

Thermoelectric Applications to Truck Essential Power

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Essential Power Systems Workshop

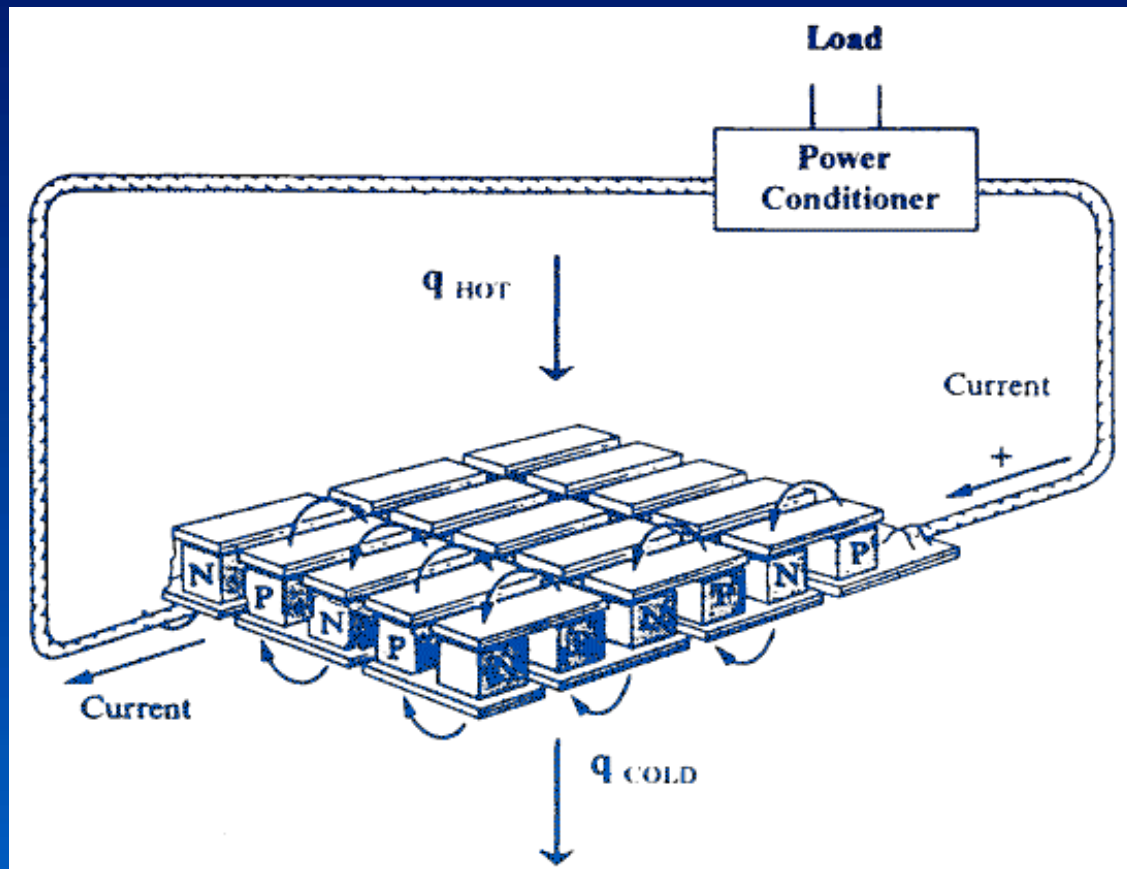
December 12-13, 2001
Washington, DC



Subjects Covered

- Thermoelectrics
 - 1-kW Generator for Diesel Engine
- Self-Powered Heater
- Power for Wireless Data Transmission
- Quantum-Well Thermoelectrics

Thermoelectric Module

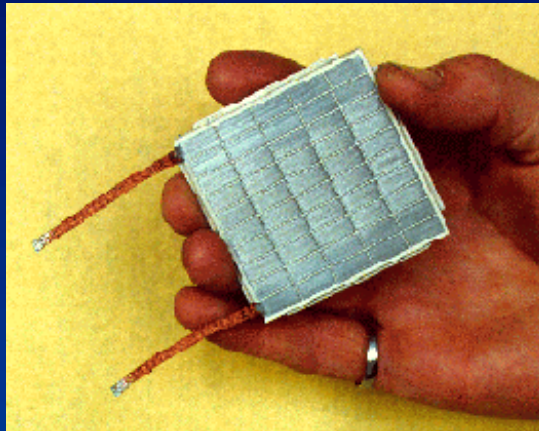


Thermoelectric Status

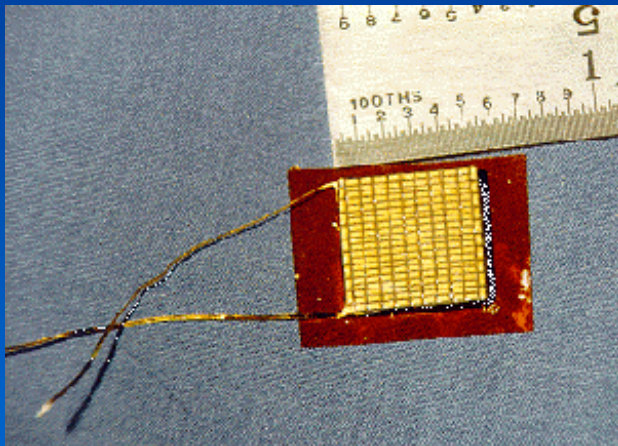
- 2- to 20-Watt Modules Commercially Available
 - Voltage per Module 1.65 to 3.3 V @ Matched Load
- New Lower Cost Production Being Evaluated
 - Preliminary Confirmatory Test
 - Prototypes in January 2002
- Quantum-Well TE Under Development
 - Test Run on 1 to 4 Couple Assemblies
 - Efficiency Test First Quarter 2002Q

