



# DELPHI

## Integrated Air Conditioning Evaporator with Phase Change Material for Thermal Storage

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# Outline

- **Power Train Trends and Climate Control Needs**
- **Objectives and Application of Thermal Storage**
- **Thermal Storage Thermosiphon Application**
- **Test Procedures and Results**
- **Conclusions**

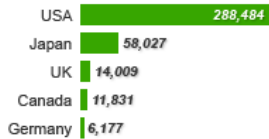
# Global Hybrid Vehicle Sales Growth

## 2007 Global Hybrid Vehicle Registrations

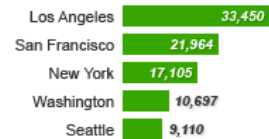
2007 global hybrid registrations



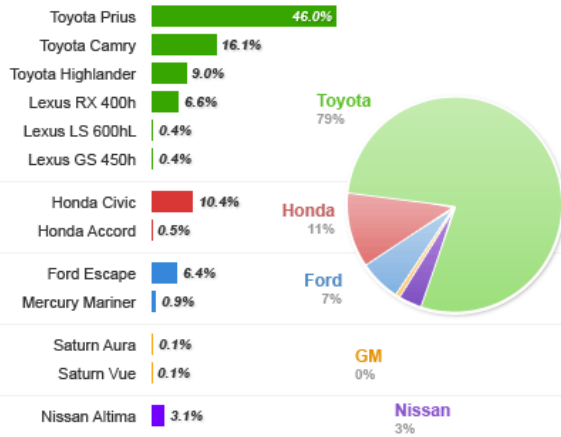
Top 5 global hybrid markets



Top 5 US hybrid markets



SOURCE: R. L. POLK & CO.

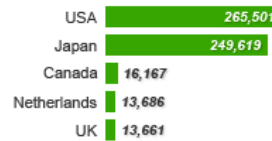


## 2009 Global Hybrid Vehicle Registrations

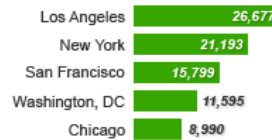
2009 global hybrid registrations



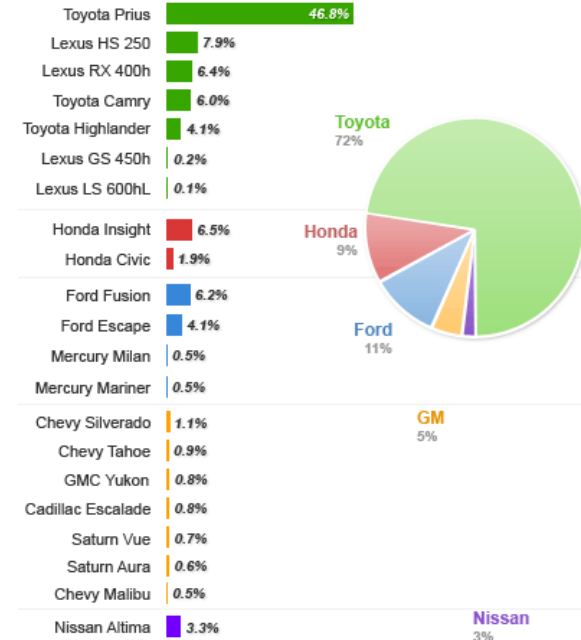
Top 5 global hybrid markets



Top 5 US hybrid markets



SOURCE: R. L. POLK & CO.



