Overview of APEEM Thermal Control Research Projects

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DOE FreedomCAR and Vehicle Technologies Program
Advanced Power Electronics and
Electric Machines Projects
FY08 Kickoff Meeting

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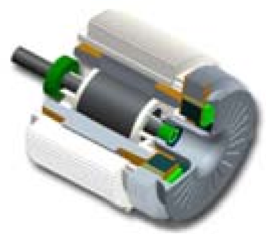
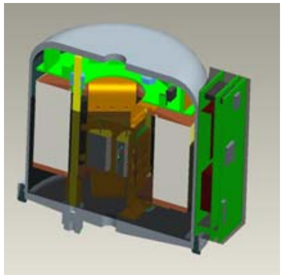
Thermal Control Research Direction

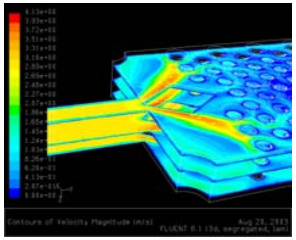
Meeting costs, specific power, power density, and efficiency targets while driving toward higher coolant temperatures :



- Motor R&D
  - **Increasing speed (Reduce Size)**
  - **Innovative concepts to lower material and manufacturing costs**
  - **Eliminate need for boost converter**
  - **Reduce stress on battery during high loads**



- Power Electronics R&D
  - **Reduce size and cost of capacitor via topology and capacitor improvement**
  - **Increase temperature rating**
  - **Reduce and dissipate heat more effectively**
  - **Reduce parts count by integrating functionality**



- **Thermal Control R&D**
  - **Enable cost and power density targets through the elimination of the separate coolant loop and development of enhanced heat transfer technologies**
  - **Parallel paths will focus on the use of engine coolant at 105°C and the development of air cooling technologies**

Technical Requirements

- Thermal control is a critical factor in PEEM performance
- Today's HEVs: dedicated 70°C PEEM cooling system
  - Cost is estimated at $175 to consumer
- PEEM target cost is $440 for 55 kW system
- Current cooling system cost represents 40% of PEEM system cost target

Conclusion – need to reduce coolant system cost

Primary focus on 105°C coolant and air cooling

Technical Approach – *105C engine coolant (T_C)*

h

Enhance heat transfer coefficient
- jet/spray cooling
- surface enhancements

Q

Improve component/system efficiency
- Improved devices

A

Increase surface area
- fin shape optimization
- surface enhancements
- thermal spreading
- double-sided cooling

$$Q = h\,A\,(T_B - T_C)$$

$$Q = \frac{(T_H - T_B)}{R_{solder} + R_{DBC} + R_{TIM}}$$

$$Q = \dot{m}\,C_p\,(T_{out} - T_{in})$$

T_H

Increase maximum allowable temperature
- PE materials development

R

Reduce Thermal Resistance
- advanced TIM materials
- low R IGBT structure

Technical Approach – *Air Cooling*

h

Enhance heat transfer coefficient
- micro-channel forced convection
- surface enhancements

Q

Improve component/system efficiency
– improved devices
– dynamic control of coolant

A

Increase surface area
- fin shape optimization
- surface enhancements
- thermal spreading
- double-sided cooling