Products

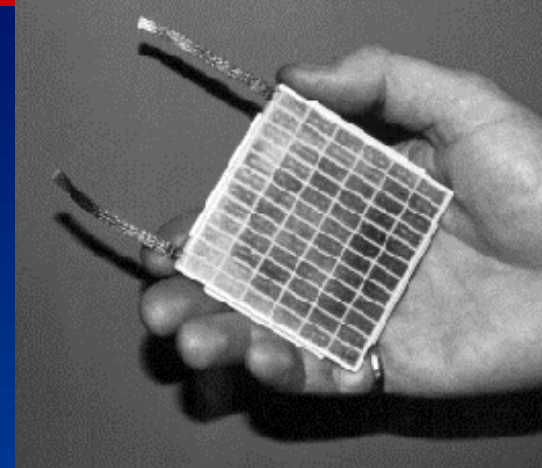
HZ-14



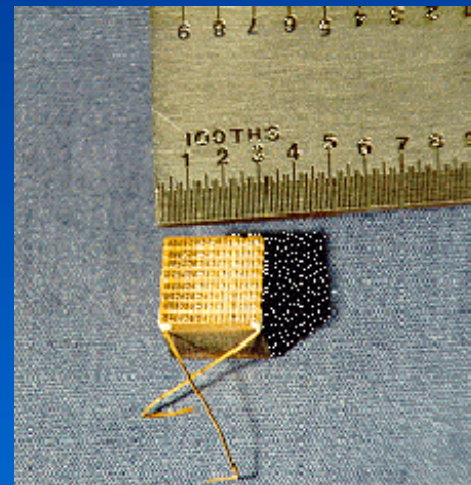
**800-mW Module for
Micro Air Vehicle (MAV)**