Source: Hybridcars.com

Global HEV Sales have increased >30% since 2007

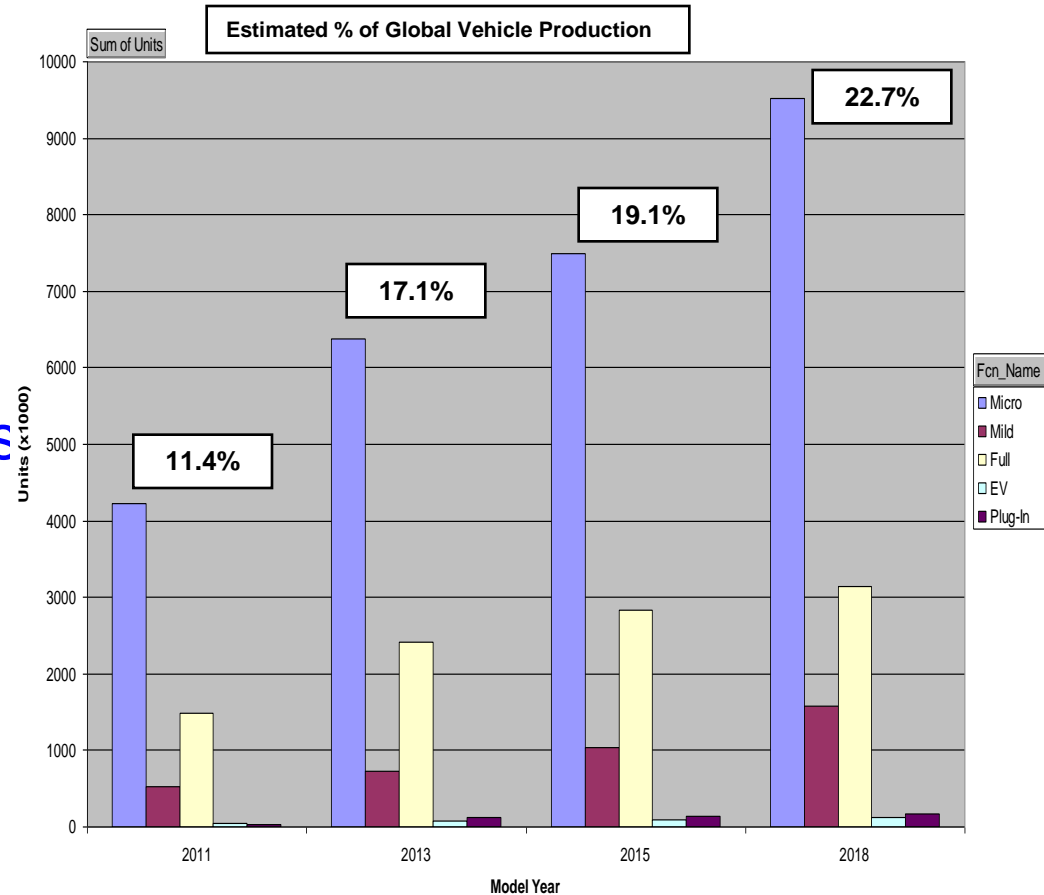
# Alternate Propulsion Vehicles

November 2009 update – Data Source “Global Insight”

## Summary of Alternate Propulsion Vehicles

- HEVs assist in meeting fuel economy & emissions regulatory targets
- HEVs / EVs offer access to another energy source – electricity
- Electrification of the powertrain occurs at many power/complexity levels

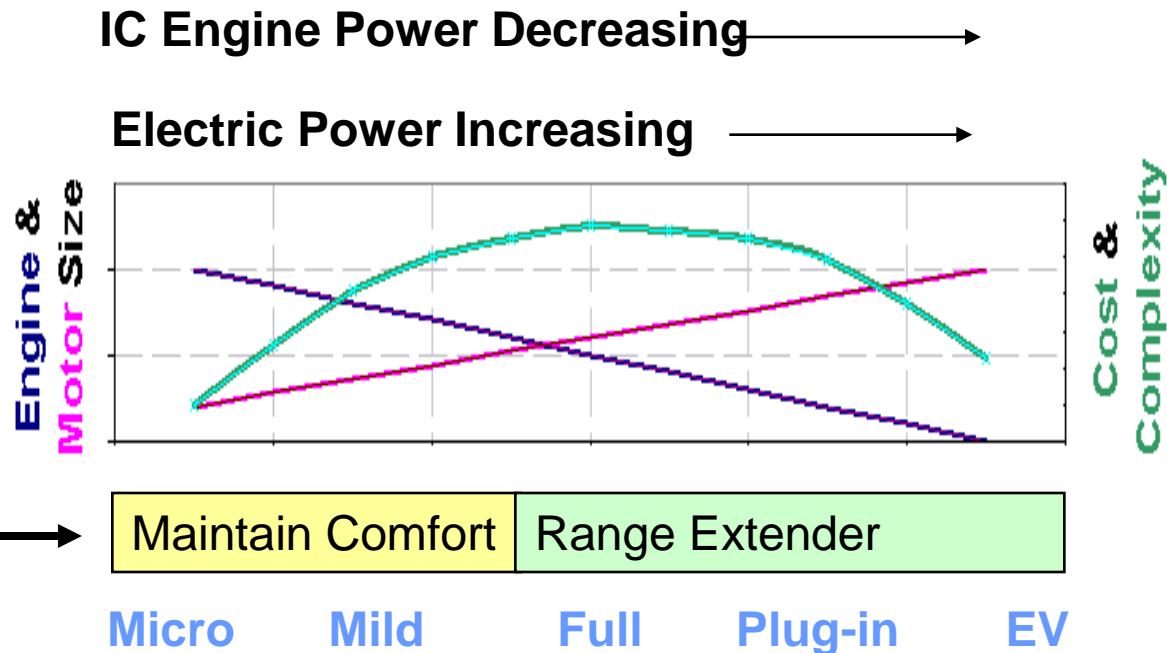
HEV Market Size - Total Global By HEV Type  
Nov 2009 Data



