A High-Performance PHEV Battery Pack

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LG Chem Power / LG Chem

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Project ID: ES002

LG Chem Power, Inc. (LGCPI)

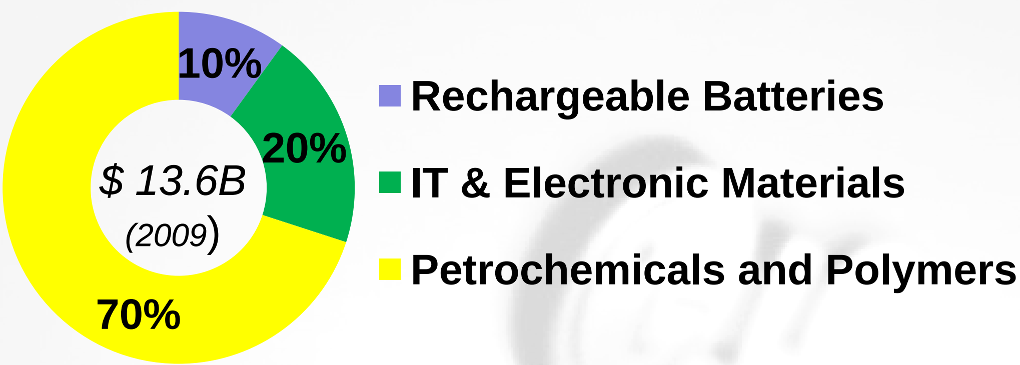
- A wholly-owned subsidiary of LG Chem, based in Troy, MI.
- Established in Colorado as Compact Power in 2000 to focus on large-format batteries.
- Battery Pack Concepts, Designs and Prototype Builds
- Battery Management Systems
- Sales and Customer Support
- Reorganized as LGCPI to separate itself from LG Chem Michigan (LGCMI), the cell manufacturing plant in Holland, MI.

LG Chem Introduction

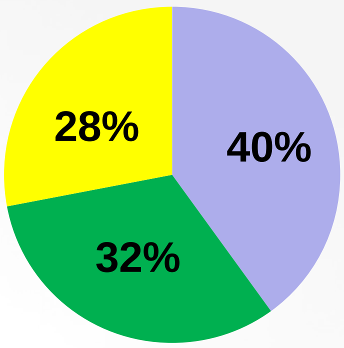
History

- 1947 Lucky Chemical Industrial Corp. founded
- 1995 Lucky Chemical becomes LG Chem

Revenue



R&D Expense Portfolio

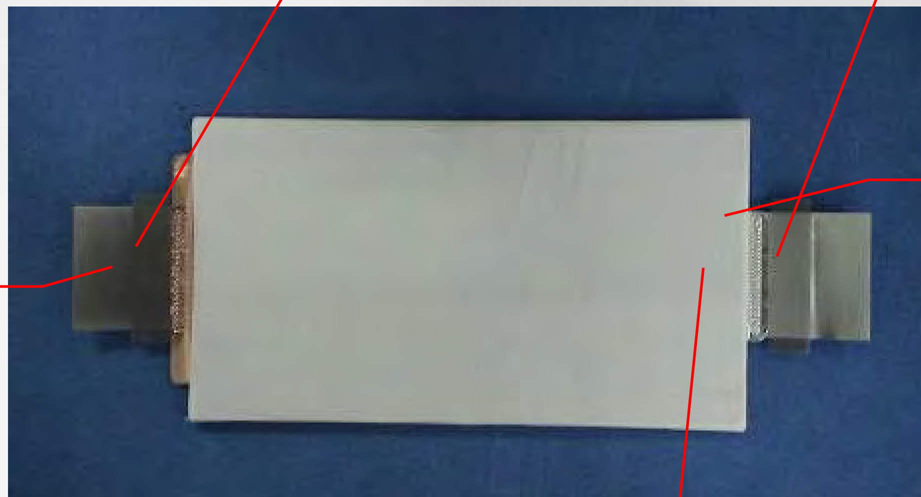


- **Revenue & Workforce in 2009 – 13.6 Billion US$ / 13,000 employees**

Cell Structure: Unique Stack- and-Fold Design

Stacking of Plates & Folding

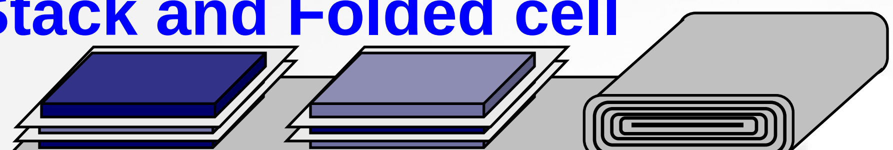
Lead film (insulation tape)