HZ-20

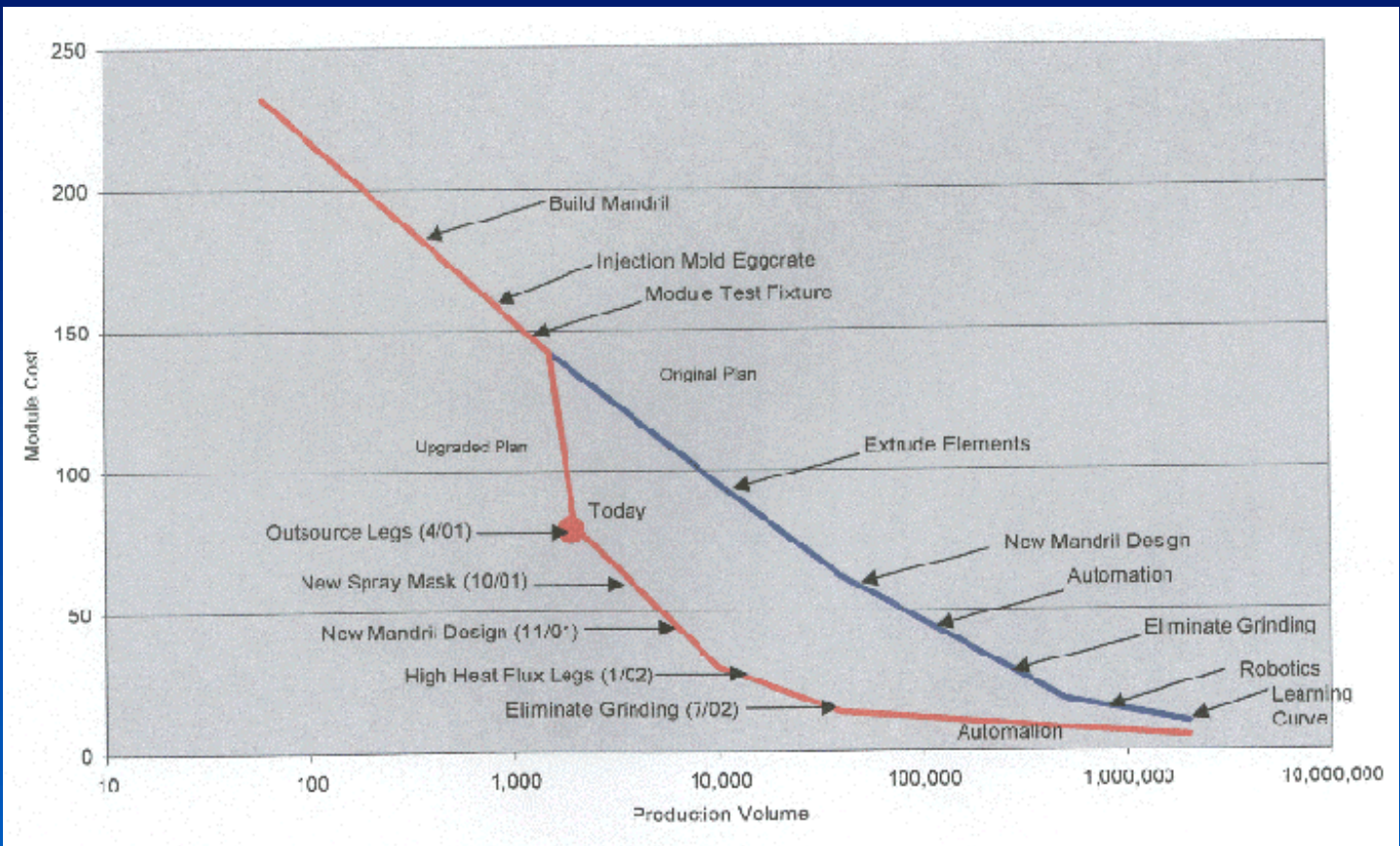


**40-mW Module for
Space Applications**



Hi-Z
TECHNOLOGY, INC.

Cost Reduction of HZ-14



Uses of 1-kW Generator

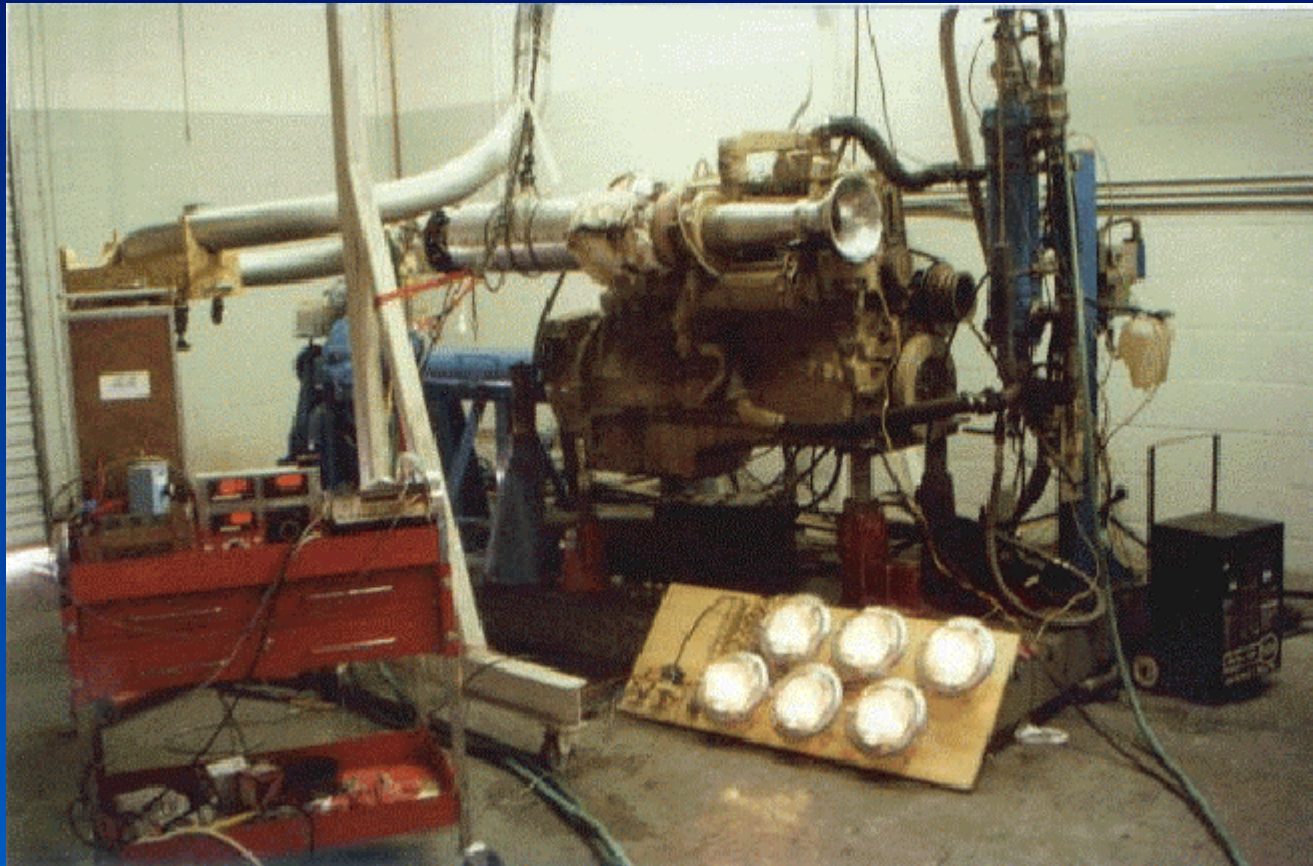
- Supplemental Power
- Emission Control Equipment
 - Plasma NOx Reduction
 - Regenerate Particulate Traps
 - Power for H2O2 Injection Systems
- Hotel Power
- Electric Boost Turbocharger
- Power for More Electric Truck