# Thermal Storage and Power Train

## Thermal Storage (TS) benefits:

- Ability to maintain comfort in Micro and Mild Hybrids during vehicle-off times
- Ability to extend vehicle range for full hybrids and electric vehicles



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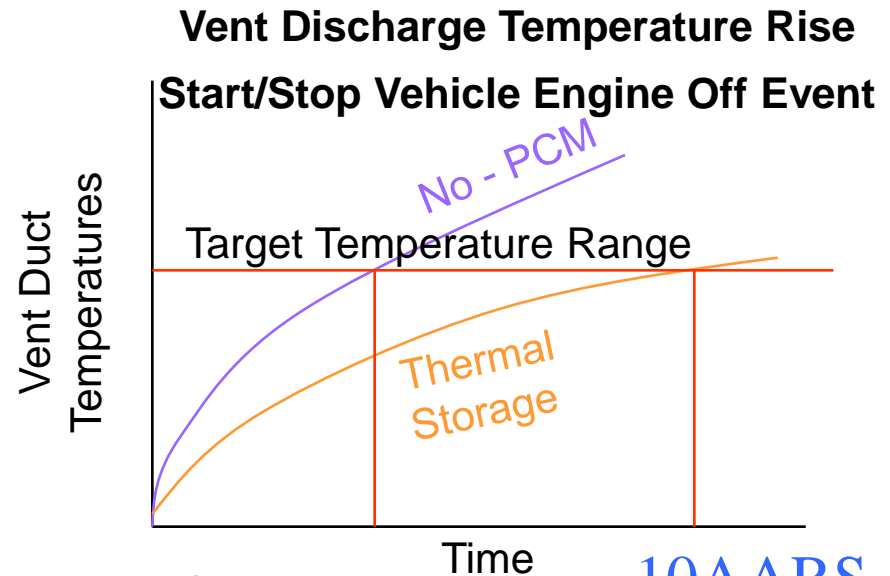
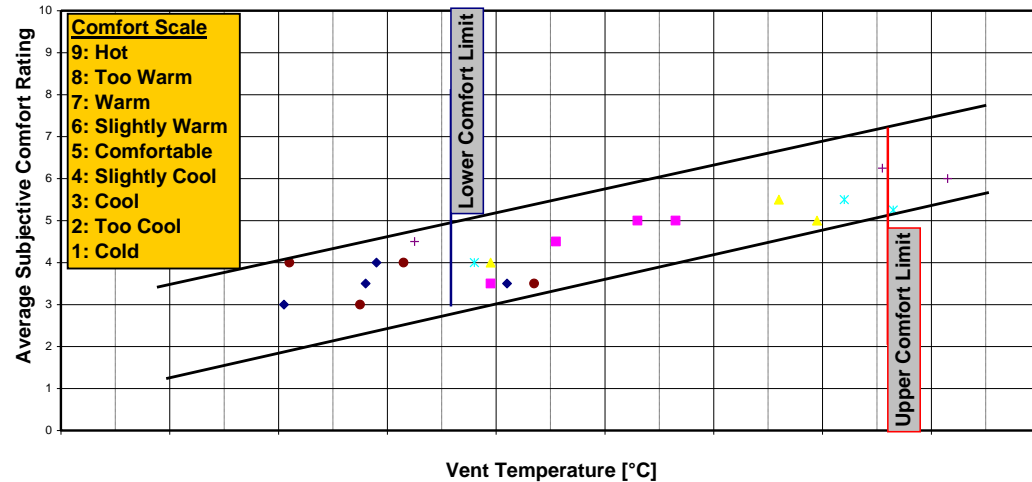
# Thermal Storage Technology Objectives

Provide an A/C Compressor “Off” Cooling Technology with the following attributes:

- Extended time with passenger cabin comfort
- Passive system- No additional pump or moving parts required
- Limited Modification to existing systems
  - No additional heat exchangers
  - Minimal impact to packaging
- Simplified, lower cost approach than current solutions

# Start Stop Vehicle Comfort Improvement

- Start/Stop vehicles need improved comfort during vehicle engine-off for extended durations
- Vent discharge temperature is correlated to passenger comfort
- Vent discharge temperature target range established through series of comfort evaluations
- Objective is to maintain comfort for an extended stop