Positive terminal

Negative terminal

Stack and Folded cell



Bi-cell

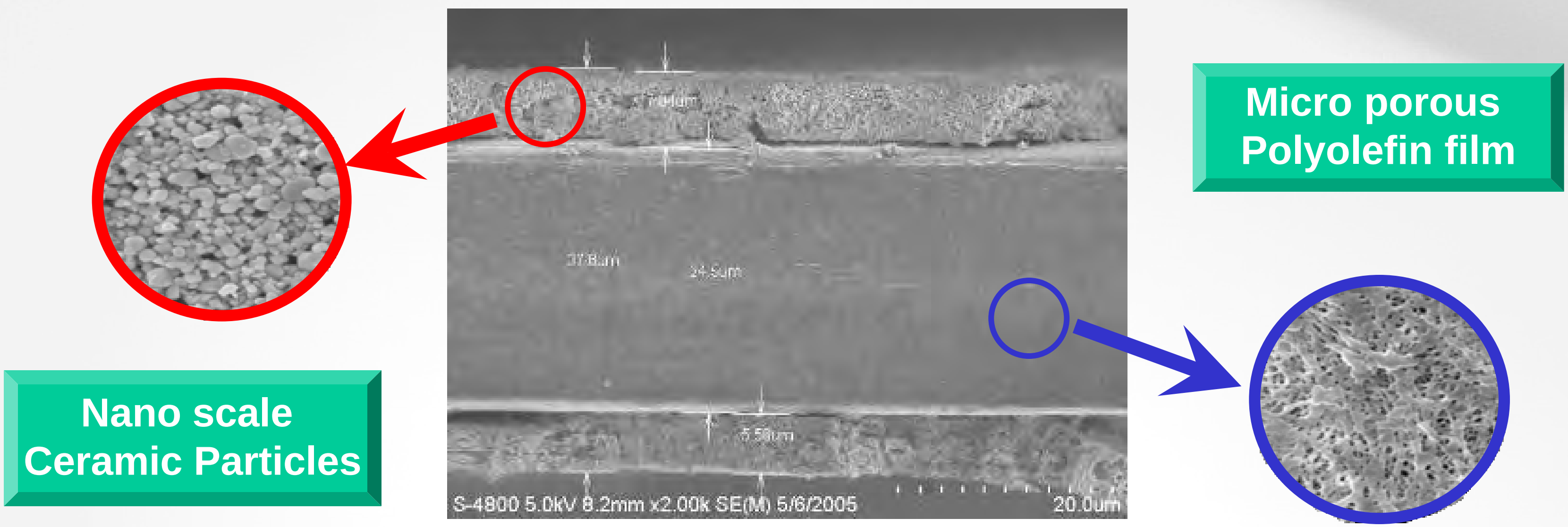
SRSTM

Laminated film

Proprietary Safety Reinforcing Separator (SRS^{TM})

SRSTM provides superior abuse-tolerance

- **By improved mechanical and thermal stability**
- **By preventing internal short circuit**
- **By providing lower shrinkage**



- **Has significantly higher puncture strength than conventional separator**

Highlights of Past HEV Program

Timeline

- Project Start: Sep 1, 2006
- Project End: Feb 29, 2008

Budget

- Total project funding: $6.3M

Barriers addressed

- Cycle-life
- Calendar-life
- Cold-Cranking Power

Cell/ Approach

- Spinel/Hard-Carbon
- Approaches used: coatings, dopants, use of electrolyte additives

Key Results

- Cycle-life improved significantly: > 550k cycles
- Calendar-life: > 10 yrs
- Excellent abuse-tolerance