Current 1-kW Generator Technology Status

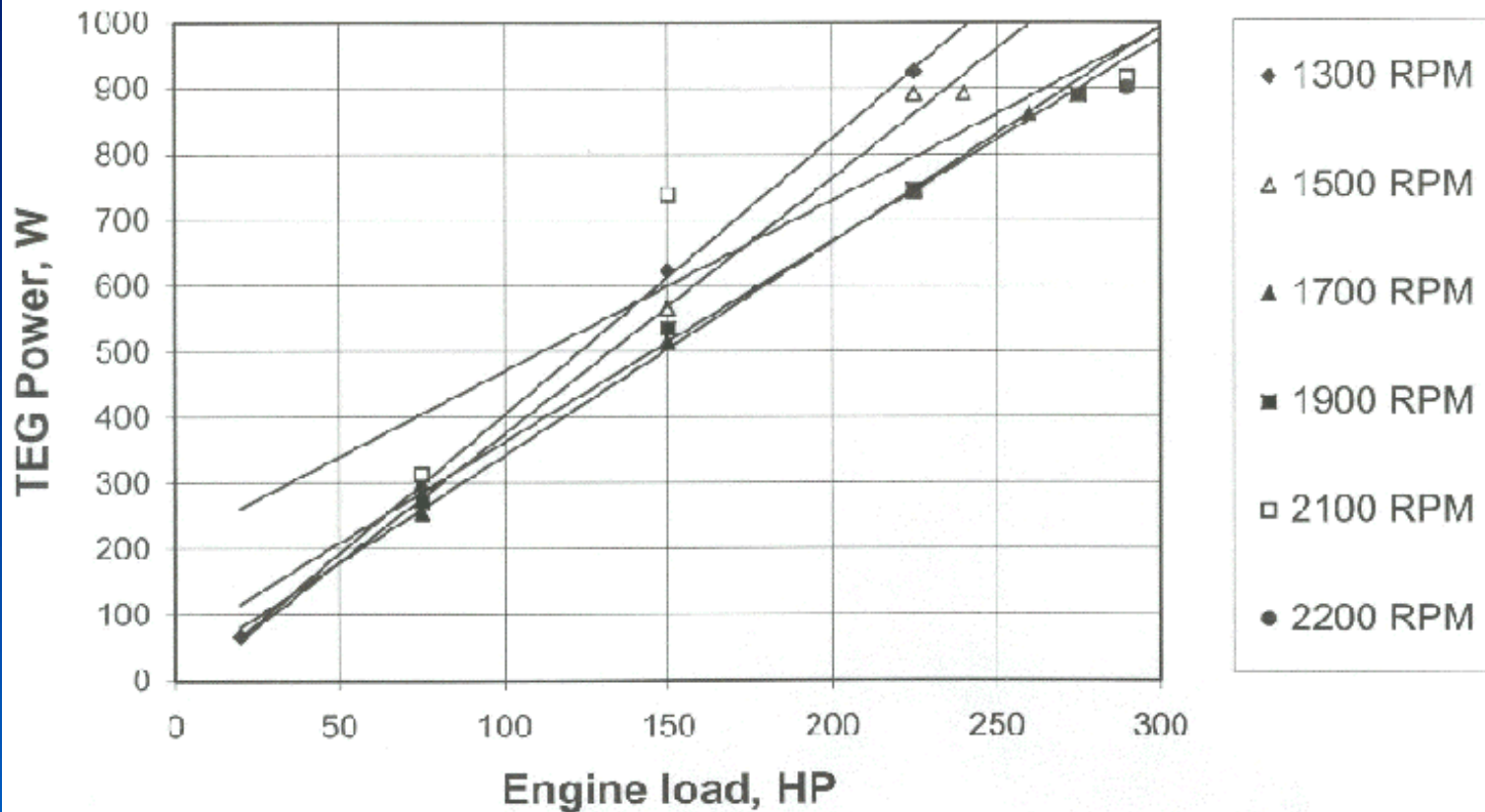
- Current Generator Program Started 12/00
- 1-kW Generator Rebuilt with New Modules
- Tested on 335-hp Engine in Test Cell
- Mounted on Kenworth Class 8 Truck
- Run for 55,000 Miles Equivalent on Test Truck
- Generator Disassembled and Modified for Improved Shock Resistance
- Second Test Run Scheduled After 01/01/02

Diesel TEG In-Cell Test

(Cummins 335 HP Engine)



In-Cell TEG Power



550-hp Truck Equipped with the TEG

PACCAR's 150 to 1 Test Track
Note Speed Bumps and Hill
Standard Test Protocols Are Used for Each Evaluation
Heavy Loaded (over 75,000 lb)
TEG Installed Under the Cabin



Under View of the Thermoelectric Generator Mounted on the Truck Showing Shock Absorption Brackets