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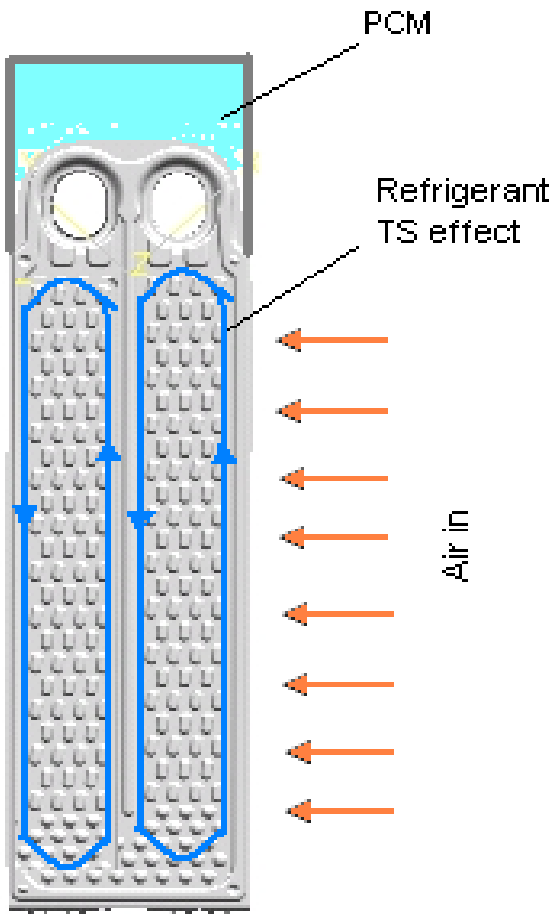


# Thermal Storage Project

- Built Thermosiphon Evaporator for thermal storage
- Installed thermal storage Thermosiphon Evaporator into vehicle
- Evaluated extended idle performance of a conventional vehicle simulating a “start/stop”
- Determined the Phase Change Material charge/discharge time
- Evaluated passenger comfort with thermal storage



# Delphi Thermal Storage Evaporator



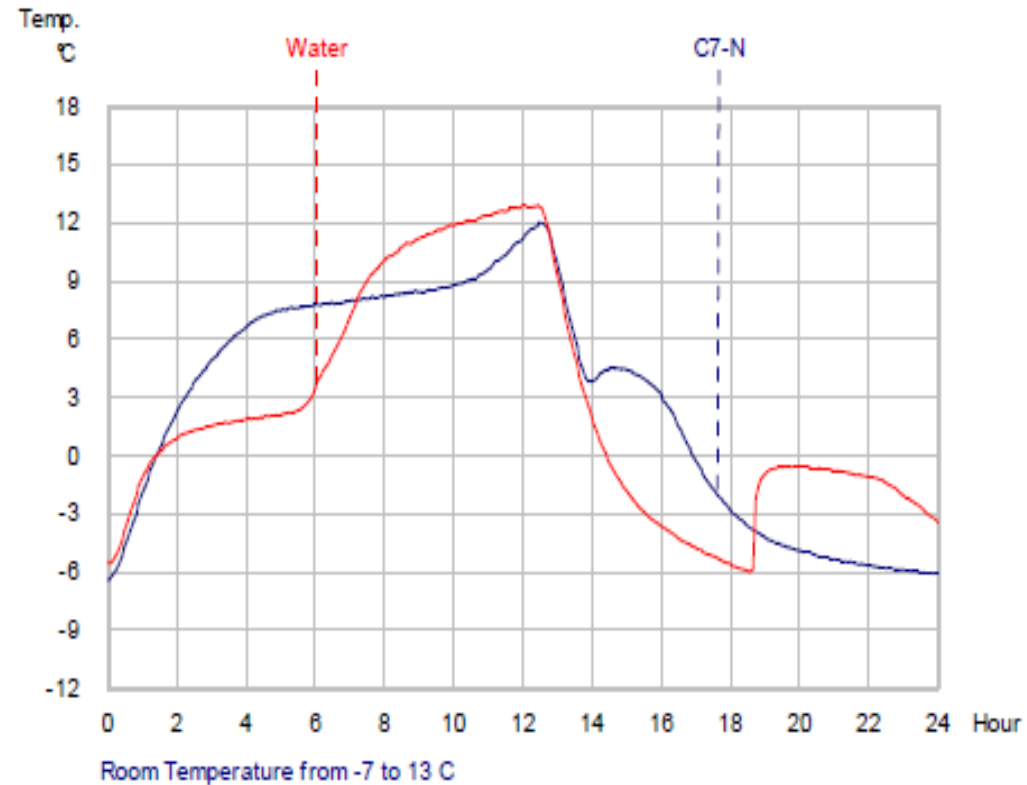
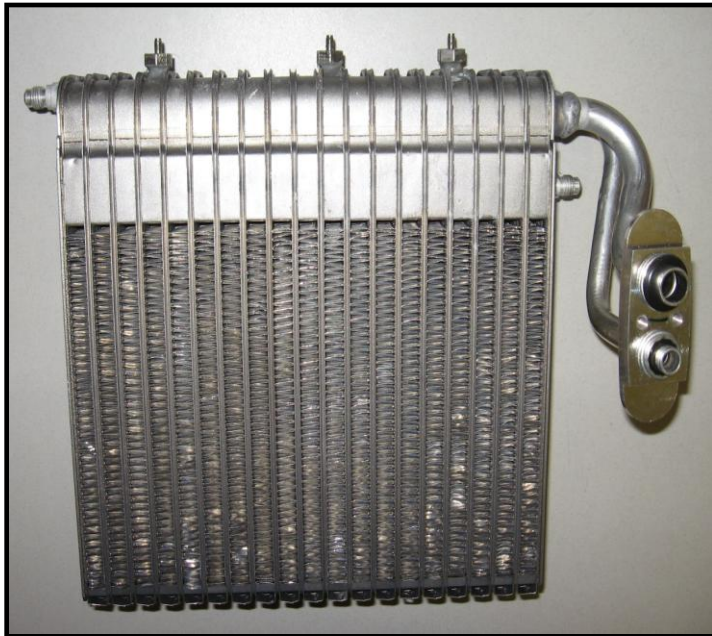
- Thermal Storage PCM surrounds upper tank of the evaporator
- PCM freezes during normal A/C operation
- PCM melts when a/c is turned off
- Evaporator becomes a series of Thermosiphons (each tube)

