Improving Energy Efficiency by Developing Components for Distributed Cooling and Heating Based on Thermal Comfort Modeling

Gregory P. Meisner

General Motors Research & Development

June 11, 2010

Project ID # ACE048

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Start date – November 2009
- End date – October 31, 2012
- Percent complete – 6%

Budget

- Total funding: $5,097,592
  - DOE* share: $2,548,796
  - Contractor share: $2,548,796
- Funding received in
  - FY09: $0
  - FY10: $16,919 (11/09-01/10)

* we thank the California Energy Commission and the DOE Vehicle Technologies Program for their support and funding of this project

Barriers & Targets

- Early stage of development for thermoelectric (TE) devices in automotive HVAC applications
- TE coefficient of performance > 1.3 to cool and > 2.3 to heat
- Reduce HVAC energy by > 30%

Partners

- Interactions / collaborations
  - *University of California – Berkeley:* Thermal Comfort testing & modeling
  - *Delphi Thermal Systems:* HVAC component development
  - *University of Nevada – Las Vegas*: Thermoelectric materials research (beginning in April 2010)
- Project lead – *General Motors*

Objectives

- Reduce the fuel used to maintain occupant comfort by at least 30% through the use of thermoelectric technology
- Develop TE HVAC components that have a coefficient of performance > 1.3 for cooling and > 2.3 for heating, then integrate & test as a system in 5-passenger demo vehicle
- Develop Thermal Comfort model to predict the response to localized heating and cooling through human subject testing
- Enhance the Virtual Thermal Comfort Engineering CAE tool to analyze localized heating and cooling for future vehicles
- Develop new thermoelectric materials to improve efficiency of thermoelectric generators for engine waste heat recovery

Milestones

FY 2010

- Identified and prioritized a list of potential distributed heating and cooling components, and also developed a list of other potential approaches to improve HVAC system efficiency – Dec. 8, 2009
- Completed comparison of GM vehicle portfolio to selection criteria for TE HVAC demonstration vehicle – Jan. 27, 2010
- Completed identification of initial set of components for distributed heating and cooling development – Mar. 31, 2010
- Complete definition of Design of Experiments for testing of Mule vehicle – May 31, 2010
- Complete build of mule vehicle for Thermal Comfort evaluation – Aug. 31, 2010

Approach/Strategy

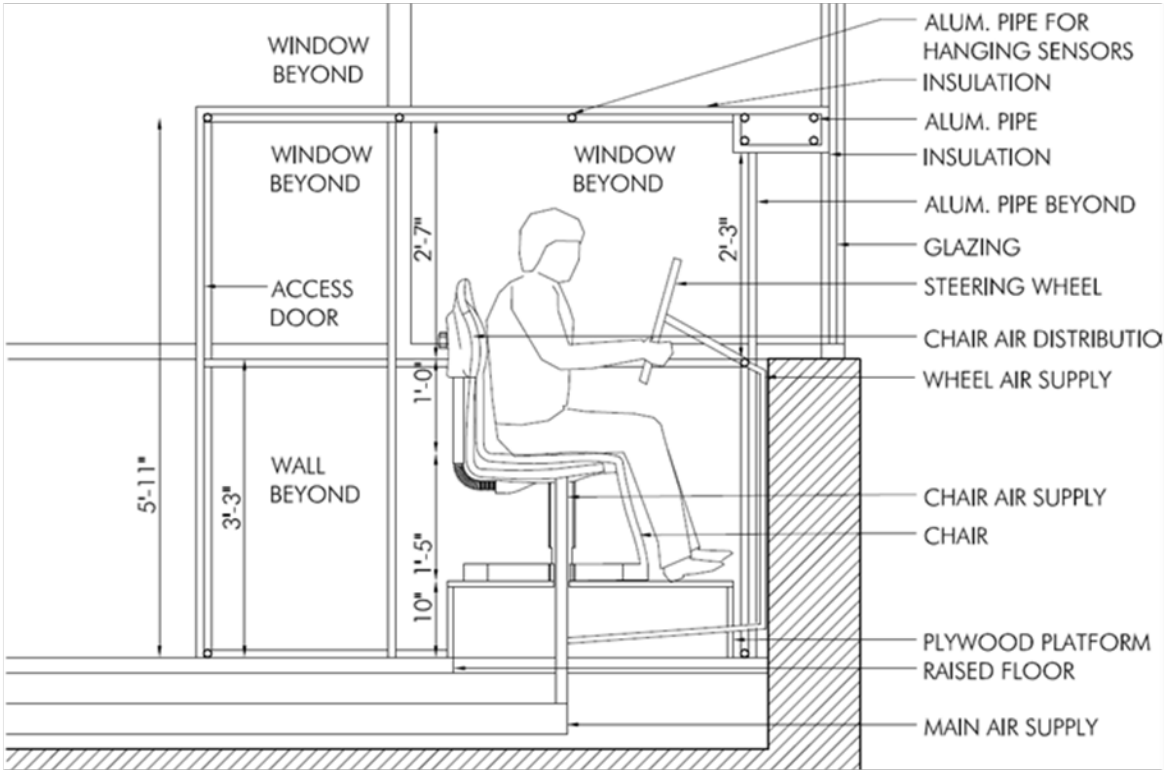
- **Phase 1** – Develop Thermal Comfort model of human responses to potential locations for distributed heating & cooling
  - Identify potential locations for distributed HVAC components and measure their physiological and psychological effectiveness
  - Use automotive mockup in the UC-Berkeley environmental test chamber to perform human subject testing
  - Use modified mule vehicle in Delphi Thermal's Climatic Wind Tunnel to perform human subject testing
  - Update UC-Berkeley's Thermal Comfort model as the key component of the Virtual Thermal Comfort Engineering computer-aided engineering (CAE) tool used by GM and Delphi Thermal Systems