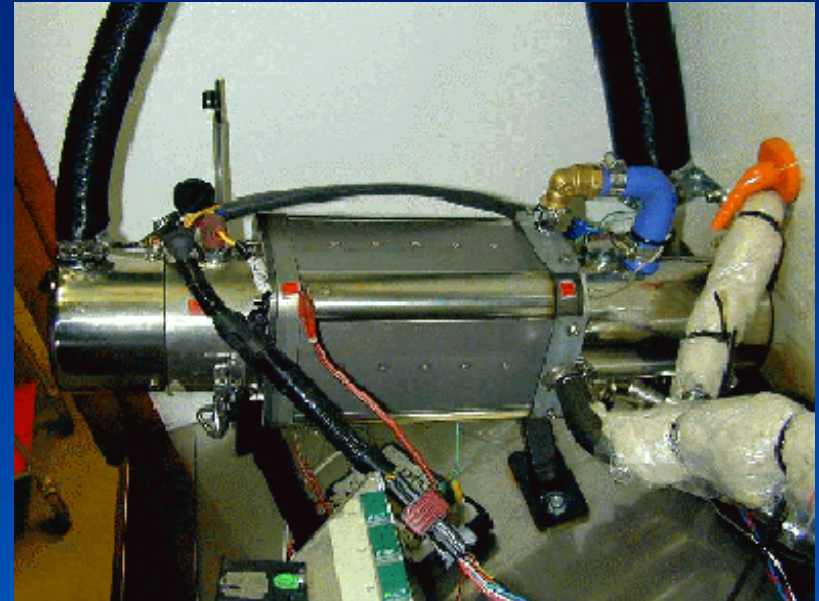


Current Technology Status of Self-Powered Cab Heater

- Cab Heater Being Developed in Sweden
- Uses 8 HZ-20 Modules
- OmniNova Scheduled to Start Production First Quarter 2002

OmniNove Self-Powered Preheater

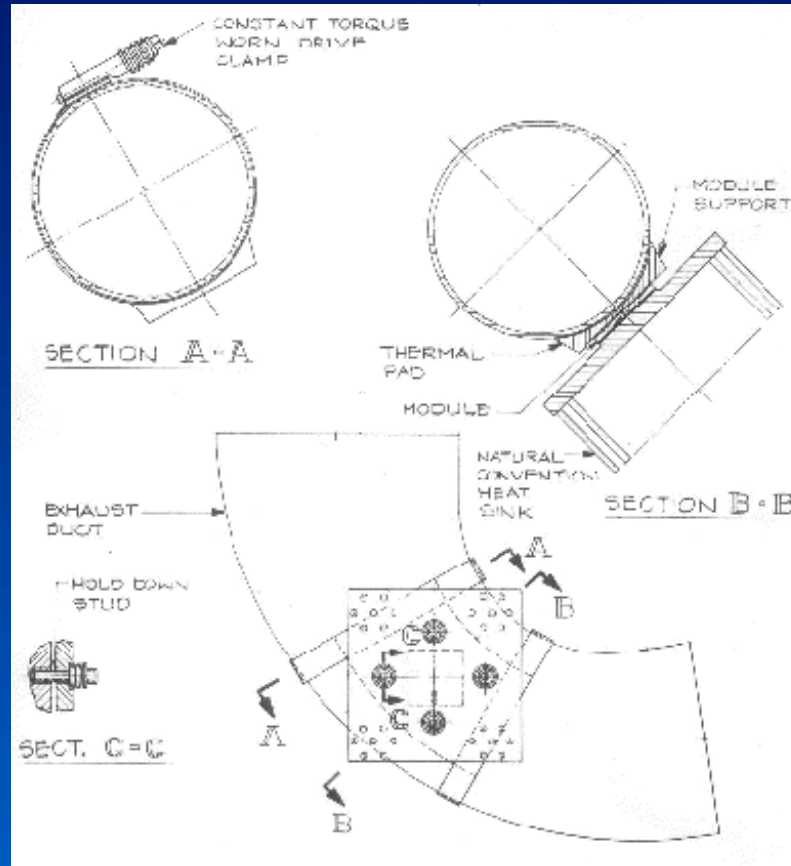
- Fuel - Diesel
- Modules - 8 HZ -20
- Fuel Input - 0.8 l/hr
- Thermal Output - 6.3 kW
- Electric Output - 100 W
- Power Consumption - 35 W
- Surplus Power - 65 W



Wireless Power

- For Remote Instrumentation
- Engine Diagnostics
- Uses Available Waste Heat from 5EC Up
- Current Programs
 - 1 MW Using Ambient Temperature
 - 1-Watt Generator on Boat With Detroit Diesel