# Thermal Storage Design/Phase Change Selection

## Thermosiphon Evaporator Statistics

PCM Designation: **C7**

PCM Mass: **685g**



# Vehicle Application

## 2008 Saturn Aura XR Configuration



*Compressor:* **Delphi Compact Variable Compressor - 6CVC140**

*Evaporator:* **Delphi Production Plate Type**  
modified with integrated phase change material

*Control Head:* Programmed to **emulate start/stop vehicle operation**

# Control Scheme

- Disengage the compressor at idle-stops
- Adjust evaporator thermistor settings for freeze protection
- The ability to re-engage the compressor during idle-stops based on evaporator or vent temperature target
- Change HVAC blower speed and air inlet source on ambient per the table below:

Temperature (°C)	Humidity (%)	Solar Load (W/m <sup>2</sup> )	Engine ON Mode		Engine OFF mode	
			Blower Speed [v]	Mode	Blower Speed [v]	Mode
25	60	600	6	Fresh	4	Recirc
30	40	800	8	Recirc	6	Recirc
35	40	1000	12	Recirc	10	Recirc

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# Test Procedures

## ■ Charge/Discharge Time Matrix (36 points)

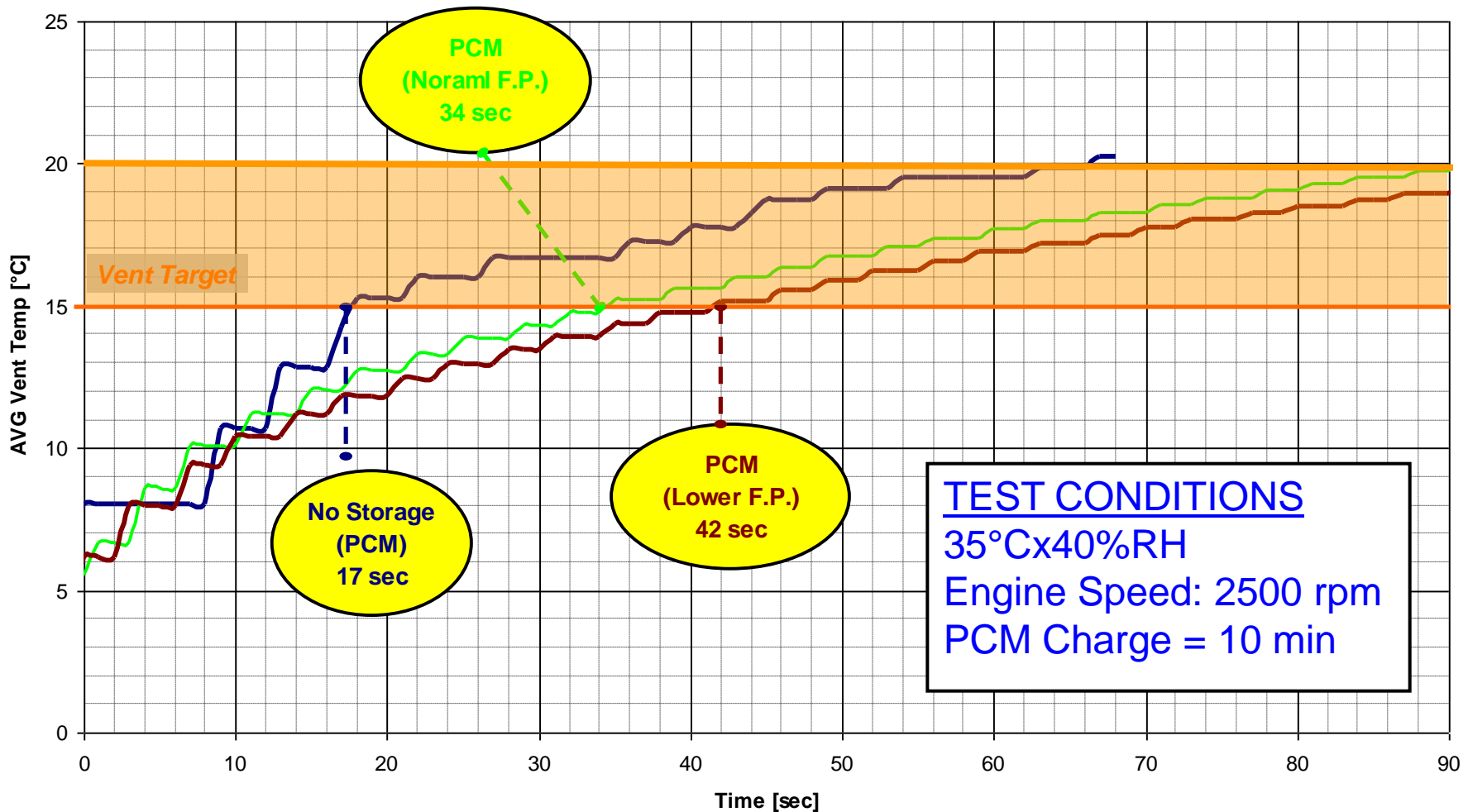
- Ambient : 25/30/35°C
- Compressor Speed: Idle/1500/2500 rpm
- PCM Charge Time: 1/2/5/10 minute
- Freeze Control Setting: Normal and Lower
- **Determine length of time to for a/c vents to reach 15°C-20°C**

