STATUS OF THE APPLICATION OF THERMOELECTRIC TECHNOLOGY IN VEHICLES

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10th Diesel Engine Emission Reduction (DEER) Conference
United States Department of Energy
August 29 - September 2, 2004
San Diego, California

Discussion

- Why thermoelectrics (TE)?
- Status of TE technology
- Expected short & medium term advancements in TE technology
- Current vehicular applications
- Prospects for future applications
- Summary and concluding remarks

BSST

Developer and producer of advanced TE systems for heating, cooling, temperature control and power generation applications

TE contractual relationships with Visteon, Government Agencies, Northrop Grumman, RTI and others

Subsidiary of Amerigon Incorporated

- World's largest commercial user of TEs
- Currently supplies TE-based climate control systems to Ford, General Motors, Nissan and Toyota
- Production in California, Mexico and China

Why Thermoelectrics?

Solid-state cooling, heating and power generation

Small, light-weight and potentially very rugged

Very few (or no) moving parts

Electrically powered

Potential contributions to vehicle system efficiency gains and pollution reduction

Enables distributed cooling/heating/temperature control and waste power recovery

What Has Limited Usage?

Cooling efficiency has been about ¼ that of freon

- Inadequate for most HVAC applications
- Limits usage to small, spot coolers and controllers
- Too inefficient for most electronic subsystem cooling

Thermal flux density has been low

- TE materials too costly
- Volume and weight too great at high power levels
- Form factor not readily adaptable to some application needs

Lack of design knowledge and effective simulation tools

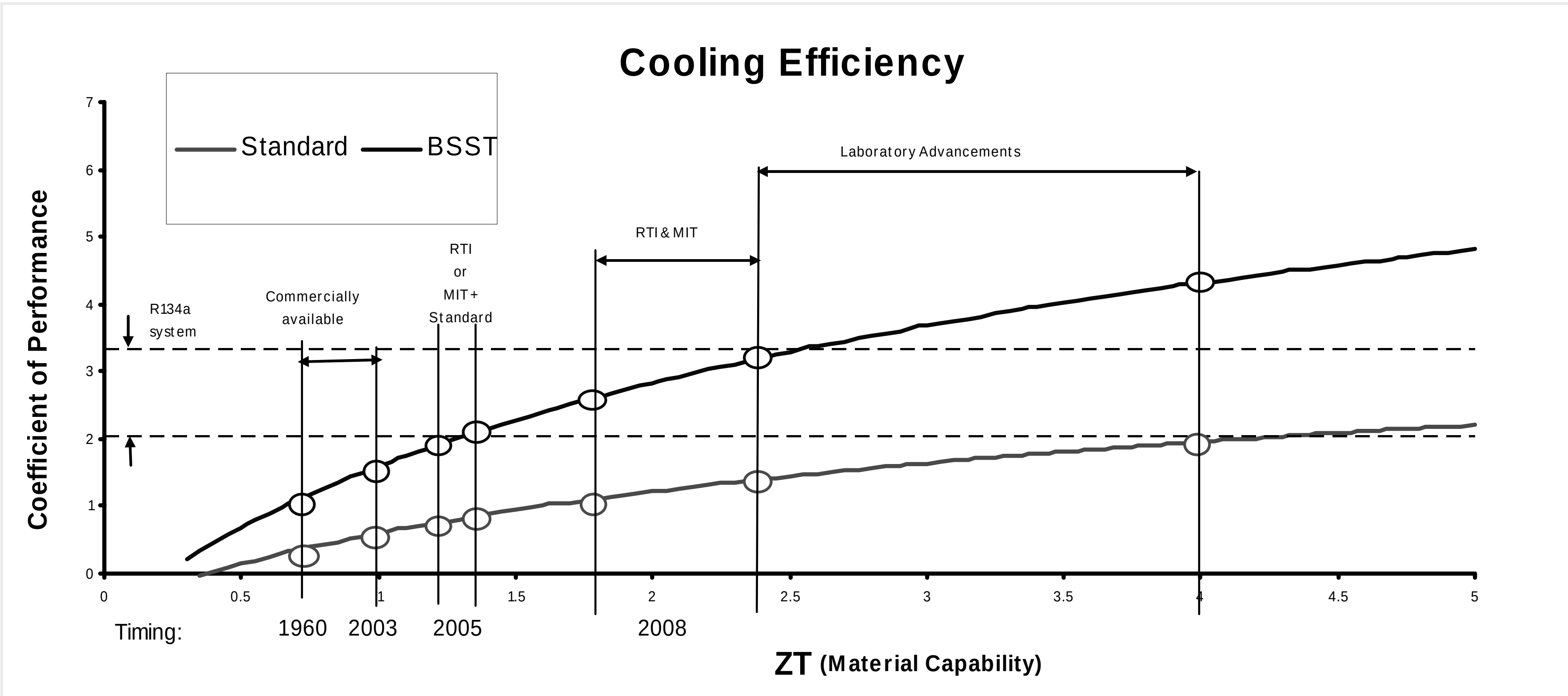
- Performance often poorer than predicted
- Characteristics and, hence response, can be a strong function of operating conditions