Overview of Last PHEV Program

Timeline

- Project Start: Jan 1, 2008
- Project End: March 31, 2010
- Percent complete: 100

Budget

- Total project funding: $12.7M
  - DOE share: $4.45M
  - Contractor share: $8.25M
- Funding received in FY09
  - $2.5M
- Funding for FY10
  - $0.4M

Barriers Addressed

- Cycle-life
- Calendar-life
- Cold-Cranking Power
- Efficient/reliable thermal management system

Partners

- LG Chem, INL, SNL, NREL
- Project lead: LGCPI

Objective

Objective:

Develop a PHEV 10 mile battery pack system that will meet the life and cost targets of USABC.

Tasks:

- **To develop a cell that is capable of delivering 5000 cycle-life and 15 yr life.**
- **Develop and deliver a pack that has a reliable and highly efficient thermal management system**

Basic Design: Large- format cells

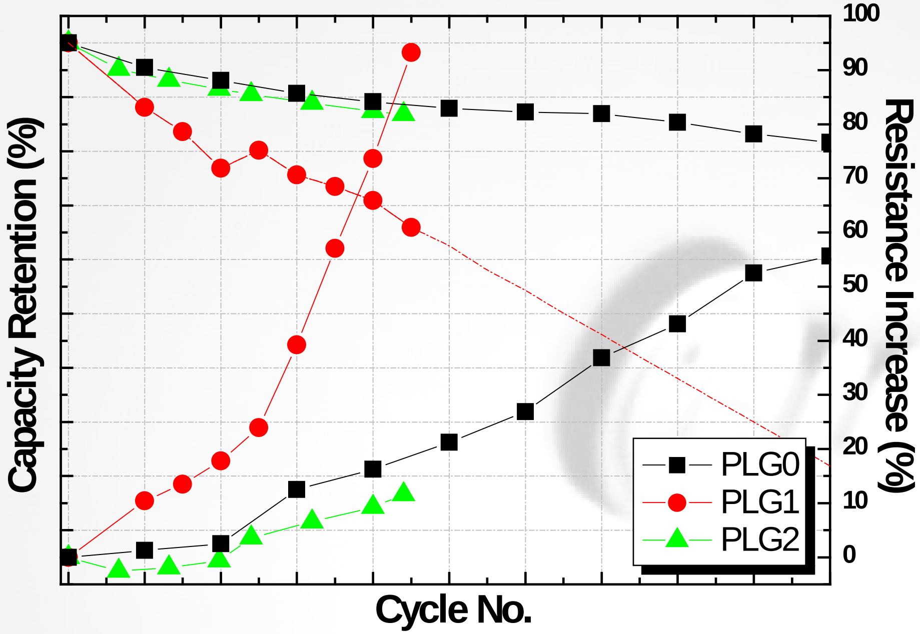
Components	Materials
Cathode	Mn-Spinel/layered mixed cathode
Anode	Graphite/Amorphous-carbon
Separator	SRS™
Electrolyte	$LiPF_6$ in Organic solvents (Gel type)
Packaging	Laminated

Cell Versions Tested

Component		PLG0	PLG1	PLG2
Cathode		$LiMn_2O_4$/layered	$LiMn_2O_4$/layered	Same as PLG1
Anode		Graphite	Graphite/Amorphous carbon	Same as PLG1
Electrolyte			• New solvent/additive compositions	Same as PLG0
Feature	Cold-cranking Power	• Does not meet at EoL	• Higher cold-cranking power than PLG0.	Similar power to PLG1
	Calendar life	• Poor	• Significantly better than PLG1	Significantly better than PLG1
	Cycle life	• Meets target	• Does not meet target	Expected to meet target