## ■ City Traffic

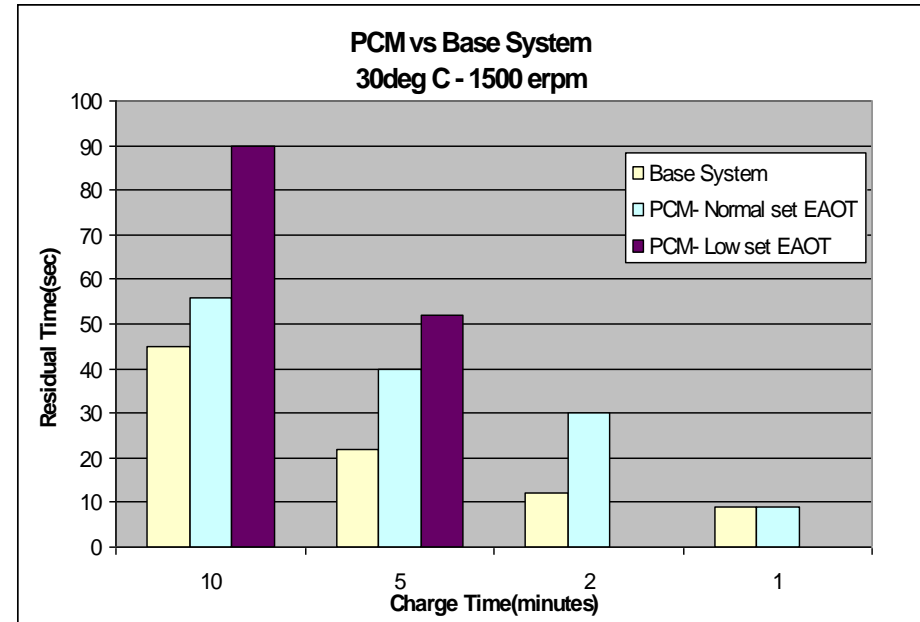
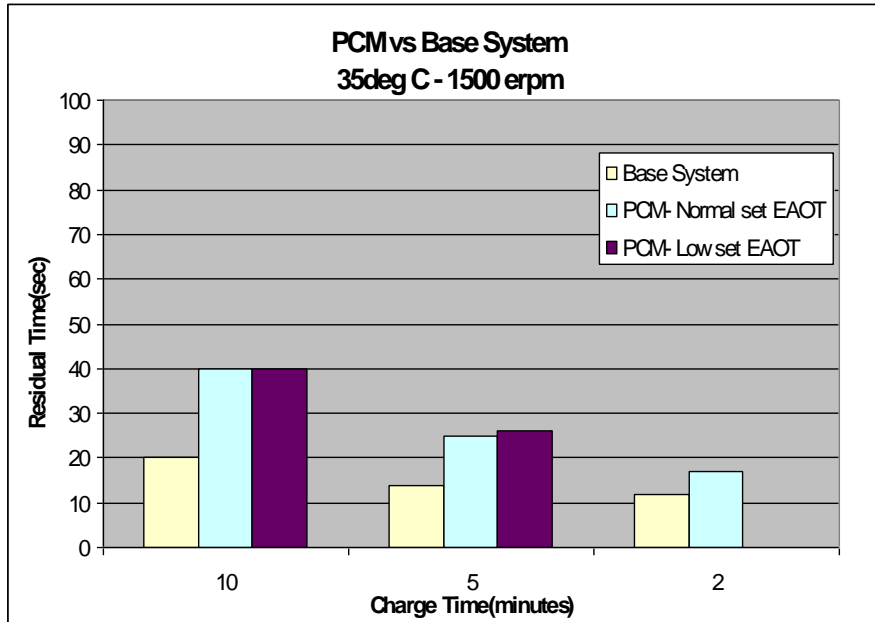
- 20-minute stabilized recirc
- 4-stop city traffic
- Freeze Control Setting: Normal and Lower
- **Determine length of time to reach discomfort**