Too inefficient for waste power recovery

Recent Performance Gains

Materials	
BiTe Thermoelectrics (1960s)	Baseline
Heterostructures (2000-2002)	+70 to 160%
Materials/Design	
Incremental improvements (1960-2002)	5 to 15%
New ancillary materials and components (1960-2002)	5 to 10%
System Level	
Isolated Element Cycle (2000-2002)	100 to 120%
Convection Cycle (2001-2002)	30 to 80%
Power Density	
Sintered micropower (2002)	Up to 25 X Increase
Heterostructure (2001)	30 to 300 X Increase

TED Performance Roadmap



Applications

CCS™ System

Provides consumer benefits with significant market pull

- Heats and cools seats (all year comfort)
- Quick response time
- Very effective with leather seating

Very high take rates

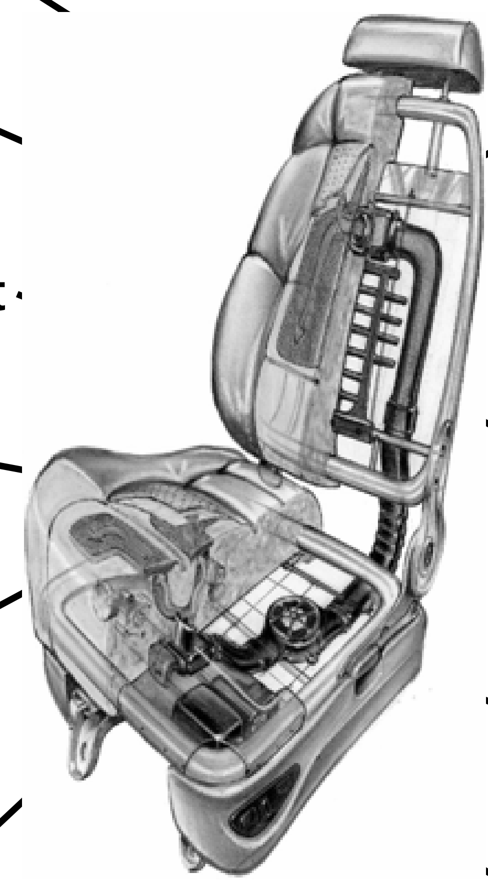
- 50% to 90% in present applications
- Sells in all climate zones

First, sustained solid state heater/cooler application in vehicles

- Quiet, effective operation
- No negative contribution to emissions
- Proven to be very reliable