$$Q = hA\left(T_S - T_C\right)$$

$$Q = \frac{(T_H - T_B)}{R_{solder} + R_{DBC} + R_{TIM}}$$

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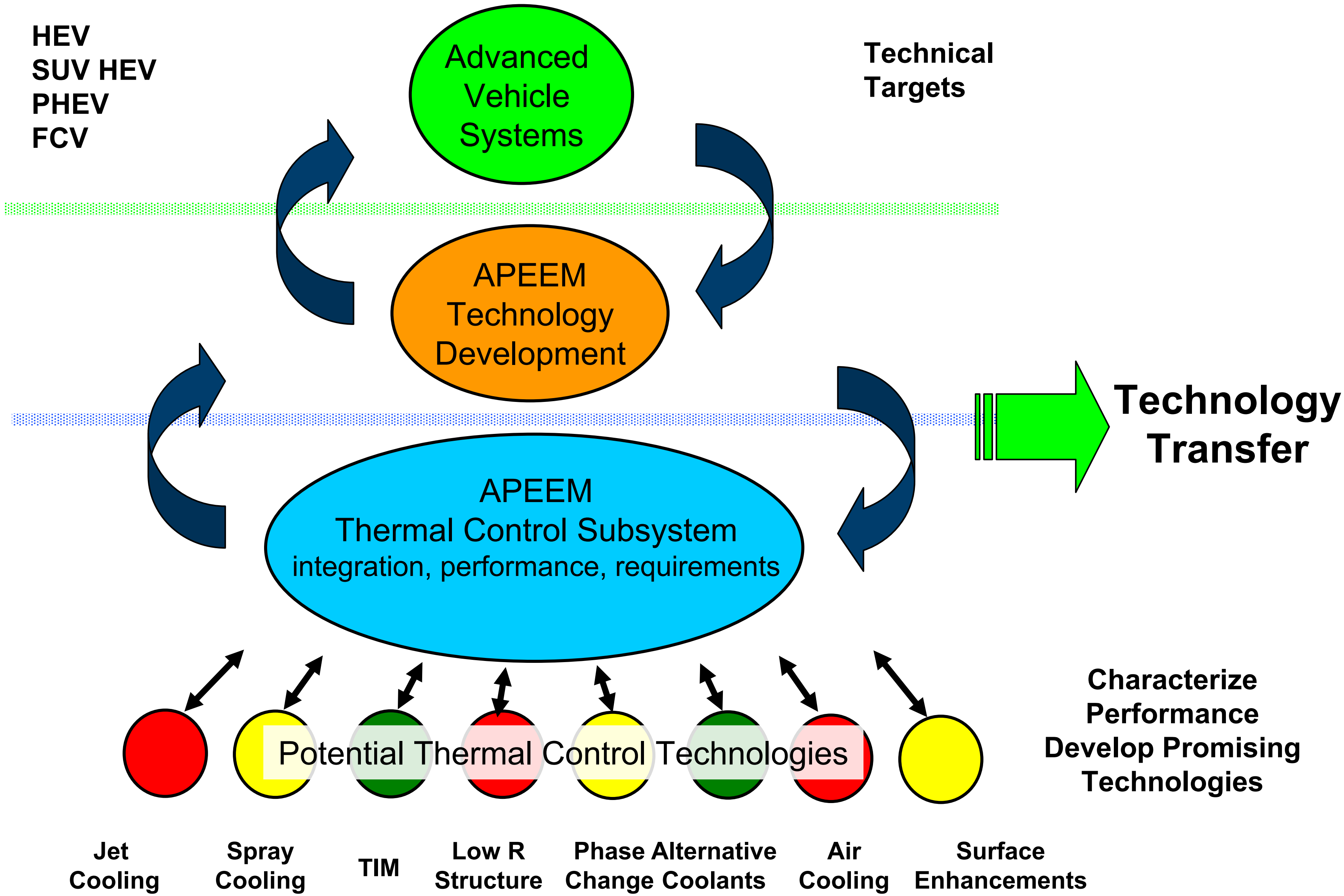
HEV
SUV HEV
PHEV
FCV
Advanced Vehicle Systems
Technical Targets
APEEM Technology Development
Technology Transfer
APEEM
Thermal Control Subsystem
integration, performance, requirements
Potential Thermal Control Technologies
Characterize Performance
Develop Promising Technologies
Jet Cooling
Spray Cooling
TIM
Low R Structure
Phase Change
Alternative Coolants
Air Cooling
Surface Enhancements

FY08 Thermal Control R&D Projects

1. Power Electronic Thermal System Performance and Integration
   – ***Kevin Bennion, NREL***
2. Characterization and Development of Advanced Heat Transfer Technologies
   – ***Thomas Abraham, NREL***
3. Research and Development of Air Cooling Technology for Power Electronics Thermal Control
   – ***Desikan Bharathan, NREL***
4. Direct-Cooled Power Electronics Substrate
   – ***Randy Wiles, ORNL***
5. Advanced Thermal Interface Materials for Power Electronics
   – ***Sreekant Narumanchi, NREL***
6. Thermal Stress and Reliability for Advanced Power Electronics and Electric Machines
   – ***Michael O'Keefe, NREL***

Questions