Approach/Strategy (cont.)

- **Phase 2** – Develop the initial prototype HVAC components and evaluate on bench & mule vehicle
  - Define control strategies and algorithms
- **Phase 3** – Develop the final prototype HVAC components and evaluate on bench
  - Estimate HVAC system efficiency improvements
- **Phase 4** – Integrate final HVAC components into demo vehicle and optimize system performance
  - Calculate efficiency improvements of HVAC system
- **Phase 5** – Develop new thermoelectric materials for waste heat recovery (in parallel with HVAC phases)

Technical Accomplishments and Progress

- Completed the design of the automotive mockup, the procurement of components, and their assembly in the UC-Berkeley environmental test chamber



Technical Accomplishments and Progress (cont.)

- Discussed the human body parts that are key influencers of perceived thermal comfort; then identified and prioritized a list of potential distributed heating and cooling components
- Collaboration between General Motors, Delphi, and UC-Berkeley on ranges of operating parameters (e.g., flow rates) for evaluating HVAC components
- UC-Berkeley performed pilot human subject tests and then identified the initial set of distributed heating and cooling components for development

Technical Accomplishments and Progress (cont.)

- Developed a list of vehicle selection criteria to aid the development of the distributed HVAC system
- GM applied the selection criteria to the vehicle portfolio plan and chose the new Cadillac SRX for this project. Mule & demonstration vehicles will be purchased with automatic tri-zone HVAC systems and heated & cooled seats; this places ductwork in locations that support our development activities
- Vehicle selection allowed Computational Fluid Dynamics Analysis to begin
- Developed a list of other potential approaches to improve HVAC system efficiency in demo vehicle

Collaboration and Coordination with Other Institutions

- **University of California – Berkeley:**
  Human subject testing & Thermal Comfort modeling
- **Delphi Thermal Systems:**
  HVAC component development and testing
- **University of Nevada – Las Vegas:**
  Thermoelectric materials research
- **General Motors Advanced Engineering and R&D:**
  Vehicle requirements and system integration,
  Thermoelectric materials research

Proposed Future Work

- **Complete Phase 1 activities by Apr. 30, 2011**
  - Use automotive mockup in the UC-Berkeley environmental test chamber to perform primary human subject testing
  - Use modified mule vehicle in Delphi Thermal's Climatic Wind Tunnel to perform additional human subject testing
  - Update the UC-B Thermal Comfort model and incorporate into the Virtual Thermal Comfort Engineering CAE tool
  - Complete identification of final set of components for distributed heating & cooling development – Apr. 30, 2011
  - Go/No-Go: Can final set meet the performance objectives?
- **Begin Phase 2 activities on May 1, 2011**
  - Start to develop the initial prototype HVAC components

Summary – TE HVAC Project

- Quantify the physiological & psychological response of people to localized heating & cooling by updating the UC-Berkeley Thermal Comfort model
- Develop distributed HVAC components that provide localized heating & cooling of vehicle occupants through the use of thermoelectric technology
- Quantify the efficiency of a distributed HVAC system that locally heats & cools vehicle occupants versus a conventional central HVAC system that provides thermal comfort by heating & cooling the entire cabin
- Enhance the Virtual Thermal Comfort Engineering CAE tool to analyze and optimize the application of distributed HVAC components in future vehicles