CCS™ Vehicle Seat Application

Production CCS™ Assembly



Current CCS™ Vehicle Lines

Cadillac Deville

Cadillac XLR

Mercury Monterey

Escalade ESV

Lincoln Navigator

Ford Expedition

Infiniti M45

Lincoln Aviator

Infiniti Q45

Toyota Celsior

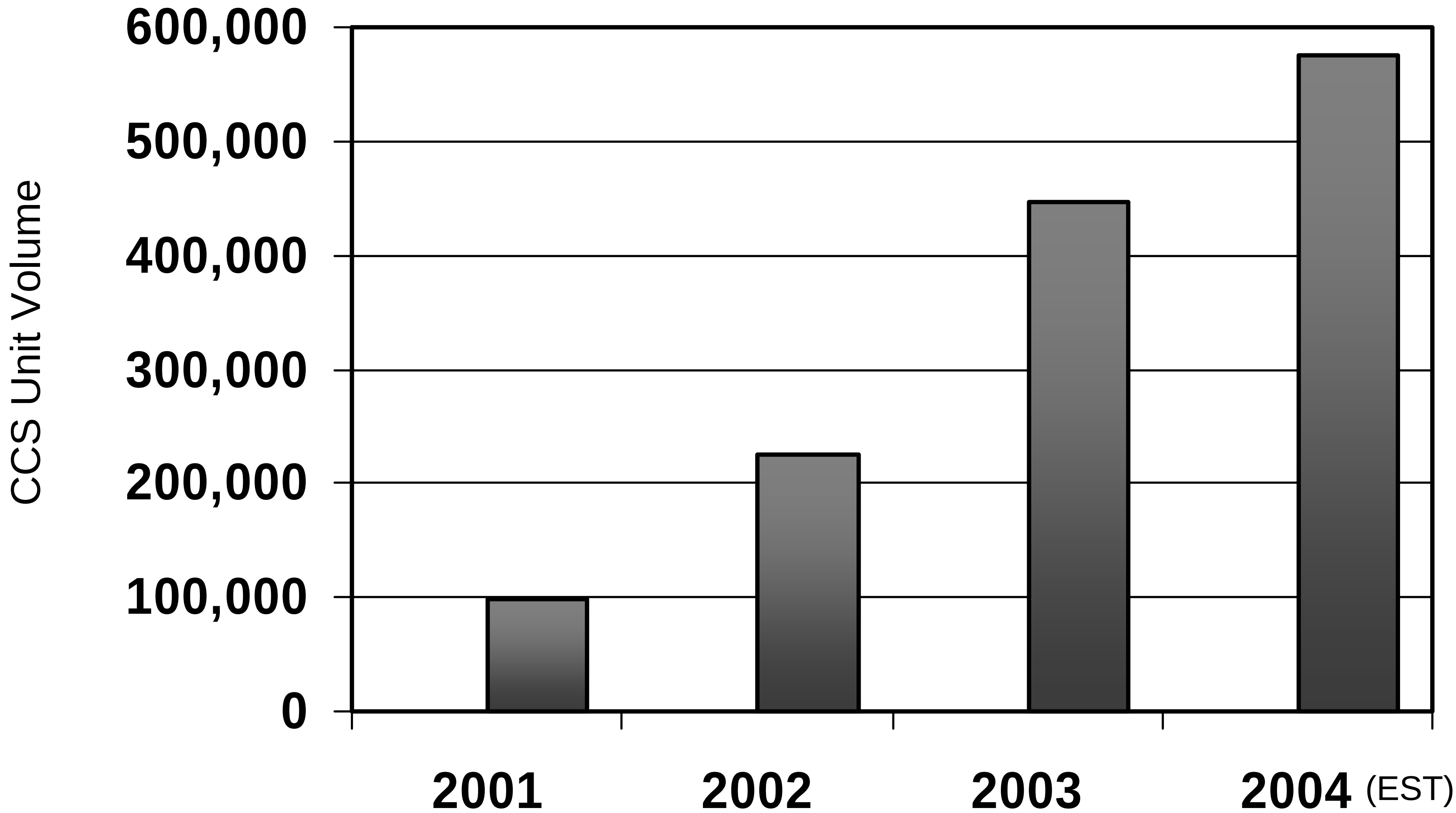
Lexus LS 430

Lincoln LS

Hyundai Equus

Nissan Cima

CCS™ Growth Rates



AMERIGON Advanced Automotive Thermal Solutions

Primary Vehicular Cooling/Heating/Climate Control

Long-standing target for TE usage

Awaits commercial availability of:

- Materials with double the present figure of merit
- Lower cost (higher power density) systems
- Source of 2-4 kW of electric power

However, these present barriers are reduced for:

- Small DI & diesel powered vehicles
- Hybrid vehicles
- Fuel cell powered vehicles

Waste Power Recovery

Over half of the energy consumed by vehicles is wasted:

- Exhaust gases
- Engine heating
- Impact of other smaller losses

Well recognized and studied opportunity

System capabilities required to make recovery systems viable:

- Factor of 1.5 to 2 TE material efficiency improvement
- Lower cost (higher power density) systems
- Capability to store recovered waste energy

However, these present barriers are reduced in:

- Vehicles with high electrical demands (trucks, vans, busses, luxury vehicles)
- Meeting governmental demands for CO_2 reduction

Long-term Trends

Vehicle Industry Trends Favor Solid State (TE) Power Conversion

Vehicles are becoming more electrified

- Higher electrical demands under nearly all driving conditions
- On board electrical energy management and storage systems are more prevalent and support adaptation

Emission reduction becoming a higher priority worldwide

- CFC reduction in HVAC, refrigeration systems
- CO_2 reduction in all vehicle types

Advanced vehicle types requiring new subsystem functionality

- Diesel and DI gasoline powered vehicles need better heating, cooling and waste recovery systems
- Hybrids, hydrogen powered vehicles need more compatible HVAC
- Fuel cell vehicles need HVAC, waste power recovery

Waste Heat Recovery May Become a Critical Necessity

Directly addresses the global need to reduce CO_2 emissions

Provides source of additional electrical power without increasing fuel consumption

Targeted by DOE for a 10% contribution toward OFCVT* initiative to increase overall efficiency by 30 to 45% for light duty applications and 40 to 55% for heavy duty applications by 2012

* Office of FreedomCar and Vehicle Technologies

Summary

Over 2 million TE modules are in use successfully in passenger car, SUV, van and light truck seating systems today

- Reliability is proven for this application
- Customer satisfaction is high
- Market is growing rapidly

Other vehicle applications are envisioned

- HVAC
- Waste power recovery

New applications are driven by

- CFC, CO_2 reduction policies
- Vehicle electrification
- Demands for diesel, DI, hybrid vehicle performance improvement

But require commercial availability of

- More efficient TE materials
- Reduced cost (high power density designs)

Concluding Remarks

Long-term societal needs for emission reduction and greater fuel efficiency are opening opportunities for solid-state TE system usage. Such systems interface well with other advanced components including electronic fuel controls, power management systems and electrical power storage systems. The trend toward further electrification of passenger vehicles offers additional opportunities for application of TE systems because of their ability to interface directly with other electronic subsystems. Thereby, the energy losses associated with converting electrical power to mechanical work in subsystems that employ electric motors, actuators or pumps for operation, are avoided.