Example of Wireless Power Supply



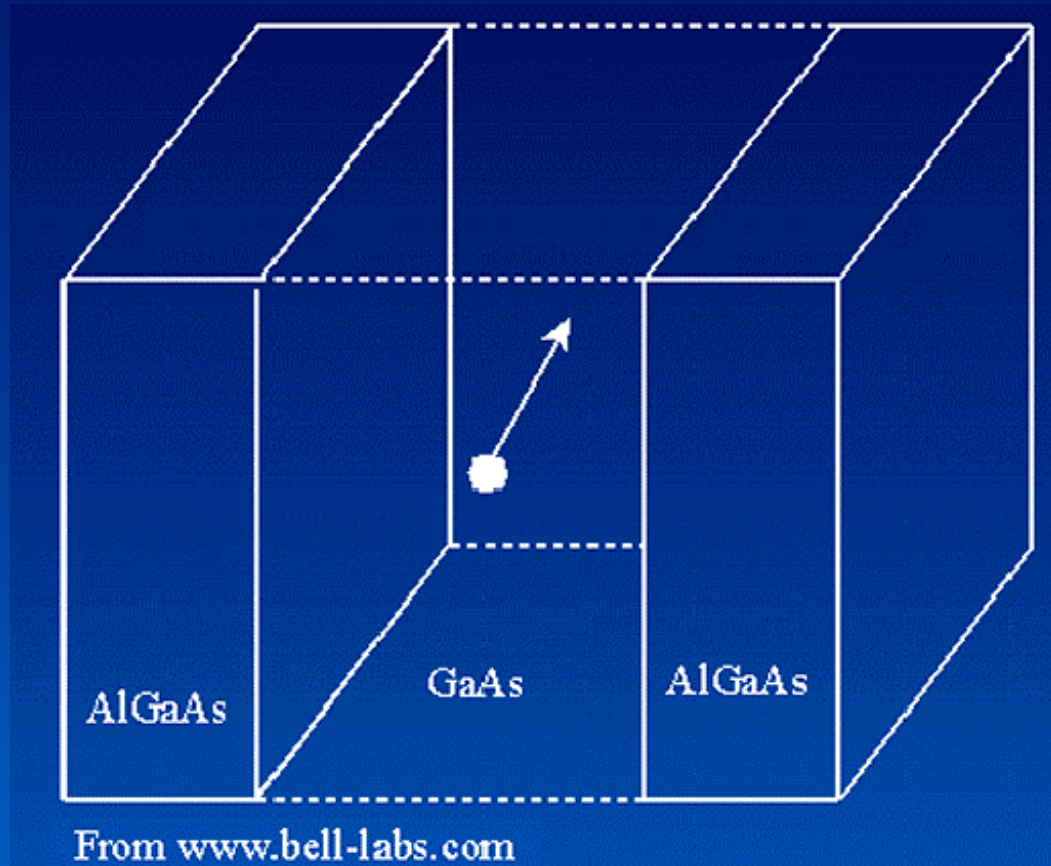
Quantum-Well Thermoelectrics

- Quantum-Well Confinement in Multilayer Films Is Achieved by the Electron Containment Between Adjacent Barrier Layers
- Active Layer (the Well) Is Sandwiched Between Materials with Band Offset to Form a Barrier for the Charged Carriers
- Improvement in ZT from an Increased Seebeck Coefficient (α) and from an Increase in the Density of States

Quantum-Well TE (cont.)

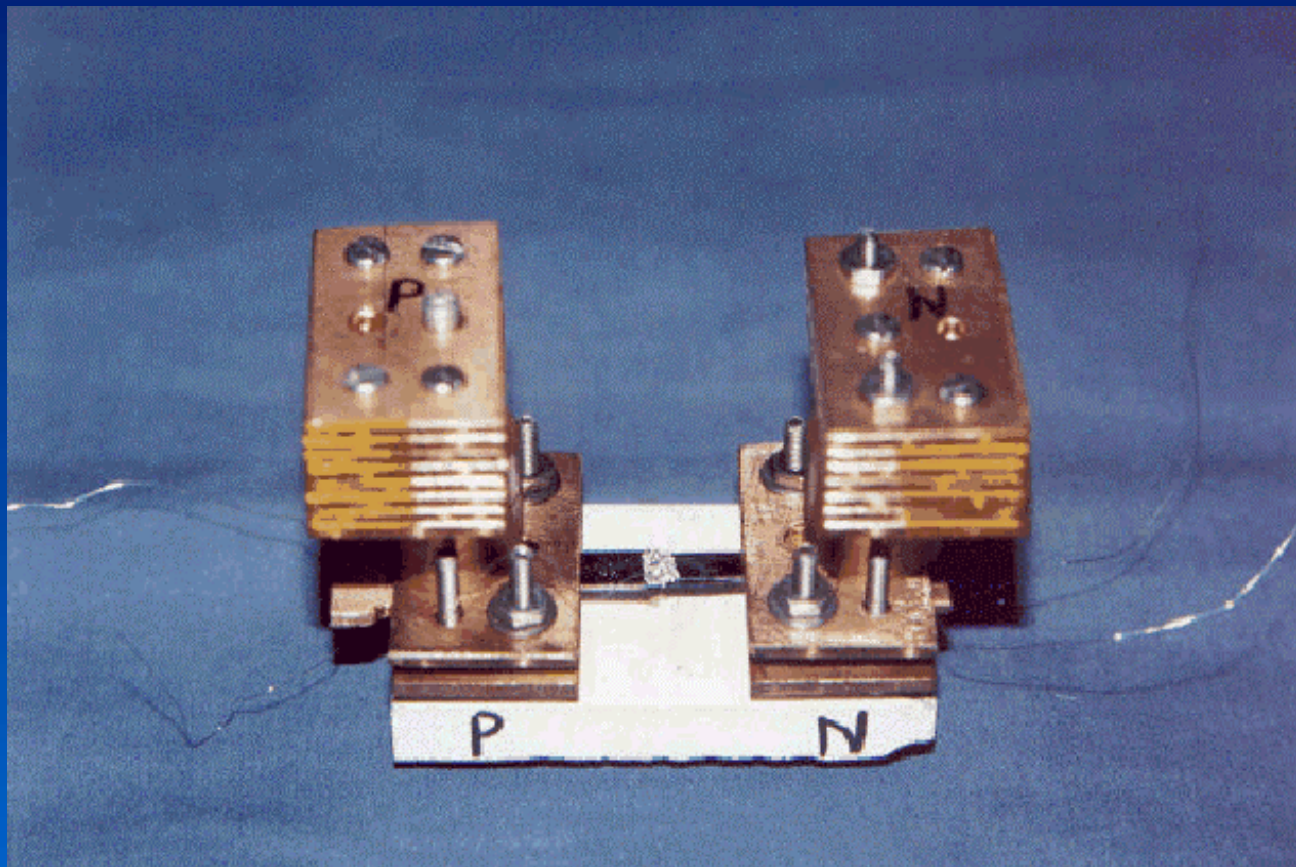
- Significant Reduction on Resistivity (ρ) Because of Quantum Confinement
- Significant Reduction on Thermal Conductivity (κ)
- Quantum-Well Effects Become Significant as the Thickness of Layer $< 200\text{\AA}$