Cycle-life

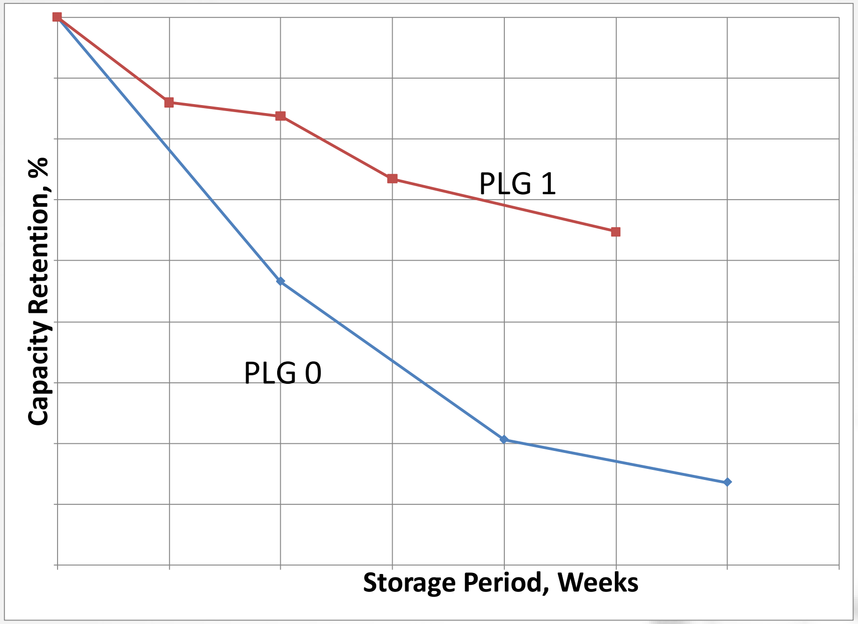
- Anode and electrolyte compositions were varied to improve cycle-life.
- PLG2 cells showed much better life than PLG0 and PLG1, and can meet USABC life-target.

