]$$

Key Thermal Material Properties: Example, how characterize product load

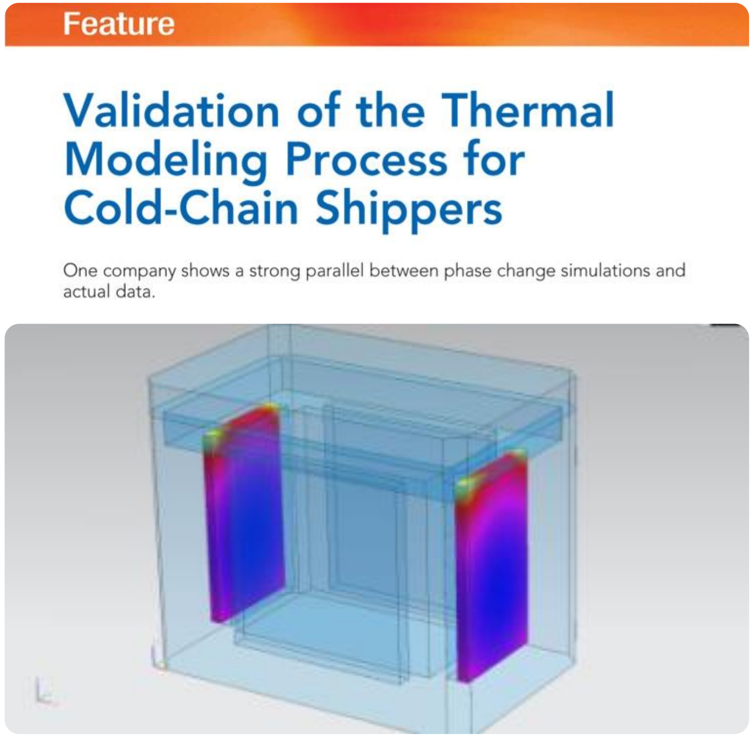
A question comes up, on how to best thermally characterize the product loads, since they can have:
- Many small intricate components made from many different materials (not practical to simulate)
- Very different amounts of internal space (e.g. very different air volumes)

VHC > 15 — Decreasing VHC → VHC < 2

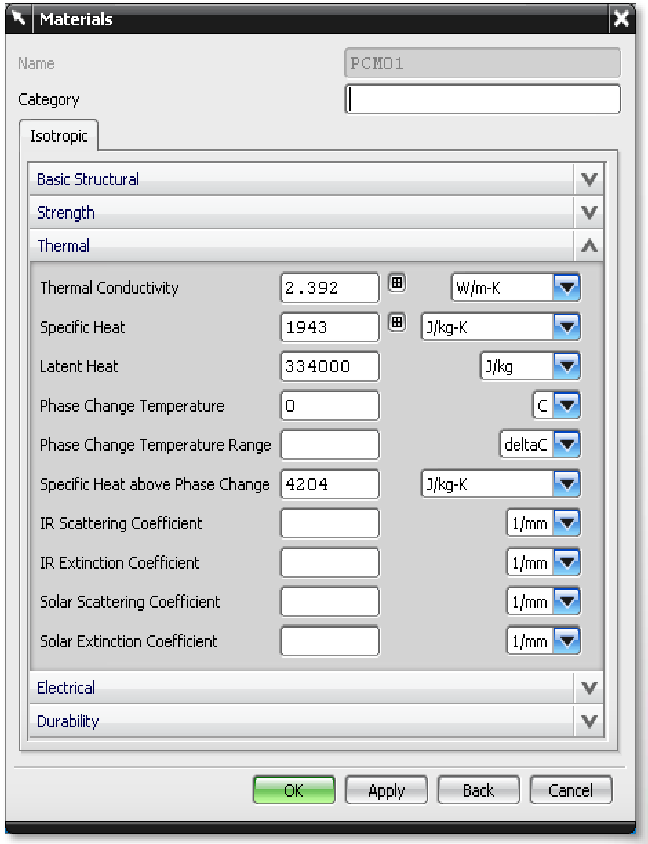
Developed method to thermally characterize complex product loads (e.g. RHS, above) such that small intricate components do not have to be solid modeled for simulation purposes, but instead can be represented by a **single isotropic (homogeneous) solid body, with constant VHC**.

Validation of Phase Change

- PCMs provide stable product temperatures
- Precise simulation of PCM physics is essential towards obtaining accurate product temperatures
- Latent heat of refrigerant effectively extends cooling duration
- Simulation models phase change effects accurately and efficiently
    - Already validated with test results (Ref. R. Formato publication)



PharmaBio Transport Supplement, Winter 2009



Thermal Management Challenge in EV

3 main systems function on trucks.

- Heating, air conditioning and ventilation (HVAC) of Cabin
  - Affect autonomy in cold climate
  - Client knowledge
- BTMS – Heating and cooling
  - Extreme temperature Pull up and Pull down are the limitation
  - Dictated by batteries suppliers
- HV cooling loop (motor, drive, rectifier/inverter, DCDC, etc.)
  - Variability of component needs – power, operating temperature, and pressure.
  - Routing difficult
- Other general issue
  - Not a priority system – No security issue unless Defrost
  - New market – Supplier ramp up and tendencies to oversize
  - Software Complexity
  - Still R&D phase for constructors

Cold Climate Challenge

- Generally Low efficiency - Thermal management system loads can reduce the drive range by as much as 45% under ambient temperatures below −10 °C. Often, cabin heating relies purely on positive temperature coefficient (PTC) resistive heating, contributing to a significant range loss

- Quebec minus –25degC for on hour

o Between 5kWh for heat

o Total 30 kWh – CSHVC – with regen

- Suppliers are not familiar with cold temp for EV