Quantum-Well Thermoelectrics

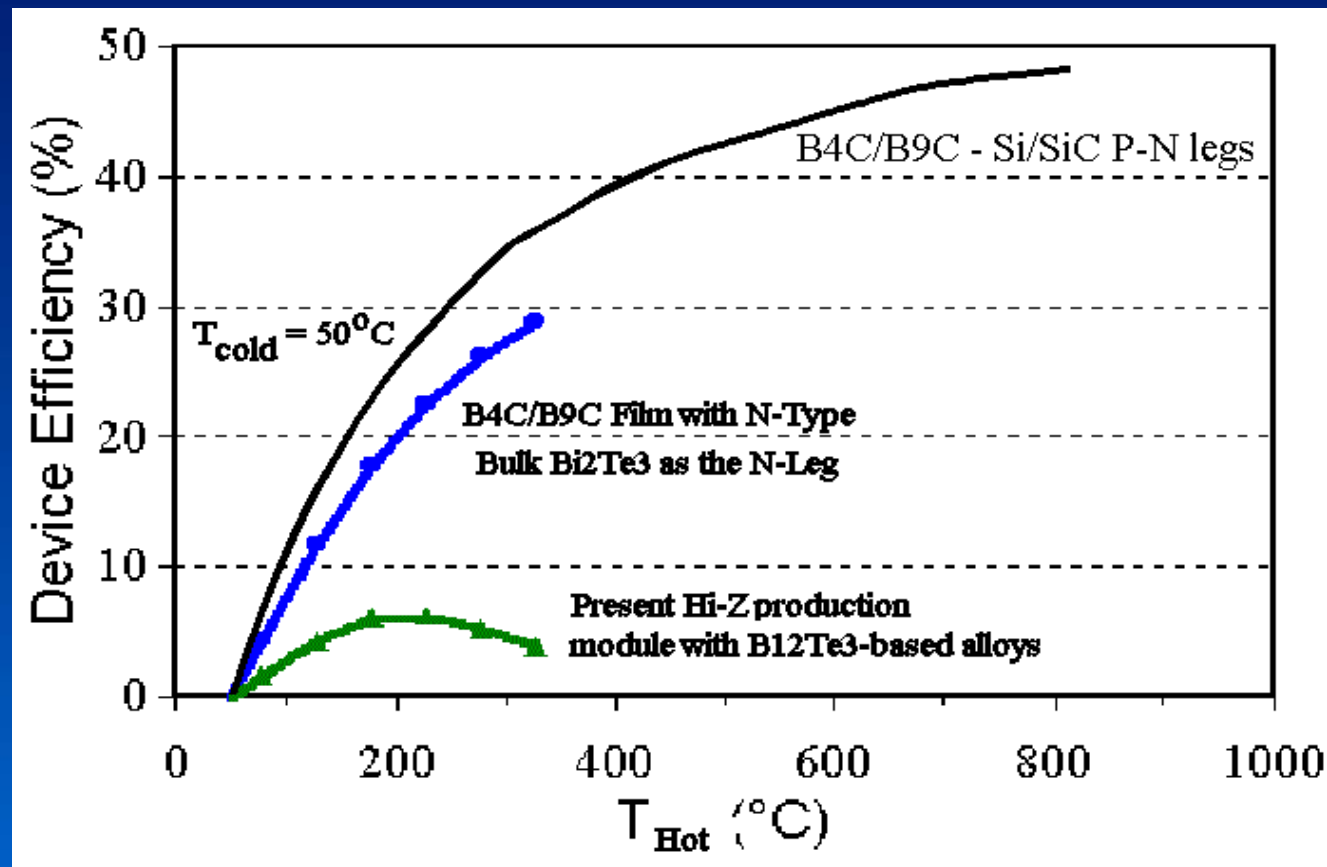


Experimental Couples

Thick-film N and P Couples



Efficiency of B_4C/B_9C Multilayer Films



Future Plans

- Thermoelectrics
 - Increase Module Production
 - Implement Lower Cost Design
- 1-kW Generator
 - Continue Over-the-Road Testing
 - Redesign Generator
 - Lighter Weight
 - Lower Cost
- Self-Powered Heater
 - Produce Modules 2002
 - Continue In-house Development

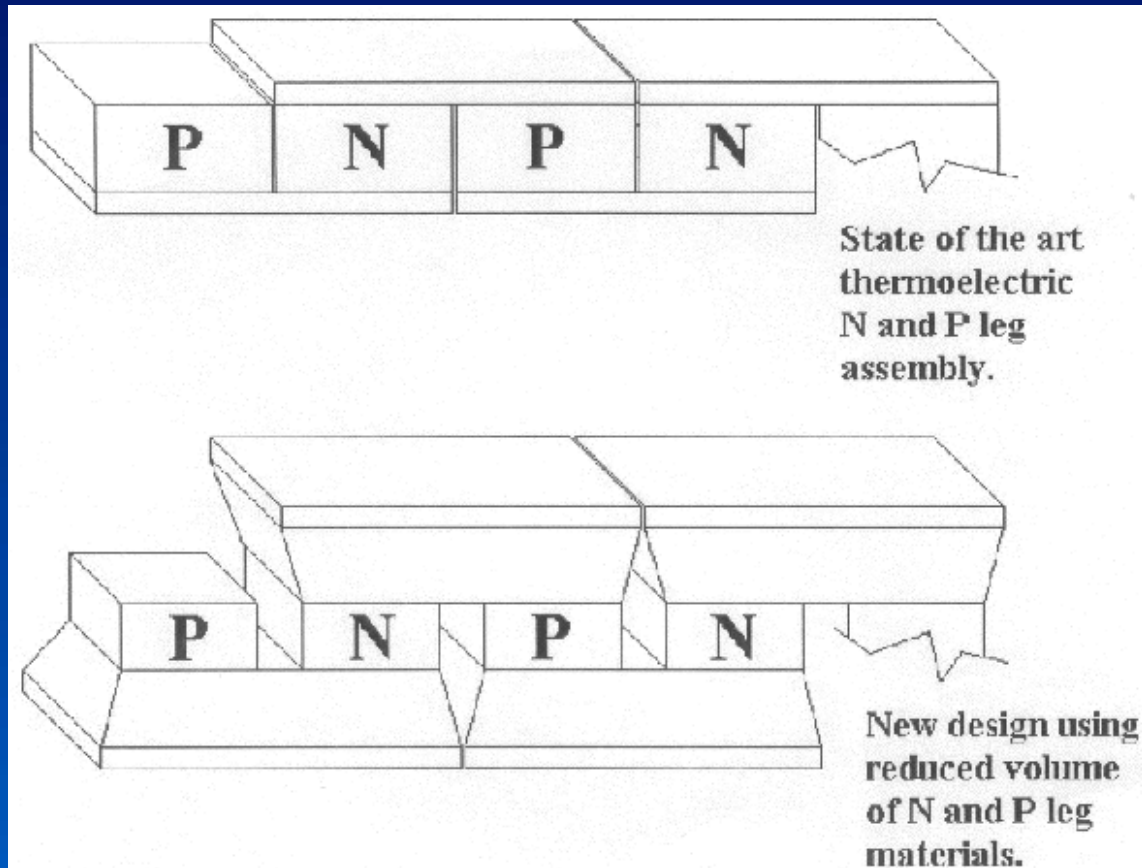
Future Plans (cont.)

- Wireless Power Supply
 - Continue Development of Marine Application
 - Solicit Interest in Truck Community
- Quantum-Well Thermoelectrics
 - Build and Test First Complete Module
 - Confirm Conversion Efficiency
 - Scale Up Production

Barriers to Technology

- Thermoelectrics
 - Need to Automate Production to Lower Cost
- Generator for Diesel Engine
 - Cut Back of Development Program - 9/11
- Self-Powered Truck Heater
 - Lack of Specific Program in United States
- Quantum-Well Thermoelectrics
 - Development of High-Temperature “N” Leg
 - Low-Volume Production Machines
 - Funding Level

Current and New TE Design



Plan for Future

- Design and Fabrication of Couples with Thicker Films and Thinner Substrates
- Multicouple Device Fabrication
- Device Efficiency Measurements
- Focus on Experimental Measurement of TE Properties in the Device
- Performance as ZT Indicator