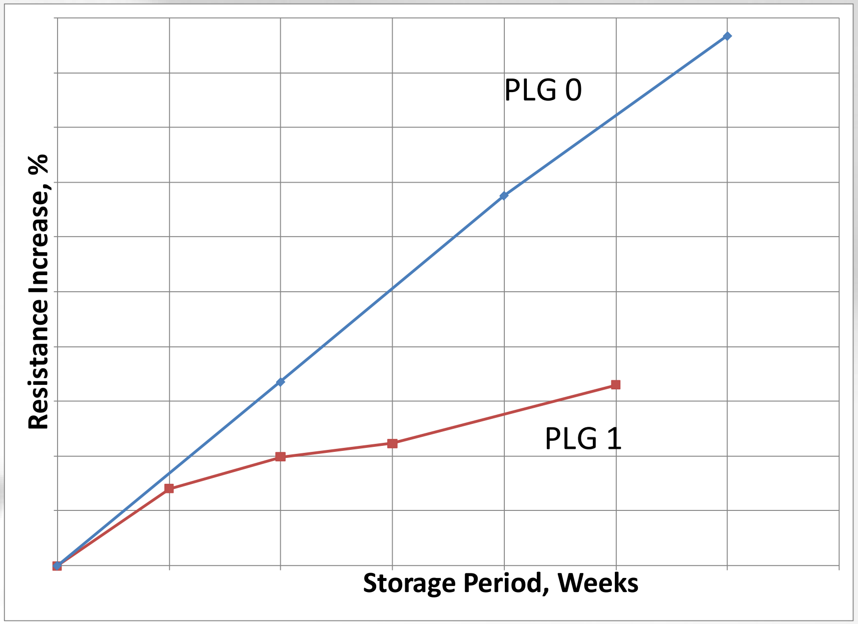


- CD Mode cycling
- 30^0C

Calendar-life

Accelerated Test: 60°C, 90% SOC

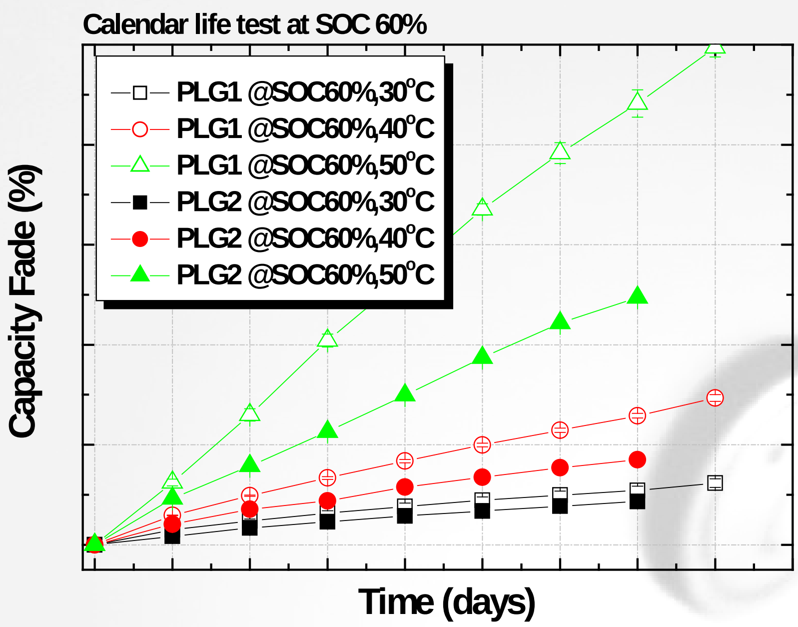


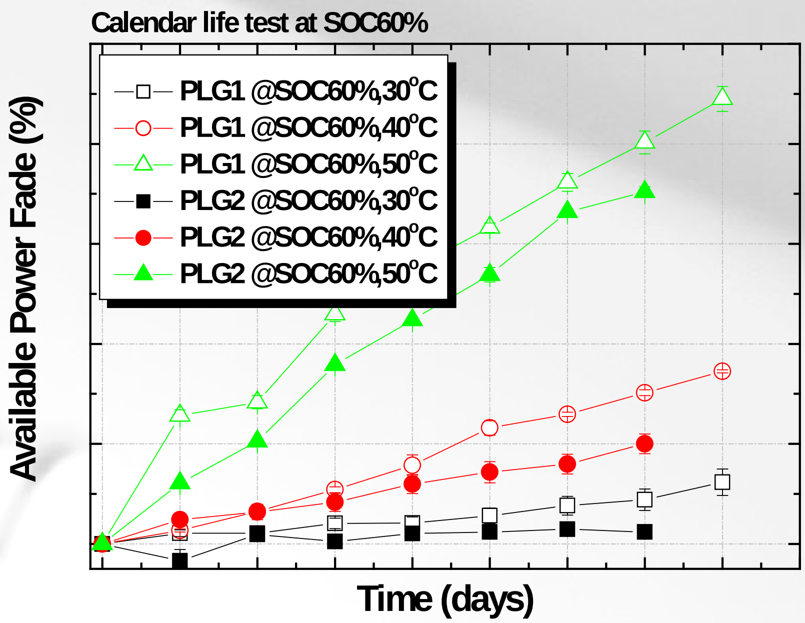


PLG0 and PLG1

Calendar-life

30, 40 and 50ºC





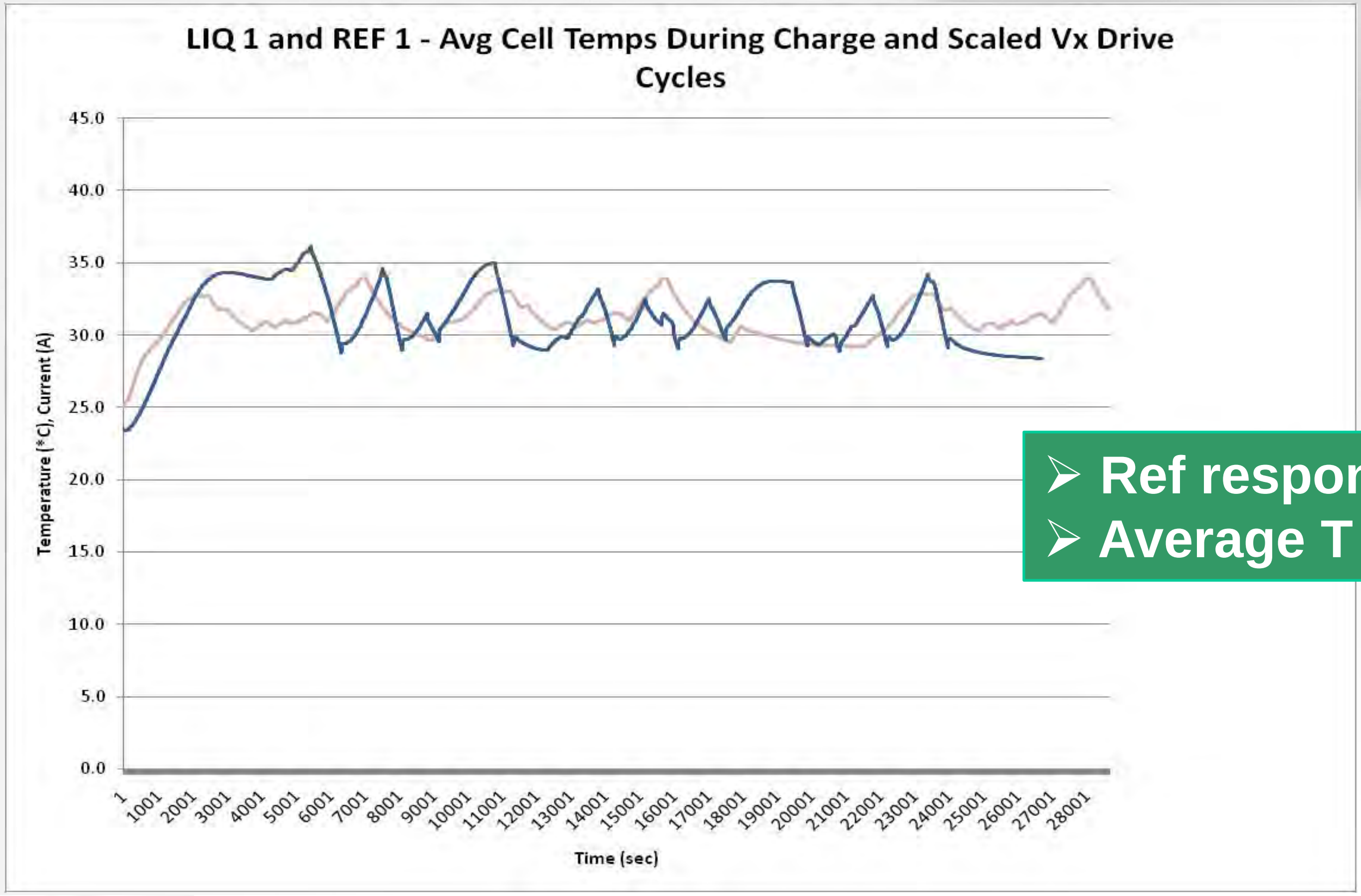
PLG1 and PLG2

Thermal Management: Refrigerant Cooling

- A refrigerant loop is used to cool the air within the battery pack, which is then slowly circulated around the cells.
- The large temperature gradient between the air and the cells facilitates efficient heat transfer without the need for high velocity air circulation.