# Results - Vent temperatures with A/C Off High A/C Load Condition

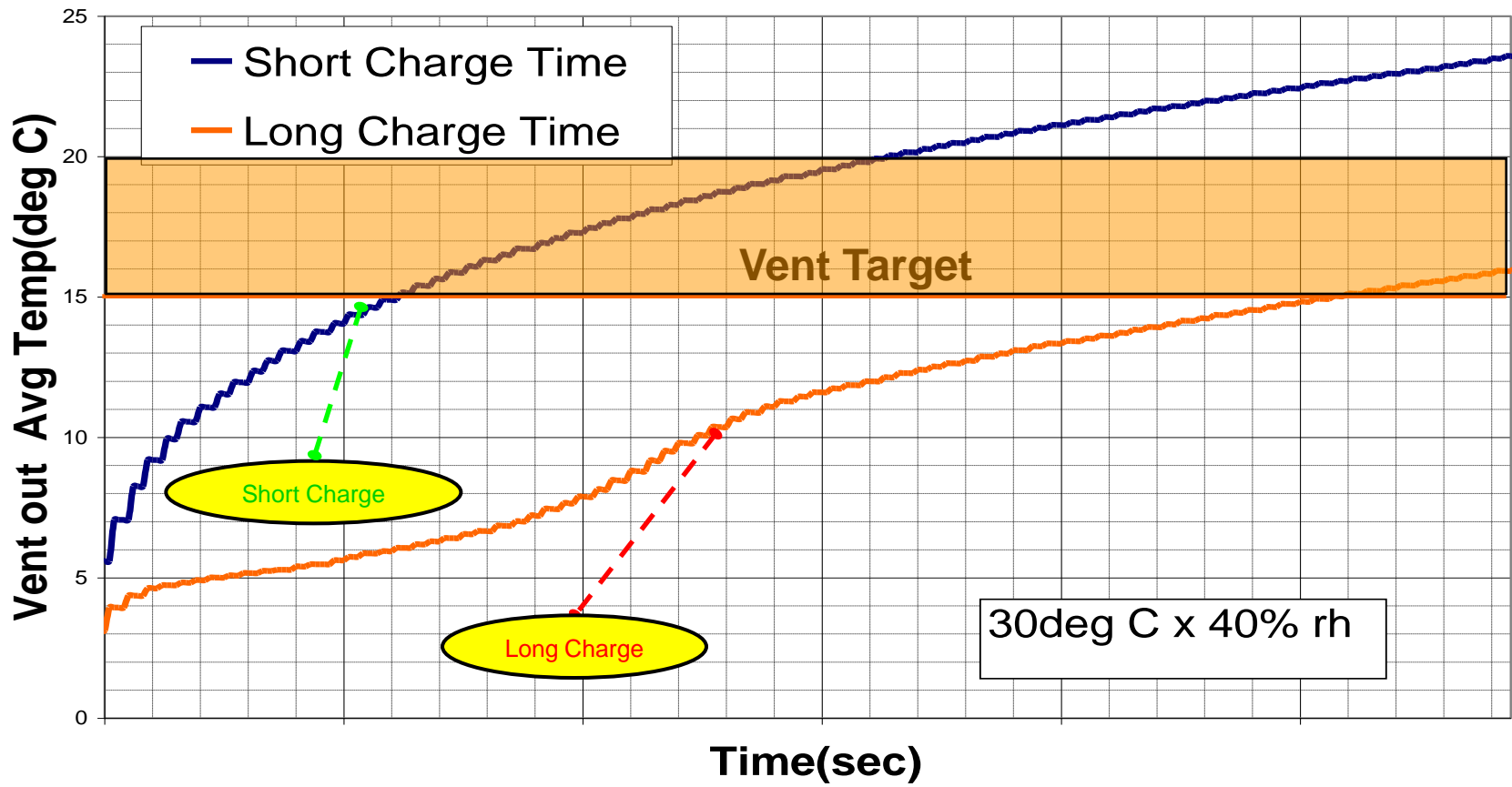


# Vent Temperatures with A/C Off Time to Reach 15°C



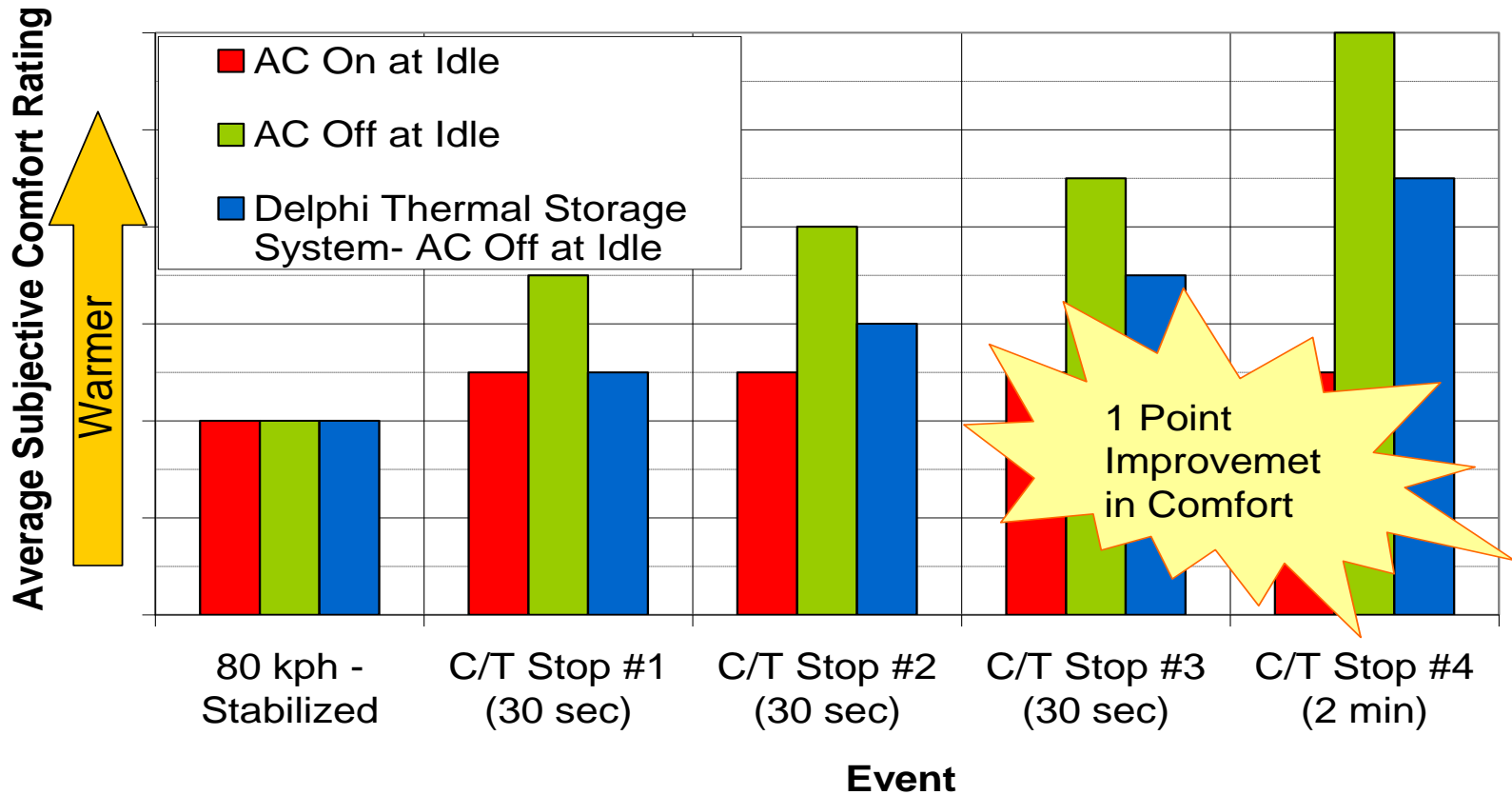
- Thermal Storage yields a significant improvement in residual cooling time with lower ambients
- Thermal Storage yields significant improvement in residual cooling time with longer charge times.

# PCM Capability with Longer Charge Times



**Cooling time increased ~400% with longer charge time**

# Comfort – HIGH ambient with optimized system



**Increased cooling times yield extended comfort during stop/start city traffic driving**

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# Conclusions

- PCM-integrated Thermosiphon evaporator is an excellent thermal storage solution for cabin comfort
- Design guides established
  - PCM with optimized freeze/melt characteristics
  - Heat Exchanger developed to increase refrigerant-to-PCM heat transfer
  - System Logic with optimized freeze point control
- PCM Thermosiphon can be integrated in plate type or micro-channel evaporator
- Extended comfort time during idle-stop enables improved fuel economy

# *Thank You*

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