- An option for certain conditions
  - High environmental heat loads, cabin air not readily available and allows zonal control.
- Requires refrigerant loop; but:
  - Avoids coolant fill and maintenance, obviates need for complex coolant manifolding and risks of leaking.
- Challenges include balancing of chilled air flow around the cells.

Refrigerant-to-Air vs Liquid Cooling

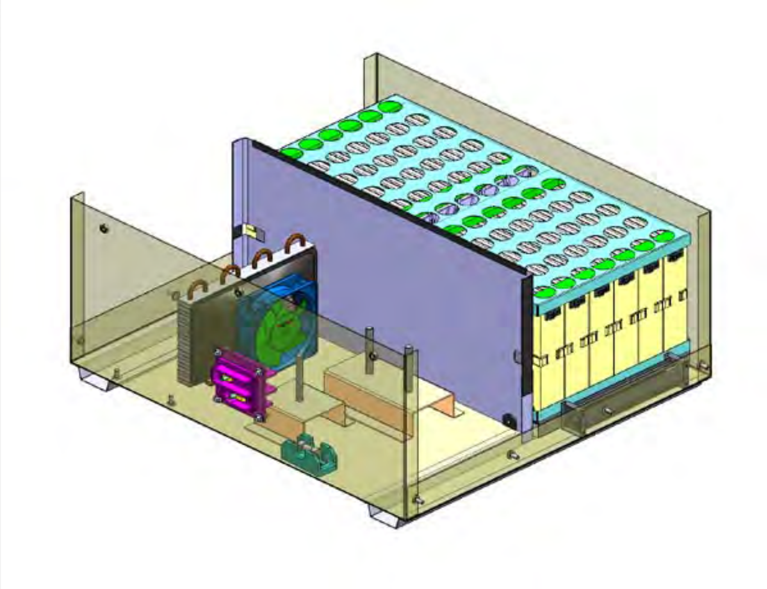
- **Initial development work**
- **Test article: surrogate pack**
- **Drive profile: proprietary**

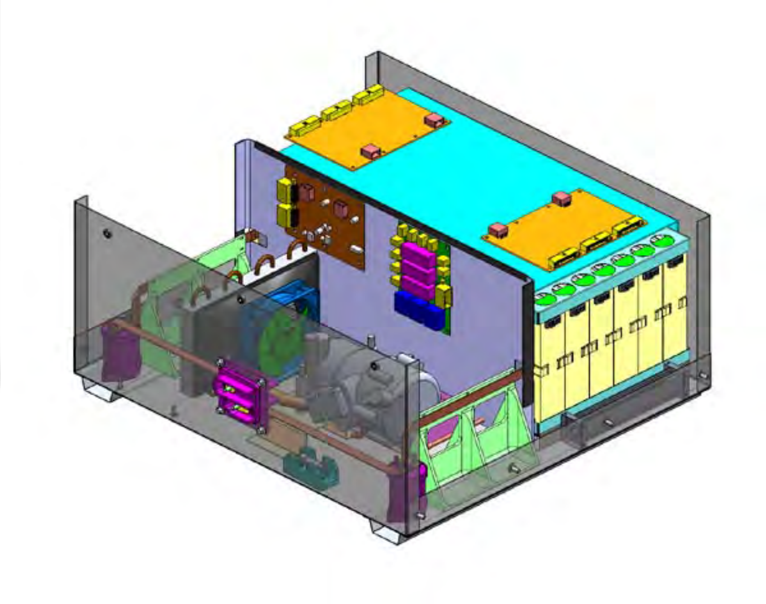


- **Ref responds faster**
- **Average T similar**

Refrigerant-to-Air Cooling

- Prototype system design
- Two thermal zones:
  - Refrigerated compartment (cells, evaporator, fan)
  - Ambient compartment (controls, compressor, condenser, fan)





Refrigerant-to-Air Cooling

Picture of a Pack delivered to USABC

Overview of Current Program

Timeline

- Project Start: April 1, 2011
- Project End: March 31, 2013
- Percent complete: 0

Budget

- Total project funding: $9.6M
- DOE share: $4.8M
- Contractor share: $4.8M
- Funding for FY11: $3.2M

Barriers

- Specific Energy and Power
- Cycle- and Calendar-life
- Cell Cost goal of <$200/kWh
- Efficient Refrigerant-to-Air cooling system

Partners

- LG Chem, INL, SNL, NREL
- Project lead: LGCPI

Objective

Objective:

Develop a PHEV 40 mile battery pack system that will meet the performance and life targets of USABC. A cell level cost target of <$200/kWh is also an important goal.

Tasks:

- **To develop a cell that is capable of delivering 5000 cycle-life and 10 yr life.**
- **Develop and deliver a pack that has a robust and highly efficient Refrigerant-to-Air cooling system**

Tasks

- Develop a cell suitable for use PHEV-40 Mile program using next generation high capacity cathode materials.
- Optimize the Refrigerant-to-Air cooling system we have developed in our previous program with respect to mass, volume, cost and power demand.
- Deliver cells and battery packs to USABC for testing.

Use of LGC's Cells

OEM	Vehicle	Cell
GM	Chevy Volt	PHEV
Ford	Focus BEV	PHEV
Hyundai	Sonata Hybrid	HEV

- **These cells benefitted directly from the USABC development programs described in this review.**

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